Gaucho Autonomous Navy Environment Robot

Liyuan Shen | Haotong Han | Xiangying Zuo | Clark Qiu | Tyler Solian |
Andrew Chhang | Daniel Cheung | Chuyue Guan | Jacob Gardner | Huaishu Huang

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Background

Every year, the U.S navy spent about 55 billion dollars on ship maintenance, and sailors' life are endangered due to extremely dangerous environments on navy ships. With our robust design of caterpillar treads, multi-link arm, and optimized center of gravity, our robot can operate in a 1/3-scale constant-shaking shipboard environment. This provides the most promising solution for the Navy to reduce the cost and save people's lives.

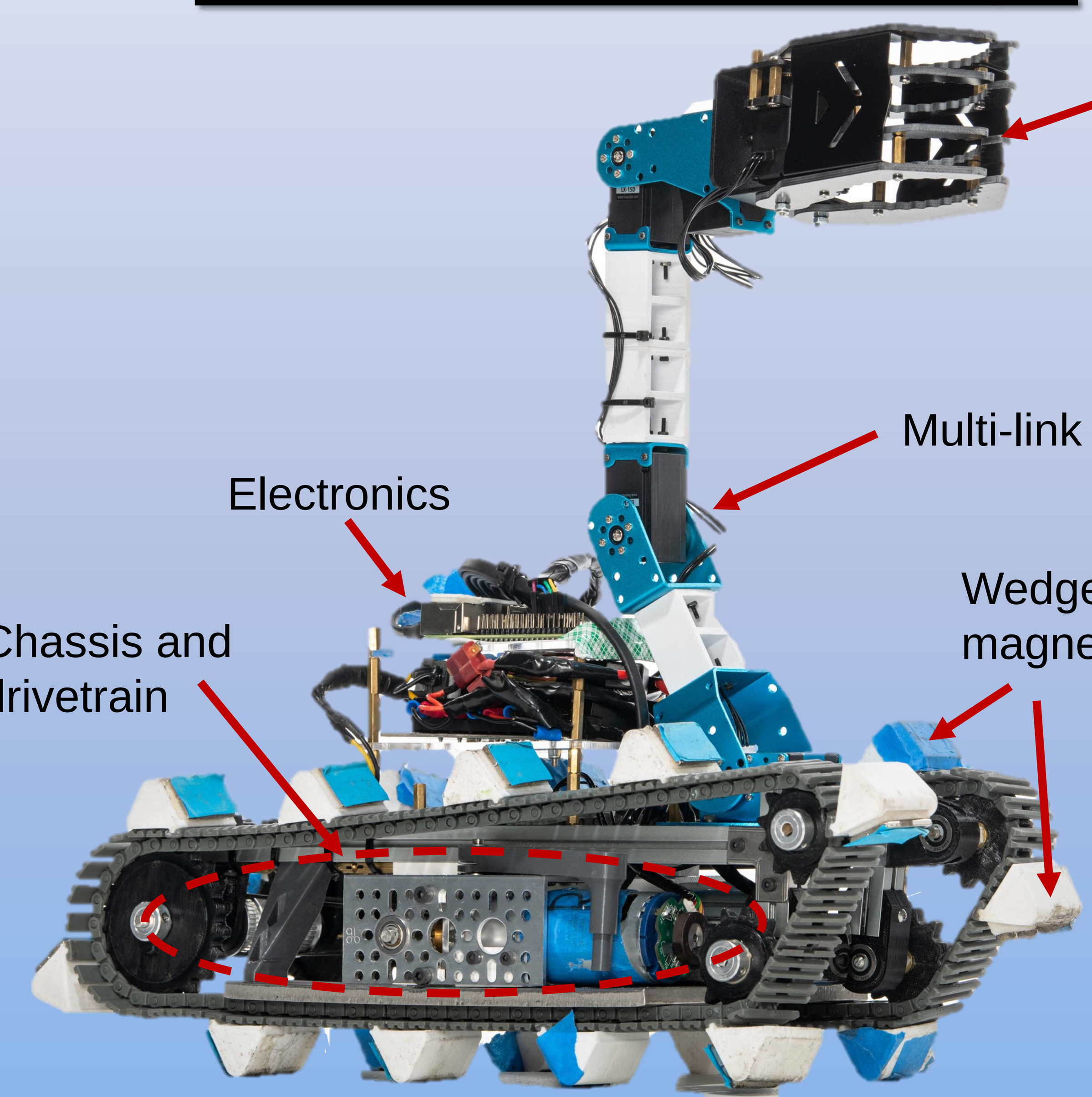
Challenge Overview

- 60° stairs
- Hatch door
- Wooden platform
- 1.25 m wave equivalent rocking
- Dial
- Light switch

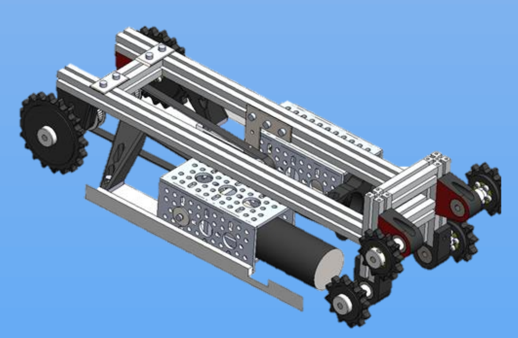
Solution Overview

Challenges	Solutions
Motion	Two motor systems propelling caterpillar treads
Stability	1. Optimized center of gravity for stabilization 2. Strong magnetic wedges
Interact with obstacles	1. Multi-link arm allows five degrees of freedom 2. High-torque gripper to interact with obstacles
Control	1. Wireless control with PS4 controller 2. Raspberry Pi 3. Inverse kinematics and Robotic Operating System (ROS) 2 4. Subroutines for semi-autonomous
Reliable	1. Wire harness

