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Team Mountaineers: Preliminary Design Review

1. Team Structure

Leadership and Membership: West Virginia University's Team Mountaineers is composed of 8 subteams (Figure 1). Each subteam is led by team coordinators who organize subteam projects and serve as representatives to other subteams and the organization as a whole. Dr. Yu Gu serves as the team's faculty advisor and undergraduate senior Kendra Gillo serves as the chief executive officer of the team. The seventy-five member team primarily consists of seniors participating in the project for their engineering senior design project, while 40% of the team members are volunteers.

Communications: Team members, coordinators, and others involved with the team collaborate regularly. Weekly full-team and twice-weekly subteam meetings ensure frequent collaboration. Outside of meetings, Slack is used as the team's main communication platform. Google Drive is used as a file sharing platform for design/review documents, tutorials, and documentation. GitHub is used for code sharing and task management, while CAD is shared using 3DEXPERIENCE. The team conducts external communications through social media and each subteam holds one outreach event per semester.

2. Team Resources

Finances: Funding for Team Mountaineers is sourced through the Department of Mechanical and Aerospace Engineering, the Lane Department of Computer Science and Electrical Engineering, grants, and private donations. The team is also actively pursuing sponsorships from industry partners. Purchased items must be approved by the team's chief financial officer. A purchase ledger is updated as items are requested to keep track of total money spent as well as other pertinent financial information (Figure 2).

Facilities: Upon completing West Virginia University's mandatory lab safety training, team members gain 24/7 access to URC's open lab and office space. These, along with the college's machine shop, include equipment for coordinate measuring, 3D printing, cutting, welding, and circuit board prototyping. The team also has access to a testing facility with a simulated "rock garden" to practice the Delivery mission.

3. Project Management Plan

Development Lifecycle Approach: The team uses a development lifecycle approach based on NASA's system design process. Subteams work collaboratively in parallel, allowing for continuous integration and rapid development in cases of changing requirements. The project management team supports integration and planning, ensuring Gantt Chart deadlines are met (Figure 3). Team Mountaineers' previous rover, Wanderer, serves as a benchmark and testbed, enabling early testing. Internal competitions are held twice a year to practice missions, fostering continuous improvement in rover development.

Systems Integration and Test Plan: Subteam coordinators meet once a week to communicate and discuss design direction. Each team member belongs to two subteams, which ensures students are informed about multiple aspects of rover design. Each subteam conducts two meetings per week to make progress, collaborate, and share information on their respective projects. In addition, the entire team meets each week for subteams to provide updates on their respective projects. Subteams use a combination of simulations, prototypes, and tests using previously designed rovers to ensure their designs can be easily integrated. Once the rover is fabricated, weekly tests will be conducted using a mock lander, an on-campus rock garden, and at local sites with features similar to the MDRS.

4. Preliminary Technical Design

The rover chassis features a split-body design consisting of two individual sheet metal boxes connected via a pivot bar. This allows the sections to roll relative to each other, maximizing contact between all four wheels and the terrain beneath the rover. The front segment of the rover will have two variants: one for Autonomous Navigation and manipulation-related tasks, and another for Science. These will be interchanged depending on the mission. Each chassis segment has two motor pods mounted beneath the chassis housing a MyActuator RMD-X10S2 motor each. The rover uses composite wheel-legs (whegs) with 3D-printed footers for improved climbing ability over loose soil.

The rover will be powered by two off-the-shelf 40-volt batteries. A custom power distribution board includes emergency stop functionality and regulates the battery power to provide the necessary voltage and current through the rover. A dedicated payload PCB controls the motors on each payload and can take input from various sensors (Figure 4). Communication between a LattePanda Sigma single-board computer and other major electrical parts of the rover is facilitated with a CAN (controller area network) bus. A Pixhawk flight controller is used in conjunction with a Pixhawk GPS module for localization.

The rover communicates using both a 900 MHz and 2.4 GHz antenna/radio system. 2.4 GHz will enable high data rates at close range and 900 MHz will support non-line-of-sight tasks for the Delivery mission. Preliminary tests show that the 2.4 GHz system has a range of over 200 meters and the 900 MHz system has been tested up to 980 meters. Camera feeds, sensor readings, and other data are transmitted back to the base station and displayed on the drive team's laptops via a graphical user interface.

For both the Delivery and Equipment Servicing missions, the rover is equipped with a single manipulator mounted on a turreted base, providing six degrees of freedom. Two RMD-X10S2 motors will be mounted at the base to provide the arm with a low center of gravity while maximizing lifting ability. The end effector will be a simplistic clamp design using a lead screw to actuate the claw (Figure 5).

