Multidisciplinary Development of an Autonomous Underwater Vehicle: Navigation & Spatial Awareness

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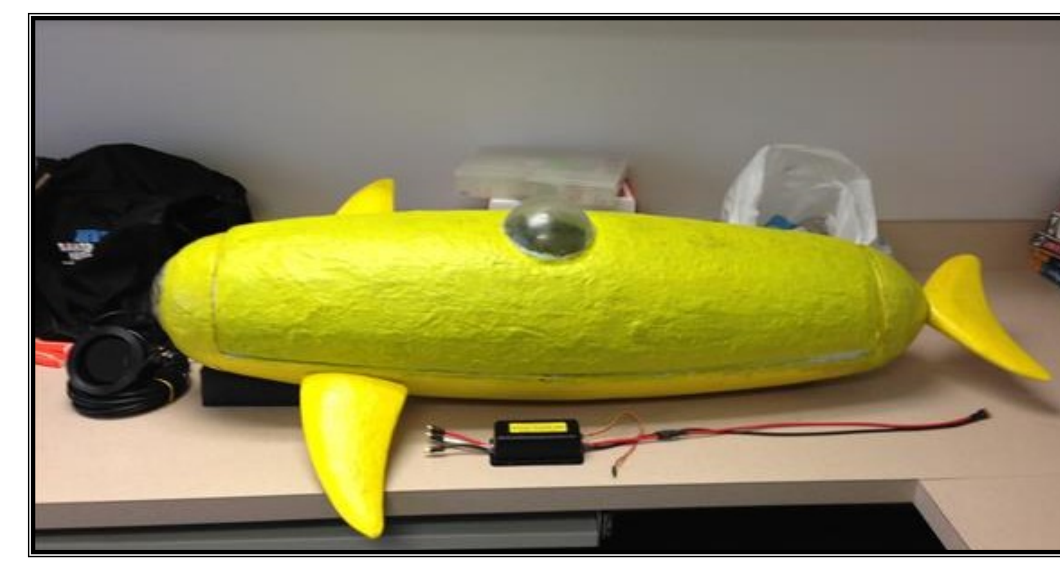
Society for Industrial Applied Society for Industrial Applied Mathematics

EMBRY-RIDDLE Aeronautical University

Abstract

The team has completed the second phase of the program that involved tracking the Dolphin while submerged underwater. This phase funded by IGNITE and titled, Navigation and Spatial Awareness System for the Eco-Dolphin, was successfully completed this summer, 2013, with three rounds of testing at Embry-Riddle's swimming pool. Apart from building the Red and Blue Dolphins, the team is also working on adding GPS system for surface tracking. We are also converting our acoustic system from tethered to wireless to make our ground station more robust.



Introduction

The goal of this project was to build the first Adaptive AUV and three buoys with Communication features. This project is the second phase of a five year program known as the Eco-Dolphin Program. The Eco-Dolphin Team of SIAM Student Chapter at Embry-Riddle received funding from IGNITE in the fall of 2012, for work on this project. This phase seeks to develop three buoys and improve the reliability of the communication hardware and

