ANATOLIAN ROVER CHALLENGE

2022

Design Report

TEAM INFO

ANATOLIAN ROVER CHALLENGE

Team Name:

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

AGH Space Systems

Rover Name:

Kalman

Contact:

Contact information and social media links of the team.

email:
aghspacesystems.rover@gmail.com

Facebook:
facebook.com/aghspace

Instagram:
instagram.com/aghspacesystems

Twitter:
twitter.com/aghspacesystems

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TEAM INFO

ANATOLIAN ROVER CHALLENGE

Academic Institution:

- Name and address of the affiliated academic institution.

AGH University of Science and Technology

Academic Consultant:

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

Mariusz Gibiec, PhD

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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.

AGH Space Systems is a student construction group established in 2014, focused on developing space technologies. Its first projects were CanSat (1st place at CanSat competition 2015) and sounding rockets. The rover team was established in 2016. The current rover, Kalman, is a proud product of 5 years of iterative development - although the team chooses to keep the name of its robot, the entire system only has a few parts which have not been completely replaced with better iterations since start of the project (most notably, the suspension and wheel mountings).

The team participated in multiple rover challenge competitions, securing many awards. These include:

- 10th at European Rover Challenge 2018
- 2nd at Indian Rover Challenge 2019
- 19th at University Rover Challenge 2019
- 2nd at European Rover Challenge 2019
- 1st at Indian Rover Challenge 2020
- 6th + Best Design + Best Presentation at European Rover Challenge 2020 (remote)
- participant at Indian Design Rover Challenge 2020
- 1st at International Mars Hackathon 2020
- participant at Virtual University Rover Challenge 2021 (no official ranking)
- 4th + Best Navigation + Best Presentation at European Rover Challenge 2021
- finalist at University Rover Challenge 2022

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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	University major	Role in the team
Adam Zagrajek	Computer science & intelligent systems	Project Lead
Jan Brzyk	Industrial automatics & robotics	Mechanics Team Lead
Paweł Karelus	Mechanical engineering	Mechanics Team
Łukasz Gliwiński	Automatics & robotics	Mechanics Team
Kacper Gładyś	Automatics & robotics	Mechanics Team
Franek Morytko	Automatics & robotics	Mechanics Team
Karol Głodek	Industrial automatics & robotics	Mechanics Team
Zachariasz Mońka	Electronics	Electronics Team Lead
Witold Woszczyna	Electrical engineering	Electronics Team
Michał Stankiewicz	Electronics	Electronics Team
Miłosz Zeman	Automatics & robotics	Electronics Team
Miłosz Łagan	Electronics & telecommunications	Electronics Team

TEAM INFO (continued)

ANATOLIAN ROVER CHALLENGE

Active Members List:

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

Name	University major	Role in the team
Błażej Fiderek	Computer science & intelligent systems	Software Team Lead
Hubert Kompanowski	Computer science & intelligent systems	Software Team
Stefan Kowalczyk	Automatics & robotics	Software Team
Jakub Kopeć	Automatics & robotics	Software Team
Przemysław Węglik	Computer science	Software Team
Igor Urbanik	Computer science	Software Team
Szymon Bednorz	Computer science	Software Team
Błażej Nowicki	Computer science	Software Team
Radosław Rejman	Geoengineering	Science Team Lead
Mateusz Olszewski	Geophysics	Science Team
Karolina Greń	Chemical engineering	Science Team

