Cross a Crater

1. Introduction

India has prominent spot in the space research domain and stands tall along with the developed nations. India has added one more feather to its cap, when on September 26, 2016, India's space agency ISRO launched eight satellites from one rocket into two different orbits. ISRO has been leading in space research since its inception in 1969 and demonstrated its technical prowess by sending “MOM: Mission on Mars” on a minuscule budget. Taking inspiration from these missions, e-Yantra has developed the theme “Cross a Crater” for eYRC-2016.

Consider the following scenario: e-Yantra has sent its robot for an expedition to the red planet Mars. The mission is to collect samples to determine if life sustainability factors exist in this planet. While returning to the base station the robot has encountered a huge crater that it needs to cross. The crater has two paths comprising of cavities along the way. These cavities need to be filled using appropriate boulders by taking a feed from the nearest satellite to make them traversable.

The above scenario has been simplified and abstracted as an arena for this theme. The arena represents a crater and comprises of two partially traversable bridges, Bridge 1 and Bridge 2 with cavities at random positions leading to the Base station. The robot takes the feed from a camera directly above it that guides it towards filling the cavities using conical structures and navigating the bridge. Navigating each of the bridges involve different challenges. The robot has to traverse using one of these bridges and reach the Base station.

The teams have to design, program and control an autonomous robot and use image processing techniques to complete the tasks. The team which traverses the bridge and reaches the base in the least possible time will be declared the Winner!

2. Theme Description

a) Terrain of an uninhabited planet is abstracted as an arena for this theme. The arena is divided into following parts:

1. **Crater Region:** This region comprises of the Start Node and Boulders.
   - **Start Node**: This is the node used as the starting point for navigation.
   - **Boulders**: These are frustums (Cones with their tops flattened) with numbers pasted over them.
   - **Boulder Zones**: these are areas where Boulders are kept. There are four Boulder Zones, marked by circles of 3cms diameter. We use BZ1, BZ2, BZ3 and BZ4 to represent Boulder Zones 1, 2, 3 and 4 respectively as shown in Figure 1.

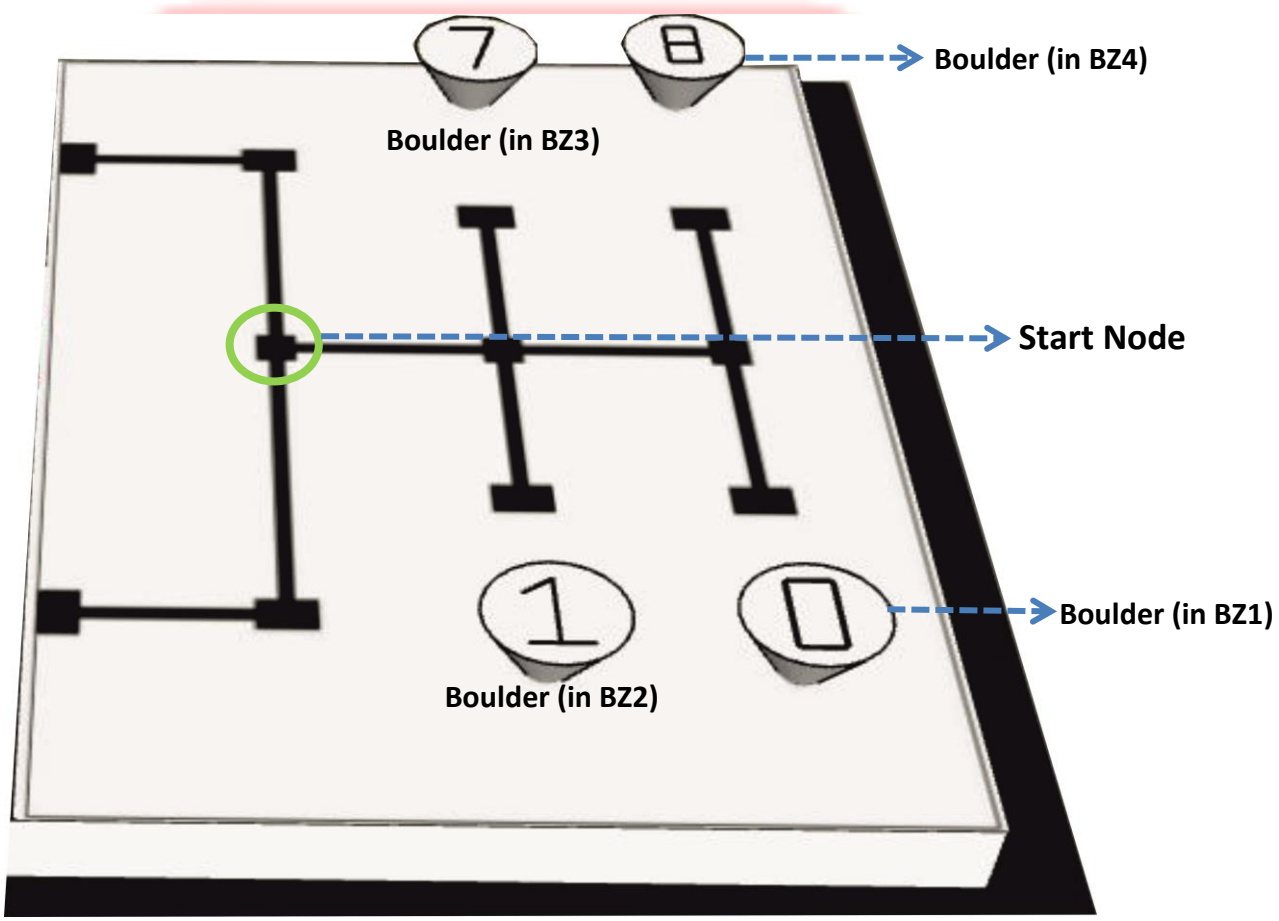


Figure 1: Crater Region

2. **Bridge Region:** With reference to Figure 2, this region comprises of
   - **Cavities**: refer to the conical pits in the bridges.
   - **Bridge 1**: refers to the narrow bridge with Cavities present only in the middle column.
   - **Bridge 2**: refers to the wide bridge with Cavities present only in the middle 2 columns.
   - **Obstacles**: are cubical blocks of dimension 4cm x 4cm x 4cm that can be present only in Bridge 2.

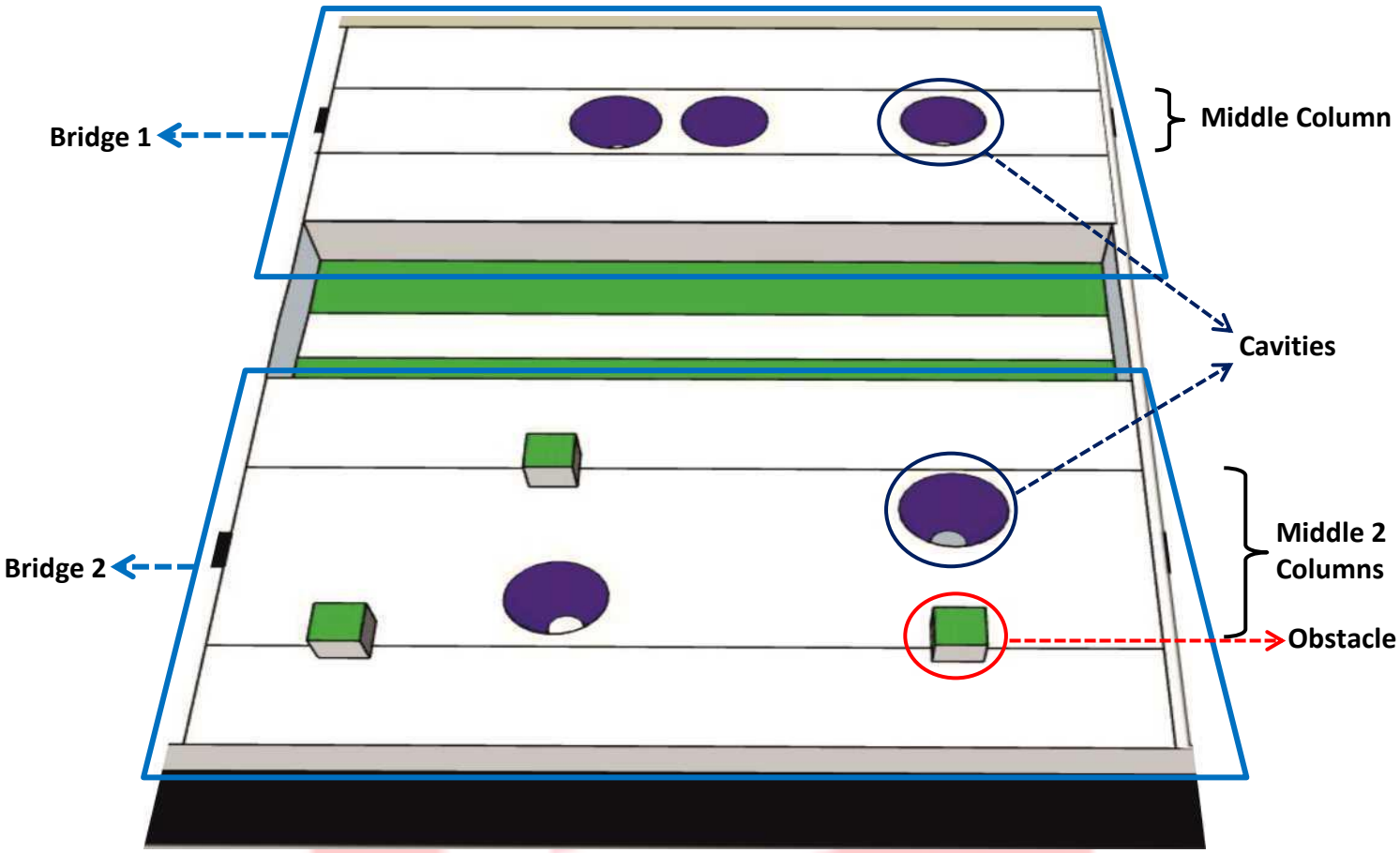


Figure 2: Bridge Region

3. **Base Station:** this region comprises of a Base Station Node representing the end point for navigation as shown in Figure 3.

