ANATOLIAN ROVER CHALLENGE

2022

Design Report

TEAM INFO

ANATOLIAN ROVER CHALLENGE

Team Name:

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

Team: Project Kratos | Rover name : Kratos Mark II

Contact:

- Contact information and social media links of the team.

kratosbitsgoa@gmail.com | +91 80739 55450 | IG: @kratosbitsgoa

PROJECT KRATOS

TEAM INFO

ANATOLIAN ROVER CHALLENGE

Academic Institution:

- Name and address of the affiliated academic institution.

BITS Pilani, K.K. Birla Goa Campus, India

Academic Consultant:

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

Prof. Toby Joseph, BITS Pilani, K.K. Birla Goa Campus | +91 94032 70043

PROJECT KRATOS

TEAM INFO

ANATOLIAN ROVER CHALLENGE

History of the Team:

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

Project Kratos was established on 12th May, 2018 by a group of students from various academic disciplines. The project has participated in the Indian Rover Challenge 2020, the International Mars Hackathon (IMH) conducted by MSSA, International Rover Design Challenge (IRDC) 2021 and URC 2022. At the International Rover Challenge 2020, Project Kratos has qualified top among the new teams. The Project has qualified for the University Rover Challenge (URC 2022) which takes place annually at the Mars Desert Research Station.

PROJECT KRATOS

TEAM INFO

ANATOLIAN ROVER CHALLENGE

Team Photo

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

PROJECT KRATOS

TEAM INFO

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	Duty
Saurabh Kalra	Physics + Mechanical	Team Lead
Rohan Khosla	Mathematics + Computer Science	Vice Lead
Sakshi Gupta	Electronics	Operations Head
Abhay Bhandari	Mechanical	Mechanical
Nikunj Bhartia	Mechanical	Mechanical
Akshay Sheth	Mechanical	Mechanical
Saurav Agrawal	Mechanical	Mechanical
C Ashwin	Mechanical	Mechanical
Avinandan Nag	Mechanical	Mechanical
Shubham Gandhi	Mechanical	Mechanical
Suhas Badadal	Biology + Mechanical	Mechanical
Nishit Pachpande	Mechanical	Mechanical
Akash Sumeet Bodhankar	Mechanical	Mechanical
Varun Lenka	Mechanical	Mechanical
Gaurav Nair	Mechanical	Mechanical
Utkarsh Samadar	Mechanical	Mechanical
Vivek Gupte	Biology + Mechanical	Mechanical
Karan Gopalani	Electronics	Controls
Sparsh Kanubhai Kachhadiya	Electronics	Controls
Sanskar Jain	Electronics	Controls
Sarvesh Garge	Electronics	Controls
Krishi Ajaykumar Agrawal	Electronics	Controls
cheriyan homey	Electronics	Controls
Hrithik Kandallu	Electronics	Controls
Pratyush Varmani	Electronics	Controls
Archit Rungta	Electronics	Controls
Abhishek Jaswal	Electronics	Controls
Akshay Valsaraj	Biology + Computer Science	Controls
Anshul Raje	Electronics	Controls
Atharva Ghotavadekar	Electronics	Controls
Aman Dudeja	Electronics	Controls
Akanksha Dasmohapatra	Electronics	Controls

Arjun Tyagi	Electronics	Life Detection
Nipun Gupta	Biology + Electronics	Life Detection
Madhen Vyass Guru	Electronics	Life Detection
Neel Bhandari	Biology + Computer Science	Life Detection
Yash Pathak	Computer Science	Life Detection
Dhruv Bhutani	Computer Science	Life Detection
Devansh Dixit	Computer Science	Life Detection
Mrunmay Shelar	Biology + Computer Science	Life Detection
Darshna Songara	Mechanical	Life Detection
Anish Jaltare	Electronics	Life Detection
Anushk Srivastav	Physics + Electronics	Life Detection
Soham Rohit Chitnis	Computer Science	Life Detection
Vardhan Manish Palod	Computer Science	Life Detection
Mrunmay Mohan	Biology + Computer Science	Life Detection
Ithihas Madala	Biology + Electronics	Life Detection
Raghuveer RM	Biology + Electronics	Life Detection
Suhaas Mahajan	Electronics	Autonomous
Hrishikesh Kusneniwar	Computer Science	Autonomous
Hardik Shah	Computer Science	Autonomous
Sushant S	Computer Science	Autonomous
Aeishna K	Computer Science	Autonomous
Mane Atharv Mahesh	Computer Science	Autonomous
Aditya Parandekar	Mechanical	Autonomous
Nirmal S	Physics + Electronics	Autonomous
Bharath Hegde	Computer Science	Autonomous
Suchetan R S	Electronics	Arm
Ishan Tandon	Mechanical	Arm
Dhyey Bhatt	Mechanical	Arm
Ayush Kishor Hinsu	Mechanical	Arm
Sriman Sridhar	Electronics	Power
Amritash	Electronics	Power
Saksham Kamath	Electronics	Power
Kunal Patil	Electronics	Power
Vikram Vaidyanathan	Electronics	Power
Rudranil Dasgupta	Electronics	Power

