ANATOLIAN ROVER CHALLENGE

2022

Design Report

TEAM INFO

ANATOLIAN ROVER CHALLENGE

Team Name:

Name of the team and if applies, name of the rover.

Project MarsWorks

Contact:

Contact information and social media links of the team.

Instagram: @project_marsworks
Facebook: @ProjectMarsWorks
LinkedIn: Project MarsWorks
e-mail: marsworks@sheffield.ac.uk

MarsWorks, University of Sheffield

TEAM INFO

ANATOLIAN ROVER CHALLENGE

Academic Institution:

Name and address of the affiliated academic institution.

The University of Sheffield
S10 2TN Sheffield, UK

Academic Consultant:

Name, affiliated academic institution and contact information of academic consultant.

Viktor Fedun
The University of Sheffield
e: v.fedun@sheffield.ac.uk

MarsWorks, University of Sheffield

TEAM INFO

History of the Team:

- A paragraph of teams history including foundation date, attended competitions and experience.

The first planetary rover team, Project MoonWorks, was formed in 2017 and joined the national UKSEDS Lunar Rover Competition 2018. It won 1st for Best Innovation, and 2nd for both Best Critical Design Review and Best Outreach. In 2019 the team rebranded into Project MarsWorks and made a debut in the European Rover Challenge (ERC) with 6 of the MoonWorks members on board. The team came 17th in the 2019 edition of ERC and considered it a success seeing as it was the first time we competed. Then COVID hit and so we were unable to work on the rover in person. This meant we did not compete in any competitions in 2020 or 2021, however we focused on lessons learnt from our previous experience and polished our designs.

Project MarsWorks have recently become funding members of the Sheffield Space Initiative (SSI) – an organisation that brings together all space-oriented, student-led projects at the University. Being a part of the SSI means that the team not only gets more publicity, but we also share our ideas and expertise with the other society members.

TEAM INFO

Active Members List:

- A table of active members including following information: Name (or initial letters), University Major, and duty in the team.

Anna Pawinska - *Civil and Structural Engineering* - **Project Leader, Operations sub-team Leader**
Ece Erkan - *Electrical and Electronics Engineering* - **Documentation and Outreach Officer**
Yash Bordia - *Computer Science* - **Logistics Officer**
Irfan Ramiza - *Mechanical Engineering* - **Treasurer**
Reuben Mitchell - *Mechatronics and Robotics Engineering* - **Project Leader, Development sub-team Leader**
Ignacio Vegas de los Rios - *Mechatronics and Robotics Engineering* - **Development Electrical Engineer**
Eleanor Hedges- *Mechatronics and Robotics Engineering* - **Development Electrical Engineer**
Joel Phillips - *Mechanical Engineering* - **Development Mechanical Engineer**
Owen Gill - *Mechanical Engineering* - **Mechanical sub-team Leader**
Alex Daniel - *General Engineering* - **Mechanical Designer**
Matthew Deans - *Mechanical Engineering* - **Mechanical Engineer**
Oliver Bowett - *Microelectronics* - **Electrical sub-team Leader**
Joseph Moore - *Mechatronics and Robotics Engineering* - **Electrical Engineer**
Ritushee Bhattacharya - *Computer Systems Engineering* - **Electrical Engineer**
Nishane Gunawardena - *Mechatronics and Robotics Engineering* - **Software sub-team Leader**
Pablo Cordoba - *Mechatronics and Robotics Engineering* - **Software Engineer**
Yue Yao - *Robotics Engineering* - **Software Engineer**
Pradyumna Madnurkar- *Robotics Engineering* - **Software Engineer**
Syed Reza - *Computer Science* - **Software Engineer**

TEAM INFO

Team Photo

- A photo/screenshot of the whole or part of the team.