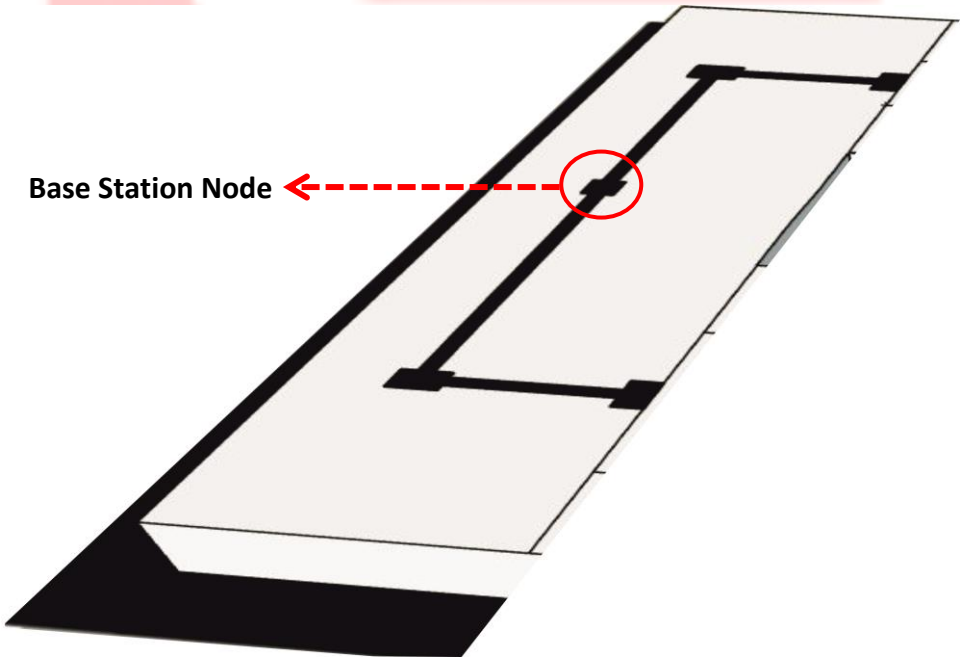


Figure 3: Base Station

4. **Satellite:** refers to the overhead camera that is to be used for image processing to navigate the arena for theme implementation.

b) Initially, teams are given a number referred to as the **Sum.** Each of the Boulders has a Number written on it. This theme involves the following:

1. Using the Satellite, recognize the numbers on the Boulders.
2. Display the detected numbers on the Boulders on the laptop console and LCD of the robot.
3. Determine the Cavities and/or Obstacles on Bridge 1 and Bridge 2.
4. Choose a bridge for traversal based on the following:
    a. Whether the numbers on the Boulders required to fill the Cavities will add up to the Sum.
    b. If both the bridges satisfy the above requirement, which bridge is faster to cross? You may choose based on your implementation.
    c. Pick up the Boulders with appropriate numbers from the Boulder Zone and fill all the cavities to cross the bridge.
5. Avoid the Obstacles if Bridge 2 is used to cross the bridge.
6. Stop at the Base Station Node and buzz the buzzer for 5 seconds.

3. Arena

The arena for the theme is a simplified abstraction of a scenario explained in the Introduction. Each team has to prepare the arena. Preparing the arena consists of the following steps:

a. Printing the Arena on Flex Sheets
b. Preparing the Crater Region and Base Station
c. Preparing the Bridge Region
d. Preparing the Sunboard
e. Preparing the Boulders
f. Preparing the Cavities
g. Preparing the Obstacles
h. Mounting the Satellite
i. Arena Configuration

a. Printing the Arena on Flex Sheets:

Teams have already printed the arena on the flex sheets in Task 3 of the competition.

WARNING: **Please be careful while handling the flex sheet – avoid folding it like a bed-sheet since the resultant folds will cause problems while the robot moves. One way of "flattening" flex if it has been compromised is to hang it for a few hours in the sun -- it tends to straighten out. Never attempt ironing it or applying heat of any kind -- it may be a fire hazard**.

Teams are not allowed to make any changes in the final arena design. Any team making any modification whatsoever will be disqualified from the competition.

i. **Base Arena:** is of dimensions 176cm x 107cm as shown in Figure 4.

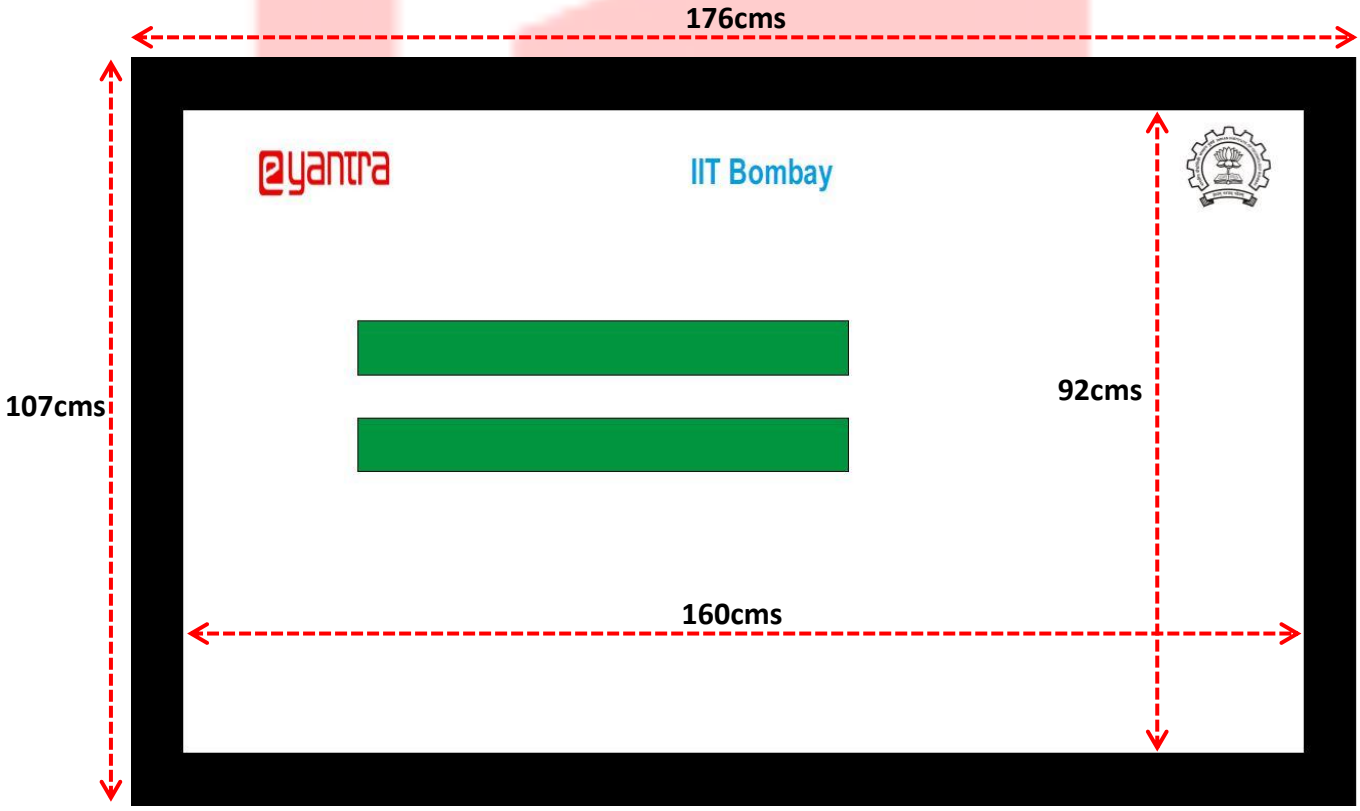


Figure 4: Base Arena

ii. **Crater Region Arena:** this part of the arena constitutes the Crater Region of dimensions 65cm x 92cm as shown in Figure 5.

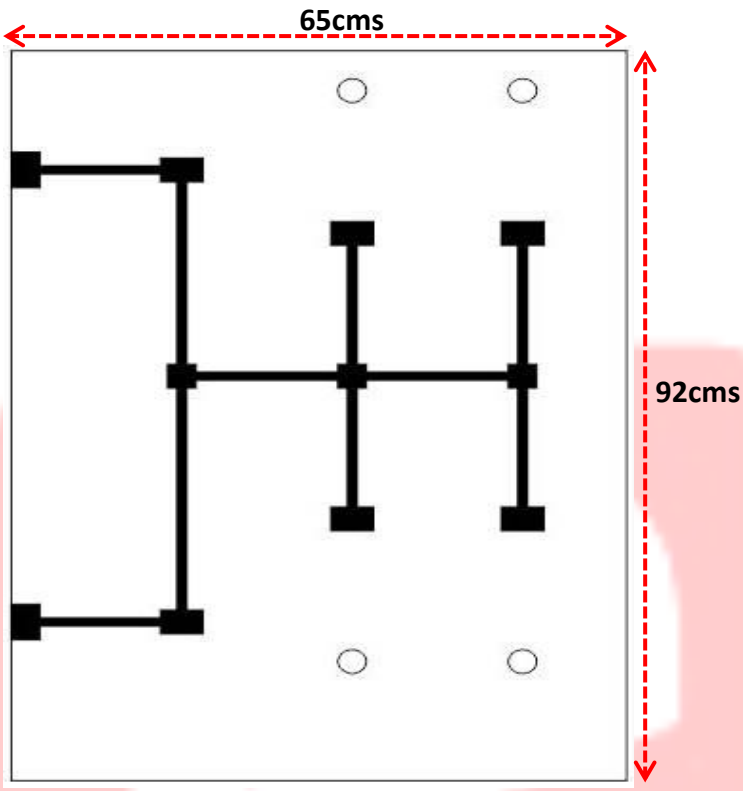


Figure 5: Crater Region Arena

iii. **Base Station Arena:** this part of the arena constitutes the Base Station of dimensions 25cm x 92cm as shown in Figure 6.

