

# *electro* *Mobility<sup>2</sup>*

**Drive an electrically actuated car,  
communicate the status and stop precisely on  
target.**

**Challenge your engineering skills!**

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**Project goal:** Each team shall build one system; the team that achieves the maximum score shall win the competition

## 1 System Overview

The project consists of 4 parts:

- **(Power Train) Brushless motor control of two electric motor actuators**
- **(Chassis and Safety) Steering using an electric motor**
- **(Interior Body & Security) Car environment data transmission**
- **(Infotainment & Connectivity) Client-Server Protocol**

Whenever they are used in the subsequent chapters, the terms below have the following meaning:

**Car** = vehicle which implements all the car related requirements, specified in chapter 3.2

**Console** = a device which implements all the requirements specified in chapter 3.3

The console can be a laptop, a personal computer, a smart phone or a console developed by the team.

**System** = Car + Console

**GUI** = Graphical User Interface

**RF** = Radio Frequency

**Control board** = electronic circuits which integrate the car logic command (software). From hardware standpoint, this is the board which integrates the micro controller

**Inverter** = electronic circuit used to command the BLDC motors

**SW** = Software developed by the team and deployed on the car and console

**HW** = Electronics hardware

## 2 General competition rules

- Each team must have 3 to 4 members.
- Each team shall participate in the competition with one system.
- Each car shall be able to run independently on a predefined track from the Start line to the Stop line.
- The car must be driven by two brushless electric motors and the steering will be ensured using different speeds for each wheel or using a motor on a steering shaft. While running, the car shall be able to transmit several car parameters to the console using a client-server protocol communication system.

Detailed requirements are presented in the following chapters.

- The competition is organized in 2 parts:
  - 1<sup>st</sup> part: system analysis
  - 2<sup>nd</sup> part: race track
- Each team shall document the hardware and software concepts in a design document.
- Each team shall send the design documents to the organizers one month before the contest, as described in the 5<sup>th</sup> contest phase (Competition rules document). Otherwise, the corresponding points are lost.
- The competition will be organized in the Continental Iasi location and will last for two days.
- The team that achieves the highest number of points during the whole event will win the competition.

- The reflashing/ calibration and adjustment of the car are allowed at any time during the entire competition day.

### 3 System and track specifications

#### 3.1 General system requirements

**R1:** Each car shall be able to run independently on a predefined race track from the START line to the STOP line

Remark: no external intervention on the car is allowed during the laps on the track, except for the Start/Stop command which is permitted.

**R2:** The steering and the traction shall be realized only with the two electric motors provided by the organizers

Remark: for further details regarding the motors, see Annex 1

**R3:** Each car shall be powered by batteries and these batteries must be carried by the car

**R4:** Each car shall be able to communicate wirelessly with one console

**R5:** Each System shall include one GUI, which shall run on the console and shall display the information exchanged by the car and the server

**Info:**

Info1: The number of car wheels will be defined by each team

#### 3.2 Car requirements

##### 3.2.1 Car electronics hardware requirements

**R6:** The motors must be driven by inverter/inverters provided by the organizers

**R7:** The control board can be manufactured by the team or a development kit can be used

Remark: the electronic circuits manufactured by the team are preferred

##### 3.2.2 Motor control and steering

**R8:** Each motor will be controlled independently

**R9:** For each car, the steering must be ensured using the two motors placed on the traction wheels or using a motor on a steering shaft and the other motor used for traction.

**R10:** If the steering is ensured using the two motors placed on the traction wheels, the steering must be realized based on the speed/torque control of the two electric motors

**R11:** When the car is lifted during the race on the track, the car wheels must stop in less than 3 sec

Remark: a solution without sensors is preferred

**R12:** One stall protection shall be implemented for wheels blocked more than 500 ms

Remark: Be aware that the protection will be tested during the evaluation

**R13:** The braking uses electric motors control functions only, no additional mechanical brakes are allowed

#### 3.3 Console requirements

##### 3.3.1 Client-server protocol requirements

**R14:** Each system shall implement one communication protocol of the client-server type

**R15:** The communication protocol support must be wireless

**R16:** The communication protocol and the communication type must be detailed in the design document

**R17:** The communication protocol and the communication type shall be robust

Remark: will be rewarded if the robustness is analyzed and proven in the design document

**R18:** During the race on the track the car must only receive the START command from the console.

However, the STOP command given by the team from the console is allowed only in case of emergency.

