Rover Advancements - Ceres

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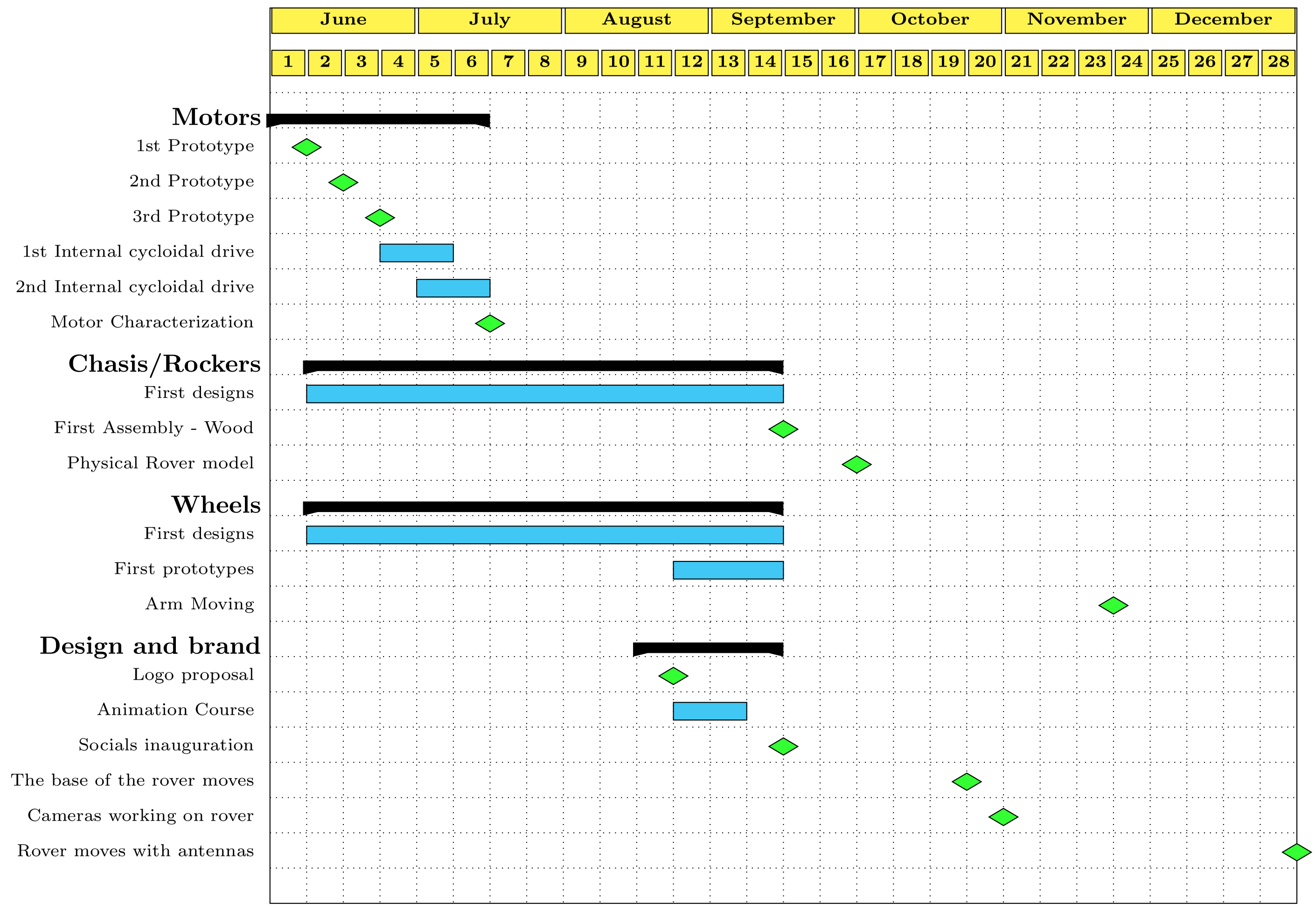
1 Introduction

We, the Ceres team, are developing a Martian exploration rover to participate in international competitions. Our project aims to expand our knowledge in various technical fields and demonstrate the expertise we've gained through past robotic experiences and our professional careers. By tackling the challenges of designing and building a rover capable of operating on Mars, we hope to advance our skills and contribute to the broader field of space exploration. We differentiate our selves with this proyect by being the only team developing our own motors from scratch. In this document we highlight our most relevant milestones, along with the main developments and learnings along the way, as well stating with our following steps.

2 Gantt Chart - Work in Progress



3 Milestones Achieved

3.1 Motors

3.1.1 First prototype

Developments

- 100mm x 10mm Stator - 3 phase Winding

Figure 1: First Motor Winding

- 3D model of the rotor with 42 poles (magnets) along with a base

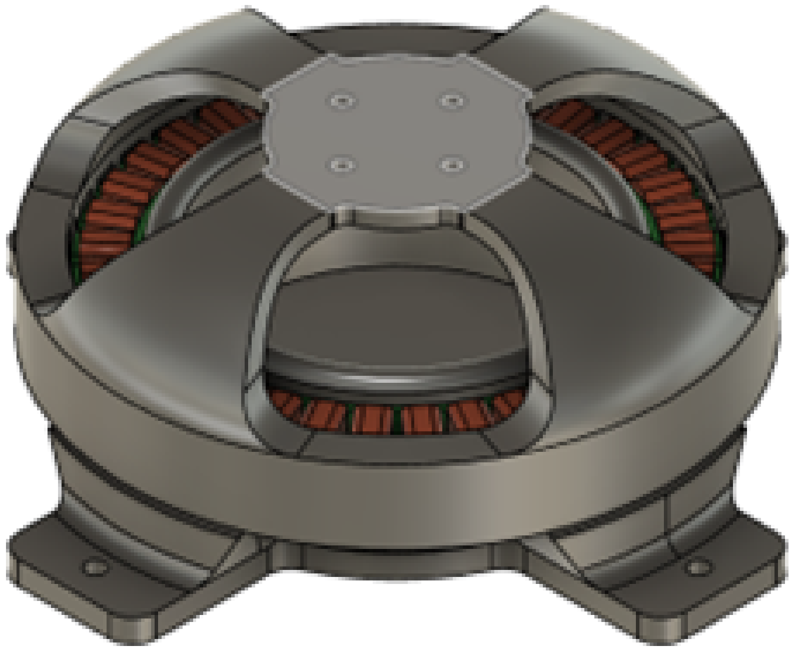


Figure 2: First Prototype 3D

- 3D Print of the motor and assembly
- Initial test with a 30A generic ESC

Results

- The motor vibrates, like triying to move Video:
- The motor winding heats up a lot and very quickly as soon at it is turned on

