BENROVER

Sept. 14, 2024

Cars4Mars
African Rover Challenge

# DESIGN & BUILD A MARS ROVER PROTOTYPE

## CARS 4 MARS CHALLENGE - 2024

**BENROVER Team**

Country: **BENIN**

1-

# TEAM PRESENTATION

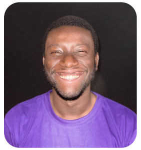
# 1- TEAM PRESENTATION

## Project Management

Mohamed
SALIFOU

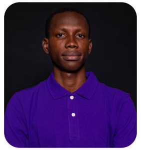
## Design Team

Louis
DOSSOU



Estève Alvin
KASSA

## Science Space Team



Prudence
AYIVI

## Mechanic Team

Arcady
RODRIGUEZ

Aymar
PITO

Edwige
KPADONOU

Florian
HONFO

## Electronic Team

Yaye Haby
SOW

Judicaël
ADIKPETO

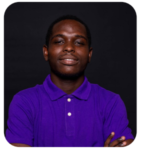
Gildas C.
CHABI

Maurel
BONOU-DAH

## Information Technology Team

Serginho
GOUNOUKPEROU

Elfried
KINZOU



Eliakim
GOUNON

Gédéon
GBEDONOU

David
TONON

# 2-
# OVERALL DESIGN

# 2.1- Logo

## Logo Design and assets


**Text Font**

**Inter**

Aa Bb Cc Dd Ee Ff Gg
Hh Ii Jj Kk Ll Mm Nn
Oo Pp Qq Rr Ss Tt Uu
Vv Ww Xx Yy Zz

**Colors**

*Copper Red*
Hex: **#C94938**

*Red Coral*
Hex: **#FF5B47**

*Midnight Blue*
Hex: **#142039**

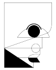
# 2.2- The Skin

## Design Inspiration

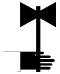
> ***" We wanted our rover to look like Hèviosso, the voodoo god of thunder in Beninese culture.***

So we created a skin for it to wear when it wants to be Hèviosso. This skin takes all the main attributes associate to this divinity in myths and legends.

Ebony black body



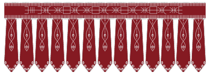
Truncated and deformed face



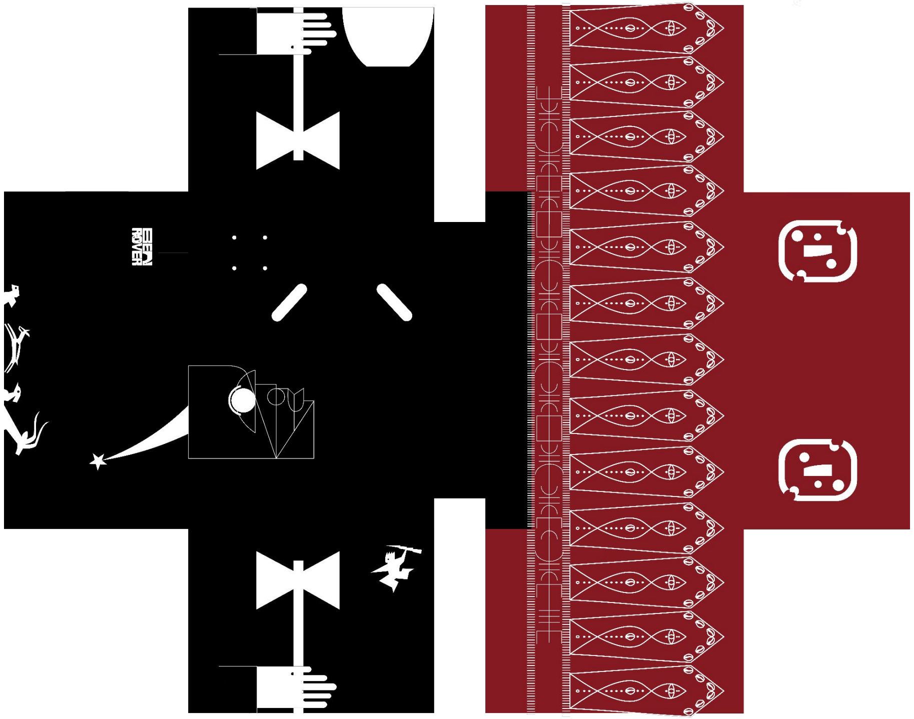
Double-edged battle-axe in hand

Thunder he master

Belier and Faisan as totem animals



Red ceremonial skirt, adorned with cowrie shells



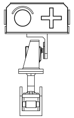
# 2.3- Mechanical Parts

## Design Inspiration

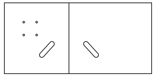
> *"We wanted our rover to look familiar, inspiring from NASA's Perseverance, the most advanced rover ever developed.*

Rocker-bogie suspension system, camera block, chassis, wheels are the main distinctive elements we use for our rover. We also use the video of *HOW TO MECHATRONICS* for most of the parts and how to assemble them.

## Materials used

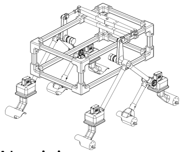


(PLA) for the Camera

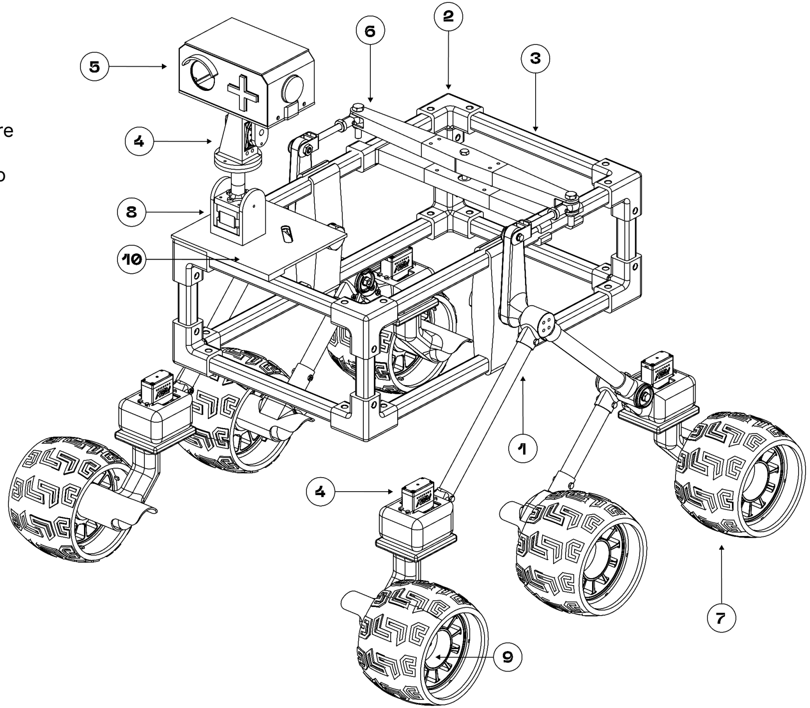


3 mm black & red Plexiglass for the skin

(TPU) wheels



Aluminium square and round tubes & (PLA) for joints, and rocker-bogie specific parts




