Marine and Naval Technological Advancements for Robotic AutonomY (MANTA RAY)

KRILL & GUPPS

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KRILL Engineering

Three main sets of hardware have been improved to reach the engineering goals. **(1)** The propulsion system was improved through the redesign of all propellers to a B-Series Design. An upgrade of the rear propulsion system to a new relative high-power circuit, with BLDC motor. There was redesign and fabrication of driveline components. **(2)** Physical and digital sensor implementations done through the addition of a Blue Robotics sonar and pressure sensor. Additional development of pixy camera integration. **(3)** Ballasting was improved to make best use of hardware changes. A custom designed receptacle specific to KRILL takes maximal advantage of limited space.

Additional improvements to the software package was done through the implementation of a computational PID based controller with non-linear modifications. The controller can be activated to have KRILL automatically reach and maintain a specified depth. Non-linear additions consists of a controller dead zone, an integration creep protection, and compensation for breaking bearing static friction in bearings.

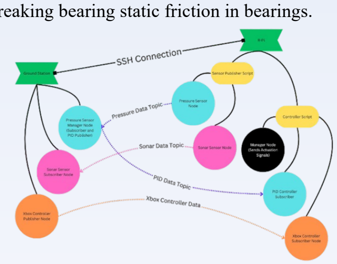


Fig 1. KRILL ROS2 nodal structure. Including how PID controller is implemented on KRILL.

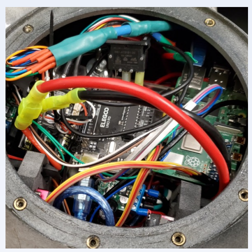


Fig 2. Internal wiring. VESC, Arduino, and R-Pi above batteries and motors

KRILL Biology

An environmental assessment of KRILL was done to ensure safety at testing sites. There are three points of environmental contact on KRILL: composition, sensors, and the propellors. The composition of KRILL consists of steel, anodized aluminum, plastic polycarbonate, and nylon polymer. None of these components will contaminate the water. The main sensor on KRILL that interacts with the environment is the sonar. Lights were also reviewed but are not on the current model. These in addition to the turbulence from the propellors resulted in the need for contingent protocol use. This protocol is:

- Visual and auditory scanning of area for marine mammals prior to deployment
- Marine mammals sighted within 450 yard, no sound above 229 dB
- Marine mammals sighted within 200 yards, cease use of sonar and avoid collisions
- Sonar use kept one wavelength distance from bottom during testing or half a meter whichever is greater

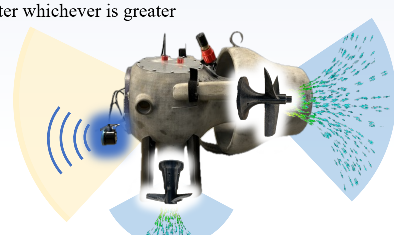
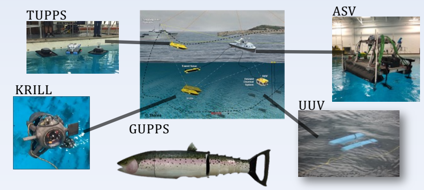


Fig 3. KRILL and visual points of environmental contact

MANTA RAY Mission

Team MANTA RAY is an interdisciplinary project dedicated to creating, maintaining, and expanding a network of marine robots for seafloor mapping and underwater perception. The network began as just the autonomous surface vehicle (ASV) and unpiloted underwater vehicle (UUV) but has expanded to include a prototype of the ASV, known as TUPPS, and two kinds of remotely operated vehicles, known as Ghost Unpiloted Performance Platform Submersible (GUPPS) and KRILL. With these systems, students work to improve communication between vehicles, develop autonomous behaviors and algorithms, and upgrade existing mechanical systems to improve precision and performance.



KRILL Mission and Goals

KRILL is an Uncrewed Underwater Vehicle (UUV) developed initially by the Naval Undersea Warfare Center, Keyport WA. The purpose of KRILL is to be an adaptable observation class UUV which can be outfitted easily to new technologies. However, KRILL before this school year, had poor dynamic performance and improvement was the main objective this last year. For testing and future use, an understanding of the environmental impact was needed to develop usage protocols for KRILL.