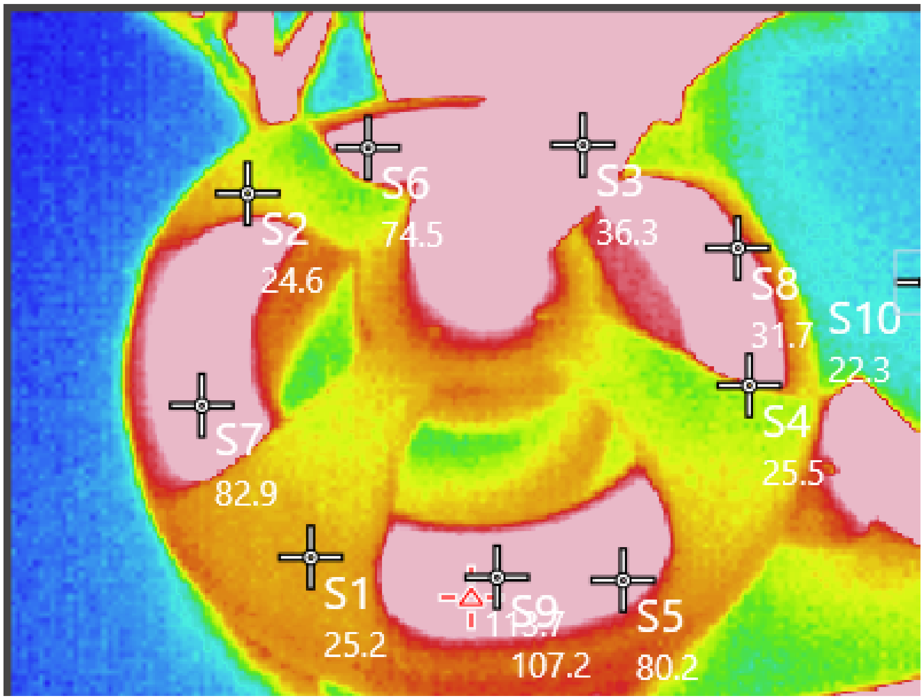


Figure 3: Motor Heat Test

- The rotor sticks to one side of the stator as it is not supported by anything at its center
- 2 ESC were broken due to the high current draw

Conclusions

- The motor base needs to have an alligment that mantains the rotor at the center of the structure
- An ESC with higher current capacity is needed for these tests.
- It is necessary to check why one of the phases was heating up to 110°C. As well as identifying if this was the cause of the motor not being able to spin

3.1.2 Second prototype

Development

- A new motor was designed, featuring a rotor (upper part) with an extension that fit into an internal base within the stator (lower part), which blocked lateral movement and limited vertical position while allowing rotational movement. Both parts were made entirely of plastic.

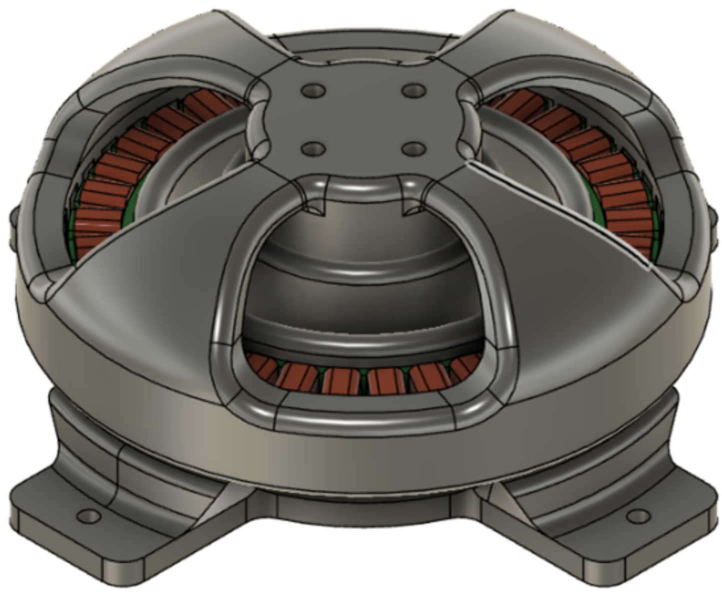


Figure 4: Second Motor Prototype

- The motor winding was redone because we found that some of them were wound in the opposite direction to what they should have been. This caused the magnetic field, responsible for generating rotation, to be constantly canceled out.
- 3D printing and assembly

Results

- An 80A 6S ESC was used in order to use higher voltage and current when trying the motor.
- The motor spins correctly, however no cuantitative methods were used to classify the success of this movement. **Video:**

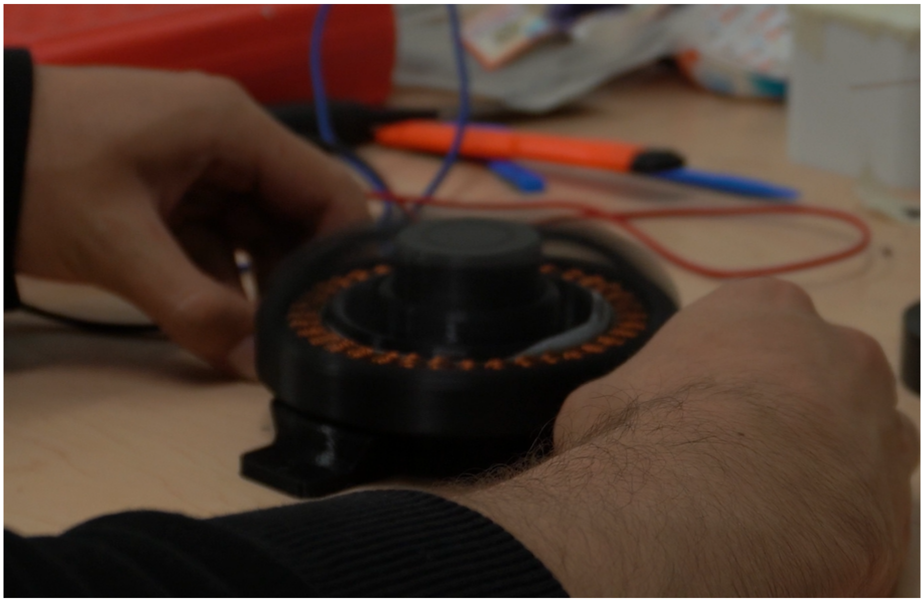


Figure 5: First Spin

- After some time of testing, the friction between the internal support of the rotor and base of the stator make them melt together.
- The rotor still isnt maintained correctly in the vertical axis.