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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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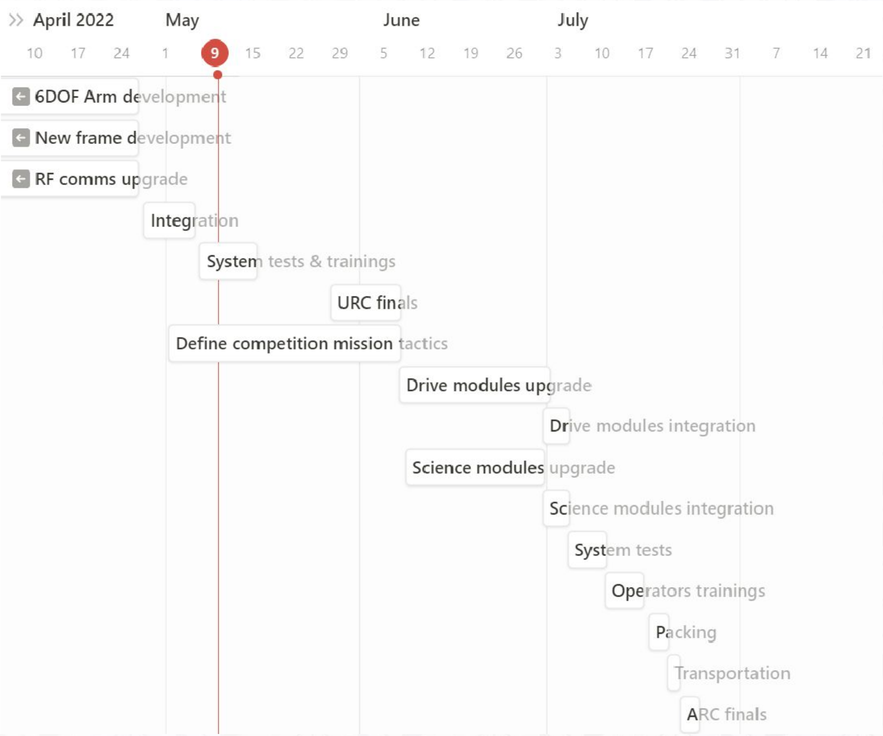
MANAGEMENT

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.

The rover team is divided into Mechanics, Electronics, Software and Science subteams. Each team has a leader who assigns tasks and organizes the work of the team members, while the project leader is responsible for coordinating the entire project. The rover team is one of the three main divisions of AGH Space Systems students construction group, alongside rockets division and marketing division. The group also has a common management board, handling logistics, formal matters and representing the group in front of outside stakeholders.

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MANAGEMENT

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 Rover Team has access to a 16 m2 meeting room and two workshops, 35 m2 each, basic mechanical and electronic tools, as well as two 3D printers and University's manufacturing facilities. Moreover, the team has access to advanced equipment like CNCs, lathes or laser cutting machines as well as advanced MJF 3D printers, thanks to the support from private sponsors.

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?

At the time of admitting this report (10th May 2022), the team has a 6,000 USD secured for development expenses, with additional 4,500 USD coming in June as a result of winning a new public grant (confirmed). Taking into account the mature status of rover's development cycle and its full operability, this is expected to be fully sufficient.

These funds however can not be reallocated to cover travel expenses, because of the nature of public funded grants from which they were secured.

To cover travel expenses to ARC 2022, the team will cover transportation expenses from team members' private funds. To send additional people (over the limit of 10 for which accommodation and food costs are covered by ARC), the team will try to obtain additional funds from the AGH University. In case these efforts are unsuccessful, the team will send a representation of 10 people to ARC 2022.

Category	Cost	Status
Transportation - base 10 people + rover	1,000 USD	secured (from team members' private funds)
Accommodation & food - base 10 people	covered by the organizer	secured
Transportation - additional people	500 USD	to be secured (from University funds)
Accommodation & food - additional people	250 USD	to be secured (from University funds)

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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)

The rover as well as team members and necessary equipment will be transported from Poland to the competition site via rented minivan trucks. This allows us to avoid disassembling the rover as would be necessary for aerial travel. The rover will be secured via straps and foam for secure transportation. Tools, spare parts and smaller modules of the rover will be placed in marked boxes, with delicate parts secured by bubble wrap (a special ESD-safe bubble wrap will be used for PCBs). Detailed checklists will be prepared by team leaders to ensure all parts are taken and to know the box they are in onsite.