**R19:** During the race on the track the car must not receive from the console any information related to:

- track specifications
- stop command
- turning or cornering left/right command

#### Indications:

Indication1: The communication protocol type can be: Ethernet based on TCP/IP or others

Indication2: The transport layer can be: RF communication, Wi-Fi, Bluetooth, Infrared, others

Indication3: A summary of the system is represented in Figure 1

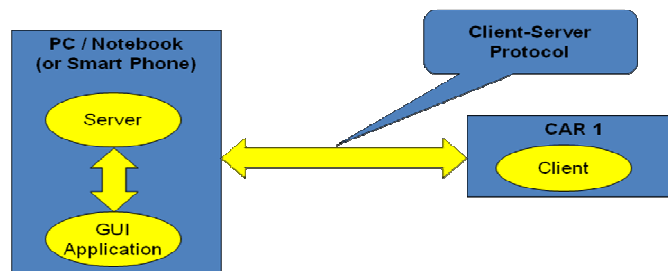


Figure 1

### 3.3.2 GUI requirements:

**R20:** The system must include one GUI to display the information received from the car

Remark: The GUI shall be displayed on the console and it shall be user friendly

**R21:** The car status displayed on the GUI shall not be older than 5 seconds

**R22:** The GUI shall implement two working modes: Test mode and Race mode

Remark: The test mode will be used only during the system evaluation. The Race mode will be used during the race on the track.

**R23:** In the Test mode, the GUI shall be able to send the following commands to the car:

- Turn both traction wheels forward / backward
- Independently turn left / right traction wheels forward / backward
- Brake command

**R24:** In the Race mode, the GUI must be able to send only the Start command and the STOP command to the car, for emergency situations.

**R25:** In the Race mode, the GUI must display the following information received from the car:

- The time elapsed from the START moment. The timer shall stop when the car reaches the STOP line.
- The battery level
- The car speed
- The distance travelled by the car from the start point
- The Left/Right traction wheels status – moving forward/backward or stopped

#### General remarks:

Remark1: In the Test mode, the stalling protection must be active

Remark2: In the Test mode, when the car is lifted, the car wheels must stop in less than 3 sec.

Remark3: In the Test mode, all the car functional requirements must be available and testable

### 3.4 Track specifications

**T1:** The track shape and its dimensions are presented in Figure 2

Remark: The participants shall consider a tolerance of 10% between the schematic and the real track dimensions

**T2:** The track is made of rubber

**T3:** The side walls are made of a dense material and will have a height of at least 100 millimeters. The material color is black mat, and it is normally used for covering the furniture (fake leather cover).

**T4:** The Start line is marked on the race track by a drawn line

**T5:** The Stop line is marked on the race track by a metallic bumper (steel bar)

Remark: The bumper dimensions are: length = track width; height 2 to 5 millimeters; width 10 to 30 millimeters;

**T6:** At the half of the track, a ramp with a slope of 18 degrees and a length of 1 m will be placed.

Remark: Except for the mentioned segment with the slope, the rest of the track is flat.

**T7:** Apart from the track curve, two obstacles will be placed on the track, but this is not mandatory.

**T8:** The obstacle position on the track will be the same for all the participants and it will be defined by the organizers

**T9:** The distance between Obstacle 1 and Obstacle 2 will be of at least 1 meter

**T10:** Each obstacle will obstruct 40% of the track width

#### Info about obstacles:

The role of the obstacles is to partially obstruct the race track width.

The obstacles are made of a similar material as the side walls and they will have the same height

The obstacles positions in Figure 2 are just for orientation. During the contest, the position of the obstacle will be different than depicted in Figure 2, but will remain the same along the entire event.

