◆IEEE **Latin American Robotics Contest LEGO Category 2007**

Objective

Two robots must work collaboratively in order to gather provisions (food) and fuel inside a space station and transport them into special compartments within a spaceship.

Story

Not so long ago, two spaceships were exploring Mars when an oil leak caused the crash of one of them in the surface of the planet. The ship's crew was seriously injured. Luckily, there were two robots on the second ship that quickly rescued the survivors and took them to the other ship, which was safe.

This ship, while traveling back to Earth, required the service of special robots that performed several tasks like providing medicines to the survivors, and throwing away toxic residues. Now, the spaceship is out of fuel and out of provisions due to this unfortunate trip, but there is an old space station called TMC-4000 luckily near the ship, and it has been detected that this station has enough food and fuel for the ship and its crew.

The spaceship has now docked with the TMC-4000. Nonetheless, the chemical composition of the gases of that place is unknown and the presence of toxic particles in the environment is very likely; for this reason, a robot will have to go into the station to prevent risking human lives.

The spaceship has only one robot capable of dealing with this hostile environment, and it is important to point out that this robot can only pick either fuel or food but not both because, for health matters, these two must not be mixed. Fortunately, inside the space station there is another robot that might be able to help accomplish this task.

Also, for security reasons, the spaceship can only be docked with the space station for a lapse of 5 minutes, so both robots should return to the spaceship before it leaves the space station.

Challenge Goal

The goal of the challenge is to bring as much fuel and provisions as possible into the spaceship within a lapse of 5 minutes.

Definitions

Robot A: The robot that starts in the spaceship.
Robot B: The robot that starts in the space station.
Turn: A *turn* will be understood to be each opportunity to accomplish the challenge. Each turn will have a maximum duration of 5 minutes including the two restarts the team is allowed. The turn starts when **Robot A**'s program is executed and ends when any of the ending criteria[1] is met.
Round: A *round* is a sequence of turns with one turn for each team, in which the order is determined by a mutually agreed procedure among the teams and the judges.
Phase: A *phase* is a sequence of one or more rounds that is used to select the teams that will advance.

Present Situation

The stage is divided in two sections: the spaceship and the space station, which are interconnected by a bridge. At the beginning, **Robot A** is located at either the fuel area or the provisions area of the spaceship (*Figure 1a*) and **Robot B** is located in the space station, which will be divided in six areas. The initial position of **Robot B** will be one of these 6 areas randomly selected by the judge. Likewise, the judge will randomly point to the team which kind of objects (fuel or provisions) **Robot A** must gather; this will also define the initial point of this robot (fuel area or provisions area). The objects will be represented by LEGO blocks assembled into little cubes as shown in *Figure 2*.
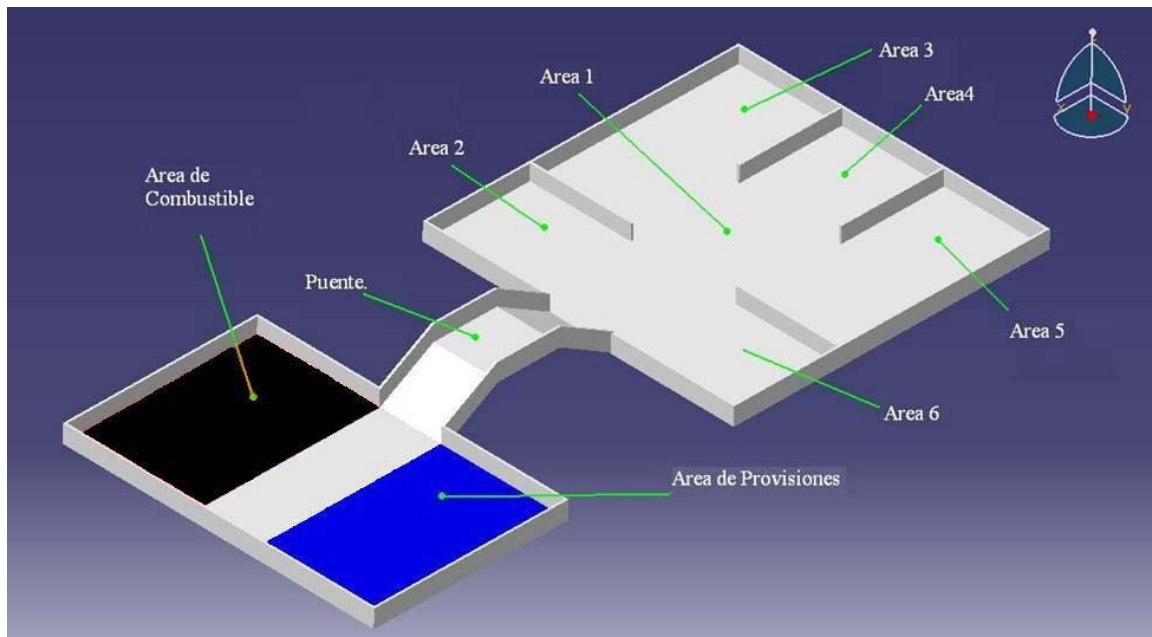