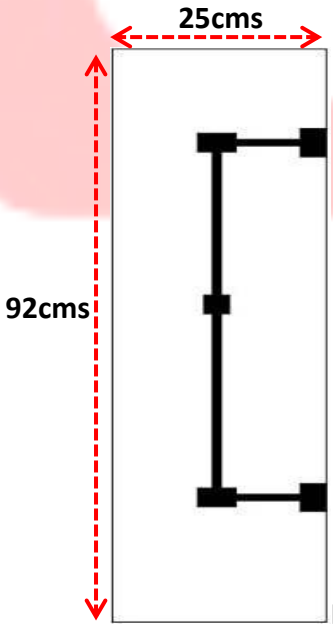


Figure 6: Base Station Arena

iv. Numbers and Patch Arena: this part of the arena comprises of a green colored patch for Obstacles and number cut-outs ass shown in Figure 7.

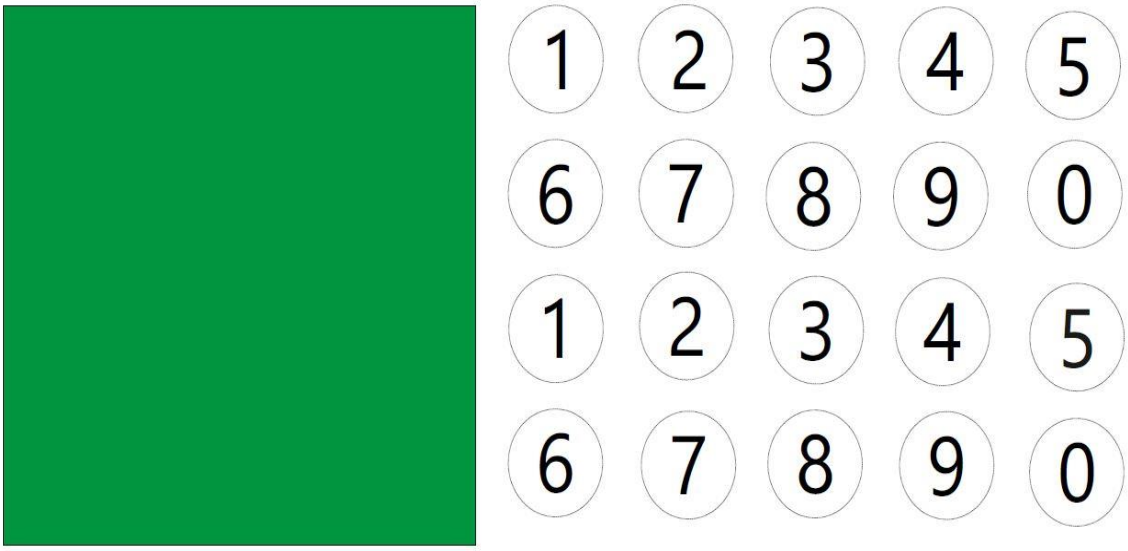


Figure 7: Green coloured patch and Numbers

b. Preparing the Crater Region and Base Station:

- Cut a thermocol sheet of dimension **92cm x 65cm x 6cm** for Crater Region as shown in Figure 8.
- Cut a thermocol sheet of dimension **92cm x 25cm x 6cm** for Base Station as shown in Figure 9.

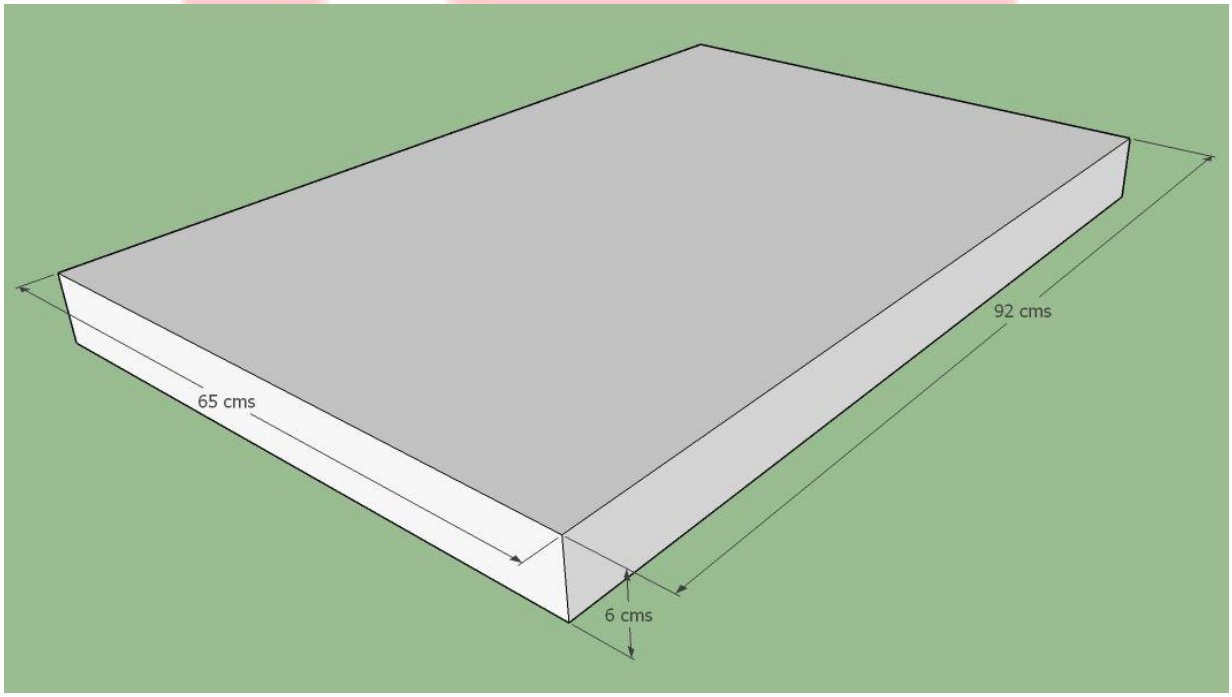


Figure 8: Crater Thermocol Cut-out

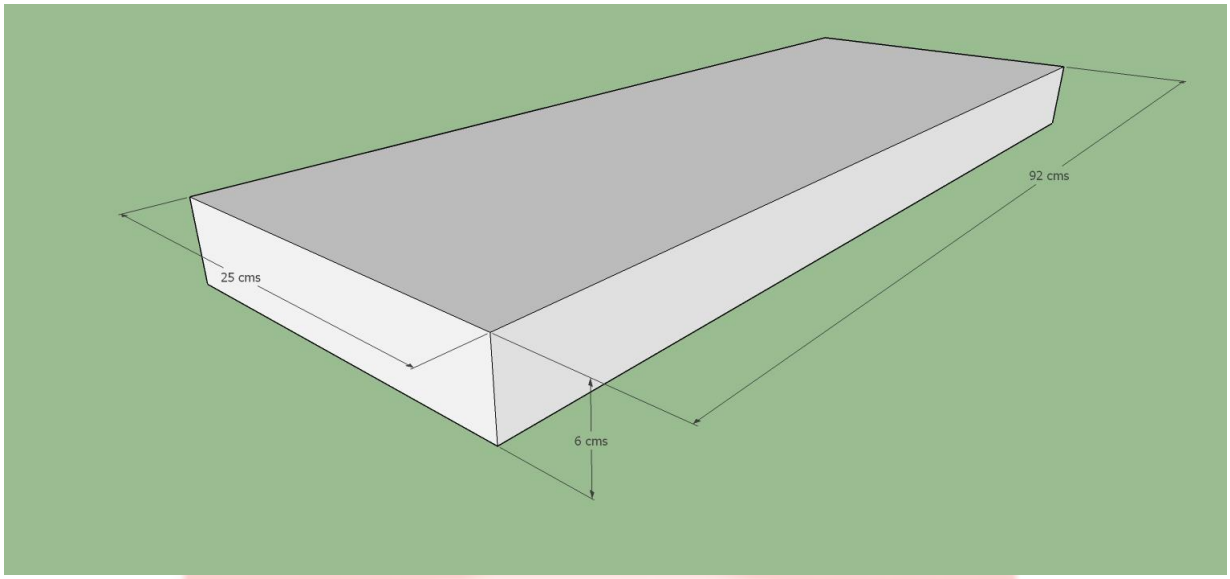


Figure 9: Base Station Thermocol Cut-out

c. Preparing Bridge Region

- Prepare **four** thermocol cut-outs of dimension **70cm x 10cm x 6cm** referred to as Bridge Cut-outs, as shown in Figure 10.
- Prepare **21** thermocol blocks of dimensions **10cm x 10cm x 6 cm** as shown in Figure 11 (the same blocks are also used to prepare Cavities).