Conclusions

- A different alternative to maintain the rotor aligned is neccessary. One that reduces friction while maintaining the center firmly in its position.

3.1.3 Third Protoype

Development

- A new 3D design of the base was created, where the connection between the base and the rotor is made using a bearing to reduce friction and improve the rigidity of the coupling between the two parts.
- An arm was designed for the rotor, which will help us have a basic understanding of the torque the motor can produce.
- The rotor design was changed so that the magnets are no longer attached with resin, allowing for faster and more efficient assembly and facilitating the effective recovery of the magnets for use in future prototypes.
- Printing and Assembly of the model

- Speed was measured with a tacometer
- Current was measured with a current clamp at no motor load **Video: (each 10mV = 1A)**

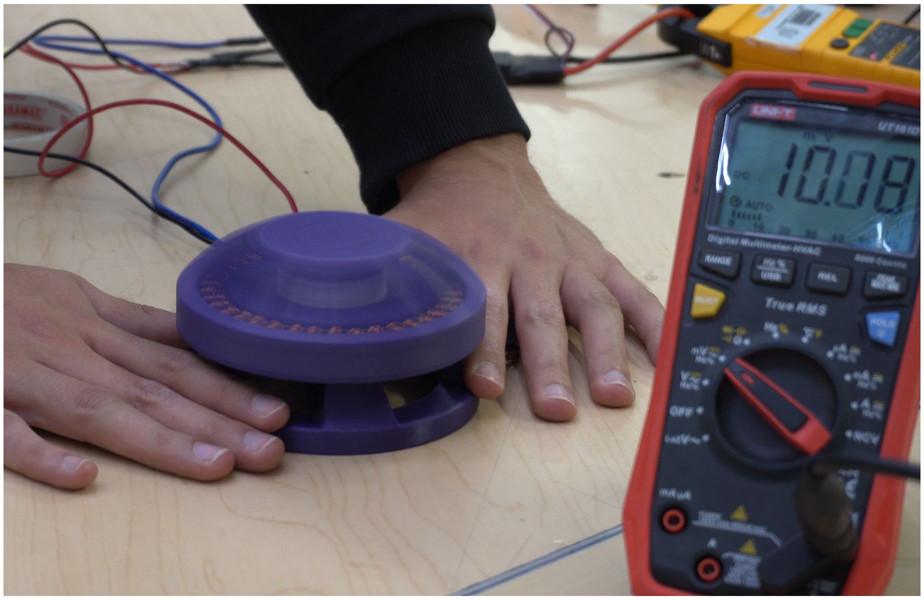


Figure 6: Current and Speed Measurement

- Simple cualitative torque tests

Conclusions

- The speed measured with the tacometer doesnt seem to be accurate, as it gave a far faster speed than expected (4000rpm vs 2000rpm) and after that failed to read in further tests.
- The motor visibly has an easier time spinnign with the bearing, as friction was greatly reduced
- Another way to measure the motor speed is neccessary.
- We need a cualitative and more safe way to measure the torque output.

3.1.4 First Cycloidal Drive prototype

Development

- A cycloidal drive was designed to fit within the stator of the motor, thereby optimizing its volume. This gearbox features a central shaft which is anchored to the motor rotor. As it rotates, the discs on the shaft (highlighted in the photo) turn with the desired reduction ratio due to the shape of the ring (highlighted in the photo). To capture this reduction, the discs have holes through which the output shaft (highlighted in the photo) is inserted, rotating with the expected reduction ratio, which in this case is 8:1. Thus, for every 8 turns of the rotor, the output makes 1 turn, but with greater torque.

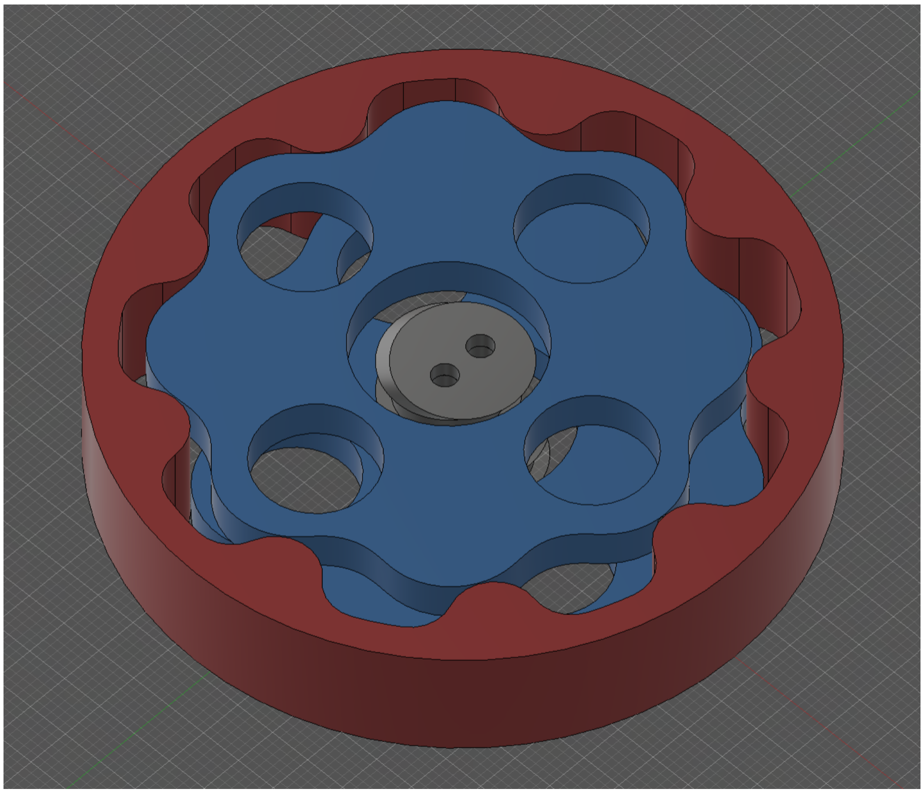


Figure 7: Cycloidal Drive first design

- Some parts were printed to test the concept with bearings and screws, and to adjust the design based on the results.
- The entire prototype was 3D printed in plastic and assembled with bearings and screws.
- Tests were made to verify that the expected reduction in terms of rotations was being achieved.

