

SEARCH AND RESCUE

Introduction

When disaster strikes, we are only left to the mercy of Mother Nature. In the aftermath of a calamity like an earthquake, it is our duty to search for Survivors and provide them with some kind of immediate medical attention they need in order to survive. In such places, humans who look for Survivors are not only doing so in a time consuming and ineffective manner, but also by putting their own lives at risk. Using autonomous robots in such applications may prove to be a more effective and also safe.

Keeping with the importance of this subject, “Search and Rescue” is one of the themes in the e-Yantra Robotics Competition Plus (eYRC+ 2015 (eLSI)). It consists of a team of two robots: a Search Robot and a Rescue Robot. Through this theme, we focus on automating the task of searching for Survivors among debris (ruins), identifying the intensity of their injuries, and giving them the appropriate medical treatment.

Teams will complete tasks related to the implementation of the Search and Rescue theme using the robotic kit they have collected from their college along with an additional robot provided to them by e-Yantra. The two robots will work in coordination: the Search Robot will scan the arena and look for Survivors present under the debris whereas the Rescue Robot will perform the appropriate medical action based on the level of injury of the Survivor.

The team that performs the task best as per the set rules will be declared the **WINNER**.

1. Theme Description

- Figure 1 shows the arena design for this theme. The arena is an abstraction of a disaster-affected area made up of a grid with the **START** Position and **Medical Camp** marked.
- The grid is made up of 16 squares called **Plots**.

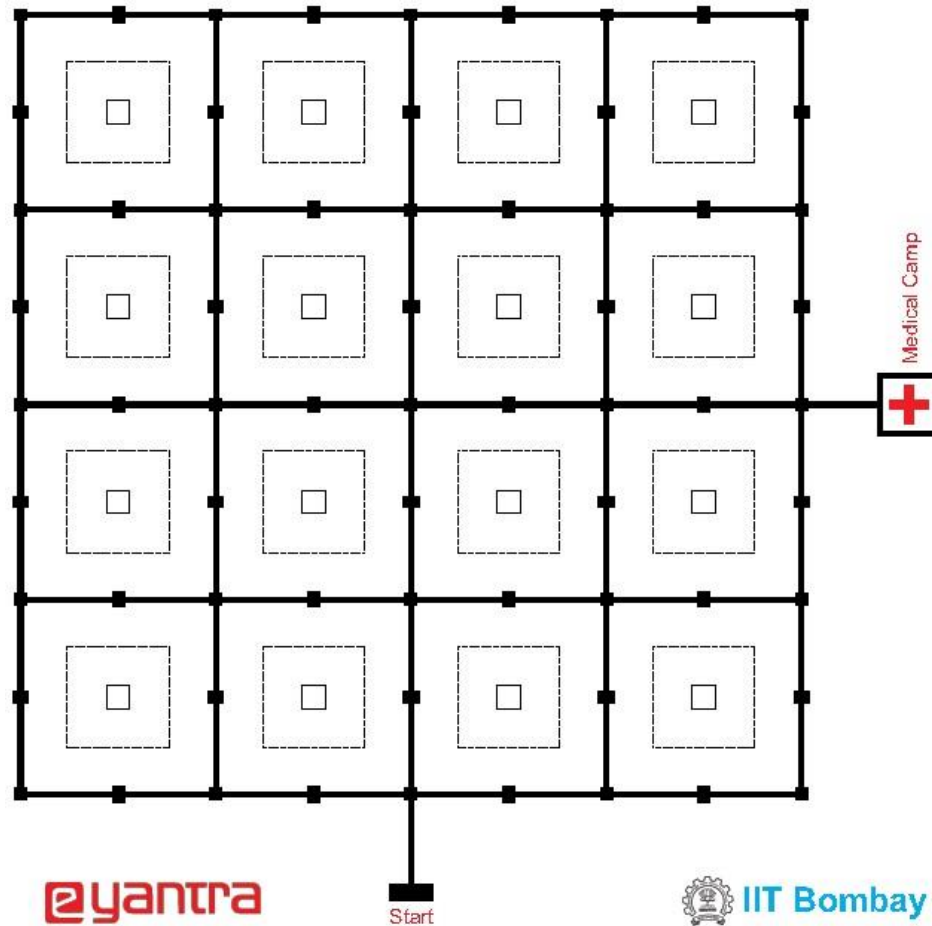


Figure 1: Search and Rescue Arena

- Each Plot has the following terms associated with it:
 - Four **Mid-Point Markers** on every path around the Plot. Figure 2a highlights the Mid-Point Markers for a Plot.
 - The **Clearing Zone**, which is shown by the dotted square of 26cm x 26cm, highlighted in the green box in Figure 2b.
 - A 6cm x 6cm **Inner Square** that is highlighted in Figure 2c.
 - Four **Nodes** present at the corners of every Plot. This is shown in Figure 2d.