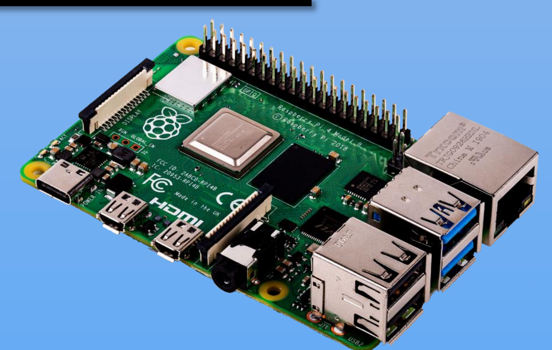
GANER Final Design



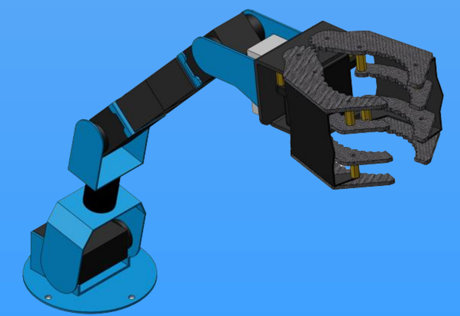
Key Components



Robotic Chassis
Steel Chassis with improved center of mass

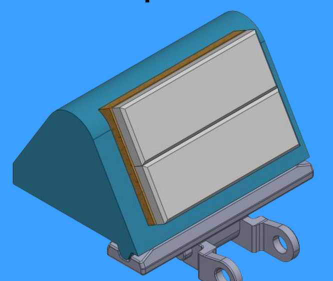


Raspberry Pi
Microcontroller compatible with ROS2

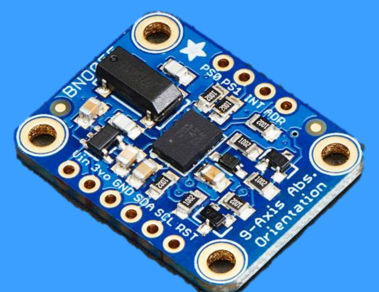


Arm with Gripper
Powerful servo motors used to open hatch door

12V DC Motor
Strong 6.76 Nm motor for the robot's driven train

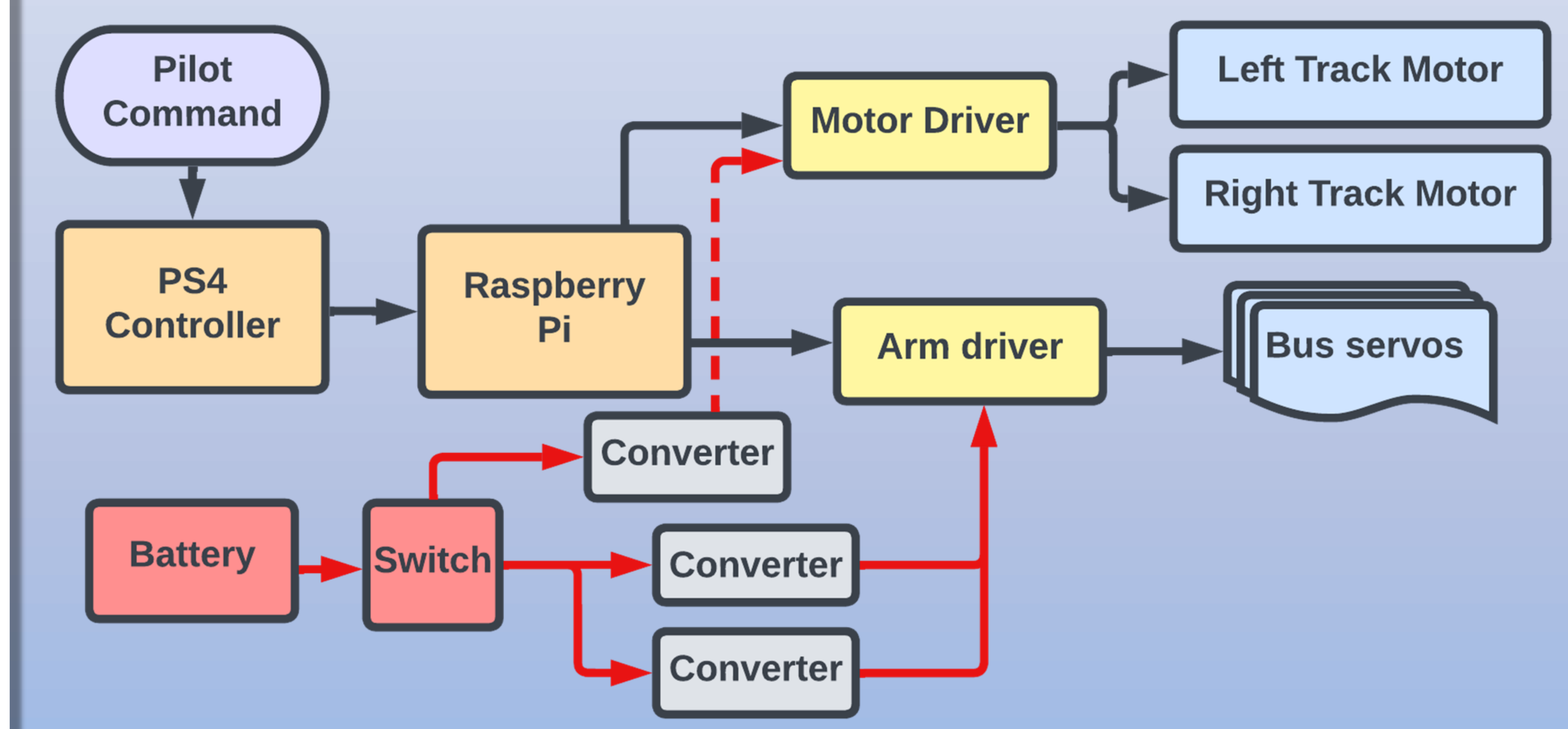


Magnetic wedges
Magnets help stabilize the robot on the shaking platform



Inertial Measurement Unit
BNO055 IMU that can measure angular velocity, linear acceleration, and direction