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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)

The rover suspension is a customized rocker design. The left and right halves of the suspension always twist in opposite directions, greatly increasing effective ground clearance, allowing the rover to overcome large obstacles and maintain stability on extremely uneven surfaces.

Each of the four wheels is turned and propelled independently. Although this requires more advanced techniques to achieve effective control and increases the overall mass, it significantly lowers the stress levels in the suspension and minimizes the risk of burying the wheels in sand. It also makes the rover more agile, providing an ability to turn in place, drive diagonally and sideways. The drive motors are hidden inside the wheels to protect them from dust and damage. The wheels are 3D-printed from elastic TPU with honeycomb structure providing shock absorption and deep treads for maximum traction on loose terrain.

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ROVER DESIGN

ANATOLIAN ROVER CHALLENGE

Mobility System:

- Unique points and inspirations (3-5 sentences)

- Rocker suspension – inspired by Curiosity rover
- 3D-printed, elastic honeycomb wheels – inspired by military offroad vehicles
- Intependently steered and propelled wheels

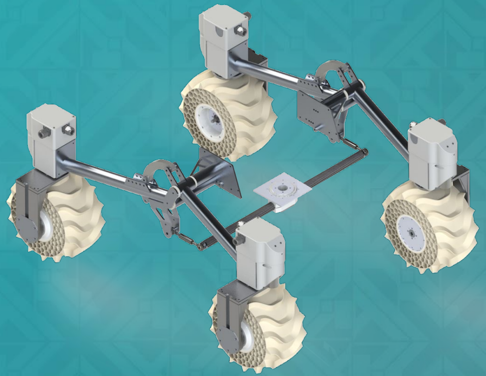
put your logo here

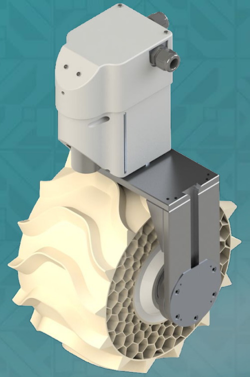
ROVER DESIGN

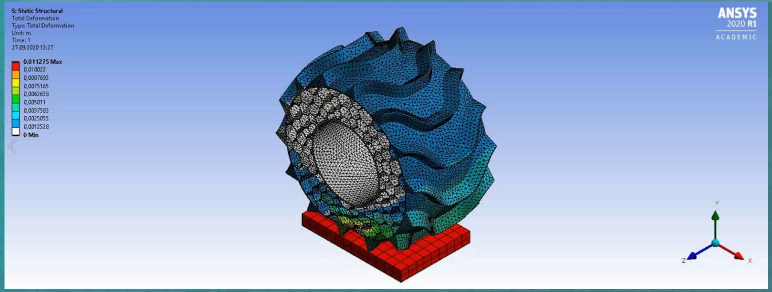
ANATOLIAN ROVER CHALLENGE

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)

Category	Description
rover dimensions	980 x 875 x 520 mm (w/o comm masts & arm)
suspension	modified rocker, 1 m drop resistance
steering	4 independently turned and propelled wheels
wheel turn modules (4 in total)	60 RPM, 12 V, brushed DC motors; planetary gear, ratio 139:1, PID, encoder
wheel drive modules (4 in total)	RS755, 24 V, 50 W, brushed DC motors, gear ratio 71:1 PID, encoder
wheels (4 in total)	diameter of 280 mm, 3D printed from TPU, honeycomb structure
max speed	1 m/s

Module	Quantity	Weight per unit	Weight
Wheel + turn module	4	5.5 kg	22 kg
Suspension	1	2.3 kg	2.3 kg
Chassis	1	6 kg	6 kg
Manipulator (new, 6DOF)	1	8 kg	8 kg

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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)

Electronic system consists of independent STM32-based modules, each responsible for a single functionality - master, motor, arm, science and power supply controller. CAN bus provides reliable communication between the modules, resistant to electromagnetic interference and supporting hardware data flow control. Each board is fitted with short-circuit, overcurrent protection, battery undervoltage and reverse polarity protection.

