FROG

FUN ROBOTIC
OUTDOOR GUIDE

Deliverable: D1.3

Customised Mobile Platform

Consortium

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SEVENTH FRAMEWORK PROGRAMME

University of Amsterdam · YDREAMS · ID mind · Universidad Pablo de Olavide Sevilla · Imperial College London · University of Twente.

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Table of Contents

1. Summary

The nature of D1.3 is a prototype resulting from the different stages of the robot platform development. Complementing this deliverable, the consortium decided to include a report to depict the main stages of the robot platform customization. As the electronics have already been described in D1.2, this report will focus the mechanical and shape evolution along the project development.

The design of the platform had to find a good trade-off between the different requirements related with on-board technology, operating conditions, safety issues and smoothly integrate them into an appealing design.

Starting from a conceptual idea, based on the project goals, the platform was evolved from sketch as the partners were defining their requirements, experiments were being performed and performance was being analysed. This process is now documented in the following sections.

2. Conceptual Idea

The first conceptual sketches for FROG were made during the elaboration of the proposal. These early drawings, depicted in Figure 1, were made by YD do illustrate the use of FROG.

Figure 1: Conceptual idea of FROG

At this stage of preparation of the project, the partners were considering a platform with the following characteristics:

- Robot Kinematics: 2 wheeled differential drive. Pneumatic tires for uneven terrain.
- Weight: 30 to 50 Kg
- Payload Capacity: 40 to 50 Kg
- Height: 1 m
- Battery Autonomy: 4 to 6 hours
- Maximum Velocity: 1.5 m/s
- Low-level sensors: battery level, motor encoders, bumpers, ground sensor, sonars, temperature, humidity, rain
- High-level sensors: lasers, IMU with GPS, standard camera, depth camera
- Actuators: 2 DC motors for locomotion
- Interaction devices: monitor for AR contents, sound, microphone, led lights. Other interaction devices like laser pointers and image projectors were also being considered.

3. Platform Development. 1st Step

In the early stages of the project, the consortium was still considering what type of kinematics to use. The use of a differential two-wheeled robot platform was still on the table. Based on this, YD came out with a first output for the robot design and the consortium started the preparation of a first integration meeting for data collection, making use of an existing differential robot platform from IDM.

3.1. Differential Two-Wheeled Robot Platform Design

YD took as input the specifications that were being discussed by the partners to make these drawings during the first months of the project. In this design, depicted in Figures 2 to 7, three features have a bigger influence on the robot shape: the stereo cameras enclosed as the “eyes” of the robot; the touchscreen for the facial expressions of the robot; and the two-wheel configuration.