Figure 1a – Areas

---

[1] See the section on *Ending Criteria*.

3	4	5
	1	
2		6

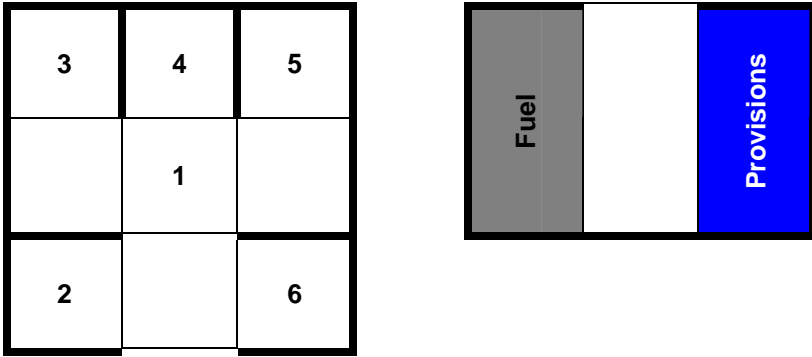|		
Fuel		Provisions

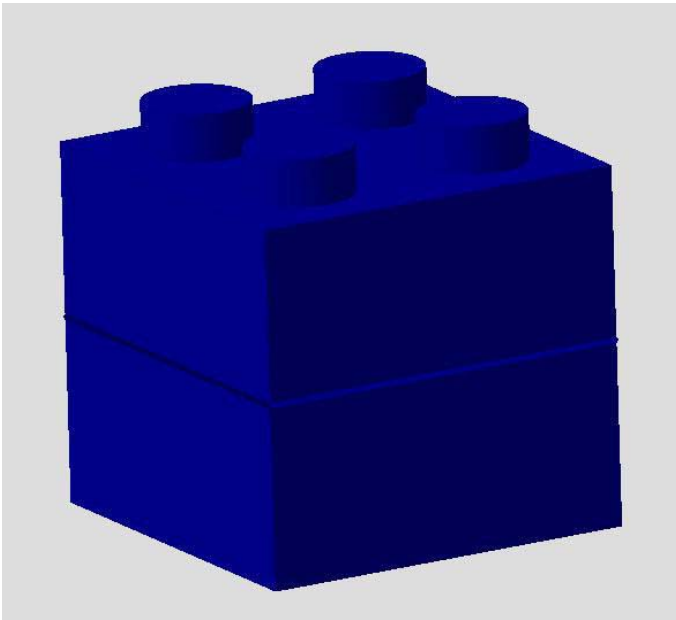*Figure 1b* – Imaginary walls of the areas

Figure 2 – Cube assembled from two 2x2 LEGO blocks representing an object.

In order for **Robot B** to start moving, it is necessary that **Robot A** touches it physically and indicates it which pieces it must gather.

Within the space station, there will be 10 blue objects representing provisions and 10 black objects representing fuel spread randomly within the station (4 per each of the five remaining areas of the space station). In addition, there will be 5 green objects that will represent garbage (one per each of the five remaining areas of the space station), which must be discarded by the robots.

