The Autonomous Flocking μ-Sub (AFμS) Project

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Introduction

Underwater exploration is a field that holds significant stakes in our future sustainability and has major financial, social, and cibarious implications. Autonomous solutions to underwater data collection are too expensive, unwieldy, or time-consuming to be usable by small research groups, universities, or local governments, even though these entities can greatly benefit from technologies such as this. Our goal is to create a product that addresses these shortcomings by creating a low-cost submarine with flocking capabilities at a size that is easily managed by a single person. Mechanical engineers Alexander Pradhan and Samuel Veith will be designing the hull, thrusters, and renewable power generator for their capstone project.

Design Specs

- Will be able to operate for at least 1 hours before needing to recharge
- Will be able to communicate with subs at a max distance of 5 meters
- Will be able to communicate with a BER of < 5%
- Will be able to travel at a relative velocity of 3 m/s
- Will be deployable by hand
- Will be operable at depths up to 100 feet
- Will cost less than $500

Test Plan

Communication Test Rig:

To ensure that our communication solutions will be functional in the environments our system is designed for, we need some method of getting feedback as we develop the hardware and software aspects of the protocol. This is implemented via a system of rods with adjustable depth, distance and modular communication equipment mount-points. Having such specific control over these variables will give us a very good idea of impeding factors, such as noise, attenuation and multipath issues.

IMU Tuning Rig:

The most affordable solution for position estimation is an IMU (Inertial Measurement Unit). The calculations to derive displacement from the measurements result in a large amount of noise and error, which needs to be filtered out. To develop and tune the filters, a rig was made which can induce known acceleration on the sensor, providing a baseline to compare the filter functionality against.
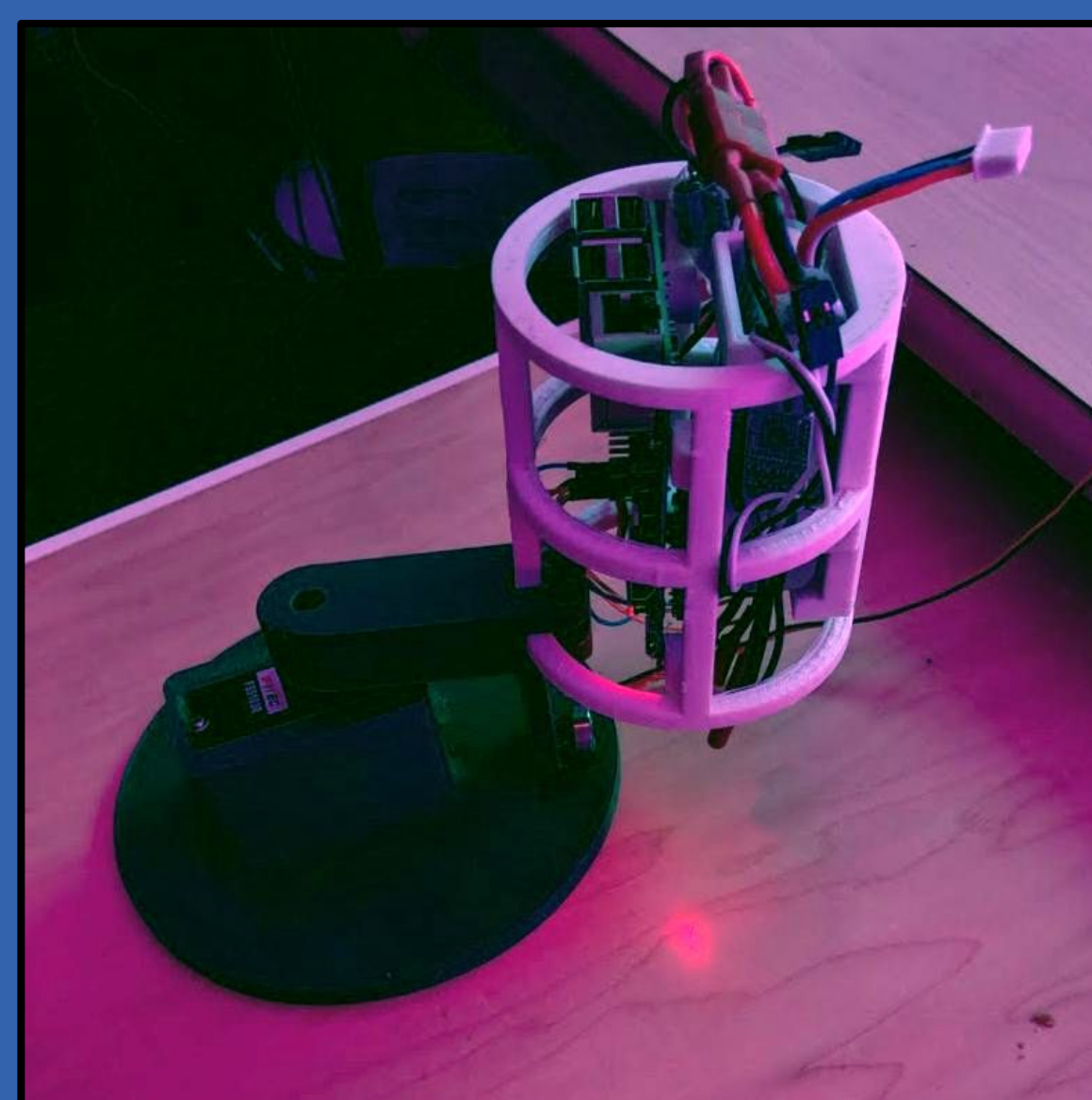
Filtered Vs Unfiltered Acceleration