Figure 2: 1st robot shell design by YD

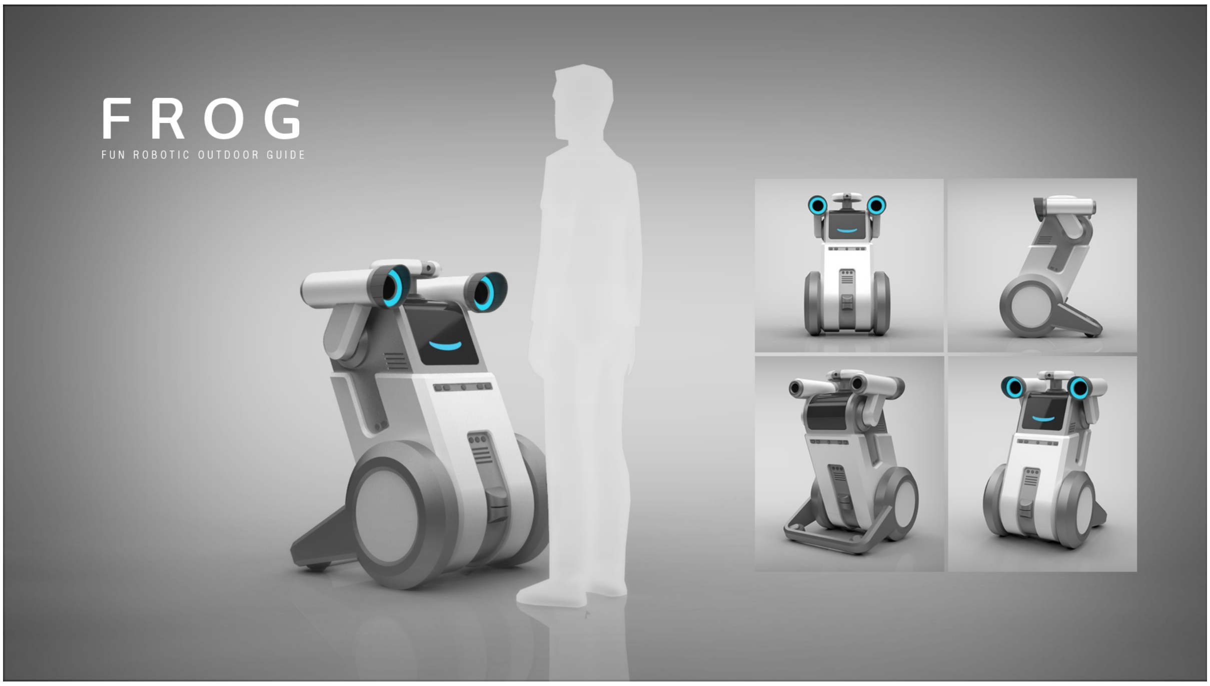

Figure 3: 1st robot shell design by YD

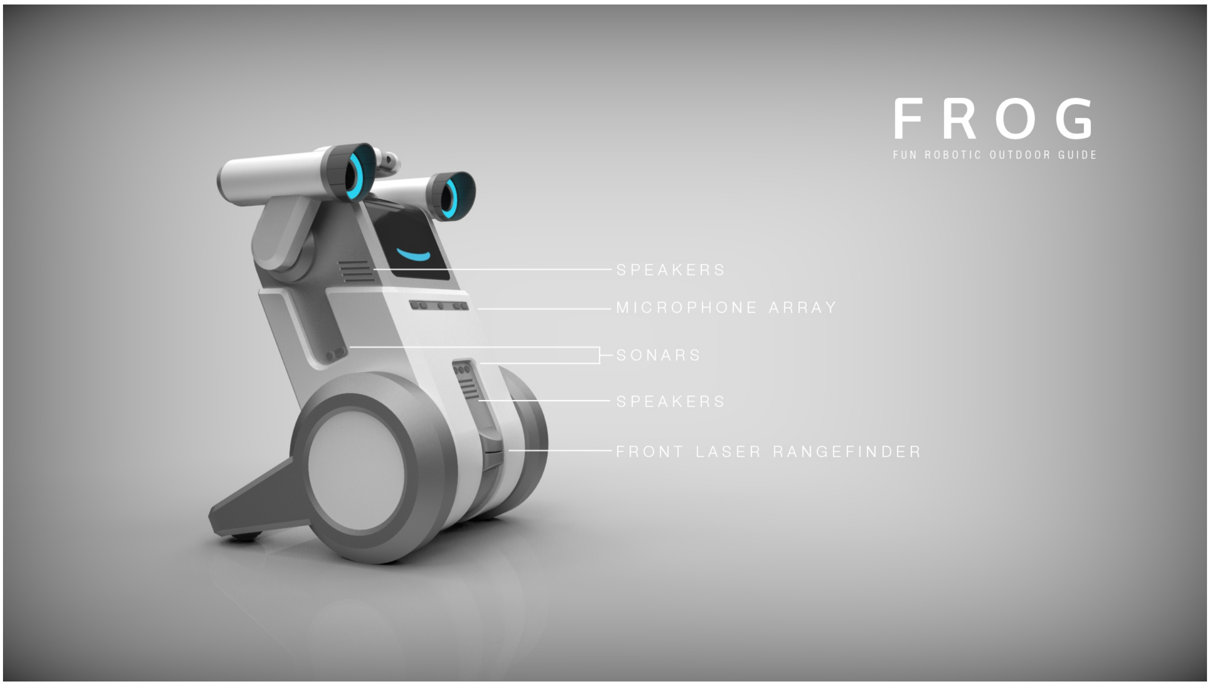

Figure 4: 1st robot shell design by YD

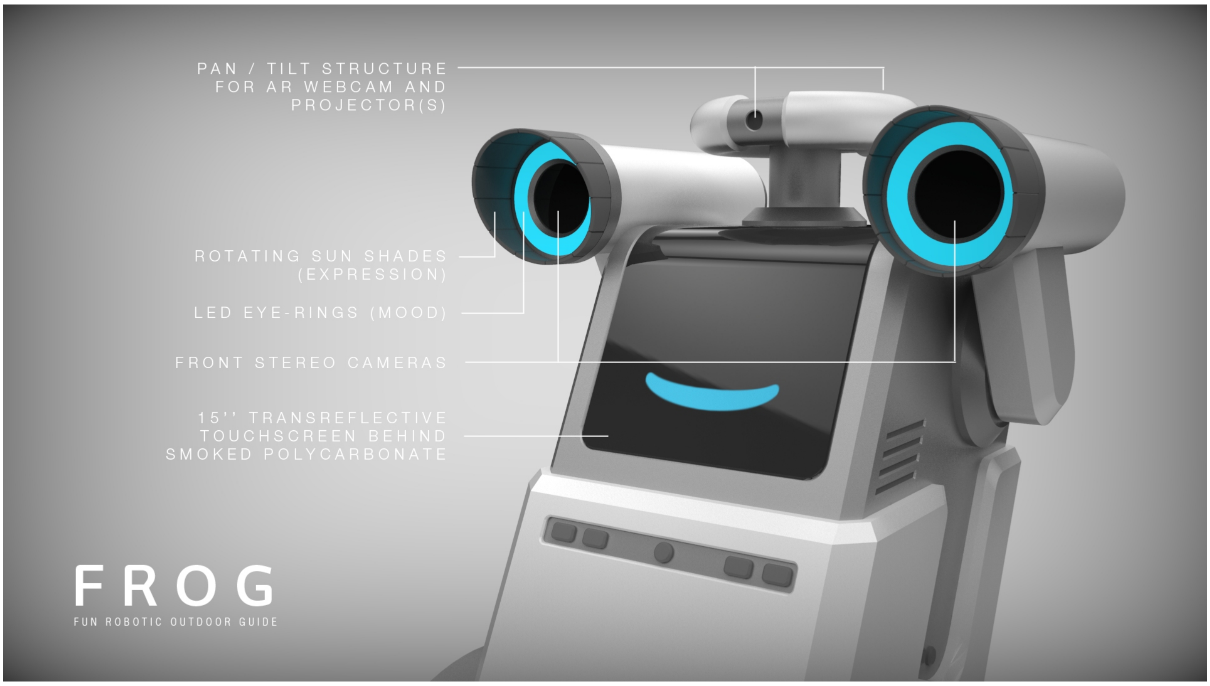

Figure 5: 1st robot shell design by YD

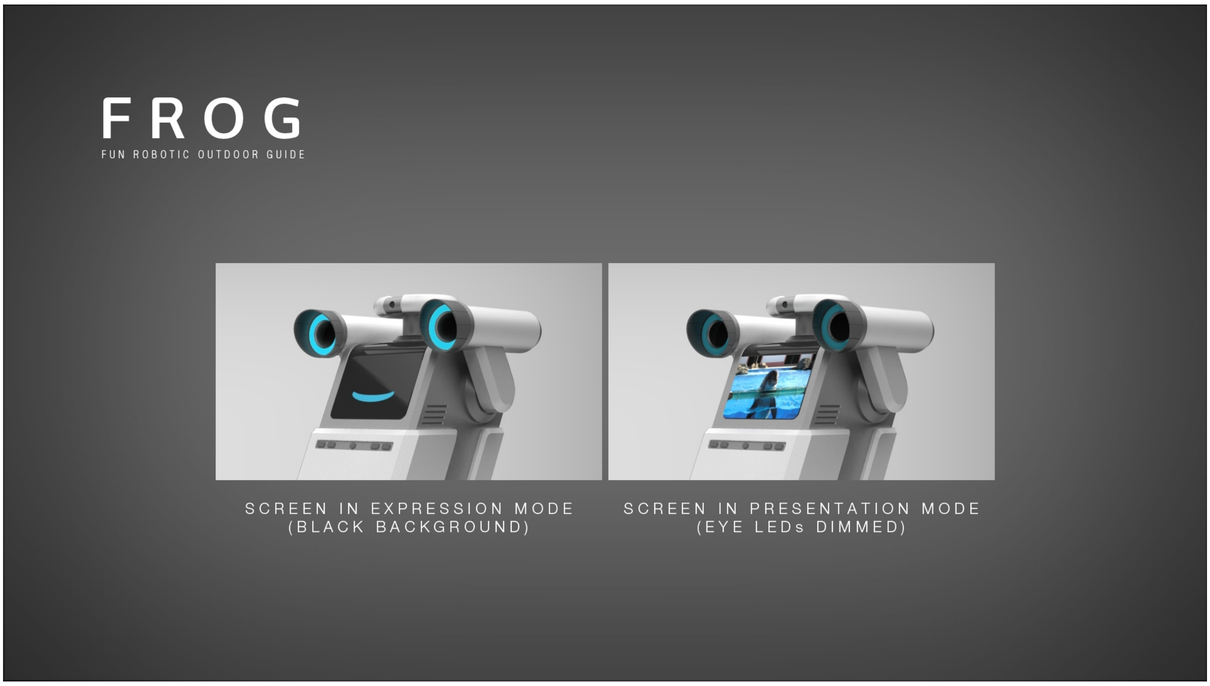

Figure 6: 1st robot shell design by YD

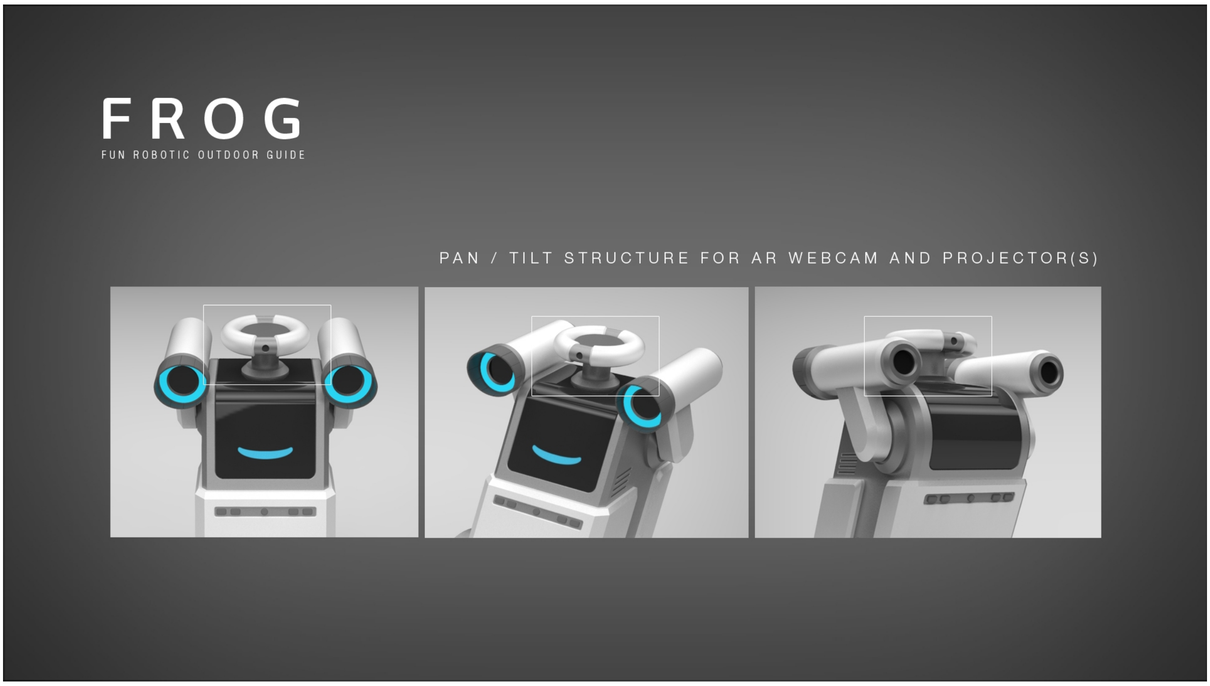

Figure 7: 1st robot shell design by YD

3.2. Data Collection Robot Platform

In the first integration meeting, held in Seville in month 8, the consortium made use of an existing differential robot platform from IDM, equipped with the project perception and navigation sensors, different processing units and the required battery power (see Figures 8 and 9). This is a two-wheel differential robot with one castor wheel on the back. The experiments were made while the robot was being controlled through an external laptop (plus joystick).

Regarding the platform kinematics, this first integration meeting demonstrated two facts. The first one was that the use of two-wheeled configuration, with a castor wheel, has some drawbacks as the robot faced some difficulties when the castor wheel (with no traction) went through small gaps in the ground. The second one, was that the payload resulting from all the on-board technology from the different partners and the inherent battery power, demanded a more stable platform with a bigger footprint.

Figure 8: 1st data collection robot platform

Figure 9: data collection during the 1st integration meeting

4. Four-Wheeled Robot Design

In an early stage of the project, based on all the specifications and foreseeing some difficulties with a traditional differential two-wheeled platform, IDM started making some drawings of a four-wheeled platform configuration. These drawings were included in D1.1 and are depicted in Figure 10.

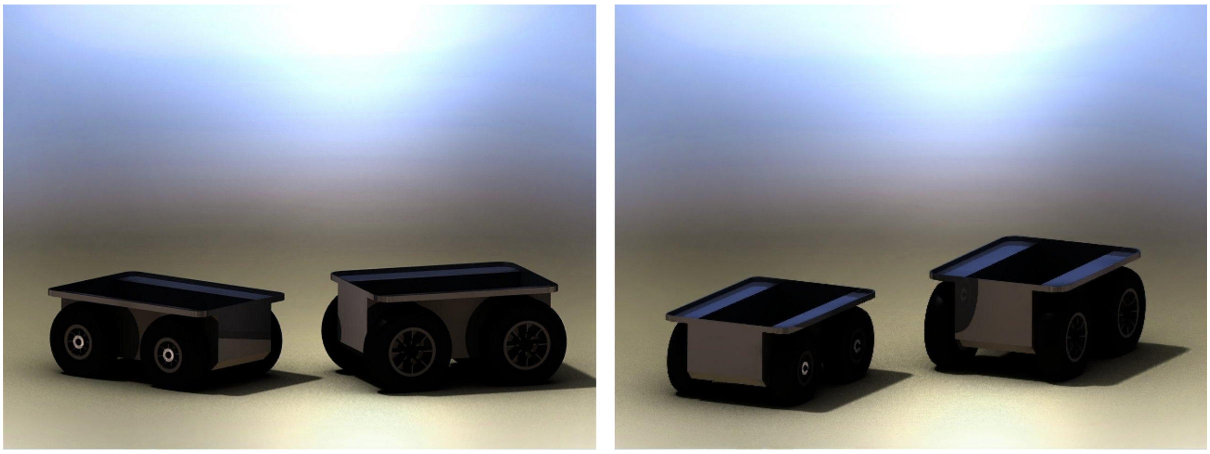

Figure 10: four wheel differential drive platform

Based on this configuration, a simplified outer-shell has been designed to give an idea of the overall dimension in comparison with a person (Figures 11 and 12).

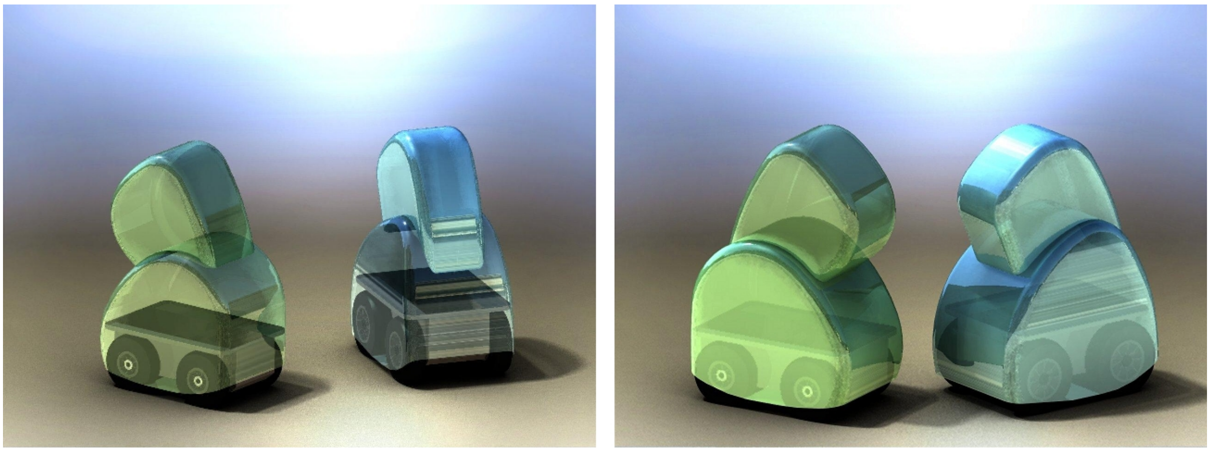

Figure 11: simplified outer shell

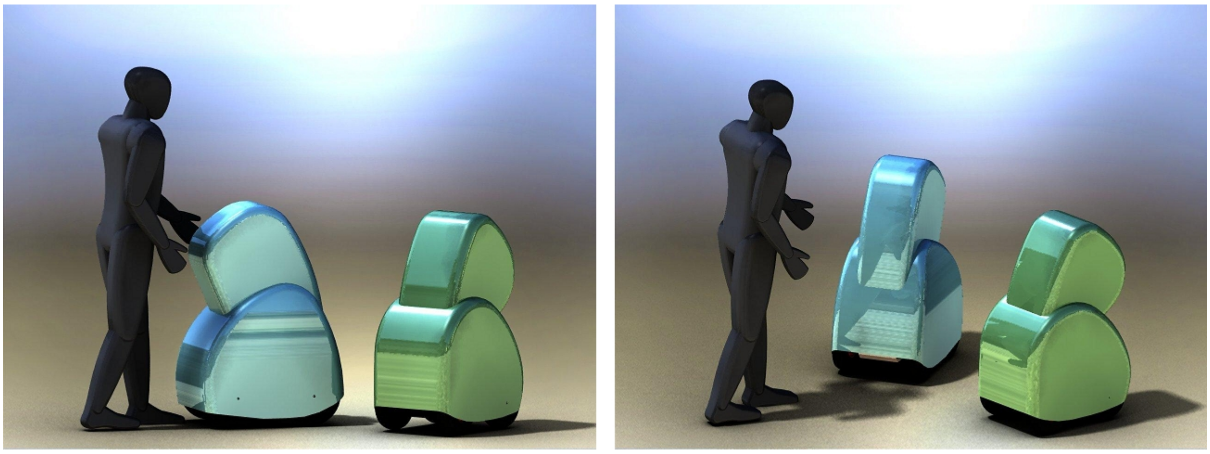

Figure 12: comparison with a person

4.1. Robot Platform Design and Mechanics

Following the first integration meeting, held in Seville in month 8, and due to the unsatisfactory performance of the two-wheeled configuration over the type of ground of this test-bed, IDM proceeded with the design of the four-wheeled configuration.

Figures 13 and 14 show the platform base CAD rendering, including the 260mm wheels, the two motors, the battery distribution, the bumpers, the sonars and the front and back laser rangers. This platform can accommodate up to ten standard 12V-17Ah lead-acid batteries (more than 2.0KWh of power). Presently, the two lateral compartments enclose the motor driver board and the charging board.

