NAVIGATE A TERRAIN

1. Introduction

After the success of Mangalyaan Mission, India has taken a huge leap in deep space exploration. As we know, humans are utilizing the resources of the planet Earth on an accelerated rate. This has led us to a problem of resource scarcity. One possible solution to mitigate this problem is to search for viable planetary options that can support human life. It is better to start early in this direction of exploration of planets which can sustain human life as our population is increasing rapidly.

We are limited by the technology of our time and the targeted planets might be more than 300 million km away from Earth. It is not possible to send a manned mission to these planets. The only option we are left with is robotic technology. Automated robotic technology will not only obviate risking the lives of human beings but also help in the reduction of overall cost for such exploration. Consider the following scenario: ePlanet-903 has been discovered with promising features for sustaining life. We have already sent a module to the planet serving as the Base Station, docked strategically at the center of a Region. A robot has to navigate its way to the Base Station guided by signals from the Base Station.

e-Yantra has abstracted such a scenario in this "**Navigate A Terrain**" theme. The Terrain is a Region consisting of five concentric rings. In the middle of the Region in the Base Station is a **"Spotter"** that provides guidance to the **"Rover",** the robot moving through the Terrain. A **Map** of the Terrain is provided indicating the **Checkpoints** along the path to the **Base Station**. Checkpoints ensure accurate tracking of the Spotter by the Rover as it navigates through the concentric rings having openings at random points. The Challenge in this theme is to design and program two independent robotic systems that can communicate with each other in order to navigate the spaces between the rings of the arena without missing the Checkpoints.

In any space exploration mission, time is a critical factor; the challenge is to navigate the terrain in the shortest time possible and reach the Base Station. The robots that perform the task best in accordance with the rules set for this theme will be declared the WINNER of the competition.

2. Theme Description

➢ **Important Definitions:**

- ✓ **Rover**: Rover is a three-wheeled mobile Robotic System constructed for the navigation of Arena.

- ✓ **Base Station:** Base Station is an immobile Robotic System with the following: (i) a controller (ii) a rotating laser pointer system called **Spotter** and (iii) a RGB LED. Base Station is placed inside the light green area at the center as shown in Figure 1.The Spotter guides the Rover with its rotating laser beam.

- ✓ **Checkpoints**: These are the positions of interest for the Rover. Rover should identify the colors of these **Checkpoints**. Checkpoints are of seven distinct colors. Color of the Checkpoints can be repeated. There is a maximum of seven Checkpoints in an Area.

- ✓ **Green Zone:** Green Zone is the designated starting location for the Rover. Rover should be kept inside the Green Zone.

- ✓ **Map**: This is a jpeg image given to the participants. This image is includes the Green Zone, Position of Checkpoints and the Red Zone.

- ✓ **Parking Area:** The area marked by a circle around the Base Station is the Parking Area. This area is divided into 4 sections: P1, P2, P3, and P4 as shown in Figure 1.

- ✓ **Red Zone**: Red Zone is the designated final destination of the Rover. Red Zone can be assigned to any one of P1, P2, P3 or P4.

- ✓ **Ring**: There are five concentric rings which are marked as R1, R2, R3, R4 and R5 around the Base Station. Rings R2, R3, R4 and R5 have **Numbered Nodes (NN)** marked as shown in Figure 1.

- ✓ **Area for Navigation (AFN):** The area between two adjacent concentric rings is called an AFN. There are four AFNs: A1, A2, A3 and A4 as shown in Figure 1.

- ✓ **Openings**: Rover traverses from one **AFN** to another with the help of the **Openings** in the **Rings**; these are marked by missing links between the NNs as shown in Figure 1. For example: R1 has Openings at: 3-4, 8-9 and 12-13. There is a maximum of three and minimum of one Opening in a Ring.

- ✓ **Sector**: Each AFN is divided into Sectors. Consider A1: We draw normal lines from each NN in R2 to R1 to find the Sectors of A1. There are 20 Sectors in A1. An example is marked by blue lines in Figure 1. Note that Sectors in A2 are created by drawing normal lines from **NNs** in R3 to R2, etc.

