ANATOLIAN ROVER CHALLENGE

2022

Design Report

TEAM INFO

ANATOLIAN ROVER CHALLENGE

Team Name: KAPSUL ROVER TEAM

Rover Name : LUMINOUS

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KAPSUL ROVER TEAM

TEAM INFO

ANATOLIAN ROVER CHALLENGE

Academic Institution:

Konya Technical University
Akademi Mah. Yeni Istanbul Cad. No:235/1, Selcuklu/KONYA

Academic Consultant:

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Academic Institution: Konya Technical University
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KAPSUL ROVER TEAM

TEAM INFO

History of the Team:

Kapsul Rover Team is formed as a result of the restructuring of the MUGET Rover Team, which was established in 2019 within the scope of Konya Technical University. Team members are studying at Konya Technical University (KTUN), Selcuk University (SU), Necmettin Erbakan University (NEU), KTO Karatay University, Konya Food and Agriculture University, Gebze Technical University, Istanbul Gelisim University, and Anadolu University. 25 people in the team are studying in the departments of mechanical engineering, electrical and electronic engineering, computer engineering, industrial engineering, molecular biology and genetics and computer programming. Team consultancy Konya Technical University Electrical and Electronics Department Lecturer Dr. Mucahid Barstugan conducts. The work is carried out by 5 main sub teams, including the Science Team, the Electronics Team, the Mechanical Team, the Organization Team and the Software Team. Each sub team has a leader. All sub-units are under the supervision of the team captain. All team members hold weekly meetings and present the results of these meetings as a progress report at the general team meeting. Thanks to these meetings, all team members have an idea about the workings of the other subsystems of the rover. Agile methodology was chosen as the management methodology in the project. With this methodology, all sub-teams continue to work with the right interaction in these disciplines. We use the Trello application for tracking and management of the project. Thus, process development follow-up proceeds more efficiently. Sub-unit leaders write their short and medium-term goals in Trello's dedicated subheadings. A start and end date are specified for each written task. Thus, processes are planned and implemented more clearly. Online platforms such as Zoom, Discord, and Gather are used so that team members can work together efficiently remotely. The team has prepared for URC (University Rover Challenge) and ERC (European Rover Challenge) competitions in the past years. The Kapsul Rover team is also preparing for the ERC onsite competition together with the ARC (Anatolian Rover Challenge). Some of the team members are the finalists of The European Rover Challenge On-Site 2021. At the same time, some of the team members are entitled to participate in the TEKNOFEST finals, Turkey's first and only aviation, space, and technology festival, while some of the team members still take part in the TEKNOFEST process, and represent their university in different events, and categories.

TEAM INFO

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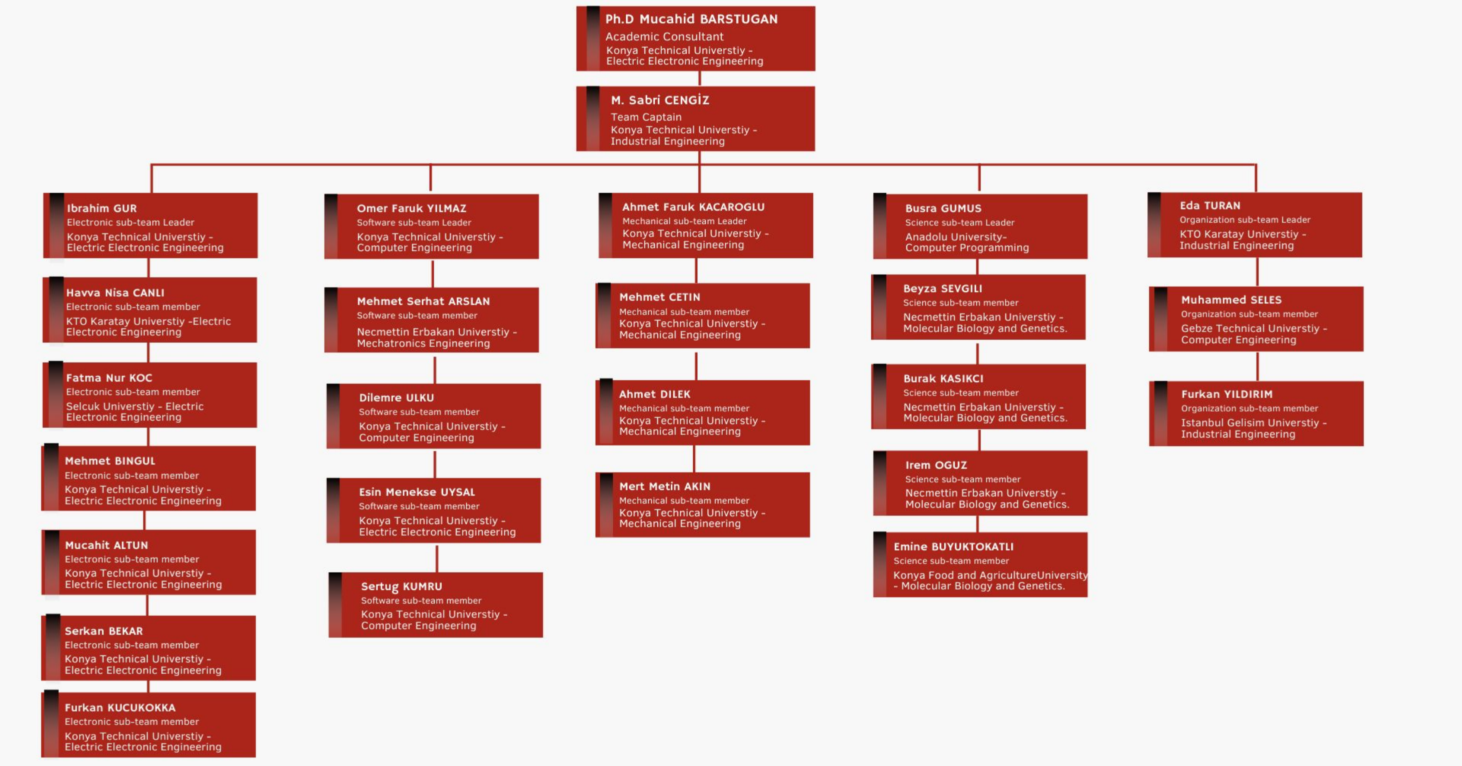