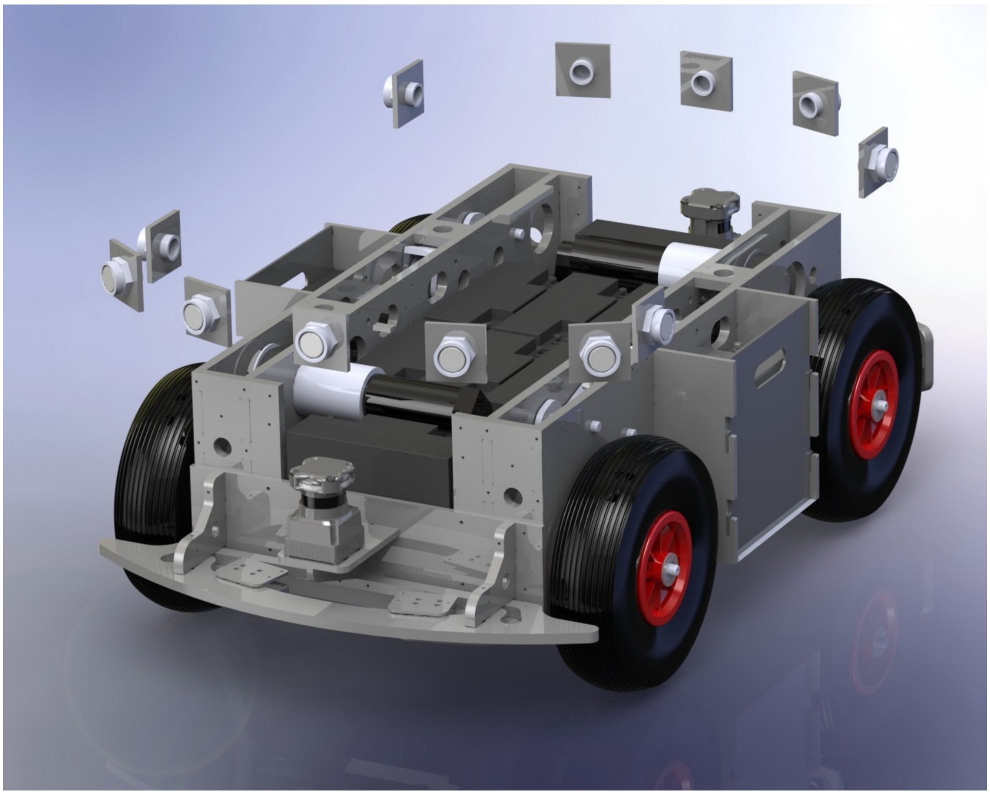

Figure 13: Mechanics CAD rendering

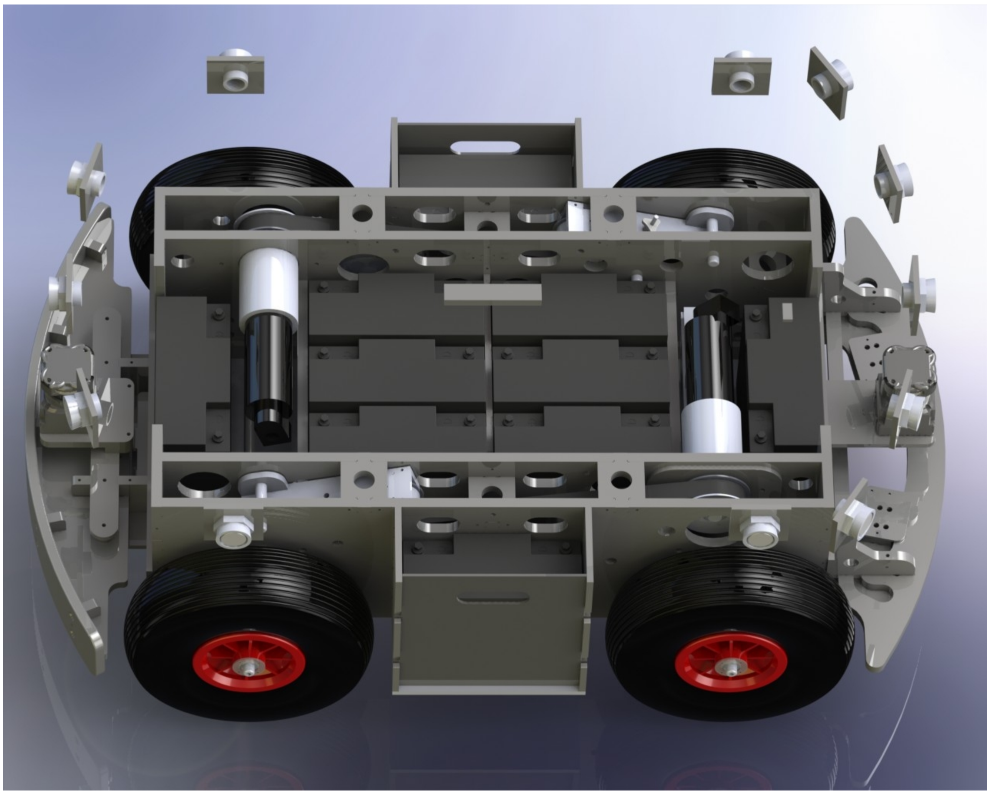

Figure 14: Mechanics CAD rendering

The platform base was concluded in month 12. The main body of this platform and the pulley system has been constructed using polyoxymethylene (POM), which is a material with high stiffness, low friction and excellent dimensional stability. Figure 15 depicts the assembled robot base.

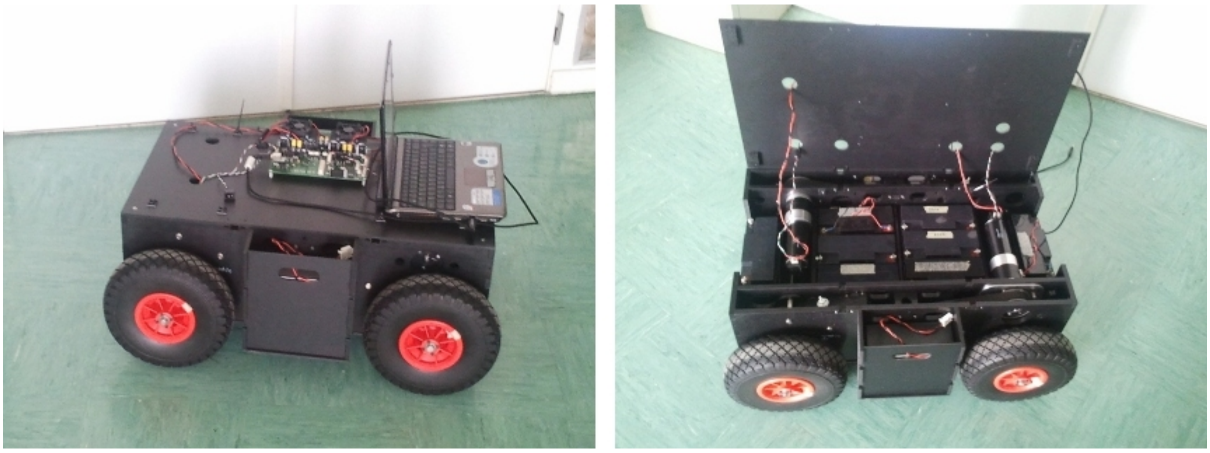

Figure 15: assembled robot base

4.2. Technical Specifications

The description of low-level electronics and also the mechanics of the platform base were included in D1.2. The technical specifications of this platform can be summarized as follows:

Construction

- Body: Polyacetal - POM (PolyOxyMethylene) 6 mm and 10 mm thick plates
- Transmission gears type/material: Toothed pulley - Polyacetal - POM 20 mm
- Belt drive type/material: HTD-8M (QB-HTD8-1904-20) - Nylon covered, fibreglass reinforced, neoprene.
- Tyres
    - Puncture-proof foam-filled tyre on polypropylene rim
    - Diameter: 260 mm
    - Load capacity: 100 kg (each)
    - Width of tyre: 75 mm
    - Length of hub: 75 mm

Locomotion

- Kinematics: Differential Four-Wheel Drive
- Motors: Maxon RE 50 200W 24V with gearbox Maxon GP 62A 19:1

Operation

- Empty weight: 30 kg (depends on configuration, minimum 30 kg)
- Operation payload
- Tile/Floor levelled: 90 kg
- Grass/dirt: 70 Kg
- Asphalt: 65 kg

Skid Steering Drive

- Turn radius: 0 mm
- Swing radius: 500 mm
- Max. Forward/Backward Speed: 1.5 m/s
- Rotation Speed: 130 degree/s
- Max traversable step: 70 mm
- Max. traversable gap: 150 mm
- Max traversable grade: 25%
- Traversable terrain
    - outdoor use: asphalt, levelled dirt terrain, trimmed grass
    - indoor use: flooring, carpet floor, tiles

Power

- Run time: 4-6 hours with 3 Batteries (with no accessories)
- Charge Time: 12 hours (standard)

Batteries

- Supports: up to 10 batteries at same time
- Capacity: (12v) 17-20 Ah 5.5 kg each
- Chemistry: lead acid or LiFePO4 block 12V batteries with PCM

4.3. On-board Equipment Positioning

The positioning of on-board equipment has been specified by the partners according to their requirements. Figures 16 and 17 depict this specification, which was then used as input for the outer shell design and also for the inner structure design that will be used to fix all the components to the robot platform base.

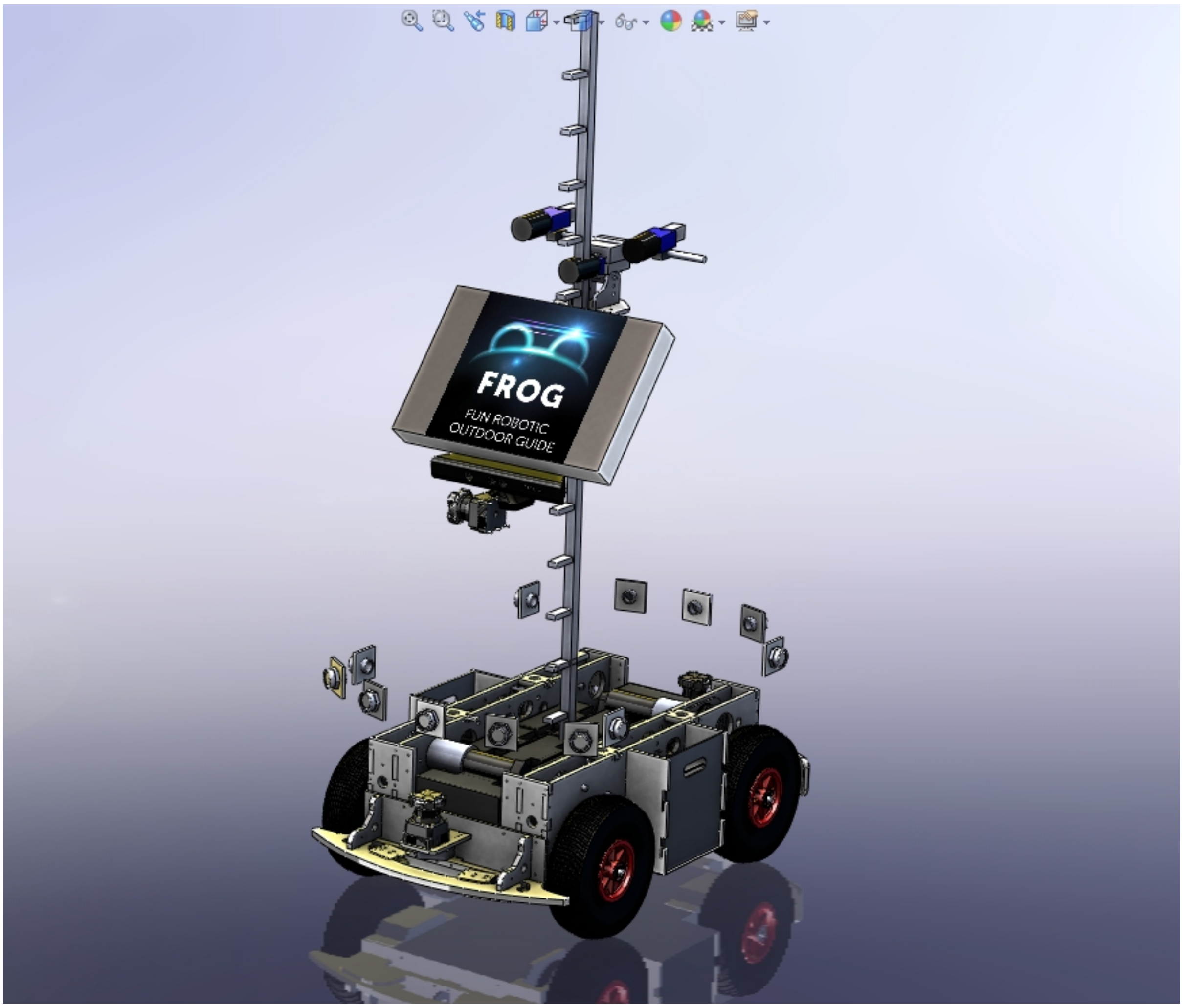

Figure 16: equipment positioning on the robot

Figure 17: equipment positioning on the robot

The following specifications were used for the equipment positioning:

Perception Sensors

- Front Stereo Vision Camera: Dalsa Genie-HM1400 XDR (2x)
    - Function: localization, obstacle detection, pedestrian detection and body orientation estimation;
    - Position on Robot Platform: looking ahead; 1.2 m high
- Front Vision Camera: Dalsa Genie-HM1400 XDR (1x)
    - Function: face analysis and fine body gestures.
    - Position on Robot Platform: looking ahead; 1.15-1.2 m high

Navigation Sensors

- Inertial Sensor IMU with GPS: Xsense MTI-G
    - Function: Localization of the robot (position and orientation)
    - Position on Robot Platform: as close as possible to the robot´s centre of gravity
- Front 2D laser range-finder: Hokuyo's UTM-30LX

        - Function: localization and obstacle avoidance
        - Position on Robot Platform: frontal and horizontal
- Front 2D laser range-finder: Hokuyo's UTM-30LX or URG-04LX
    - Function: obstacle avoidance (3D perception of ramps, slopes, etc)
    - Position on Robot Platform: frontal, tilted or vertical orientation; 0.75 m high
- Rear 2D laser range-finder: Hokuyo's UTM-30LX
    - Function: obstacle avoidance
    - Position on Robot Platform: on the rear and horizontal
- Sonar Sensors: XL- MaxSonar®- WRC1™
    - Function: obstacle detection (ex:glass wall or objects)
    - Position on Robot Platform: ring of sonars around the robot

Interaction Sensors

- Microphone array: Kinect Microsoft
    - Function: user sound feedback for natural user interaction
    - Position on Robot Platform: turned to the users; under the touchscreen
- Touchscreen
    - Function: user feedback on specific contents
    - Position on Robot Platform: turned to the user

4.4. Shell Design

The design of the shell had to be completely redefined according with the new kinematics configuration. This new design concluded in month 14 and is depicted in Figures 18 to 20, took also into consideration the specifications for the on-board equipment positioning. It also considered the inclusion of a new interaction element: a small robotic arm with a laser pointer. This device mounted over the robot head, will point to specific points of interest and it will make use of a class 1 [1] green laser.