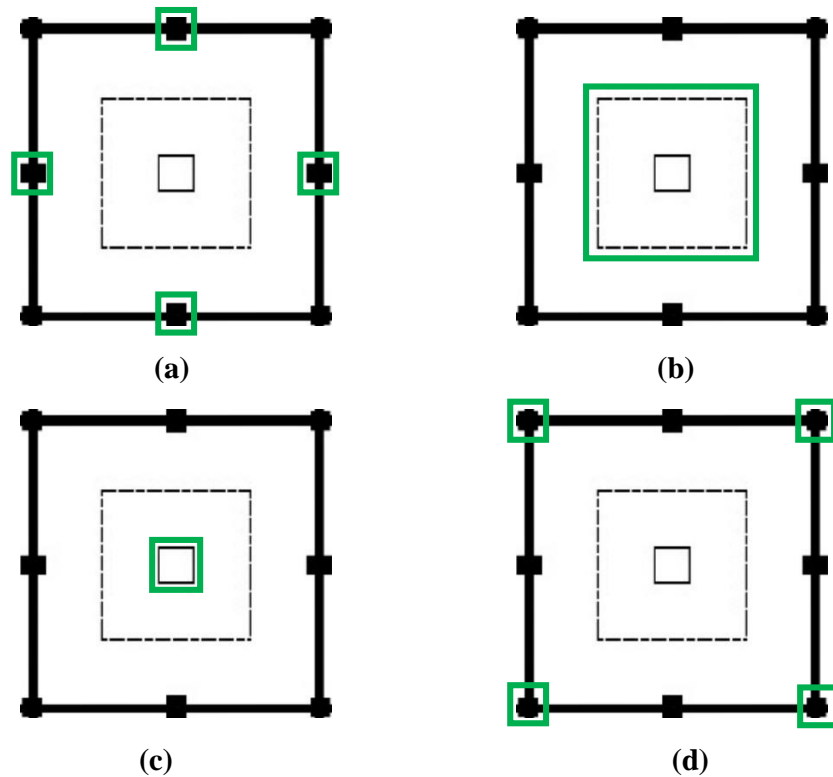


Figure 2: Illustration of Terms Associated with a Plot

- Rectangular/Cuboidal thermocol blocks are used to represent debris. Two colors, Black and White are used to represent the **types** of debris. The **Black Debris** represent pieces of debris strewn on the roads which cannot be moved, thus causing a roadblock. The **White Debris** represent collapsed houses, under which there are injured **Survivors**. Figure 3 shows White Debris and Black Debris. Creating the White and Black Debris is discussed in **Section 2.1**.

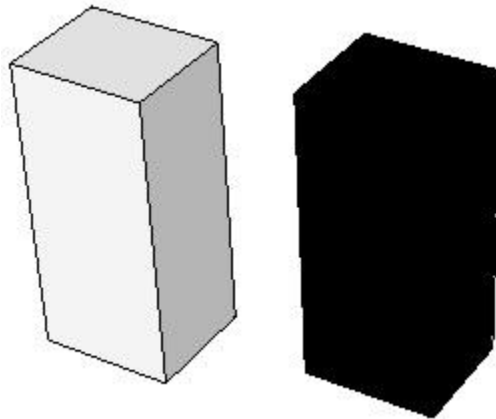


Figure 3: White and Black Debris

- There are two kinds of Survivors defined for this theme (i) **Green Survivors** and (ii) **Red Survivors**. They are represented by the colors **Green (G)** and **Red (R)**. Green Survivors are those with minor injuries and Red Survivors are those with severe injuries. Figure 4 shows the two types of Survivors in the arena. Creating the Green and Red Survivors is discussed in Section 2.3.

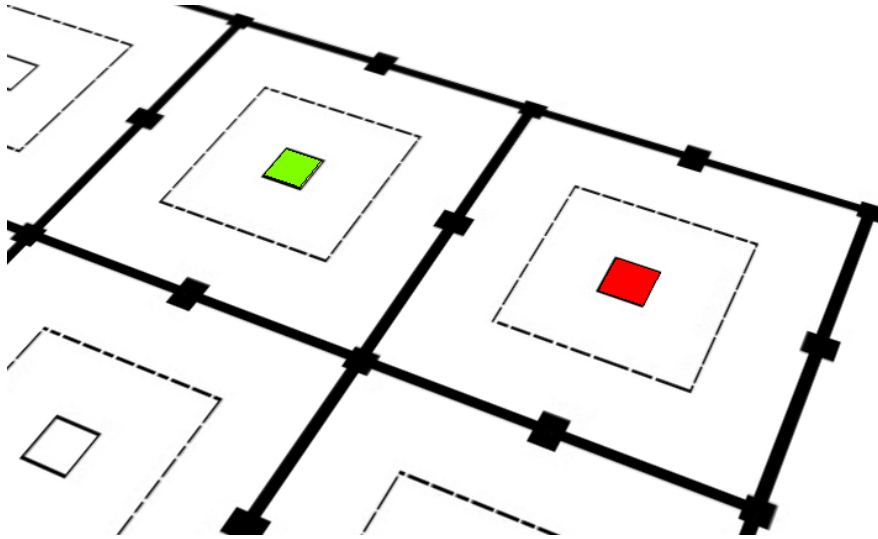


Figure 4: Red and Green Survivors in the Arena

- Red Survivors need to be **transported** to the **Medical Camp** for immediate medical attention. On the other hand, Green Survivors do not need to be transported to the Medical Camp. Instead, a **First-Aid Kit** must be deposited near them to treat their minor injuries.
- The First-Aid Kits are represented by **white wooden boxes** of dimensions 1.5cm x 1.5cm x 1.5 cm. Figure 5 shows the First-Aid Kits. Steps to create these First-Aid Kits are given in Section 2.2.

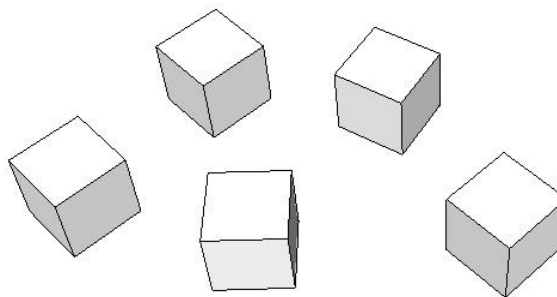


Figure 5: First-Aid Kits

- For the purpose of this competition, (i) any of the 16 Plots may contain **White debris** (ii) exactly **one** Survivor will be found under **every** White Debris in the arena and (iii) **Black debris** may be placed on Mid-Point Markers of any of the Plots such that every Plot in the arena will have at least one path for the robot to service the Survivors.