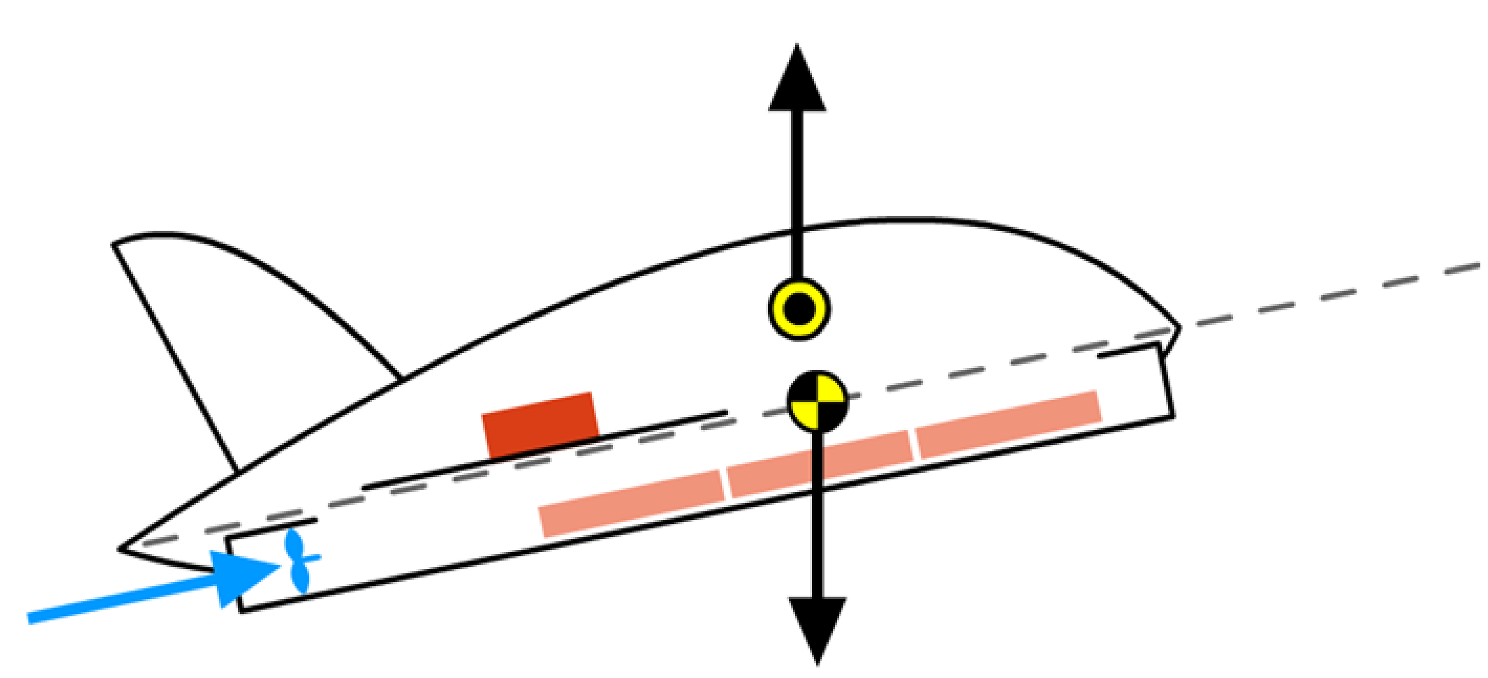
Electronics control Box

The Waterproof Electrical Box was manufactured to an 8 inch internal diameter. It hosts the GPS, a single board computer, battery and adapter cable. Internal LED warning light prevents obstacle collision in nighttime operations. The Cover is designed from a 4" PVC Pipe and its total length is 5 feet which calculated through the steps below. The hydrophone and transmitter is designed to be positioned on the bottom section of the Cover for the acoustic network. It is going to be linked to the electrical dome by a tether cable and the adapter card.

Ballast Attitude Control Unit

The Eco-Dolphin Ballast Control Unit has been in the development phase for the fall semester of 2013.It is now at the construction phase. This unit will allow the Blue Eco-Dolphin to shift the center of gravity based on the calculation for the mass displacement. It is control by an Arduino Uno and a Stepper Motor Control Board. The Nema 17 stepper motor is a precise and efficient source of power connected to the torque screw that allows us to shift the main weight located inside the body of the Eco-Dolphin.

The heaviest components of the body are the 12 lithium batteries connected in series around the torque screw that will power the stepper motor. It will be an independent attitude control system that will allow the Blue Eco-Dolphin to dive or emerge from the ocean floor. As an emergency system there are two limit switches located at the top and the bottom of the torque screw that are connected directly to the Arduino Uno. These limit switches will shut down the stepper motor once it has reach the upper and bottom limits. This safety feature will ensure a correct positioning for the center of gravity as well as protect the mechanism from over turning. The Ballast Attitude Control Unit will be completed by Summer 2015.



Conclusion

The set of three buoys allows the Eco-Dolphin team to track the location of a group of AUV's while they are submerged below water. The buoy system acts as the relay station from surface operations to underwater operations, which is a necessary link in communication required for navigation and spatial awareness of the platform design. This segment started with designing the three buoys, taking the product into manufacturing, and redesigning details to fulfill the tasks required of the network. Testing was performed on both the buoyancy and stability of the buoys in the ERAU pool through prior appointment. The acoustic component of the NSA System consumed all the financial resource that was in the budget such that the GPS component of the NSA System could not be worked on. Hence the GPS navigation remains to be a future research component for the organization.

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Acknowledgment

Dr. Hong Liu., The Mathematics Department, Honors Program, IGNITE Office, Embry-Riddle Annual Fund, SGA and Hydroplus Engineering LLC.

