National Aeronautics and Space Administration

Autonomous Operations For An Ocean Worlds Submersible

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Program: Topic Area

Project Objective:

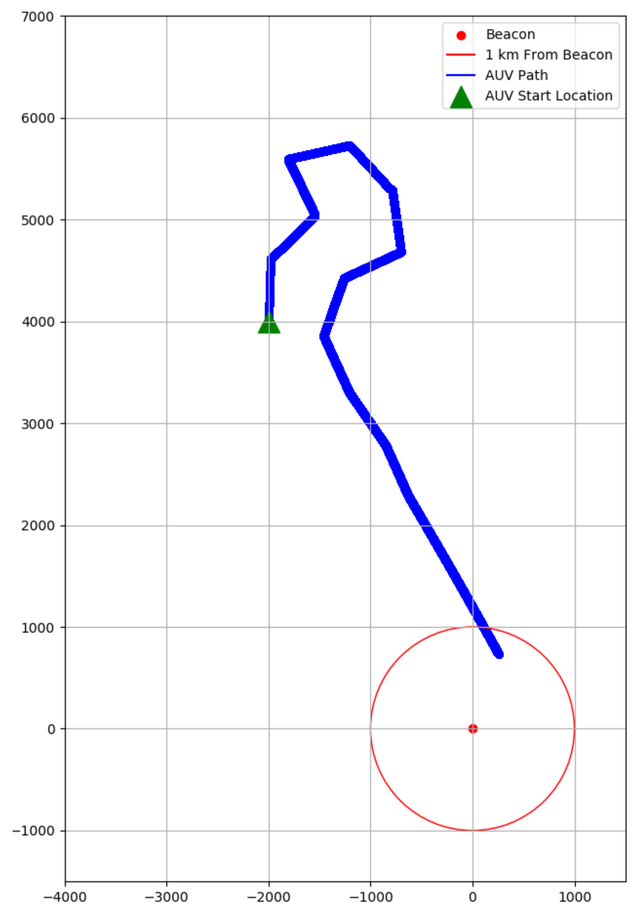
Icy-world oceans such as those on Europa and Enceladus present some of the most promising habitats for discovering exolife in our solar system. Unfortunately, even after transit through the icy shell to access the ocean world, an exploration vehicle would need to operate largely independently from Earth-based ground operations teams. With terrestrial like endurances and speeds, to explore a significant portion of the ocean, the submersible would require excursions involving weeks to months away from communications with Earth in an unknown and dynamic environment.

Our approach would utilize a submersible deployed from a surface-linked base station capable of two-way communication with Earth. The base station would use a single acoustic beacon to communicate with and provide ranging data to the vehicle to enable navigation. The submersible would incrementally explore and map the ocean, successively venturing farther and farther from the base station to explore larger portions of the sub-ice environment to search for life signatures and habitats (e.g. hydrothermal vents). Autonomous operations are crucial on the path to enable direct study of the subsurface oceans on Ocean Worlds. The autonomy challenges covered in this work are to respond to science signatures while acquiring/maintaining sufficient positional knowledge to locate/measure/map phenomena and return the data safely to the base station, all within a dynamic 3D environment of currents and unpredictable scientific phenomena of interest.

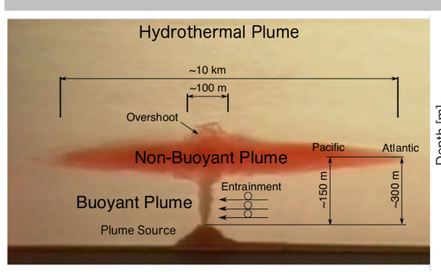
The objective of this project is to develop and validate autonomous operations behaviors to study scientific features of interest and enable navigation for months long underwater explorations to map and hunt for life and habitats from a single base station. Specifically, we were interested in autonomous targeting of underwater fronts and hydrothermal venting and enabling a vehicle to return to within acoustic communication range of a single range-only acoustic beacon.

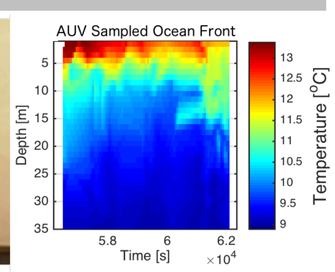
Single Range-Only Beacon Homing

Traditional AUV navigation methods are unlikely to be feasible on an Ocean World due to required size and power. Two constraints drove the development of this navigation method. First, we assume we only have a single range-only acoustic beacon on the base station which we can use for navigation. Second, due to the large magnetic field of Jupiter and time varying induced magnetic field of Europa we assume no magnetic navigation would be possible. We use a modified Golden Selection Search to locate the heading which results in the largest change in distance to the beacon, periodically restarting this search to account for errors.



