Tech Expo, Fall 2025– Team 14

Biomimetic Platform for Swarm Aiming

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Problem Statement

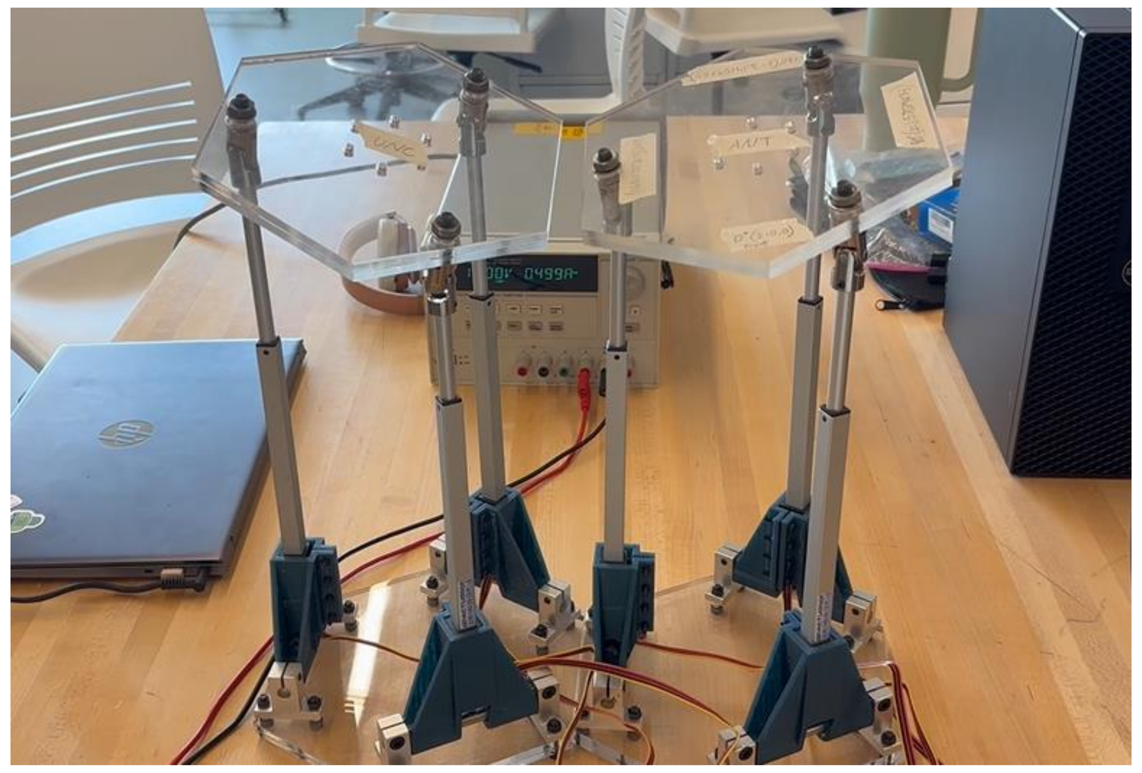
Unmanned surface vessels face constant motion, vibration, and harsh environmental exposure that disrupt precision and system reliability. High winds, corrosion, and debris demand platforms that can withstand and adapt to unpredictable conditions. Naval operations therefore require robotic systems that are both resilient and highly adaptable, maintaining speed, accuracy, and dependable performance despite continuous environmental and mechanical challenges.

Customer Background

As the largest of the Navy's five system commands, the Naval Surface Warfare Center does research and development, testing, and engineering for ship systems for the United States Navy. They have 10 locations across Washington, California, Indiana, Florida, Virginia, Rhode Island, Philadelphia, Maryland, and Washington D.C. Their vision is "to be the Navy's trusted partner for identifying and providing innovative, cost –effective technical solutions to the warfighter" (NAVSEA).

Requirements

The system must support interchangeable weighted payloads through a secure gripping mount, with each module capable of motion in the x, y, and z directions. Modules must also provide a ±45-degree tilt range to ensure flexible positioning and control. Additionally, all modules must be programmed to operate both independently and collaboratively within a larger multi-module system, and the overall architecture must be scalable to accommodate expanding numbers of modules and increasing operational demands.