Inside the spaceship there are two defined storage areas where the fuel and the provisions must be delivered.

Turn Setup Procedure

Before each turn begins the following steps must be followed in the indicated order:

1) The starting point of **Robot B** is randomly[2] chosen by the judge within the six areas in the space station.

2) The team places **Robot B** in the designated area[3] and its program is executed. From this moment on this robot must not be manipulated anymore and it must not move at all until it is physically touched by the other robot.

3) The ten blue and ten black objects are placed inside an opaque bag and one of the team members randomly pulls four of them at a time, adds a green object, and then places[4] the five objects in each of the five remaining areas in the space station proceeding in ascending order according to the numbering of the areas. The judge will take note of the number of objects of each kind in each area in case a restart is needed.

4) The starting point of **Robot A** is chosen as well as the kind of piece that it must gather (fuel or provisions). The team places[3] **Robot A** in the designated area.

5) **Robot A**'s program is executed and the chronometer is started.

Turn Rules

1) During the challenge, both robots must act in an autonomous way; both robots must operate without human intervention. However, communication between the robots is allowed and encouraged.

2) The teams will have two chances of restart for each turn. A restart can be requested by the team or forced by the judge due to violation of a rule. When the request for a restart is signaled, the judge will pause the chronometer and will allow reasonable time[5] for the team to execute the *Turn Reset Procedure* as indicated below. Score will be reset to 0 after each restart, but a penalization will be taken for each restart according to the *Scoring* section.

3) **Robot B** must wait for physical contact with the spaceship robot in order to start operating. If **Robot B** starts moving before being physically touched by **Robot A** then they will be forced to restart.

4) The provisions must not be mixed with the fuel so the robots must avoid entering[6] the other area. (The robot gathering provisions must not enter the fuel area and vice versa). If a robot violates this rule then the team will be forced to restart.

5) Each robot will be allowed to *deliver*[7] a maximum of two objects of the correct type each time it crosses the bridge towards the spaceship[8]. If any robot delivers

---

[2] It is suggested to use a dice for this purpose, however the judges may choose to use some other random procedure as long as all teams are notified of this procedure and that it is used consistently throughout the competition.

[3] The precise orientation and position of the robot in the designated area will be defined by the teams as long as the robots are completely contained within the imaginary walls of the respective area (*Figure 1b*).

[4] The four objects pulled may be placed anywhere inside the corresponding area as long as there is at least 15cm from each object in that area to the nearest imaginary wall and to the nearest object in that area. All objects must be placed with the hollow face towards the floor as shown in *Figure 2*.

[5] One minute is suggested.

[6] See *More Definitions* for a definition of "entering an area" below.

[7] See *More Definitions* for a definition of "delivering an object" below.

more than two objects in the corresponding area, only two objects of the correct type (fuel or provisions in accordance with the kind of object it must gather) will be registered by the judge and the rest of the objects of that type will be discarded for the rest of the turn.

- o Example: Assume the robot must gather provisions and after crossing the bridge into the spaceship it delivers 6 objects (2 fuel, 3 provisions and 1 garbage) into the provisions area, then one provisions object will be discarded (taken out by the judge) and the remaining ones will be counted towards the scoring of that turn[9] according to the scoring rules.

6) The bridge was designed to be wide enough for only one robot. However, even if the teams manage to design a pair of robots small enough to cross the bridge in opposite directions at the same time this action will not be allowed. Both robots may be using the bridge simultaneously, but they may not cross each other in opposite directions while on the bridge. A violation of this rule will be penalized with a forced restart.

Turn Reset Procedure

1) The team places **Robot B** in its designated area following the same restrictions as for the *Turn Setup Procedure* and its program is executed. From this moment on this robot must not be manipulated anymore and it must not move at all until it is physically touched by the other robot.

2) All objects (including those that might have been successfully delivered or discarded by the judge) are returned to their corresponding areas making sure the distribution of objects to areas matches the original one.

