ANATOLIAN
ROVER CHALLENGE

2022

Design Report

TEAM INFO

ANATOLIAN ROVER CHALLENGE

Team Name:

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

Student's Association of Unconventional Vehicles - OFF ROAD, Project Scorpio, rover name: Scorpio 7

Contact:

Contact information and social media links of the team.

Website: www.scorpio.pwr.edu.pl;
Facebook: https://www.facebook.com/ProjektScorpio;
Instagram: https://www.instagram.com/projektscorpio;
E-mail address: offroad.pwr@gmail.com;

SCORPIO
Projekt Koła Naukowego OFF-ROAD

TEAM INFO

ANATOLIAN ROVER CHALLENGE

Academic Institution:

Name and address of the affiliated academic institution.

Wrocław University of Science and Technology,
Address: Wyb. Wyspiańskiego 27, 50-370 Wrocław

Academic Consultant:

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

Laboratory of Off-Road Machine and Vehicle Engineering at the Faculty of Mechanical Engineering, Mariusz Kosobudzki PHD,
Phone number: 71/ 320 28 89 E-mail: mariusz.kosobudzki@pwr.edu.pl

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TEAM INFO

ANATOLIAN ROVER CHALLENGE

History of the Team:

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

Our team has been founded in 2009 as Student's association OFF-ROAD, but we are more commonly known as Project Scorpio, which is the name of our main project. Even though we have been working on projects such as Project Eagle (Martian lander) and Twardovsky Colony (Martian colony), we focus on Martian rovers. So far, we have constructed 7 different rovers, with Scorpio 7 being the latest. As one of best-known associations in Poland, we are a part of dozens of events every year, including international competitions.

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History of the Team:

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

Our most recognizable successes include:

- As first in Poland we tested 5G technology, in cooperation with NOKIA, during plenary session BEREC in Sopot (2018).
- II place at University Rover Challenge (2013)
- I place at European Rover Challenge (2014)
- III place at University Rover Challenge (2015)
- III place in Phobos finals at University Rover Challenge (2016)
- II place in Freestyle category and Audience Award at Robotic Arena (2017)
- I place in Freestyle category at XII Robotic Arena 2020
- II place at Mars Colony Prize 2019 – kolonia Twardowsky
- V place at Canadian International Rover Challenge 2019
- I place at RobotShow during XII Innovation Forum in Tarnów
- I place in Smart Robots category at Students construction Competition 2019
- I place at Robotex 2018 International in Entrepreneur category
- II place at Red Eagle 2018 – lander Eagle Scientific Project of the Year– ProJuvenes (2014)
- University Rover Challenge 2020 finalist (competition cancelled)
- III place in Smart Robots category at Students construction Competition 2021
- University Rover Challenge 2021 finalist (competition cancelled)

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Besides competitions, we are actively cooperating with local scientific organizations. We take part in many events every year both for kids and adults. One of them is DFN – Lower Silesian festival of science, one of the biggest and best know scientific event in our region, where we conduct lectures and workshops about, inter alia, rovers, mechanical engineering and 3D printing. Other than that, we organised Space Day, took part in DAS (Student Activity Day, were we won best stand award) and conducted multiple presentations for universities and sponsors.

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Projekt Koła Naukowego OFF-ROAD

TEAM INFO

Active Members List:

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

Name and Surname	University	Department	Duty in Team
Adrian Krzemiński	Wroclaw University of Science and Technology	W10 - Faculty of Mechanical Engineering	CEO, Leader of Public Relations and Finance departments
Zofia Stypułkowska	Wroclaw University of Science and Technology	W4N - Faculty of Information and Communication Technology	vice-CEO, Public Relations and Finance specialist
Gabriel Ratajczak	Wroclaw University of Science and Technology	W10 - Faculty of Mechanical Engineering	Leader of Software and Electronics departments
Krzysztof Ratajczak	Wroclaw University of Science and Technology	W9 - Faculty of Mechanical and Power Engineering	Leader of Mechanics department
Krzysztof Szczupak	University of Wroclaw	Chemistry department, University of Wrocław	Leader of Science department
Konrad Arent	Wroclaw University of Science and Technology	W10 - Faculty of Mechanical Engineering	vice-Leader of Mechanics department
Michał Wnuk	Wroclaw University of Science and Technology	W3 - Faculty of Chemistry	vice-Leader of Science department
Natalia Wilczyńska	WSB University in Wrocław	Philological	vice-Leader of Public Relations department
Szymon Trembecki	Wroclaw University of Science and Technology	W4N - Faculty of Information and Communication Technology	vice-Leader of Software department