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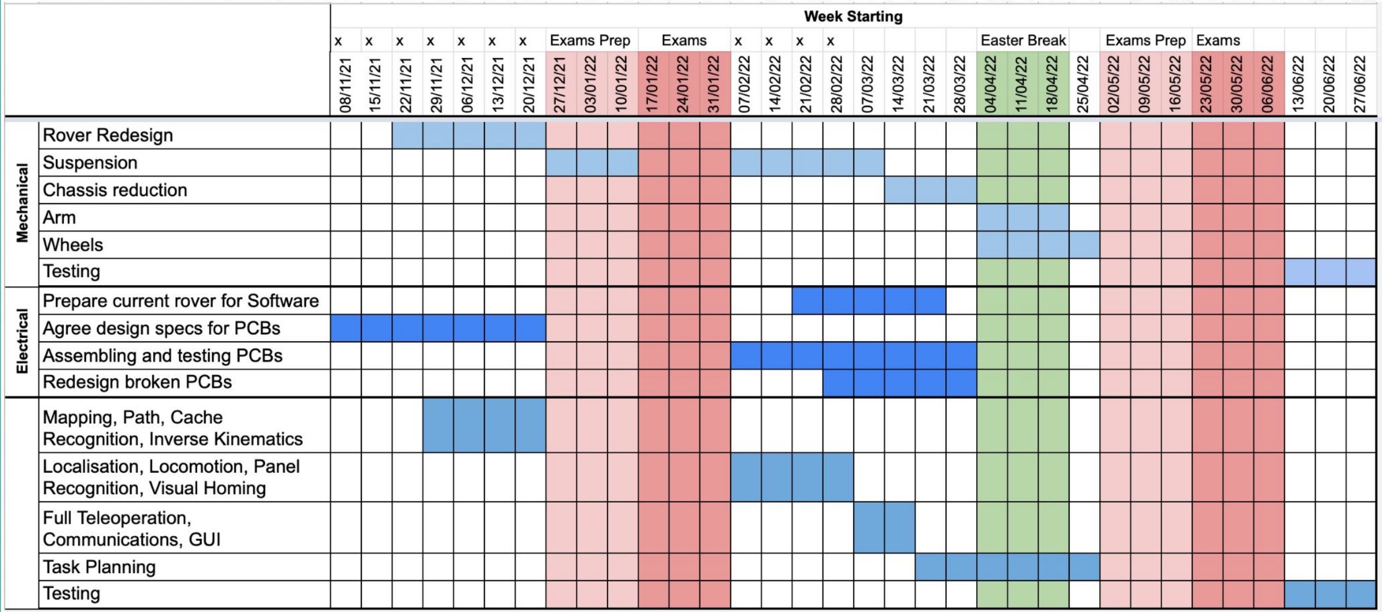
MANAGEMENT

Work Calendar:

- Explain the work on the project by a gantt chart. Include 10-15 items in the Gantt chart.



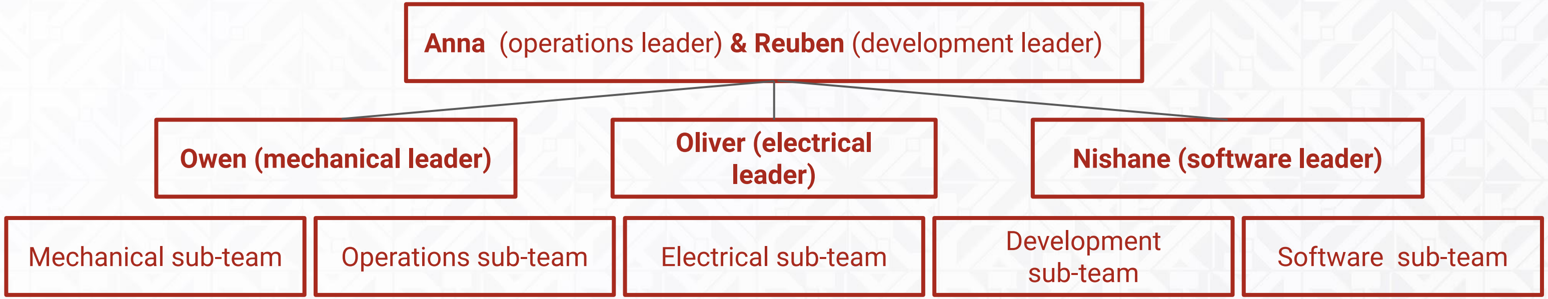
MANAGEMENT

ANATOLIAN ROVER CHALLENGE

Team Formation:

- How is the team workforce structured? (2-3 sentences) Include a graphic to explain the structure as well.

There are 5 sub-teams within Project MarsWorks, which are further divided into technical and non-technical ones. The sub-teams are: Mechanical - in charge of the rover structure and stability systems; Software - working on the operational systems within the rover and communications; Electrical - combines the physical structure of the rover and its software into a functional system; Operations - the non-technical team responsible for the logistics, outreach and finances of the team; Development - a team between technical and non-technical focusing on training future project members. The project is led by two project leaders - Anna Pawinska and Reuben Mitchell who also lead the operations and development sub-teams.