PROJECT KRATOS

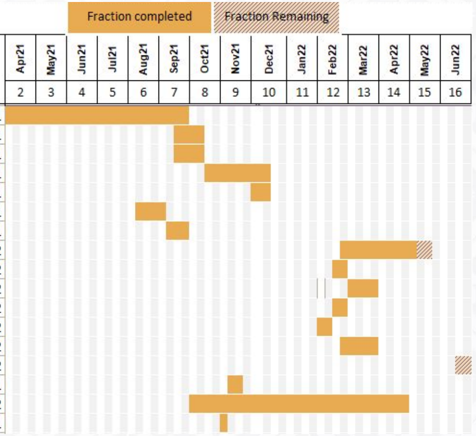
MANAGEMENT

Work Calendar:

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

PROJECT KRATOS ARC 2022

ACTIVITY	START DATE	END DATE
Double Lambda Rocker Bogie Suspension designing, prototyping, testing with old chassis and manufacturing	01-04-2021	30-09-2021
Chassis Structural Design Improvements and manufacturing and integration with suspension	15-09-2021	15-10-2021
Prototyping and 3-D printing wheels	15-09-2021	15-10-2021
Designing and manufacturing of wheel assembly	15-10-2021	15-12-2021
Integration of electronics and testing of entire core rover	01-12-2021	15-12-2021
Designing and 3-D printing arm gripper	10-08-2021	10-09-2021
Designing, manufacturing and assembling Pitch and Roll Mechanism- Bevel Gear	10-09-2021	30-09-2021
Implementing Feedback for Inverse Kinematics in the Arm and testing of arm and gripper	22-02-2022	22-05-2022
Manufacturing Arm Base Rotation and integrating entire arm on rover	15-02-2022	20-02-2022
Designing and ordering custom PCBs for arm, science and drive and PDB	01-03-2022	30-03-2022
Designing and manufacturing of Electronics Box and Integration with Chassis	15-02-2022	28-02-2022
Designing, prototyping, and manufacturing Ratchet Wheel Mechanism	05-02-2022	20-02-2022
Integration and testing of Rachet wheel on rover	25-02-2022	05-04-2022
Testing Rover for Competition Tasks + 3D Printing Spare Parts	15-06-2022	15-07-2022
Development and Testing AR Tag Detection using ZED Camera via OpenCV	10-11-2021	25-11-2021
Development and Testing of A* Path Planning Algorithm for Autonomous Navigation with ZED Point Cloud & GP	01-10-2021	01-05-2022
Development and Testing of Stanley Path Controller for Smooth Curve Traversal	01-11-2021	10-11-2021

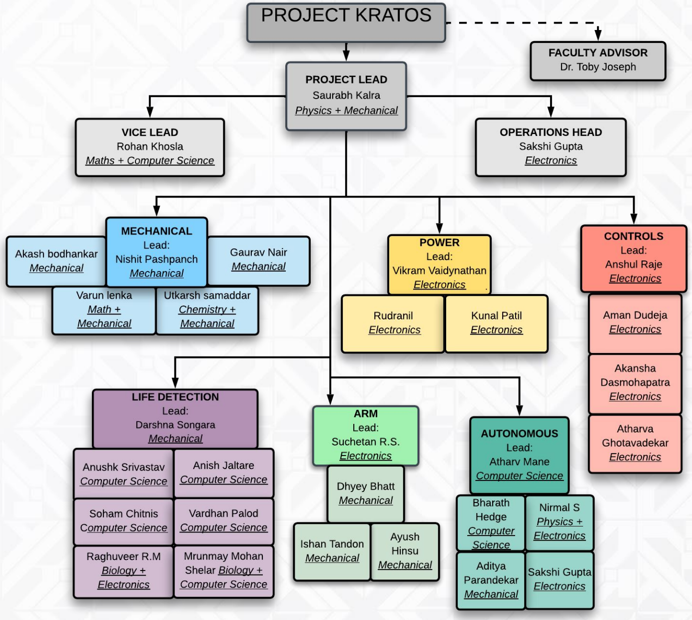


MANAGEMENT

Team Formation:

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

The team of 70+ students is divided into 6 subsystems - Mechanical, Controls, Arm, Autonomous, Life Detection and Power. The subsystem leads are responsible for the design and development of their individual subsystems. The Team leads are committed to overall development, finances and co-ordination among the subsystems.

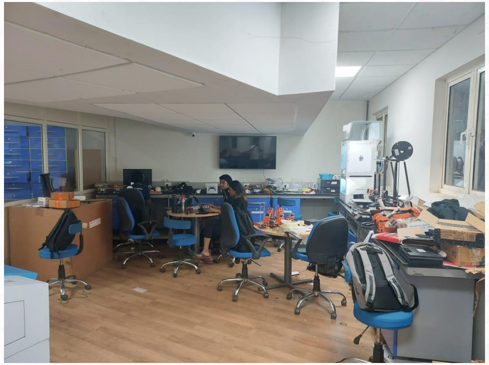


MANAGEMENT

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.



The complete assembly of our rover is designed in SOLIDWORKS, which is followed by prototyping, assembly and testing. The assembly was tested on various nearby terrains including rocky, sandy, gravel, smooth tiles, grass and on the road. The mechanical parts are manufactured using different jobs such as CNC, Lathe etc in an in-house workshop. The subsystems work in a Students Robotics Lab provided by the university, which is used for housing our equipment, electrical appliances such as 3d printers, soldering iron, Arduinos, motor drivers etc.

PROJECT KRATOS

MANAGEMENT

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?

- The project has sufficient funding by virtue of the constant financial support received from the University and Alumni network. Public crowdfunding is done to gather support from external sources. We plan to sell project Merchandise to expand the outreach and get more funds.
- Our team has reserve funds for adverse situations that can be liquidated as and when required. Moreover, the University provides funds for emergency situations. Alumni can also be contacted to further the reach. In case of an emergency, the team members can contribute an amount that the university can later reimburse.

Description	Month	Expenditure
April '21 - July '21 (Projected)		
Electronics equipment	April- May	$2,097.52
Spare parts	May	$996.15
Base Station Equipment	May	$483.29
Travel Expenses (20 people)		
Flights and Visa	May	$16731.2
Accommodation	June-July	$600
Grand Total		$20,908.16

PROJECT KRATOS

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)

Keeping in mind the competitions that we participate in, the rover is designed to be modular. We plan to carry different parts of the rover in multiple check-in baggages to save the overall cost . Materials like batteries and chemicals will be bought locally in Istanbul since airplanes will not allow batteries with such a high wattage rating. In order to avoid any difficulties at airport, we plan to carry a list stating the names and photographs of the rover parts. We will be exploring this path for the upcoming University Rover Competition.

PROJECT KRATOS

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)

- Our rover has a box-shaped lightweight Aluminium chassis, with separate mounts for Arm and Science Assembly. A modified double-lambda rocker-bogie suspension system along with 3D printed TPU-95A wheels have been implemented. A stereo camera is used to get odometry and point cloud data which is then converted to laserscan using a ROS package. Scripts written using Servoing algorithms are used to follow the visual markers.

- The suspension helps to provide ground contact at all times and the wheels provide the required shock absorbance. Rigorous testing has been done using tools like FEA on ANSYS and conducting physical drop tests of chassis and wheel. The A* Algorithm implemented for navigation task gives quick and definitive path through the obstacle course and has been tested on Gazebo simulation and real life environment. The algorithm itself becomes computationally heavy and for overcoming these shortcomings, Jetson Xavier was used.