- There are two Robots involved in this task (i) a **Search Robot** and (ii) a **Rescue Robot**.
- The **Search Robot** will use the following components:
 - (i) **Distance Sensor**: To identify the presence of White Debris in the plots.
 - (ii) **Buzzer**: To provide any indications.
 - (iii) **RGB LED**: To provide visual indications of the color of the Survivor.
 - (iv) **Color Sensor**: To identify the color of the Survivor under the debris
 - (v) **White Line Sensors**: To help it navigate along the black lines of the arena.
 - (vi) **Rotary Encoders**: To help it move precise distances and make precise rotations.
 - (vii) **Debris Clearing Mechanism**: To help it move the White Debris to the Clearing Zones of the plots.
 - (viii) **Zigbee Wireless Communication Module**: To help it wirelessly communicate any information with the Rescue Robot.
- The **Rescue Robot** will use the following components:
 - (i) **Distance Sensor**: To identify the presence of White Debris in the plots.
 - (ii) **Buzzer**: To provide any indications.
 - (iii) **RGB LED**: To provide visual indications of the color of the Survivor to be serviced.
 - (iv) **White Line Sensors**: To help it navigate along the black lines of the arena.
 - (v) **Rotary Encoders**: To help it move precise distances and make precise rotations.
 - (vi) **First-Aid Kit Depositing Mechanism**: To help it deposit the First-Aid Kits to the Green Survivors.
 - (vii) **Zigbee Wireless Communication Module**: To help it wirelessly communicate any information with the Search Robot.
- The **Search Robot** and **Rescue Robot** perform the following tasks:
 - * **Search Robot**
 - This robot will start from the **START** position of the arena.
 - It must traverse around the arena and check for the presence of a White Debris in each plot.
 - i. If a White Debris is not present in the Plot, the robot must indicate so by glowing **Blue** on the LED and ringing a buzzer for 2 seconds. This indication can be done only from one of the Mid-Point Markers associated with that empty Plot.
 - ii. If a White Debris is present, it must complete an **Identification Routine (IDR)** as specified below:
 - It must move the White Debris completely into the **Clearing Zone** of the same Plot and reveal the Survivor present under it. The correct method of moving the White Debris is explained in **Section 3**.
 - The Search Robot must scan the color of the Survivor. It must light the RGB LED with the corresponding color for a period of 2 seconds and transmit the location and type of Survivor to the Rescue Robot.

iii. The Plot will be considered **Scanned** if and only if (i) or (ii) is performed correctly by the Search Robot for that Plot, otherwise it will be considered **Missed**.

- The Search Robot may scan the Plots in any order.

* Rescue Robot

- This robot will start from the **Medical Camp**. At the start of the run, the RGB LED of the robot will be switched OFF.
- It must receive information about the locations and types of injury of the Survivors identified by the Search Robot.
- For every Survivor it receives information about, it must perform a **Medical Service Routine (MSR)** as specified below:
 - i. It must light an RGB LED indicating which type of Survivor it is about to provide Medical Service to. This will also indicate that it has started the **MSR**.
 - ii. It must travel towards the plot containing Survivor of the corresponding color. It may only access a Survivor in a Plot from any of the **Mid-Point Markers** associated with that Plot.
 - iii. Depending upon the color of the Survivor, it must perform the appropriate **Medical Action**:
 - **Red Medical Action:** In case of a Red Survivor, the Rescue Robot must **turn to face** the Survivor and ring the Buzzer for a **period of 1 second**. This indicates that the Survivor has been **picked up**. The robot must then travel back to the Medical Camp. Once it reaches the Medical Camp, it must **switch OFF** the LED and ring the Buzzer for a **period of 1 second**, indicating that it has **transported the Red Survivor**.
 - **Green Medical Action:** In case of a Green Survivor, the Rescue robot must deposit **one** First-Aid Kit. It must then **switch OFF** the LED and ring the Buzzer for a **period of 1 second**.
- The Rescue Robot must give priority to the Red Survivors over the Green Survivors. However, once it has begun the **MSR** for a particular colored Survivor, it must **complete the current MSR** for that Survivor before it is allowed to serve another Survivor. If the robot has made a decision to service a Green Survivor and glowed its LED Green, it must complete the MSR for a Green Survivor on the arena irrespective of whether the Search Robot has uncovered a Red Survivor after it has lit the LED.
- The following points illustrate different cases of the order in which the Survivors must be serviced by the Rescue Robot:
 - i. If there are **ONLY** Red Survivors on the arena to be serviced, the Rescue Robot may perform the **MSR** in any order.

- ii. If there are ONLY Green Survivors on the arena to be serviced, the Rescue Robot may perform the **MSR** in any order.
- iii. If there are both Red and Green Survivors on the arena to be serviced:
 - If the Rescue Robot is **not** performing any **MSR**, it must service the Red Survivors first (in any order) and then service the Green Survivors (in any order).
 - If the rescue Robot is currently performing an MSR for a Green Survivor, it must first complete the current MSR. After completing that MSR, it must first serve all the Red Survivors (in any order) and then the Green Survivors (in any order).
- * The robots must not collide with each other at any point in time.
- * They must not touch/displace the Black Debris during the run.
- * They may communicate any individually sensed information about the arena to each other wirelessly through the Zigbee Wireless Communication Module.
- * They must continue to perform the task until **BOTH** the following conditions are fulfilled:
 - i. ALL plots have been scanned
 - AND**
 - ii. ALL Survivors have received Medical Service
- * When both the above conditions are satisfied, the Rescue Robot must ring a **continuous buzzer** of at least **5 seconds** to indicate the end of the run.

2. Arena Configuration and Setup

2.1. Preparing the Black and White Debris

Materials required for preparing the Debris:

1. Thermocol sheet for making the Debris.
2. Black color and White color chart paper.

Preparing Debris:

Teams will prepare two kinds of Debris - A and B. Characteristics of these Debris are given in Table 1.

Debris	Length	Width	Height	Color	Number
A	5	5	10	White	10
B	5	5	10	Black	15

Table 1: Debris Characteristics

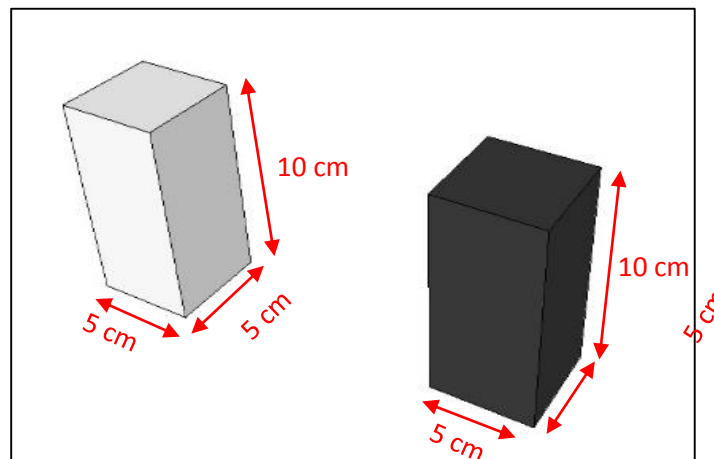


Figure 6: Dimensions of Black and White Debris

After the Debris have been prepared from the thermocol sheets, they must cover the Debris using Black and White Chart paper. This is the final form of the White and Black Debris to be used in the theme.