## Parts

1. Rocker-bougie
2. Corner joint
3. Square tube
4. Servomotor
5. Camera
6. +Rod+
7. Wheels
8. Stepper Motor
9. Rim
10. Skin Plate

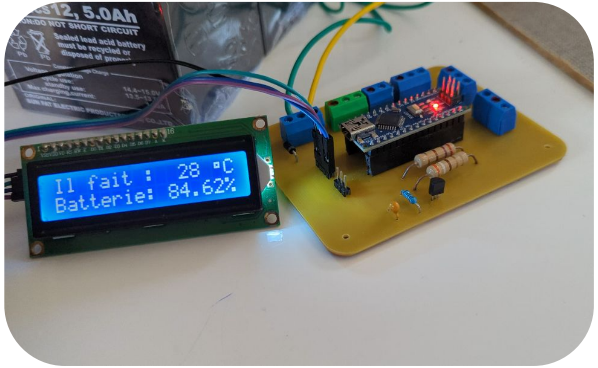
# 2.4- Electronic system (1/4)

## Power Management System

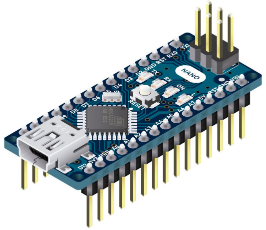
For efficient power system management, we have opted for the following configuration:

- The rover's power supply consists of two parallel-connected 12-volt batteries, each rated at 5 Ah.
- An Arduino nano manages this power supply and displays on I2C LCD screen the temperature of the block via an LM35 sensor and the battery charge level using a resistor bridge.
- An emergency stop button is integrated between the power pack batteries and the rest of the system. This button allows you to shut down the entire system if necessary.

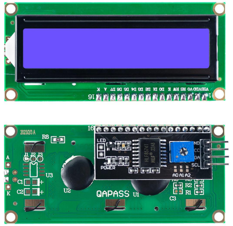
With our current power supply we have a capacity of 10 Ah (Capacity = current * time), offering a maximum autonomy of 5 hours if the system consumption reaches 2A. However, this autonomy can be reduced by various factors, such as variations in component consumption, circuit losses, and temperature fluctuations.




Battery Block



Arduino Nano




I2C LCD Display

LM35 Temperature Sensor

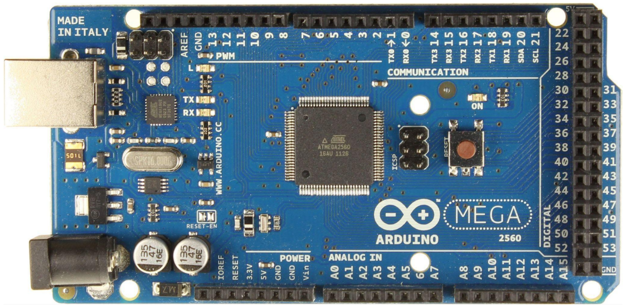
# 2.4- Electronic system (2/4)

## Command System

To control the actuators such as the 5 servo motors, the 6 continuous motors, the stepper motors we used an Arduino Mega.

the servomotors from REV ROBOTICS which we supplied with a voltage of 12V and which require a maximum dropout current of 2A, we used TIP122 transistors to amplify the low current of 20 mA supplied by the Arduino Mega.

To reduce electrical interference, we have added capacitors which filter the noise produced by the motors which are powered through their drivers by 12V.

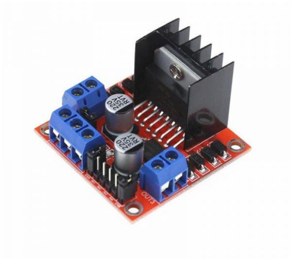



Arduino Mega


Rev Robotics Servo motor

DC Motors

A4988 Stepper Motor Driver



L298N DC Motor DRIVER

# 2.4- Electronic system (3/4)

## Navigation System

### Radio Command

To control the actuators we used the Flysky FS-I6 RC and its FS-IA6 receiver which offers a control distance between 500 ~ 1500 m in free space

The receiver is connected to the Arduino Mega

| Channel | Usages |
|---|---|
| Channel 1 – Right Joystick, Left/Right | Controls four (04) servo motors each connected to the Rover's front and rear wheels to enable turning movements |
| Channel 2 – Right Joystick, Up/Down | Controls six (06) motors each connected to the Rover's wheels to allow the rover to move forward and backward |
| Channel 3 – Left Joystick, Up/Down | Control the rotation (in two directions: clockwise and counterclockwise) of the stepper motor connected to the Rover's neck for a 360° rotation of the camera |
| Channel 4 – Left Joystick, Left/Right | Controls one (01) servo motor connected to the Rover camera block to allow tilt movements (up-down) |

**Flysky FS-I6 RC**


**FS-IA6 receiver**

# 2.4-Electronic system (4/4)

## Navigation System

**Sensors**

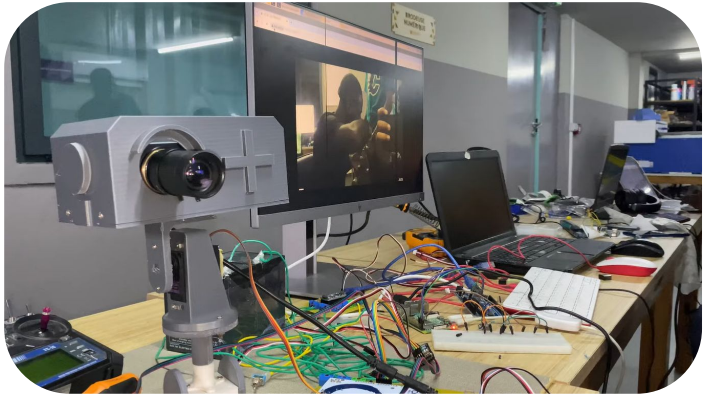
A Raspberry Pi 4 model B controls the sensors (MPU6050, USB Camera )

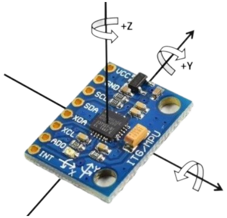
The MPU6050 is connected via I2C and sends temperature, gyroscope and accelerometer data. This data, plus data from the power supply received via i2c (temperature, battery level), is sent to an online database.