Results

- The cycloidal drive was operational.
- The expected reduction ratio of 8:1 in terms of rotations was achieved.
- Some screws collided due to the dimensions of the parts and the screws themselves, causing friction that hindered the gearbox's movement.
- The alignment method was insufficient, causing the gearbox to twist during operation.

Conclusions

- Details such as the sizes of the parts and screws need to be adjusted so that tolerance does not interfere with the movement.
- The efficiency of torque transmission in the reduction needs to be calculated.
- With the necessary adjustments, the cycloidal drive will be ready to be assembled with the motor for testing maximum torque, speed, and consumption.

3.1.5 First Internal Cycloidal Drive prototype

Development

- A design was created to connect the rotor (motor output) to the cycloidal drive shaft (gearbox input) located within the stator to optimize motor volume. Additionally, an external base was designed to cover the motor and support and stabilize the cycloidal drive output.

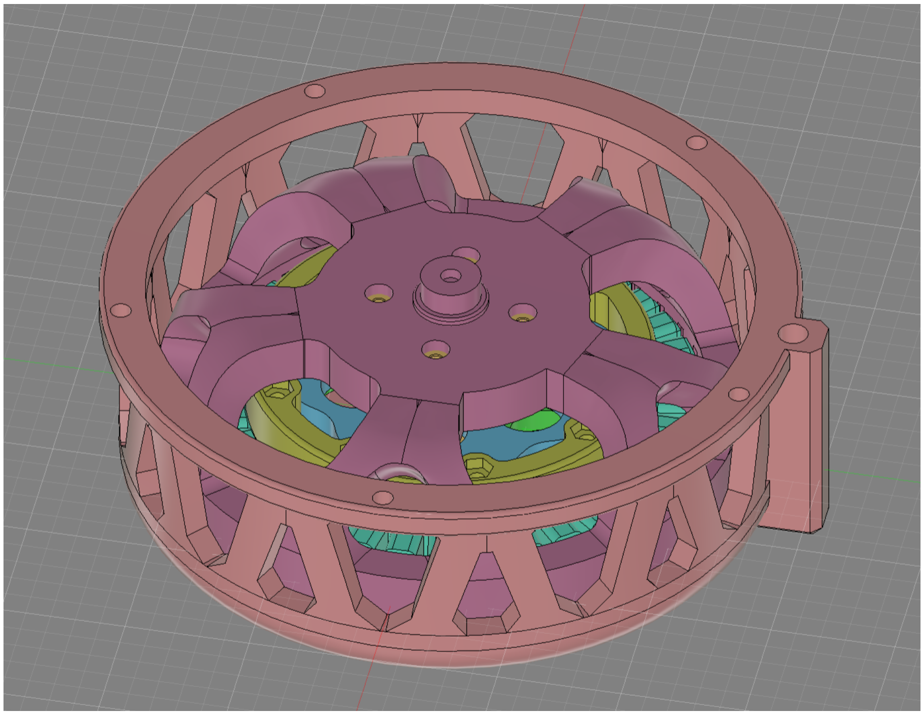


Figure 8: Internal Cycloidal Drive First Version

- The entire prototype was 3D printed in plastic and assembled with bearings and screws.
- Tests of motor and the cycloidal drive movement were made with this new design.

Results

- The Internal Cycloidal Drive was operational. Video: Video:

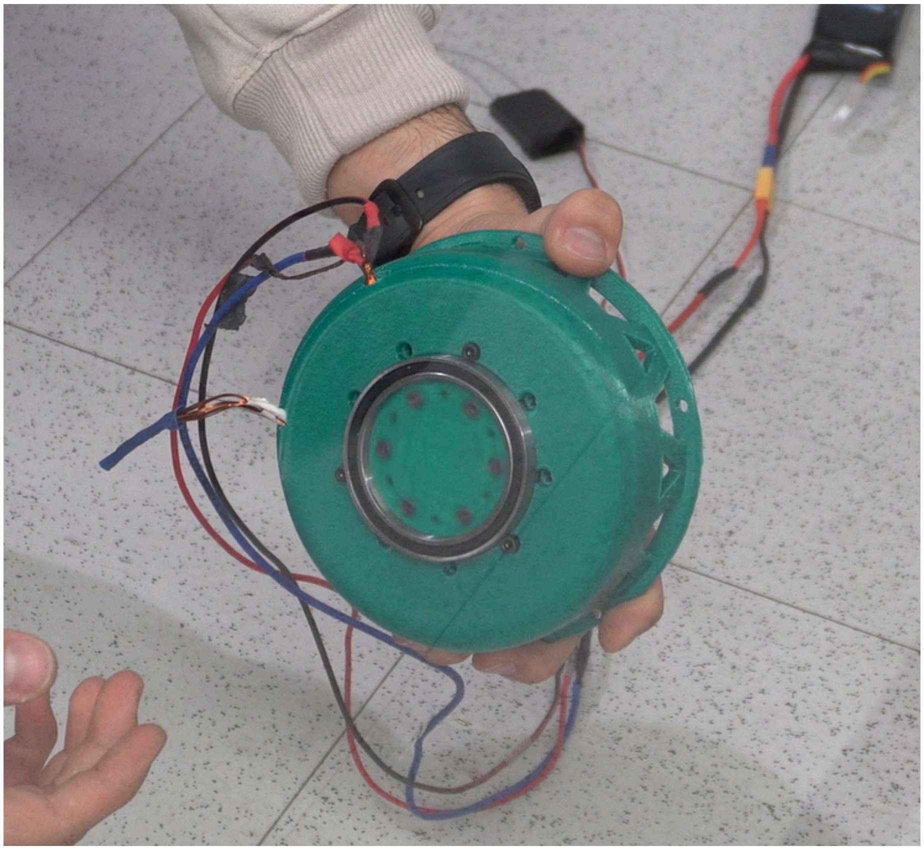


Figure 9: Internal Cycloidal Drive First Version

- Some parts were too close together, causing friction and slightly hindering the motor's movement.
- The base lacked a component to prevent unwanted rotation of the cycloidal drive shaft, causing the motor to stop on some occasions.