1 A Class 1 laser is safe under all conditions of normal use

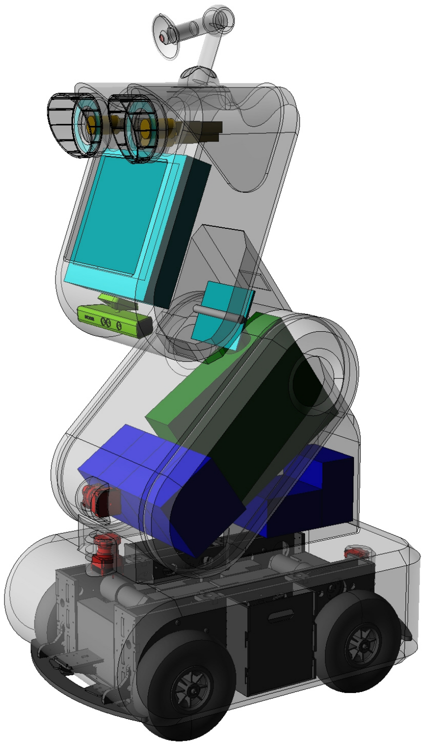

Figure 18: shell design for the 4 wheel configuration


Figure 19: 3D rendering of the new design

Figure 20: 3D rendering of the new design

5. Refining the Robot Platform

In order to conclude the robot platform, some final adjustments had to be performed. These adjustments included an upgrade to the bumper system, the design and assembly of an upper structure to support all the equipment and consequently the necessary changes to the shell design.

5.1. Bumper Upgrade

After the first review meeting, and following some issues related with safety that were raised during this meeting, IDM started the development of an upgrade to the existing bumper system. The new solution, depicted in Figures 21 to 24, is based on a band made of a soft material (polyethylene foam), surrounding the robot platform base and associated with the bumper sensors. This foam acts as a shock absorber and prevents direct contact with rigid components of the structure. It can detect contact from any direction (even side contact).