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Name and Surname	University	Department	Duty in Team
Adam Nowak	Wroclaw University of Science and Technology	W12N - Faculty of Microsystem, Electronics and Photonics	Electronics Specialist
Agnieszka Czekan	Wroclaw University of Science and Technology	W10 - Faculty of Mechanical Engineering	Mechanics specialist
Agnieszka Pieczara	University of Wroclaw	Chemistry department, University of Wrocław	Science specialist
Aleksandra Kawka	University of Wroclaw	Chemistry department, University of Wrocław	Science specialist
Aleksandra Szlachta	Wroclaw University of Science and Technology	W11 - Faculty of Fundamental Problems of Technology	Science specialist
Anna Hołubowska	Wroclaw University of Science and Technology	W10 - Faculty of Mechanical Engineering	Public Relations specialist
Armin Ernst	Wroclaw University of Science and Technology	W1 - Faculty of Architecture	Public Relations specialist, Main Graphic Designer
Bartłomiej Lorek	Wroclaw University of Science and Technology	W10 - Faculty of Mechanical Engineering	Mechanics specialist
Dorota Oboza	Wroclaw University of Science and Technology	W3 - Faculty of Chemistry	Science specialist
Filip Górajewski	Wroclaw University of Science and Technology	W4N - Faculty of Information and Communication Technology	Software specialist
Jakub Olejnik	Wroclaw University of Science and Technology	W12N - Faculty of Microsystem, Electronics and Photonics	Software specialist
Jakub Oleszczuk	Wroclaw University of Science and Technology	W4N - Faculty of Information and Communication Technology	Software specialist
Jakub Pawlasty	Wroclaw University of Science and Technology	W10 - Faculty of Mechanical Engineering	Public Relations and Finance specialist

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Name and Surname	University	Department	Duty in Team
Jan Hernas	Wroclaw University of Science and Technology	W4N - Faculty of Information and Communication Technology	Software specialist
Jan Odrobiński	Wroclaw University of Science and Technology	W10 - Faculty of Mechanical Engineering	Mechanics specialist
Julia Lisik	Wroclaw University of Science and Technology	W10 - Faculty of Mechanical Engineering	Mechanics specialist
Julia Szymańska	Wroclaw University of Science and Technology	W1 - Faculty of Architecture	Public Relations specialist, Graphic Designer
Kamil Sudoł	Wroclaw University of Science and Technology	W10 - Faculty of Mechanical Engineering	Mechanics specialist
Kamil Wośko	University of Wroclaw	Chemistry department, University of Wrocław	Science specialist
Karolina Miśkiewicz	Wroclaw University of Science and Technology	W10 - Faculty of Mechanical Engineering	Science specialist
Kosma Kotschmarów	Wroclaw University of Science and Technology	W4N - Faculty of Information and Communication Technology	Finance specialist
Łukasz Kaptur	Wroclaw University of Science and Technology	W4N - Faculty of Information and Communication Technology	Software specialist
Makary Musiałek	Wroclaw University of Science and Technology	W6 - Faculty of Geoengineering, Mining and Geology	Science specialist
Malwina Joachimiak	Wroclaw University of Science and Technology	W6 - Faculty of Geoengineering, Mining and Geology	Science specialist
Mateusz Klenart	Wroclaw University of Science and Technology	W2 - Faculty of Civil Engineering	Public Relations and Finance specialist