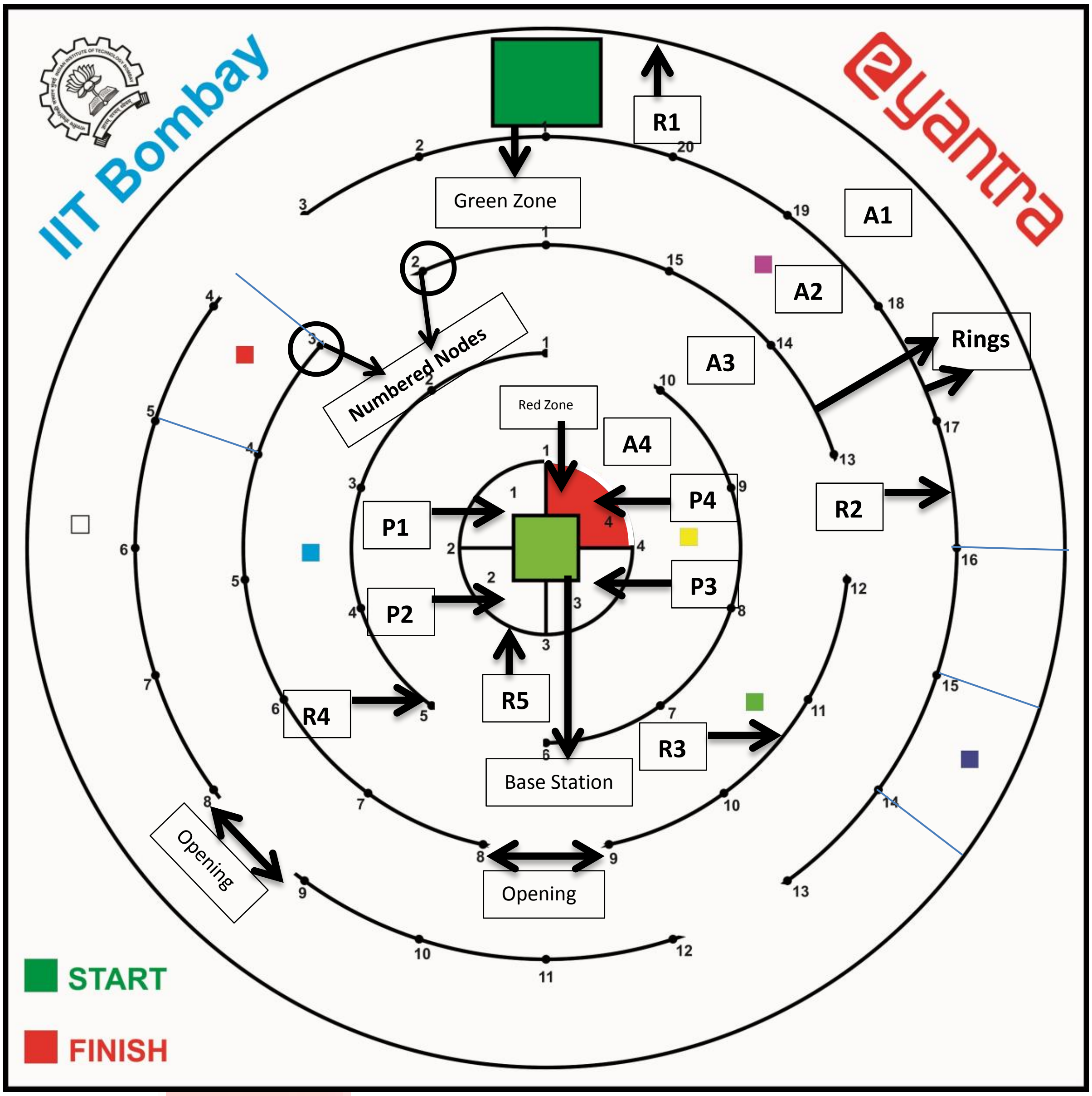

Figure 1: Arena with Checkpoints Placed

The task is divided into two parts:

a) Reading the Map
b) Navigating the Terrain

2. a. Reading the Map

Map is an image which is shown in Figure 2. Note that in the Map the positions of Checkpoints are indicated by black squares. Participants should process this image using the knowledge of image processing and Python programming (Refer to Task 1 and Task 2). After processing the **Map,** important information is extracted related to **Green Zone, Checkpoints, Openings and Red Zone**. According to this information a path is planned from **Green Zone** to **Red Zone** visiting all the **Checkpoints** and traversing through the **Openings**. Reading and processing the Map is done on a separate Computer System and information related to path planned is sent to the **Base Station** wirelessly.

