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;
Academic Institution:
Wrocław University of Science and Technology, Address: Wyb. Wyspianskiego 27, 50-370 Wrocław

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
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.
History of the Team:

A paragraph of team's 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)
History of the Team:

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

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.
# TEAM INFO

**Active Members List:**

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

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<thead>
<tr>
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<th>University</th>
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<tbody>
<tr>
<td>Adrian Krzeminski</td>
<td>Wroclaw University of Science and Technology</td>
<td>W10 - Faculty of Mechanical Engineering</td>
<td>CEO, Leader of Public Relations and Finance departments</td>
</tr>
<tr>
<td>Zofia Szyipulkowska</td>
<td>Wroclaw University of Science and Technology</td>
<td>W4N - Faculty of Information and Communication Technology</td>
<td>vice-CEO, Public Relations and Finance specialist</td>
</tr>
<tr>
<td>Gabriel Ratajczak</td>
<td>Wroclaw University of Science and Technology</td>
<td>W10 - Faculty of Mechanical Engineering</td>
<td>Leader of Software and Electronics departments</td>
</tr>
<tr>
<td>Krzysztof Ratajczak</td>
<td>Wroclaw University of Science and Technology</td>
<td>W9 - Faculty of Mechanical and Power Engineering</td>
<td>Leader of Mechanics department</td>
</tr>
<tr>
<td>Krzysztof Szczupak</td>
<td>University of Wrocław</td>
<td>Chemistry department, University of Wrocław</td>
<td>Leader of Science department</td>
</tr>
<tr>
<td>Konrad Arent</td>
<td>Wroclaw University of Science and Technology</td>
<td>W10 - Faculty of Mechanical Engineering</td>
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<tr>
<td>Michał Wnuk</td>
<td>Wroclaw University of Science and Technology</td>
<td>W3 - Faculty of Chemistry</td>
<td>vice-Leader of Science department</td>
</tr>
<tr>
<td>Natalia Wilczyńska</td>
<td>WSB University in Wrocław</td>
<td>Philological</td>
<td>vice-Leader of Public Relations department</td>
</tr>
<tr>
<td>Szymon Trembecki</td>
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<tr>
<td>Armin Ernst</td>
<td>Wroclaw University of Science and Technology</td>
<td>W1 - Faculty of Architecture</td>
<td>Public Relations specialist, Main Graphic Designer</td>
</tr>
<tr>
<td>Bartłomiej Lorek</td>
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TEAM INFO

Team Photo

A photo/screenshot of the whole or part of the team.
Work Calendar:

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

How is the team workforce structured?

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.
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.
Funding:

How are the funds of the project at the time of submission of this document?

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.
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.
Mobility System:

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

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).
Mobility System:

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

Mobility System:

- Visuals of the system
  (2 photos/screenshots)
Mobility System:

- Technical Specifications including mass and size (3-5 sentences)
- Discuss system's adequacy for its 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.
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 tasks, 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.
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.
ROVER DESIGN

Electronics and power system:

- Visuals of the system (2 photos/screenshots)
Electronics and power system:

- Technical Specifications including mass and battery duration (3-5 sentences)
- Discuss system's adequacy 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.
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.
Manipulation system:

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.
ROVER DESIGN

Manipulation system:

- Visuals of the system
  - (2 photos/screenshots)
Manipulation system:

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

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.
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.
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.
ROVER DESIGN

Science Payload:

- Visuals of the system
  (2 photo/screenshots)
Science Payload:

Technical Specifications including mass and battery duration (3-5 sentences)

Discuss system’s adequacy for its role in competition missions. (3-5 sentences)

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.
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 Ubiquiti 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.
Ground station equipment and communication system:

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.
ROVER DESIGN

Ground station equipment and communication system:

- Visuals of the system
  - (2 photos/screenshots)
Ground station equipment and communication system:

- 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.