Block Diagram



Key Results

Specification	Target	Actual
Stair Stabilization Limit	20°	30.4°
Magnetic Tread Force	7.5 N	11.5 N
Center of Mass Location	Δx = 25 mm Δy = -5 mm	Δx = 29.41 mm Δy = -24.06 mm
Motor torque	15 Nm	57.23 Nm
Arm motor torque	1.2 Nm	3.5 Nm
Reliability	70 %	**82.5 %**
Completion time	10 min	**5 min 16 sec**

Conclusion and outlook

In conclusion, GANER presents a significant leap in maritime robotics technology. Its design is thoughtfully crafted to navigate the complex, dynamic interiors of naval vessels. The robust mechanical and electrical design of GANER ensures reliable and efficient performance, even in challenging conditions. Looking forward, we believe GANER has vast potential to revolutionize maintenance and operational tasks within the Navy, reducing costs, and more importantly, mitigating risks to human life.

Acknowledgements:

Fanthomwerx Lab, Geoff Tsai, Tyler Susko, Trevor Marks, Ilan Ben-Yaacov, John Jacobs, Danny Iland, Doug Bradley, Nick Willis, Destin Wong, Alan Jaeger, ASME, Tyler Hattori, Samuel Fei, Chris Cheney, UCSB Machine Shop, Austin Chen, Christopher Lew, Jack Carpino, João Hespanha, Kegan Woodhouse, Alex Ackerman