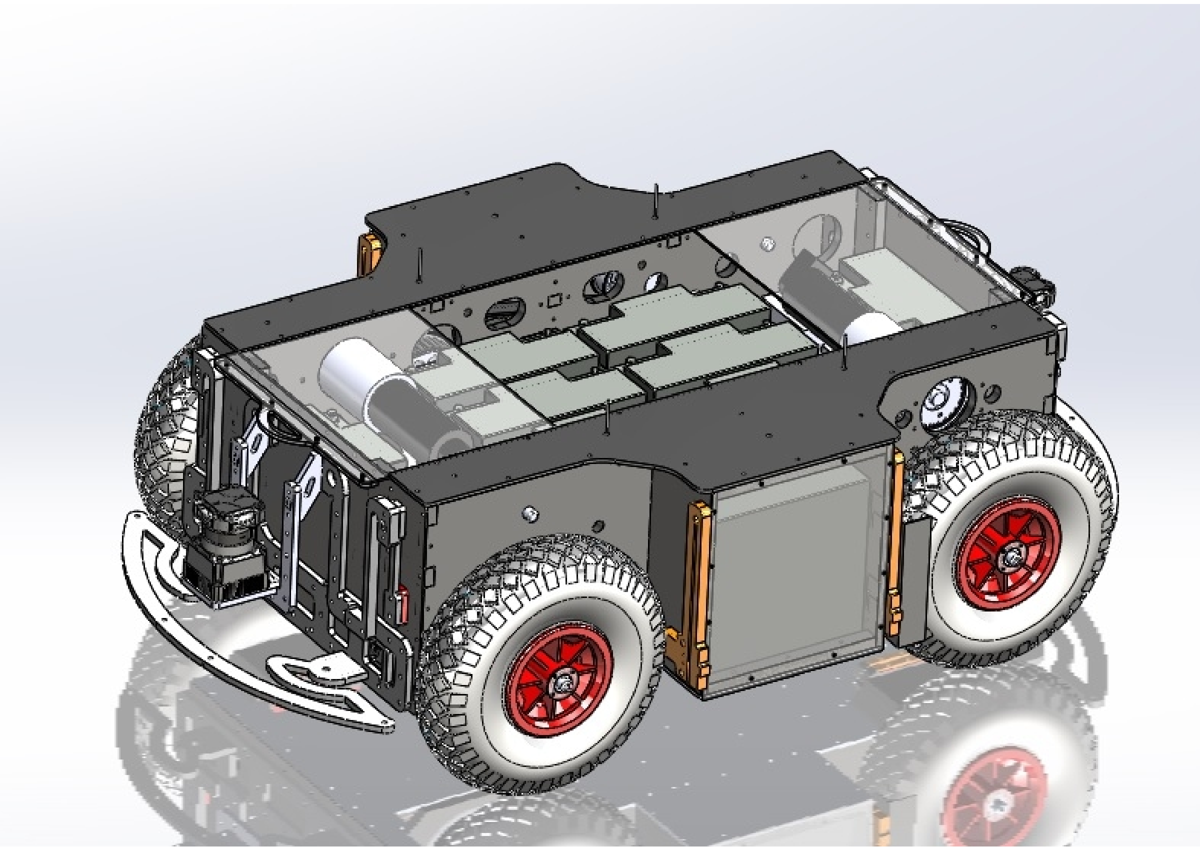

Figure 21: modified robot base to accommodate foam band

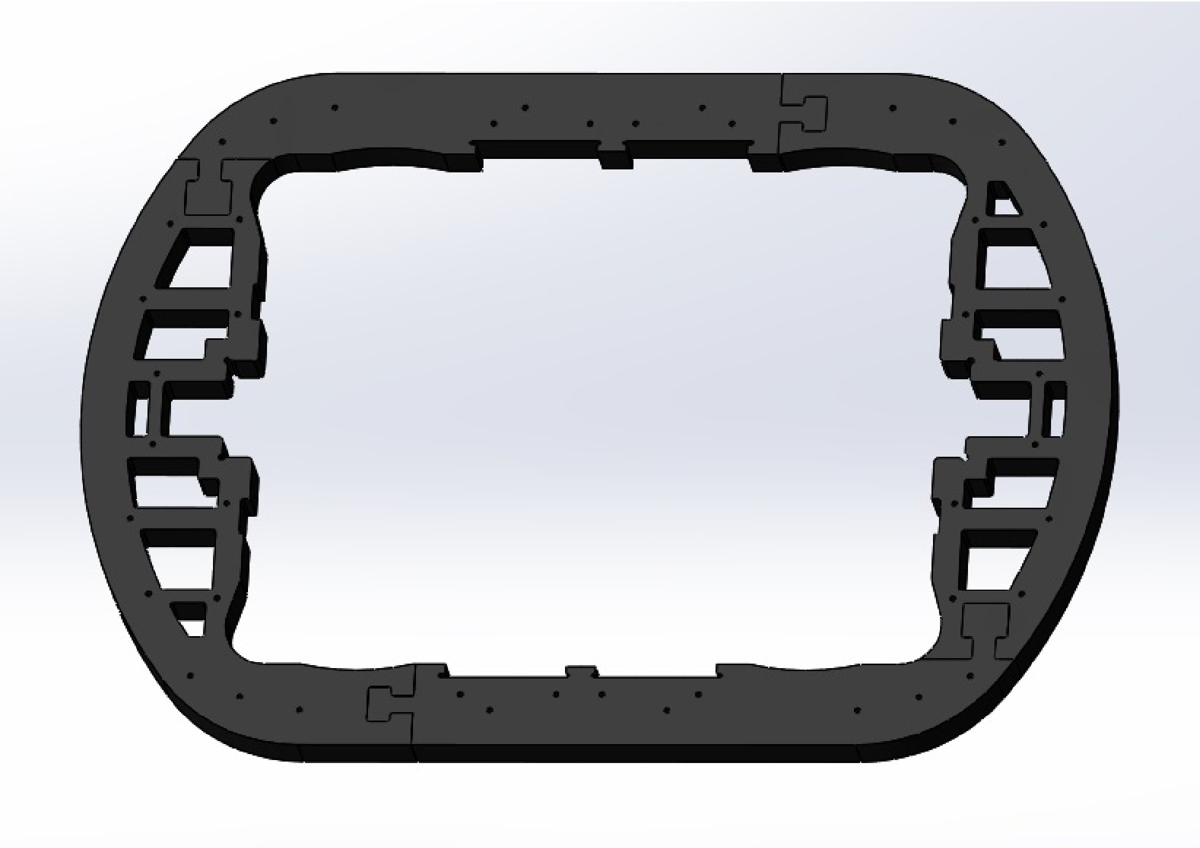

Figure 22: polyethylene foam bumper

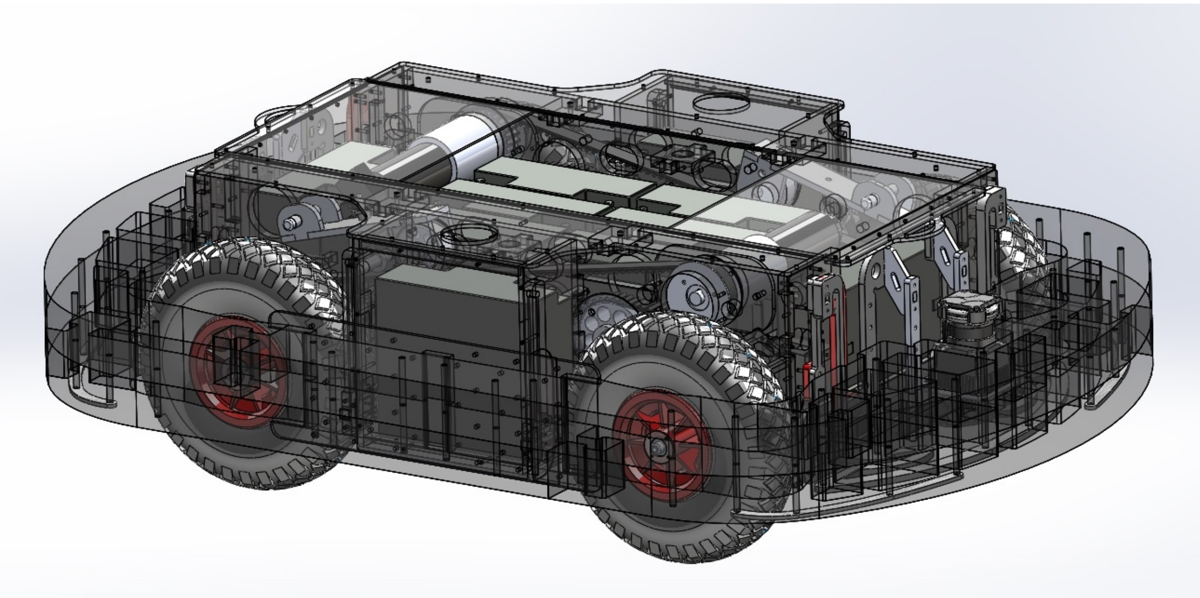

Figure 23: robot base with foam bumper

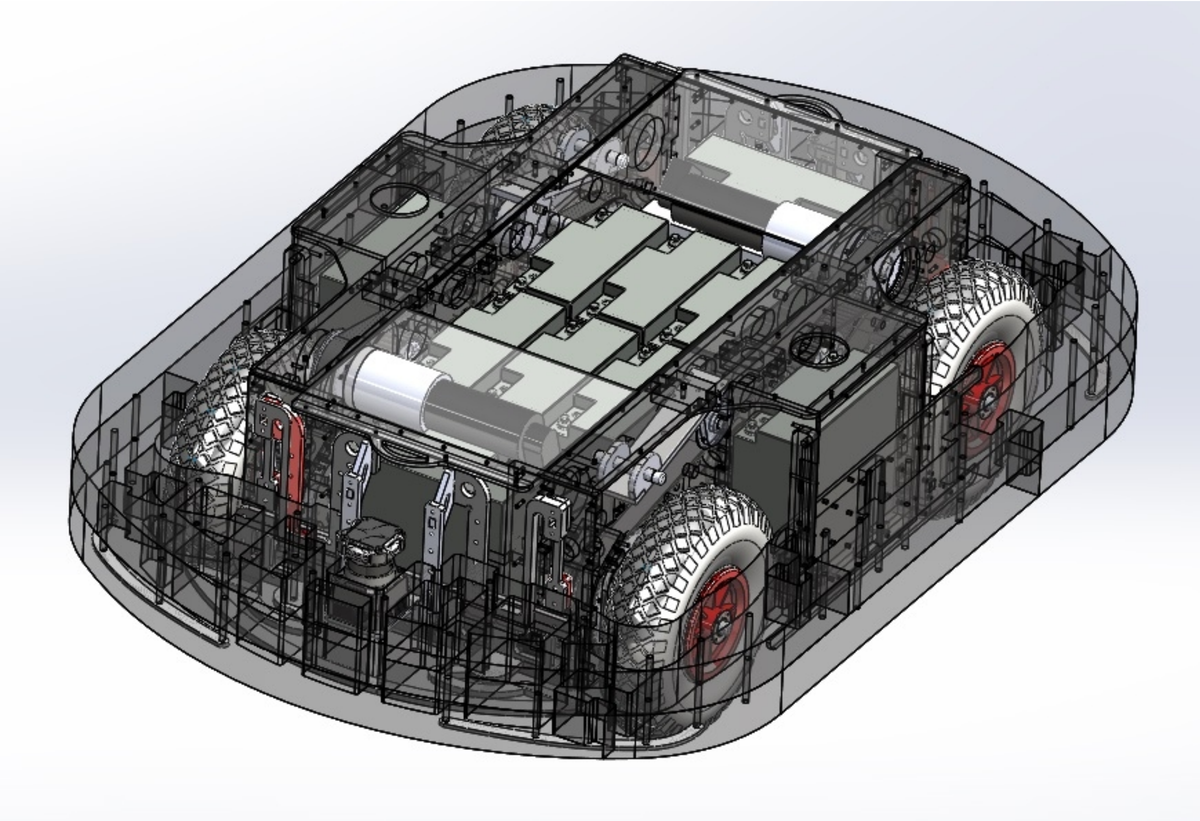

Figure 24: robot base with foam bumper

5.2. Upper Inner Structure

IDM developed a lightweight aluminium structure to support all the on-board equipment as depicted in Figures 25, 26 and 27. The following devices were attached to this structure:

- mini-box computer running the navigation component from UPO
- mini-ITX computer running the stereo-vision component from UvA
- laptop computer running the vision component from ICL
- mini-ITX computer running the interaction component from YD
- video projector
- touchscreen
- kinect camera with microphone array
- vertical laser ranger
- front stereo vision camera pair
- front vision camera
- backward vision camera
- DC/AC power inverter

These pictures also depict a LED light solution that is currently being developed for the robot eyes.

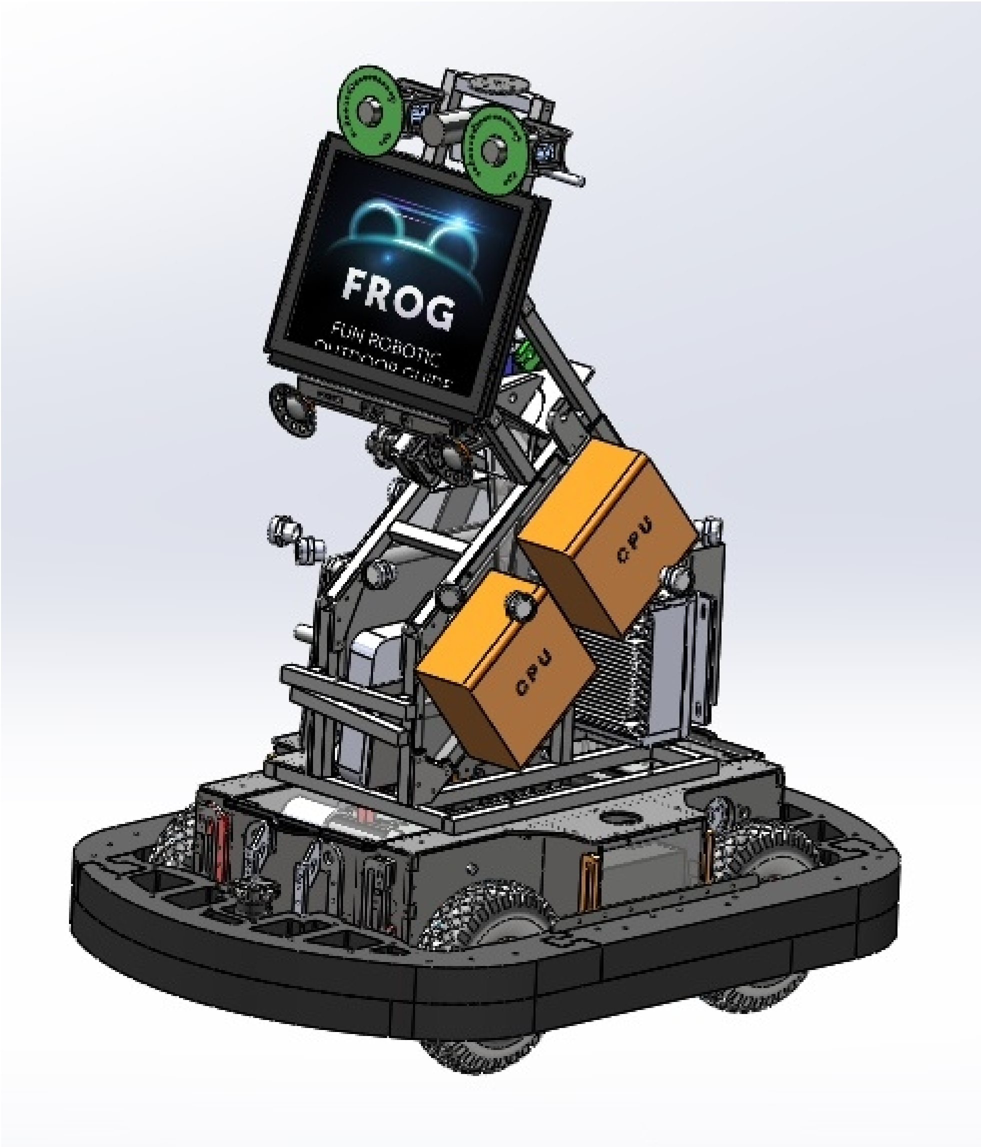

Figure 25: FROG robot platform

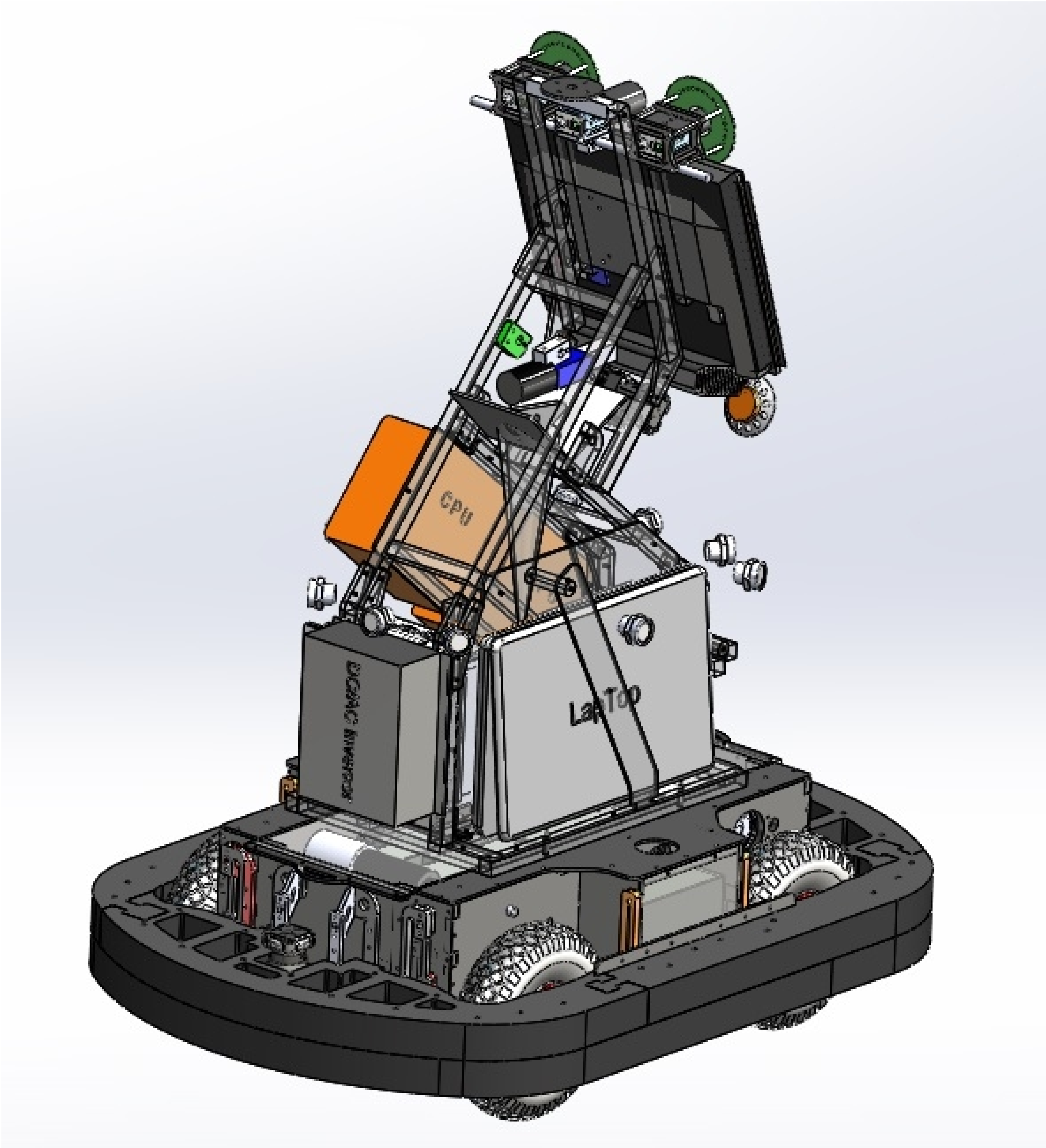

Figure 26: FROG robot platform

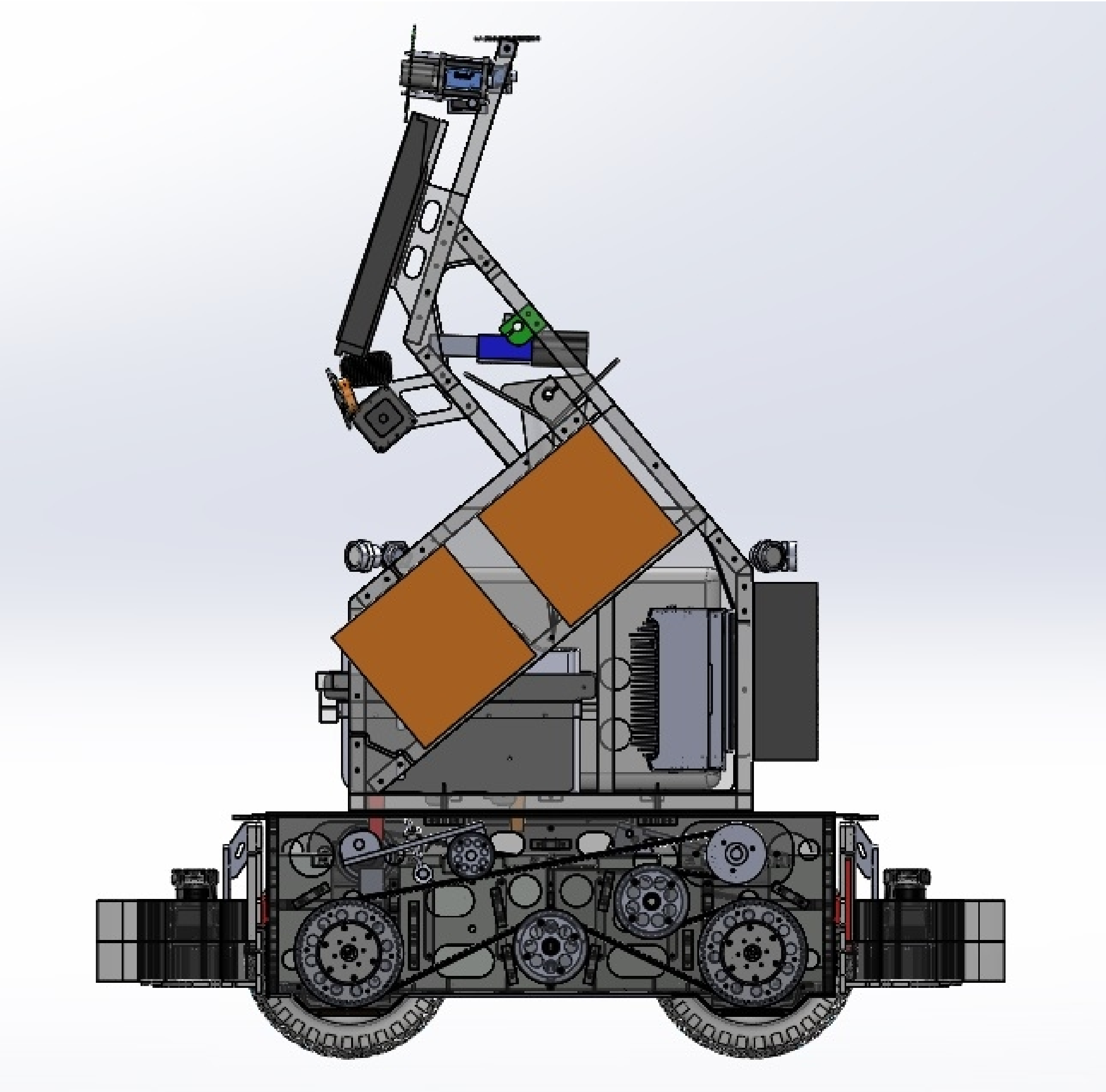

Figure 27: FROG robot platform (mechanics detail)