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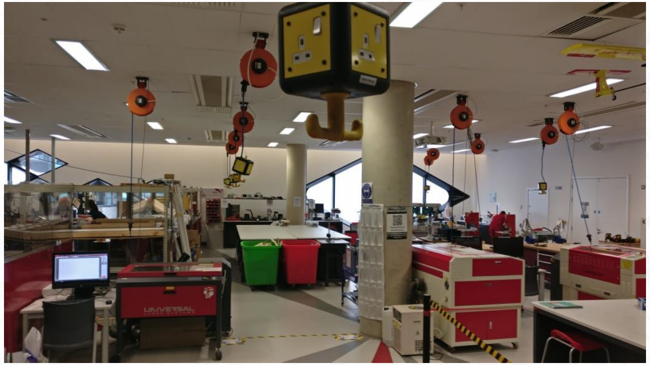
MANAGEMENT

ANATOLIAN ROVER CHALLENGE

Workplace:

- How the team design, build and test the rover physically? Explain the workplace. (2-4 sentences) Include a photo/screenshot of the workplace.

All the student-led projects within the Faculty of Engineering at the University of Sheffield have been given a dedicated space to work on their designs. MarsWorks were given a room to share with another project - bionics, where we share equipment, store the rover and parts (right image). When it comes to some of the more complicated manufacturing processes, our team are free to use the University Makerspace - the iForge (left image). There, we can use a wide range of equipment ranging from soldering irons to water jet and laser cutters, provided that we complete the necessary training.



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MANAGEMENT

ANATOLIAN ROVER CHALLENGE

Funding :

- How are the funds of the project at the time of submission of this document?
- How much spending is expected for the development costs? How much spending is expected for the travel costs?
- What is the team's plan in an insufficient funding situation by the competition date?

In September 2021 the project received funding from the Faculty of Engineering at the University as well as the Alumni Fund equal to £3,754. We have later secured a £250 prize from RS components.

Now, at the time of submission, the team have spent most of this money on components and parts for the rover. We currently have about £500 left in our account that we plan on spending on further developing the wheels of the rover and completing manufacturing in the coming weeks before the competition.

The University have a dedicated travel fund for all teams that qualify for international competitions, which is how we plan to cover our travel costs.

In the unlikely event we find ourselves needing more funds, our academic supervisor has been extremely helpful in applying for more funding in the past. We also have a few ideas for fundraising events to organise within the University.

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MANAGEMENT

ANATOLIAN ROVER CHALLENGE

Logistics:

- What is the team's plan to package and bring the rover to competition site by July? (4-6 sentences)

Having spoken to our academic supervisor the team have decided that the most convenient way of bringing the rover to Istanbul would be by car. We would rent out a van and have three or four team members take turns driving it to Turkey. It would take us around 3 days, however this way we would be able to take all the equipment with us and we wouldn't have to worry about any damage being caused to our rover. In case anything goes wrong, we would also be able to work on the rover on the way to the competition site. The rest of the team would most likely fly into Istanbul.

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ROVER DESIGN

ANATOLIAN ROVER CHALLENGE

Mobility System:

- What is used? Describe the system (3-5 sentences)
- Why the system is chosen? What are the considerations? What are weaknesses and strengths? (3-5 sentences)

6 e-bike motor driven wheels power the rover, with 3 wheels on each side of the chassis. Rocker-bogie suspension system is used for the front two wheels on each side allowing them to pivot around the rocker to improve stability whilst moving. The rear wheel is a single suspension rod and piston. The wheel have been 3D printed in aluminium to produce an effective thread pattern and save weight by controlling the infill density. The rover will be using a Intel realsense depth camera and an A* based slam algorithm to produce a valid path using coordinates provided from the ground station.

The rocker bogie system was selected to help maintain traction when the rover is navigating rocky terrain or driving in and out of craters by pivoting around the rocker to maintain contact with the surface. Receiving drive from all 6 wheels of the rover also help improve traction when in challenging terrain, this will be a key strength in the competition. A potential weakness of the design is the steering is achieved by varying wheel speeds on both sides of the rover as opposed to a traditional caster wheel steering design. We have decided to an A* based algorithm because it requires less computation resources and it is easy to apply. An Intel realsense depth camera is used because it is low power,lightweight, easy to use and can communicate well with our Jetson Nano.