FATHOMWERX

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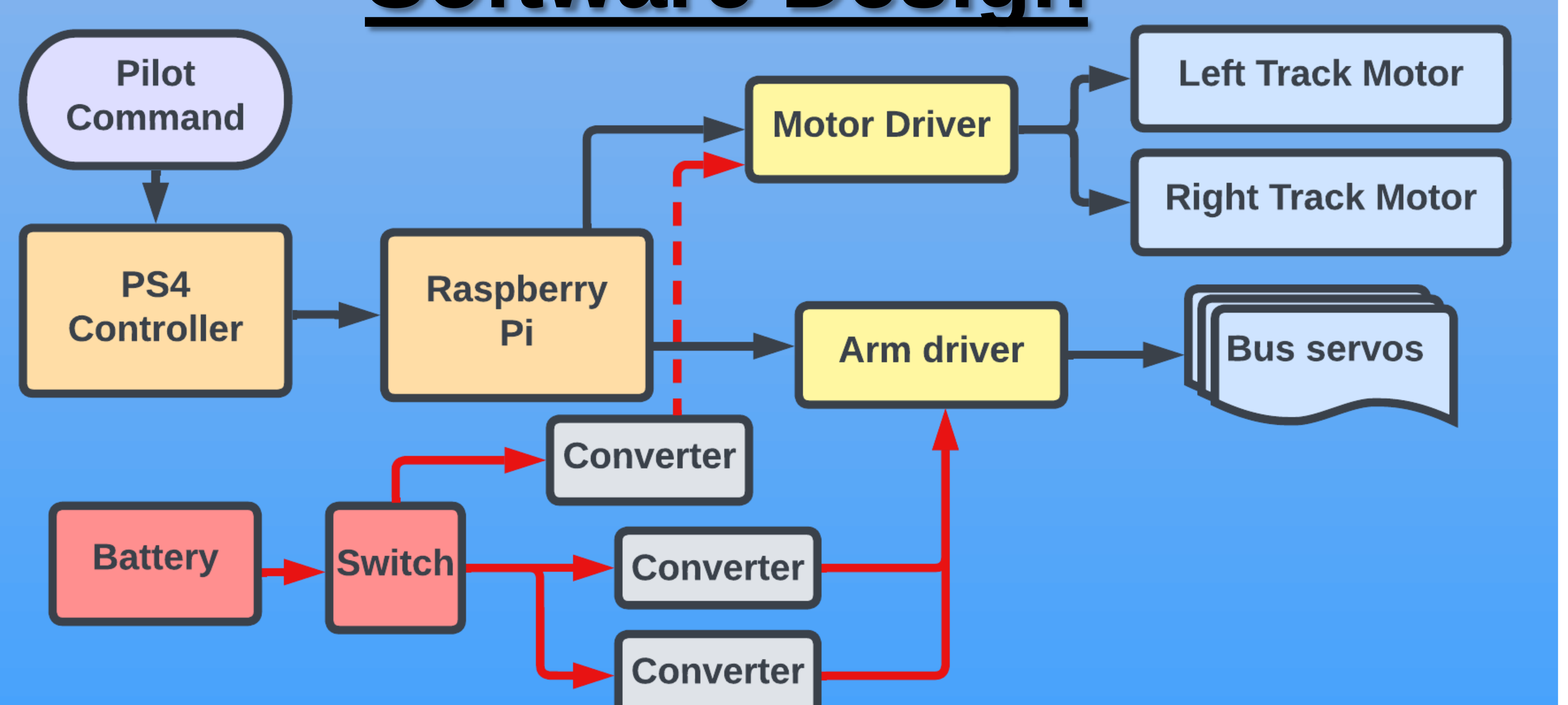
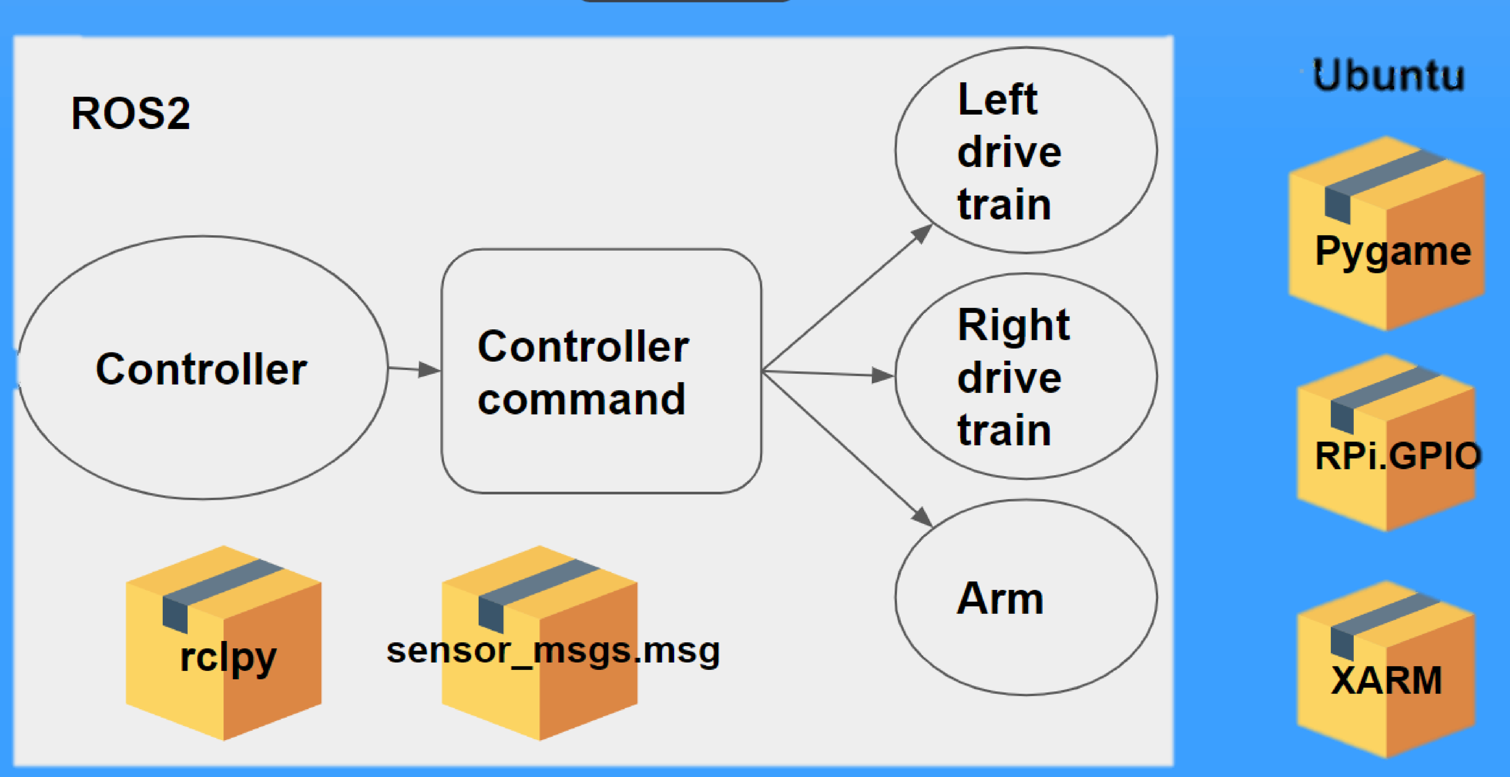
Design overview