Table 1: Active Members List

KAPSUL ROVER TEAM

TEAM INFO

ANATOLIAN ROVER CHALLENGE

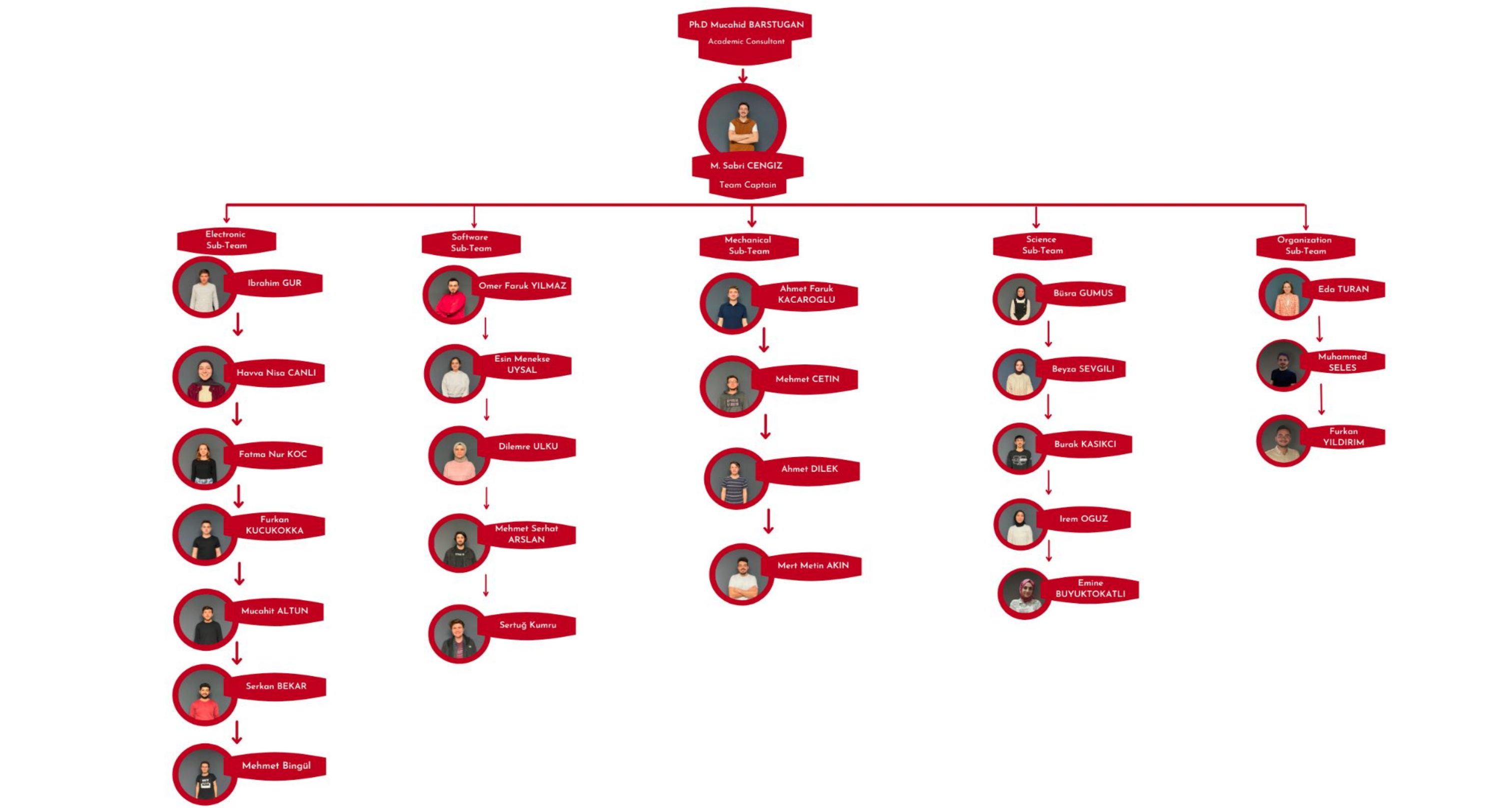

Table 2: Team Photo

KAPSUL ROVER TEAM

MANAGEMENT

Work Calendar

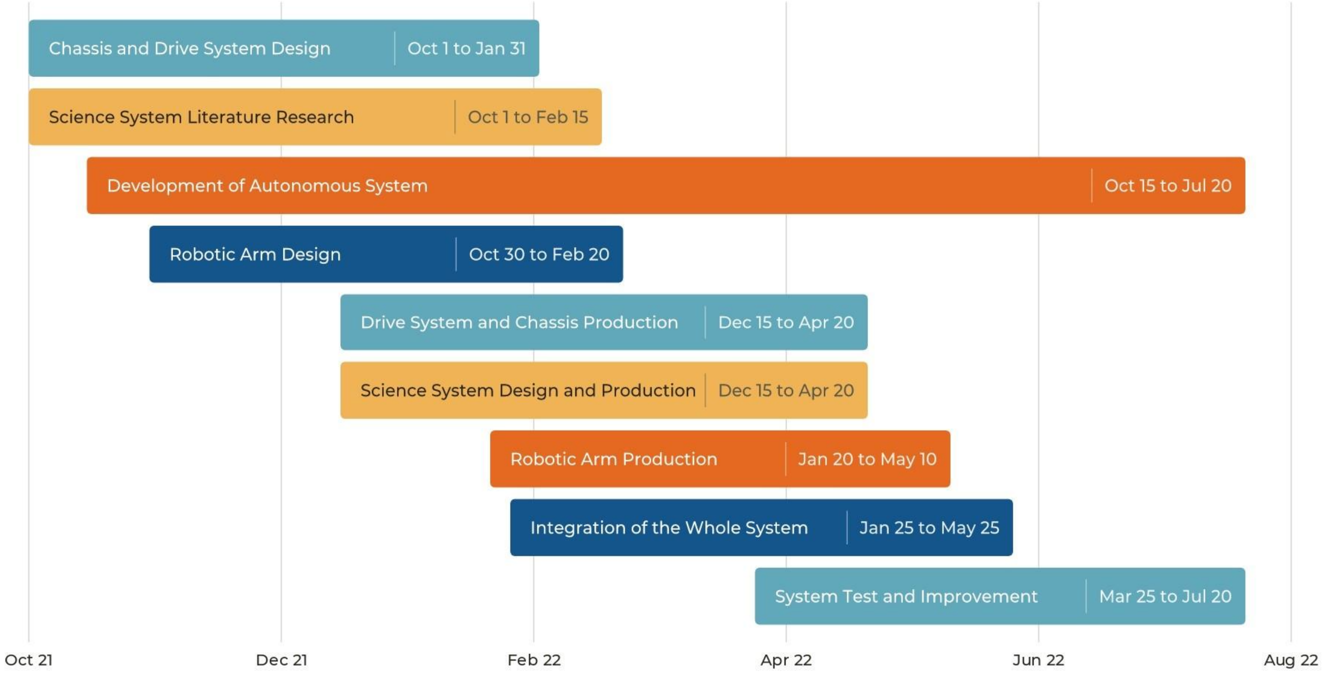

Figure 1: Gantt Schema

MANAGEMENT

Team Formation

Team members are included in sub-teams based on their skills and interests. For the work that needs to be done, relevant team leaders conduct an in-team work section and follow the processes. These processes are recorded in the Trello app to ensure that all team members are aware of each other.

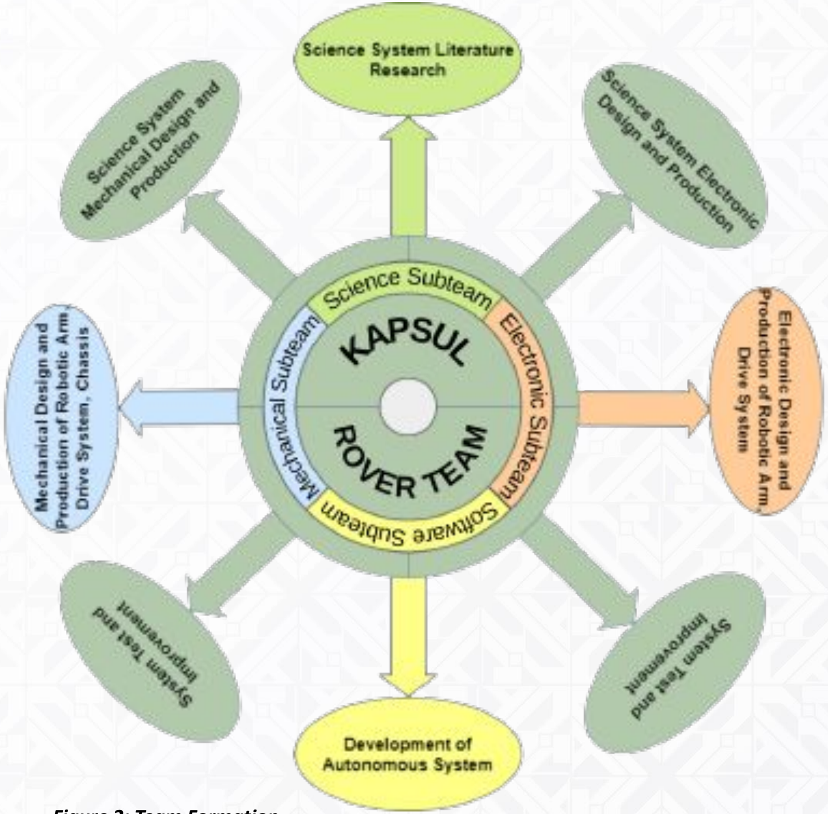

Figure 2: Team Formation

MANAGEMENT

Workplace

The Kapsul Technology Platform is a nonprofit organisation that provides workshops, materials, and mentorship to students and teams who qualifying. The entirety of the design, production, and testing procedures are performed in the workshops and offices provided by the Kapsul Technology Platform. Konya Technical University provided mechanical tools and office support while the science team continued their biological and chemical studies in the laboratories of Necmettin Erbakan University and Selcuk University.

Figure 3:Workplace

Figure 4 :Workplace

KAPSUL ROVER TEAM

ANATOLIAN ROVER CHALLENGE

MANAGEMENT

ANATOLIAN ROVER CHALLENGE

Funding

The Kapsul Technology Platform is the main sponsor of the Kapsul Rover Team. Kapsul Technology Platform; has met the workshop needs of the team and has covered all electronic materials, mechanical materials and labor costs, and continues to fund the necessary material and labor fees. Even in the event of the cancellation of the sponsorship, all electronic equipment and most mechanical materials for our team's needs have already been provided and the project will not be interrupted. Remaining supplies and science mission materials will be procured from local companies.