Figure 1: the acceleration test rig

Figure 2: Filtered Vs. Unfiltered acceleration values from the rig

The initial filter results show significantly improved values, but they must be much cleaner to be of value. Currently, tests are being run to test the effectiveness of these filters across a range of induced accelerations and their parameters will be tuned accordingly.
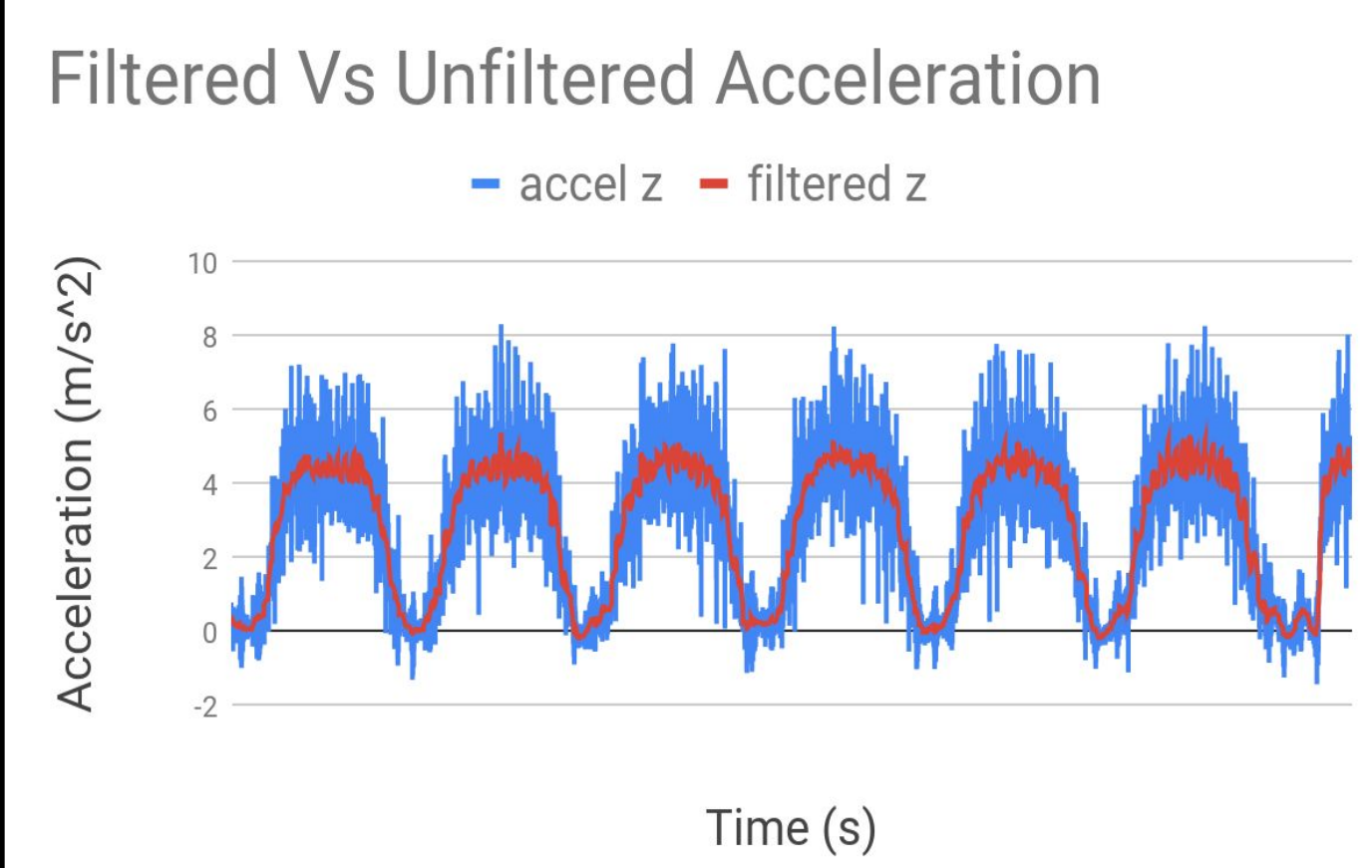
Acknowledgements