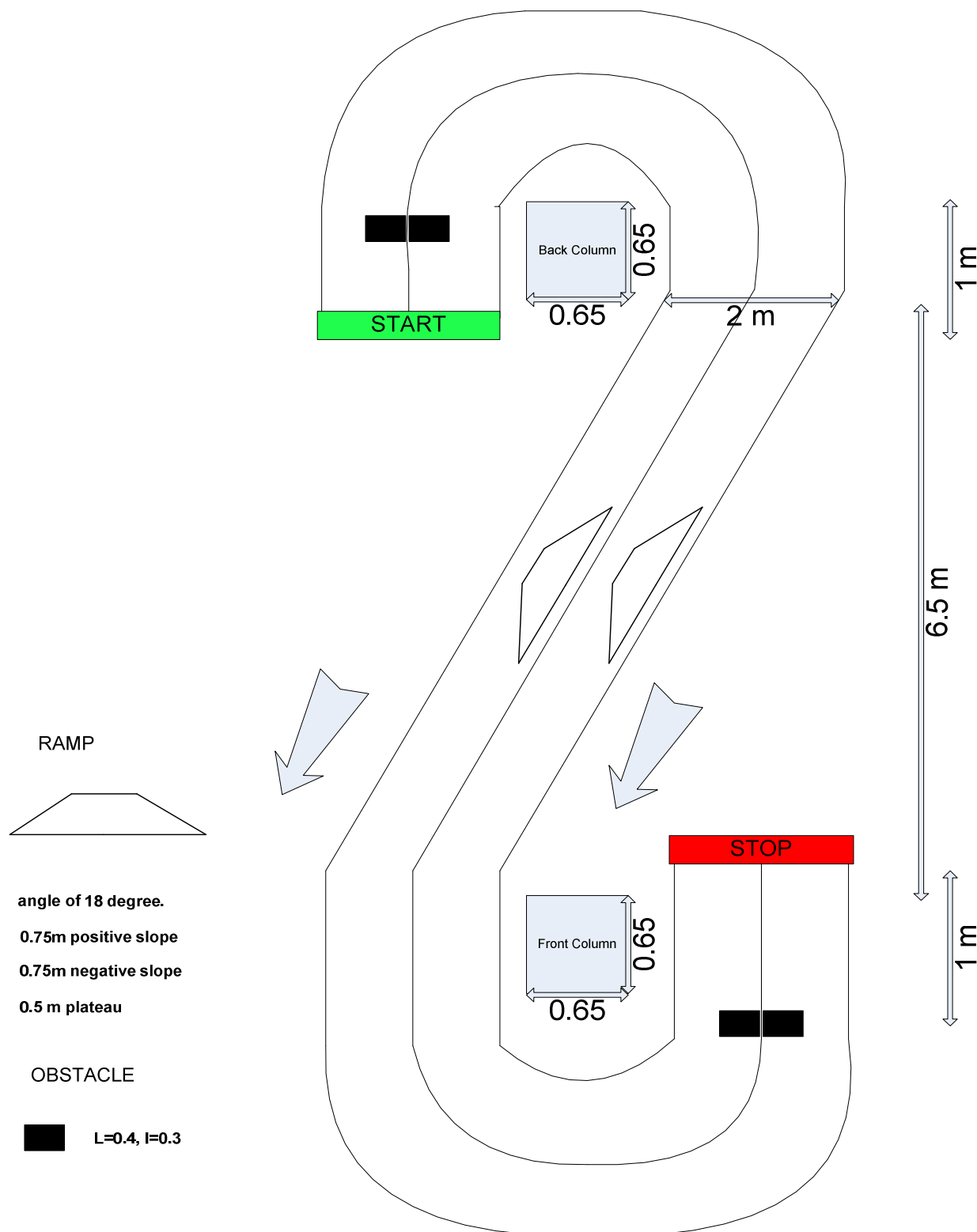


Figure 2

**Observation for Figure 2:** The current positions of the obstacles (represented in black) are just for your information. The positions will be defined by the jury and will be different than depicted.





Figure 3 Track pictures from Open Doors 2012

## 4 Evaluation

The competition shall be evaluated as follows:

- **Step1 - System evaluation:** the following aspects are evaluated: the presentation, the design document and the car features.