5.2.1. Double Projection System

From the beginning of the project, the consortium had the idea of including a video projector inside the robot body to be used in some particular points of interest with proper light conditions (shaded zones). An innovative solution has been developed that allows the simultaneous projection of two independent images in two opposite directions. Inside the robot body, two angled mirrors divide the projector beam into two different projected images: one is projected over the floor in the front of the robot and the other is projected over a rear wall. This system is presented in Figures 28, 29 and 30.

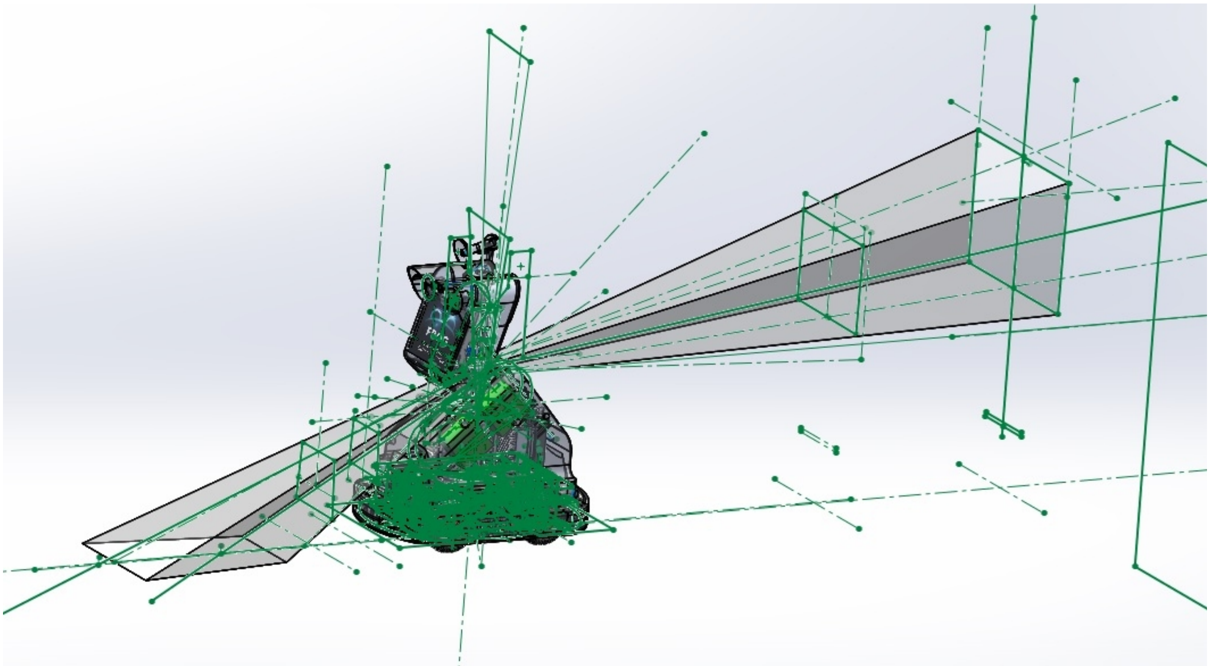

Figure 28: projection angles study

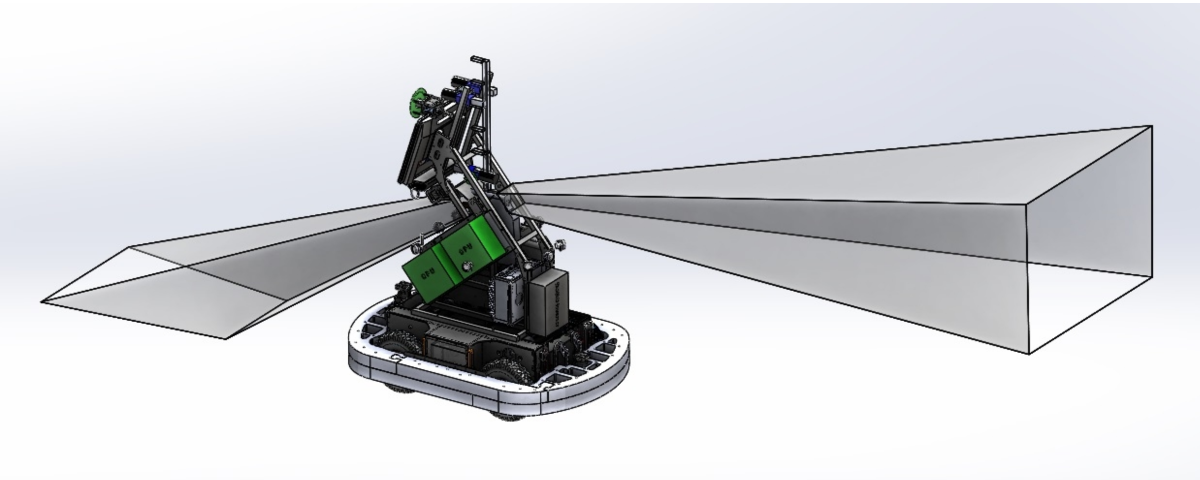

Figure 29: double projection

In comparison with only one side direct projection, this configuration has two drawbacks. The first one is the reduction of the resolution as the original image of 1280X800 pixels is being divided into two projected regions of 800x640 pixels. The second one is that the reflection of light is not perfect as the mirror absorbs part of the light power (which is 3,000 ANSI lumens).

Low-power pocket LED projectors still do not have enough light power for the projected scenarios. For FROG we opted for a projector based on laser and LED hybrid technology which is consuming a maximum power of 110W to 210W[2]. This projector has also a serial port that allows the control of some important features, like the zoom, focus and power mode. The projector can be put in stand-by mode when not in use and it will be consuming only 0.4W in this mode.

2 210 W (Eco Off) / 170 W (Eco On Level 1) / 110 W (Eco On Level 5)

Figure 30: double projection

5.3. 2nd and 3rd Integration Meetings

The second and third integration meetings occurred, respectively, in May 2013 in the Royal Alcázar of Seville and July 2013 in the Lisbon Zoo. For these meetings, the consortium made use of the complete robot platform with all its components. Figures 31 to 34 depict these two weeks of experiments.

Figure 31: experiments at the Royal Alcázar

Figure 32: experiments at the Royal Alcázar


Figure 33: experiments at the Lisbon Zoo


Figure 34: experiments at the Lisbon Zoo

5.4. New Shell Design

Some changes were introduced in the previous shell design. One of the most important changes is related with the new bumper system. The second change was motivated by another safety issue that was raised during the first review meeting. This was related with the previous shell design that could favour children's attempts to ride on the robot. To avoid this, the new design avoids, as much as possible, step-on platforms on the robot shell. Figures 35 to 45 depict the last version of the shell design which should now be close to the final one.