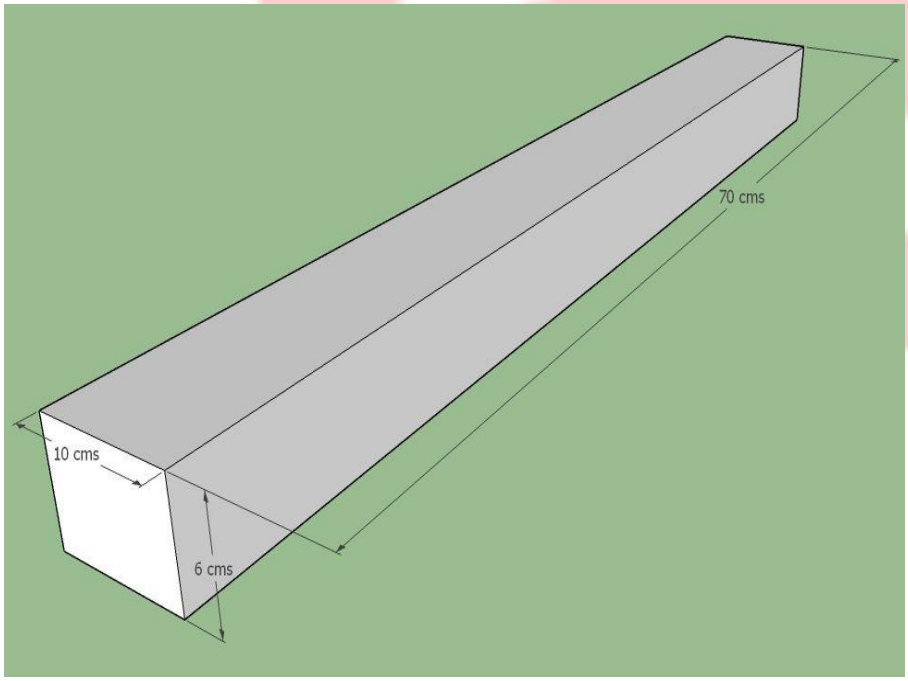


Figure 10: Bridge Cut-out

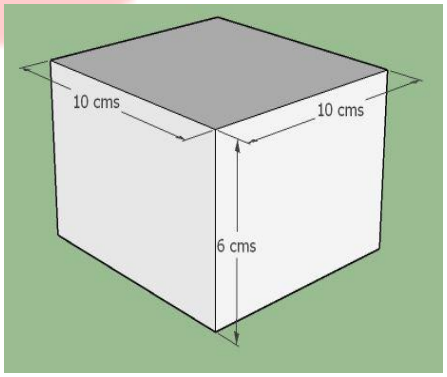


Figure 11: Block

Assemble two of the Bridge Cut-outs and seven blocks to create **Bridge 1** as shown in Figure 12.

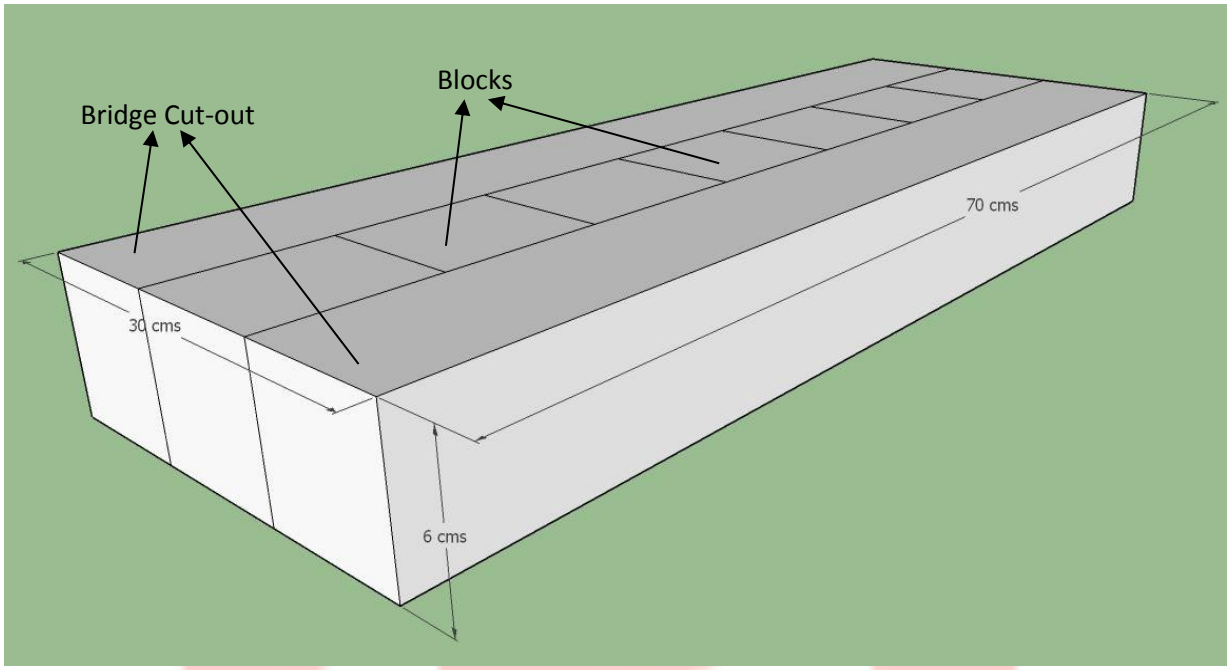


Figure 12: Bridge 1

Assemble the remaining two Bridge Cut-outs and fourteen blocks to create **Bridge 2** as shown in Figure 13.

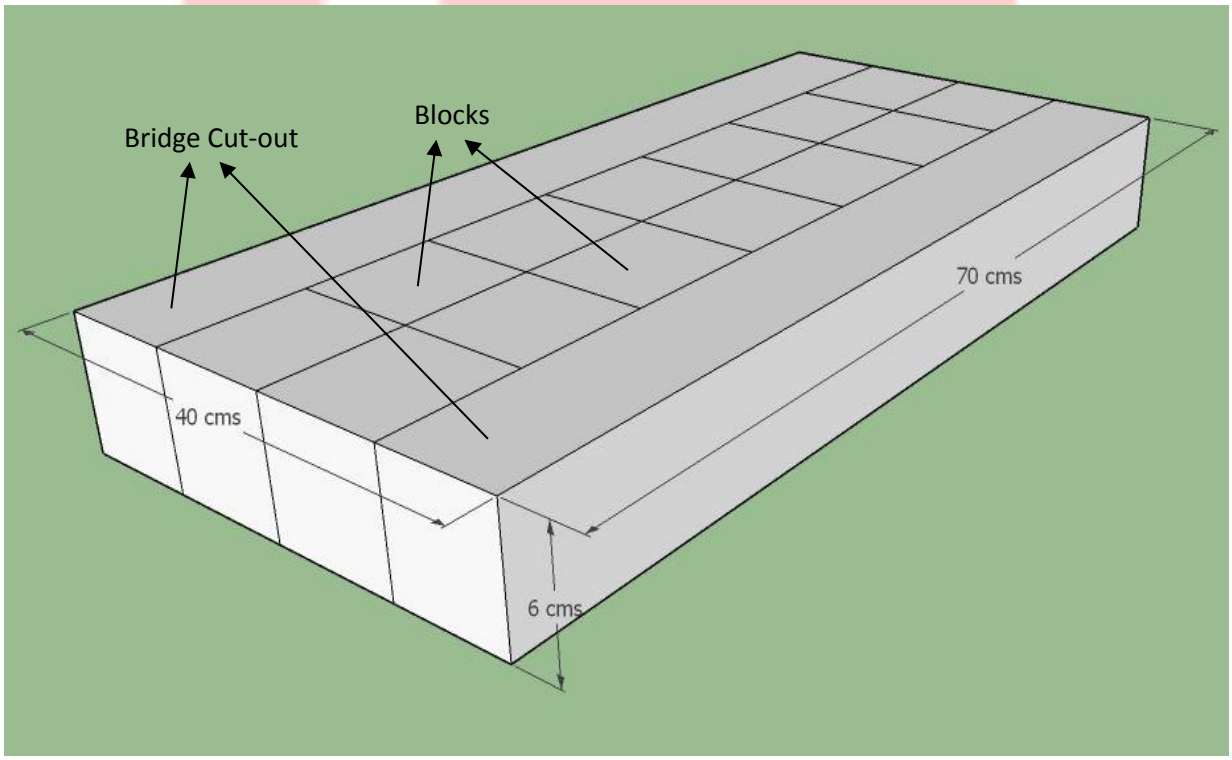


Figure 13: Bridge 2

d. Preparing the Sunboard

Procure a sunboard sheet of dimensions **160cm x 92cm** (Please use the sample sunboard piece provided in the kit to ensure good quality).

Prepare a cut-out as shown in Figure 14. The dimensions and cut should be perfect to make sure that the robot traverses smoothly over it.

Note: DO NOT throw away the Inner Cut-outs; these will be used as explained in Section 5: Preparing the Boulders.