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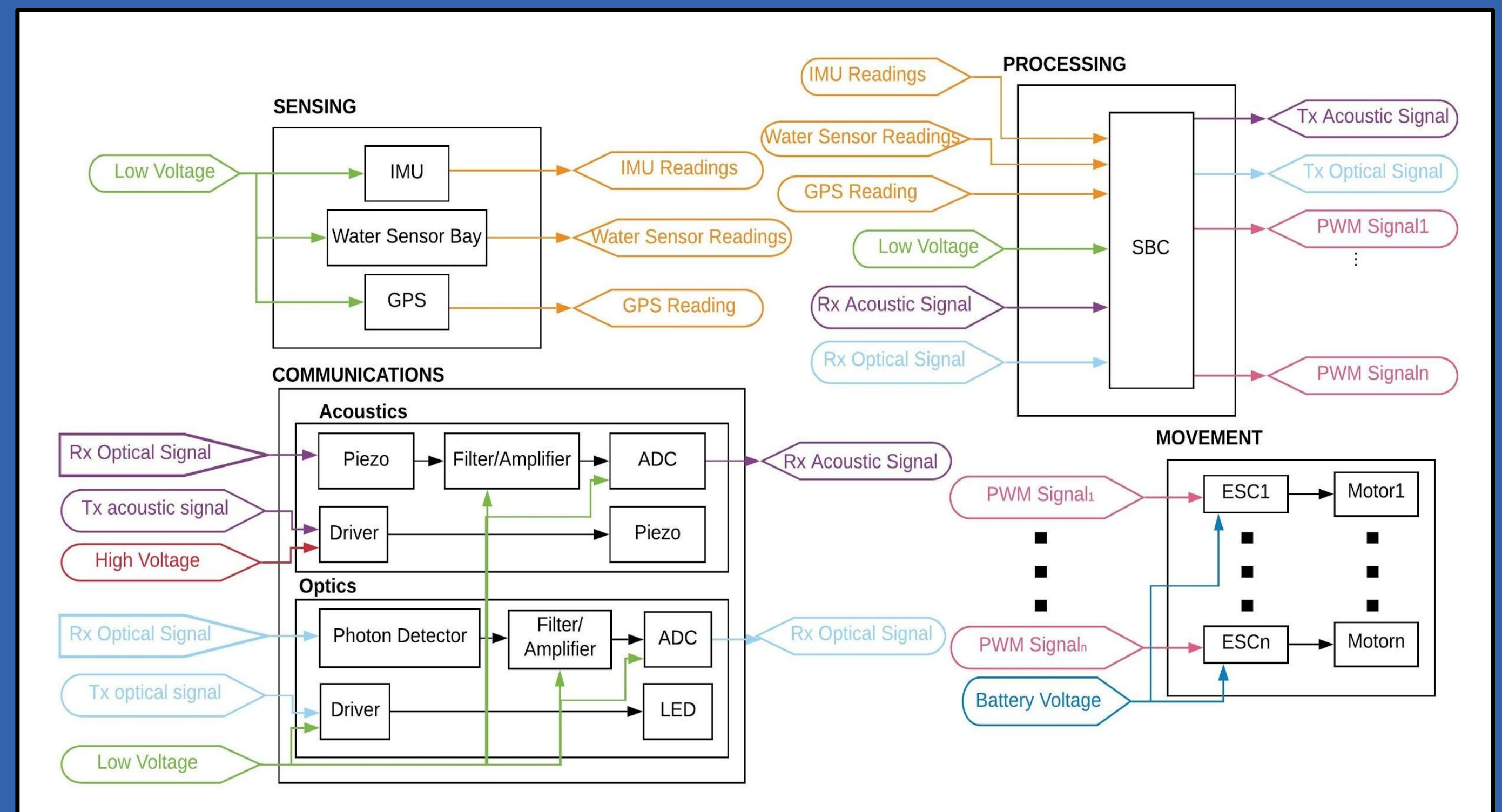
System Overview

Figure 3: Hardware I/O Block Diagram (omitted: Power block)

Design Plan

A minimum-viable product approach is taken to ensure both computer/electrical and mechanical engineering teams can iteratively design and test various functionalities as they continue development. Two prototypes are planned, followed by the final sub.