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TEAM INFO

ANATOLIAN ROVER CHALLENGE

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Name and Surname	University	Department	Duty in Team
Michał Górecki	Wroclaw University of Science and Technology	W10 - Faculty of Mechanical Engineering	Software specialist
Michał Grzesiak	Wroclaw University of Science and Technology	W6 - Faculty of Geoengineering, Mining and Geology	Science specialist
Michał Mendelak	Wroclaw University of Science and Technology	W10 - Faculty of Mechanical Engineering	Mechanics specialist
Michał Pracz	Wroclaw University of Economics	Faculty of Economic Sciences	Public Relations specialist
Michał Szleger	Wroclaw University of Science and Technology	W12N - Faculty of Microsystem, Electronics and Photonics	Software specialist
Paulina Krupa	Wroclaw University of Science and Technology	W12N - Faculty of Microsystem, Electronics and Photonics	Electronics specialist
Piotr Łazik	Wroclaw University of Science and Technology	W4N - Faculty of Information and Communication Technology	Software specialist
Rafał Bernat	Wroclaw University of Science and Technology	W10 - Faculty of Mechanical Engineering	Mechanics specialist
Tomasz Guziak	Wroclaw University of Science and Technology	W10 - Faculty of Mechanical Engineering	Finance specialist
Wiktor Dębowski	Wroclaw University of Science and Technology	W12N - Faculty of Microsystem, Electronics and Photonics	Science specialist
Wiktoria Siedlecka	Wroclaw University of Science and Technology	W11 - Faculty of Fundamental Problems of Technology	Public Relations specialist
Zofia Kaczmarek	Wroclaw University of Economics	Faculty of Management	Public Relations and Finance specialist

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TEAM INFO

ANATOLIAN ROVER CHALLENGE

Team Photo

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

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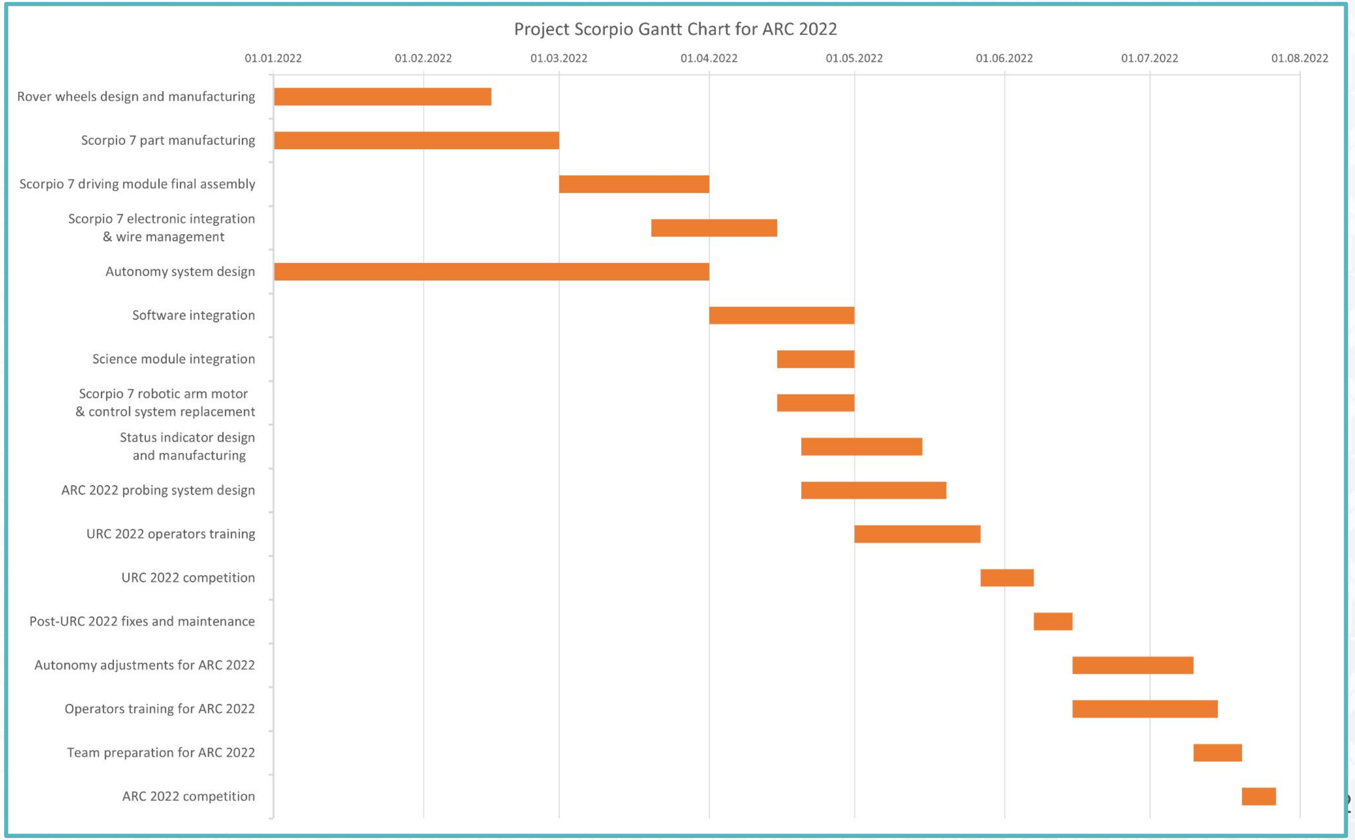
MANAGEMENT