The rover's control software utilizes the ROS 2 framework for handling communication between rover software components, while custom software libraries are being written to interface with the rover's hardware devices (Figure 7). To streamline the rover development process, a simulation environment has been built (Figure 6). This environment will be used for testing software in each mission configuration prior to testing on the physical rover hardware. The rover's autonomous navigation stack will be controlled at the top level by a behavior tree responsible for handling control flow. The A* path-planning algorithm will be used to plan routes between objectives on a global map composed of lidar data. As the rover travels between objectives, a sliding window approach will be used to iteratively update a local map using data from an onboard lidar unit in order to adjust the global route to avoid obstacles. Once the rover arrives at an objective, the behavior tree will transfer control to a Boustrophedon Cellular Decomposition algorithm to search for ArUco markers and other objects of interest. A YOLO v8 model is being trained to detect ArUco markers, hammers, and water bottles.

The science team will select sample sites based on topographical signs of water evaporation and flow via panorama images. Captured images will be used to create stratigraphic profiles of each site's geological history. Collected surface soil samples will be analyzed with a visible light spectrometer to detect indicator chemicals as they react with compounds indicative of extinct or extant life. The experiments aim to detect calcium carbonate which indicates the presence of extinct life, biological pigments such as carotenoids and chlorophyll, proteins such as albumin, and cellulose. A second analysis will be performed using the colorimetric Biuret test, checking for the presence of amino acids. A site for sub-surface analysis will be determined based on the surface characteristics and composition (Figure 8) in regards to habitability and signs of life. A capacitive probe with a thermistor will be used to determine the soil moisture and temperature and will descend alongside the coring bit to mitigate changes to the soil after coring. From an engineering perspective, the science payload will include panoramic and high-resolution cameras for site detection and observing the stratigraphic profile of MDRS. Surface soil will be scooped and deposited into reservoirs of isopropyl alcohol, which will then be transported via peristaltic pumps into a rotating carousel of cuvettes for mixing and analysis. For collecting subsurface samples, the rover will use a coring drill capable of excavating different types of substrate. The coring drill bit features a hollow center cavity containing a stationary sample cache tube. As the coring drill excavates, a core sample will be fed into the cache tube. The cache tube is then sealed, preserving the sample's integrity and allowing for identification of the portion of the sample that was collected from below 10 cm. At the end of the mission, the cache tube can be removed from the drill (Figure 9).

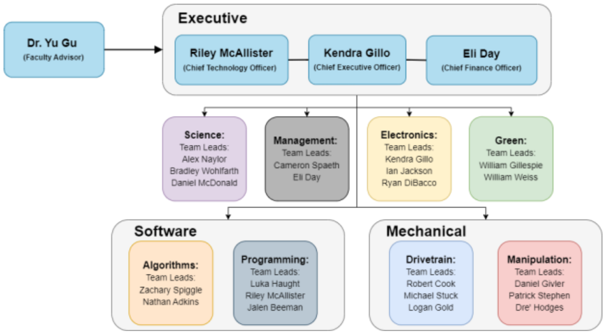
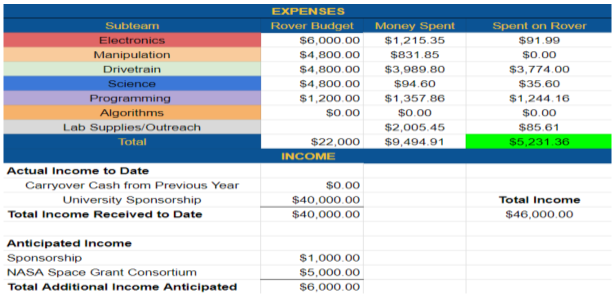


Figure 1. Team Structure



EXPENSES			
Subteam	Rover Budget	Money Spent	Spent on Rover
Electronics	$6,000.00	$1,215.35	$91.99
Manipulation	$4,800.00	$831.85	$0.00
Drivetrain	$4,800.00	$3,989.80	$3,774.00
Science	$4,800.00	$94.60	$35.60
Programming	$1,200.00	$1,357.86	$1,244.16
Algorithms	$0.00	$0.00	$0.00
Lab Supplies/Outreach		$2,005.45	$85.61
Total	$22,000	$9,494.91	$5,231.36
INCOME			
Actual Income to Date			
Carryover Cash from Previous Year	$0.00		
University Sponsorship	$40,000.00		**Total Income**
Total Income Received to Date	$40,000.00		$46,000.00
Anticipated Income			
Sponsorship	$1,000.00		
NASA Space Grant Consortium	$5,000.00		
Total Additional Income Anticipated	$6,000.00		

