# Palouse Robosub Technical Report

## Abstract

Our team aimed to complete the pre-qualification, start gate, hit a die, path marker, and roulette wheel tasks. To support this we aimed to perform in-water tests weekly with little to no interruptions due to modifications. Based on a survey of the previous year's top 8 teams we aimed for 400 in-water hours between the 2017 RoboSub Competition and the 2018 RoboSub Competition. We were able to consistently test weekly as the submarine's systems are modular and has already undergone intensive testing of critical systems such as control, sensors, and vision. To accomplish our primary goals we aimed to cut weight, add a hydrophone subsystem, and add a marker dropper subsystem.

## Competition Strategy

First, we wanted to test as much as possible. A survey of last year's finalists told us that on average each team in the finals had about 300 hours of in-water testing, with the winning team being an outlier at about 600 hours. In an effort to be comparable to these successful teams, we scheduled a four hour test every weekend with the goal being 400-500 hours total. Second, we wanted new features to have minimal impact on testing. To do this, we broke our goals down into changes small enough that they could be installed during the week and testing could continue, unimpeded, on the weekend. Coming into this year the sub was able to maneuver effectively, and receive sensor data. We had a fully functioning control system and a deep learning vision system for object detection which needed work. We could see that our focus should be on reliable vision, reliable AI (Artificial Intelligence), and developing a hydrophone localization subsystem. We planned two different sets of goals for the year, primary and secondary goals. Primary goals were tasks along our desired route that we considered our critical path. Secondary goals were tasks close to our desired route that we would include if we had extra engineering and testing time. Our primary goals were: pre-qualification, qualification gate, hit a die, follow path markers, and the roulette wheel task. We estimated that this approach would take us into the finals. Although we acknowledge that there is significant variance in competition scores, so our estimate could easily be too high or too low. Our secondary goals were: shoot craps and play slots. Both of these tasks are close to our primary route and mostly required testing time with little modification to the submarine.

## Design Creativity

In an effort to meet the Computer Science goals for this year, we placed considerable effort into software process refinement. This approach of focusing our attention on automating particularly slow parts of our process had a significant impact on our overall effectiveness. For example, a lot of work was placed in expediting our image labelling workflow as it quickly became a bottleneck on progress given our rigorous testing schedule. This allowed us to eventually have an approximately 5 day turn around on image labeling and training of our deep neural network for object detection. By improving our ability to test and prove our object detection systems, we found the next bottleneck to be our AI development process. In an effort to increase the amount of reusable code for the entire system, we opted to move from a strictly mission scripting-based system towards a Hierarchical State Machine system. This allowed us to not only encapsulate AI operations into more user friendly, higher level concepts, but to also reuse previously written states. This way, once a lower level AI task had been proven to work, it could be easily reused and incorporated into other tasks. We found that the simulator created in the previous year, though not perfect, was very effective in testing this logic to the point where many in-water tests became a matter of tuning parameters for the real world. This reduced the amount of time the submarine was idle in water and greatly increased the efficiency of tests. At this point in development, we were able to focus on other systems, such as the hydrophones to localize the submarine in the pool, as well as incremental improvements for our deep neural network and AI without worrying about interfering with the testing schedule.

## Experimental Results

Our testing began with proving the stability of existing systems in-water. These tests turned out very promising and allowed us to move on to testing the vision subsystems in-water in parallel with testing AI systems in simulation. This directed mechanical and electrical systems towards making improvements that did not require taking the submarine out of commission for long periods of time as well as allowing in-water tests to be focused on new software rather than ensuring seaworthiness. Given that software could be developed from virtually anywhere, students could commit more time knowing that their code would be tested regularly. Alongside this, new hardware subsystems could be developed and tested without requiring the submarine's platform. This meant that individual portions of the submarine could be proven as prototypes and then time could be scheduled to install them on the submarine itself. Simulation testing also allowed software for these portions to be tested without needing the physical prototype. Once these systems were installed, minor software changes were required to get them fully functional onboard.

## Discussion

While considerable efforts were put into planning, we believe we fell short in terms of project management and time management. Projects in the critical path, often, would have benefited from tighter deadlines which were more strictly enforced. Additionally, our overall timeline was often unclear to most team members. We also did not prioritize work time towards the beginning of each semester, leading to project drift into the end of each semester when students had less time to commit. Another area where we had shortcomings was in organizing work time. We had scheduled many meetings to talk about plans and goals (2 per week) when we should have been scheduling time to work on projects and team building. Despite these flaws, we still made significant advancements to the capabilities and the stability of the submarine. The hydrophone subsystem was successfully added, the deep vision system was stabilized, and the power system was redesigned to reduce weight and increase reliability.

## Acknowledgements

We would like to acknowledge our sponsors and mentors for their generous donations of time and resources. Their contributions allow us to continue improving our submarine and educating new engineers to ensure a successful future.
Our primary sponsor is NAVSEA. They contribute the majority of our funds and provide technical mentorship in the form of two of our mentors, Alex Read and Aaron Darton. We are particularly grateful to both Alex and Aaron. Their encouragement and advice has helped us avoid pitfalls and develop as a team.
Finally, we are grateful to our advisors, Dr. Matthew Taylor, Dr. Aaron Crandall, and Dr. Patrick Pedrow, for providing invaluable advice.

## References

### Appendix A: Component Specifications

| Component | Vendor | Model | Specs | Cost |
|---|---|---|---|---|
| Frame | Custom made | | | |
| Waterproof housing (bulkhead) | Custom made | | | |
| Waterproof housing (ESC cases) x2 | Blue Robotics | Watertight Enclosure for ROV/AUV | 3” series | $143 |
| Waterproof Connectors (Penetrators) | Blue Robotics | Penetrators | 6mm and 8mm | $4-5 |
| Thrusters x8 | Blue Robotics | T200 thruster | | $169 |
| Motor Control x8 | Blue Robotics | Basic ESC | 30A | $25 |
| High Level Control | OSH Park | Custom Printed PCBs | | Varies |

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|---|---|---|---|---|
| Actuators | dfrobot | DF15RSMG | 360 degree motor (20kg) | $18 |
| Battery | Tattu | Z160218014100006 | 16000mAh, 14.8V, LiPo | $223 |
| Converter | Droking | X000Q0Z0DR | LM2596 Buck Converter | |
| Regulator | Droking | X000Q0Z0DR | LM2596 Buck Converter | |
| CPU | Intel | NUC | Intel Core i5 | |
| Internal Comm Network | Netgear | GS108 | 1Gb network switch | |
| External Comm Interface | Subconn | Subconn Circular Series | 8 pin | |
| Programming Language 1 | | C++ | | |
| Programming Language 2 | | Python | | |
| Compass | PNI | TRAX | | |
| IMU | PNI | TRAX | | |
| Cameras x3 | Pointgrey | Fl3-GE-14S3C-C | 1.4MP, 1384x1032, 18FPS | $895 |
| Hydrophones | Aquarian Scientific | AS-1 HYDROPHONE | | |
| Algorithms: Vision | | Deep Neural Network | SSD Inception, Tensorflow | |
| Algorithms: Acoustics | | Time Delay Cross Correlation | | |
| Algorithms: Localization and Mapping | | Kalman and Particle Filter | | |
| Algorithms: Autonomy | | Hierarchical State | | |

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|---|---|---|---|---|
| | | Machine | | |
| Open Source Software | | ROS, OpenCV | | |
| Team Size | | | 25 | |
| HW/SW Expertise Ratio | | | 60/40 | |
| Testing Time: Simulation | | | ~600 hrs | |
| Testing Time: In-water | | | ~180 hrs | |