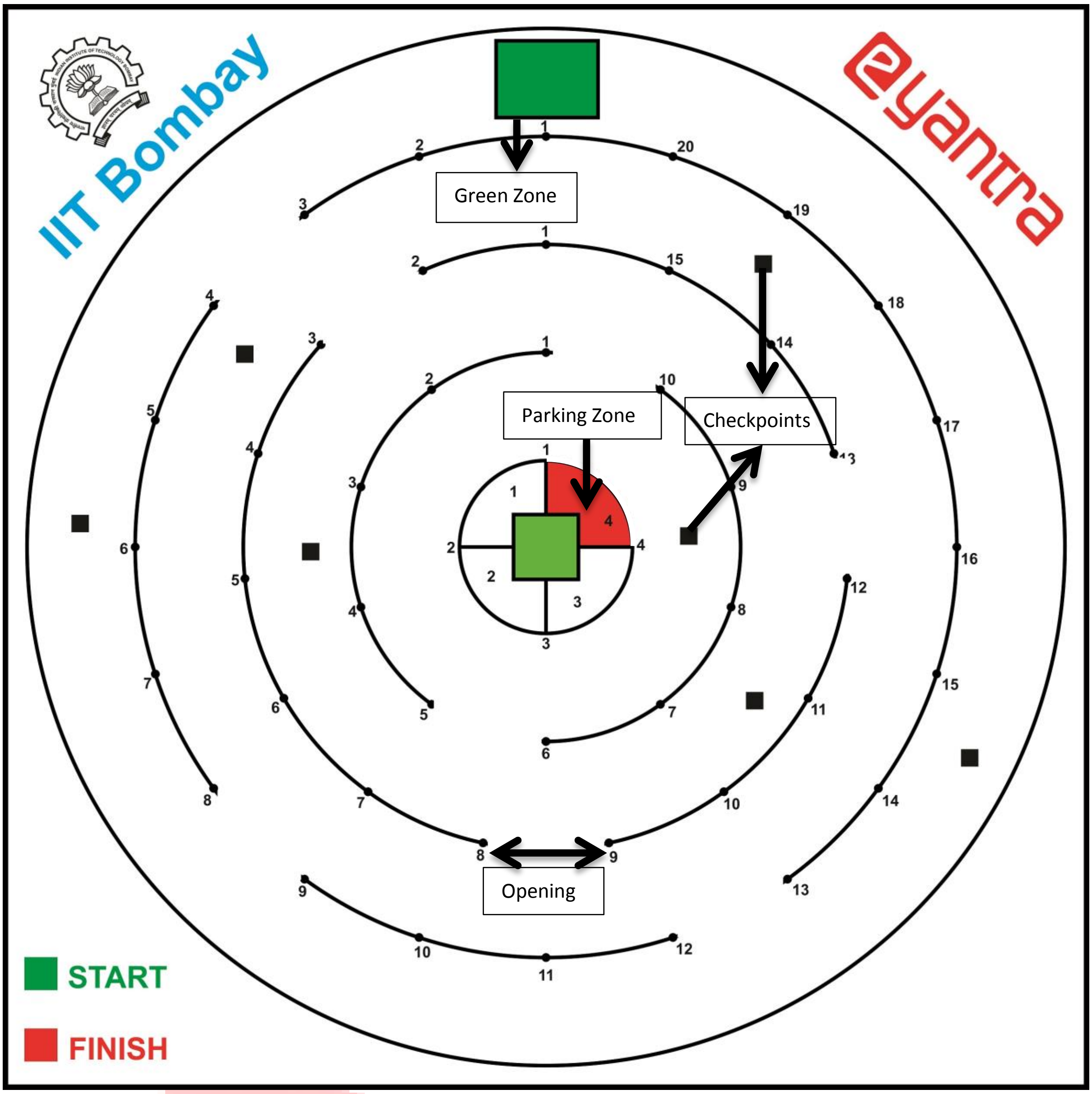

Figure 2: Map

2. b. Navigating the Terrain

Make two autonomous robotic systems namely:

- **Rover**
- **Base Station**

➢ Tasks Performed by Rover:

1. The Rover starts from **Green Zone** of the arena (Refer to Figure 1).
2. Rover traverses from one AFN to other using Openings in the Ring.
3. Rover identifies the color of each Checkpoint and glows the RGB LED on the Rover. This is called **Identifying a Checkpoint**.
4. Rover sends the information related to the identified color to the **Base Station**. (**Base Station** glows a RGB LED of the identified color. This is called **Acknowledging a Checkpoint.)**

5. After navigating through the AFNs and Identifying all the Checkpoints, Rover has to stop at the **Red Zone**.

➢ Task Performed by Base Station:

1. Spotter is a pan/tilt system attached to a laser and is a part of Base Station. The main objective of the Spotter is to guide the Rover from Green Zone to Red Zone using a laser as shown in Figure 3.
2. Base Station includes all the circuitry to control the Spotter. Spotter projects a laser dot to guide the Rover. Spotter moves the laser dot and the Rover follows the laser dot.