PROJECT KRATOS

ROVER DESIGN

ANATOLIAN ROVER CHALLENGE

Mobility System:

- Unique points and inspirations (3-5 sentences)

- The new and unique, modified double lambda rocker-bogie suspension design for better traversal at faster speeds and worse terrains. 3D printed Wheels with modified honeycomb support pattern absorb vibrations during traversal.
- All the non data filtering scripts used in autonomous traversal are custom written scripts, thus allowing more flexibility with rover control. To follow the path provided by the Autonomous Subsystem, we are using the Stanley Controller which was developed by Stanford University and won the 2005 DARPA Challenge. The Controller allows the Rover to move in smooth curves instead of moving from one point to the other and turning on the spot to align itself to the destination.

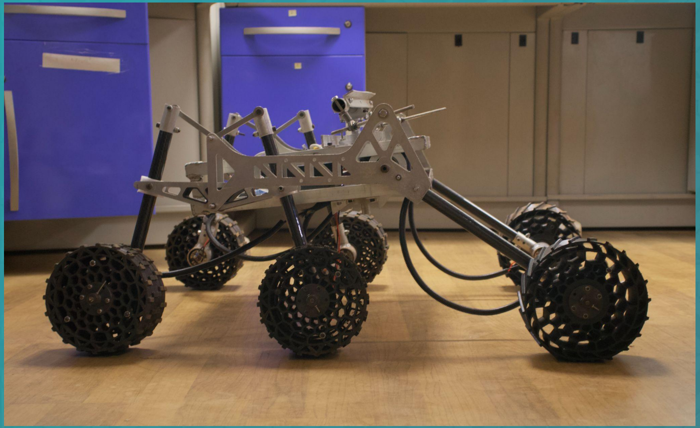
PROJECT KRATOS

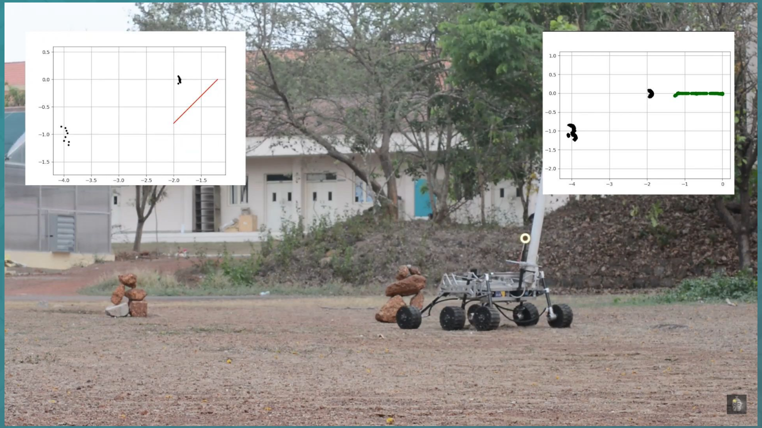
ROVER DESIGN

ANATOLIAN ROVER CHALLENGE

Mobility System:

- Visuals of the system (2 photos/screenshots)





PROJECT KRATOS

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)

- The rover with the arm and antenna weighs 37.5kg whereas, its standalone weight is 27.88kg. Our rover fits the dimension of 1.5m * 1.5m * 1.5 m. Jetson Xavier AGX is used as an onboard computer which stores the entire code stack and the ZED 2i is a stereographic camera which allows us to gain depth perception of nearby obstacles using Point Cloud to Laser Scan conversion. Moreover, we have webcams which allow us to gain a feed of the nearby environment, mechanical arm and the rover itself.

- The rover can easily traverse a terrain under a 60-degree inclination. The wheels are designed to reduce shock for vertical drops up to 1.5m. TPU wheels, Aluminum motor housing and Carbon fibre rods together ensure safe and smooth traversal over rough terrain. During autonomous traversal, the rover can avoid large obstacles using the A* path planning algorithm. Detecting and following of Aruco markers is implemented using Logitech USB cameras, aruco detection script and visual servoing algorithms.

PROJECT KRATOS

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)

- A combination of Lithium Ion and LiFePO4 batteries with built-in BMS and Cell balancing has been used to power the rover. We have made custom PCBs for every major electronic system present. We are using 2 Cytron MDDS30 as motor drivers to control the 6 wheels of the rover. Along with this, an electronic box is implemented to ensure safety of all the electronics components from voltage or current surges, dust, heat and vibrations. An emergency kill switch is used to shut down the entire rover immediately in case of any difficulties.

- Lithium-based batteries has been opted owing to their high energy/kg. Custom PCBs and wire connectors are chosen due to their ease of use once integrated, along with them being more reliable than individual wires. Designing the electronic components of the rover has been done keeping in mind ease of use and modularity.