Apart from Kapsul Technology Platform, our team receives various supports such as workshops and mentorship from Konya Metropolitan Municipality, Konya Science Center and 5 universities in the city.It is planned to spend USD 7,661.39 on development costs. It is planned to spend approximately USD 1,309.64 for travel and accommodation expenses.

In case of financial inadequacies, new supporters will be sought. If no new supporters are found, travel and accommodation expenses will be covered by individual budgets.

KAPSUL ROVER TEAM

MANAGEMENT

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Logistics

Our team continues its work in Konya, Turkey. It is planned to provide transportation to Istanbul, Turkey by private vehicles on the dates of the competition. The Rover is designed and manufactured to be easy to disassemble and assemble. All sensors, batteries, robot arm parts, chassis and drive system parts are planned to be disassembled, packaged and transported to Istanbul by road.

KAPSUL ROVER TEAM

ROVER DESIGN

ANATOLIAN ROVER CHALLENGE

Mobility System:

Mechanichal: Body system is composed of 30x30 aluminum sigmas. It is aimed to create a vehicle with a height of 510 mm, with a rigid rectangular frame measuring 430*700 mm and in addition to this, wheel connections to hold the wheels together in pairs to ensure movement. In order for the body to remain as stable as possible and the devices on it not to be affected by the impacts, a suspension system has been designed with movable joints and diagonal rise and fall of the wheels.

Electronic: The control of the driver boards (VNH2SP30) used to drive the motors synchronously is provided by ATMEGA2560. Maximum performance has been achieved with less energy and fast processing capacity with ATMEGA2560. High torque has been obtained by using a 188/1 ratio gearbox and RS-775 motor to ensure the movement of the rover. RS-775 is a high torque motor with 12V voltage and 240 watts of power. VNH2SP30 motor driver is used to drive high-power motors properly. Driving currents can be up to 12-14A. They can be used up to 6A without a cooler.

Software: Jetson Xavier NX computer and ROS middleware are used to control the Rover. In autonomous driving, wheel encoder, LIDAR, IMU, RGB camera, depth camera, and GPS coordinates to be provided by the competition committee will be used for localization. TD3, a reinforcement learning algorithm, is being studied as an autonomous driving algorithm. If the desired result cannot be achieved with TD3, alternative path planning algorithms are studied. Other path planning algorithms examined; DWA and Costmap are TEB local planner algorithms.

KAPSUL ROVER TEAM

ROVER DESIGN

ANATOLIAN ROVER CHALLENGE

Mobility System

Choosing the materials used in production as the sigma profile has ensured that the system is as light as possible and its cost is less than the aluminum profile. It has also ensured that the system can be completely disassembled without the need for any welding etc. The quality of the fasteners and some assembly difficulties due to the sigma profile are the weaknesses of this system. TD3, which is a reinforcement algorithm, is used to eliminate the uncertainty of the competition area and faulty or delayed data from the sensors. Maximum performance has been achieved with less energy and fast processing capacity with ATMEGA2560.

KAPSUL ROVER TEAM

ROVER DESIGN

ANATOLIAN ROVER CHALLENGE

Mobility System

One of the biggest advantages of our system is that the system has completely detachable connections and no non-dismountable connections. In addition, instead of using any spring, hydraulic, etc. system to fulfill the suspension task, this task was carried out purely mechanically. TD3 is a derivative of another reinforcement learning algorithm, DDPG, which is one of the most used algorithms for continuous control problems such as robotics and autonomous driving. A separate motor is used for each wheel. Thus, if any wheel is damaged on rough terrain, the other wheels will continue to work in a coordinated manner.

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ROVER DESIGN

ANATOLIAN ROVER CHALLENGE

Mobility System

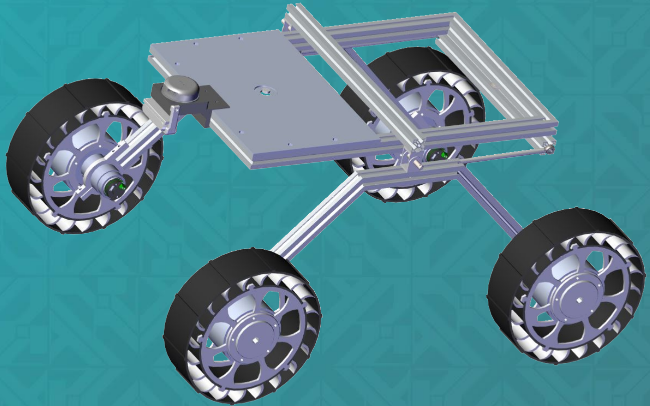

Figure 5: CAD of the rover

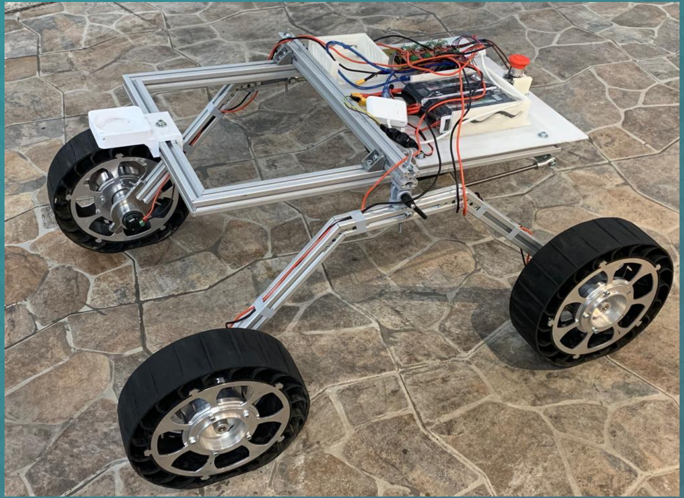

Figure 6: Manufactured mobility system

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ROVER DESIGN

ANATOLIAN ROVER CHALLENGE

Mobility System

The system is designed within the dimensions given in the rule book and its weight is aimed to be around 40 kilos. The overall dimensions of the system are planned to be 430*700*510 in mms. A mechanism consisting of 4 wheels enabling the movement of the system and 4 motors driving each of these wheels was used. The wheels were chosen as rubber airless wheels. The weight of each engine is 340 grams. The total weight of the motors is 1360 gr.