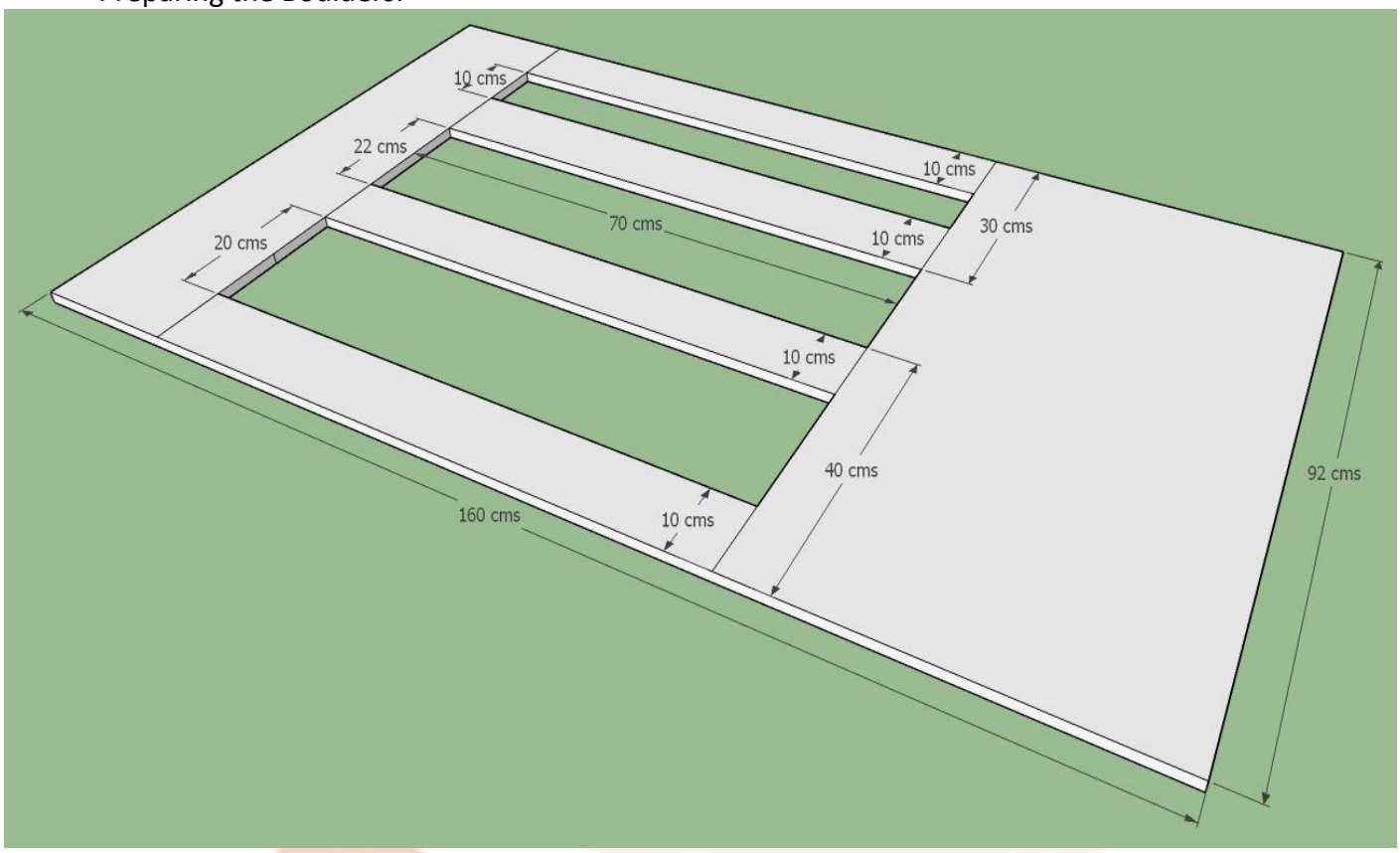


Figure 14: Sunboard Cut-out

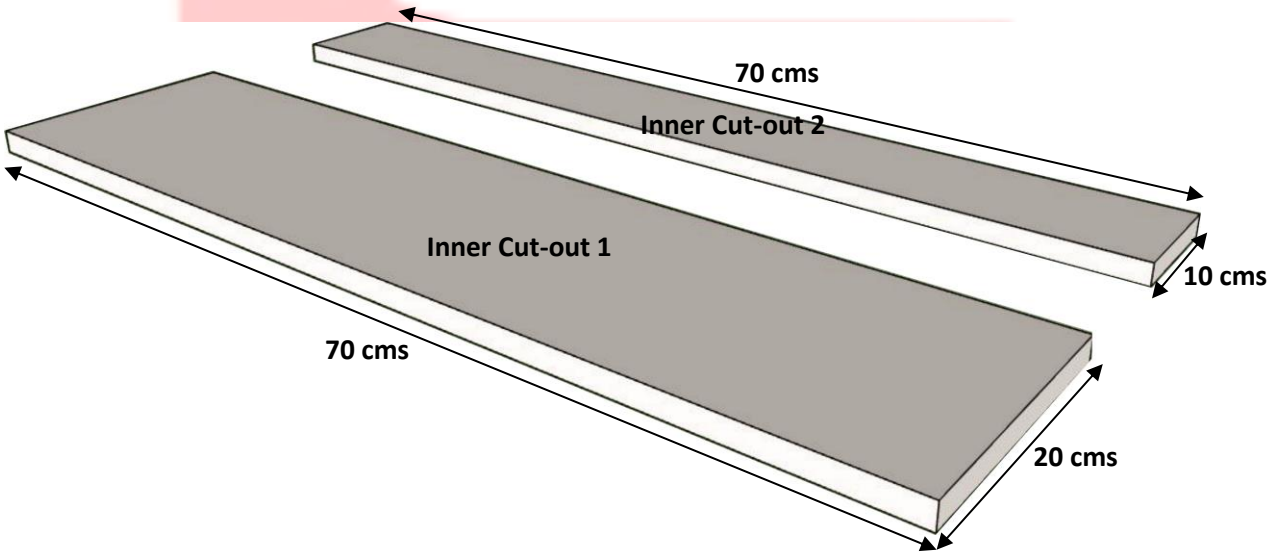


Figure 15: Inner Cut-outs (thickness is not to scale)

e. Preparing the Boulders

Four funnels are provided to the team in the kit.

- Fill the funnels using any material (e.g. clay, ball bearings, wood, scrap etc.) to increase the weight of the funnels to 60 grams.
- Draw a 7X2 grid of **10cm x 10cm** cells over the Inner Cut-out 1 and a 7x1 grid of **10cm x 10cm** cells over the Inner Cut-out 2 as shown in Figure 16.
  Grids can be drawn using a pencil and are just for visual reference.
- Choose a few cells in the grid and draw a circular boundary using a funnel's top rim at the middle of the cell.
- Cut along the marked circular boundary in the cell meticulously as shown in Figure 16.
- Stick the circular cut-out on the funnel after filling the funnel, sealing the top (refer to Figures 17 and 18).
- Cut numbers from the Numbers_and_Patch flex along the marked circular boundary.

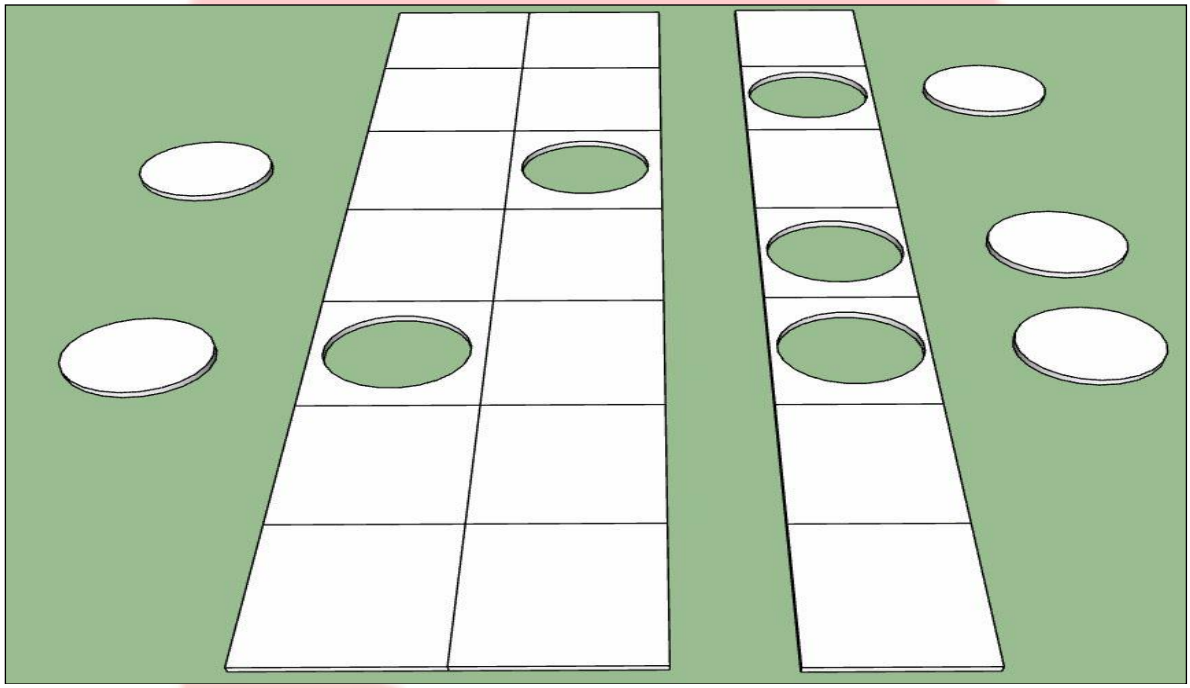


Figure 16: Circular Cut-outs from Inner Cut-out 1 and Inner Cut-out 2

Figure 17: Funnel filled with clay and Circular Cut-out

Figure 18: Sealed Funnel

- Finally, stick the Number Patchover the funnel. Note that the Number Patch is temporary – you have to practice with different Number Patches.
  Yes! You have successfully prepared a Boulder that will resemble Figure 19. Prepare three more Boulders.

Figure 19: Boulder

Note: Team may have to file the Boulders from bottom and the top rim so that it fits properly in the Cavities (explained in the next section).

f. Preparing the Cavities

- Take a block of 10cm x 10cm x 6cm as used in "Preparing the Bridge" section. Place the outer rim of the Boulder at the center of the block as shown in Figure 20.
- Trace the outline of the Boulder rim. You should carve along this outline and scoop the thermocol from inside the outline such that a conical cavity emerges.
- NOTE: As you scoop, place the Boulder inside the Cavity and scoop as much as required to fit the Boulder snugly inside the Cavity. The resulting shape should look like Figures 21 and 22.