ANATOLIAN ROVER CHALLENGE

Work Calendar:

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



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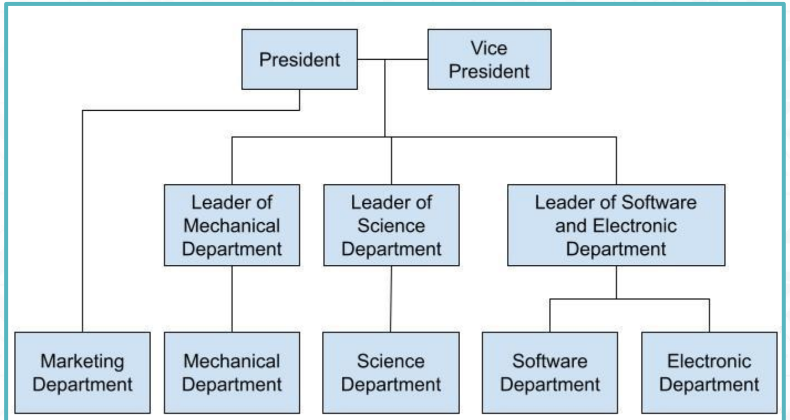
MANAGEMENT

ANATOLIAN ROVER CHALLENGE

Team Formation:

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

Our team consists of 45 members, divided into different departments: mechanical, electronic, software, marketing and science. Each department has its leader, who is also a member of the Management Board. The Management Board, led by the President and Vice President of the Association, supervises the entire project, especially in organisational terms while department leaders are responsible for technical aspects. Temporarily, the President also leads the Marketing Department and the Software & the Electronic Department are managed by the same person.



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MANAGEMENT

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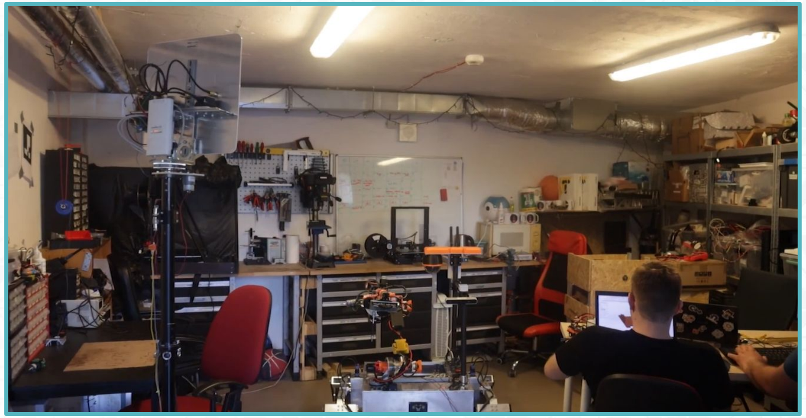
Workplace:

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

The team design and build the rover in our small workshop, assigned to us by the University. We have access to basic tools and materials, such as, among many others, soldering irons, digital oscilloscopes, screwdrivers or 3D printers. More sophisticated components are made by external contractors, sponsors or by a university technician. While basic tests are performed at the workshop, more complex one, like range and autonomy tests, are performed at a nearby parking lot, a park or an abandoned airfield.