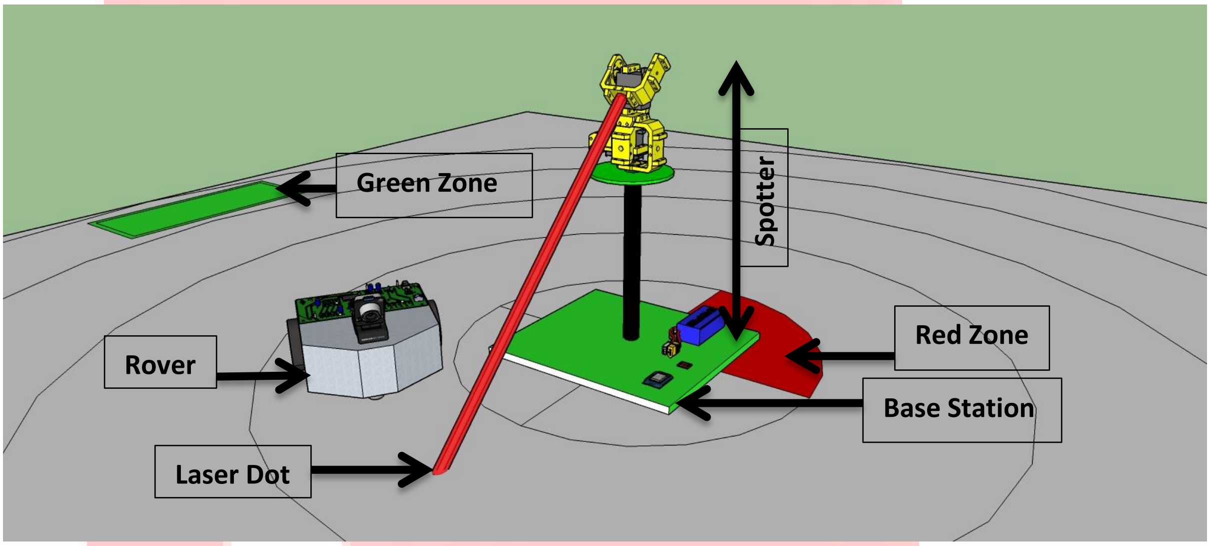

Figure 3: Base Station with Spotter

3. Base Station glows a RGB LED to **Acknowledge a Checkpoint** identified by the Rover.

4. As explained in Section 2.a., the **Base Station** receives the information of the path planned. According to this data **Spotter** guides the Rover from Green Zone, to traverse through the Openings, acknowledging the Checkpoints, to Red Zone.