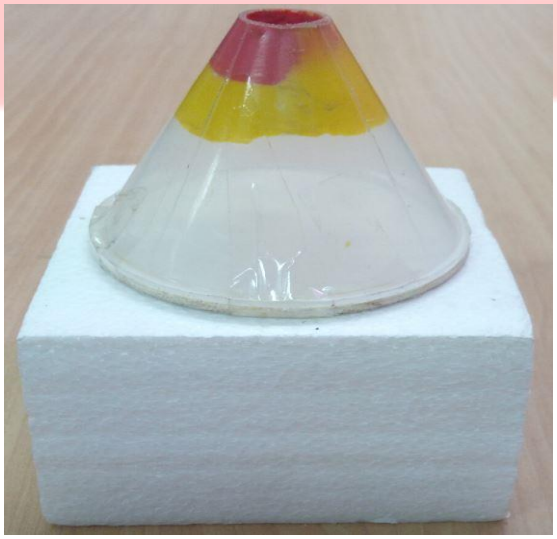


Figure 20: Boulder over Block

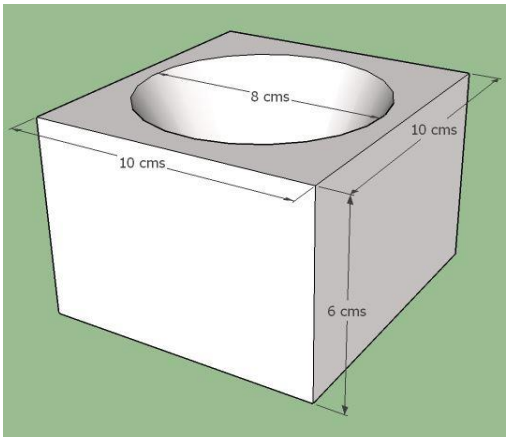


Figure 21: Cavity side-view

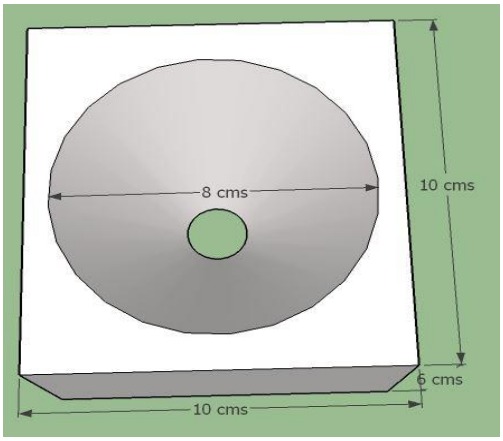
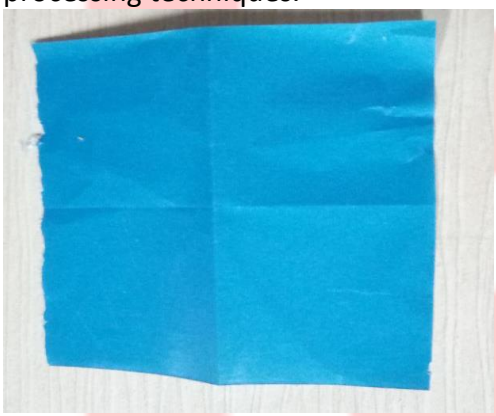


Figure 22: Cavity top-view

- Finally, team should cover the prepared Cavity with a blue colored sheet (A sample sheet is provided in the kit) following the steps shown in Figures 23a, 23b and 23c. This is required so that the Satellite can easily detect the Cavities using image processing techniques.



Figures 23a: Step 1—Blue sheet (approx. 10cm x 10cm)

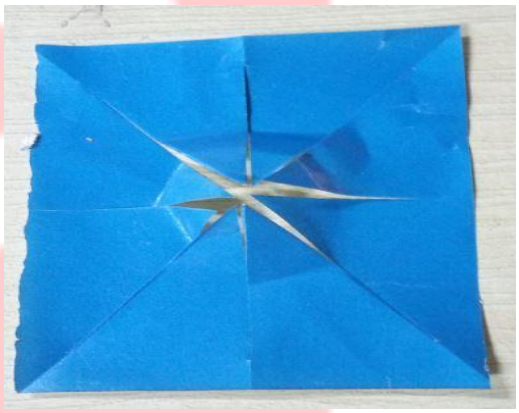


Figure 23b: Step 2—Cut frills

Figure 23c: Frilled sheet pasted on the block

g. Preparing the Obstacles

- Prepare four thermocol blocks of dimensions 4cm x 4cm x 4cm (Refer to Figure 24).
- Paste a Green colored patch of 4cm x 4cm from Numbers_and_Patch flex sheet on one of the surfaces of the block. This is referred to as an Obstacle.

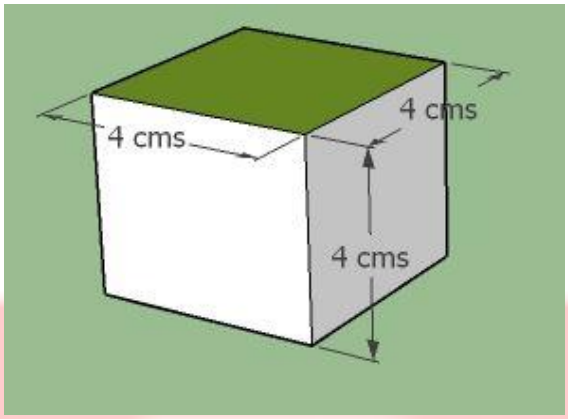


Figure 24: Obstacle

h. Mounting the Satellite

- Team is provided with a USB camera and USB-to-USB extension cable in the kit.
- Provided camera should be mounted such that it has a complete top view of the arena. Camera should be above the center of the arena at a height of approximately 7 feet and 7 inches.
- Teams can design any arrangement using their creativity to mount the camera, for example, hanging from ceiling, constructing a frame etc. An example setup is shown in Figure 25.
- USB-to-USB extension cable is very useful to connect the camera to the PC/laptop.

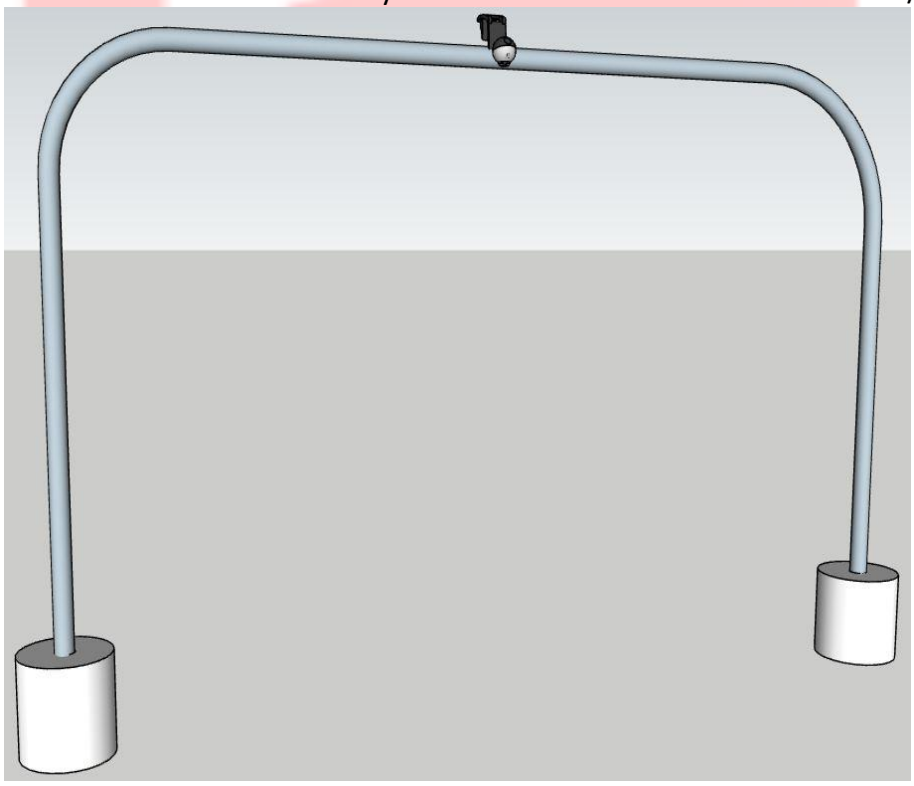


Figure 25: Satellite Mounting Example (Not to Scale)

i. Arena Configuration:

When you are ready with all the above steps, you have to set up the Arena according to a given Configuration.

Each Configuration involves the following:

- **Boulder Table:** This table provides the Number on the Boulder and its Boulder Zone position. An example in illustrated in Table 1.
- **Sum:** This is a numerical value provided initially and is an input to Team's code. For example consider a value, **Sum = 16**.
- **Final Arena Image:** this image represents the final set up of the arena with all the Cavities, Obstacles and Boulders placed.

Table 1: Boulder Table

S. No.	Boulder Zone	Number over Boulder
1.	BZ1	0
2.	BZ2	1
3.	BZ3	7
4.	BZ4	8

A **2D view** of the arena for the above example Configuration is shown in Figure 26.