Conclusions

- Tolerances and the placement of some screws need to be corrected in the design to prevent collisions.
- A component should be implemented to keep the cycloidal drive shaft stable.
- Since the motor operates with its cycloidal drive, it is necessary to conduct speed and torque tests on the next prototype. Therefore, a test setup with the necessary sensors should be designed to obtain these data.

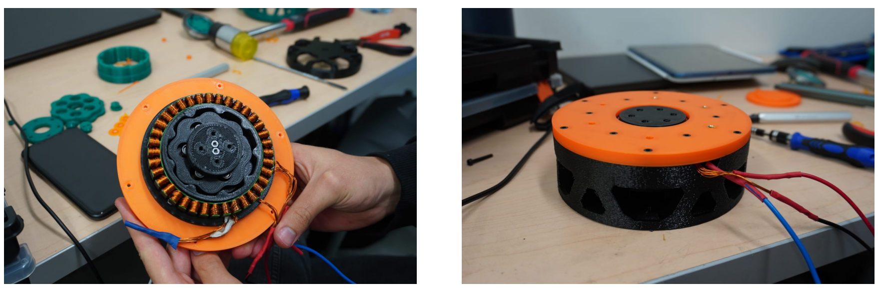
3.1.6 Second Internal Cycloidal Drive prototype

Development

- A new prototype of the Internal Cycloidal Drive was designed, in which the screws on the output shaft holding the bearings were replaced with steel pins to support bushings, improving its stability. Additionally, sizes and distances between parts were corrected to prevent friction and reduce motor performance. A cover was also implemented on the base to stabilize the rotor and the cycloidal drive shaft.
- The entire prototype was 3D printed in plastic and assembled with bearings, bushings. steel pins and screws.

Results

- The assembly was fully done, which is easier than the previous prototype



(a) Internal View (b) Fll Assembly

Figure 10: Internal Cycloidal Drive - Second Prototype

- The motor Spins correctly and its much more stable when spinning. **Video:**

Figure 11: Internal Cycloidal Drive Second Version

Conclusions

- It is neccessary to test the maximun torque of the motor
- A design made in more durable materials is neccessary for long term application, so CNC machining some pieces is needed to be explored
- There are some aspects about the design that need to be polished

3.2 Chasis

3.2.1 First Prototype

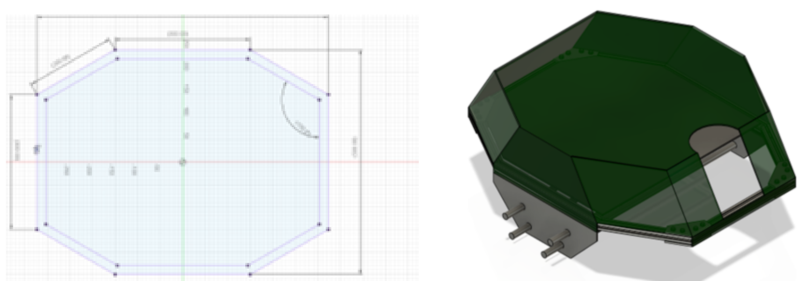
Development

- Qualitative analysis of the possible viable structures for the Rover's chassis
- CAD design of the desired chassis structure
- Material and component analysis of how the chassis will be
- Three alternatives were presented for the chassis model. The first was a traditional square design, which had advantages in terms of ease of assembly and manufacturing, a simple and stable design but not very innovative.

On the other hand, an irregular octagon design posed a structural challenge in terms of weight and simplicity but was innovative, compact for the necessary components, and had personality. Finally, a race car design that was not developed because it was far too complex; it was more attractive than functional.

Results

- Based on the analysis made according to the possible chassis designs we opted for the irregular octagon as it represented a balance of innovation and personality with manufacturability and stable structure.
- A CAD design of the base structure was developed with the appropriate measurements to contain all components in an orderly and clean manner.



(a) Chasis V1 - Sketch (b) Chasis V1 - 3D

Figure 12: Chasis concept

- Various profiles and extrusions were reviewed, determining that 20x20 aluminum extrusions are versatile and offer ideal modularity for the Rover. However, the idea of using sheets is not discarded, as further research might allow manufacturing a chassis with good integrity and strength, depending on the design, sheet gauge, and support points. Manufacturable couplings were also created to assemble the Rover easily.

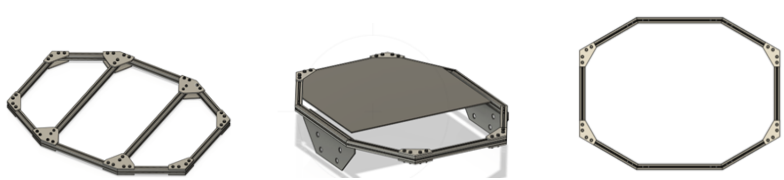


Figure 13: Extrusions Assemblies

- Based on the design and possible materials for these supports and couplings, 1020 steel was selected because its low carbon concentration allows for a softer and more ductile material, meaning it can be easily deformed without cracking, and 6061 aluminum, as these materials meet our needs for strength, durability, and lightness.

- The weight of the chassis, including screws and supports, is approximately 6 kg.
- The structure has a safety factor of 1.75, which means that the design will not fail but is open to improvements regarding the supports and load distribution. The image shows an adjusted deformation, but the actual deformation is 1.731mm, so it will not affect the integrity of the structure. Additionally, it can withstand up to 157.185 MPa, making it reliable.