Figure 2. Budget

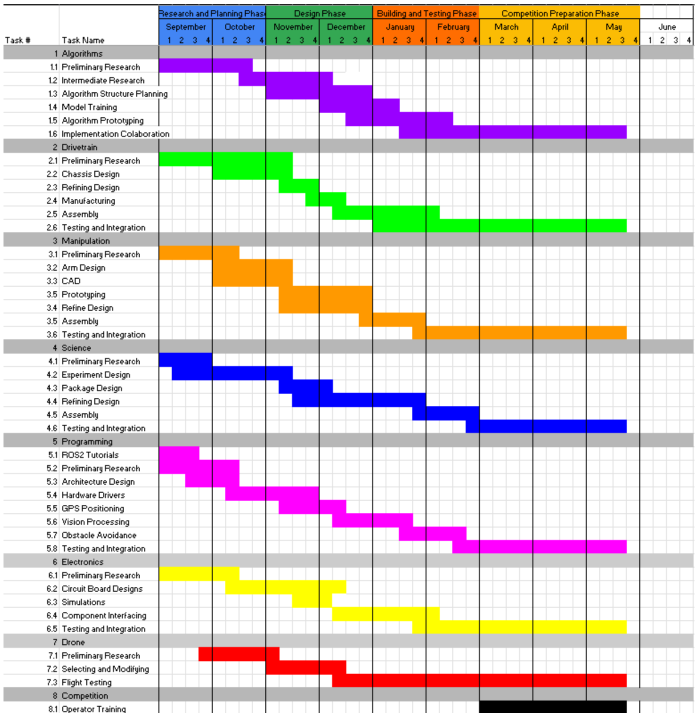


Figure 3. Timeline Until Competition

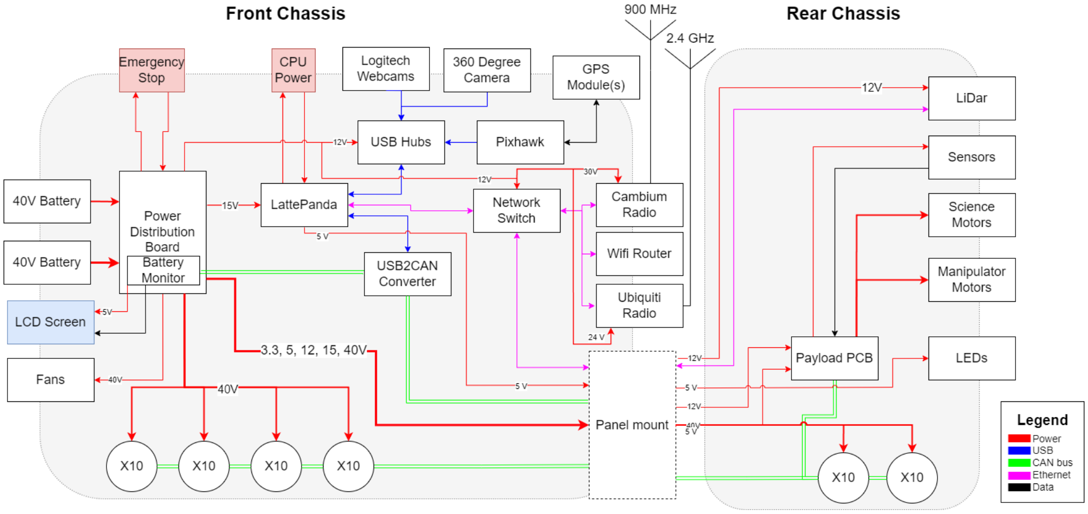


Figure 4. Electronics System Diagram

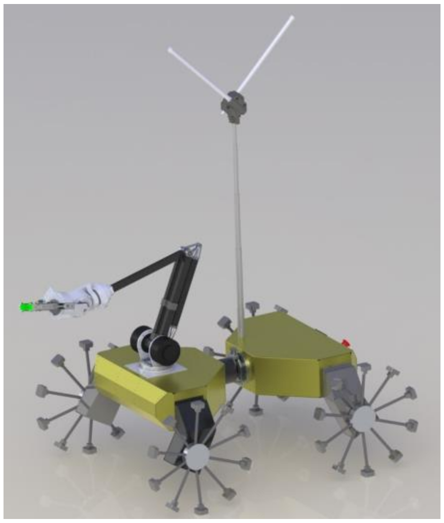


Figure 5. Manipulator Design