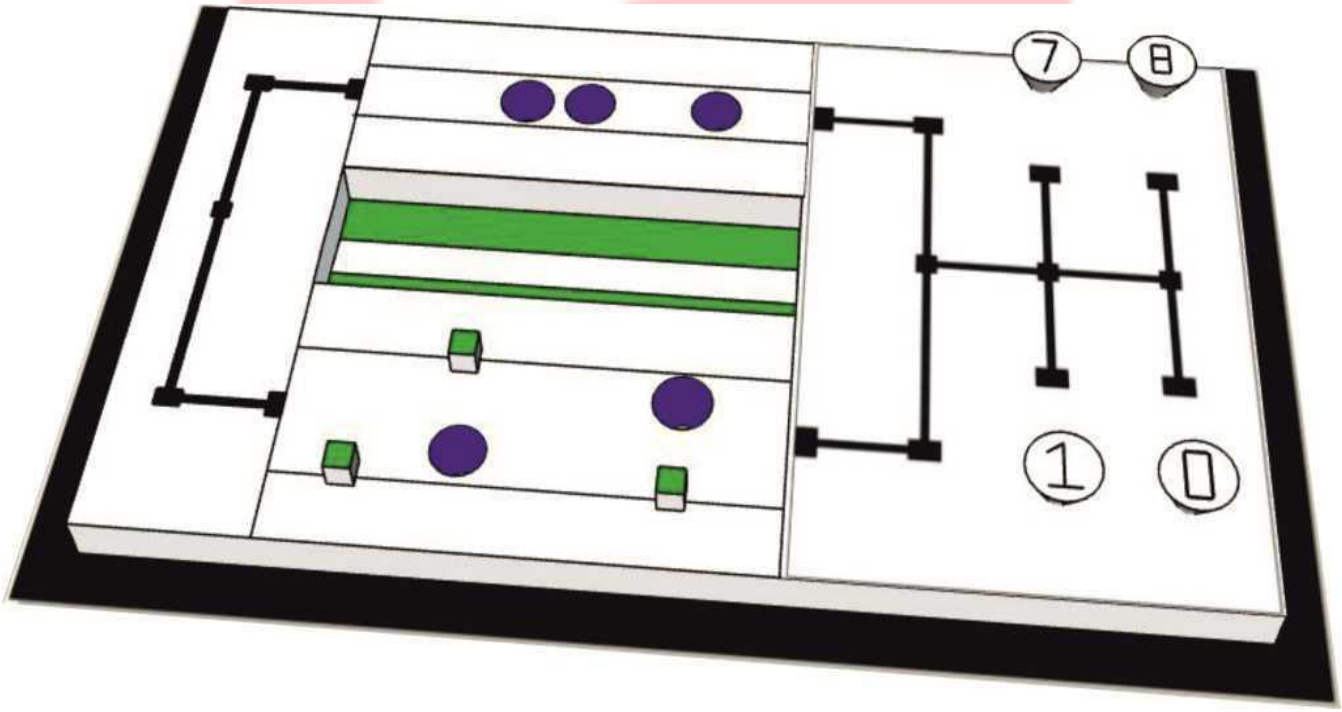


Figure 26: Example Arena

A **3D view** can be referred to from the link: Cross a Crater Arena

Steps for setting up the final arena:

1. Mount the Satellite.
2. Place the Base Arena such that Satellite has complete top view of the Base Arena.
3. Set up the thermocol cut-outs for Crater Region, Bridge Region (along with Cavities) and Base Station Region.
4. Place the prepared sunboard sheet over the thermocol cut-outs properly.
5. Stick Crater_Region and Base_Station flex sheets on the sunboard sheet (make sure each and every dimension is perfectly matching).
6. Place the Boulders over their respective Boulder Zones following the Boulder Table.
7. Place the Inner Cut-out 1 and Inner Cut-out 2 over the Bridge 1 and Bridge 2.
8. Place the Obstacles according to the Final Arena Image provided.
9. Re-check the final arena alignment using the Satellite.

Note: In the Final Arena Image, placement of Obstacles will be according to the following rules:

- Obstacles will only be present on Bridge 2.
- Obstacle will NEVER be present on the periphery of a block that has a Cavity.
- Two Obstacles will NEVER be present on the adjacent horizontal Cells.

An example of valid placement of Obstacles is given in Figure 27.

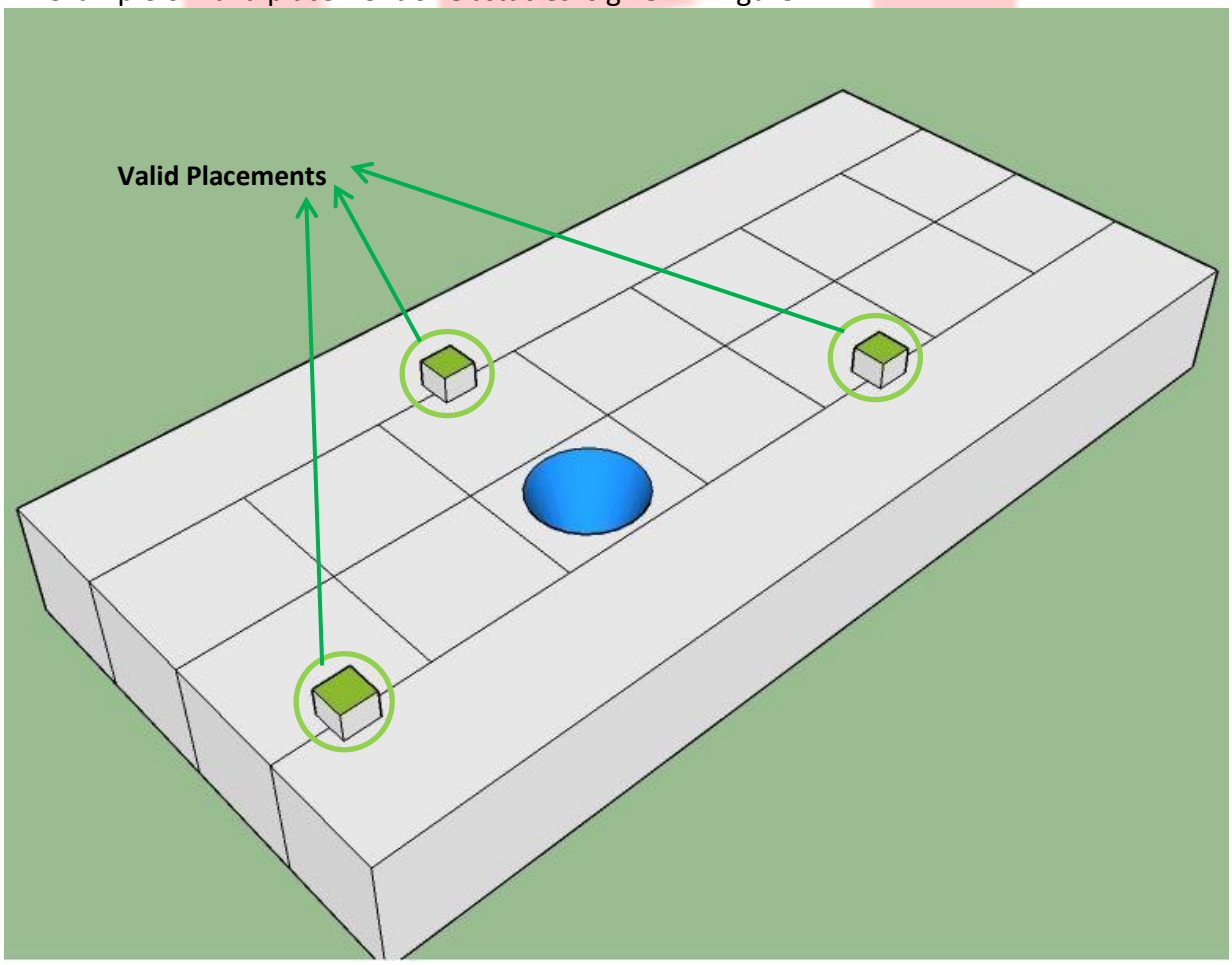


Figure 27: Example - Valid placement of Obstacles

An example of Invalid placement of Obstacles is given in Figure 28. Note that any Configuration provided to the teams will be such that there is enough room for the robot to easily traverse through Bridge 2.

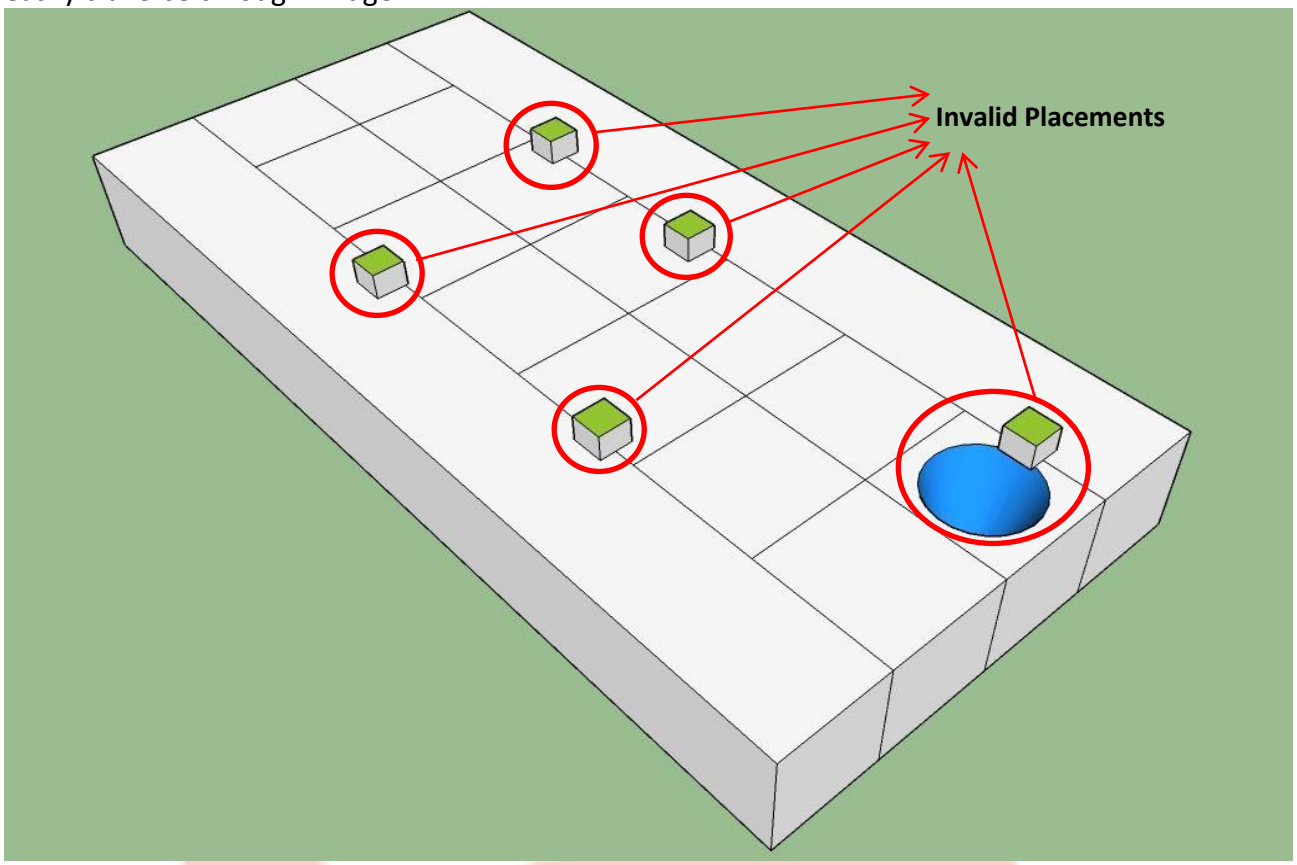


Figure 28: Example - Invalid Placement of Obstacles

Note that any Configuration provided to the teams will be such that there is enough room for the robot to easily traverse through Bridge 2.