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ROVER DESIGN

ANATOLIAN ROVER CHALLENGE

Mobility System:

- Unique points and inspirations (3-5 sentences)

3D printed wheel designs is a unique feature of the rover as it allows the desired thread pattern to all be one solid piece. The wheel manufacture also provides a more sustainable solution as opposed to CNC machining from a solid block as a lot of material would need to be removed increasing cost and waste. The rocker bogie suspension was inspired by NASA's Curiosity rover as it showed great strength when driving over uneven surfaces.

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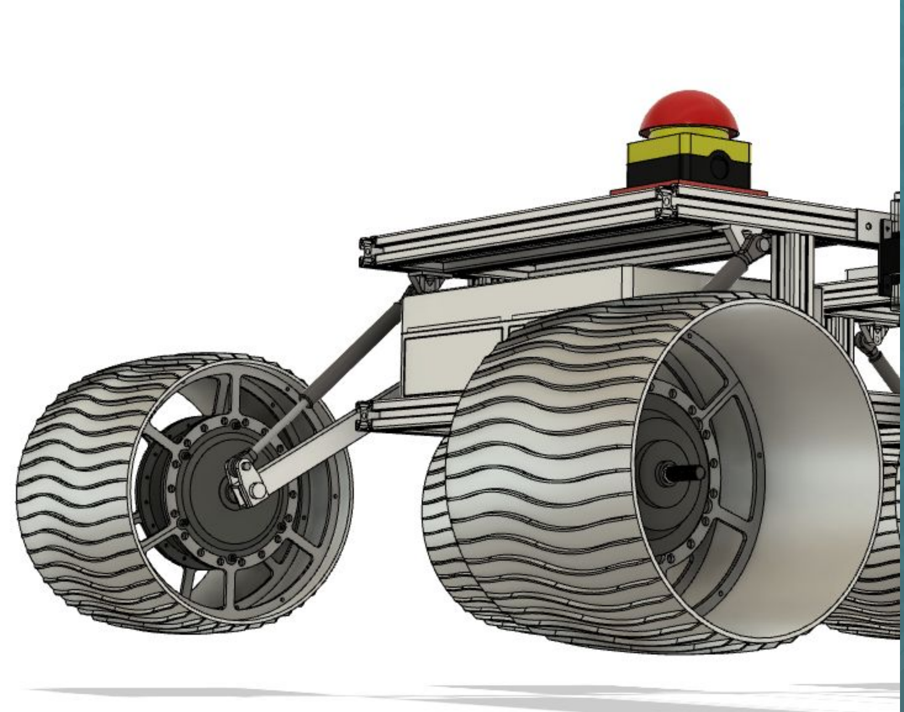
ROVER DESIGN

ANATOLIAN ROVER CHALLENGE

Mobility System:

- Visuals of the system (2 photos/screenshots)



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ROVER DESIGN

ANATOLIAN ROVER CHALLENGE

Mobility System:

- Technical Specifications including mass and size (3-5 sentences)
- Discuss system's adequacy for its role in competition missions. (3-5 sentences)

Technical Specification:
Mass per wheel : 6.8 kg
Chassis Dimensions : width 997 mm x length 1360 mm x height 400 mm

The suspension and mobility design of the is well suited to the terrains described in the mission briefs especially the caters. The rocker bogie suspension allows the rover to drive up the crater walls and once it reaches the top pivot on its axis to maintain traction to all 6 wheels reducing the risk of getting beached. The design also helps ensure the rover maintain balanced throughout the missions.The IMU sensor within the realsense camera will prove to be useful in detecting craters and any other objects that would be present in the MarsYard when undertaking the competition missions mainly the mission 2 and 3 where the rover will have to navigate autonomously during the mission.

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ROVER DESIGN

ANATOLIAN ROVER CHALLENGE

Electronics and power system:

- What is used? Describe the system (3-5 sentences)
- Why the system is chosen? What are the considerations? What are weaknesses and strengths? (3-5 sentences)

- The electrical system has been designed so each subsystem on the rover has its own dedicated circuit board, based around the ATMega32u4 microcontroller.
- Power is provided by a 24v Lead Acid battery pack. We anticipate this being a 2S2P configuration of 9Ah cells.
- The power from the battery is regulated for use with 5v and 12v subsystems of the rover and the will wheels run directly off the 24v batteries.

This system was chosen as it is a reliable, efficient and low cost method of providing the power necessary for the rover over the required operating period. The main weakness is that lead acid batteries are much heavier that other technologies for a given capacity, increasing the overall mass of the rover.