KAPSUL ROVER TEAM

ROVER DESIGN

Mobility System

Sample and Launch Mission

Scoop engines positioned on the rover for the task of sampling from the soil are strong enough to take samples from a depth of at least 5 cm. The robot arm is designed with precision to carry the USB stick and sample box stably. Batteries and motors of suitable power for refueling transportation are preferred. The batteries and motors used above have been selected for the competition to complete the tasks within the specified times.

Autonomous Search Mission

It is aimed to overcome obstacles by using distance sensors in addition to LIDAR in the recognition of shrapnel fragments. High-torque motors of 240 watts, which can overcome the 30-degree slope of the crater, were preferred.

Rescue Mission

The carrying capacity of the rover system has been designed taking into account the weights of the repair kit and the oxygen cylinder.

KAPSUL ROVER TEAM

ROVER DESIGN

Electronics and power system

DC motors (RS-775) with 28 RPM output speed are used in the rover driving system. It has a system that uses the VNH2SP30 engine control module and ATMEGA2560 (MCU) to drive the engines. The engine control unit used for motion motors calculates the required speed and torque value according to the commands from the development board (Jetson Xavier NX), and transmits this to the motors as a PWM signal from the motor drive part. Communication between Rover and MCUs will be provided by SPI (I2C, UART) protocols. The VNH2SP30 will be used as a motor driver running at 14A continuously.

One of the advantages of the system is the use of high-powered engines to increase the Rover's mobility over rough terrain. A modular driver board is designed to drive the motors synchronously and eliminate cable clutter. Thanks to the built-in encoders on the motors, it is easier to determine the position and direction of the motor, and also ease of assembly is provided. While selecting the engines, engines with 40 Nm power and able to climb 40% steep slopes were preferred. It is possible to use higher powered motors thanks to the drivers giving continuous 15A output.

ROVER DESIGN

Electronics and power system

In addition to the emergency stop button, a circuit breaker is used without the need for external intervention to prevent unwanted high currents from occurring in the event of an unexpected failure on the rover.
In order to give the rover an autonomous mobility, the rover's position, speed and direction information is obtained by using encoders mounted on the motors.
PWM (Pulse Width Modulation) is used as a motor driving technique to control the speed and direction of the motors.

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ROVER TEAM

ROVER DESIGN

Electronics and power system

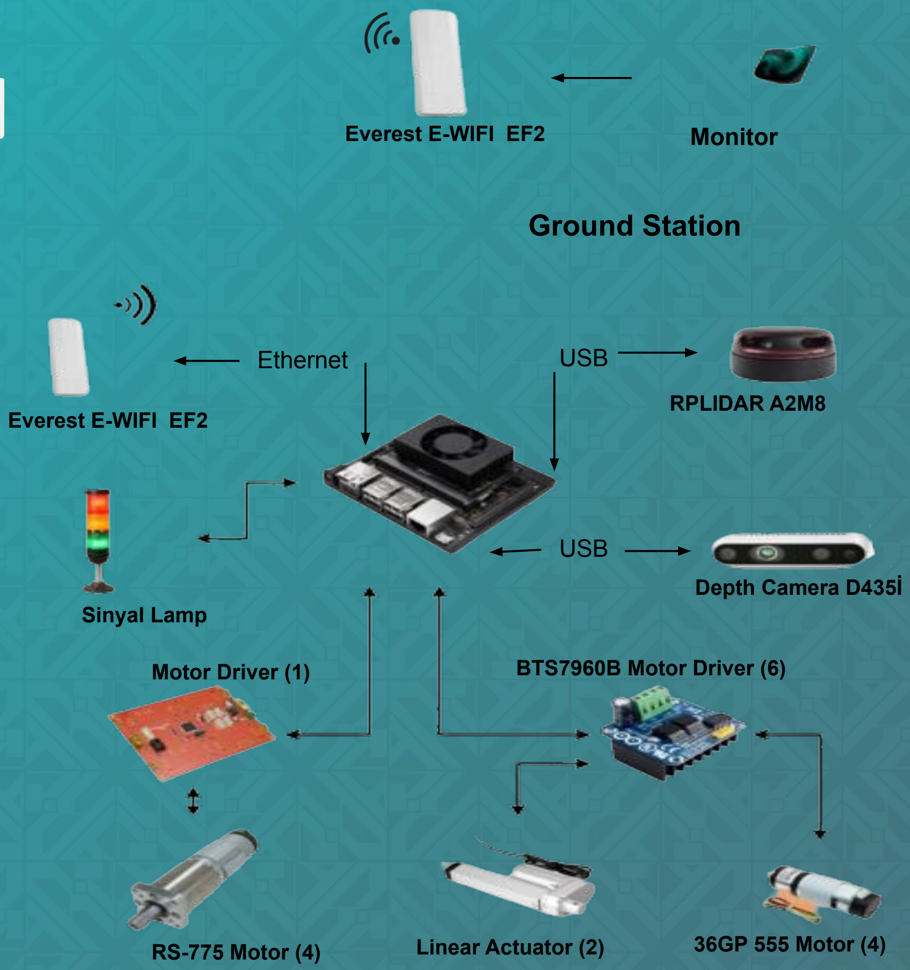

Figure 7: Electronic System Diagram-Electronics and power system visual 1

ROVER DESIGN

ANATOLIAN ROVER CHALLENGE

Electronics and power system

Figure 8: Power System Architecture-Electronics and power system visual 2

KAPSUL ROVER TEAM

ROVER DESIGN

ANATOLIAN ROVER CHALLENGE

Electronics and power system

3 lipo 4S2P 8000 mAh and 2 6S1P 12000 mAh batteries were deemed appropriate to provide the rover's energy. The power requirement of all units, especially the motors, will be met by the battery. The weight of each of the Lipo 4S2P batteries is 960 gr, and the weight of each of the 6S1P batteries is 1532 gr. Total battery weight is 5944 grams.