PROJECT KRATOS

ROVER DESIGN

Electronics and power system:

- Unique points and inspirations (3-5 sentences)

- Power Distribution Board (PDB) with a buck converter has been integrated in the system to step down the voltage as per our requirement. This enables us to use the same power source for various electrical equipment with different voltage requirements without damaging them. Our unique electronics box encapsulates all the components with its purpose to protect the components from dust, heat, water etc. The motors for the bogie in the rocker-bogie suspension are coupled in the motor drivers to help with the differential drive mechanism.

- The inspiration behind this system was the modularity of a laptop. We wanted our system to be as modular as possible, with each component being hot swappable like the peripherals in a laptop, with the PCBs being the core of the system.

PROJECT KRATOS

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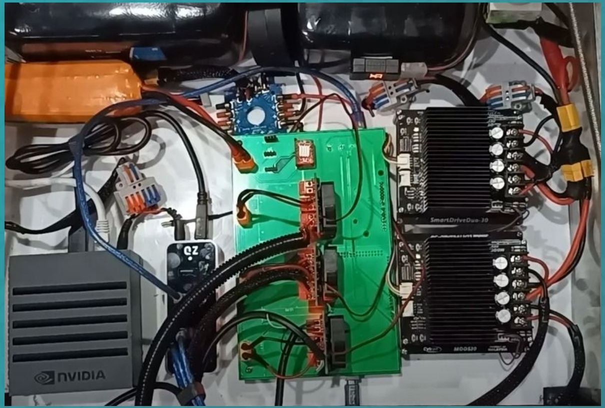
CHALLENGE

ROVER DESIGN

Electronics and power system:

- Visuals of the system (2 photos/screenshots)



PROJECT KRATOS

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)

- The rover has a LiFePO4 battery and a LiPo battery, each with 6 cells that weigh 2.75 kg and 2.60 kg respectively. Cytron MDDS30 are used as motor drivers which has been set to operate in serial simplified mode with a baud rate of 115200. We use buck converters with input range of 4V - 40V and output of 3.5V - 35V to step down the voltage wherever required.

- The rover has been tested for 90 mins of continuous traversal in multiple terrain. Electronics box has been manufactured keeping in mind the dusty and rocky terrain of competition site. No dirt particles or stones can enter the rover, thereby protecting the electronics equipments within.

PROJECT KRATOS

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 manipulator uses a closed loop feedback control system to maneuver the end effector in a 3D space. It's driven by 2 heavy duty linear actuators through which we have successfully implemented inverse kinematics with a high accuracy of 96%. For the end effectors roll and pitch motion, a differential bevel gear mechanism is used.
- The combination of 2 linear actuators was chosen because of its capability to lift heavy weights and be of complete use to an astronaut.
  Considering the precision tasks to be performed, an allen key with a lead screw is incorporated for screwing as well as button presses.
- The arm is capable of lifting weights upto 9 kgs without much of play and due to a well developed custom made feedback for the actuators, the rover can perform tasks with an error of less than 1.5%. Due to the constraint posed by the actuators, the workspace of the end effector is slightly restricted which is however compensated with the roll and pitch of the gripper.

PROJECT KRATOS

ROVER DESIGN

ANATOLIAN ROVER CHALLENGE

Manipulation system:

- Unique points and inspirations (3-5 sentences)

- A PID controller is incorporated into the control system to avoid jerky movements in the arm. Integration of an allen key with a lead screw mechanism helps us perform screwing tasks along with high precision tasks such as typing on a keyboard and pressing click button. For further developments, we plan to implement a feedback system on the base motor to convert inverse kinematics to 3D before the competition.

- Our inspiration for this robotic arm is a human's arm itself. Just like our human arm has two links (shoulder and elbow) and a wrist, that can perform roll and pitch motion, our robotic arm is proficient in doing the same.