3) The team places **Robot A** in its designated area and its program is executed. The judge restarts the chronometer and the turn proceeds.

Turn Ending Criteria

A turn is over when any of the following criteria is met:

1) When the 5 minutes are gone.

2) When the team needs a restart but the two restarts allowed in the turn have been used, whether by request of the team or forced due to a rule violation.

3) When the team let the judges know that they have finished the turn, retaining the points obtained up until that moment.

More Definitions

Entering an Area: A robot is considered to have *entered an area* if any of its parts touches the floor or the <u>physical</u> walls of that area. This definition is to be used both for the prevention of a robot entering the wrong area as well as for the requirement of the robots returning to their respective areas prior to the 5 minutes running out.

---

[8] Collaboration is an essential part of this challenge. This rule forces the teams to program their robots to collaborate in sharing the bridge because the only way to complete the task is by crossing the bridge several times, and the bridge is wide enough for only one robot at a time.

[9] The next time the robot enters the bridge towards the space station or when the turn has ended, the judge will remove all objects delivered (whether of the correct color or not) and all excess objects will be discarded.

Delivering an Object: An object is considered to be *delivered into an area* when at least part of the object is touching the floor of that area. Delivery of an object is evaluated only after the robot reenters the bridge towards the space station or after the turn has ended, whichever comes first. When either of these events takes place, the judge will remove all objects from the spaceship discarding any excess objects[10] and count towards the score all remaining objects according with the *Scoring Rules*.

About the Robots

It is important to remember that only pieces in their original state and official LEGO sensors are allowed; micro or regular LEGO motors can also be used. However, it is not allowed the use of glues of any kind to set the pieces. It is allowed to participate with both RCX or NXT platforms, participating all within the same category.
Number of components: For this challenge, there is no limit in the number of building blocks, sensors, motors and programmable blocks (RCX or NXT).
Dimensions: At all time, each robot must fit into a cubic box[11] with internal capacity of 30cm per side. It doesn't matter how the robot is made to fit in this box (horizontally, diagonally, up side down, or in any other orientation).
Weight: There is no weight restriction for the robots in this challenge. However, the local organizing committees are advised to build a bridge that can withstand weights in excess of 5kg.

Colors and Marks

Walls: Matte white color.
Floor: Matte white color.
Provisions area: Matte blue[12] color.
Fuel area: Matte black color.
Cubes of provisions: Blue LEGO cubes built as shown in *Figure 2*.
Cubes of fuel: Black LEGO cubes built as shown in *Figure 2*.
Cubes of garbage: Green LEGO cubes built as shown in *Figure 2*.

Lighting Conditions

The local organizing committee should provide uniform, indoor, diffuse lighting conditions at least of 500 LUX. Nevertheless, teams must come prepared to calibrate their robots based on the lighting conditions at the venue. Every effort will be made to keep ambient shadows, incandescent lamps and natural lighting as low as possible. However this may not be totally eliminated. Therefore it is highly recommended that teams design their robots to cope with variations in lighting and magnetic conditions, as these vary from venue to venue. Once competitions have begun, teams will play under existing lighting conditions without further discussions or requests.

---

[10] See *Turn Rule #5*.
[11] The local organizing committee must provide a box satisfying this specification in order for the judges to be able to evaluate this restriction unambiguously.
[12] In order to offer uniform conditions across different venues, local organizing committees should strive to match as closely as possible a PANTONE 302 PC, C:100 M:43 Y:12 K:56 for this blue color. Pantone guides are usually available at paint shops.

Ranking Criteria

First criterion: Gained points during the turn.
Second criterion: The time elapsed during the whole turn.
Third criterion: The time of the first delivery.