In the Sample and Launch Mission; Scoop engines positioned on the rover for the task of sampling from the soil are strong enough to take samples from a depth of at least 5 cm. The robot arm is designed with precision to carry the USB stick and sample box stably. Batteries and engines suitable for refueling equipment transportation are preferred. The batteries and motors we used above have been selected to complete the tasks within the specified times for the competition.

In the Autonomous Search Mission; It is aimed to overcome obstacles by using distance sensors in addition to lidar in the recognition of shrapnel fragments.High-torque motors of 240 watts, which can overcome the 30-degree slope of the crater, were preferred.

In the Rescue Mission; The carrying capacity of the rover system has been designed taking into account the weights of the repair kit and the oxygen cylinder.

KAPSUL ROVER TEAM

ROVER DESIGN

ANATOLIAN ROVER CHALLENGE

Manipulation system

The manipulator was made from aluminum from the 6000 series, which is the most cost effective option when considering the desired strength and cost. Our manipulator's drive system consist of which has 6 degrees of freedom, consists of a 1000 Nm linear actuator motor in the 2nd and 3rd axes, and a brushed dc motor in the other 3 axes and gripper. It is covered in flexible TPU material, which would be a soft materials with high friction coefficient, so that the Gripper may readily grasp the objects it needs to grasp, maintain the grip, and not damage the object it grasps. The robot manipulator control circuit will use BTS7960 motor drivers driven by a STM32F4 microcontroller with Arm architecture Cpu, and the instantaneous progress of our manipulation will be monitored thanks to the encoders built into the motors. An inertial measurement unit sensor (IMU) to measure speed and acceleration data, a stereo camera to detect depth, IP cameras to perform object detection with different views in a more efficient manner, and raw data from these sensors will be processed on the robotic manipulator in order for it to be used within the scope of the competition. The data will then be sent into the control algorithms that will allow the robot arm to move autonomously. The task will be performed totally autonomously utilizing robot operating system middleware, and the inverse kinematics calculations of our robotic arm were accomplished using MoveIt and transported to simulation platforms like Rviz and Gazebo.

The STM32F4 microcontroller, which is part of the Arm architectural microprocessor family, will be used to implement the control algorithms that will allow our manipulator system to move autonomously. This microcontroller is used in our system because it has the ability to perform more operations per unit time than its competitors, has larger memory storage, better Adc resolution, and greater noise immunity. While these benefits were considered when creating our system, the price penalty of being more expensive was ignored.
The minimum and maximum stroke spans of the linear actuators utilized in the manipulator are noticed to slightly constrain the movements of the robot arm. Considering the analyses, it was decided that this deficit would not be a barrier to accomplishing the competition tasks.

KAPSUL ROVER TEAM

ROVER DESIGN

ANATOLIAN ROVER CHALLENGE

Manipulation system

Robot manipulation reinforcement learning policies with the most realistic outcomes are difficult to generate due to high-dimensional continuous actions, unmodelable parameters, disregarded circumstances when linearizing nonlinear systems, and complex physics-based dynamics. Nevertheless, because reinforcement learning depends on the accuracy of the underlying mathematical model for its effectiveness, it is vulnerable to failure when flaws in the model occur. We apply a data-driven operational adaptive and robust control algorithm in the software of the manipulation system we designed to compensate for modeling errors by extracting key dynamic parameters from cycle trajectories.

The smooth motions obtained by the Kuka robot's minimum resolution value inspired the design of the robotic manipulator. In this context, we considered the concept of resolution in the design and analysis of the manipulation system, which is the smallest value that we can enter into the robotic arm.

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ROVER DESIGN

Manipulation system

Figure 9: CAD of the Manipulator System

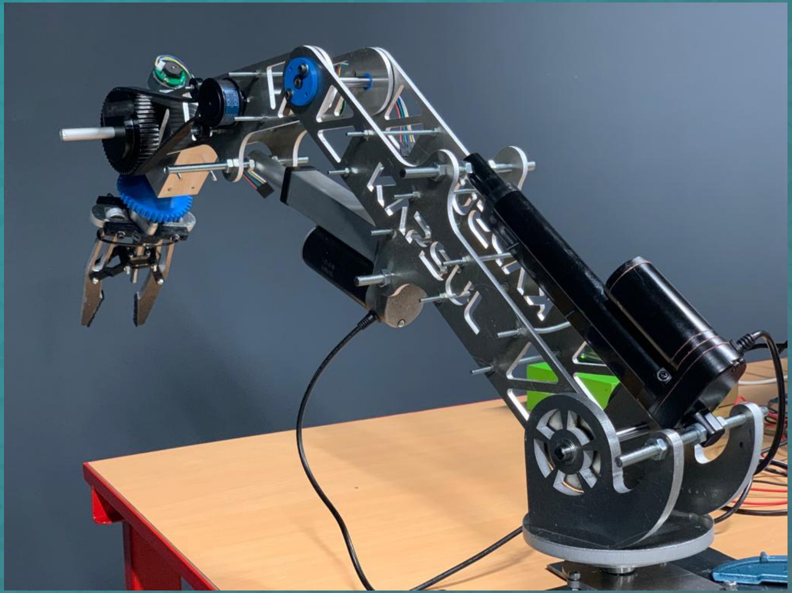

Figure 10: Manufactured Manipulator System

KAPSUL ROVER TEAM

ROVER DESIGN

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Manipulation system

Our manipulator is 120 mm in length from end to end and weighs about 15 kilos. The carrying capacity of the robot arm is boosted using linear actuators, and it effectively fulfills various tasks thanks to the higher power and more stable movement it gives. Using geared dc motors in other axes generates large torque values and provides the required power conditions estimated for the work with a minimum safety factor of 1.5 times. Given these circumstances, our manipulator system will be able to successfully complete the transport tasks necessary to finish various tasks within the competition's scope.