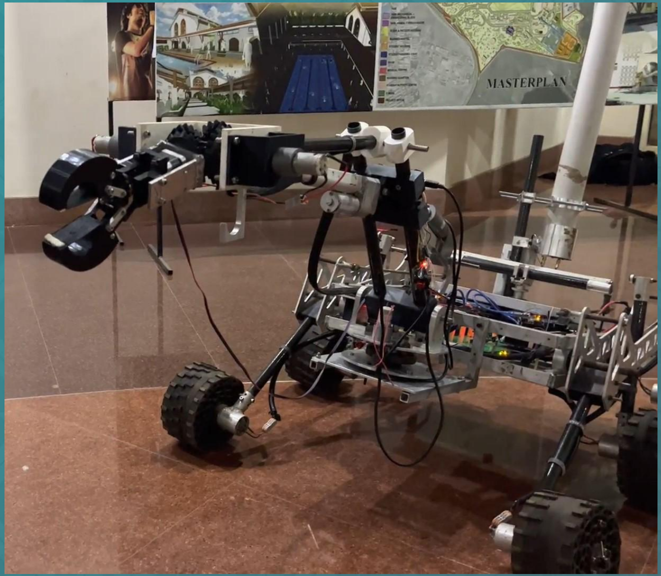
PROJECT KRATOS

ROVER DESIGN

ANATOLIAN ROVER CHALLENGE

Manipulation system:

- Visuals of the system (2 photos/screenshots)



PROJECT KRATOS

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)

- The arm has 5 degrees of freedom and weighs around 7.7 kilograms without the weights attached. The maximum payload of 9 kilograms has been recorded. It can reach heights of upto 1.1 meter and can manipulate at ground level. It can grip weights with a diameter of upto 6 cm.
- The robotic arm is rigorously tested to perform all the tasks in the rover challenge. Owing to the high accuracy inverse kinematics mechanism, alongside the differential bevel gear roll and pitch motion, the arm can perform tasks such as flipping switches and inserting USB sticks with ease. The smooth and efficient spur gear base rotation is useful in small movements of objects around the rover without having to move the rover.

PROJECT KRATOS

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)

- The science setup is equipped with a ratchet wheel for soil sampling which is actuated on a lead screw mechanism. A 360 degree cylindrical panorama of the sampling site is generated using OpenCV library. Presence of atmospheric and soil sensors on the setup further provide with essential information like temperature, moisture and humidity in atmosphere and concentration of gases of importance like CO_2,CO and CH_4 respectively along with UV levels.

- Keeping in mind the fact that rover requires to traverse through different terrains for surveying purpose,the versatile design of the ratchet wheel enables the rover to collect samples from any type of soil. Common gases which are indicators of life can be detected fairly easily with the help of gas sensors. The approximate quantities give a rough estimate of the possibility of life (extinct, extant) which can be further confirmed using wet tests.

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ROVER DESIGN

ANATOLIAN ROVER CHALLENGE

Science Payload:

- Unique points and inspirations (3-5 sentences)

- The smooth movement of the ratchet wheel setup to collect sufficient soil from required depth is facilitated by a lead screw mechanism. After collection from each site, the soil is transferred into an insulated chamber to avoid any type of contamination. Photographs of the sampling site taken will not only be used to generate a panorama as per the requirement of mission 1, but also serve as a basis of initial optical analysis.

- Our inspiration for the current system is the lead screw mechanism employed on 3-D printers which is used for motion in the vertical axis.

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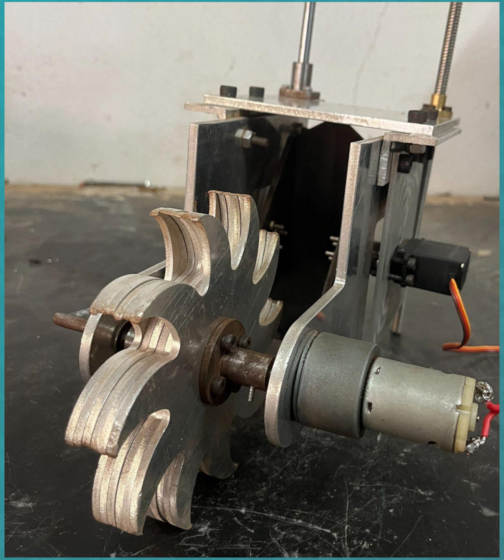
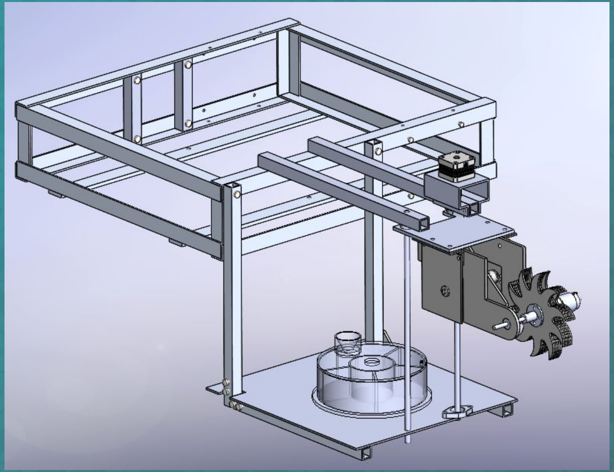
ROVER DESIGN