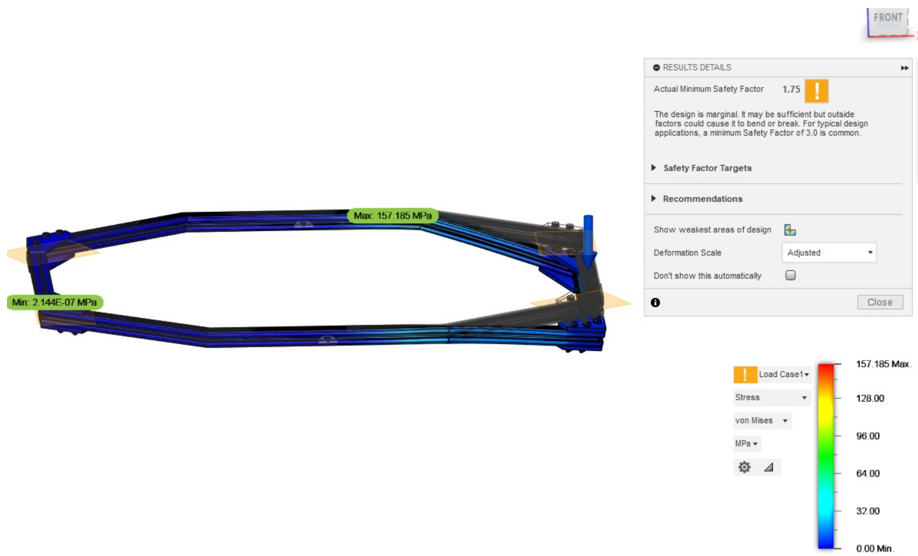


Figure 14: Chasis Simulation

Conclusions

- The final geometry of the chassis is an irregular octagon due to its compactness, innovation, and personality. However, it is necessary to deepen the analysis of static and dynamic loads to ensure the success of the design.
- The use of 6061 aluminum and 1020 steel is ideal for the Rover's applications and requirements.
- It is necessary to deepen the analysis of the support points with the rockers to finalize the chassis model and ensure a proper structure.
- An analysis of the arm with the Rover is required, since, despite being a stable structure, it is important to review the forces that the arm can

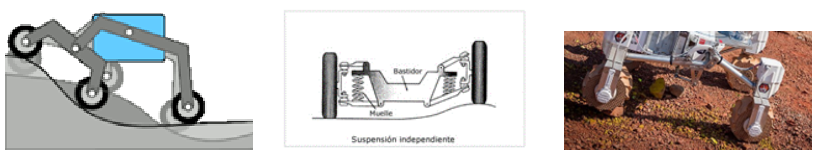
generate when assembled in the Rover, as well as consider the weight of the parts it may lift.

3.3 Rockers

3.3.1 First Prototype

Development

- Brainstorming, analysis, and generation of concepts for a stabilization system for the Rover.
- Preliminary CAD design of the selected geometry.
- Estimation of materials and manufacturing costs for the chosen design.
- Various options were presented and analyzed:



(a) First Concept (b) Second Concept (c) Thrid Concept

Figure 15: Rockers Concepts

Results

- After evaluating factors such as reliability, weight, performance, cost, and adaptability to change, among others, an independent suspension system was selected. This system would significantly enhance the Rover's versatility in traversing uneven terrains and greatly improve its resistance to tipping over.

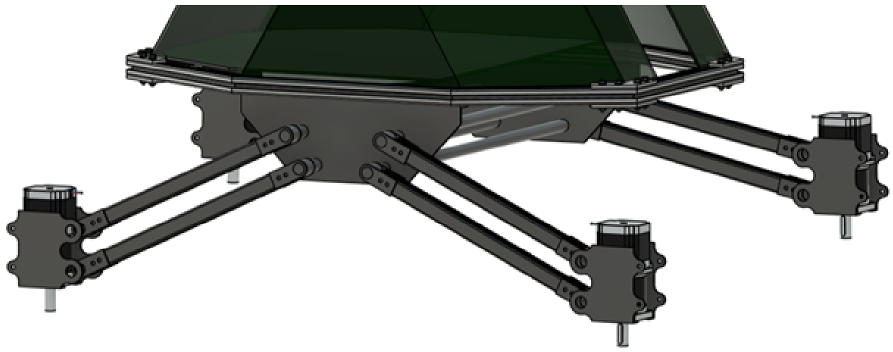


Figure 16: Rockers 3d Model with Chasis

Conclusions

- The final geometry of the rocker system implements a 4-bar parallel system, ensuring that the motors responsible for the vertical rotation of the wheels remain perpendicular to the ground.
- Aluminum extrusions and steel sheets will be used for constructing the structure.
- The axles will be built using copper and steel bushings.
- The selection of shock absorbers is pending, depending on the final geometry of the chassis and the weight distribution within it.
- Simulations and geometric adjustments will determine the final version of the system.

3.4 Wheels

3.4.1 First Protoype

Development

- A tire prototype was created, consisting of a single piece of TPU (Thermoplastic Polyurethane) material.
- A support ring made of stainless steel was added to withstand the forces.

(a) Front View (b) Side View

Figure 17: First Wheel prototype - 3D

- Simulations were conducted to determine the approximate weight of the assembly using TPU and stainless steel.

Results

- Simulations showed that the complete tire assembly would weigh a little over 4 kg.
- This weight was significantly higher than planned, exceeding the weight limit of 2 kg.
- Various strategies were attempted to reduce the weight, including material removal and additional structural analyses.