Note: Teams have already prepared the White and Black Debris during Task 1.

2.2. Creating the First-Aid Kits

Materials required for preparing the First-Aid Kits

1. Wooden Blocks (provided in kit)
2. Markers/Pencils
3. White Chart Paper
4. Cutting Tools

Preparing First-Aid Kits

Every team has been given two long blocks of wood along with the Robotic Kit. The colors and lengths of these blocks have no significance. These blocks have base dimensions of approximately 1.5cm x 1.5cm. Figure 7 shows the blocks given.

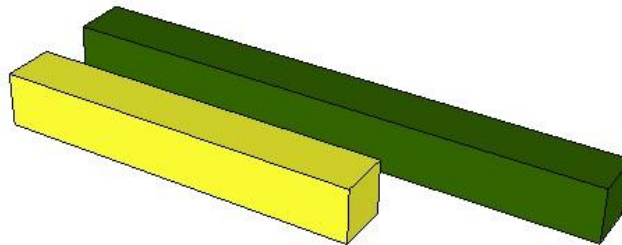


Figure 7: Colored blocks provided with kit

Every team must prepare the First-Aid Kits from these blocks. Each first aid kit will have an approximate dimension of 1.5cm x 1.5cm x 1.5cm. Teams must visit a carpenter or contact their college workshops to prepare the First-Aid Kits. The blocks must be marked at every 1.5cm as shown in Figure 8 and cut into pieces.

Please note: It is sufficient to cut only 5 pieces. The second block is only an extra block and can be used in case the first block is insufficient to cut the pieces due to any damage or mistake.

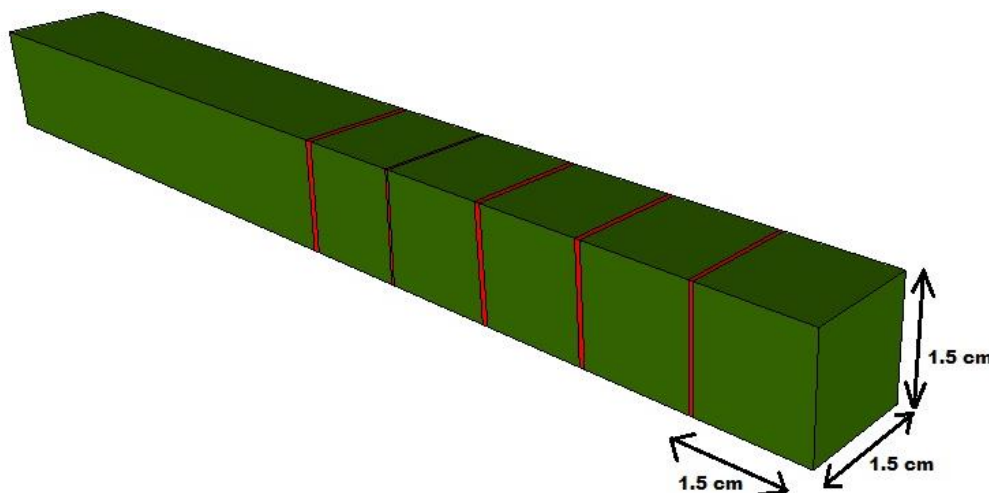


Figure 8: Marking the Block at Every 1.5cm

After cutting the pieces, you must cover them in white chart paper as shown in Figure 9:

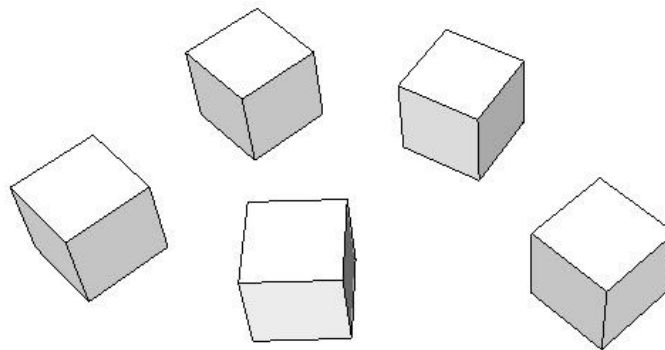


Figure 9: First-Aid Kits

2.3. Preparing the Colored Survivors

Materials required for preparing the Colored Survivors:

1. Colored Paper
2. Scissors
3. Sellotape

Preparing the Colored Survivors:

Teams are required to obtain colored paper from local stationary shops similar to the samples provided in the Robotic Kit.

You must cut these into **square patches** of **6cm x 6cm**. These patches must be stuck in the appropriate Plots according to a **White Debris Configuration String** (details of this are given in **Section 2.5**), inside the **Inner Square** of the Plots. You must use transparent sellotape to stick these patches. Figure 10 shows a Green Survivor stuck with transparent sellotape in the Inner Square of a Plot.