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ROVER DESIGN

Electronics and power system:

- Unique points and inspirations (3-5 sentences)

A unique feature is the use of a CAN network for communication on the rover, a method commonly employed in automotive design. This allows any of the subsystem controllers to communicate with any other point on the network.

If a fault is found in any subsystem during operation, this allows it to be reported and acted upon immediately via direct communication with the relevant controller.

E.g., Arm controller detects actuator runaway -> communicated across network -> Main controller logs error & BMS cuts off power

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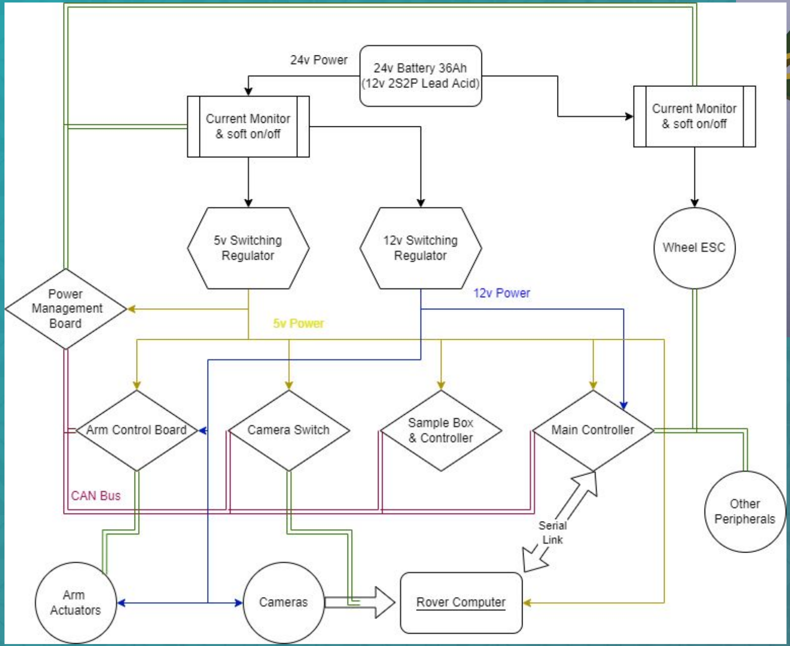
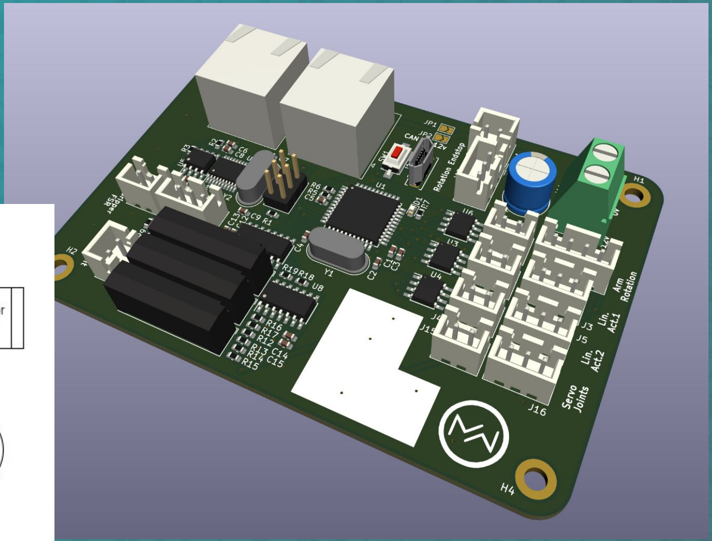
ROVER DESIGN

Electronics and power system:

- Visuals of the system (2 photos/screenshots)

Simplified diagram of the proposed electrical system





Render of arm control board

ROVER DESIGN

ANATOLIAN ROVER CHALLENGE

Electronics and power system:

- Technical Specifications including mass and battery duration (3-5 sentences)
- Discuss system's adequency for it's role in competition missions. (3-5 sentences)

Estimated Mass

Battery: 10kg
Electronics (boards & wiring): 1.5kg
Actuators: 4kg
Total: 15.5kg

Estimated Minimum Battery Duration: 118 mins

This system will allow the rover to operate close to maximum power usage up to the time limits specified by both field tasks (Missions 1 & 2). This will remove the need for battery changes or charging between the most intensive tasks, and gives us provision to operate at a lower power consumption and decrease the battery capacity, decreasing the rover's total mass.