Figure 35: last version of shell design

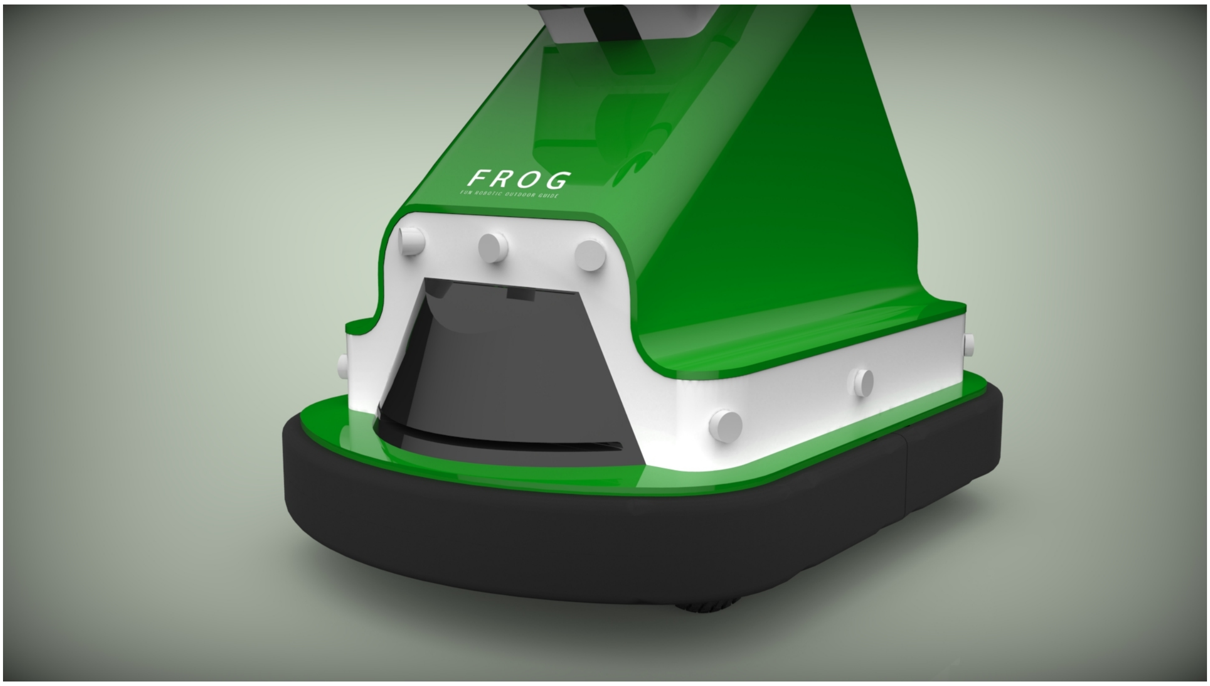

Figure 36: last version of shell design

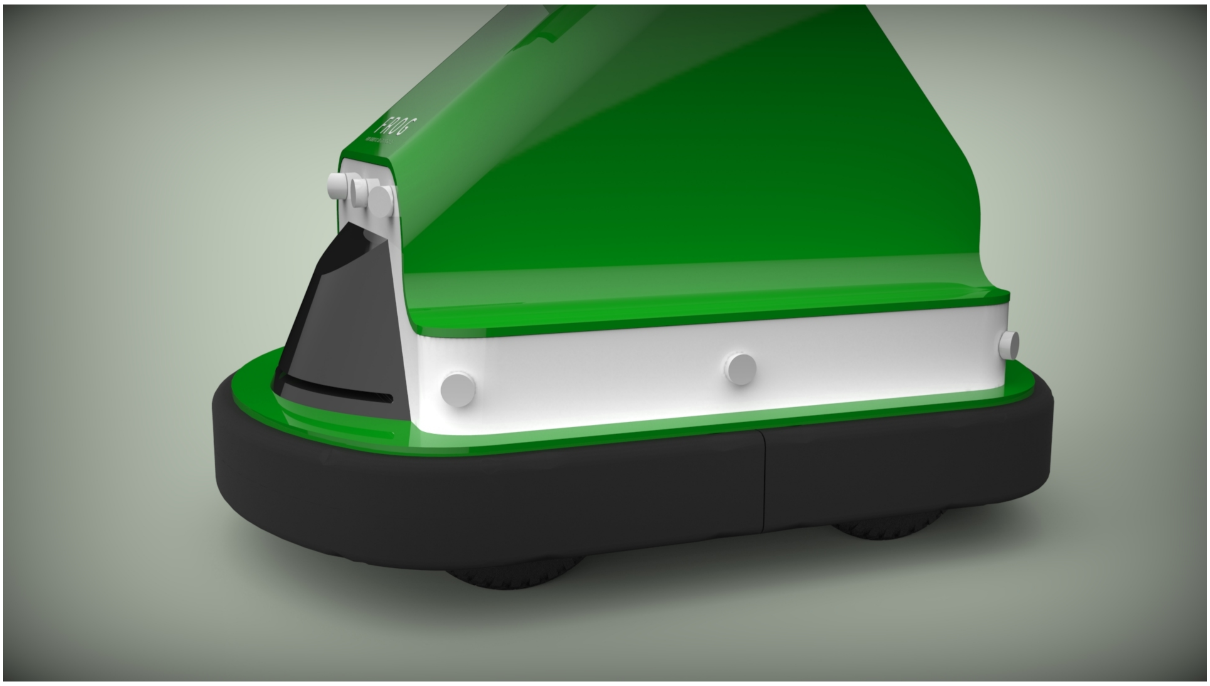

Figure 37: last version of shell design

Figure 38: last version of shell design

Figure 39: last version of shell design

Figure 40: last version of shell design

Figure 41: last version of shell design

Figure 42: last version of shell design

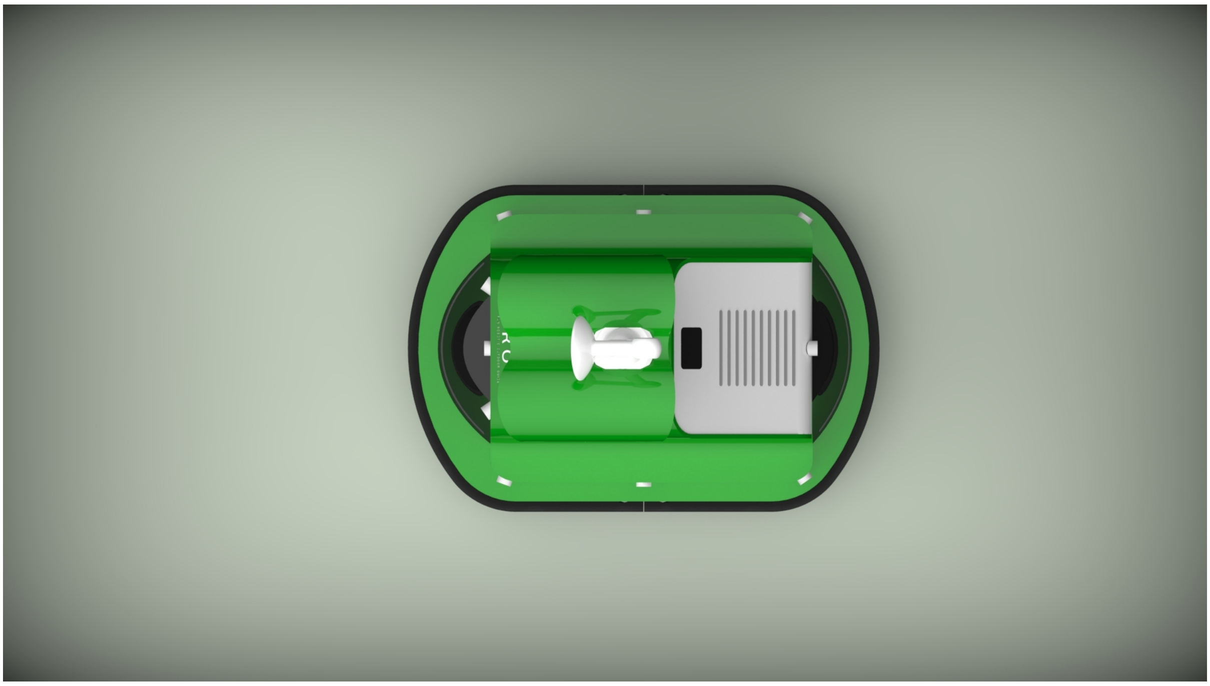
Figure 43: last version of shell design

Figure 44: last version of shell design

Figure 45: last version of shell design

This design is now being refined according with the tools and techniques that will be used for the production of the shell parts. Some small, last minute adjustments will have also to be included. For example, based on UPO tests, the front and back lasers will have to be raised by 10cm. Based on IDM tests, the sonars will have to be also a little bit higher and all at the same height from the floor. There might be also some small adjustments in the colour palette.

5.5. Charger Docking Station

One charger docking station is being developed to be installed in a service area, where the robot can enter and plug itself in. This docking station will provide the necessary power for the on-board battery chargers to charge the batteries. IDM has already concluded the design of the mechanics of the docking mechanism, on-board the robot and on the docking station. Figures 46 and 47 depict the on-board charging contacts.

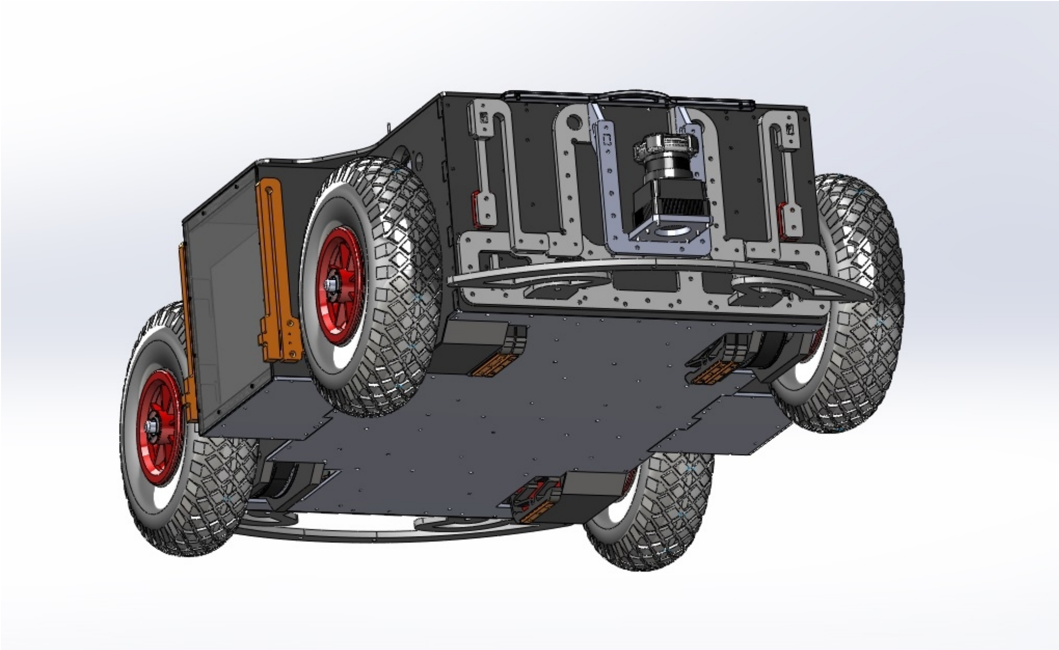

Figure 46: charging contacts under the robot platform base

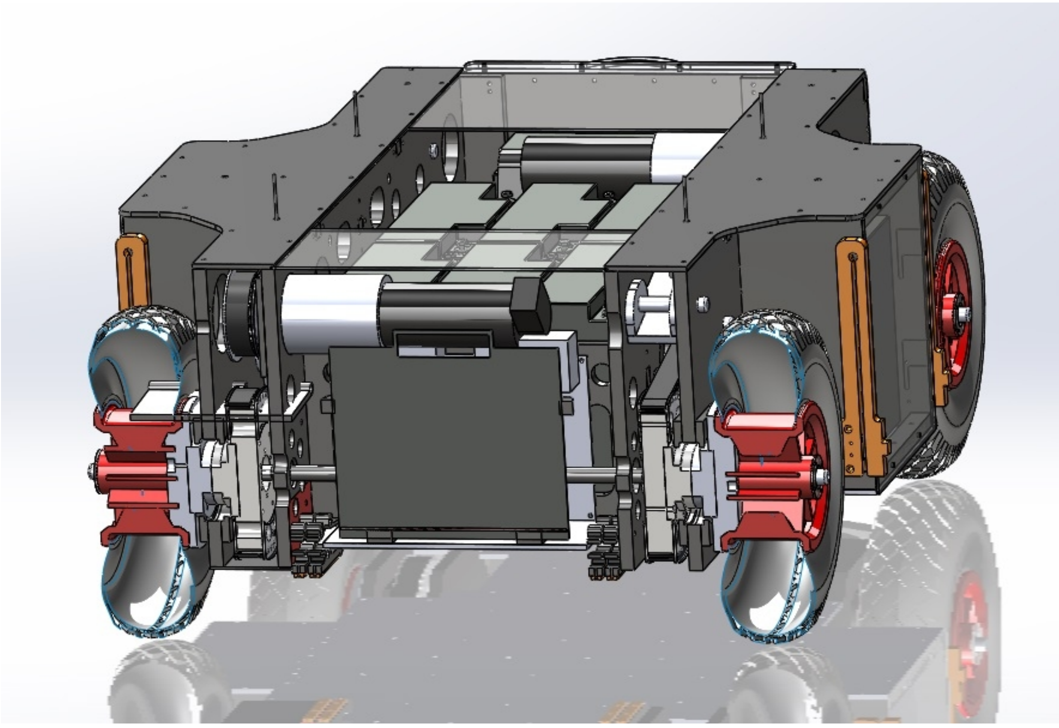

Figure 47: profile cut close to the charging contacts

Figures 48 to 53 depict the charging station and docking of platform into the station. The shape of the charging station was designed in a way that the alignment of the robot with the station will be mechanically corrected while the robot is entering the charging station.