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MANAGEMENT

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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?

At time of submission, our funds are based on three various sources: scientific grants, sponsors and university-based funding. Besides from already secured funds from our main sponsor and a special university support for distinguished projects, we are actively looking for new sponsorships to extend the number of people we can send to take part in various competitions.
The majority of crucial components are already purchased. We received a scientific grant ”Students scientific projects, create innovation” from the Ministry of Science and Higher Education - from it the sum of over 15 000 USD was used in the purchases. Other components were re-used from the previous rover, Scorpio X. Our current main sponsor provided us with the majority of needed components as well. We expect to send between 10 and 15 people to take part in the ARC, depending on available funds. Based on that, we expect that travel costs will be between 8 000 USD and 15 000 USD.
We have already considered various scenarios in the case of insufficient funding. First of all, we would reduce the number of sent people, keeping in mind essential skills needed during the competition and the emergency situations. Secondly, we would apply for a special, additional fund for such situations, available for projects at the University. Thirdly, we would try to redistribute, if possible, funds that are already assigned to other purposes.

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MANAGEMENT

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Logistics:

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

We already have vast experience in rover transportation, earned during previous competitions and travels. We would use checked baggage to transport the rover. Usually to do so our mechanical department designs and builds two boxes in which we put an already disassembled driving module, manipulation system and ground station equipment. Before each competition, every department creates a list of essential tools and components to take. They are later transported, if allowed, in the teammate’s luggage. We are also able to print missed or damaged parts as we take a 3D printer with us.

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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 strenghts? (3-5 sentences)

Scorpio 7 has a dependent four wheel rocker suspension system. Rockers are connected by two triangular levers linked by a beam. The driving module features all-wheel drive with BLDC motors. To provide good traction on both the Mars field and Moon field, we use special tires made of Cordura fabric.

This mobility system has a very low center of mass, which allows us to overcome steep angles up to 45 degrees. The dependent rocker suspension system increases the stiffness and stability of the whole suspension. Thanks to that, it can cross extreme terrains, such as obstacles up to the diameter of the wheel (~30 cm).

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ROVER DESIGN

ANATOLIAN ROVER CHALLENGE

Mobility System:

- Unique points and inspirations (3-5 sentences)

Driving module is inspired by rocker-boogie system, which has been adjusted to our needs.

For good traction wheels are made of military material – cordura fabric, which we filled in with shape memory foam. This increased rover stability and amortization. It is our original idea, which we implemented in the previous version of the rover and it worked very well.

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 adequency for it's role in competition missions. (3-5 sentences)

To comply with the rules, our rover fits in a cube with a side length of 1.2m. The whole suspension system weighs 36kg. Scorpio 7 mobility system construction is made of aluminium and partly 3D printed of PET-G plastic.

The construction of the driving module of our rover is light and durable. Thanks to 350W bldc motors in each wheel, our rover is able to overcome difficult terrain on both the Mars field and Moon field.

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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)

For many simple task, we have developed a universal control board containing MCU (STM32F303), protected power supply including over voltage, reverse polarity and over current protection, EEPROM for setting storage and CAN for communication. We are using Nvidia Jetson TX2 as a rover's main computing unit. It is coordinating the working of all single-board computers (Raspberry Pi) and microcontrollers. SBCs support the master device in calculations that do not require a graphics processing unit. We have two main types of communication buses in our rover: Ethernet, which is used to connect onboard cameras and equipment with heavy data traffic, and CAN bus, which serves as the main data link within the rover.

Using CAN gives us a reliable communication, unfortunately CAN requires a special scheme and has a low bandwidth. Using universal boards allows us to quickly replace damaged components, the disadvantage of this solution is the limitation of circuit applications. Selected computers enable us to process images efficiently.