Experimentation and Concepts

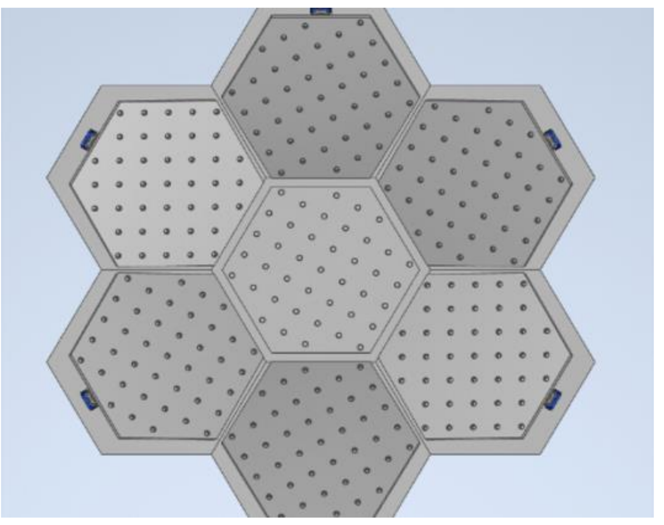
Multiple different biomimetic design concepts were considered to achieve the goal of aiming while on a ship. Some designs meant to closely mimic the behavior of the human neck with a series of stacked joints were considered.

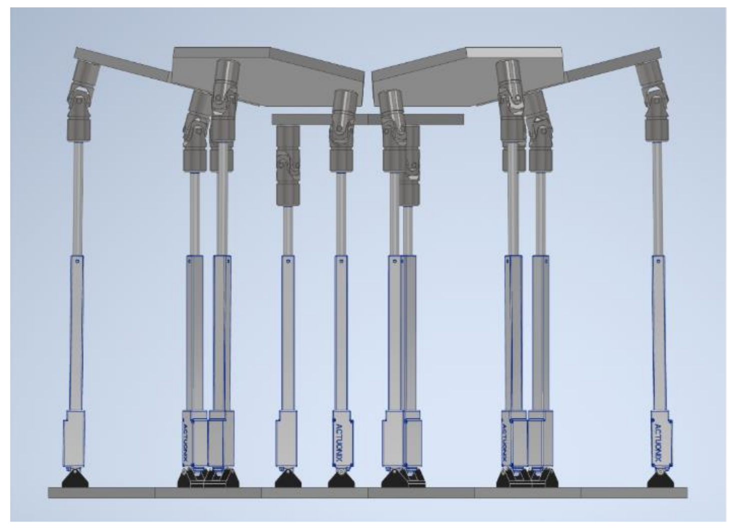
The concepts had various forms of controls including cables and pulleys, hydraulics, pneumatics, and electric linear actuators.

Experimentation focused mainly on the ROS2 environment and micro-ROS for communicating between embedded and non-embedded systems.

Iterative experimentation and development with kinematics and motor control code allowed for controlling the platform with target poses.

Later experimentation with inverse kinematics allowed aiming using a desired point instead of a desired pose.