The vision will be assured by a USB camera connected to the Raspberry Pi. The package 'motion' installed on the Raspberry Pi will then be used to stream video via Wi-Fi.

The control station will be connected on the same network as the Raspberry Pi which gives us access to the continu video feed through a web browser at the Raspberry Pi Ip address with the port onto which the video feed is playing. (example : 10.10.10.5:9000). After some tests, we got images with an appropriate resolution.

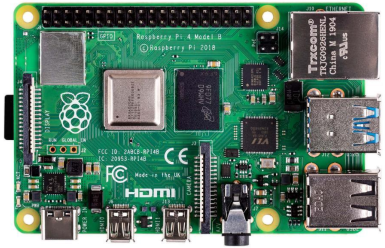
Live feed from camera






MPU6050

USB Camera



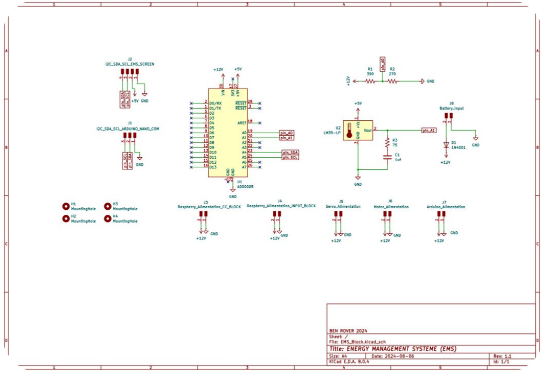

Raspberry Pi 4 Model B

# 2.5- PCB Manufacturing (1/4)

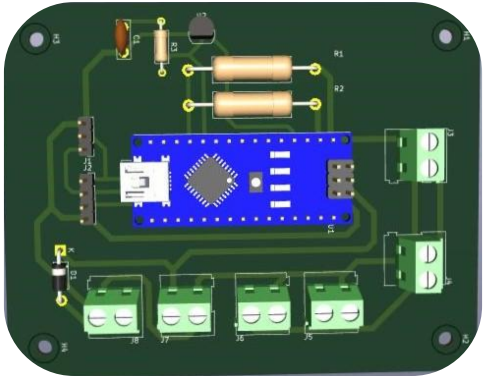
## Power Management PCB

We designed **three (03) distinct PCBs**, each tailored to specific functionalities of the rover. The design process considered key factors such as size constraints, durability, and signal.. The PCBs were designed using KiCad, focusing on optimizing the layout for power distribution and signal integrity.

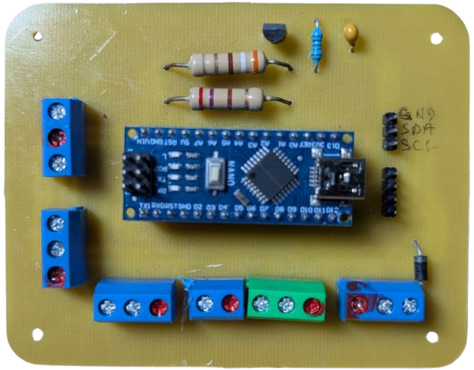
Designed for monitoring and distributing electrical power to all subsystems. The board combine an Arduino Nano Board which use an voltage divider resistor bridge and a LM35 temperature sensor to analyse and show the voltage level and the temperature of the circuit on a LCD display. The board is also equipped with terminal block connector to ease the power connection to all the rover's components .




KiCAD Schematics



PCB Design

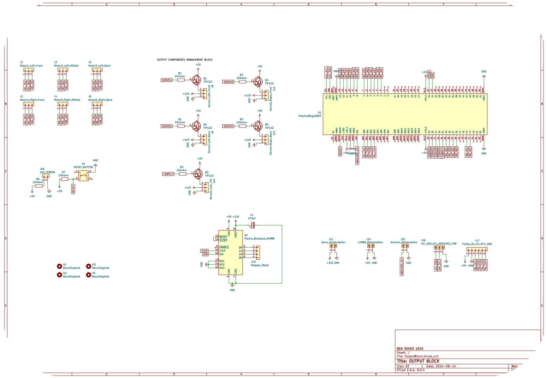


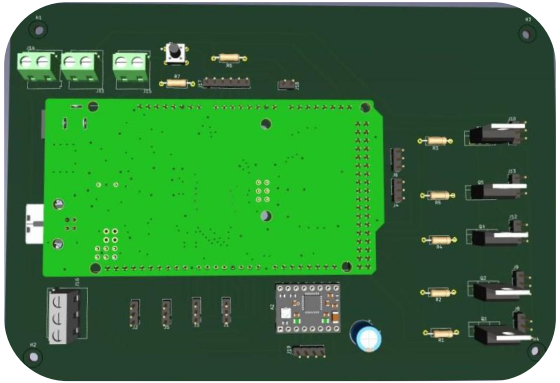

PCB Production

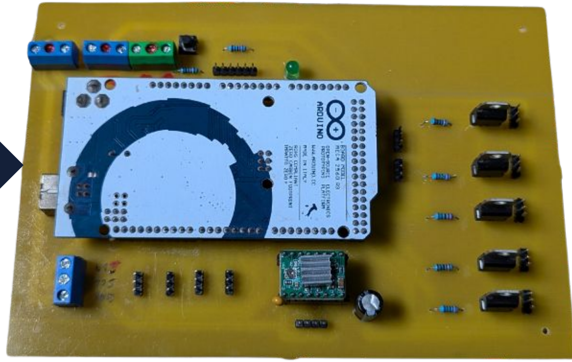
# 2.5- PCB Manufacturing (2/4)

## Motor Control PCB

Designed to handle the high current required for driving the rover's motors. This board includes motor drivers and protection circuits, with built-in feedback from encoders to allow precise speed and position control. The board is also equipped with TIP122 transistors circuits for driving step motors, power connectors and a reset button.