3. Arena

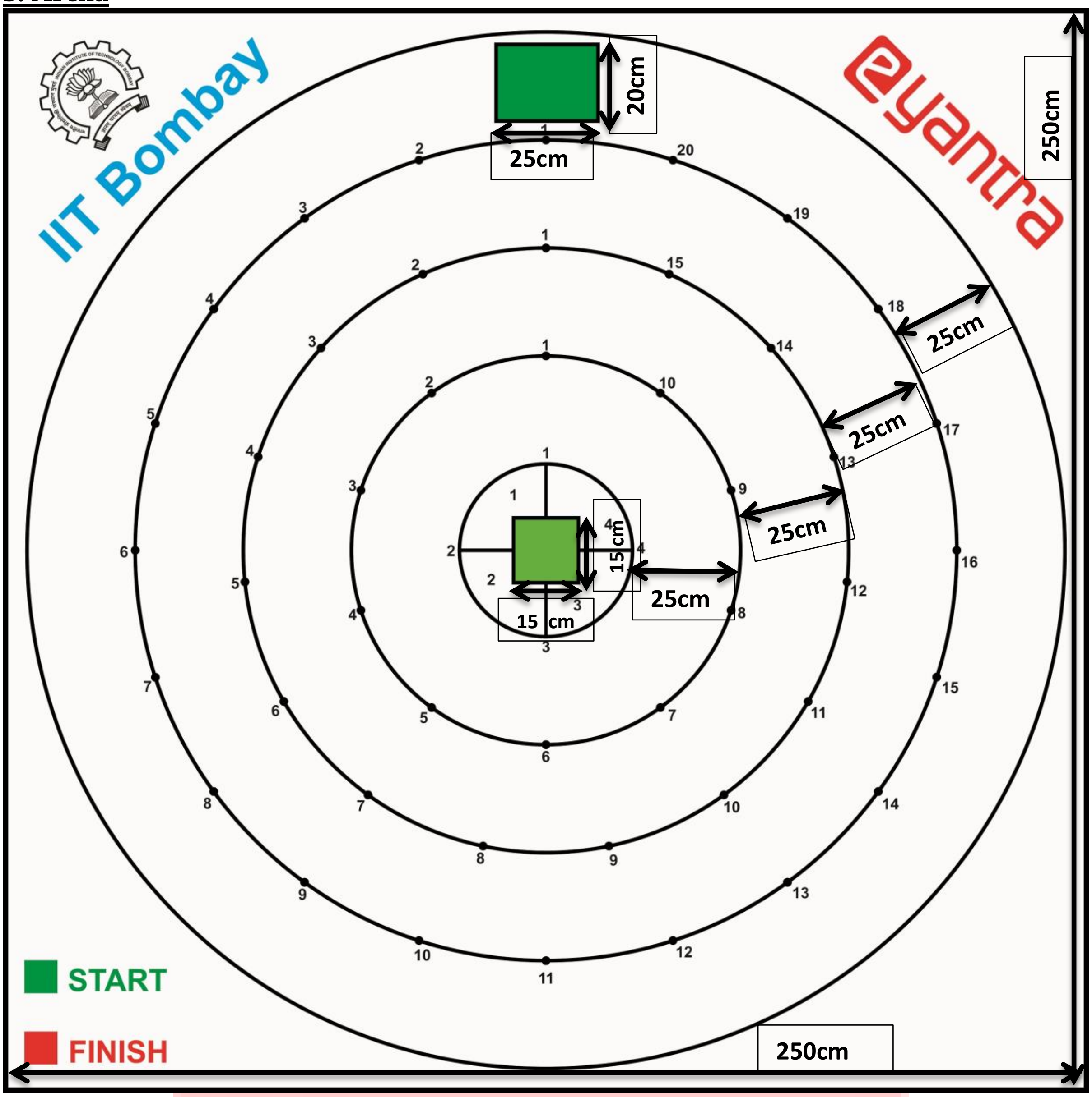

Figure 4: Arena Design with Dimensions

Preparing the Arena:

Each team has to prepare the arena. Preparing the arena consists of three steps.

1. Printing the arena design on the flex sheet.
2. Preparing and Placing Checkpoints.
3. Preparing the Red Zone.

NOTE: Teams are not allowed to make any changes in the arena design. Any team making unauthorized modifications will be disqualified from the competition.

3.1. Printing the arena design on flex sheet:

A .pdf file containing the flex design will be provided to the teams. Each team prints the flex design according to the direction given in the .pdf file.

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.

Details of arena design:

- Dimension of the flex sheet is 250 cm x 250 cm.
- The distance between each adjacent concentric ring is 25cm.
- There is a light green square at the center 15cm x 15cm.
- All the **Rings** in the arena are numbered as shown in Figure 4.
- According to the **Map of the Arena** (Figure 2), stick white tape between two consecutive numbers on a ring printed on flex. This will create openings in the ring for the rover to shift from one Region to other. For example: In **C2** there is an opening between **"2" and "3"** as shown in Figure 1,please stick the white tape on the arena in such a manner that it covers the curved line of **C2** between **"2" and "3"(**Figure 5**).**

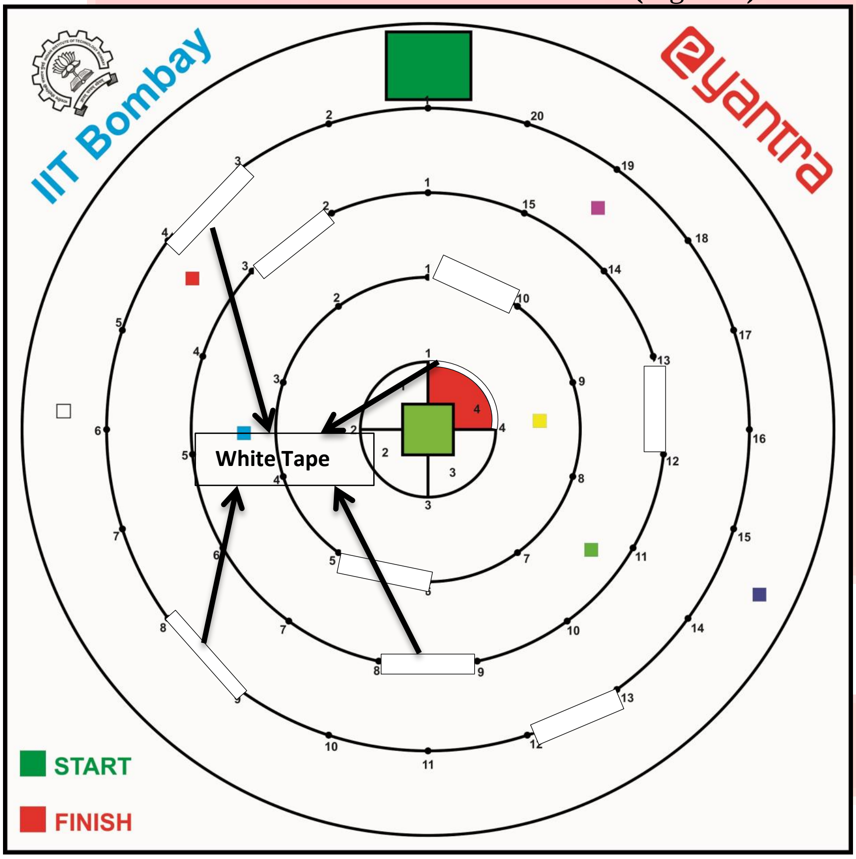

Figure 5: Arena after Sticking White Tape

- Arena will look like Figure 5 after applying white tape according to Map of the arena shown in Figure 2.

NOTE: Figure 5 shows rectangular boxes to depict the white tape.There is no black outline on the tape.