The chassis houses most of the PCBs inside a 3D-printed rack system, to allow for quick replacement in case of malfunction. The new battery mountings are placed outside the chassis to allow for quick replacement, better heat management and easy monitoring of each cell's condition displayed by their voltage monitor boards.

The rover is powered with up to 6 independent lithium-polymer batteries with a total capacity of 24 Ah. The power is distributed separately to effectors and logical components. The system has been modified to suit the new battery mountings outside the rover chassis. Custom designed protection board allows for hot-swapping batteries without interrupting platform operation.

The new Motor and Arm controllers feature a network of modules responsible for only up to 1-2 motors each, instead of centralized units. Apart from minimizing risk it reduces weight and complexity of cable harness. In case of damage, it also makes replacement quicker and cheaper. Each drive and arm motor is fitted with an encoder or potentiometer and a dedicated PID controller with customizable settings. This allows for accurate control during precision-oriented tasks.

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ROVER DESIGN

Electronics and power system:

- Unique points and inspirations (3-5 sentences)

- Hot-swappable batteries
- CANbus – inspired by automotive industry
- Modular, distributed control system
- PCBs mounted on 3D-printed rack system inside rover’s chassis

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ROVER DESIGN

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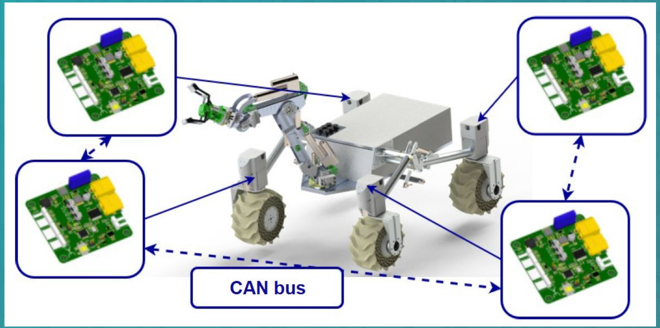
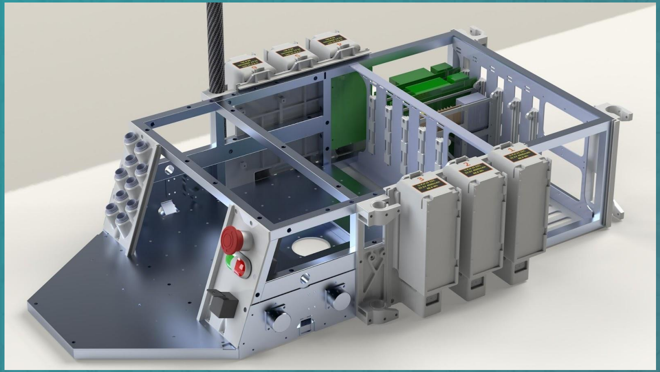
Electronics and power system:

- 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 activity	Current consumption
Lab tests, wheels hovering in the air, 5 cameras powered, 22 V power voltage	
Idle	1.35 A
Driving at 25% PWM	1.9 A
Driving at 50% PWM	3 A
Driving at 75% PWM	4.4 A
Driving at 100% PWM	5.5 A - 6.3 A
Wheel turn modules (constant movement)	2.5 A
Wheel turn modules (change of direction)	9 A peak
Terrain tests, driving on grass, 5 cameras powered, 22 V power voltage	
Driving at 30% PWM	5 A
Driving at 50% PWM	5 - 10 A
Turning (normal use)	3 - 6 A

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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)

The new, 6DOF manipulator, drastically increases the range with its approx. 1.5 m length. BLDC motors and harmonic drive gear reducers are used to ensure precision and reliability, while carbon fiber based, highly modular construction allows for lower weight and easier maintenance than the previous design. It even allows for customizing its length. Durability has been verified using FEM, Multibody Dynamics analysis, Static analysis and empirical tests. Its custom, decentralized control system is capable of handling IK calculations.