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ROVER DESIGN

Electronics and power system:

- Unique points and inspirations (3-5 sentences)

The most unique part of our electronics are the universal boards we created. Initially, they were inspired by servomechanisms and were supposed to enable connection of an encoder and precise position control of a manipulator part. Currently, universal boards control DC motors, BLDC motors, and a status indicator.

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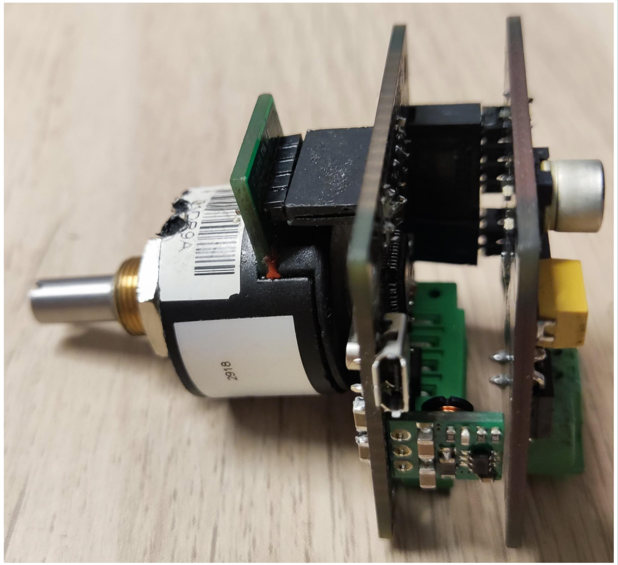
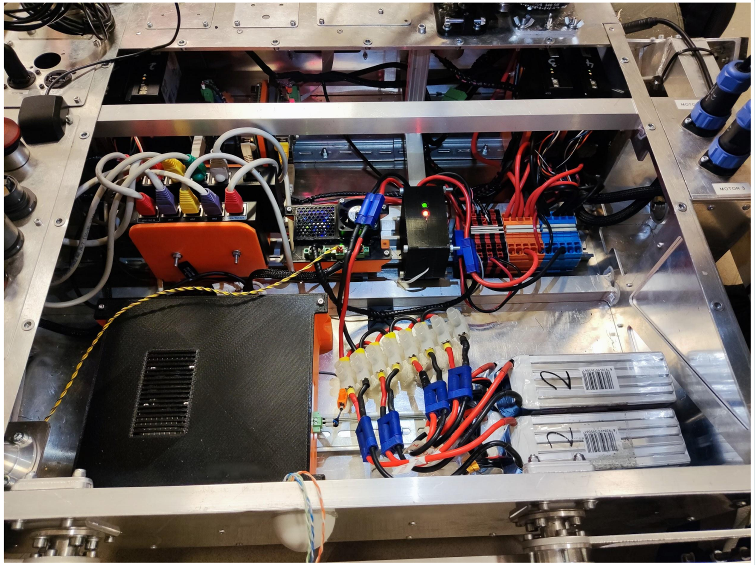
ANATOLIAN ROVER CHALLENGE

ROVER DESIGN

Electronics and power system:

- Visuals of the system (2 photos/screenshots)





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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)

Rover will be powered by four identical lithium-polymer 6S batteries connected in parallel. It gives us overall capacity of 16000 mAh and around 3 hours of operational time. Batteries weigh 2.3 kg. For each our PCB we implement some form of safety measure including: surge stoppers, over voltage and over current protections.

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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)

Our robotic arm has 6DOF. Depending on the joint we use both BLDC and DC motors. For our BLDC motor joints we use custom made planetary gearboxes with harmonic gear reductors. Our gripper is based on trapezoidal screw kinematic layout. There is also an additional DC motor on the effector, which is used for screwing.

Main goals during system design was for the arm to be able to lift up to 5 kg, to be stiff and lightweight. Those upsides were all accomplished. Main weakness of our robotic arm is that we did not implement inverse kinematics yet.

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ROVER DESIGN

ANATOLIAN ROVER CHALLENGE

Manipulation system:

- Unique points and inspirations (3-5 sentences)

Our custom made 3D printed planetary gearboxes are the most unique solution on our robotic arm. They are very lightweight and cheap to manufacture compared to those available on the market.