Scoring Rules

1) 2 points will be obtained for every object delivered (objects touching the floor) at the respective region if both robots are located at the delivery area and both deliver equal number of elements.
   - *Example 1:* if each robot deliver one correct piece, the score for this attempt will be of 4 points, (2 for each object)
   - *Example 2:* if a robot deliver one correct piece but the other do not deliver anything the score for this attempt will be of 0 points.
   - *Example 3:* if a robot deliver two correct pieces and the other one delivers only one, the score on that delivering attempt will be of 4 points (2 for each correct object).
2) 1 point will be lost for every object that is left at an incorrect area (fuel at the provisions area or vice versa).
3) 5 points will be gained for the first physical robot-robot contact.
4) 2 points will be lost for the first restart.
5) 1 point will be lost for the second restart.
6) 1 point will be lost for every object delivered if both robots are not located at the delivery area.
7) Garbage may be delivered at any area without affecting the score.
8) 2 points will be gained for every robot that stay in the spaceship at the end of the 5 minutes or when the team tells the judge that they have concluded the challenge with both robots inside the spaceship.

In order to understand unambiguously the *Scoring Rules* above judges and team members must refer to the following scoring formula:

$$5c + 4R\min(f_f, p_p) - f_p - p_f - 2r_1 - r_2 + 2N_R$$

c = 1 if physical contact between the two robots occurred and 0 otherwise

f_f = number of fuel objects delivered at the fuel area at the end of the turn

p_p = number of provision objects delivered at the provisions area at the end of the turn

f_p = number of fuel objects delivered at the provisions area at the end of the turn

p_f = number of provisions objects delivered at the fuel area at the end of the turn

r_1 = 1 if the first restart occurred and 0 otherwise

r_2 = 1 if the second restart occurred and 0 otherwise

R = 1 if <u>both</u> robots entered[13] their respective areas at the end of the turn and 0 otherwise

N_R = Number of robots inside any part of the spaceship at the end of the turn

---

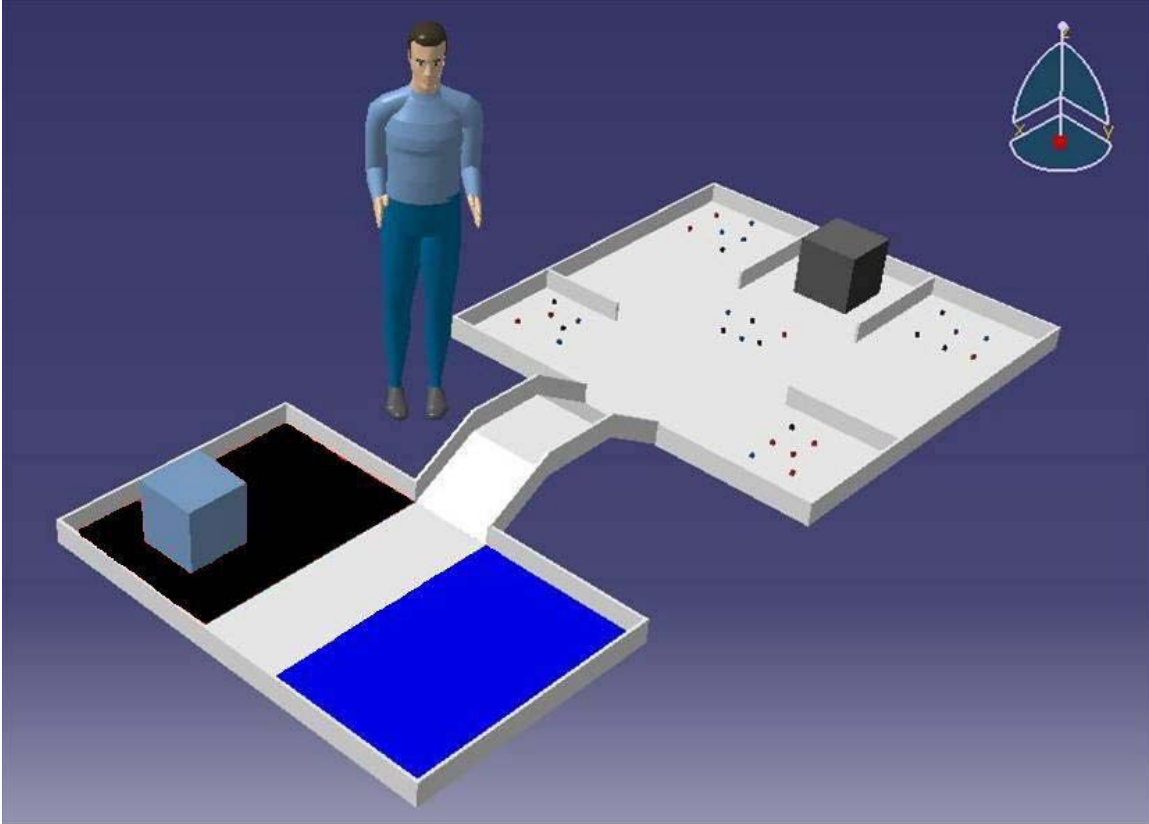[13] See *More Definitions* for a definition of "entering an area".

