Executive Summary

We were tasked to design and manufacture a bio-inspired active suction system for whale tags. Researchers use whale tags to monitor and record marine animal behavior and noise in order to understand the impact of ocean noise pollution on the animals from objects such as ocean freighters and military sonar devices. Active suction uses electronic elements to regulate the pressure differential between the suction cup and the atmosphere. The current whale tags use passive (store bought) suction cups to attach to the animal. Passive suction has no way of regulating the internal pressure of a suction cup, which can cause inconsistent attachment times for the whale tags. We solved the inconsistent attachment time problem through active suction. Our active suction whale tag provides a more reliable attachment time by enabling us to monitor and change the pressure differential between the suction cup and the environment when the differential gets too low. It operates and withstands the fluid forces of cyclic diving for at least 24 hours while weighing less than 250 grams, taking up less than 500 cm^3 in volume and enduring the water pressures up to 1000 meters below the sea surface. The delivered tag is functioning, though it is not waterproof and a 3D printed analog is used instead of the designed syntactic foam because of long lead times.

We broke the problem down into three major functions, which were pressure regulation, suction cup type and system type. We focused on two concepts to regulate pressure. The first used a micropump to remove fluid from the cup and the second utilized active valving with a solenoid valve and a passive pump. We then had to determine what kind and size of suction cup would work best for our whale tag. We considered elements such as slippage, weight and fluid force resistance, and it came down to three types of cups: soft bell shaped, flat semi-rigid and hard plastic case. The final function was the system type, open or closed; we needed to figure out which concept best suited our project requirements.Using concept selection techniques, we determined that our whale tag would be an open system, and use active valving with a semi-rigid flat suction cup. From this proposed concept, we had to objectively determine a final design. After careful experimentation and analysis we determined that a flat suction cup with an 11.7 cm diameter can withstand the fluid forces required and is drastically lighter in weight than larger tested cups. We found a micro solenoid valve that is lightweight with low power consumption. We found the stroke size of the passive pump through suction cup leakage testing and mass flow calculations. Our design uses 3D printed plastic as an analog for low density syntactic foam for buoyancy, and can be encased in a urethane housing to keep it waterproof. We designed for a check valve to allow fluid to release to the atmosphere to keep the system open. The pressure differential will be measured through two pressure sensors, one of which will be inside the suction cup and the other will be exposed to the atmosphere. The overall shape of the whale tag will resemble a pill capsule.

We machined the passive pump out of acrylic using a mill. The syntactic foam analog was 3D printed. The prototype is functioning and proves the active suction concept, however, it does not have the designed buoyancy and is not waterproof. We validated the function through cyclic pressure testing in a pressure cooker, 24 hour suction testing, leakage testing and pull tests. We have validated our system, and with more time, could have delivered an ocean proof prototype.