Goal:

Run Krill at 1m/s at 10ft of depth with two sensors running

GUPPS Mission and Goals

GUPPS is one of newest additions to the MANTA RAY fleet. The purpose of GUPPS is to unobtrusively investigate underwater areas of interest using a biomimetic robotic fish. Ultimately, GUPPS will be deployed in local AquaFort steelhead trout fisheries in Newcastle, NH. Last year, GUPPS team goal was to enable the biomimetic fish to swim in a straight line at a constant depth of 1 m. This year's goal was to upgrade to a microprocessor, to add pectoral fins and improve turning, as well as test the behavior of trout towards the hull.

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GUPPS Biology

Sea Grant's Aquafort in Newcastle, NH, is an offshore aquaculture platform hosting blue mussels, kelp, and *Oncorhynchus mykiss*, or steelhead trout. In farms such as Aquafort, it is vital to monitor the conditions and health of the fish. In this study, GUPPS will determine if there is a behavior change with different colors. We tested two hull colors and recorded the trout behavior with video. The footage was reviewed using an ethogram of stress behaviors exhibited below. From the data, it was determined that there was a behavior change upon introduction of the two hulls to the pens. There was no statistical difference in behavior between the painted hull and the black hull.

Behavior Type	Behavior	Code	Description
Overt Aggressive	Biting	BIT	Physical contact with GUPPS with mouth open
	Ramming	RAM	Physical contact with GUPPS with mouth closed
Restrained Aggressive	Lateral Display	LAT	Parallel to GUPPS, dorsal and anal fin flared, open mouth and stiff body, limited to no body motion
	Wigwag	WIG	Lateral display with large body motions
	Fast Approach	FAS	Fast direct approach, no physical contact with GUPPS
Submissive	Rapid Retreat	RET	Rapidly traveling away from GUPPS
	Submissive	SUB	Depressed dorsal and anal fin, partially folded caudal fin

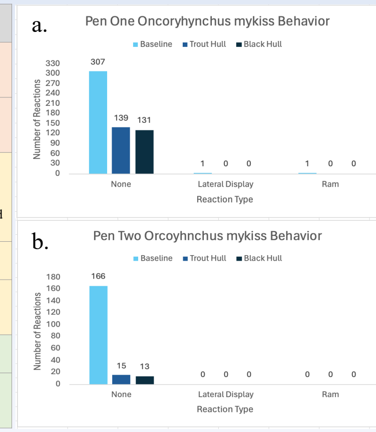

Fig 4. Ethogram representing possible trout behavioral displays

Fig 5. Bar graphs of the baseline, trout hull, and black hull reactions recorded every 10 seconds in a total of 5 minutes in Aquafort pen 1 (Fig. 5a.) and pen 2 (Fig. 5b).

GUPPS Engineering

GUPPS engineering goals included adding pectoral fins and redesigning the tail and hull size. **(1)** The head was modified to attach servo motors for controlling two pectoral fins individually. These fins will work together with a buoyancy control unit to adjust pitch and depth in water. **(2)** The tail was redesigned to enhance flexibility. The tail was lengthened, and a fixed rod was used to allow the third tail piece to rotate freely. A new caudal fin was made from durable TPU be easily replaceable. **(3)** The main body was adapted to fit a waterproof enclosure from Blue Robotics, housing a battery, buck, and Raspberry Pi. This required enlarging the body and adding a collar at the rear for added strength, replacing previous tabs connecting the tail and body. Additionally, GUPPS was upgraded to be operated with a tether and a game controller. Previously GUPPS was only able to execute simple programs run on a microcontroller.

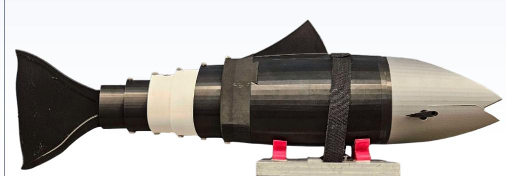

Fig 6. Redesigned Hull

Fig 7. Waterproof enclosure and internal wiring