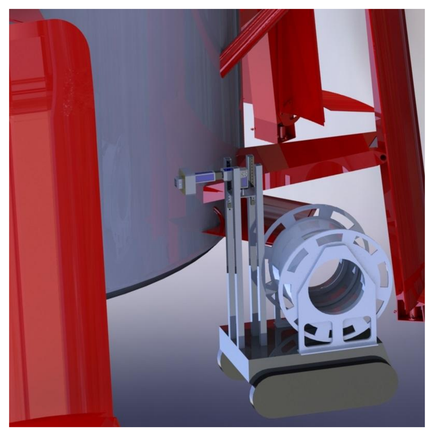
New Glenn Booster Robotic Approach

Aaron Misola, Cole Morgan, Jon Hall, Julianna Bethune, Nathan Mars, Nicholas Greenwood, Tommy Pryor, Trevor Hedges
Advisor: Dr. Kristi Morgansen, Industry Mentor: Chad Schepel

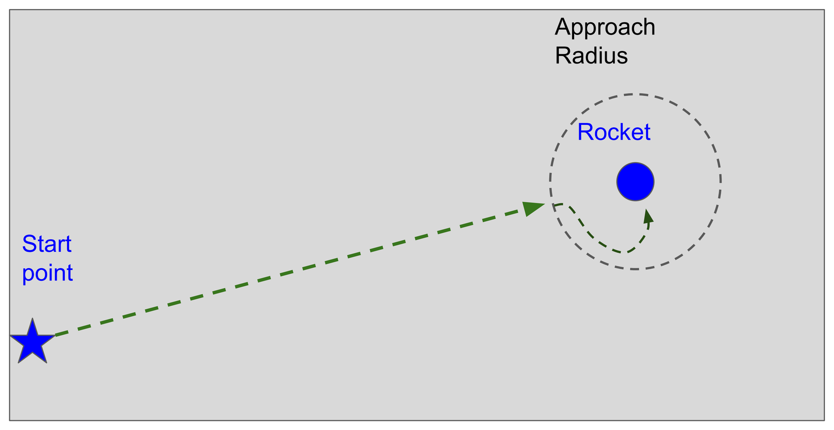
Introduction

The first stage of the New Glenn rocket is designed to land autonomously on a ship at sea. After landing, connections for power, gas, and communications must be made quickly to minimize the commodities carried onboard the rocket. Due to safety concerns, the ship will not have crew members onboard during the landing operation. A significant operational advantage would be gained by having a robotic system approach the launch vehicle and make the necessary connections shortly after landing. The purpose of this project is to develop a robust, conceptual design for an autonomous robot capable of navigating to the booster and making the required connections as quickly as possible after landing.



Approaching the Rocket

Rocket Recognition and Path Algorithms



The robot will receive orientation and location telemetry data from the landed rocket booster. It will then plot a path and autonomously navigate to the booster. The orientation data will inform the robot of which side the panel is on; once determined, the robot will move in an arc around the rocket booster's landing legs until it is squared with the side which has the panel. From here, the robot relies on a stereovision camera as a more precise navigation tool to approach the panel and plug in the end effector.

Drivetrain Selection

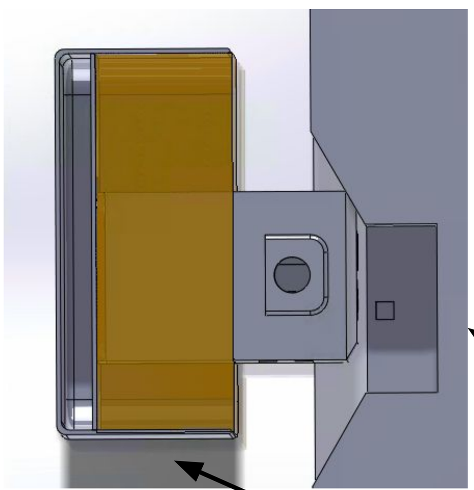
Due to the conditions that the robot will be operating in, there is a need to maximize the amount of traction the robot will get, while still allowing the robot to move quickly in order to accomplish the mission. Treads will be used on the robot in order to allow for better traction, power efficiency, and movement over different surface conditions (such as a wet deck) than standard wheels. Since the robot will be routinely serviced, the tread's potential lack of durability is not a major concern, as they will be able to be evaluated and replaced as needed.

Reel and Connection Cables

The robot must deliver several power wires, a gas flex hose, and ethernet cables to the New Glenn booster. Dragging the cables across the deck of the ship would impede the robot's movement due to excessive and increasing friction force. Instead, the robot will carry a reel which will dispense cable, thus continually lightening its load as it moves toward its target.

Making the Connections

Panel Detection and Unlocking



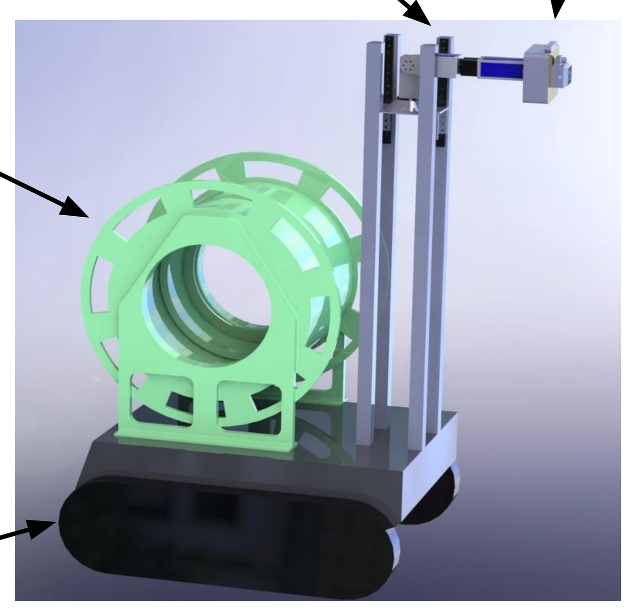
While making the final approach to the landed booster, a stereo vision camera will capture the surrounding environment. Computer vision algorithms will detect the location and expected geometries of the panel.