ANATOLIAN ROVER CHALLENGE

Science Payload:

- Visuals of the system (2 photo/screenshots)





PROJECT KRATOS

ROVER DESIGN

ANATOLIAN ROVER CHALLENGE

Science Payload:

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

- The science setup is of the dimension 288 x 550 x 353 mm^3. The sensors used and their applications are mentioned in the table below-
- The sampling mechanism is able to dig soil upto a depth of 7 cm, collecting approximately 60 grams of soil in 12 seconds. Our system is capable of accommodating 5 such samples without any chances of cross contamination. The soil and atmospheric sensors used, collect data of the surroundings and quantifies gases of importance like CO,CO2 and CH4 and accurately measures UV levels. Photographs of the sampling site can also be used to cross check the results of experiments.

Sensors used	Use (Measures)	Inferences drawn
BME 280	Pressure, temperature and humidity	PT&H determine whether the environment is conducive for life to exist
GY1145	UV radiation	Low UV index indicative of dense cloud cover or presence of ozone in the atmosphere
MQ7	CO concentration	Life supporting gases; higher the concentration greater the chances provided other conditions are satisfied
MQ4	CH4 concentration	
MG811	CO2 concentration	
SKU:SEN0193	Soil moisture	Presence of water in the soil; checks essential conditions for microbial life to thrive
DS18B20	Soil temperature	

PROJECT KRATOS

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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- Our system incorporates 2 Ubiquiti Rocket M2 modules, one with an omnidirectional antenna on the rover and another with the sector antenna on the base station. A folding mount is attached to the rover with a locking mechanism for the antenna. We are also using an Edimax N150(EW-7611ULB) Bluetooth 4.0 adapter.
- The Ubiquiti Rocket M2 is a 2.4GHz rugged, hi-power, linear, 2x2 MIMO radio with enhanced receiver performance. It has a reliable performance range of over 50km and has a breakthrough TCP/IP speed of 150+Mbps. The system has been tested for a robust non-line of sight communication of 1km and low latency for video feed applications over SSH.
- The system operates at 2.4 GHz which is free to use but is crowded due to interference from other devices. In order to overcome this, we use airView to find the least crowded spectrum within the 2.4GHz band and operate accordingly.

ROVER DESIGN

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Ground station equipment and communication system:

- Unique points and inspirations (3-5 sentences)

- In case of a broken connection, recovery mode is activated which enables the rover to retrace its trajectory to the previous checkpoint. Latency for the system remains low for voice and video applications as network scales. The H.264 video encoder baked in the Nvidia Jetson Xavier and the OpenCV compression algorithm has been implemented. Foldable mount with locking mechanism for antenna is also incorporated.

- For reading and scanning for Bluetooth devices, we are using the Bluez package which provides bluetoothctl utility which is used for continuous scanning of nearby devices as this utility displays both mac address and user-friendly name of a nearby device together.

PROJECT KRATOS

ROVER DESIGN

ANATOLIAN ROVER CHALLENGE

Ground station equipment and communication system:

- Visuals of the system (2 photos/screenshots)

PROJECT KRATOS

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)

- Ubiquiti AM-2G15-120 with a frequency range of 2.3-2.7 GHz has been used as the base station sector antenna which provides a 15 dBi gain, and is configured as an access point. The omnidirectional antenna, Ubiquiti AMO- 2G13 has frequency range of 2.35 - 2.55 GHz. The sector antenna has a noise floor of -90dBm, whereas for the omnidirectional antenna, the noise floor is -85dBm, thereby providing a decent noise resilience.

- Given that the ARC field is 40m in diameter, our communications equipment is capable of working and handling the mission tasks robustly. Non line of sight communication upto 1 km has been rigorously tested. In case of a broken connection, recovery mode is activated which enables the rover to retrace its trajectory to the previous checkpoint.

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