NASA/NIA RASC-AL Exploration Robo-Ops Competition

WestVirginiaUniversity

BENJAMIN M. STATLER COLLEGE OF ENGINEERING AND MINERAL RESOURCES

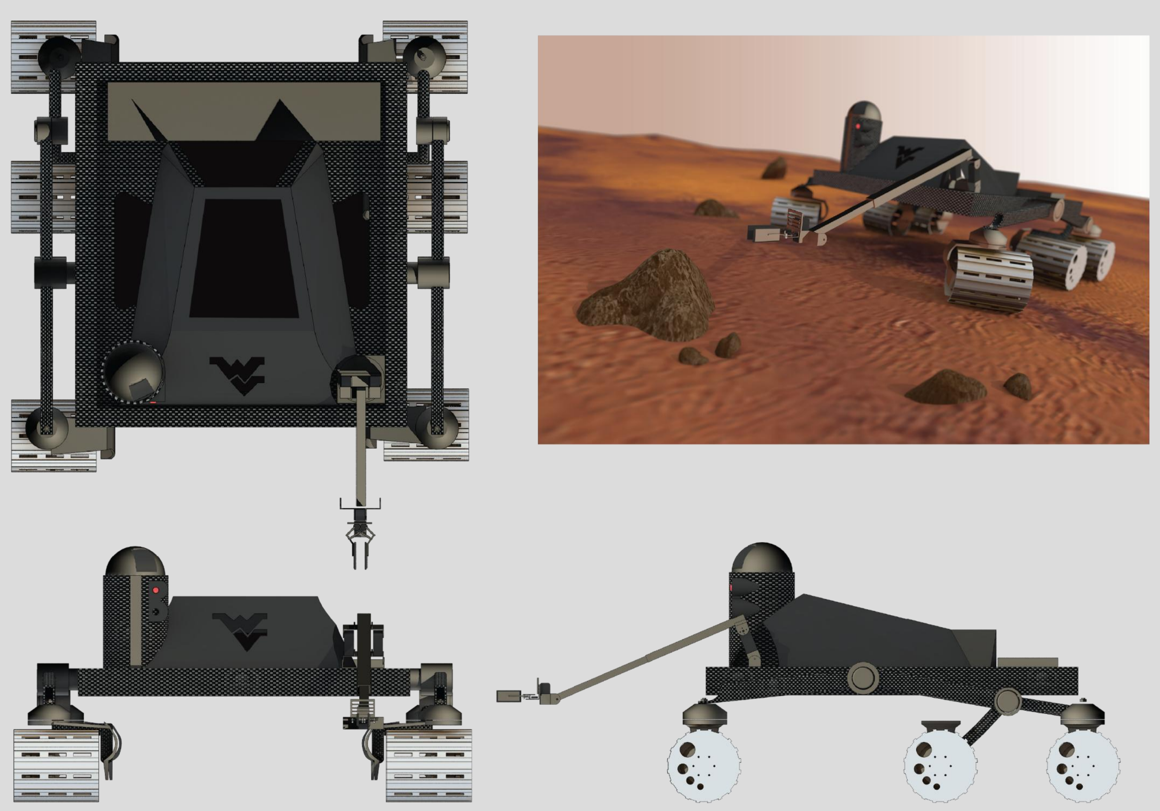
Introduction

The 2012 RASC-AL Exploration Robo-ops Competition purpose is to challenge university teams to build and demonstrate a planetary rover at the Johnson Space Center (JSC) Rock Yard. The competition supports the NASA mission "to engage the public in its missions and research." The rover project was chosen as the focus of two courses offered at WVU: a special topics courses offered to undergraduate and graduate students, both titled *Experimental Robot Design*. The team included students from both courses, cadets from Air Force ROTC Detachment 915, and a senior design team focusing on the rocker-bogie chassis design. The team consists of students from varying disciplines including: aerospace, civil, computer, electrical, mechanical, and systems engineering as well as computer science.