Conclusions

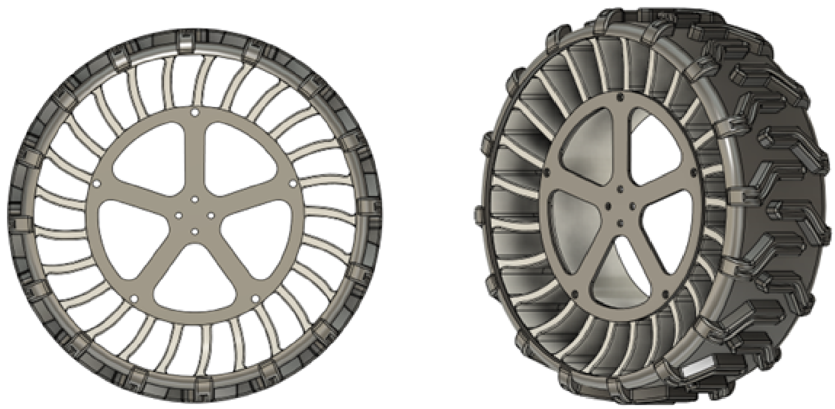
- The initial prototype was not viable as its weight exceeded the established limit.
- Despite efforts to reduce the weight, the desired goal was not achieved.
- Other design options and materials need to be explored to meet the weight requirements.

3.4.2 Second Protoype

Development

- A 3D model of the rover's tire was designed, with static structural simulations conducted to evaluate its performance. The tire was divided into two parts:
  - Internal Part (Ring): Made with PLA using 3D printing.

– External Part (Tread): A thin layer of TPU, also 3D printed.



(a) Front View (b) Side View

Figure 18: Second Wheel prototype - 3D

- Various shapes and structures of the ring were evaluated to ensure it could support the weight of the rover.

Results

- Simulations indicated that the design would support the rover's weight while minimizing the total weight of the tire.

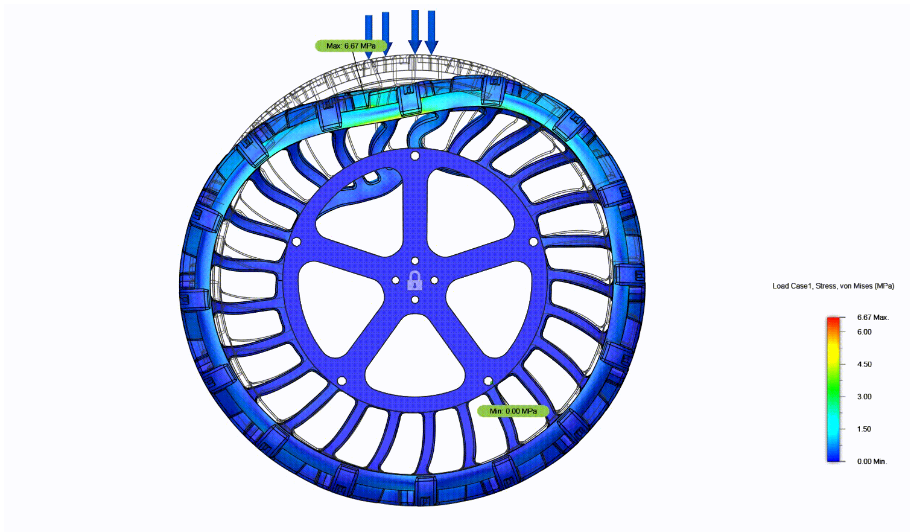


Figure 19: Second Protoype Simulation - 50kg of pressure

- The simulation gave a security factor of 15.
- The approximate weight of the tire, including all its parts, was estimated to be around 2 kg.
- The use of polymer resin was considered as an alternative to PLA and TPU to reduce production times.

Conclusions

- The current tire design is structurally viable and meets the objective of minimizing weight.
- Manufacturing using 3D-printed PLA and TPU can be optimized by using polymer resin, which could significantly reduce production time.
- Reducing manufacturing times is crucial for the efficiency of the project, and this alternative is being actively investigated.

3.5 Design and Brand

3.5.1 Defining Mision, Vision, Objectives and Values

Development

- Investigated examples of robotics' teams and companies for reference. Those references were rather visual or conceptual, which helped us to define our possible contribution in the robotic industry (local or global).

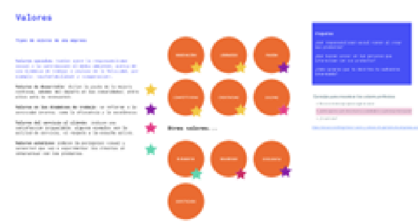
Figure 20: Miro Board

- Brainstormed with the team members keywords and phrases which we thought would describe our work.
- Started writing paragraphs which connected the ideas from the brainstorm to create the mission, vision and objectives.

(a) First version - Mision

(b) First version - Vision

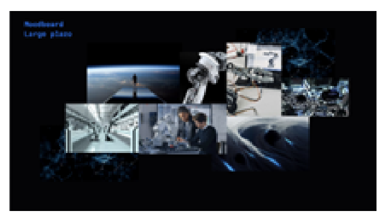
(c) First version - Objectives



(d) First version - Values

- Created mood boards according to the objectives and motivations of the team, representing sensations, collaborative goals and how consumers will perceive us as a team.

(a) Medium term Mood Board



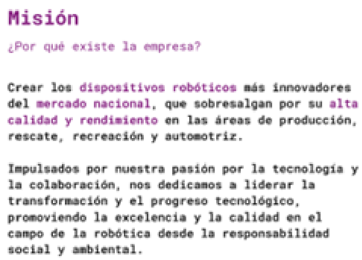
(b) Long Term Mood Board

Figure 22: Mood Boards

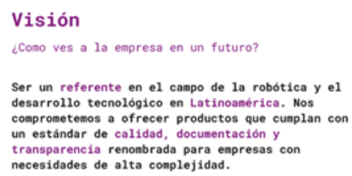
Results

- A first version of the items was written and reviewed as a group.
- Important ideas were highlighted and kept for a final version. During the discussion, we decided to be more specific and innovative regarding our contribution in the robotic industry,
- A second brainstorming session was held, with more specific guiding questions to finalize details.

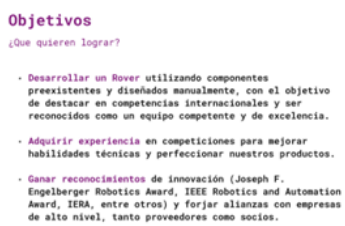
- A second and final version of the items was written.



(a) Second version - Mision



(b) Second version - Vision



(c) Second version - Objectives

(d) Second version - Values

Conclusions

- The group was excited to see their ideas and desires captured in clear words.
- We want to stand out through our quality and high performance, by developing components from scratch and having social and environmental responsibility.
- We describe ourselves as an innovative, passionate, sophisticated (among other values) team.
- Clear goals were set.