Figure 3 – Example of an Initial Position of the Robots and the Objects (Fuel, Provisions and Garbage).

About the Competition

The number of phases[14], the number of rounds within a phase, and the number of teams that will advance to the next phase will be determined by each local organizing committee in consultation with the local judges to allow enough time according to the number of teams registered and the available time for the competition. However, this will be announced to all teams before the competition starts. Teams will be selected for advancement into the next phase by taking into account the best turn taken by the team in that phase according to the ranking criteria.

Local organizing committees are advised to assign at least two judges per competition stage in order to ensure that all regulated details can be properly appreciated by them.

Arena Specifications

The spaceship will be a rectangular surface of 2m wide and 1.22m long. The space station will be a square area of 2m per side.

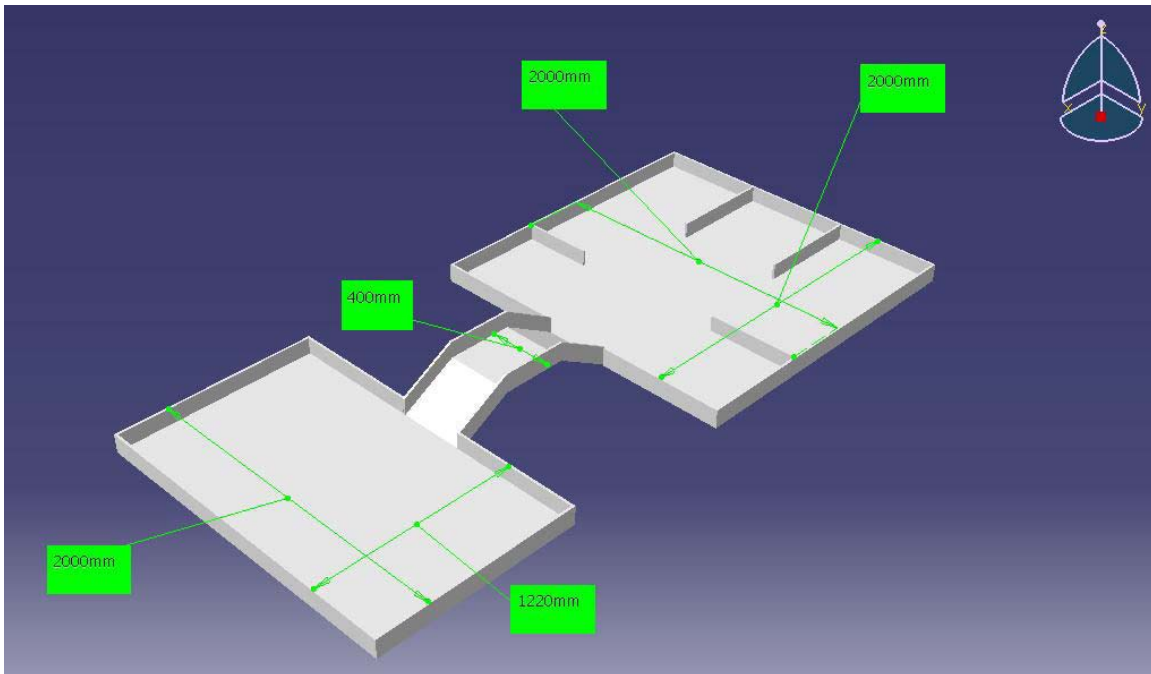[14] See the definition for *phase*, *round* and *turn* in the *Definitions* section.