Golden Selection Search homing example



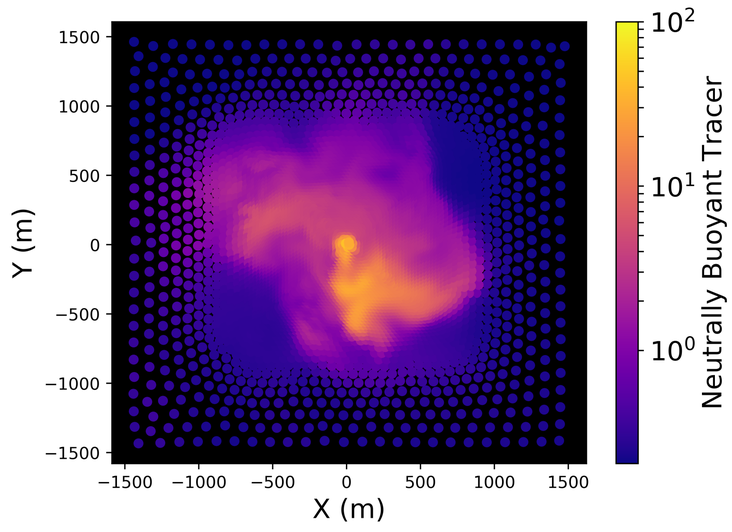


Target science features hydrothermal plumes (left) and ocean fronts (right)

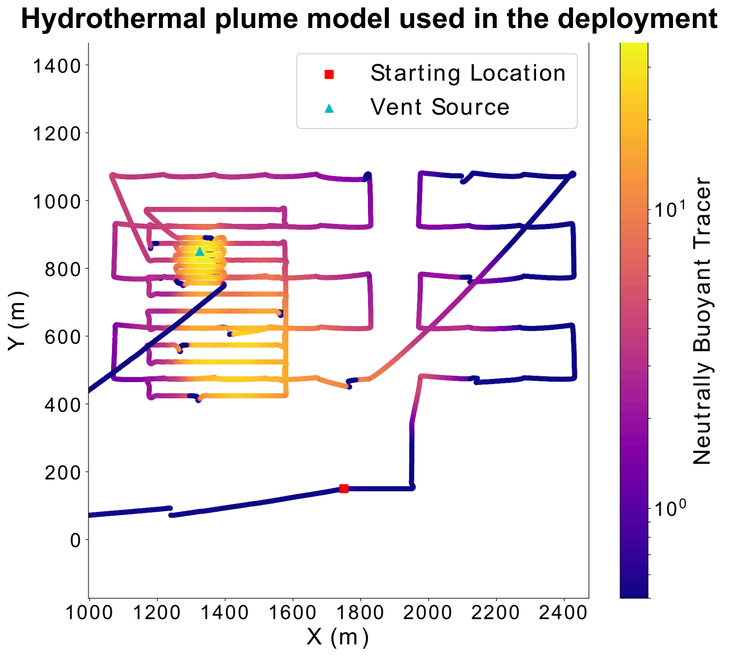
Hydrothermal Nested Search Demonstration

From 3 June to 7 June 2019 the RTD Team along with NRL deployed an OceanServer Iver2 AUV executing a hydrothermal vent localization algorithm in Chesapeake Bay, MD. As there is no hydrothermal venting in the deployment area, we used simulated data from a FVCOM based hydrothermal plume model. This search method uses nested lawnmower patterns of increasing resolution and decreasing size to localize the hydrothermal vent. This is based on a field tested manual approach.

Iver2 AUV on the shore of NRL's Chesapeake Bay Detachment



Hydrothermal plume model used in the deployment



Mission performed during the deployment

Benefits to NASA and JPL (or significance of results):

These technologies enable an Ocean Worlds submersible mission and further under-ice exploration on Earth by allowing the pursuit of unscripted science features. Collaborations performed through this work with other oceanographic institutions provide pathways for more involved deployments to test these autonomous systems in under-ice locations on Earth as an analog for sub-ice oceans on Ocean Worlds.

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