Please maintain the arena in a good condition. If the arena is found damaged or in a condition not good enough to properly evaluate the team, e-Yantra has the right to disqualify the team. The final decision is at the discretion of the reviewer.

4. Hardware Specifications

4.1 Use of Firebird V:

- All participating teams must use **only** the Firebird V robot sent to them in the kit. **Only one** robot given in the kit is allowed per team.
- Team shall not dismantle the robot.
- The robot should be **completely autonomous**. The team is not allowed to use any wireless remote while the robot is performing the task.

4.2 Use of additional components not provided in the kit:

- No other microcontroller-based board shall be attached to the Firebird V robot.
- Teams **may connect external actuators** along with their driver circuits to the Firebird V robot only on the condition that the actuators must be controlled through the Firebird V robot.
- The team is **NOT allowed** to use any other sensors apart from those provided in the kit.

4.3 Power Supply:

- The robot can be charged through battery or auxiliary power supply. These are shipped with the robot.
- The team cannot use any other power source for powering the robot.
- The team can use auxiliary power during practice but the final demonstration should only be made using only battery powered robot.

5. Software Specifications

- e-Yantra has provided all teams with ATMEL STUDIO 6, a free software for programming AVR microcontroller. Participating teams are free to use any other open source Integrated Development Environment (IDE) for programming AVR microcontroller.
- As per e-Yantra policy, all your code and documents are open-source and maybe published on the e-Yantra website.

6. Theme Rules

1. The maximum time given for completing the task is 600 seconds. A maximum of **two runs** will be given to a team (the better score from the two runs will be considered as team's final score).
2. Participants are not allowed to keep anything inside the arena other than the robot.
3. The **maximum** number of **Cavities** in Bridge 1 in any configuration is four.
4. The **maximum** number of **Cavities** in Bridge 2 in any configuration is three.
5. The **maximum** number of **Obstacles** in Bridge 2 in any configuration is four.
6. The **maximum** number of **Boulders** in the Crater Region in any configuration is four.
7. The **weight** of the Boulder should be approximately equal to 60 grams.
8. Teams can pick and drop the appropriate Boulders in any order.
9. Teams must NOT use any sensor except those provided with the kit.
10. Teams may use extra actuators for the implementation of the theme.
11. Teams can develop **any pick-drop mechanism** according to their desire and creativity.
12. The code and algorithm should be generic such that the robot can work under any configuration assigned.
13. The code must have a function wherein the **Sum** can be entered for a particular configuration (similar to the one used in Task1 and Task2).
14. Color schemes provided to the team (samples are provided in the kit) must not change. The same colors will be used in the Finals.
15. The robot is not allowed to make any marks while traversing the arena. Any robot found damaging the arena will be immediately stopped; repositioning will be allowed as per the rules. The final decision is at the discretion of the e-Yantra team.
16. At start of a run, robot should be kept at the **Start Node** with the castor wheel of the robot positioned over the node facing in the direction opposite to the Base Station.
17. The orientation of numbers over Boulder will be same as shown in Arena configuration.
18. Team should switch ON the robot and start the execution of the code when told so by the reviewer. The timer will start at the same time.
19. When the robot deviates from the Black line or goes off the arena it can be Restarted or Repositioned according to the rules in the **Restart and Reposition** section given below.
20. A run ends and the timer is stopped when:
    - The robot completes all the tasks and reaches the Base Station Node and buzzes the buzzer for 5 seconds or
    - The robot stops and sounds a continuous buzzer for more than 5 seconds or
    - If the maximum time limit for completing the task is reached or
    - If the team has exhausted all Restart/Reposition options.
21. Time will be considered maximum (600 seconds), if the robot is not able to cross the bridge.
22. Second run will start once again whilst resetting the score, timer and arena. The score of both runs will be recorded and best of two runs will be considered as the team's score.
23. The time measured by the reviewer will be final and will be used for scoring the teams.
24. Time measured by any participant by any other means is not acceptable for scoring.
25. Once the robot starts moving on the arena, participants are not allowed to touch the robot except when there is a need for Restart, Reposition and manual adjustment (explained in Judging and Scoring System). **The final decision is at the discretion of the e-Yantra team.**

NOTE:

- You will be given A Boulder Table, Sum and Final Arena Image just before the submission of Task 5: Video submission along with instructions to complete this task.
- After completion of all tasks, teams will be selected as finalists based on their cumulative scores across all the tasks. Complete rules and instructions for the finals at IIT Bombay will be sent to those teams that qualify for the finals.
- In case of any disputes/discrepancies, e-Yantra's decision is final and binding. e-Yantra reserves the rights to change any or all of the above rules as we deem fit. Any change in rules will be highlighted on the website and notified to the participating teams.

7. Restart and Reposition

In both Restart and Reposition, the timer is NOT stopped.

Restart: In each Run for a given configuration, Restart refers to the following steps:

- switching off the robot
- keeping the robot on the Start Node
- switching on the robot
- restarting the code on the laptop

Please note that the **arena will be reset** and **the timer keeps running.**

Reposition: In each Run for a given configuration, Reposition refers to:

- Keeping the robot at the position (i) it started wandering off from or (ii) on any of the nodes it has visited **before it started wandering off**.

Please note that the **arena will not be reset and will remain** as it was before the Reposition and **the timer keeps running.**

Teams can decide whether to switch off the robot or keep it turned on during Reposition.

Each team will be provided two Runs for a configuration for the video submission (Final Task). In each **Run** the team can choose only one of the following cases:

1. two Restarts
2. one Reposition and one Restart
3. two Repositions

If the task is incomplete even after exhaustion of any of the above cases, **the run will be ended and the maximum time for the Task will be considered for that run.**

8. Judging and Scoring System

- The competition time for a team starts from the moment the robot is switched ON. The timer will stop as soon as the robot finishes the task.

The team's total score is calculated by the following formula:

Total Score = (600 – T) + (BP*100) + (BD*100) + BC1 + BC2+ (CBD*100) – (AP*60) - (P*60) + OB

Where:

✓ **Total time (T):**
T is the total time in seconds taken to complete the task.
Time will be considered maximum (600 seconds) if the team is **unable to cross the bridge**.

✓ **Boulder Pickup (BP):**
BP refers to picking up the Boulders from the Boulder Zone. The maximum value of BP is equal to the number of Cavities in the chosen bridge.

✓ **Boulder Drop (BD):**
BD refers to the dropping of the Boulder in the Cavity of the Bridge. The maximum value of BD is equal to the number of Cavities in the chosen bridge.

✓ **Bridge 1 Cross (BC1):**
BC1 is **100** points awarded if the robot chooses and **crosses the Bridge 1** to reach Base Station Node. BC1 is only awarded once in a run.
BC2 = 0 in this case.

✓ **Bridge 2 Cross (BC2):**
BC2 is (100*Ob) points awarded if the robot chooses and **crosses the Bridge 2** to reach Base Station Node.
Ob refers to the total number of Obstacles present on Bridge 2 for a given Configuration.
BC2 is only awarded once in a run.
BC1 = 0 in this case.

✓ **Correct Boulder Detection (CBD):**
CBD refers to each correctly detected number over the Boulder in order to satisfy the given **Sum.** The maximum value of CBD is equal to the number of Cavities in the chosen bridge.

✓ **Adjustment Penalty (AP):**
Adjustment Penalty refers to **60** points deducted from the total score each time the team needs to **manually adjust the dropped Boulder in the Cavity** for smooth traversal of robot over the Bridge.

Note: Teams can ask for manual adjustment **only if** a portion of the dropped Boulder is inside the Cavity.

✓ **Penalty (P):**
Penalty where **60** points are deducted each time the robot dashes or displaces the arena and/or arena components during the run.

✓ **Overall Bonus (OB):**
A bonus of **200** points is awarded if the robot completes all the tasks below:

- Picks all the Boulders
- Drops all the Boulders in the Cavities
- Correctly detects all the numbers on the Boulders
- Crosses the chosen Bridge
- Incurs no penalty (AP and/or P)
- Takes no Restart or Reposition during a run.
- Buzzes the buzzer for 5 seconds at the Base Station Node

Refer to Table 2 to get an idea of the sample scores for different cases.

Table 2: Sample Scores

T	BP	BD	BC1	BC2	CBD	AP	P	OB	Total	Remarks
240	4	4	1	0	4	2	0	0	1540	Bridge 1 is chosen
220	3	3	1	0	3	1	0	0	1320	Bridge 1 is chosen
220	3	3	1	0	3	0	0	1	1580	Bridge 1 is chosen; OB awarded
600	3	2	0	0	3	1	0	0	740	Bridge 1 is chosen; Bridge not crossed
200	2	2	0	3	2	0	1	0	1240	Bridge 2 is chosen
180	2	2	0	3	2	0	0	1	1520	Bridge 2 is chosen
600	2	1	0	0	2	0	0	0	500	Bridge 2 is chosen; Bridge not crossed
200	2	2	0	3	0	0	0	0	1100	Bridge 2 is chosen