AFμS Test System (ATS) Mk. 1:

ATS Mk. 1 will exhibit the capability of free movement in two dimensions. Testable behaviors for this system include:
- point-to-point travel
- position holding
- heading realignment

The primary focus of this prototype is to confirm the base functionalities of our Inertial Measurement Unit (IMU)/extrapolated motion data and movement control system. An adjustable weight slide will allow us to submerge the system to a shallow depth.
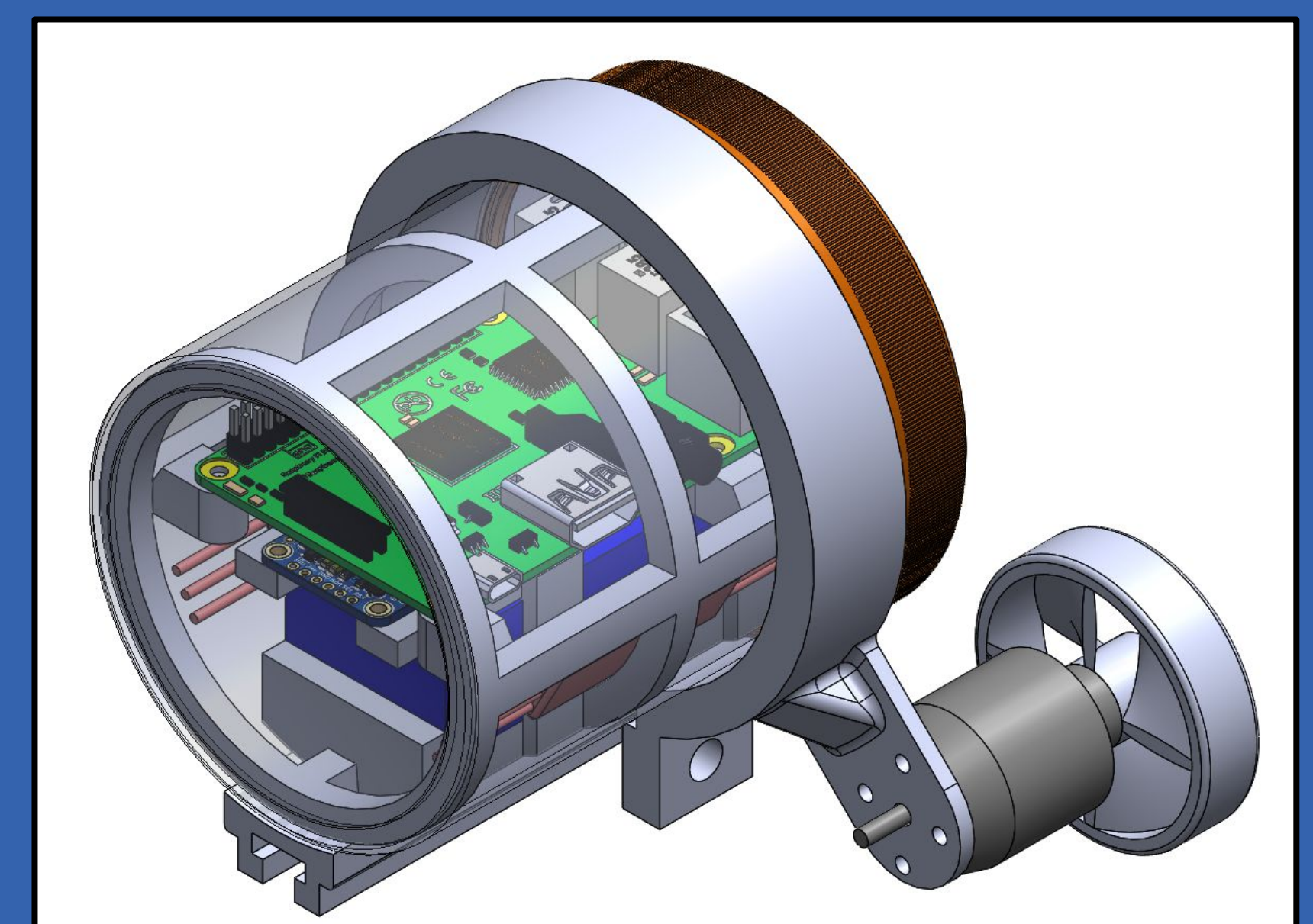
Figure 4: 3D model of ATS Mk. 1

AFμS Test System (ATS) Mk. 2:

ATS Mk. 2 will exhibit the capability of of three-dimensional movement and communicate acoustically/optically. Testable behaviors include:
- flock coordination
- data transmission
- data reception

The primary focus of this prototype is to extend two-dimensional motion capabilities into free movement in 3-space and test communication systems in mobile bodies.