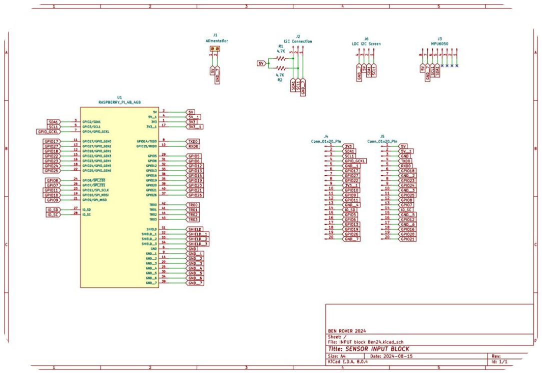


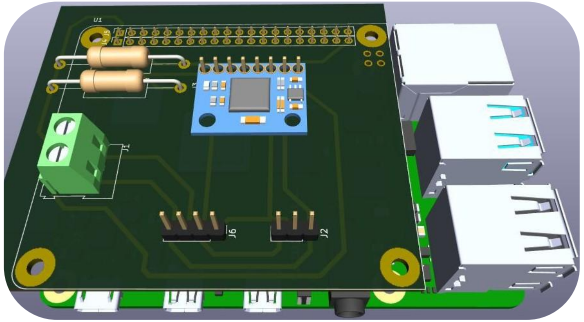


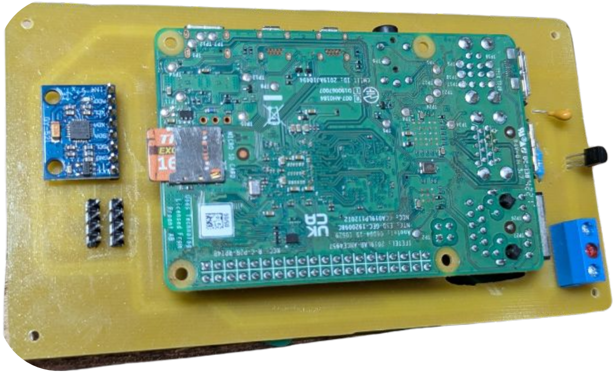
# 2.5- PCB Manufacturing (3/4)

## Sensor Input PCB

The circuit below is an exploitation circuit for the Raspberry Pi4. We have equipped it with a MPU6050 sensor for gating axial position and acceleration data of the rover. Via the I2C circuit on the board, the Raspberry is able to gate and send data to all the orders boards. Let’s remember that the Raspberry is equipped with a high definition camera.





# 2.5- PCB Manufacturing (4/4)

## Layers Design

The PCBs were fabricated using a CNC milling machine, ensuring precise trace routing and accurate drilling for through-holes and surface-mount components. But between the PCB design and its fabrication with the CNC machine, there is an important step. This step consist of creating the CNC Jobs files with the logiciel FLATCAM. The picture on the right side shows the process while we were creating the files for the Output Board. The principle of this step is to indicate the different drilling bits we are using on our CNC machine and other important configurations.

**KiCAD** is a software for designing the electronics circuit we want to produce.

**Flatcam** is a software for generating the CNC jobs G-codes.

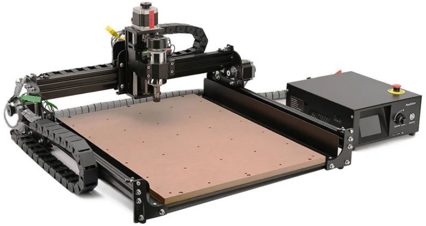
Candle Cnc Software Tutorial

CNC Philosophy

**Candle** is a software for controlling the CNC machine.

## CNC Milling and drilling

The PCBs were fabricated using the Fox Alien 4040-XE showed on the picture right here. By using appropriated milling bites we have been able to make our Printed Circuits Boards with a really high finesse of quality.



## Soldering and testing

After fabrication, components were mounted on the PCBs and soldered manually. Despite the high density of the pins on the boards, our electronic team members have been able to solder them without any short circuit and have adjusted the circuit as needed in function of the inconvenience occurred.

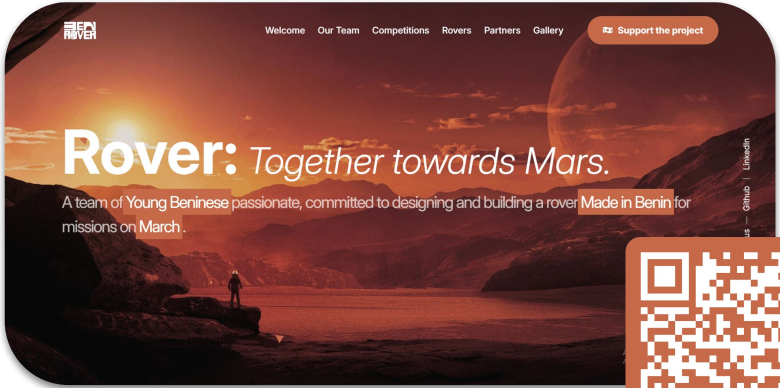
# 2.6- Software Development

## Interface

The interface of a Mars rover serves as the critical link between the rover and mission control, enabling scientists and engineers to control and monitor the rover's activities. This interface is designed to be robust, user-friendly, and capable of handling complex operations remotely. Key components include: a User Dashboard serving as a central hub for mission control receiving metrics and navigation data, and the Camera and Sensor Feed helping us get a comprehensive view of the rover environment and surroundings. Our main Software System for operating the Rover and support our Interface will be in ROS2 for a more reliable and distributed design.

## Website

The BenRover website showcases competition details, team info, and an interactive 3D rover model. It includes crowdfunding and partnership sections, a progress gallery, and links to a separate technical documentation site. The platform serves as both a public information hub and a comprehensive team resource.



# 3-

# BEST FEATURES

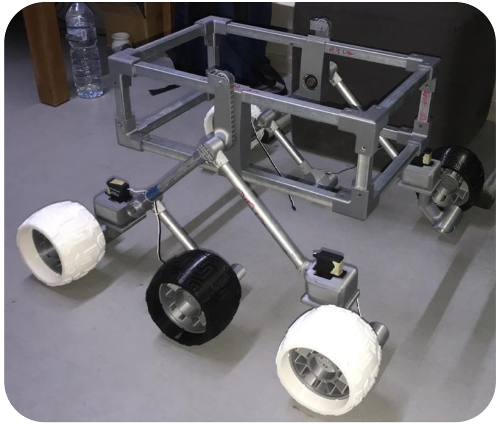
# 3- BEST FEATURES (1/2)

## Flexible wheel

Our rover is equipped with 6 3D printed flexible wheel in TPU, to make it easily accommodate difficult terrain and environment. This helps the rover navigate easily in the martian environment and carry mission seamlessly.