The rover features carbon-fiber composite construction, six-wheel independent drive, four-wheel steering, and rocker-bogie suspension. It incorporates a Navigation Assistance System (NAS) that increases navigation precision and provides useful feedback about the mission environment to the operator. The rover houses a sample acquisition system comprising a 5 degree-of-freedom and camera installed to assist the operator to collect samples. The communications framework employs a wireless CDMA modem to allow operators to control the rover from WVU while it is in the JSC Rock Yard and simulate the data lag present in interplanetary communications.

Systems Engineering

The Mountaineers Rover Team began the systems engineering process upon initiation of the project proposal effort, late in the Fall 2011 semester. Initial requirements analysis lead to a preliminary design presented in our project proposal. The development of the proposed design commenced in January 2012. This necessitated implementation of an aggressive nineteen week schedule and a solid systems engineering process. The systems engineering approach taken is based on the Capability Maturity Model Integration (CMMI) process-improvement model for product development. The team's project plan details the project goal, deliverables, schedule, budget, risk mitigation, and team organization. The plan was developed per the *Project Planning* (PP) and *Project Management and Control* (PMC) process areas outlined by CMMI.



Initial proposed conceptual Rendering

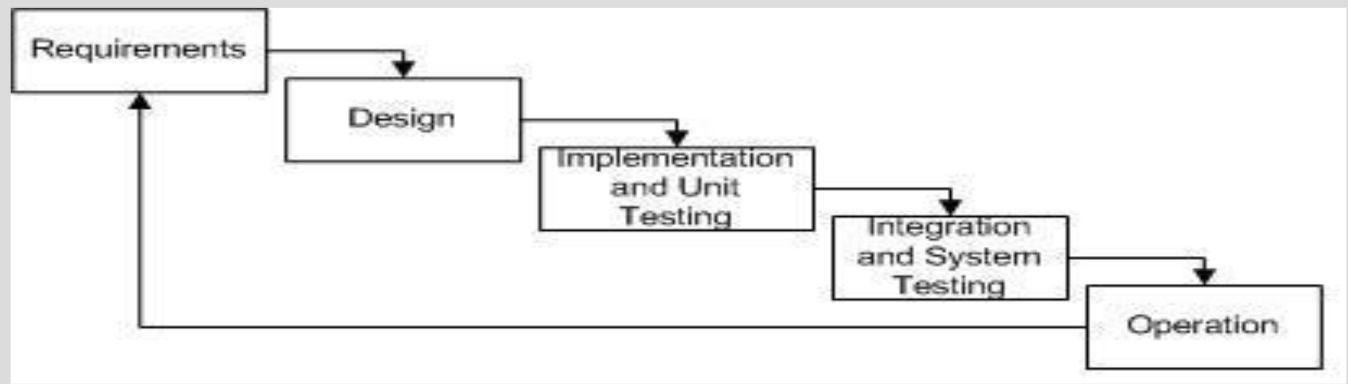
Schedule

A project schedule was developed through analysis of the team's capabilities, and the 19-week period between project inception and departure for the competition.

ID	Task Name	December	January	February	March	April	May
1	Project Award	12/19					
2	Develop Design						
8	Fabricate Rover						
13	Develop Software						
20	Midpoint Project Review				3/26		
21	Validate and Improve Rover						
27	Video, Website, Streaming Link, E/PO d					4/30	
28	Registration and Payment due						5/1
29	Final Technical Report due						5/11
30	Robo-Ops Forum in Houston, TX						