It is designed to detect various tasks with the help of sensors on the robotic manipulator. So because robot arm's flexibility allows it to be changed on a task-by-task basis, the tasks will be performed in a more stable way within the competition's scope. In simulation environments, the suitability of our utilized for a variety competitive tasks will be assessed, and improvements and improvements will be made. As little more than a consequence, problems arising unexpected during the competition will be minimized.

KAPSUL ROVER TEAM

ROVER DESIGN

Science Payload

The science package prepared for the science mission will include a glucose biosensor, spectrometer, fluorescence microscope, USB microscope, and Bradford experimental setup in order to detect the macro and micro resources necessary for the survival of living systems in the soil in the laboratory. Methane, ozone, carbon dioxide, and multiple gas sensors (oxygen, carbon monoxide, nitrogen, hydrogen) will be used for measurements of essential gases necessary for life on the rover. In addition to these sensors, sensors that measure humidity, temperature and pH will be used. The USB microscope integrated into the Rover will provide information about the field. Image processing techniques will be used to support the hypothesis.

For the hypotheses planned to be supported, the system was selected according to the necessary parameters to detect the existence of living things in the environment. The advantages of the system are the selection of methods that can be made fast, efficient, and compact, and the simultaneous performance of 4 different analyzes on the planned science disk. With the data obtained from the selected devices being numerical and computer-aided interpretation, the analysis results will be easier to understand in the limited time given. Producing the designed devices using a 3D printer will provide advantages in terms of rapid prototyping and rapid production, but due to the budget determined in the competition, the materials used in the production are of medium quality, so while obtaining the data, the accuracy rate may be below the expected level. Unexpected weather conditions in the environment and the presence of rocks with degraded morphological features may affect the performance of image processing algorithms.

ROVER DESIGN

ANATOLIAN ROVER CHALLENGE

Science Payload

A science disc has been created for the science package. The disc; contains a glucose biosensor, spectrometer, pH meter, and Bradford experimental setup. The science disc is aimed to complete these 4 analyzes together and quickly. While the analyzes on the science disc are being completed, in the laboratory under a USB microscope and fluorescent microscope can be analyzed carried out simultaneously so that all analyzes can be completed within the time given by the competition committee. The use of a petri dish instead of a labels in the fluorescent microscope is easy for sample placement and time.

KAPSUL ROVER TEAM

ROVER DESIGN

Science Payload

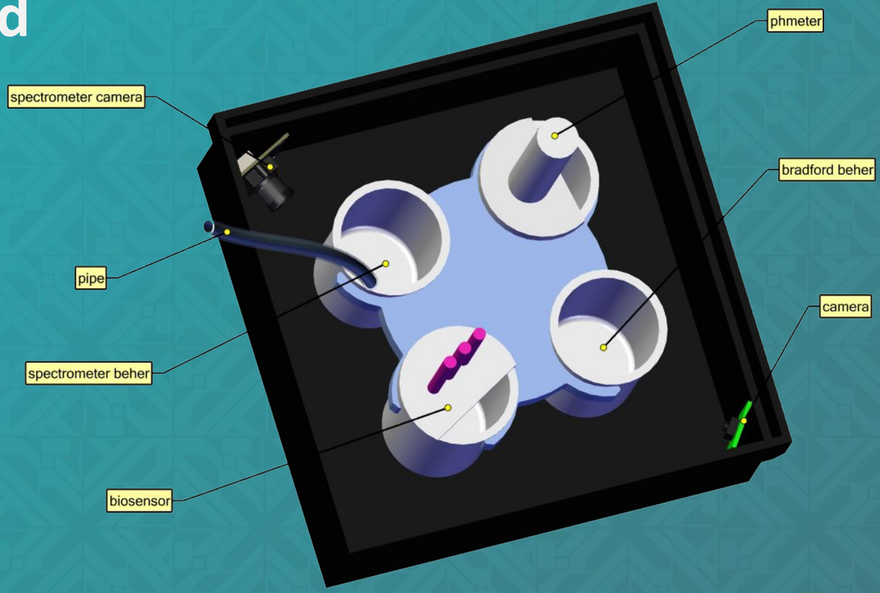

Figure 11: Science Disc

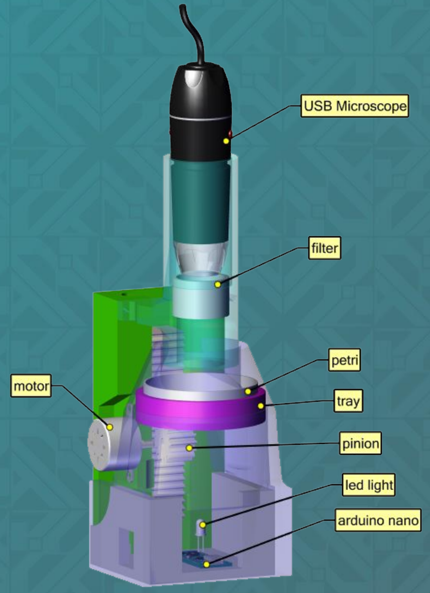

Figure 12: Fluorescence Microscope

ROVER DESIGN

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Science Payload

The science disc in the science package is made of 3D printing, has a compact structure of about 5 kg, and there are 2 LEDs and a camera in the container. The rotating disc in the middle ensures fast and simultaneous analysis. While humidity, temperature, and ph sensors operate in the 3.3 V-5V voltage range, multiple gas sensors operate with 5V voltage and give an analog output according to the gas density in the environment. The operating temperature range of the temperature sensor is between -50ºC and +150ºC and has linear output values. The operating current of the humidity sensor is between 0.5 mA and 2.5 mA.