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ROVER DESIGN

ANATOLIAN ROVER CHALLENGE

Manipulation system:

- What is used? Describe the system (3-5 sentences)
- Why the system is chosen? What are the considerations? What are weaknesses and strengths? (3-5 sentences)

Manipulation is achieved using a robotic arm controlled by linear actuators with a claw style end effector. The end effector claw is driven by a single worm gear simultaneously opening 4 claw arms. The 4 axis arm allows for 270 degree reach around the rover. In terms of software, ROS moveit toolkit will be run on the jetson nano which will carry out all the kinematics calculations in real time with many types of control algorithms.Using this toolkit, we will be able to send electric signals to the linear actuators to achieve the unique orientation required by the arm to reach the coordinates sent by the ground station.

Claw end effector design was chosen to precisely pick up a range scientific payload geometries securely within the claw end grips. Securely carrying the payloads, large surface area to operate switches and the ability to operate the end effector using only one motor were the main considerations. Worm gears wearing out due to use and controlling claw opening speed are potential weaknesses of this design. Only using one motor saves weight and power requirements saving weight. ROS moveit toolkit provides us with many advantages with the main advantage being able to undertake the task of motion planning of the arm, it also provides several off-the-shelf planners which has its own pros and cons depending on the application.

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ROVER DESIGN

Manipulation system:

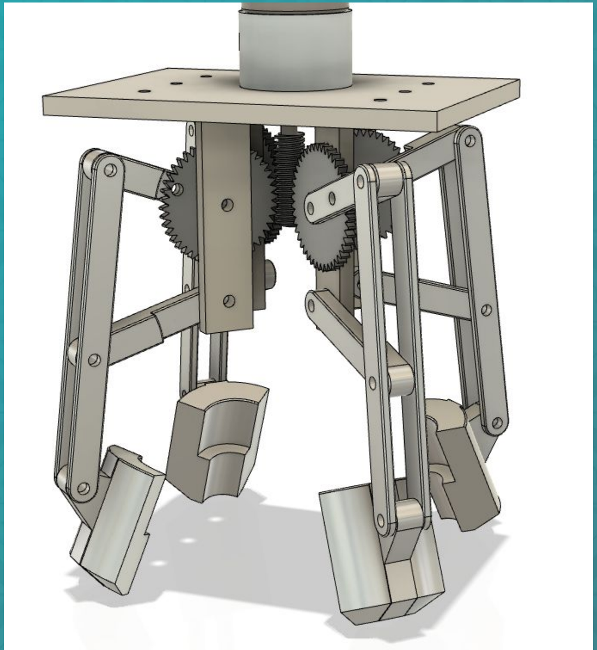
- Unique points and inspirations (3-5 sentences)

Due to the modular nature of our design the grip ends can easily be interchanged depending on the task needs, such as introducing overlapping hooks to carry medical supply boxes or finger like ends for intricate switch tasks. Only requiring one motor is a unique feature which helps to save weight and ensures the arms open and close synchronously. The design was inspired by manufacture robot and the claw style designs used when picking on the production line.

ROVER DESIGN

Manipulation system:

- Visuals of the system (2 photos/screenshots)



ROVER DESIGN

ANATOLIAN ROVER CHALLENGE

Manipulation system:

- Technical Specifications including mass, max payload and size (3-5 sentences)
- Discuss system's adequacy for it's role in competition missions. (3-5 sentences)

Technical Specifications:

Mass : 16.8 kg
Max Payload Diameter: 110 mm
Max Payload: 4-5 kg vertical lift mass

The chosen design is highly applicable to the missions with interchangeable end effector grips optimising the rovers capabilities based on the task. The 4 lever arm claw allows the rover to pick up and interact with a range of payload geometries without adjustments. Ros moveit toolkit will be especially useful in undergoing missions 1 and 3, where complex arm manipulation may be required. It will help simplify the programming and mathematical calculations of the arm significantly hence will help us complete the mission in a more efficient manner. One such example could be that it could help find the self collision matrix on it own rather having to program it manually which will aid us avoid programming errors as the missions goes along.

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ROVER DESIGN

ANATOLIAN ROVER CHALLENGE

Science Payload:

- What is used? Describe the system (3-5 sentences)
- Why the system is chosen? What are the considerations? What are weaknesses and strengths? (3-5 sentences)

Payload storage cache attached to the side of the rover chassis stores large payload items. Additional science boxes located on the rover chassis store and weigh ground samples collected by the end effector scoop. Science boxes around the chassis use servo motors to open and close the lid ensuring the sample is not contaminated is transit.