The end effector gripper can be equipped with elastic 3D-printed jaws which provide firm grip and precision to manipulate small elements on the maintenance panel. The jaws can be easily replaced with a soil scoop.

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ROVER DESIGN

ANATOLIAN ROVER CHALLENGE

Manipulation system:

- Unique points and inspirations (3-5 sentences)

- 6DOF structure
- Modular design
- BLDC motors

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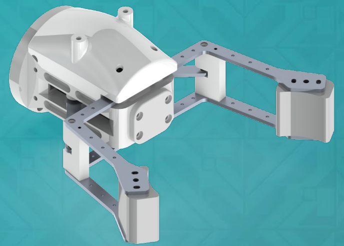
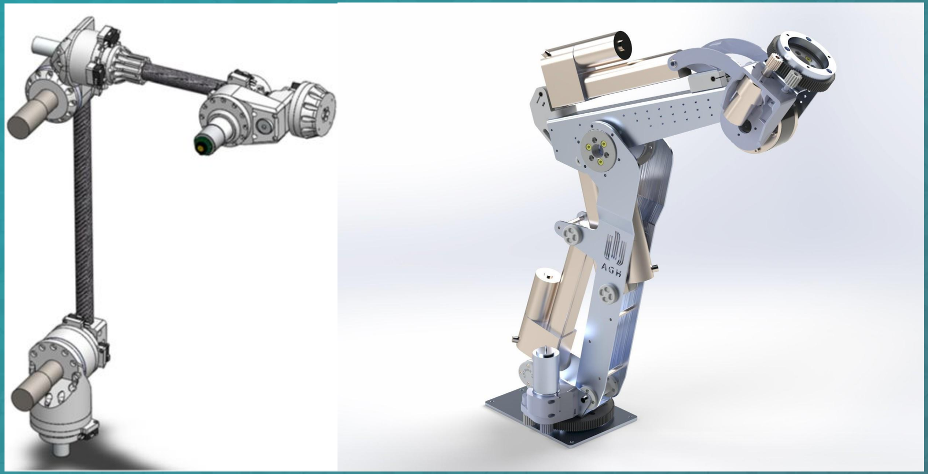
ROVER DESIGN

Manipulation system:

- Visuals of the system (2 photos/screenshots)



Gripper end-effector



New 6DOF vs old 5DOF arm

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)

Category	Description
control system	decentralized, each PCB responsible for 1-2 motors
new manipulator	6DOF, 8kg lift, 1.5m range IK algorithms with trajectory planning capabilities
old manipulator (backup)	5DOF, 5kg lift
gripping tools	elastic 3D-printed jaws, soil scoop

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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)

Soil samples are collected using dedicated scoop end effector mounted on the gripper, and then transported using the manipulator to an onboard lab.

The first stage of the onboard lab consists of sealable soil containers. Each container features two chambers – one „dry”, where soil is probed using electronic sensors for humidity, temperature and pH. Other one „wet”, where soil is mixed with distilled water and resulting mixture gets pumped to a series of tubes, where it is chemically tested for presence of biomarkers.

Additional scientific context of the site is provided by atmospheric sensors, which indicate air's humidity and temperature.

A macrocamera is also mounted on the manipulator's gripper in order to provide high-zoom photographic documentation of collected samples.