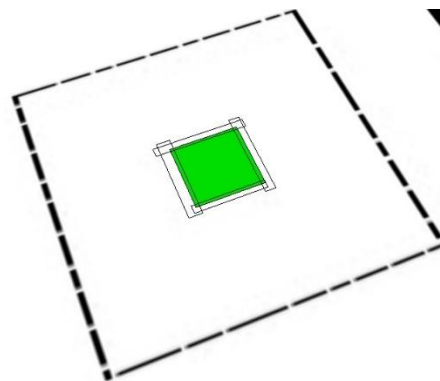


Figure 10: Sticking the Colored Patch with Transparent Sellotape

2.4. Arena Configuration

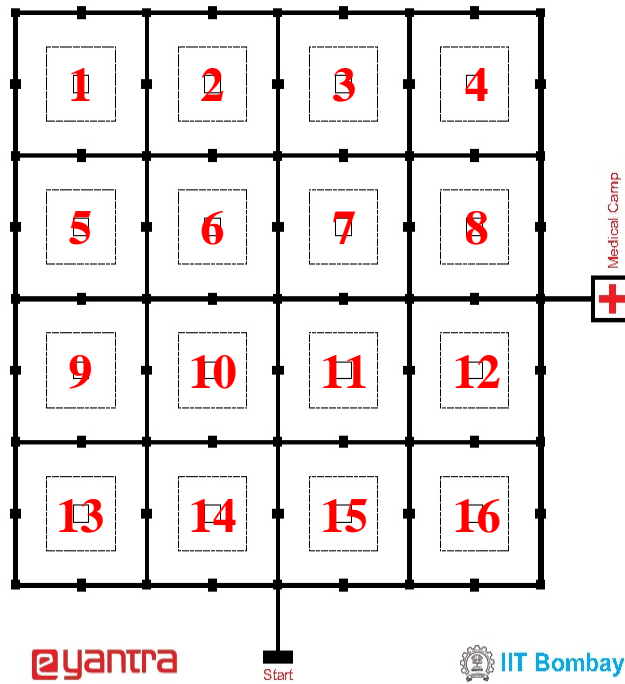


Figure 11a

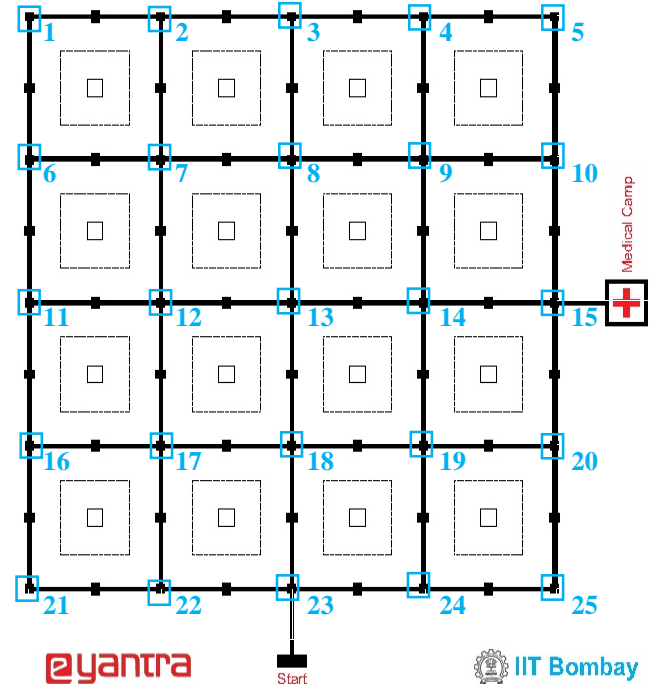


Figure 11b

For ease of reference:

- The Plots in the arena are numbered from 1 through 16 as illustrated in red in **Figure 11a**.
- The Nodes in the arena are numbered from 1 through 25 as illustrated in blue in **Figure 11b**.

Two types of **Arena Configuration Strings** will be given as input to the teams for the **Video Demonstration (Task 6)**:

- The White Debris Configuration String and
- The Black Debris Configuration String

White Debris Configuration String

This string will be used for the placement of the White Debris and Survivors on the arena.

It is a random string of numbers (between 1 and 16) of any length. These numbers correspond to the plots in which you must place the White Debris. Each number will also be accompanied by a character (R or G) indicating the color of the Survivor to be placed beneath the White Debris in that Plot. Refer to the example below for further clarity.

Example of White Debris Configuration String:

[(1-R), (3-G), (6-R), (9-R), (10-G), (12-G), (13-R), (16-R)]

(1-R) means that plot number 1 will have White Debris having a 'Red Survivor' beneath it.

Placement of White Debris on the arena involves the following two steps: (i) sticking the appropriate colored Patch and (ii) placing the White Debris on it. These two steps of Placement for (1-R) are illustrated in Figures 12a and 12b.

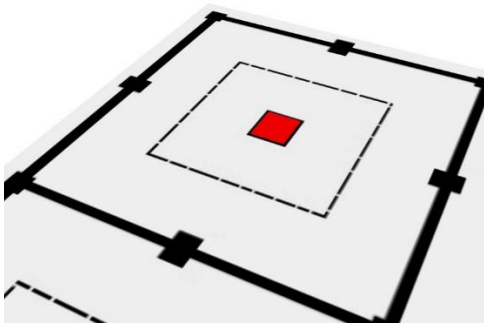


Figure 12a: Red Survivor in Plot 1

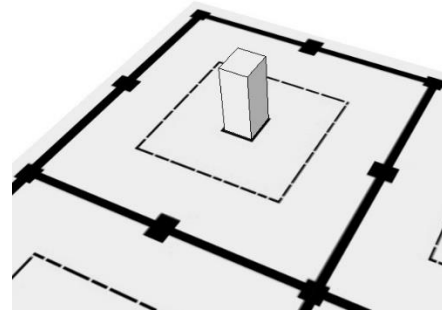


Figure 12b: White Debris in Plot 1 placed over the Red Survivor

For the given White Debris Configuration String, the Colored Survivors will be stuck to the arena as shown in Figure 13. White Debris Blocks must then be placed over these colored patches. Refer to Figure 14 for the setup of the arena corresponding to the White Debris Configuration String.