## Strong and versatile structure

The rover is build with a strong and light structure made of 3D printed parts and metal bar to ensure the strength of the whole structure to support constraint and long term exploitation. With the design strategy adopted, the main body containment can be modified to hold more or less payload.



# 3- BEST FEATURES (1/2)

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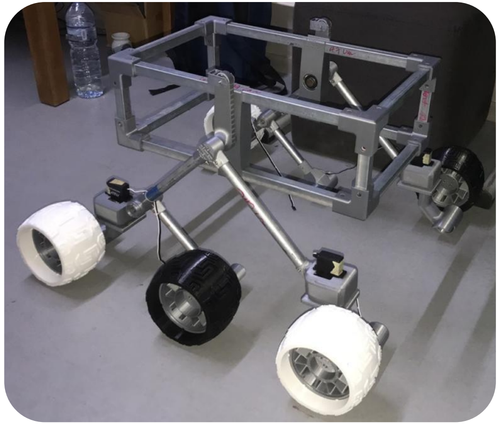
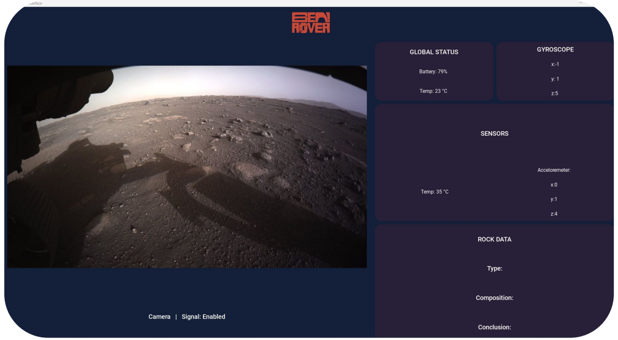


## Live data communication

The rover has a redundant communication system, to avoid any failure in case of main system of communication failure. The electronics data and sensors are collected by two microcontrollers with a top single board computer in charge of system control and actuation. The sensors data are collected and send in live to remote database as well as saved on a SD card on the rover for safety. The data are display through user-friendly interface to facilitate their reading.




## High resolution camera

The rover is mounted with a top 360° x 80° rotating camera with a range of +15m and 3x zoom. This camera help have a great situation awareness of the surrounding environment to make decision in advance and plan mission.

# 4-
# LESSONS LEARNED

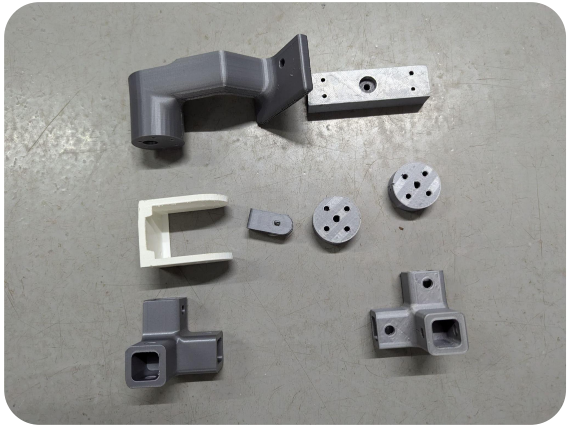
## Recycling and reusing

The critical challenges we face during this competition are the lack of material to build and assemble the rover from electronics components to mechanical tools.

Due to the lack of materials, we have adopted recycle and reusing methodologies to use the most possible low-cost and locally available components. We have then adapted our rover design to match these constraints and achieve the result.


## Versatile and adaptive design strategy

The lack of materials and funding needed to build our first standard rover design, force us to adapt our project strategy to low expectation while meeting the competitions requirements. We have developed 4 different rover design for various step and road in order to adapt to our equipment.



## Testing and iteration

With a volatile and adaptive design strategy we have conduct a lot of testing against each material we have, to select the most suitable to meet the critical requirements and our expectations. This lead to various iteration from mechanical design to assembly and electronics.

## Team management

As this project a first of its kind, we gather different profile and skills to help us have the best we may need to succeed. As the number of team member growth, and we have developed different project strategy, we faced confusion in each member role and contribution to the project. We faced also team engagement problem as some of the member doesn't contribute as expected and other wasn't able to. This lost us a lot of time in the project accomplishment, and we have done team revising to adapt to our strategy and need.

## Lack of Funding

Our main issue to carry out this project is finance, as we are supposed to finance the project on our own, it's hard to do it as students. This was intensified by the fact that, we lack the critical materials in Benin so we need to order them from abroad with huge shipping cost. Lastly, we have been able to develop sponsoring method and adapt our strategy to get some fund from partner. But most part of the rover has been build with the materials freely available from maker center of government facility, our main sponsor. We have faced the issue of lack of funding to sponsors STEM projects and activities.

## Resilience

Resilience is the first lessons we learned from participating in this competition since the beginning. As the face a lot of unseen technical and management challenges we have to be resilient in front of these situations to move forward and learned lessons from these difficulties. From electronics components failures, to 3D printing errors and failures, and lack of funding, we have developed personal and collective force and energy to resolve and overcome these problems.

# 5-

# PLANS FOR THE FUTURE

## Communication and STEM Outreach

With this collective success our first plan is to communicate about our accomplishment on social media, to show to our fellow and our country what we can do. We want to use this achievement to communicate about STEM importance and the necessity to invest in STEM education and project to develop finest skills that will be valuable for our country development.We are planning to organize on exposition event about our STEM project, with the rover at the center to share our journey with all and communicate about our solutions to grab support and ignite passion for youth

## Improve the rover

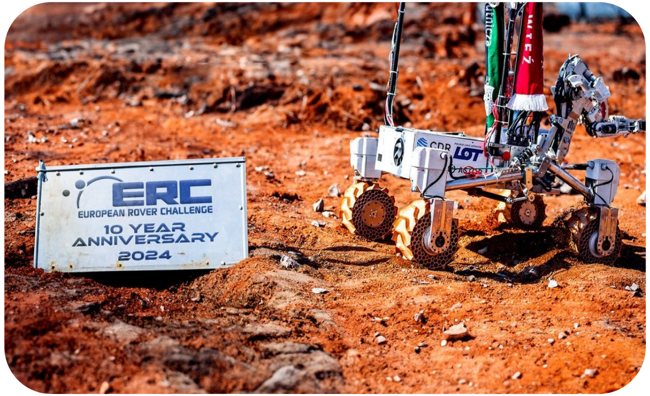
Since the beginning, we always wanted to build a fully semi-autonomous and autonomous rover but we do according to the competition rules. In the month, we will be working first to make the rover fully autonomous, which can carry out programmable tasks to match the spirit of a martian rover. We are also planning to revise the structure to add more components (lidar, anemometer, camera, etc) to perform more missions.