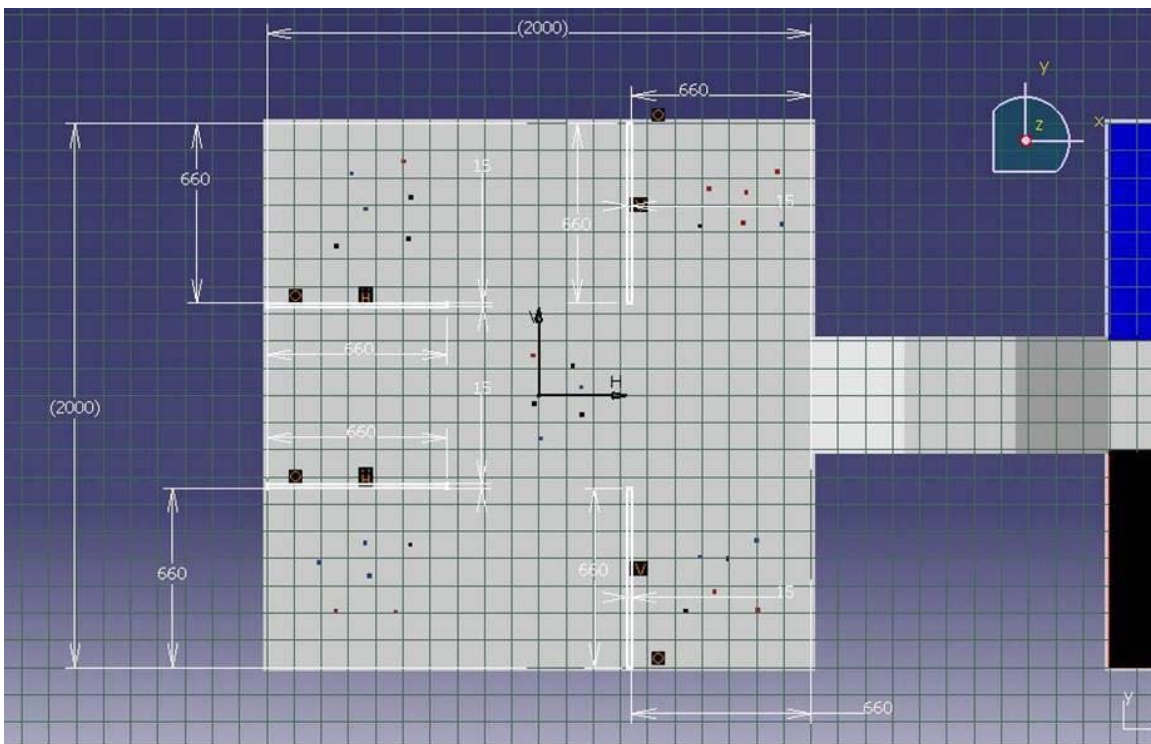*Figure 4* – Arena dimensions (Top View).