Project Lifecycle

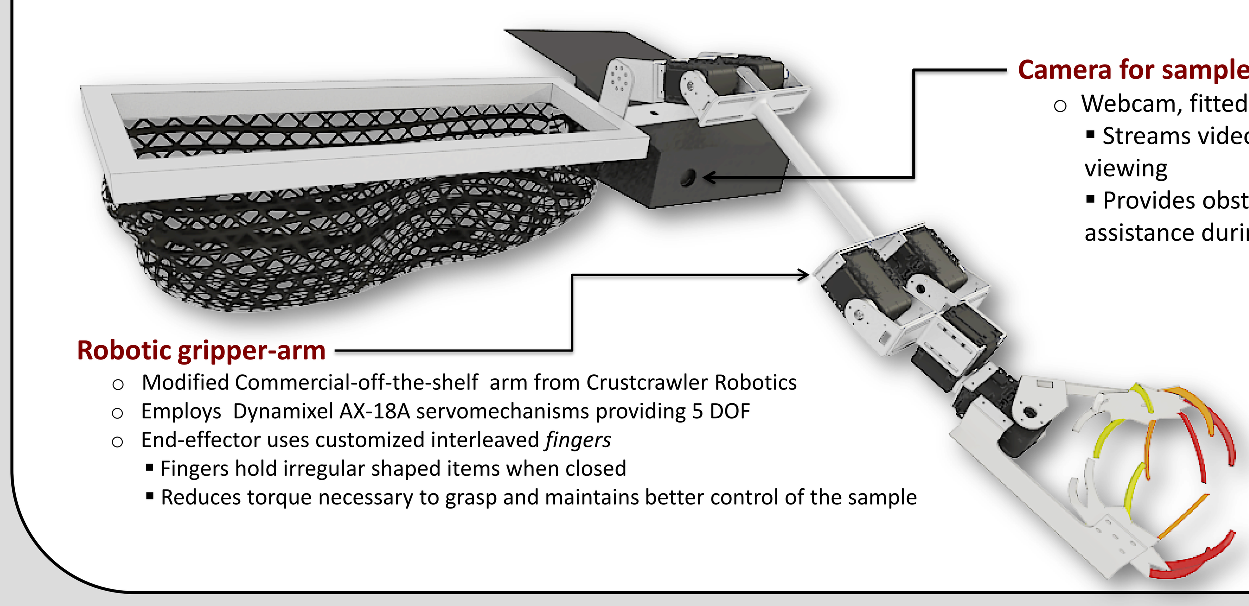
The *incremental project lifecycle* model was chosen for this project.



Sample Acquisition System

Collection bin

- Constructed of light weight high-strength nylon mesh



Camera for sample acquisition and navigation

- Webcam, fitted with a fish-eye lens
  - Streams video to the WVU Mars Rover UStream site for public viewing
  - Provides obstacle navigation during rover traversal and visual assistance during sample acquisition
- Pan Tilt Zoom camera
  - Used to identify samples from long range and paths to the samples
  - Provides second viewing angle during sample acquisition increasing depth perception

Robotic gripper-arm

- Modified Commercial-off-the-shelf arm from Crustcrawler Robotics
- Employs Dynamixel AX-18A servomechanisms providing 5 DOF
- End-effector uses customized interleaved *fingers*
  - Fingers hold irregular shaped items when closed
  - Reduces torque necessary to grasp and maintains better control of the sample

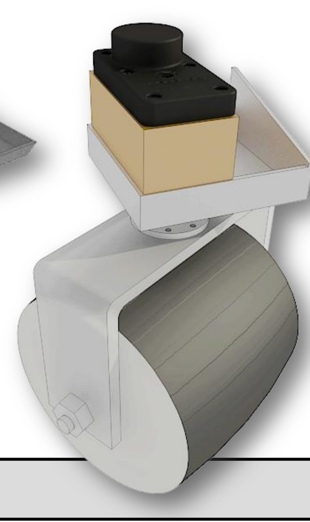
Drive System

Rocker-bogie suspension system with six independently brushless DC motor driven wheels

- Carbon-fiber reinforced plywood and aluminum provide a strong, lightweight foundation