## Train and inspire

Since the beginning our objectives were to master skills needed and prove our capability in order to inspire more youth to do so and do more. We want to inspire more young to embrace STEM, robotics and space. We are going to organize training sessions around the rover to train more youth on rover building, with a local competition rover building competition in order to share our skills and have more team participating to international rover challenge.

## Participate in more rover challenge

Yes, we plan to participate to the next years Car4Mars rover challenge to perpetuate this heritage and to reach to more height. We are already working to participate to the next year European Rover Challenge.



BEN ROVER

Cars4Mars
African Rover Challenge

# Thanks

We are open for questions

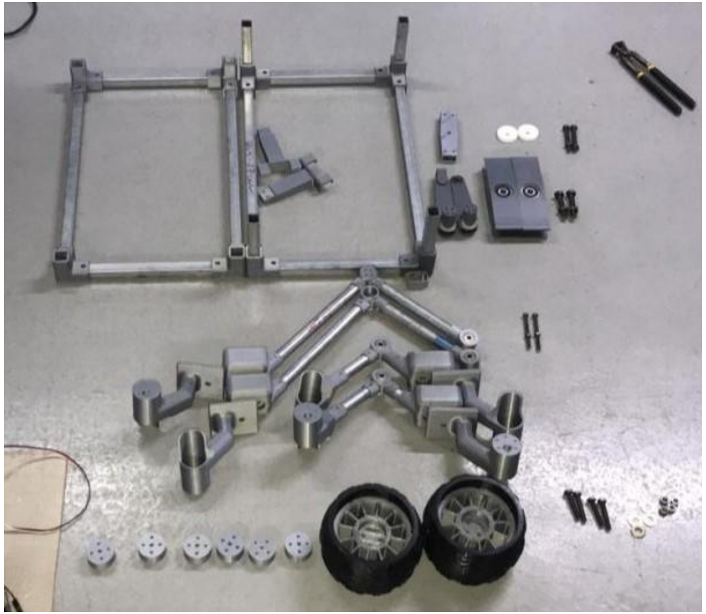
https://benrover.tekbot.io/

https://github.com/benrover-24

# 2.3- Mechanical

## Design Inspiration

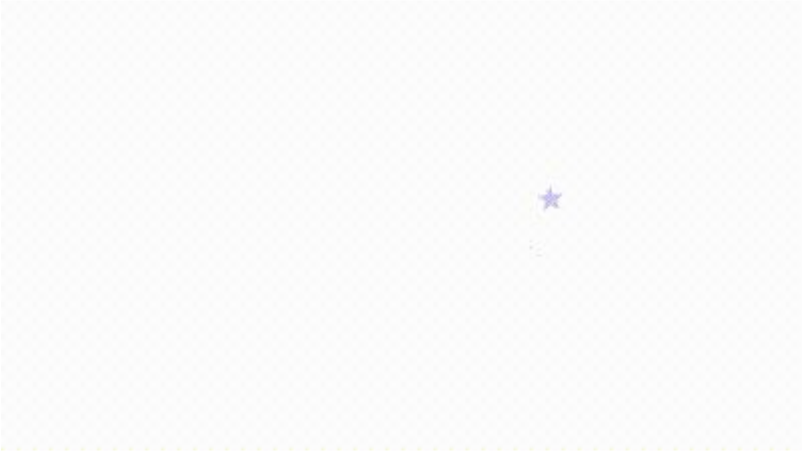
Our design is primarily inspired from the Perseverance Rover from the NASA. We also inspired ourselves from the video of HOW TO MECHATRONICS for most of the parts and how to assemble them. We made the structure for the chassis in an aluminum alloy with joints printed in PLA in a cuboid form. The rocker-bogie suspension system is also made in aluminum alloy with some parts to connect  the whole system together which is also in PLA. We also made a block for the camera which will be fixed on the chassis, containing the camera and motors to procure the different rotation on different axis. The wheel were made in TPU which is a flexible material that give our wheel the ability to deform when in contacts of rocks to match the shape and takes back his original state.



## Materials used

The materials used for conceiving the rover from a mechanical standpoint are mostly:

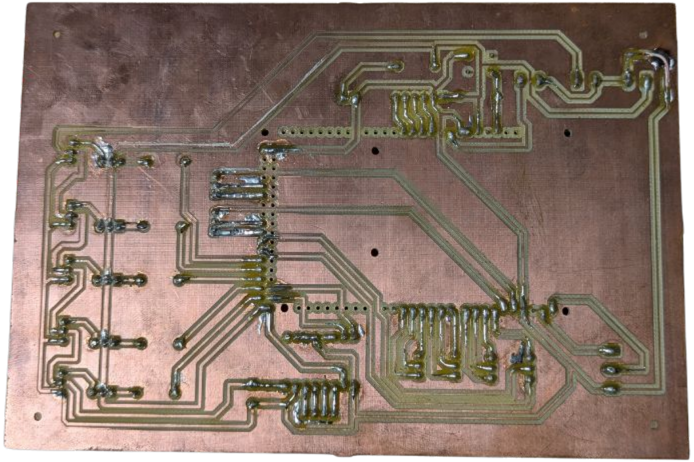
- aluminum alloy for the chassis and the rocker-bogie system
- PLA for the parts like joints, camera, and rocker-bogie specific parts
- TPU for the wheels
- Screws and bolts
- Bearings
- Rod-ends



# 2.5- Fabrication Process

## Soldering and testing

After fabrication, components were mounted on the PCBs and soldered manually. Despite the high density of the pins on the boards, our electronic team members have been able to solder them without any short circuit and have adjusted the circuit as needed in function of the inconvenience occurred.