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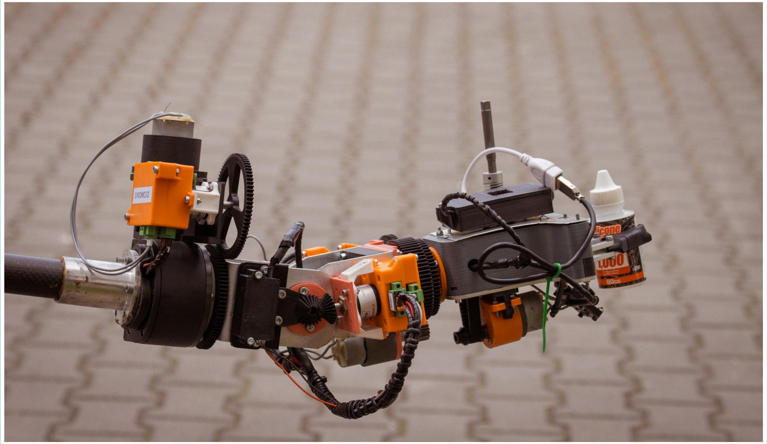
ROVER DESIGN

ANATOLIAN ROVER CHALLENGE

Manipulation system:

- Visuals of the system (2 photos/screenshots)



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ROVER DESIGN

ANATOLIAN ROVER CHALLENGE

Manipulation system:

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

Our robotic arm weighs about 8 kg. It is mainly constructed from carbon fiber tubes, aluminum and 3D printed parts. It has a maximum range of 1.2 m and can lift up to 5 kg on maximal extension.

The gripper construction allows us change the end tips of the effector to adapt it to different tasks such as taking soil samples. It's designed to simplify panel operation during Sample and Launch Mission.

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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)

Our rover is equipped with many sensors: temperature, humidity and pH, but the most important are nitrogen, potassium and phosphorus sensors (NPK). We also designed a module to test soil samples in base, which is made of a soil composition sensor, as well as a self-developed Raman spectrometer.

The robotic arm’s gripper is capable of taking soil samples and putting them in the isolated container - ULEP (Universal Landscape Exploration Platform). Main advantage of the ULEP is capability of storing multiple (5) independent samples.

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ROVER DESIGN

Science Payload:

- Unique points and inspirations (3-5 sentences)

Our self-developed raman spectrometer was inspired by publications about making low cost devices capable of making proper spectra. One of our strengths is our web app capable of collecting all data from sensors is done by our and making it easy to view and analyze. We can present results in the form of charts, tables and reports, all generated in real time.

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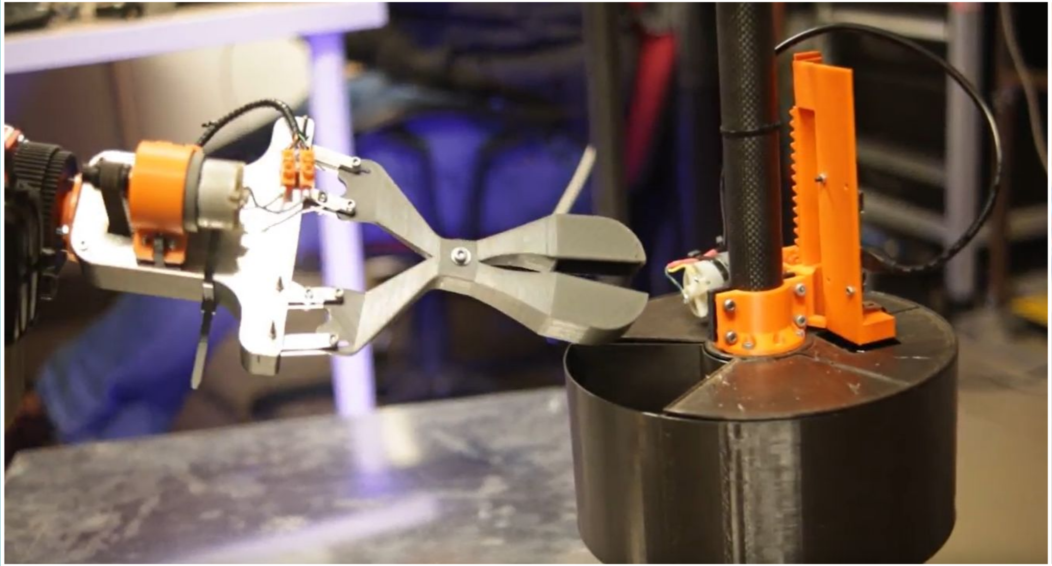
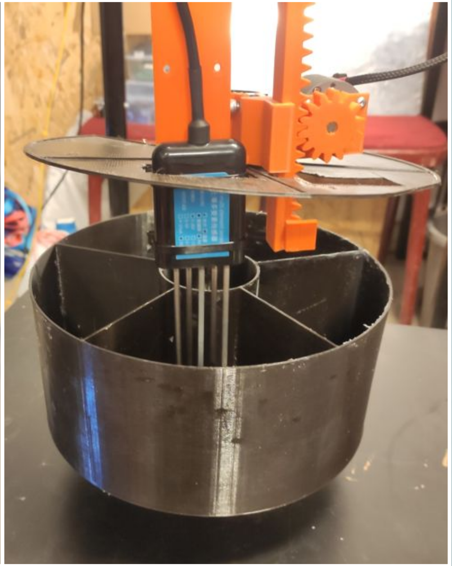
Science Payload:

- 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 adequency for it's role in competition missions. (3-5 sentences)

Our rover is equipped with many sensors: temperature, humidity and pH, but the most important are nitrogen, potassium and phosphorus sensor (NPK). Our whole science module weights 2,5kg.

To complete the Sample and Launch Mission we redesigned the robotic arm's gripper, which is also capable of taking soil samples and putting them in the Universal Land Exploration Platform - ULEP. ULEP is capable of storing up to 5 samples, isolated from the environment. Our planned analysis consists of using a Raman spectrometer. Spectral data received from this device will be crucial for examining the composition of the sample. Our team will be looking for Raman shifts characteristic for compounds such as amino acids, which will state the presence of life.

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ROVER DESIGN

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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)

Wireless communication system utilized to establish reliable link between command station and Scorpio 7 rover is based on airMAX protocol. Our radio systems on both base station and rover are Ubiquiti Rocket M2 provided by Ubiuqiti Networks. We are also utilizing 2.4GHz wifi connection for on-rover communication between 2 Raspberry Pi modules.

In order to assure high quality and reliable signal between base station and rover we've decided to use high gain directional panel antenna. In order to do that we have built antenna rotor mounted on our mast. Thanks to that, our directional antenna has the capability of establishing good quality connection to Scorpio 7 rover at 360 degrees.

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Ground station equipment and communication system:

- Unique points and inspirations (3-5 sentences)

Antenna rotor created by us is capable of directing our antenna to the azimuth of the rover. This is achieved thanks to Raspberry Pi mounted on the rotor which is responsible of performing calculations of rover's azimuth. It is doing that by gathering rover's position data in the real time, gathering the current azimuth data of the rotor (provided by Inertial Measurement Unit mounted on the rotor). After the calculations are done, the angle that the antenna needs to be directed is known and the Raspberry Pi is capable of autonomously controlling DC Motor to rotate the antenna. At any point human operator can disable the rotor autonomy and take over manual control if it's needed.

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ROVER DESIGN

ANATOLIAN ROVER CHALLENGE

Ground station equipment and communication system:

- Visuals of the system (2 photos/screenshots)

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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)

Base Station communication system consists of:
- antenna rotor mounted on 2.5m antenna mast,
- 2.4 GHz Ubiquiti Rocket M2 airMAX radio,
- 3x16.6 dBi directional panel antenna.
- 32H 35V radiation angles

Ubiquiti Rocket M2 is capable of securing a stable PtMP connection with signal strength as low as -96dBm and SINR as low as 8dBm. It provides us a high efficiency point to multipoint connectivity using airMAX protocol. Wide range of configuration options available for this module allows us to establish stable connection from base station to rover for up to 2 kilometers.

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