The Competition

The rover was designed to complete the tasks laid out in the 2019 Mars's Society University Rover Challenge (URC) competition rules.

1. Science mission - The rover must conduct an in-situ analysis to determine the presence of life, either extinct or extant, at designated sites.
2. Extreme retrieval and delivery - The rover must pick up and deliver objects in the field while traversing a wide variety of terrain no further than 1 km.
3. Equipment servicing - The rover must perform operations on an equipment system after travelling up to 0.25 km.
4. Autonomous traversal mission - The rover must autonomously traverse between markers across moderately difficult terrain up to a total distance of 2 km.

Requirements developed according to the tasks of the competition and developments during the design process. The design of the arm was based on the following requirements.

Carrying Capacity and Reach
1. The arm shall be able to lift up to 5 kg at a 1 ft extension from the front of the rover without loss of stability or structural failure.
2. The arm shall be able to lift objects with handle features up to 5 cm in diameter and up to 40 x 40 x 40 cm in total volume.
3. The arm shall be able to reach 3.5 ft vertically from the ground when mounted to the rover.

Safety
1. The arm shall be equipped with a stop switch (separate from the rover stop switch) to stop all motion of the arm in case of loss of control.

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System Design

The arm is the Gearwurx Arm 3.0. This arm was chosen for its ability to lift over a 5 kg payload and reach 3.5 feet which meets the requirements set by this team. The rover arm originally purchased from Gearwurx was kept intact and not equipped with any permanent attachments or adjustments. The arm has six degrees of freedom and is composed of three linear actuators, three servo motors, and casing made of aluminum and carbon fiber.

The rover arm is powered by 12 DC volts at 7.5 peak amperes. An emergency button interrupts power to the arm if necessary. A slider controller purchased from Gearwurx or a Logitech F310 controller are capable of controlling the arm. When the Logitech controller interfaces with the arm motors, software designed to mimic the Robotic Operating System (ROS) MoveIt package runs to control the position of the motors.

The manipulation team met all of the system requirements, including those related to lifting 5 kg, reaching 3.5 ft, grasping 5 cm in diameter objects, and performing dexterous movements such as pulling levers, pressing buttons, opening drawers, and operating hand tools.

In the next iteration of the rover, we would like to implement a slip-ring at the wrist of the end manipulator to allow for a continuous rotation servo. Continuous rotation at the wrist would significantly decrease the difficulty of operating a screwdriver. We would also like to see a method for improved visibility through the rover's cameras when using the custom-made screwdriver. Future software iterations would solve forward or inverse kinematics to more precisely control the end manipulator. For electronics, a future iteration would include a remotely controlled relay switch to stop power to the arm in case of an emergency, instead of the current wired version.

The rover's manipulation capabilities meet the requirements set by the team. This will allow the rover to properly interact with the objects that it would encounter during the competition. The science needs of the team are also met for the competition. A fiber optic probe for spectroscopy mounts to the Gearwurx Arm 3.0 allowing for detection of life, either extinct or extant, during the competition.

The rover arm is the Gearwurx Arm 3.0. This arm was chosen for its ability to lift over a 5 kg payload and reach 3.5 feet which meets the requirements set by this team. The arm on the original rover was kept intact and not equipped with any permanent attachments or adjustments. The arm has six degrees of freedom and is composed of three linear actuators, three servo motors, and casing made of aluminum and carbon fiber.

Methods and Testing

Precision, Accuracy and Tools Test
- Test - Opening/Closing latches, typing on keyboard, pushing buttons, fastening screws and moving joysticks. Created and used a 3D printed screwdriver.
- Result - Successfully grabs, presses, and turns high precision. The 3D printed screwdriver works, but the point is not visible from the camera location.

Reach and Range Test
- Test - Determine maximum reach and the range within which the arm can operate.
- Result - Arm reaches 3.5 ft and operates at all locations of interest.

Torque and Stress Test
- Test - Verify arm is capable of picking up an object with a handle diameter of 5 cm.
- Result - Able to lift objects with diameter of 5 cm while hand is lifted upwards.

Size Capacity Test
- Test - Verify arm is capable of picking up an object with a handle diameter of 5 cm.
- Result - Able to lift objects with diameter of 5 cm while hand is lifted upwards.

Control Test
- Test - Verifying ability to control arm with slider block controller or video game controller.
- Result - Able to control with slider blocks. Easier to control with gaming controller.

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Conclusion

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Reach and Range Test
- Test - Determine maximum reach and the range within which the arm can operate.
- Result - Arm reaches 3.5 ft and operates at all locations of interest.

Torque and Stress Test
- Test - Verify arm is capable of lifting 5 kg and operate with no damage.
- Result - Able to lift 5 kg with difficulty. Able to lift up to 10 kg with noticeable difficulty.

Size Capacity Test
- Test - Verify arm is capable of picking up an object with a handle diameter of 5 cm.
- Result - Able to lift objects with diameter of 5 cm while hand is lifted upwards.

Control Test
- Test - Verify ability to control arm with slider block controller or video game controller.
- Result - Able to control with slider blocks. Easier to control with gaming controller.

Attachments were added to help the arm fulfill the requirements, including:
- 3D printed screwdriver.
- Mount for the fiber optic probe.
- Rubber bands to improve grip.
- Mount for a camera.

• Robot arm purchased from Gearwurx holding 6 kg and a 5 cm diameter handle.

• Robotic claw purchased from Gearwurx with Arm 3.0.