The system evaluations consist of a Static evaluation and a Dynamic evaluation

The details about the system evaluation criteria are defined in chapter 4.1

- **Step2 - Race on the track:** each car will run on the track and the time from START to FINISH will be recorded

The details about the race on the track evaluation criteria are defined in chapter 4.2

Each team will be awarded a number of points for each evaluation step.

The weight for each step is the following:

- **Step1** – 50%
- **Step2** – 50%



The maximum number of points for each step is 100.

The final results will be calculated as a weighted sum of Step1 and Step2.

Ex:

Team X gets 80 points for Step1 and 60 points for Step2. The final number of points is:  
 $80 \times 50\% + 60 \times 50\% = 70$  points

The team that obtains the highest number of points wins.

## 4.1 Step1: System evaluation

The system evaluation comprises 2 sub-steps:

- one **Static evaluation** which will evaluate the documentation and the project presentation
- one **Dynamic evaluation** which evaluates the system responses in Test mode

### 4.1.1 Details for the static evaluation:

- Each team shall make a brief presentation of the project (e.g.: ppt) – with a duration of maximum 8 minutes and present it in front of the jury, visitors and competitors. All the competing teams will present their materials using a desktop computer (which will be equipped with at least Microsoft Office 2007: Office, Excel, PowerPoint) and a projector provided by the organizers.
- The presentation shall be focused on the technical details of the system
- Before or after the presentation, the jury will go to the stand and will evaluate each project using the defined criteria and questioning the team about the system technical details

Static evaluation					
Evaluation step	Discipline	Evaluation criteria		Points	
Project system evaluation	SW Evaluation	Project presentation evaluation		- project overview - team spirit - project advertising	10
		SW design		- document overview (relevance of the contained information)	3
				- SW abstractization level and SW modularity (software decomposition)	2
				- SW interfaces	2
		System design	Motor functions (Low level functions)	- Motor control: - torque loop - 2p - speed loop - 3p	5
				- steering	3
				- braking	2
				- route calculation algorithms	3
				- obstacle detection algorithms	3
				- power management	2
			Communication protocols	Wireless - Communication standards ( Wi-Fi (IEEE 802.11), Bluetooth, Radio Frequency Communication (Modulators / Demodulators), IR Communication)	2
				- protocol robustness	2
				-protocol features (how was the protocol chosen)	2
			Diagnostic functions	- diagnostic services implementation (see Annex 1)	2
			Graphical Interface	- GUI usability and design	3
			SW robustness	- SW can recover from possible error states	2
				- SW solution for HW protections is implemented	2
				- HW malfunction detection	2
	HW Evaluation	HW schematic and layout		- HW schematic design	5
				- HW robustness (range values, protection implementation)	5
				- HW layout	3

Table 1

#### 4.1.2 Details for the dynamic evaluation

In this round, the jury will evaluate each system – checking how the required functionalities are implemented. For this round the car will not be placed on the track, the evaluations will be done on each stand. Each team shall implement a Test mode which supports diagnostic commands, to make it possible for the system to be evaluated accordingly

Observations:

- For this round, the organizers do not intent to physically interact with the system, so that the results are not influenced. Therefore, the teams must define methods to prove that the required functionalities are working properly.
- Also, the organizers do not intent to use high precision tolls to measure the system parameters. The required parameters will be measured using basic tools if necessary or by free observations.
- The organizers encourage the teams to be creative. Therefore, at the end of Step 1, the project overall concept and creativity will be marked.

Dynamic evaluation			
System functions evaluation	CAR function	<ul style="list-style-type: none"> <li>- both motors spin forward/backward</li> <li>- both motors spin forward/backward independently</li> <li>- the motor(s) stop in less than 3 seconds if the wheels spin freely</li> <li>- the motor stops if the stalling conditions applied</li> <li>- brake command</li> </ul>	10
	Communication	- how fast is the car-server connection established	2
		- CAR – server data exchange: all the information has a refresh rate of 5 seconds	3
	GUI	Evaluate the GUI usability : <ul style="list-style-type: none"> <li>- start button</li> <li>- history clean up</li> <li>- commands for vehicle control</li> <li>- evaluate look and feel (intuitive, user friendly )</li> </ul>	5
		Info sent by the car: <ul style="list-style-type: none"> <li>- recorded time</li> <li>- car speed</li> <li>- car running condition (going left/right, on slope, stalling..)</li> <li>- battery level</li> <li>- the car is lifted</li> <li>- CAR malfunctions</li> <li>- travelled distance</li> </ul>	5
Overall project	Creativity	- overall concept and creativity	10