Final AFμS:

The third and final iteration will display all planned behaviors. The final AFμS will exhibit the added capabilities of data collection from n water sensors, GPS-assisted referencing, renewable recharging, and detection of immediate surroundings. Testable behaviors include:
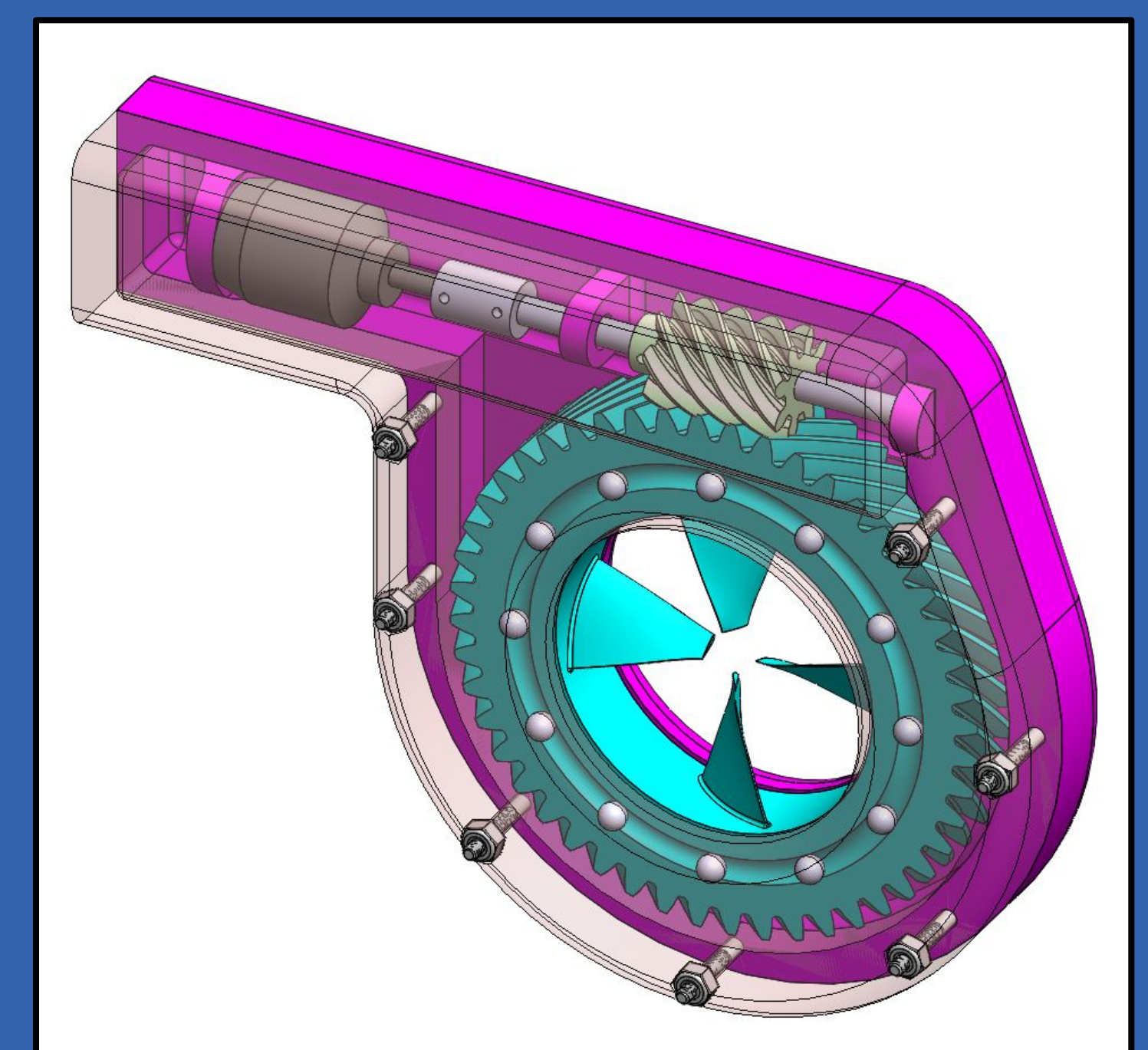- real-time data mapping
- residency
- obstacle avoidance

Figure 5: 3D model of hubless rim-driven helical gear thruster