The system was selected to securely collect and transport science payloads onboard the rover. Major considerations included ensuring the stored payload orientation is readily accessible to the manipulation arm, hence a test tube rack insert was designed for the cache which can vary in height ensure end effector can grip the payload. Potential weakness of storing payloads on the side of the chassis is rover unbalance, however equipment positioning in the centre of the rover has been adjusted to accommodate for this.

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ROVER DESIGN

Science Payload:

- Unique points and inspirations (3-5 sentences)

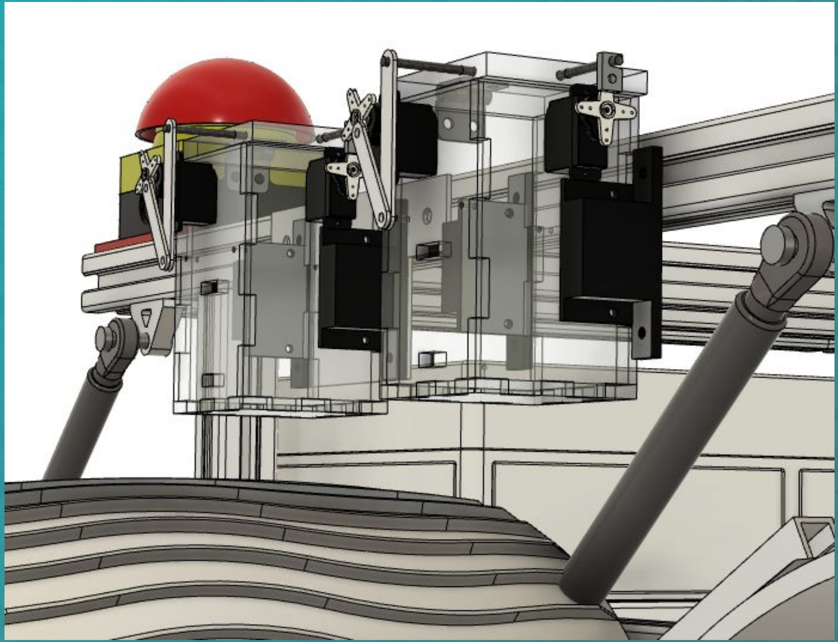
The payload chase takes inspiration from test tube holder racks to vertical position payload to ensure the rovers claw style end effector can collect and deposit the payload. A unique feature of our science boxes is automated enclosure lids which open and close to store soil samples and reduce the risk of contamination. Additionally our rover is able to store and weigh the sample simultaneously removing the need for further instrumentation to calculate a samples mass. The removable insert of the payload cache allows for a variety of different sized payloads

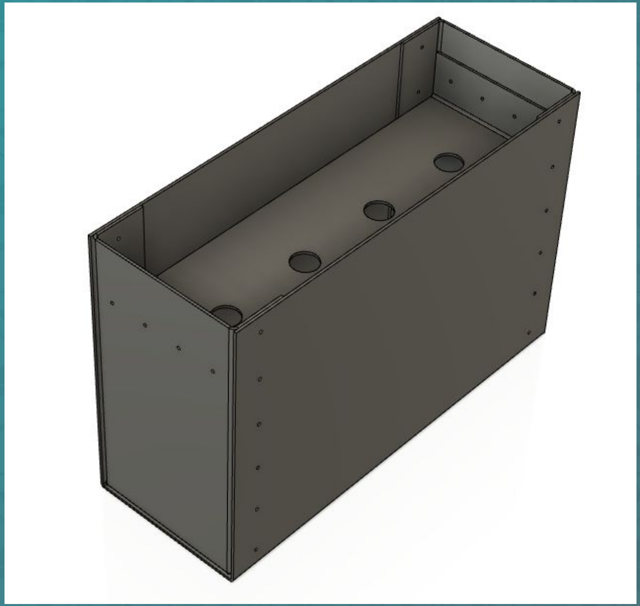
ROVER DESIGN

ANATOLIAN ROVER CHALLENGE

Science Payload:

- Visuals of the system (2 photo/screenshots)





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ROVER DESIGN

ANATOLIAN ROVER CHALLENGE

Science Payload:

- Technical Specifications including mass and battery duration (3-5 sentences)
- Discuss system's adequacy for its role in competition missions. (3-5 sentences)

Technical Specifications:
Science Box mass: 450 g per box
Payload Cache : 3.2 kg
Battery Duration : 60-80 minutes

The current system is moderately adequate for the mission tasks the store and interact with the variety of payloads. Updates will be made however to further improve adequacy such as adjusting insert holes to fit the oxygen bottle payload and the container depth and accessibility to carry the supplies case.