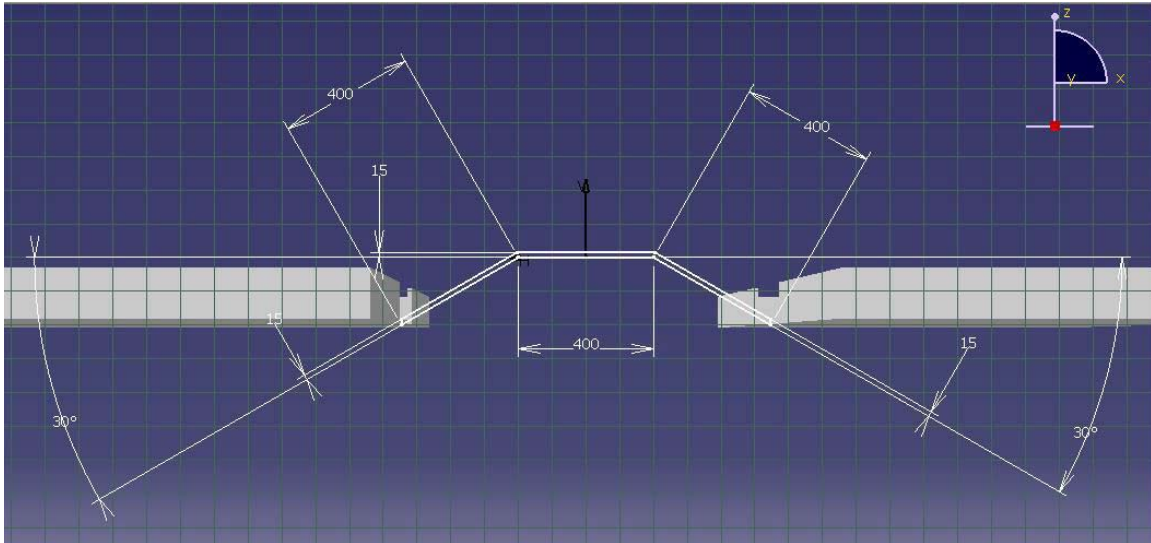

Figure 5 – Arena dimensions (Bottom View).

Figure 6 – Bridge Measures (Lateral View).

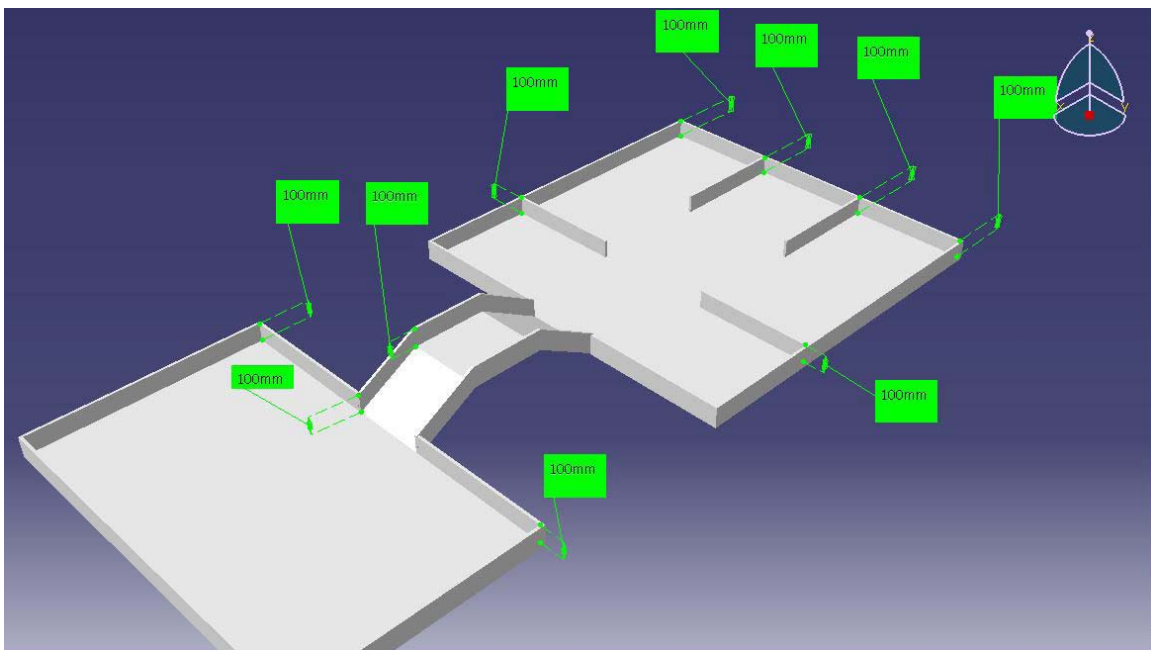All walls must be 10cm high.

Figure 7 – Arena's Walls Measures.

The dimensions are indicative ones and can vary some mm due to the thickness of the event's table.