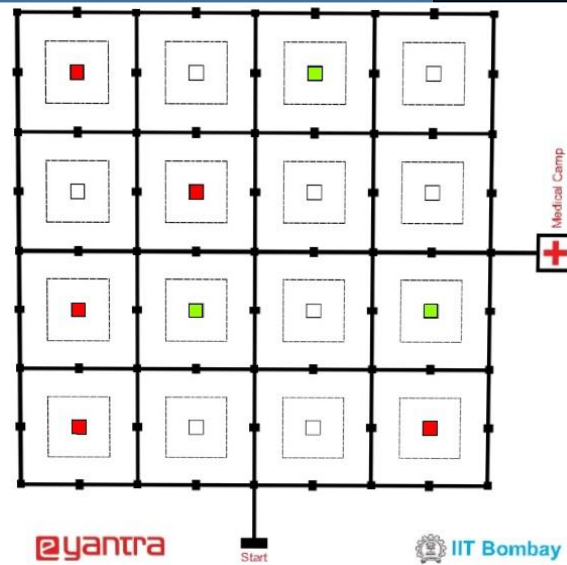


Figure 13: Placement of Patches According to White Debris Configuration String

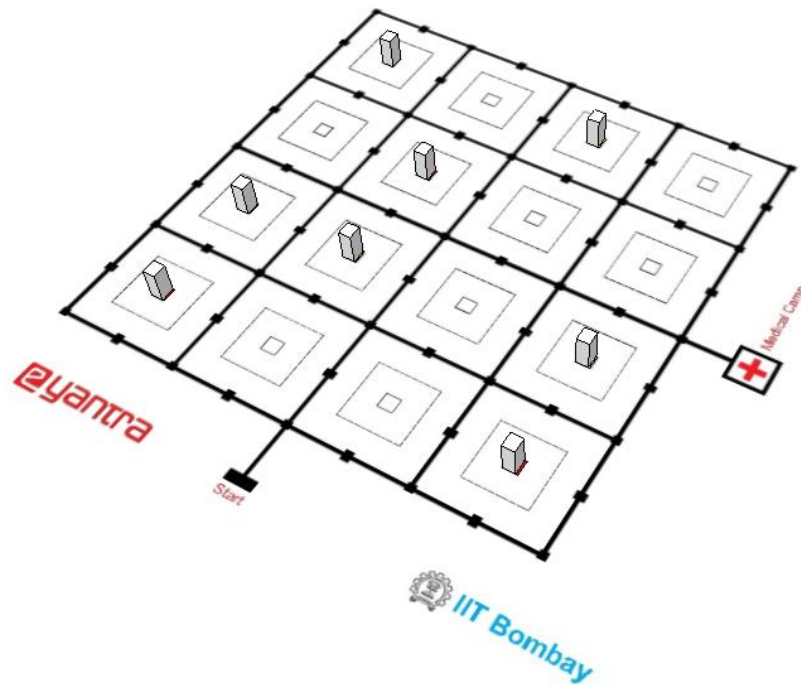


Figure 14: Placement of White Debris According to White Debris Configuration String

Incorrect Placement of White Debris

The White Debris must only be placed as shown in Figure 12b. Please note that placing the White Debris as shown in Figure 15 will not be accepted.

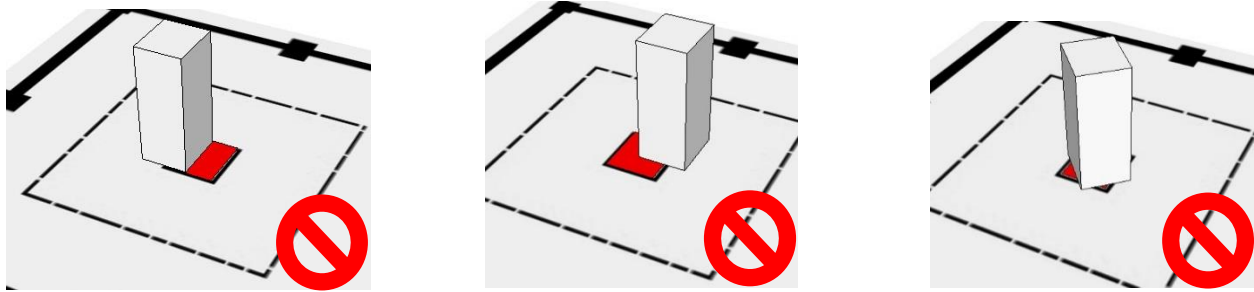


Figure 15: Incorrect Placement of White Debris in Plots.

Note: The White Debris which your team has made using thermocol has base dimensions of 5cm x 5cm. As the patch is 6cm x 6cm, there will be some part of the patch visible when the White Debris is placed over it. As long as the White Debris is placed inside the 6cm x 6cm square, it will be accepted. Refer to the Figure 16.

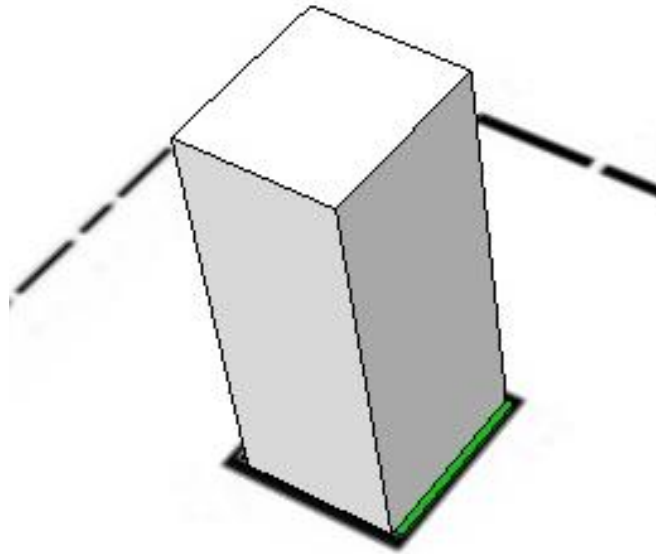


Figure 16: Permissible Visible Part of the Patch

Black Debris Configuration String

This string will be used for the placement of the Black Debris on the arena, which will serve as roadblocks. It consists of random pairs of numbers. Each pair of numbers will refer to a pair of nodes in the arena and in turn represent the path between those nodes. A Black Debris must be placed on the Mid-Point Marker of the path indicated by that pair. For further clarity, refer to the example given below.

Example of Black Debris Configuration String:

[(1-6), (3-8), (4-9), (7-8), (9-10), (11-12), (13-14), (15-20), (16-17), (17-22), (19-20), (21-22), (24-25)].

Here (1-6) represents the path between node 1 and node 6 (pointed at by **Red Arrow** in Figure 17) where the Black Debris has to be placed.

You must place the Black Debris on the Mid-Point markers of the paths represented by the pairs of numbers in the Black Debris Configuration String. For the example Black Debris Configuration String, the arena will look like Figure 17, when all the Black Debris are placed.