3.2 Checkpoints for the Rover.

These are colored patches of dimension 4cm x 4cm.The color of the checkpoints can be Red, Green, Blue, Sky-blue, Yellow, Pink and Black bordered white.

- Please cut the colored papers provided in the kit to a perfect square of dimension 4cm x 4cm. For white Checkpoints use black marker to outline the edges of thickness 0.5cm.
- The placement of colored Checkpoints will be according to the Table 1 given below:

	Ring	Number on the ring (**Sector**)	Color
1	R1	5-6	White
2	R2	3-4	Red
3	R3	3-4	Sky blue
4	R4	1-4	yellow
5	R1	14-15	blue
6	R2	14-15	Pink
7	R3	7-8	Green

Table 1: Colored Checkpoint Placement

- Figure 6 depicts the placements of colored Checkpoints according to Table 1 and map in Figure 1.Note that this is an example configuration. You must practice with different configurations for the competition.
- Each Checkpoint should be placed as per the position (as accurately as possible) indicated in the Map. An example is shown in Figure 6.

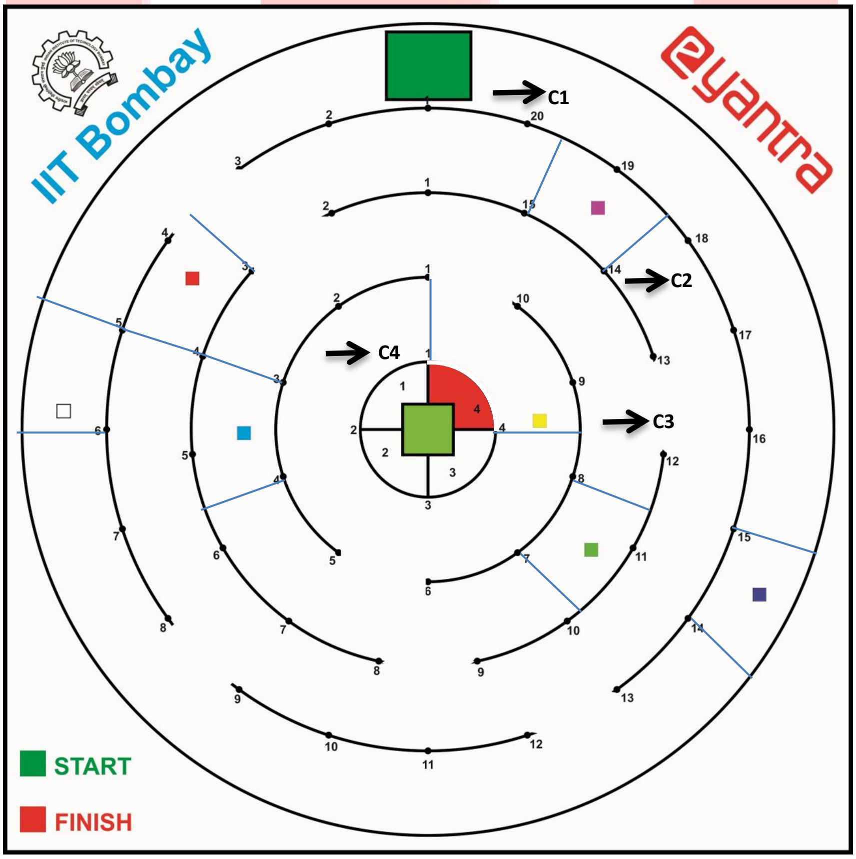

Figure 6: Placement of the Checkpoints

Note: Please know that Table1 will be given just before start of a run during the finals. Teams have to use image processing techniques to identify the colors.

3.3 Red Zone:

- A red colored patch is used to indicate the **Red Zone**.
- Cut a red chart paper according to dimensions**,** shown in Figure 7.

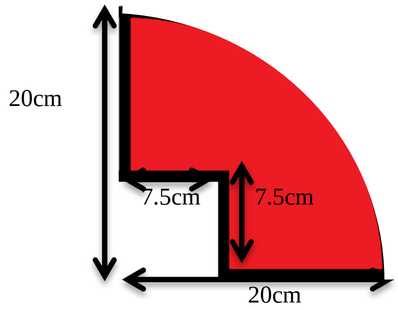

Figure 7: Dimensions of Red Zone

- Place the patch at the appropriate Parking Area as indicated in the Map.

4.Robots

Constructing the Robots:

Each team has to construct the following two robotic systems:

1. Rover
2. Base Station with the Spotter

4.1 Rover

Rover is a three wheeled mobile robot, constructed for the navigation of Arena.

- The height of the rover should not be more than **30cm.**
- Assembling the rover includes appropriate connections between RGB LED, chassis, motor driver, battery pack, Raspberry_pi, camera and wifi_dongle (Separate documentation is provided for Rover Assembly).
- Male and female connectors are given to make appropriate connections between the components.
- Figure 8 displays the setup of a Rover. Your Rover might not look the same.