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ROVER DESIGN

Ground station equipment and communication system:

- What is used? Describe the system. (3-5 sentences)
- Why the system is chosen? What are the considerations? What are weaknesses and strengths? (3-5 sentences)

- Long range Wifi will be used to communicate with the rover
- At 5GHz this gives us an expected range of around 300m from the ground station
- The development of the GUI is done using a Qt framework as it has an inbuilt support for ROS libraries
- The sensor data is published as ROS messages on ROS topics which can then be subscribed by other modules which are considered as subscribers.
- By linking the subscriber data to the respective Qt widgets, we can visualise the subscriber data inside the GUI which will allow us to analyse and execute the appropriate commands for the rover.
- This is system is chosen due to ROS being a highly flexible platform.
- Ros is really challenging to use alone for command windows which is why it is overlay with a Qt framework.

ROVER DESIGN

Ground station equipment and communication system:

- Unique points and inspirations (3-5 sentences)

- This allows easy transmission many kinds of information (video, commands, sensor data etc.) without using multiple communication systems & protocol
- Increased bandwidth and data rate compared to lower frequency radio communication
- ROS has a package that can link with a system with a GUI made using Qt widgets and Qt contains classes that give easy access to ROS nodes.
- The IMU module in ROS will be used to access the data from the IMU sensor in the depth camera which will show the rover's current orientation data,velocity data and acceleration data back to ground station.
- The video module will be used stream live video captured by the camera as the input for our slam algorithm.
- Camera module will be used to subscribe to and analyse the camera images
- The teleoperation module will allow the user to choose the mode of manual control of the rover such as a Xbox controller

ROVER DESIGN

ANATOLIAN ROVER CHALLENGE

Ground station equipment and communication system:

- Visuals of the system
(2 photos/screenshots)

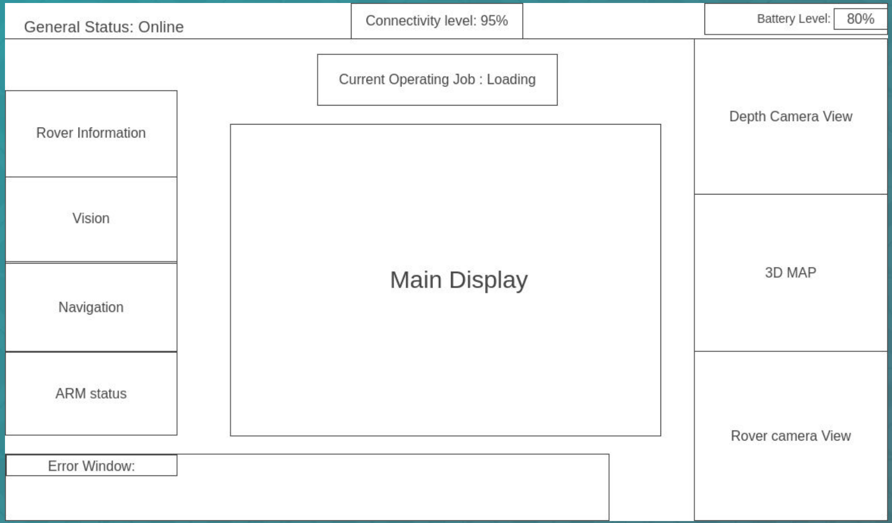

Figure : Main Panel Display for Ground Station

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ROVER DESIGN

ANATOLIAN ROVER CHALLENGE

Ground station equipment and communication system:

- Technical Specifications including resilience to noise and communication range (3-5 sentences)
- Discuss system's adequency for it's role in competition missions. (3-5 sentences)

- TP-Link EAP225-Outdoor Access Point
  - 2x 4dBi Antennas at 5GHz
  - 300m Range at 5GHz
  - Beamforming and adjustable transmission power (up to 27 dBm) increase noise resilience and range
- Laptop with Ubuntu and ROS Melodic downloaded
- This system is adequate for the mission tasks which involve navigating to certain checkpoints and taking pictures of certain objects during the mission.
- For navigation tasks, the IMU module and GPS module will be used with the rover's depth camera to produce a valid path to the checkpoint
- The camera module will be used to analyse the pictures takes on the sampling site, astronauts and the repair kits which will take place during the missions.

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