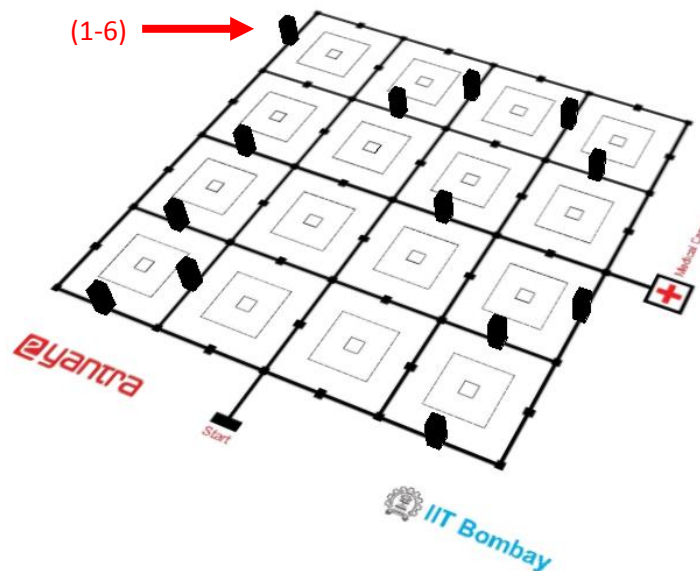


Figure 17: Placement of Black Debris According to the Black Debris Configuration String

Incorrect Placement of Black Debris

Black Debris must be placed only on the Mid-Point Marker of the paths. Please refer to Figure 18 for the incorrect placement of Black Debris on the paths:

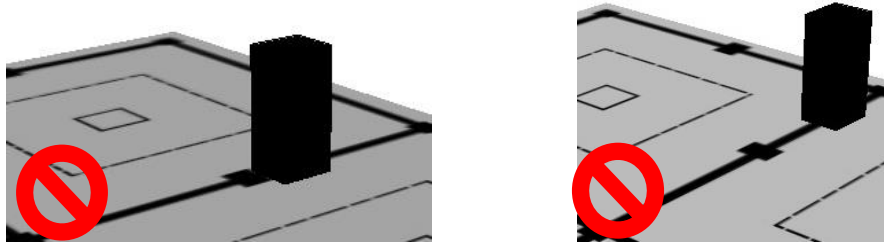


Figure 18: Incorrect Placement of Black Debris on Paths

Final Arena Setup

Figure 19 illustrates the final Arena Setup, showing the placement of both, White Debris and Black Debris according to the Arena Configuration Strings given in the examples above.

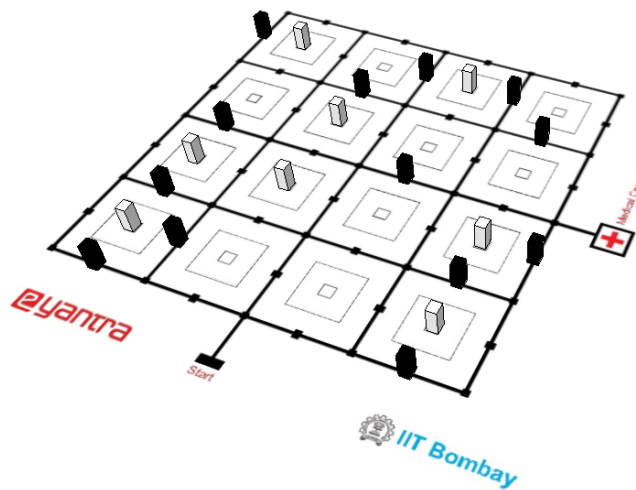


Figure 19: Arena Setup for the Given Configuration Strings

NOTE: You will be given the White Debris Configuration String and the Black Debris Configuration String for the video demonstration 24 hours before the deadline of the Video Demonstration (Task 6).

3. Theme Rules

- The maximum time allotted to complete the task is 10 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 per robot** (explained below) will be allowed in each run.
- The Search Robot should be kept at the **START** line with the castor wheel of the robot positioned on the line. The Rescue Robot should be completely inside the Medical Camp, with the Robot facing towards the arena.
- The team should switch **ON** the robots when told to do so by reviewer. The **start of a run** is when one of the robots is switched on. The timer will start at the same time.
- Once both the robots are switched on, human intervention is **NOT** allowed.
- Robot is not allowed to traverse through the Plot, it always has to follow the black line for traversal.
- For the finals, the **Arena Configuration Strings** will **NOT** be given to any of the teams. The robots must navigate through a randomly setup arena and autonomously detect the White and Black Debris, identify the Survivors and rescue them without any prior knowledge of the arena configuration. Note that you **MUST** have a generic solution that can handle any setup, in real-time.
- **Moving the White Debris**
In order to access the Survivor under the White Debris, the Search Robot must move/drag it completely into the **Clearing Zone** of the Plot. The robot must not move the White Debris outside the **Clearing Zone**. Refer to Figure 20 for the correct and incorrect clearing of White Debris:

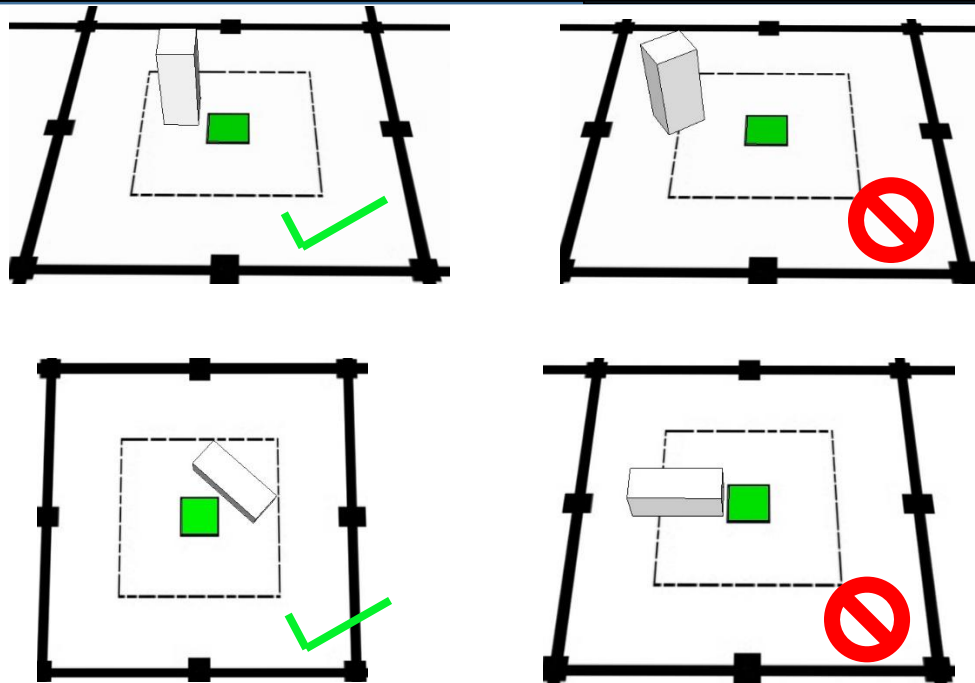


Figure 20: Correct and Incorrect White Debris Clearing

- Buzzer sound for more than **5 seconds** will be considered as continuous buzzer.
- A run ends and the timer is stopped when:
 - i. The Rescue Robot stops and sounds the continuous buzzer or
 - ii. If the maximum time limit for completing the task is reached or
 - iii. If the team needs repositioning but has used all repositioning options of either robot for 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 two 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 the Robots:**