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ROVER DESIGN

ANATOLIAN ROVER CHALLENGE

Science Payload:

- Unique points and inspirations (3-5 sentences)

- Soil scoop end effector mounted on the gripper
- Sealable soil containers
- Unambiguous chemical tests for biomarkers
- Macrocamera

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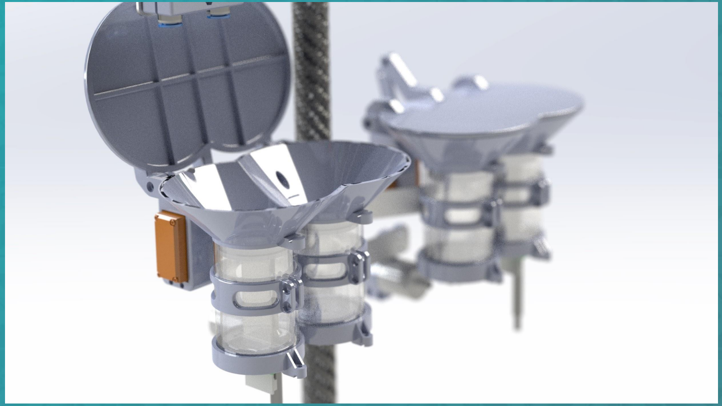
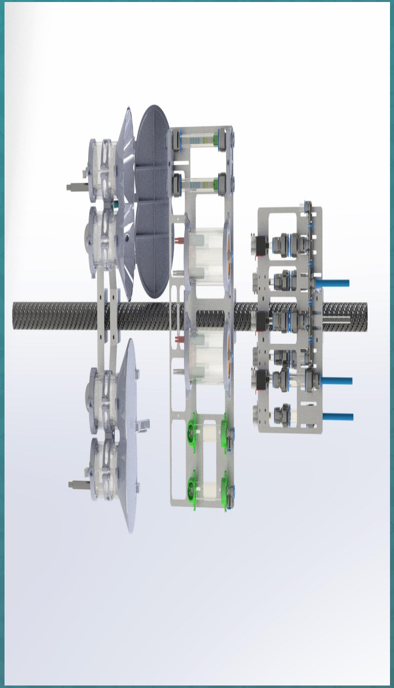
ROVER DESIGN

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

- Onboard lab weight: 3 kg
- Module is easily detachable

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ROVER DESIGN

ANATOLIAN ROVER CHALLENGE

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)

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433 MHz industry grade full-duplex RF modules are being used for data transfer between the rover and the ground station. A multi-layer verification protocol has been implemented, so that only fully correct data packets received from the ground station are allowed into the master logic module. Motor and arm controller boards further validate the packets in case of electromagnetic interference. RF communication proved reliable on 2 km distances on 2x19200 bps baud rate.

The ground station software gives the operators full control over every functionality of the rover - including driving, manipulator control and operating the science subsystem. Operators can remotely change any parameters in the electronic modules if need be, such as PID controllers settings. It also visualizes commands and the current state of the rover in real-time, including a visualization of the rover state Wheels and the manipulator are controlled separately by two operators.

CAN bus handles the dataflow between the rover’s subsystems. It allows for easy expansion of the module network, so that the team may keep adding more functionalities to the rover. It also provides reliable communication between subsystems despite high levels of electromagnetic interference caused by the motors.

Communication system based on RF instead of e.g. Wi-Fi requires us to create much more custom solutions and limits the amount of data possible to send, however it greatly increases system’s reliability on long distances as well as video-feedback latency.

ROVER DESIGN

ANATOLIAN ROVER CHALLENGE

Ground station equipment and communication system:

◆ Unique points and inspirations (3-5 sentences)

- industry grade full-duplex RF modules
- multi-layer verification protocol
- rover controlled by two operators (one for drive system & one for arm)
- operation via game pads
- web based ground station app
- rover’s state visualization in the ground station app

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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)

Main telemetry link:

- Model: SATELLINE-EASy
- Frequency: 433MHz (400-470MHz)
- Bandwidth: 25kHz
- RF power: up to 1W
- Modulation: 4FSK & GMSK
- Antennas on rover and ground station: omnidirectional, 0dBi

Analog vision link:

- Model: TBS UNIFY PRO 5G8 HV SE
- Frequency: 5.8GHz (5362-5945MHz)
- Bandwidth: 8MHz
- RF power: up to 1W
- Modulation: FM
- Antenna on rover: RHCP, 2dBi

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