Aluminum torque tubes and differential

20 cm diameter wheels made of PVC



Mounts for four steering servos and wheel assemblies

Navigation Assistance System

- Provides precise inertial data onboard the rover for performing measured movements. The output of the NAS provides gyroscopic input to a control algorithm to properly rotate the robot according to the input of the operator

System Testing

The rover, with full payload, was tested in the environments listed in the project requirements: rocks, sand, and a 33% grade. The rover was able to make multiple consecutive traversals across a 12 ft. sandbox, overcome a 10 cm rock, and ascend and descend a rocky 30% grade in addition to a 54% obstacle strewn grade. Tests were carried out with the operators quarantined in the server room, operating using rover video. The NAS has been independently tested and has demonstrated heading accuracy within 2 degrees and acceptable GPS accuracy.

Education and Public Outreach

The WVU Mountaineers rover team combined forces with the WVU Lunabotics team, the Society of Women Engineers (SWE), the NASA West Virginia Space Grant Consortium (WVSGC), and the NASA Independent Validation and Verification (IV&V) center to provide a large amount of quality public outreach informing students about opportunities in STEM fields and encouraging them to pursue studies in the STEM disciplines. The Mountaineers dedicated 100 hours of training and 201 quality hours outreach activities. They interacted with 2,500+ different students.

Sponsors

The project budget was projected to be $20,000 based on projected travel and fabrication expenses. Funding for the budget was received through generous sponsorships from the NASA WV Space Grant Consortium and the WVU Benjamin M. Statler College of Engineering and Mineral Resources, as well as the stipend received from NASA/NIA. The budget covers all costs associated with fabrication and travel activities.

NASA WEST VIRGINIA SPACE GRANT CONSORTIUM

Physical Dimensions	
Length	100 cm
Width	92 cm
Height (Stowed)	50 cm
Height (Deployed)	80 cm
Mass	45 kg

Control and Communication Systems

Robot Control Unit (RCU)

Onboard computer receives and dispatches operator commands, interfaces to the robot's subsystems, processes video from all cameras, and performs autonomous macros to aid the operators in driving the robot, navigating the Rock Yard, and operating the sample acquisition

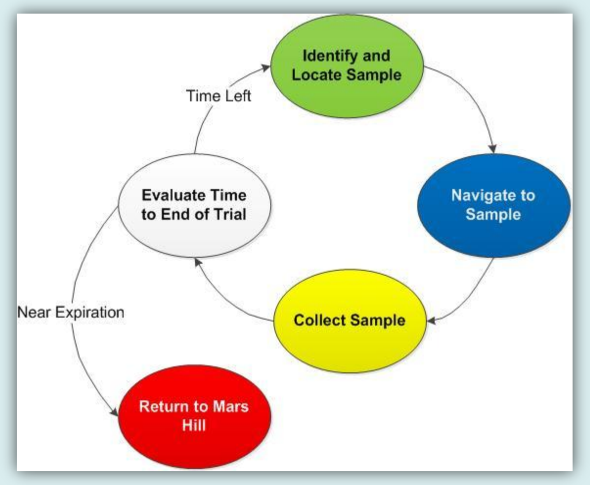
Operator Control Unit (OCU)

- Server on the WVU network and two USB-connected Xbox 360 controllers
- Dual monitors to give the rover and arm operators their own displays

Software

- Provides teleoperation of the rover from the remote site on WVU's campus through a Verizon wireless modem located in the RCU
- Commands from OCU to RCU, such as camera movement and rover movement, are sent via a TCP link
- Manual operation using an Xbox 360 controller
- Provides semi-autonomous macros to store and move end-effector to preset positions using kinematics solver

Concept of Operations



Power System

- Designed to provide ample power for a full 60 minute competition run and isolate the power used for the motors from the C^2 components. It includes over-current protection for the control electronics and includes an external battery cutoff switch to allow for quick disconnect of power if necessary
- Comprised of three lithium polymer (LiPo) batteries, motor controllers, DC-DC voltage converter, circuit protection, and E-Stop.