The analyzes to be applied for the science hypothesis were tested in preparation for the competition. Glucose biosensor and Bradford experiment from selected systems have been proven in international glucose-protein determination. For the spectrometer to be used in the determination of the elements necessary for life, analyzes were made on the soil and the desired data were obtained. Remains left by living organisms and their own existence were observed with USB fluorescence microscopy. The aforementioned and other experimental procedures were approved by the science team members to test the hypothesis.

KAPSUL ROVER TEAM

ROVER DESIGN

ANATOLIAN ROVER CHALLENGE

Ground station equipment and communication system

In the widely used 2.4 GHz frequency range, Everest E-WIFI EF2 offers a good solution for long-distance communication, and devices can be configured as access points so that they can be connected to a network via ethernet or wireless. A 12dBi MIMO antenna with multiple send and receive technology is connected to the router, which was created to solve the speed problem caused by bandwidth limitations in communication systems. Thus, the connection between the rover and the ground station is made taking into account the time differences between the reception of each signal, the added noise and interference, and the lost signals. Ground station and Rover on the same network are interconnected by ROSNetwork.

It is designed to work in severe weather conditions. It has an internal outer coating that is protected against severe climatic conditions and is resistant to temperatures (-40°C~70°C). Environmental factors reduce the signal quality. Electronic devices with electromagnetic waves between the main modem and your wireless receiver reduce the signal to a certain extent. Thanks to its 3km range, it will be able to meet all competition requirements.

KAPSUL ROVER TEAM

ROVER DESIGN

ANATOLIAN ROVER CHALLENGE

Ground station equipment and communication system

By using Wifi communication between the vehicle and the control station, a low-latency high-speed (300Mbps) communication is achieved. A high-range Wifi communication module was preferred due to the tasks will take place in different conditions in the competition area.

In order to determine the accuracy of the data coming to our ground station, which will be designed with Qt, we will implement the CRC (Cyclic Redundancy Check) error detection algorithm.

KAPSUL ROVER TEAM

ROVER DESIGN

Ground station equipment and communication system

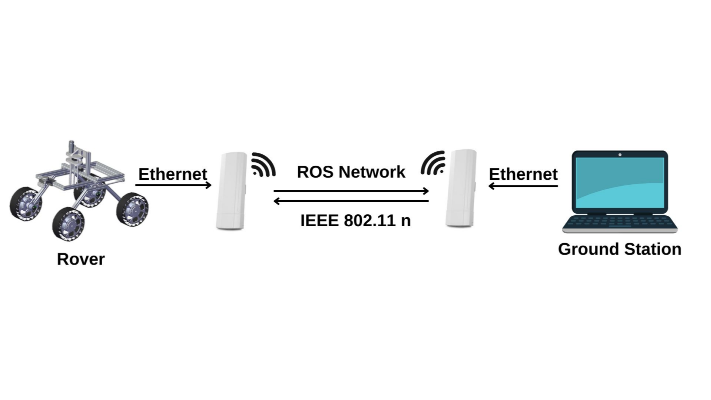

Figure 13: Communication Schematic

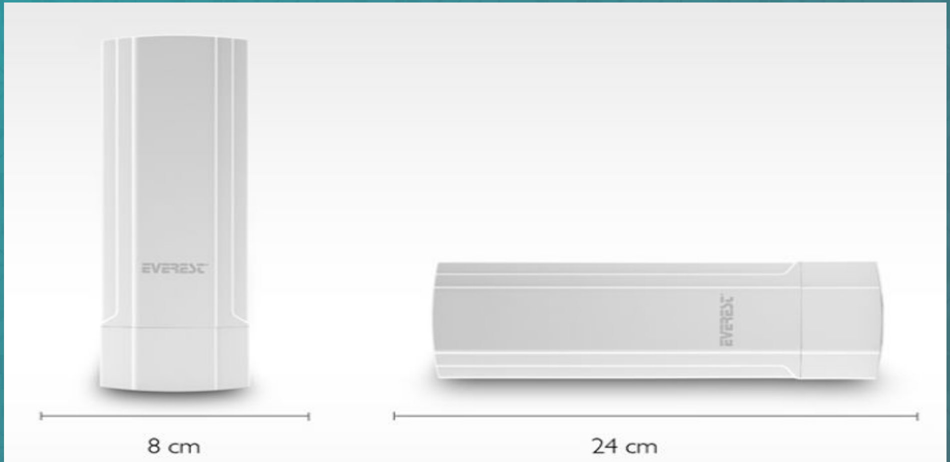

Figure 14: Everest E-WIFI EF2

ROVER DESIGN

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Ground station equipment and communication system

The communication module, which provides 20/40 bandwidth communication at 2.4GHz Frequency, has 12dBi MIMO antennas and this two equivalent antennas used are designed to operate in severe weather conditions. It has an internal outer coating that is protected against severe climatic conditions and is resistant to temperatures (-40°C~70°C).Uninterrupted communication is aimed between the Jetson Xavier NX and Raspberry Pi used in the system and the control station. In this context, Everest EWIFI EF2 was preferred, which can provide low latency for vehicle controls. IEEE 802.11 b/g/n standards will be used.

Considering the characteristics of the competition area, the coverage area of the antennas will provide sufficient performance. A communication system has been established to meet the requirements of the competition, with a range of 3 km and a speed of 300Mbps.

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