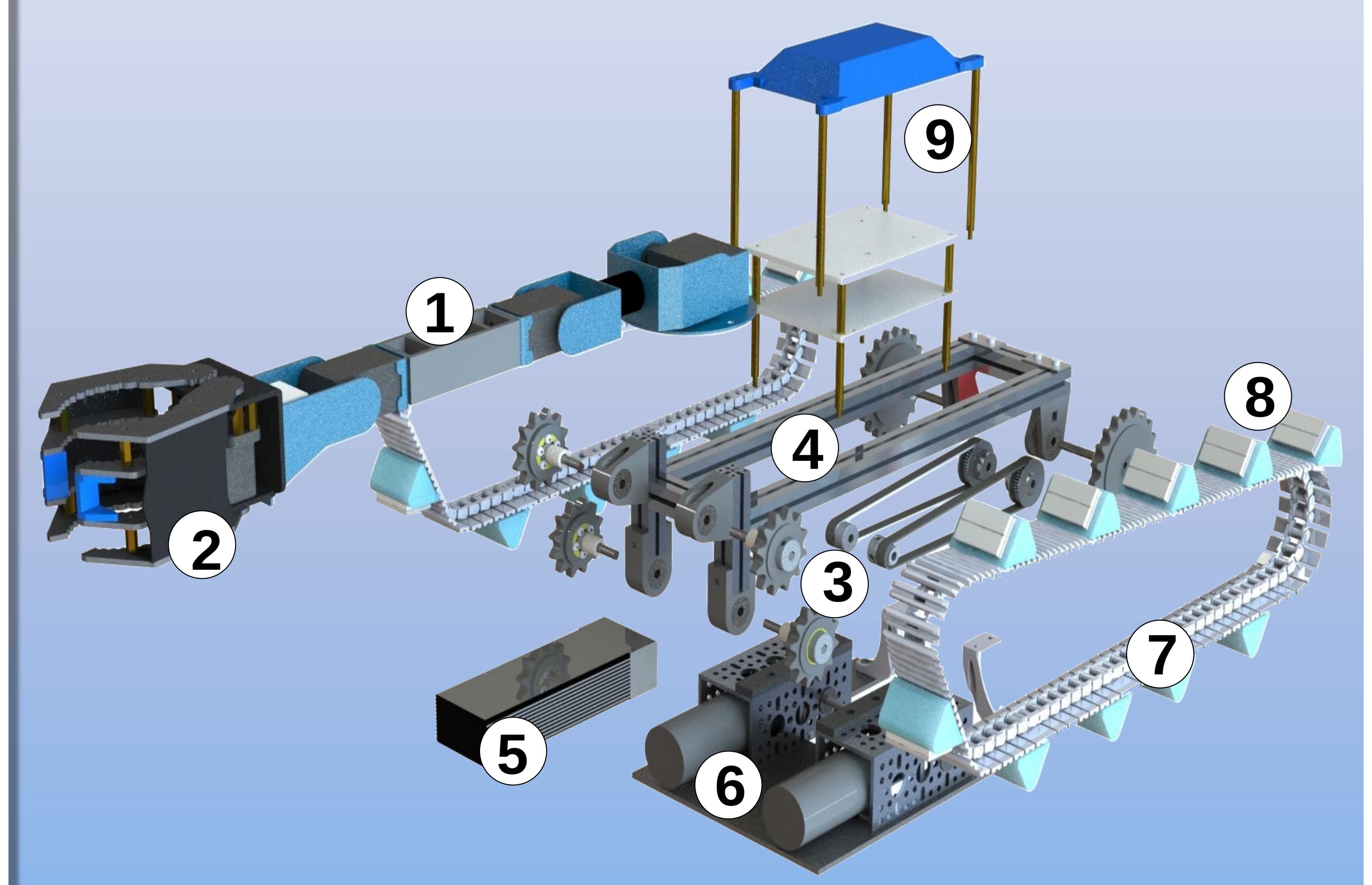
The Gaucho Autonomous Navy Environment Robot (GANER) is a meticulously engineered robot powered by a robust mechanical design and an advanced electrical system. Its movement is realized by a two-motor system propelling caterpillar treads through a well-designed drivetrain. A wedge and magnet combination stabilize the robot on the stairs, while a multi-link arm with a flexible gripper interacts with a range of obstacles. Moreover, GANER is controlled wirelessly through a PS4 controller, with signals processed by a Raspberry Pi to control drivetrain and arm movements. Leveraging an inverse kinematics algorithm and the robotic operating system, GANER can interact with complex obstacles like dials and switches. This sturdy design enables operation in a 1/3 scale, constantly shaking shipboard environment, positioning GANER as a cost-effective, life-saving solution for the Navy.