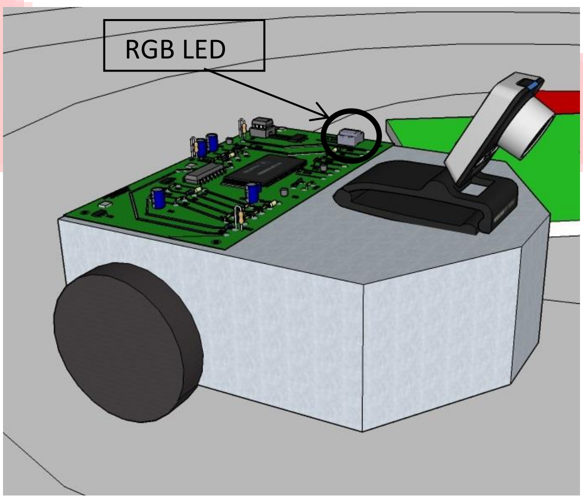

Figure 8: Rover with RGB LED

4.2 Base Station with spotter

Base Station controls a rotating laser pointer system called Spotter. The Spotter will guide the Rover with a rotating laser beam.

- Base Station is made of a small plate (any material of choice) of dimension 15cm x 15 cm.
- Base Station includes node_mcu (controller), logic_level_converter, lipo_battery, RGB LED, servo motors (Separate documentation is provided in “Working with Node_MCU”).
- Spotter is at the center of the Base Station.
- The height of the Base Station including the Spotter should not be more than **60cm**.
- Spotter is a small tower made of PVC pipe (any material of choice) fitted to the Base Station. On the top of the Spotter, two servo motors work in a pan/tilt fashion.
- This Pan/Tilt system is attached to a laser as shown in Figure 9 so that laser pointer can cover the entire surface of the arena.

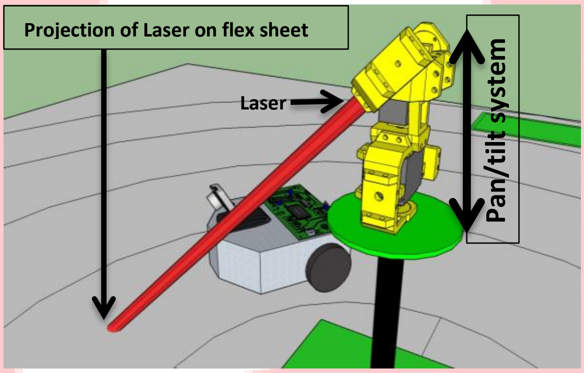

Figure 9: Spotter with Pan/Tilt System

- You are allowed to use additional actuators to design the Spotter though only two are provided with the kit which is sufficient to build a Pan/Tilt system. Use your creativity to come up with a sleek design.
- Designing and assembling of all the components of Base Station and Spotter will be done by the team. This will include appropriate connections between the provided components and construction of the structure as shown in Figure 3 with appropriate dimensions.

5. Hardware Specifications

5.1 Use of Raspberry Pi:

- All participating teams must use **only** the Raspberry Pi sent to them in the kit. **Only one** Raspberry Pi is allowed per team.
- The Raspberry Pi robot assembled by the teams should be **completely autonomous**.

5.2 Use of Node_MCU:

- All participating teams must use **only** the Node_MCU sent to them in the kit. **Only one** Node_MCU is allowed per team.
- The Node_MCU based robotic system assembled by the teams should be **completely autonomous**.

5.3 Components:

- Along with the Raspberry Pi, teams shall receive a Wifi Dongle, a 16GB memory card, an Intex USB Camera, Intex 6000 mah Power Bank, Chassis, node_mcu (controller), logic_level_converter, lipo_battery, RGB LEDs.

- The team is NOT allowed to use any other sensors apart from those provided in the kit. However, they are allowed to create any type of mechanical structure for mounting the camera within the allowed dimensions.
- Teams may connect external actuators along with their driver circuits to the robots, only on the condition that the actuators must be controlled through Raspberry_pi or Node_MCU.

5.4 Power Supply:

- The Raspberry Pi can be powered through the power bank that is shipped in the kit.
- Node_MCU can be powered through the lipo_battery that is shipped in the kit.
- The team may use alternative power sources during practice. However, during the video demonstration and final run, the team will not be allowed to use any other power source for powering the Raspberry Pi and Node_MCU.

Note: No other expansion and/or microcontroller-based boards shall be attached to the Raspberry Pi or Node_MCU.

6. Software Specifications

- e-Yantra has provided all teams with Python and OpenCV, pre-installed in the raspbian image that can be downloaded from the Resources tab on the portal.
- The teams must use OpenCV and Python to write their code.
- Use of any **non-open source libraries** is not allowed and will result in disqualification.
- As per e-Yantra policy, all your code and documents are open-source and maybe published on the e-Yantra website.