e-Yantra will nominate two members to monitor the movement of each robot. Suppose while traversing the arena, one of the robots strays off the black line, the designated member of e-Yantra team will place the robot on the previous node (node already traversed by the robot) by dragging (not lifting) the robot back to the line in such a way that both the wheels of robot are parallel to the node and castor wheel is on the black line. This is termed as a **Reposition**. Note that the timer used for measuring the task completion time in the competition will be

continuously running during a Reposition and robot will not be switched off. **Each robot** is given **only two repositions** per run. If any one of the robots has been repositioned twice and requires a third reposition, the run will **be ended and the timer will be reset**.

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.

4. Hardware Specifications:

4.1 Use of Firebird V:

- All participating teams must use **one** Firebird V robot collected by them from their college and one Firebird V Robot provided to them by e-Yantra. **Only two** robots are allowed per team.
- Team shall not dismantle the robots.
- The robots should be **completely autonomous**. The team is not allowed to use any wireless remote or any other devices such as a camera while the robot is performing the task. The robots are only allowed to communicate with each other using the Zigbee Wireless Protocol Modules provided to the teams.

4.2 Use of additional components:

- No other microcontroller-based board shall be attached to the Firebird V robot.
- Teams are allowed to connect external actuators or structural hardware to the Firebird V robot.
- The team is not allowed to use any additional sensor apart from the following sensors already provided with the Robots:
 - Two 3 White Line Sensors Modules (1 for each robot)
 - Two SHARP IR Range Sensor
 - Left and Right Wheel Encoders
 - 1 Color Sensor
- The participants may choose to use any of the 5 slots for the SHARP IR Range Sensors on each robot.

4.3 Power Supply:

- The robot can be charged through battery or auxiliary power supply. These are provided with the robotic kit you have collected from your college.
- The team cannot use any other power source for powering the robot.
- The team can use auxiliary power during practice but the video demonstration should only be made using only battery powered robot.

5. Software Specifications:

- e-Yantra has provided all teams with AVR STUDIO 4 and ATMEL STUDIO 6, free software for programming AVR microcontroller. Participating teams are free to use any other open source Integrated Development Environment (IDE) for programming AVR microcontroller.
- 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.

6. Judging and Scoring

- The timer for the run will start when one of the robots is switched on.
- The best score of the two runs will be considered as the final score of the team.
- The formula for calculating the final score is made up of the following:
 - i. Time of the run.
 - ii. Search Robot Score
 - iii. Rescue Robot Score
 - iv. Collision Penalties

Search Robot Score:

$$\text{Search Robot Score} = (SP \times 30) - (MP \times 50) + (C_{MWD} \times 20) + (C_{IS} \times 30) - (P_{Search} \times 10) + B_{Search}$$

The Search Robot's score will depend on the following factors:

- **Scanned Plots (SP)** – Number of Plots which are considered **Scanned**
- **Missed Plots (MP)** – Number of Plots which are considered **Missed**
- **Correctly Moved White Debris (C_{MWD})** – Number of White Debris moved correctly to the Clearing Zones
- **Correctly Identified Survivors (C_{IS})** – Number of Survivors whose colors are correctly detected by the Search Robot
- A **Penalty Count P_{Search}** incremented for every:
 - i. Black Debris touched/moved
 - ii. Repositioning of the Search Robot
- A Bonus of 50 Points B_{Search} if all the Plots are scanned correctly

Rescue Robot Score:

Rescue Robot Score =

$$(C_{SV} \times 30) - (W_{SV} \times 50) + (C_{MAP} \times 20) - (W_{MAP} \times 30) - (PV \times 30) - (P_{Rescue} \times 10)$$

The Rescue Robot's score will depend on the following factors:

- **Correct Survivor Visited (C_{SV})** – Number of Survivors correctly visited by the Rescue Robot whose colors are the same as that of the LED during an MSR.
- **Wrong Survivor Visited (W_{SV})** – Number of Survivors visited by the Rescue Robot whose colors are not the same as that of the LED during an MSR. This also include visiting an empty Plot
- **Correct Medical Action Performed (C_{MAP})** – Number of correct Green and Red Medical Actions performed
- **Wrong Medical Action Performed (W_{MAP})** – Number of incorrect Green and Red Medical Actions performed.
- **Priority Violation (PV)** – Number of times the Red-Green Priority of the MSR is violated by the Rescue Robot. (Refer **Section 1 - *Rescue Robot**)
- **A Penalty Count P_{Rescue}** incremented for every:
 - i. Black Debris and/or White Debris touched/moved
 - ii. Dropping the First-Aid Kit while traversing the arena
 - iii. Repositioning the Rescue Robot
 - iv. Servicing any plot more than once

$$Total\ Score = (600 - T) + Search\ Robot\ Score + Rescue\ Robot\ Score - P_{Collision}$$

Where:

- ❖ T is the total time of the run in seconds
- ❖ Search Robot Score is as calculated above
- ❖ Rescue Robot Score is as calculated above
- ❖ B is a bonus of 100 marks awarded if all the operations are performed correctly and no repositions are used
- ❖ $P_{Collision}$ is a penalty of 50 marks imposed if the robots collide at any point during the run. **Note: In the event of a collision, the robots will be repositioned on the arena. In this case, only a Collision Penalty will be imposed, and not the individual reposition penalties for each robot (P_{Search} and P_{Rescue}). However, it will be counted as one reposition for EACH robot.**

ALL THE BEST!!!