Software Design





Key Components



Index	Name	Specifications
1	Robotic Arm	Five degrees of freedom.
2	Arm Gripper	Powerful with 3.5 N·m torque.
3	Veg Cogs and Belts	Robust structures for torque transmission
4	Robot Chassis	Steel chassis with a low center of mass
5	Lithium Battery	12V battery powers the electrical system.
6	Drivetrain Motors	6.77 N·m motor that drives the robot
7	Caterpillar Tread	120-link tread system with high reliability
8	Magnetic Wedges	Magnets and foams attached to 3D-printed wedges that improve stability
9	Electronics Mount	Acrylic platform and 3-D printed cap that protects the electronic components

Key Simulations

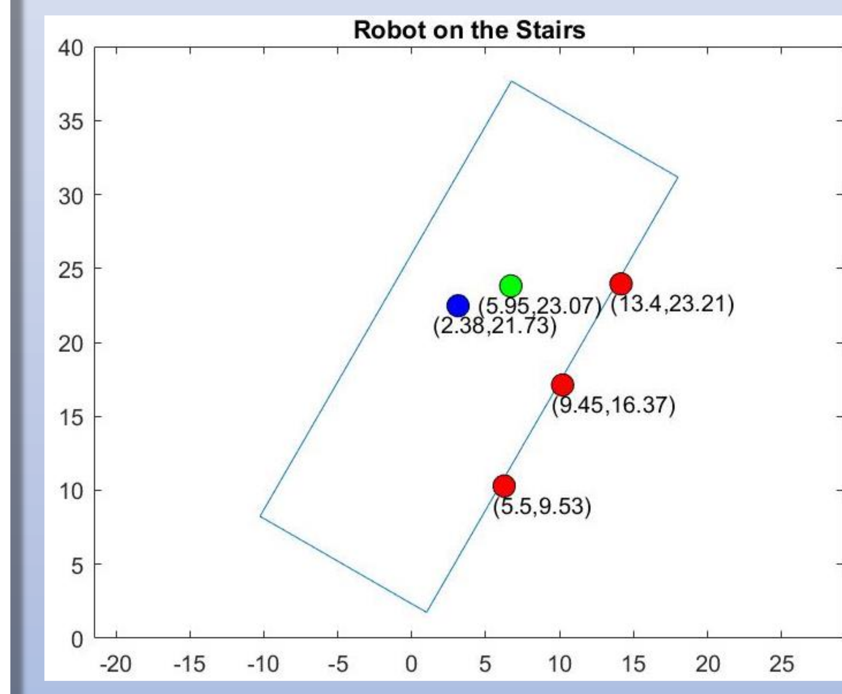
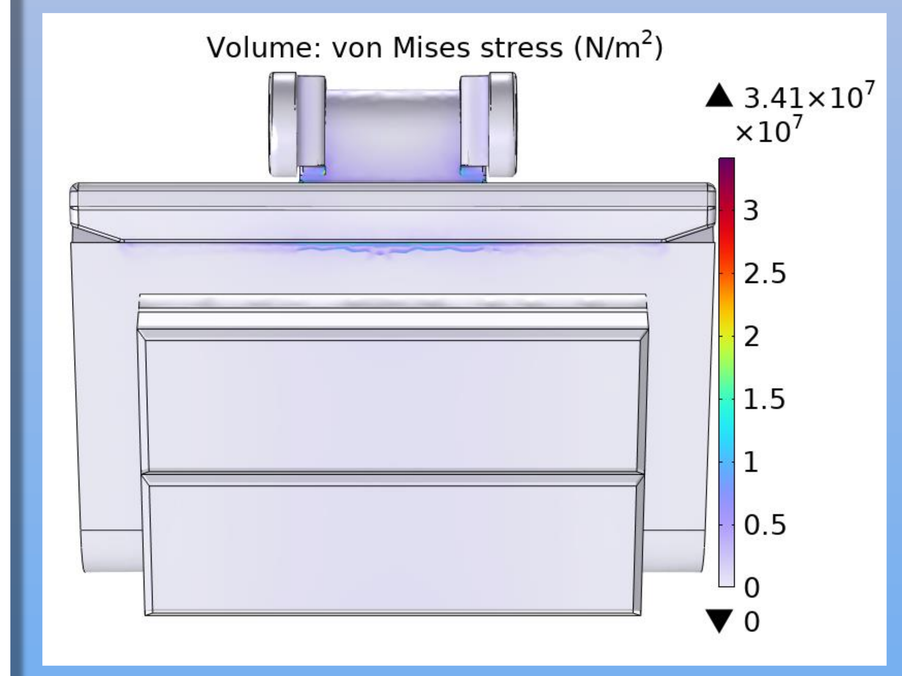
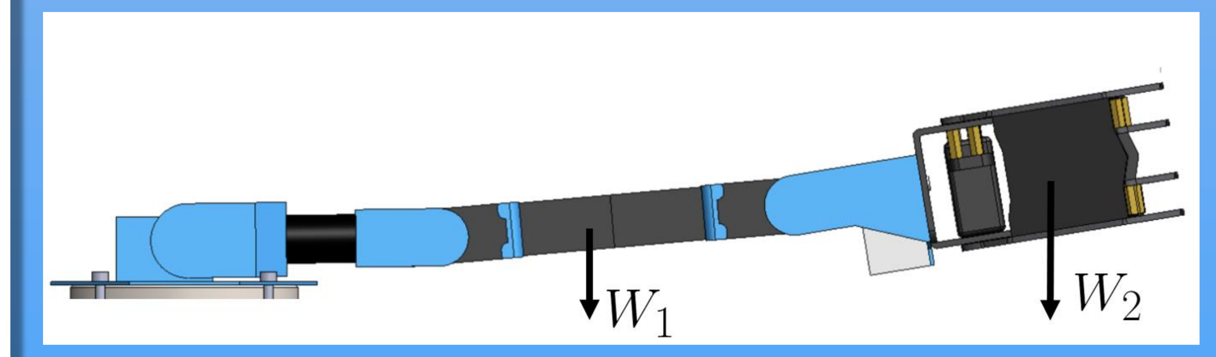


Figure 1 shows the center of gravity simulation on a 60-degree staircase. Red dots indicate the position of weight-bearing wedges, blue dot is the original center, and the green dot is improved center of gravity. The center of gravity improved Δx = 29.41 mm and Δy = -24.06 mm.



In Figure 2, a tread link's maximum stress is simulated to be 29.8 MPa, which is significantly smaller than the yield strength of the material (60-85 MPa).



In Figure 3, the arm's weight provides a total torque of 1.2 N·m. and the base servo torque we have is 3.5 N·m.

Final Results

The maximum angle of stability is **30.4°**, much larger than sea state 3, around 7°. The robot completed the course with **82.5%** reliability after multiple testing on rocking platform. Most importantly, the robot completed all the obstacles in **5 minutes and 16 seconds** and broke the record of this competition.

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