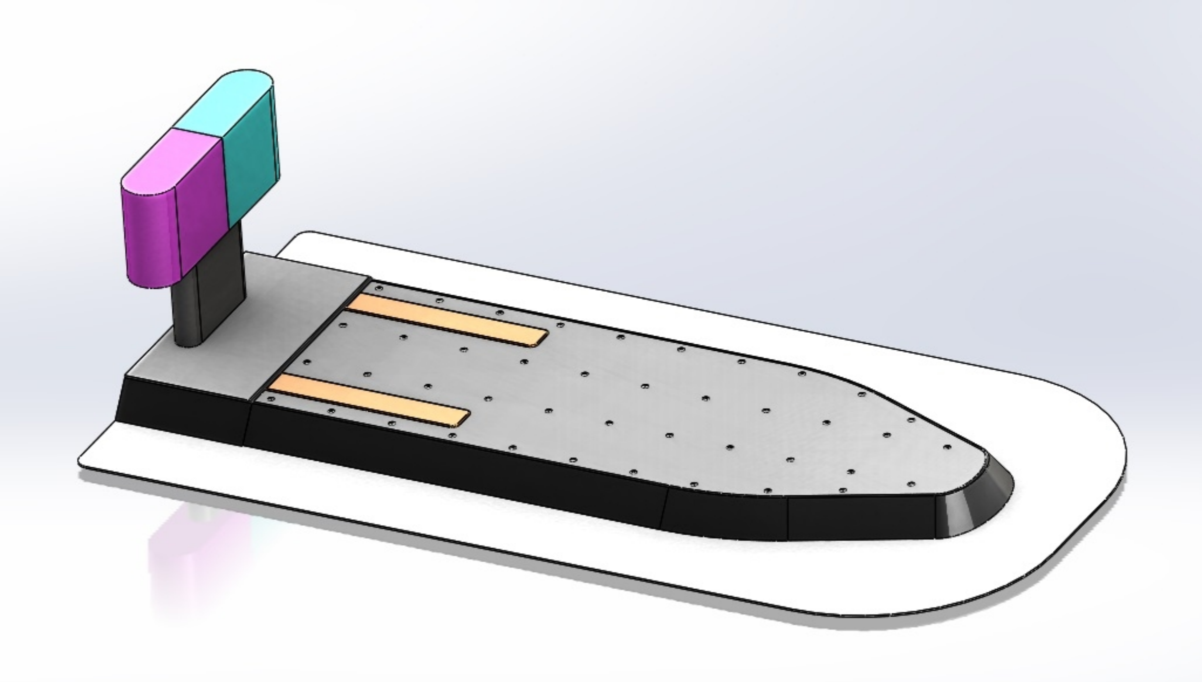

Figure 48: docking station

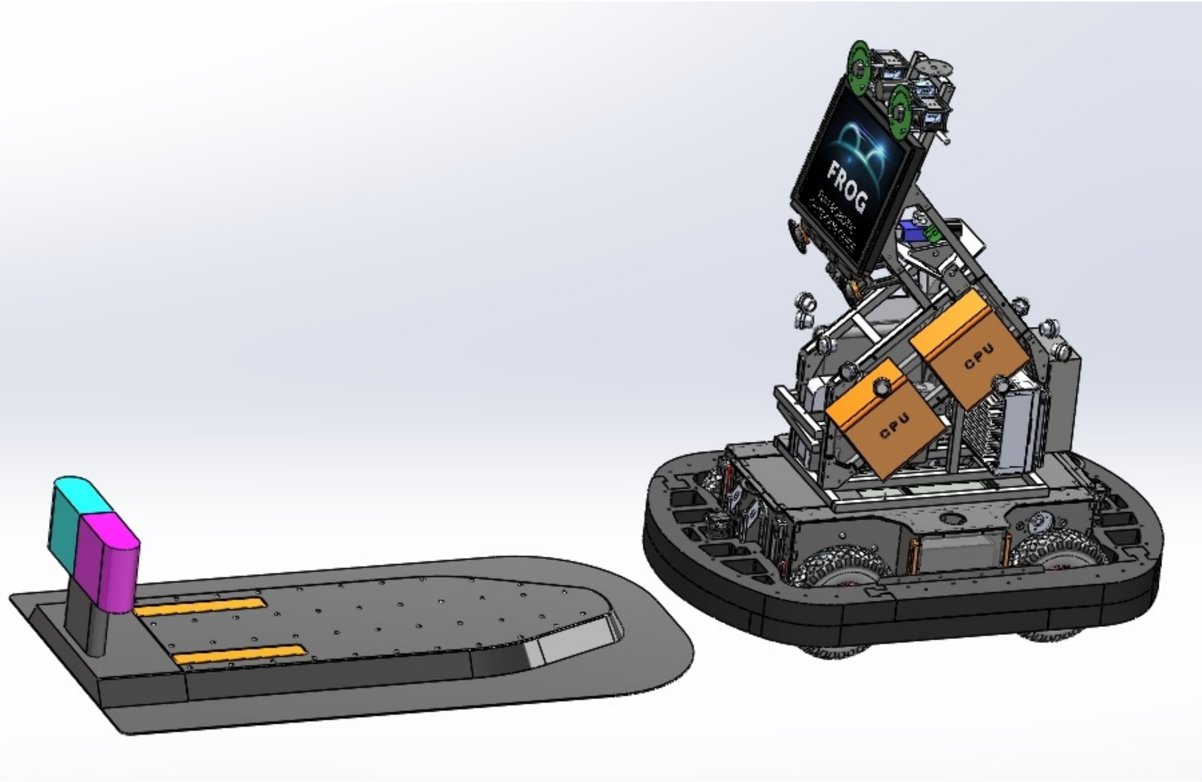

Figure 49: robot approaching the charging station

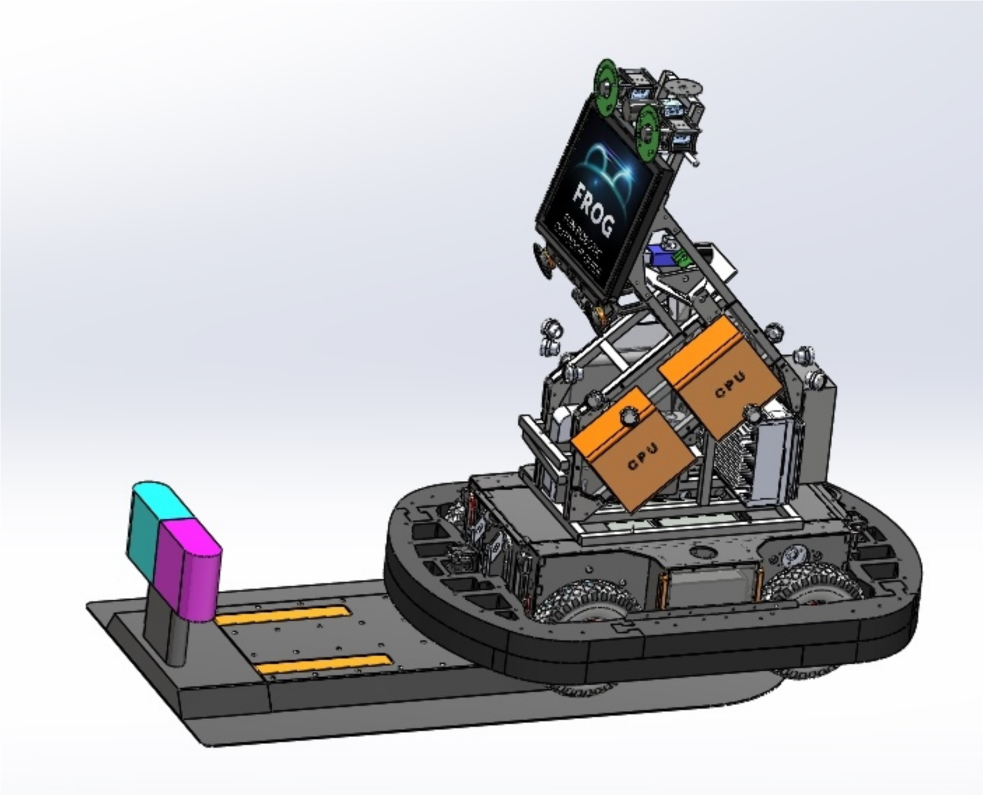

Figure 50: robot entering the charging station

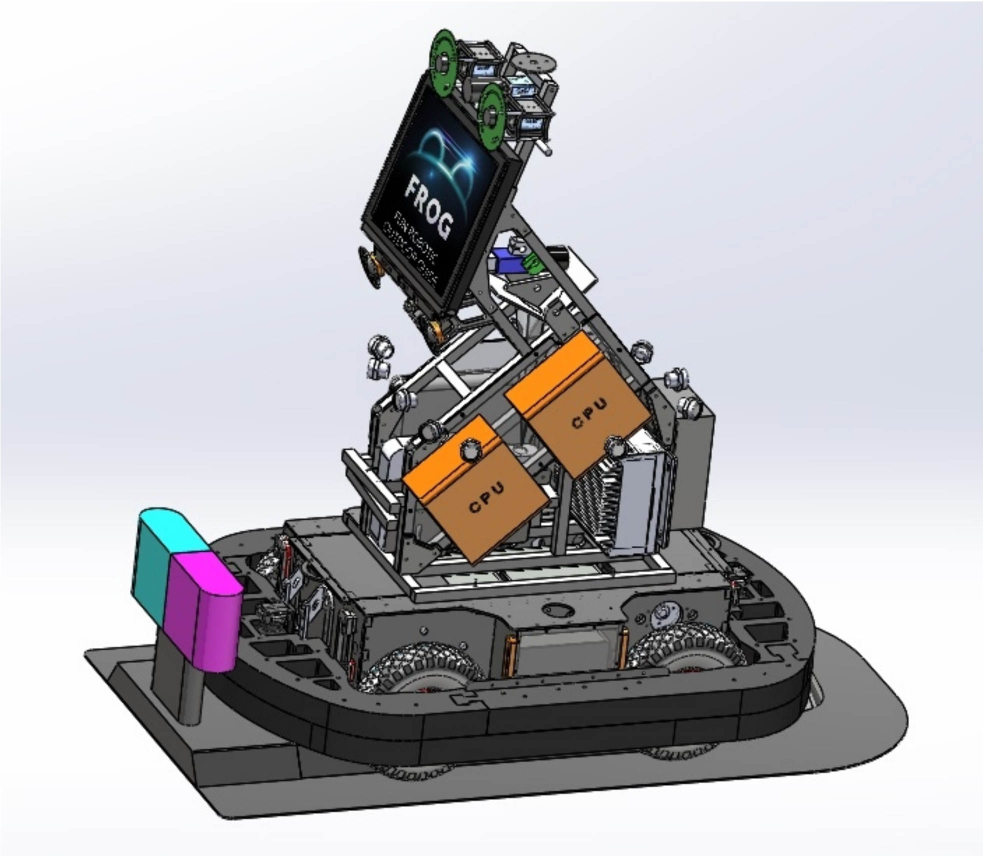

Figure 51: docking completed

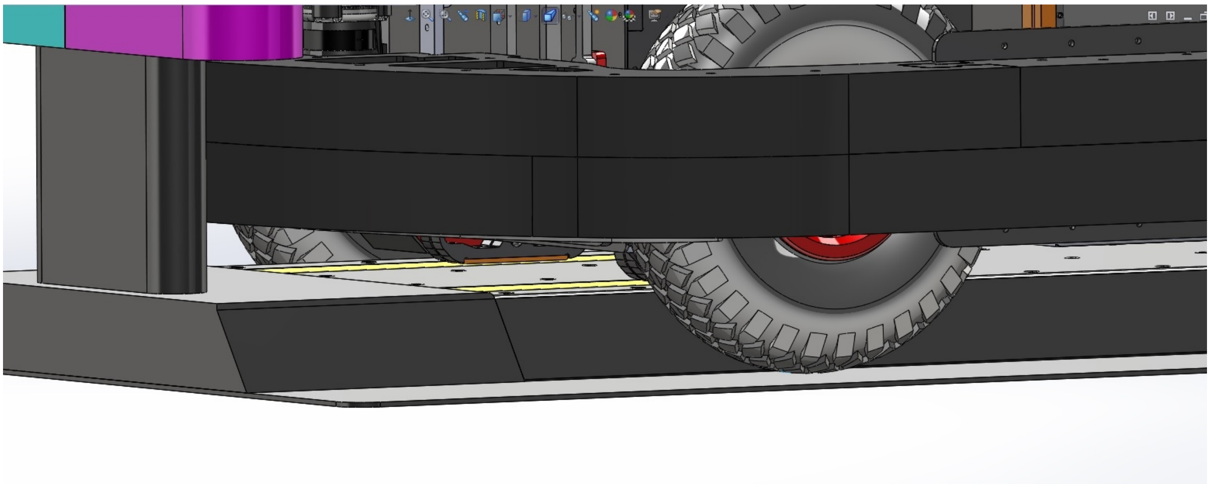

Figure 52: charging contacts detail

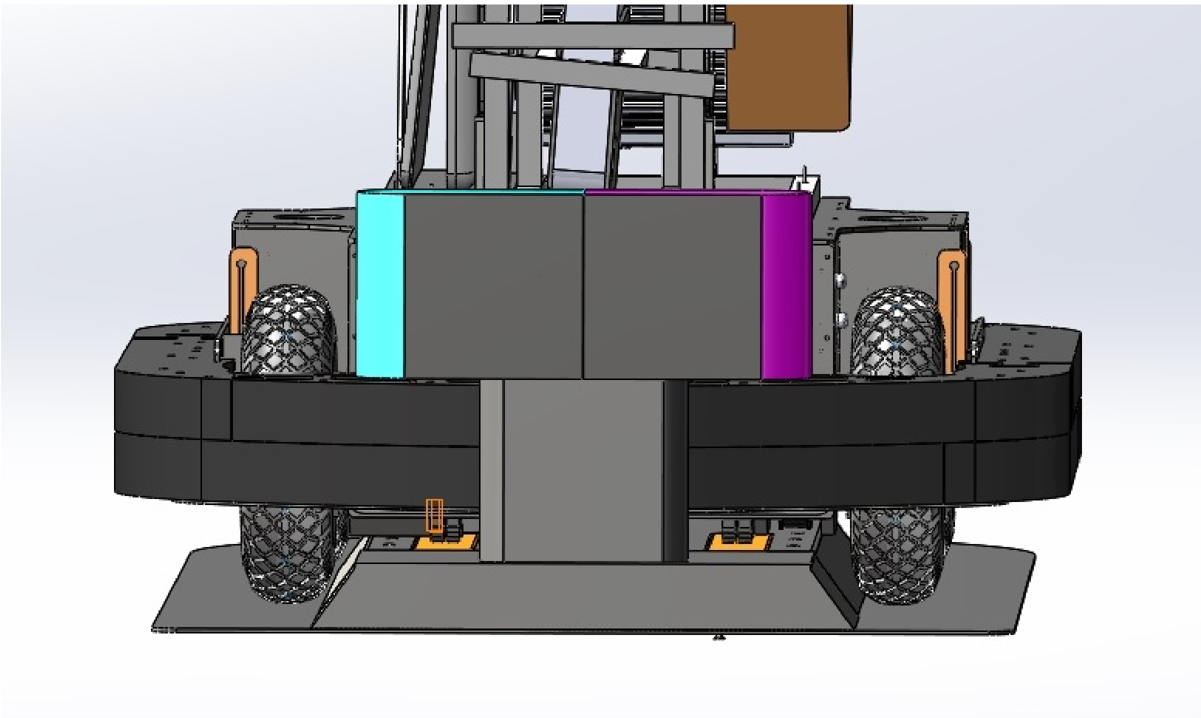

Figure 53: charging contacts detail