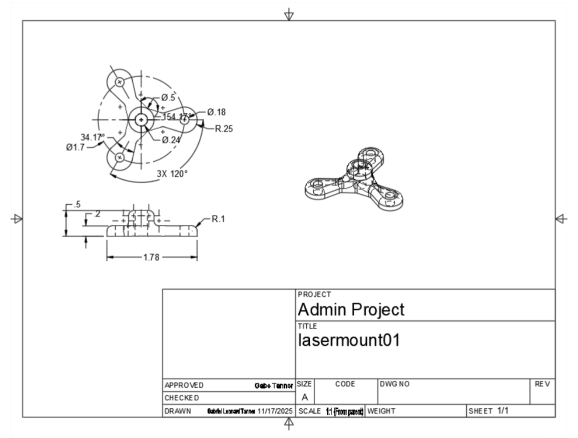


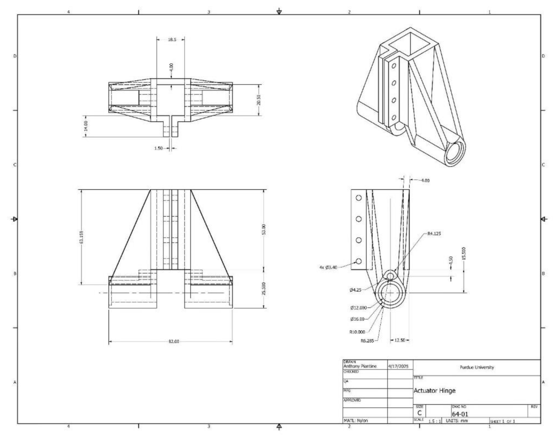


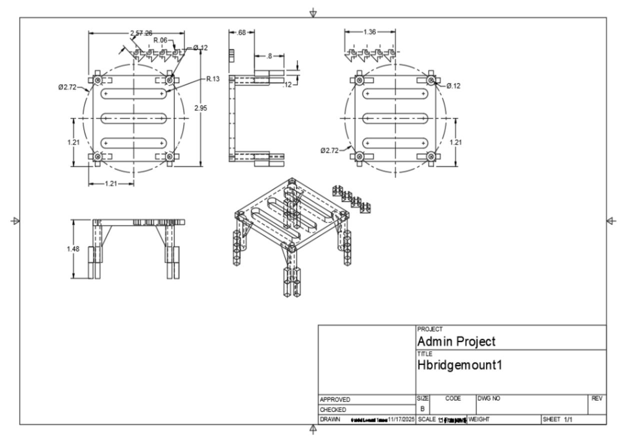
Final Design

The final design consisted of two individual platforms each consisting of three actuators. Underneath each platform is an Arduino Nano and two twin H-Bridge control boards to drive the linear actuators. The actuators contain integrated potentiometers, allowing for positive position feedback. While the current design only incorporates two platforms due to budgetary constraints, a full network of seven platforms is recommended for advanced swarm testing.

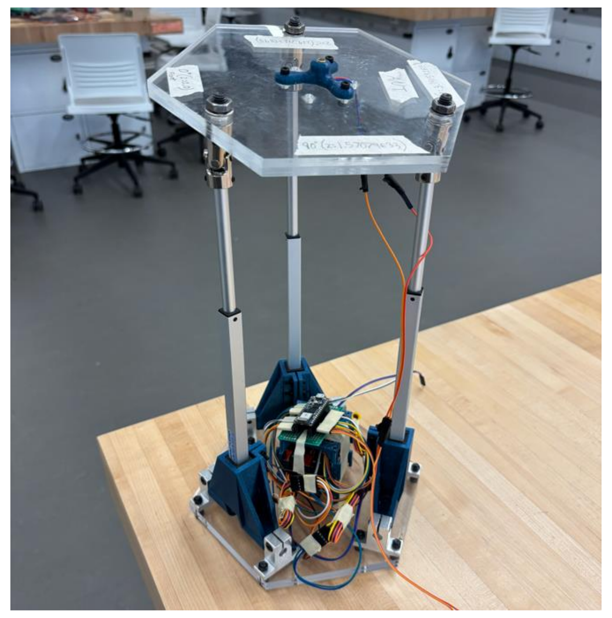
- Hexagonal base and face plates allow for theoretical unlimited surface coverage
- Wide actuator mounts contribute to rigidity and dimensional accuracy
- Holes on face plate allow for easy mounting of end effectors
- Electronics "pallet" allow for easy replacement and maintenance







Testing and Results



Testing focused on verifying the platform's positional accuracy and usable motion range. The module was homed at 0° with the actuators at mid-stroke, then commanded through a series of flat, ±X, and ±Y tilt tests from 15° to 48° while the actual platform angle was measured. Across all tests the system consistently returned to its home state between moves and achieved each commanded angle with an accuracy of about ±1°, indicating that the motion-planning logic and calibration were reliable and repeatable.

Some limitations were observed at the edge of the workspace. Tilts above roughly 40° generally required the actuators to operate near the upper height limit, and a homing step was needed between small moves because of the programmed tolerance band. These results show that the prototype meets its accuracy goals but would benefit from future optimization of angle–height relationships and tolerance handling to expand the effective aiming envelope.

8	Step	Action	Expected Result	Pass	Fail	N/A	Comments
9	1	Set the platform to fully retracted	Platform is a minimum height				
10	2	Measure plate angle	Light point is directly centered above platform (0)				Initial calibration test
11	3	Set the platform to +48 degree y-axis tilt	Platform is tilted +48 degrees in the +Y axis	Y			height of (-0.04 to -0.02)
12	4	Measure plate angle	level reads 48 degrees	Y			47
13	5	Set the platform to +45 degree y-axis tilt	Platform is tilted +45 degrees in the +Y axis	Y			height of (-0.04 to -0.02)
14	6	Measure plate angle	level reads 45 degrees	Y			44
15	7	Set the platform to +42 degree y-axis tilt	Platform is tilted +42 degrees in the +Y axis	Y			height of (-0.04 to -0.02)
16	8	Measure plate angle	level reads 42 degrees	Y			41
17	9	Set the platform to +40 degree y-axis tilt	Platform is tilted +40 degrees in the +Y axis	Y			height of (-0.04 to -0.02)
18	10	Measure plate angle	level reads 40 degrees	Y			39
19	11	Set the platform to +35 degree y-axis tilt	Platform is tilted +35 degrees in the +Y axis	Y			
20	12	Measure plate angle	level reads 35 degrees	Y			34
21	13	Set the platform to +30 degree y-axis tilt	Platform is tilted +30 degrees in the +Y axis	Y			
22	14	Measure plate angle	level reads 30 degrees	Y			29