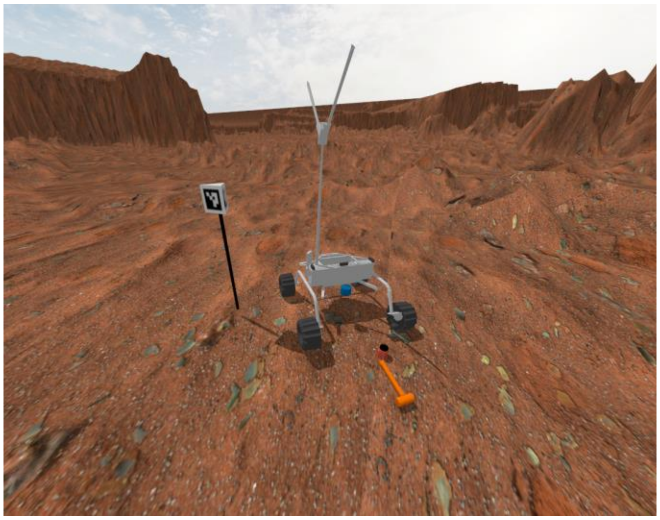


Figure 6. Rover Simulation

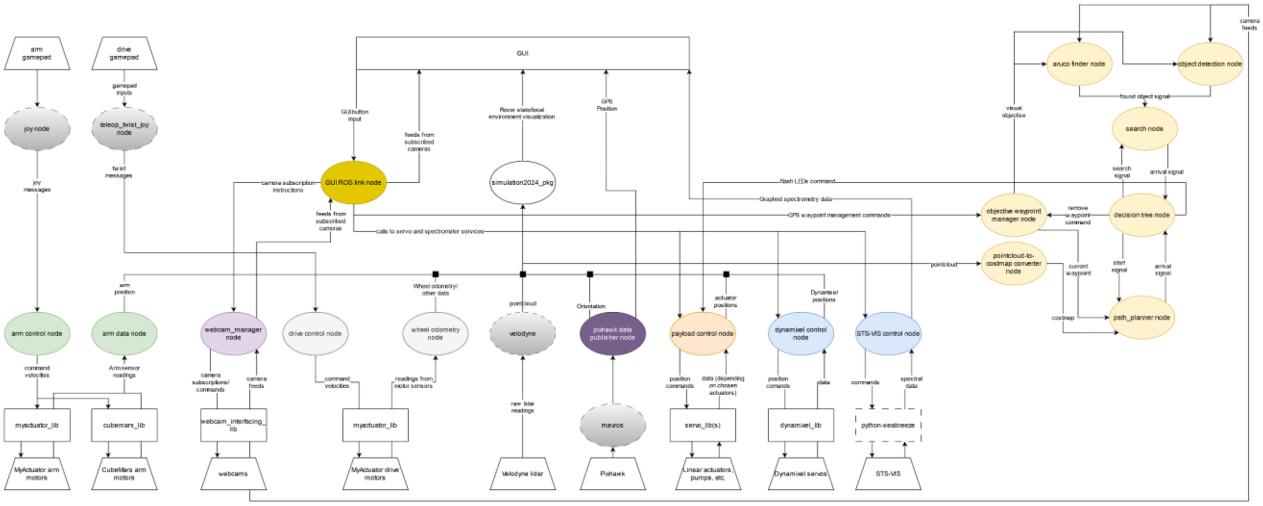


Figure 7. Rover Software Architecture

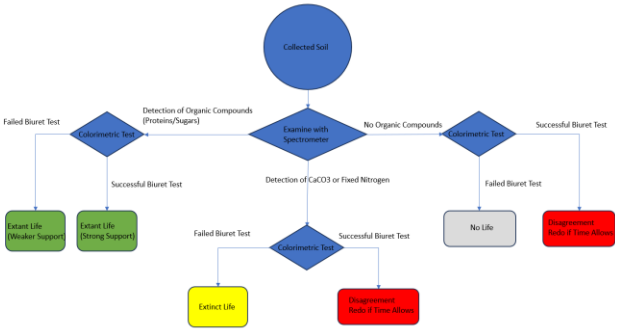


Figure 8. Science FlowChart.

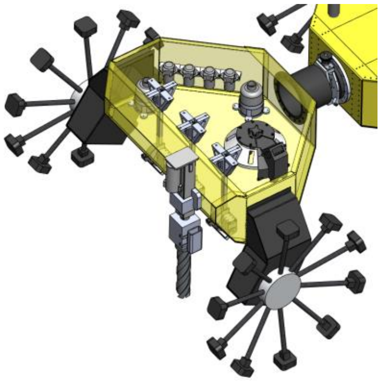


Figure 9. Science Package