7. Theme Rules

- The maximum time allotted to complete the run is 12 minutes. A maximum of two runs will be given to a team (the better score from the two runs will be considered as the team's score). A maximum of two repositions (explained below) will be allowed in each run.
- All teams will be asked to submit their Rover and Base Station (both should be turned OFF).
- Before the start of the run, Rover should be kept in the Green Zone and the Base station should be kept at the center covering the light green area.
- Each team will be given a laptop with the **Map.**
- The team should switch **ON** the **Rover** and **Base Station** when told to do so by reviewer. Rover should not move at this point.
- Once the robots are switched on, human intervention is NOT allowed.
- Team is given two minutes to connect the laptop to Base Station's WIFI. Failure to connect will result in end of the run.
- Team is asked by the reviewer to run their Python code on the laptop provided. The timer will start at the same time. This is the start of the run.
- After receiving the data from the laptop, Base station should start rotating the laser.
- Rover should start to move and follow the laser in the AFNs.
- Rover traverses from one AFN to another **only** through the Openings; it should not go over the Rings.
- While traversing through an AFN, if the Rover encounters any Checkpoint, it must **stop**, **Identify the Checkpoint** and transfer this information to the Base Station. Base Station should glow the RGB LED according to the identified color **Acknowledging the Checkpoint**. Rover starts following the laser again.

- Note that the Rover starts moving from a Checkpoint only after RGB LED is glowed on the Base Station.
- Rover should not step over the rings on the arena. Crossing and touching the ring will result in penalty.
- Rover should stop at the Red Zone. This will be considered as end of the Run.
- While parking at the Red Zone, the Rover should not cross any of the other sections of the Parking Area.
- A run ends and the timer is stopped when:
  - ✓ The robot stops at Red Zone or
  - ✓ If the maximum time limit for completing the task is reached or
  - ✓ If the team needs repositioning (explained below) but has used both repositioning options of that run.
- 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.
- Participants are not allowed to keep anything inside the arena other than the robots. The time measured by the reviewer will be final and will be used for scoring the teams.
- Time measured by any participant by any other means is not acceptable for scoring.
- 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.

➢ **Repositioning of robot:**

Robot repositioning is done under following circumstances:

- If the Rover gets stuck in the arena or goes off the arena, teams can ask for the reposition.
- For a reposition, the Rover is moved immediately to the last traversed **Sector** upon signal from the reviewer. During a reposition, the timer will not be set back to zero.
- Each team is allowed a maximum of two repositions in each run. All repositions require the approval of the reviewer; the team will be disqualified if the robot is handled within the arena without approval.
- During repositions, a participant must not feed any information to the robot. A participant may not alter a robot in a manner that alters its weight. The reviewer’s decision is final.
- After reposition, the robot has to complete the remaining task; the Identification and Acknowledgment of Checkpoints done correctly will be counted in the score.
- Points for Identification and Acknowledgement of a Checkpoint will be considered only once after a Reposition.

NOTE:

• 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.

8. Judging and Scoring System

- The competition time for a team starts from the moment python code is run on the Computer system. The timer will stop as soon as the robot finishes the task.
- The better score of the two runs for a team will be considered as the final score of the team.
- The team's total score is calculated by the following formula:

Total Score = (720 - T) + (CIC*50) + (CAC*50) + (CP*50)-(RP*70)-(P*30) +OB

Where:

- **Total time (T):**
  T is the total time in seconds taken to complete the task.

- **Correct Identification of Checkpoints:**
  CIC is the total number of Correctly Identified Checkpoints by the Rover. CIC is counted only on glowing the RGB LED after identification of the color by Rover.

- **Correct Acknowledgement of Checkpoints (CAC):**
  CAC is the total number of Correctly Acknowledged Checkpoints by the Base Station. CAC will be counted only on glowing RGB LED by Base Station after receiving the information from the Rover.

- **Ring Penalty(RP):**
  RP is Ring Penalty where 70 points are deducted each time Rover crosses a Ring to go from:
  I. One AFN to another.
  II. AFN to the Red Zone.

- **Correct Parking (CP):**
  CP is the Correct Parking of the Rover. CP is counted when Rover stops in the Red Zone.

- **Penalty (P):**
  P is penalty where thirty points are deducted each time the robot:
  (i) Touches a ring while traversing through AFNs.
  (ii) Parks in a section other than the Red Zone.

- **Overall Bonus Points (OB):**
  100 Bonus points will be awarded, if ALL of the following are done:
  1. All the Checkpoints on the Arena are Identified and Acknowledged.
  2. The Rover is parked in the Red Zone.
  3. No penalty is incurred.

ALL THE BEST…!!!