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Project Oswald – Final Executive Summary

Oceans are the lifeblood of planet earth and mankind, holding 97% of the planet's water. Consequently, humans have always been interested in ocean exploration, both in terms of mapping the ocean's floor as well as understanding the wildlife that inhabits it. To this end, there has been significant research on the development of underwater robots that can integrate into the sea seamlessly and become useful members of it by collecting data from the underwater ecosystem. Many of these robots try to imitate marine animals and their biological features that enable them to be such great swimmers.

Our project draws inspiration from penguins, which constitute one of the most extraordinary animals that can swim underwater, thanks to their unique propulsion mechanism, guided by the flapping motion of their flippers and their streamlined body. The most successful attempt of building a penguin bio-inspired robot is Festo's AquaPenguin robot, which is using a flapping mechanism to produce thrust and can navigate autonomously in underwater environments. However, AquaPenguin's developers did not focus on optimizing the flapping motion, especially in terms of the impact of the flipper design on the overall resulting motion. We believe that there is significant potential for improvement in the flapping motion in correlation with the flipper design. This project investigates this hypothesis by building a robot that takes advantage of penguins' special thrust producing mechanism and examining the effect of different flipper designs on the robot's speed and energy efficiency.

The robot has a hydrodynamic outer body which consists of a series of ribs and spars made of acrylic, ensuring the structural integrity of the design, as well as a tail for stability. Enclosed in the outer body lies the 3D printed mechanism that produces the desired flapping motion. This mechanism is inspired by mechanisms currently used by robotic birds, allowing for rotation of the flippers in all directions in order to replicate penguins' motion in a realistic way. For waterproofing, we incorporated a three-layer protection system in our design, comprised by a waterproof box that stores all sensitive electronic components, followed by a two-layer waterproof cloth protection that fits directly onto the outer surface of the body. Finally, we designed three types of flippers that differed from each other in terms of length, curvature and compliance.

We tested each subsystem of the robot separately, ensuring that all electronics function properly and all key components remain completely dry. After achieving the desired flapping motion on land, we proceeded to test the entire robot in a water tank in order to validate the overall efficacy of our waterproofing system as well as our research hypothesis. Even though our simulations had clearly shown that our different flipper designs reduce the drag force, offering increased speed and energy efficiency to the robot, we were not able to demonstrate these findings by testing in the water. A key component of our mechanism failed and we were not able to conduct as many experiments as needed to test all the different flipper designs. However, all the electronics remained untouched by water and our robot was able to produce thrust and forward propulsion, which indicates that we have a fully functional underwater robot.

We believe that by incorporating minor modifications into our design, such as by replacing the 3D printed mechanism with the same mechanism made of steel, we could increase its robustness and conduct more experiments. In this way, we are confident that we will be able to validate our hypothesis and successful simulation results experimentally.