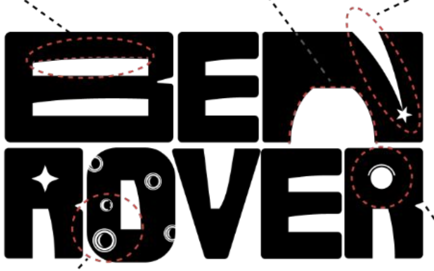
# 2.1- Logo

## Logo Design and assets

*This shape symbolizes ascent, global exploration and the quest for knowledge*

*Mount Olympus, an imposing mountain from Mars, a symbol of strength and collaboration*

*Depressions formed from the impact of a crater on the surface of the Red Planet*



*These points represent the diversity of talents and efforts required to conquer new horizons*

*Ability to see beyond the unknown and capture the essence of discovery*

**Text Font**

**Inter**

Aa Bb Cc Dd Ee Ff Gg
Hh Ii Jj Kk Ll Mm Nn
Oo Pp Qq Rr Ss Tt Uu
Vv Ww Xx Yy Zz

**Colors**

*Copper Red*
Hex: **#C94938**

*Red Coral*
Hex: **#FF5B47**

*Midnight Blue*
Hex: **#142039**

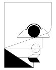
# 2.2- The Skin

## Design Inspiration

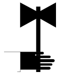
> ***"We wanted our rover to look like Hèviosso, the voodoo god of thunder in Beninese culture.***

So we created a skin for it to wear when it wants to be Hèviosso. This skin takes all the main attributes associate to this divinity in myths and legends.

Ebony black body



Truncated and deformed face

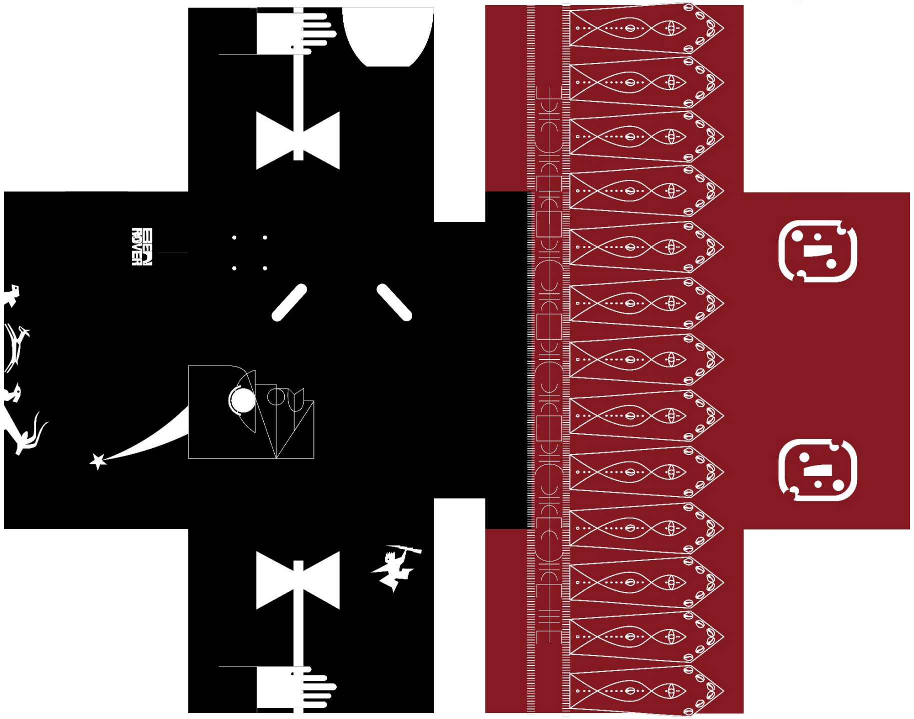


Double-edged battle-axe in hand

Thunder he master

Belier and Faisan as totem animals

Red ceremonial skirt, adorned with cowrie shells



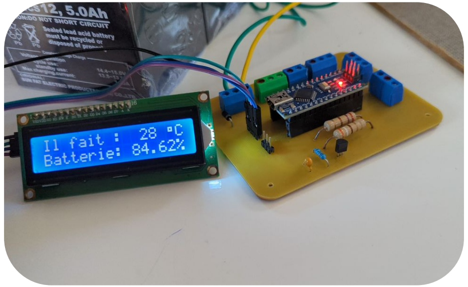
# 2.4- Electronic system

## Power Management System

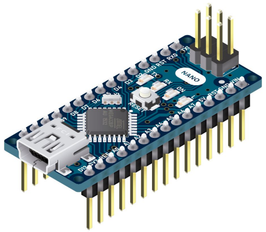
For efficient power system management, we have opted for the following configuration:

- The rover's power supply consists of two parallel-connected 12-volt batteries, each rated at 5 Ah.
- An Arduino nano manages this power supply and displays in I2C LCD screen the temperature of the block via an LM35 sensor and the battery charge level using a resistor bridge.
- An emergency stop button is integrated between the power pack batteries and the rest of the system. This button allows you to shut down the entire system if necessary.

With our current power supply we have a capacity of 10 Ah (Capacity = current * time), offering a maximum autonomy of 5 hours if the system consumption reaches 2A. However, this autonomy can be reduced by various factors, such as variations in component consumption, circuit losses, and temperature fluctuations.




Battery Block



Arduino Nano

# 2.4- Electronic system

## Navigation System

**Radio Command**

To control the actuators we used the Flysky FS-I6 RC and its FS-IA6 receiver which offers a control distance between 500 ~ 1500 m in free space

The receiver is connected to the Arduino Mega

| Channel | Usages |
|---|---|
| Channel 1 – Right Joystick, Left/Right | Controls four (04) servo motors each connected to the Rover's front and rear wheels to enable turning movements |
| Channel 2 – Right Joystick, Up/Down | Controls six (06) motors each connected to the Rover's wheels to allow the rover to move forward and backward |
| Channel 3 – Left Joystick, Up/Down | Control the rotation (in two directions: clockwise and counterclockwise) of the stepper motor connected to the Rover's neck for a 360° rotation of the camera |
| Channel 4 – Left Joystick, Left/Right | Controls one (01) servo motor connected to the Rover camera block to allow tilt movements (up-down) |

**Flysky FS-I6 RC**

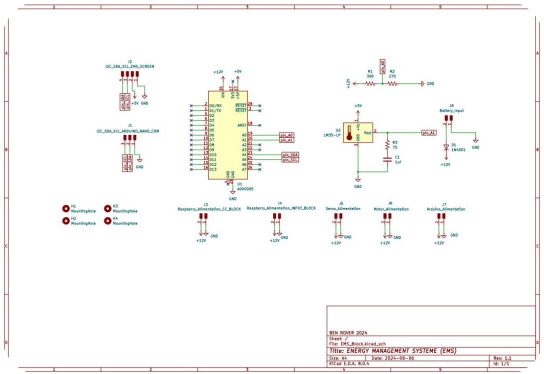

**FS-IA6 receiver**

# 2.5- PCB Manufacturing

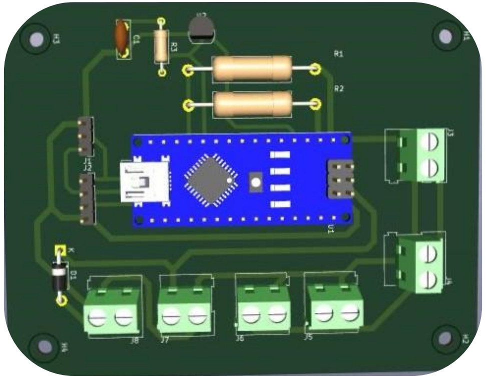
## Power Management PCB

We designed **three (03) distinct PCBs**, each tailored to specific functionalities of the rover. The design process considered key factors such as size constraints, durability, and signal.. The PCBs were designed using KiCad, focusing on optimizing the layout for power distribution and signal integrity.