We investigated multiple panel unlocking mechanisms for added redundancy in case of failure. Sensitive magnetic resistors, ultrasonic waves, and an external antenna resistant to extreme temperatures, all allow the panel to reliably open on approach.

Arm and Manipulator Design

A 4 degree of freedom arm will be used to plug into the panel on the rocket. The arm will have 3 rotational axes as well as a linear actuator, for the final motion of plugging in the manipulator to the panel.

A manipulator at the end of the arm carries the gas, power, and communication lines. The manipulator will plug into an opened panel on the rocket with corresponding ports. To ensure proper insertion even with slight error, a spring system is used similar to conical docking ports used for spacecraft docking. The spring system is filled with foam, to increase damping of the system and reduce manipulator vibration.



Analysis of Final Design

Ability to Meet Requirements

The designed system will meet all critical requirements with further refinements. Most critically, testing of the prototype needs to be completed. The testing process will refine parameters for the control system and train the detection system to recognize rocket-shaped objects and find the panel. Testing will also confirm the mechanical systems will operate on a rocking deck as expected.

LIDAR imaging

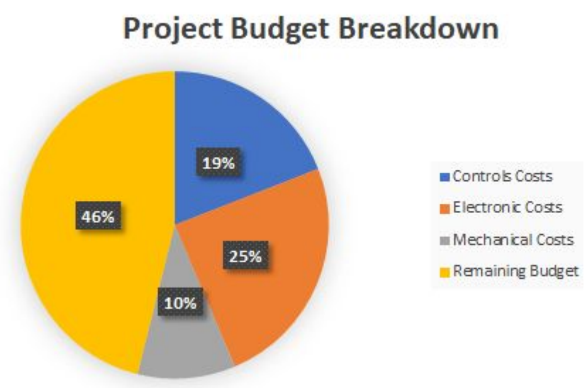
Ethical Considerations

Rocket reuse reduces launch costs. A robotic approach eliminates the need for any humans to be present on the ship during rocket landing by delivering power and gas in a potentially dangerous marine environment. The connections made provide an opportunity for rocket diagnostics before people board the ship. A rapid response from the robot will reduce the need for engine maintenance by decreasing the length of time that the rocket is exposed to corrosion-causing seawater.

Budget and Schedule

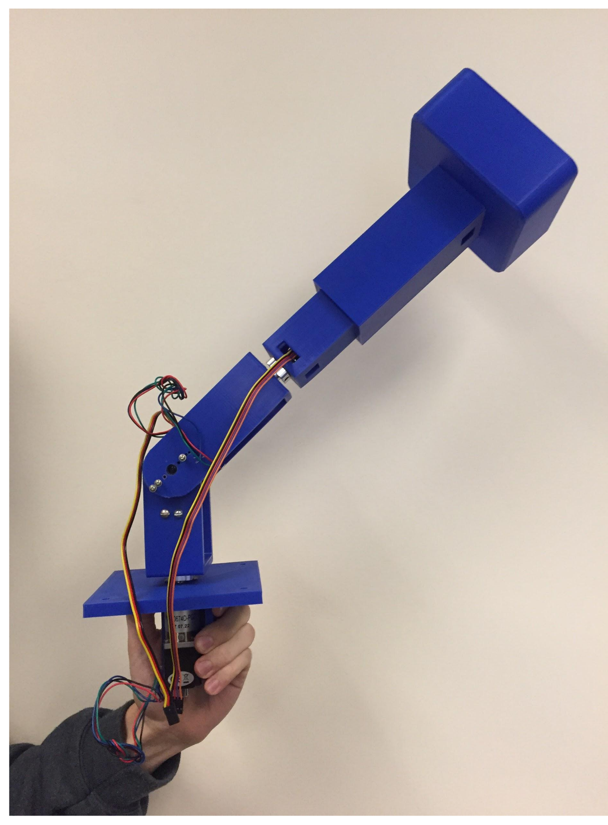
A majority of the project was completed, including prototype construction, but testing was not completed.

Of the available $4,000 budget, only $2,156 was spent, so the project came in well under budget. The overall cost of the robot is also reasonable, coming in a $22,725.



Conclusions and Lessons Learned

This project combined mechanical, electrical, and software design elements to resemble mission operability in a harsh environment. Unfortunately, a set of frequent, critical design changes set back the milestones we had scheduled, including building a small-scale demo robot and completing a full suite of navigation and manipulator arm tests. However, we have assembled a manipulator arm, designed a proprietary PCB, and demonstrated that a stereo vision camera and neural network setup would provide the base for an autonomous application.



Acknowledgments

The team would like to thank the Aeronautics & Astronautics department of the University of Washington, as well as Blue Origin for providing the opportunity for and funding of this project. We would also like to thank our adviser, Dr. Kristi Morgansen, and industry mentor, Chad Schepel, for their support and guidance throughout this project.

WILLIAM E. BOEING
DEPARTMENT OF AERONAUTICS & ASTRONAUTICS

BLUE ORIGIN