Table 2

## 4.2 Step2: Race on the track

The race on the track is carried out in 2 rounds:

- **Qualification Round** – details in chapter 4.2.1
- **One-on-one race on the track** – details in chapter 4.2.2

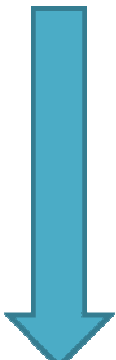
### 4.2.1 Qualification Round

The Qualification round will be used as a preparation round for the last contest stage – The One-on-one race on the track.

In the Qualification round, each car will run on the track and the total time for finalizing one lap will be recorded.

Depending on the recorded time, the teams will be ranked as depicted in Table 3.

**Example:** Table 3 presents a possible scenario with 11 teams.

Qualification Round		
Rank	Team	
1	Team A	<div>Minimum time</div>  <div>Maximum time</div>
2	Team B	
3	Team C	
4	Team D	
5	Team E	
6	Team F	
7	Team G	
8	Team H	
9	Team I	
10	Team J	
11	Team K	

**Table 3**

Observation:

- The cars, which do not finish one lap during the qualification round, will be ranked depending on the distance covered from the START line
- If the lap time and/or distance criteria cannot be applied (e.g. equal lap times, equal traveled distance), the cars will be ranked based on the evaluation score obtained in the previous step (System evaluation).

**Rules for the race on the track within this round:**

- The teams will enter in this round based on the evaluation score obtained in the previous step ( System evaluation), starting from the lowest score to the highest.
- In this round, two cars will run on the track simultaneously, having as a target to obtain the best individual result. Among the two cars, the one with the lowest score in the previous step ( System evaluation), will run on the inner lane of the track, while the other car will run on the outer lane of the track.
- All the cars will start the race from the START line.
- From standstill position at the START line, the car is started by the pushing of the START button available on the GUI.
- A lap will be considered finished when the front wheels of the car pass the STOP bumper

### 4.2.2 One-on-one Round

In this round, the teams will compete one-on-one on the track, based on a pyramidal format.

To determine the competition order, the results from the Qualification round will be used.

The number of participants is calculated as a number that is a power of 2 and is also lower or equal to the maximum number of participants.

Among the two cars, the one with the lowest score in the previous step (Qualification round), will run on the inner lane of the track, while the other car will run on the outer lane of the track.

**Example:**

If 11 teams are present after the qualification round, only 8 ( $2^3$ ) teams will compete one-on-one.

One-to-one round	
Rank	Team
1	Team A
2	Team B
3	Team C
4	Team D
5	Team E
6	Team F
7	Team G
8	Team H
9	Team I
10	Team J
11	Team K
<b>Legend:</b> The green colored cells qualify for the Race on the track.	