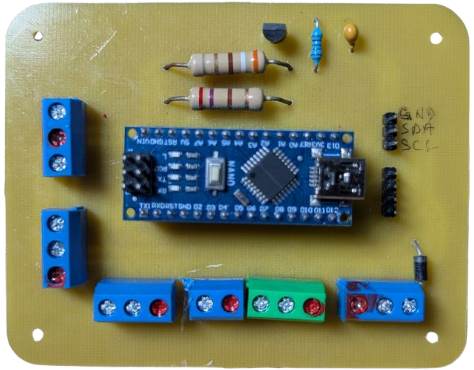
Designed for monitoring and distributing electrical power to all subsystems. The board combine an Arduino Nano Board which use an voltage divider resistor bridge and a LM35 temperature sensor to analyse and show the voltage level and the temperature of the circuit on a LCD display. The board is also equipped with terminal block connector to ease the power connection to all the rover's components .



KiCAD Schematics



PCB Design

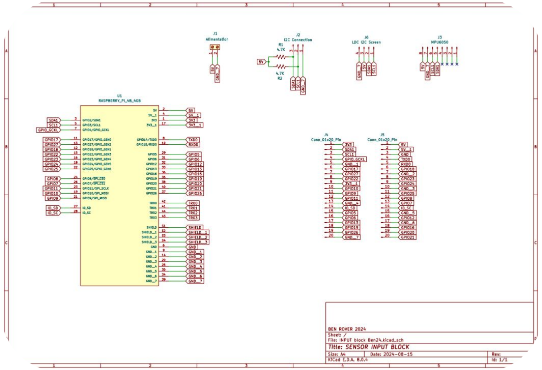


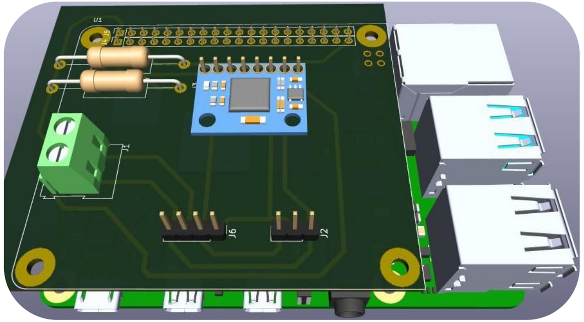
PCB Production

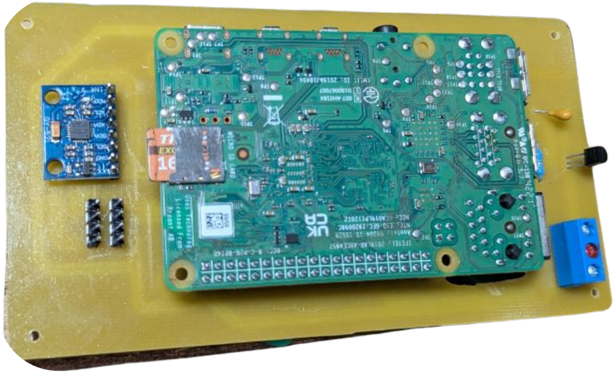
# 2.5- PCB Manufacturing

## Sensor Input Board

The circuit below is an exploitation circuit for the Raspberry Pi4. We have equipped it with a MPU6050 sensor for gating axial position and acceleration data of the rover. Via the I2C circuit on the board, the Raspberry is able to gate and send data to all the orders boards. Let's remember that the Raspberry is equipped with a high definition camera.





# 2.5- Fabrication Process

## Layers Design

The PCBs were fabricated using a CNC milling machine, ensuring precise trace routing and accurate drilling for through-holes and surface-mount components. But between the PCB design and its fabrication with the CNC machine, there is an important step. This step consist of  creating the CNC Jobs files with the logiciel FLATCAM. The picture on the right side shows the process while we were creating  the files for the Output Board. The principle of this step is to indicate the different drilling bits we are using on our CNC machine and other important configurations.

**KiCAD** is a software for designing the electronics circuit we want to produce.

**KiCAD** is a software for designing the electronics circuit we want to produce.

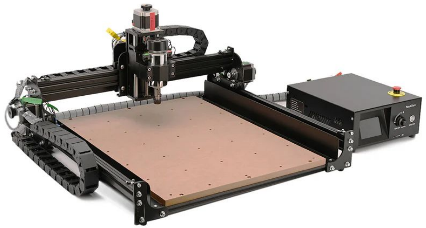
Candle Cnc
Software Tutorial

CNC Philosophy

**KiCAD** is a software for designing the electronics circuit we want to produce.

## CNC Milling & Drilling

The PCBs were fabricated using the Fox Alien 4040-XE showed on the picture right here. By using appropriated milling bites we have been able to make our Printed Circuits Boards with a really high finesse of quality.



## Soldering & Testing

After fabrication, components were mounted on the PCBs and soldered manually. Despite the high density of the pins on the boards, our electronic team members have been able to solder them without any short circuit and have adjusted the circuit as needed in function of the inconvenience occurred.

# 2.6- Software Development

## Interface

The interface of a Mars rover serves as the critical link between the rover and mission control, enabling scientists and engineers to control and monitor the rover's activities. This interface is designed to be robust, user-friendly, and capable of handling complex operations remotely. Key components include: a User Dashboard serving as a central hub for mission control receiving metrics and navigation data, and the Camera and Sensor Feed helping us get a comprehensive view of the rover environment and surroundings.

## Website

The BenRover website showcases competition details, team info, and an interactive 3D rover model. It includes crowdfunding and partnership sections, a progress gallery, and links to a separate technical documentation site. The platform serves as both a public information hub and a comprehensive team resource.