3.5.2 Defining Name, Color Palette and Fonts

Development

- Within the design team, a first brainstorm was performed, in which each member suggested at least one name, color palette and title and text font.
- Out of the first brainstorm, the design team selected their preferred options to show to the rest of the team.

- Among the team, the favorites were voted. Suggestions were made, and a second brainstorm was performed to reselect color palette and fonts.
- The new ideas were presented in a meeting. The color palette was built between all the team members.

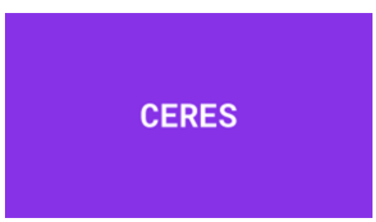
(a) Color Palette Proposal

(b) Side View

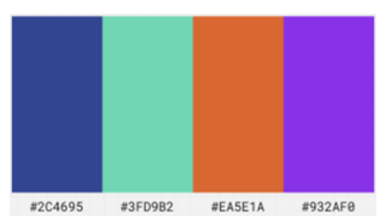
Figure 24: Color Palette Development

Results

- The name of team was chosen.
- The color palette was chosen.



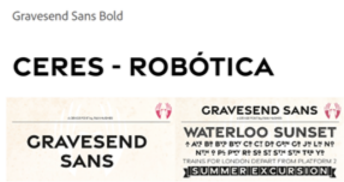
(a) Name



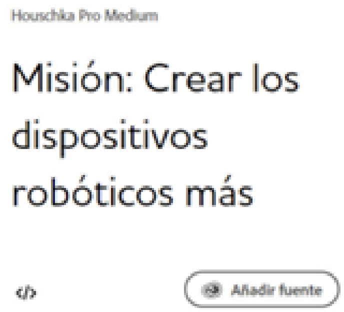
(b) Color Palette

Figure 25: Name and Color Palette

- The title and text fonts were chosen.



(a) Title Font



(b) Normal Text Font

Figure 26: Fonts

Conclusions

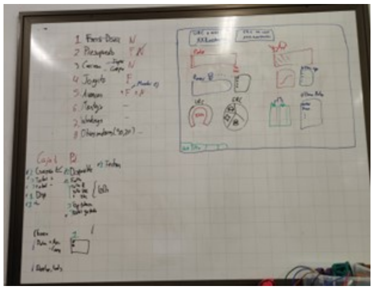
- The team was able to come to an agreement on the first items of the brand identity.
- The team agreed to develop a novel brand identity that confronts the usual robotic scheme, using bold colors and a light typography to connect with customers in an innovative way.
- The team was happy and excited to have an official name, color palette and fonts for representation.

3.5.3 Budget Panel

Development

- We watched a tutorial to learn how to turn tables of data in Microsoft Excel into an interactive dashboard.
- We drafted an idea of how the data will be distributed, emphasizing in the information that is more relevant for us and for potential sponsors.
- We made the interactive board with the purpose of making complex data legible for external parties, using mostly graphs and conventions.

(a) Reference



(b) DashBoard Brainstorm

Figure 27: Dashboard creative Process

Results

- The dashboard was organized and properly linked to the data, using buttons and formulas to display different information.
- Several graphs were shown (lineal graph and ring graphs)
- The color palette previously selected was properly used.

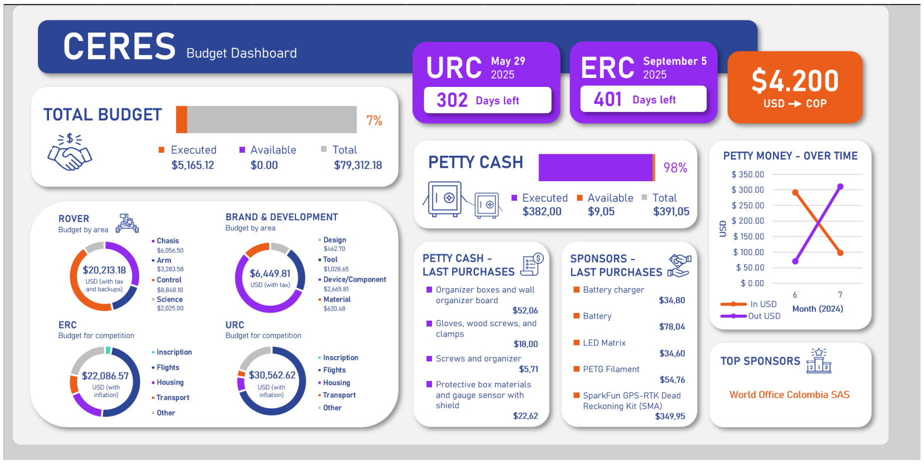


Figure 28: Dashboard

Conclusions

- The dashboard was done to show the team and sponsor candidates all the resources and data in an organized and clear way.
- The interactive tools, such as buttons and formulas, makes the information more precise and legible for the viewers.

- The information hierarchies work effectively, making it clear to the viewer which data is most relevant within what the dashboard presents.

3.6 Screen

Development

- Characterization of the LED matrix (64*32)
- Connection with Raspberry Pi Zero 2W
- Exploration of available libraries for its manipulation

Results

- Visualization of test commands where it was possible to see the lighting and dimming of all the LEDs in the matrix as well as their color changes.
- Display of text input.
- Display of images, videos and .gif files.

  Video:

Figure 29: Video Display in Screen

Conclusion

- The LED matrix is easy to operate.

- Various visual elements can be displayed automatically by generating a folder of files stored within the controller.
- To achieve appropriate visualization, it is important to consider the dimensions of the input files relative to the matrix.
- To run a video file on the matrix, it will be necessary to implement a controller with greater capacity.

4 Future Goals and Objectives

The Following steps that are the most important for the development of the project are the following

- Winding of the 4 motors of the wheels
- Test the control devices that arrived

Figure 30: First Sponsor Items

- Do a full characterization of the motor
- Finish the Chasis and Rockers desing to start the first assembly in Wood
- Continue simulation and brainstorming for the wheels

- Develop and select a Logo
- Start brainstorming the design od the arm