**Table 4**

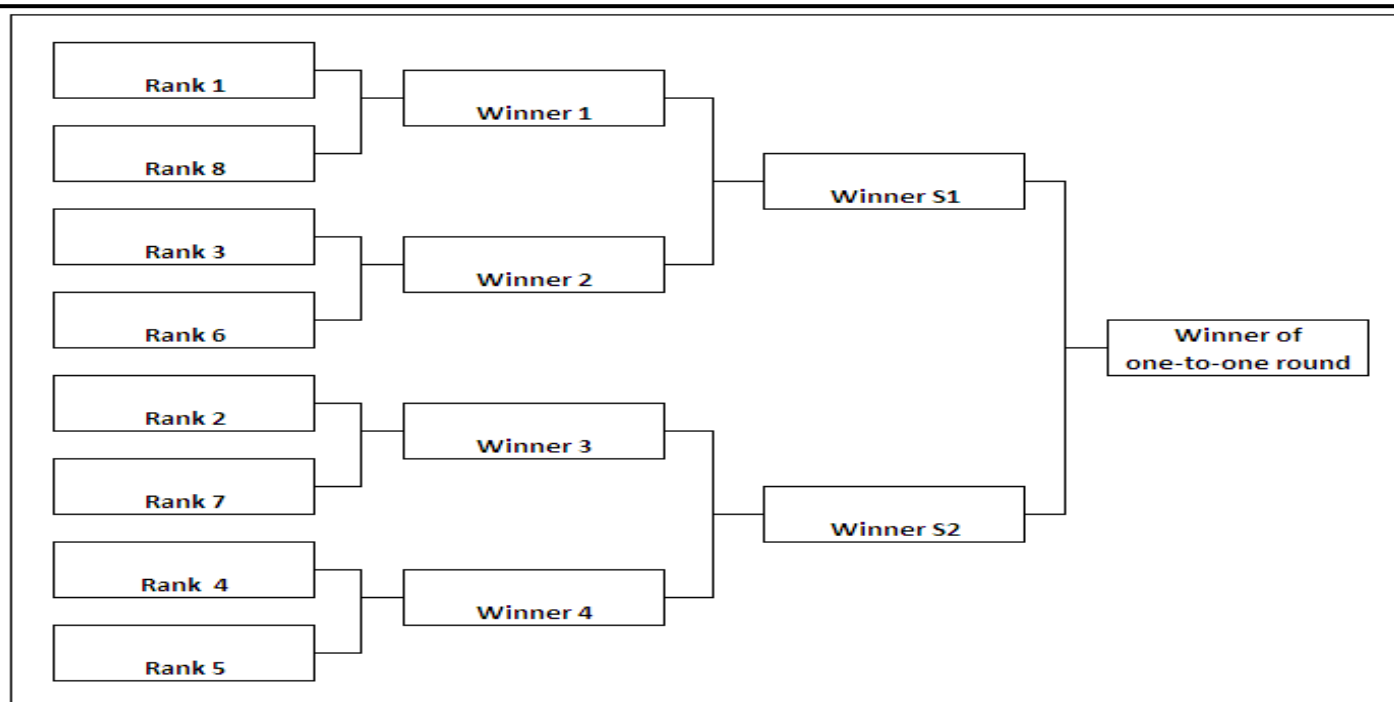


Figure 4

After this round, the points will be distributed according to Table 5.

Results after the one-on-one race	
Place	Number of points
Winner of the race	100
Second place	80
Places 3-4	70
Places 5-8	50
Places 9-16	40
Places 16-32	30

Table 5

The cars which do not finish the entire lap will be ranked depending on the distance travelled on the track.

#### Rules for the race on the track within this round:

- All the cars will start the race from the START line.
- From standstill position at the START line, the car is started by the pushing of the START button available on the GUI.
- One lap will be considered finished, when the front wheels of the car pass the STOP bumper
- The car must stop having the STOP line between the front wheels and the rear wheels – otherwise, the team will get a penalty of 15 seconds.

**Observations:** The STOP condition must be reached by using the track information (distance, speed, acceleration, STOP bumper etc).

## ANNEX 1:

Brushless motor characteristics will be provided when the motors will be handed over to the teams.



Figure 5: Brushless Motor picture

### Diagnostics – short overview

#### 1. Why

It is important for service shops (to diagnose the problems with the car or to flash the updated SW). Therefore, we ask you to provide the test mode

It is important for driver (information appears on board when a problem is detected). Therefore, we ask you to provide some information about the car status in the GUI

It is important for passenger safety. Some of the functionalities can be disabled automatically when they are working in poor conditions. This is why we suggest you to have a mechanism to disable the motors when they are blocked for more than a certain period of time.

#### 2. How?

Application Layer -> Diagnostic Layer-> Transport Layer -> Physical Layer

The diagnostics is not performed separately, but is part of a multi-layer concept. The algorithm itself is implemented by each application, but the services share the same format.

#### 3. Diagnostic Trouble Codes

Coming back in the service shop, the engineers there need to know what troubles you might have.

There is a defined code for each possible problem and this is stored together with the mileage and time stamp.

This is also an approach for debugging during the development.