Eco-Dolphin – Cooperative Fleet for Surveillance Mission

SIAM, Society for Industrial & Applied Mathematics, members have been working for two years on the design, construction and testing of three highly integrated and streamlined autonomous underwater vehicles called Eco-Dolphins. This project is being developed at Embry-Riddle Aeronautical University's Daytona Beach campus. The Leverage lab is used to create detailed mathematical models and conduct preliminary research for both electrical and mechanical systems. The campus Composites lab is used for the fabrication of structural and aesthetic components used by the high adaptable platform. The Autonomous Underwater Vehicle testing is conducted in the Universities Nonlinear Waves lab. The first phase of design, production and assembly of the yellow Eco-Dolphin prototype has been done in twelve months. The design includes an internal attitude control system, combined with internal propulsion from brushless direct current thrusters, thus allowing the vehicle to ascend and descend. The Eco-Dolphins promise is to be a unique, highly optimized and a competitive underwater vehicle fleet. The team has also successfully completed the second phase of the program, which involved tracking the Eco-Dolphins while submerged underwater. Work has been conducted to add a GPS system for surface tracking. Converting the acoustic system from tethered to wireless to make the ground station more robust. The Eco-Dolphin is configured with recently developed control system software that utilizes a relay combination of Wireless, Sonar and GPS radio wave communication. The current progress on the blue Eco-dolphin will be completed by the summer of 2014, for testing in littoral waters of central Florida. Through the addition of three sequential (yellow, blue, red) vehicles, therefore allows for better position and orientation data to be sent to the teams buoy network. The three vehicles, three buoy communication structure, multiply the data points collected for surveillance and underwater mapping purposes. This additional complexity improves the reliability and increases the application of the product through error elimination software. The team gives hands on research experience to SIAM members through applied mathematics. The outcome of the research goals, results in the application of many fields of study beyond mathematics. When combined the fleet can cooperatively fulfill multitask missions, advanced surveillance and environmental monitoring can be conducted. This opportunity opens the way for better balance between sustainable developments of the coastline.

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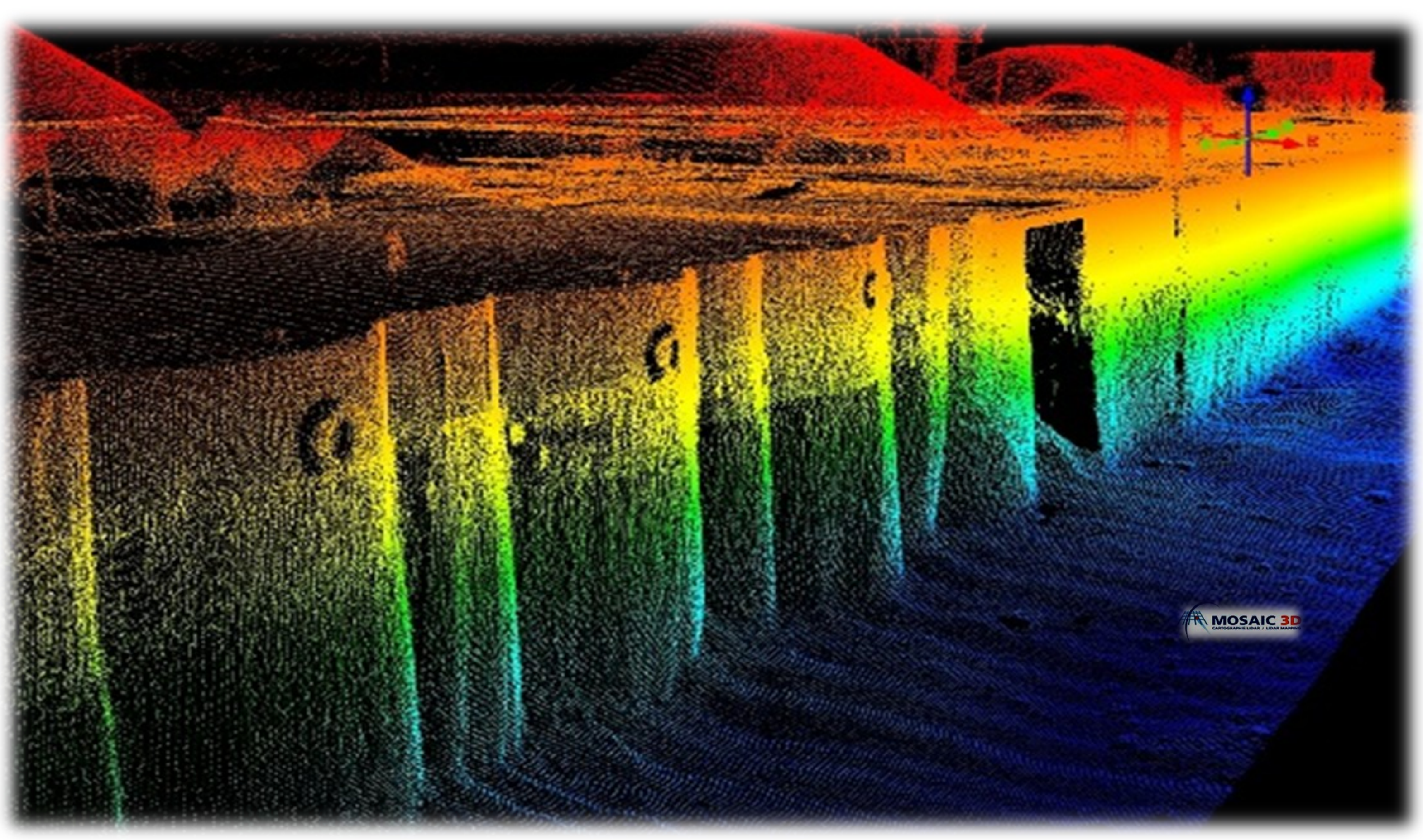
Society for Industrial Applied Mathematics

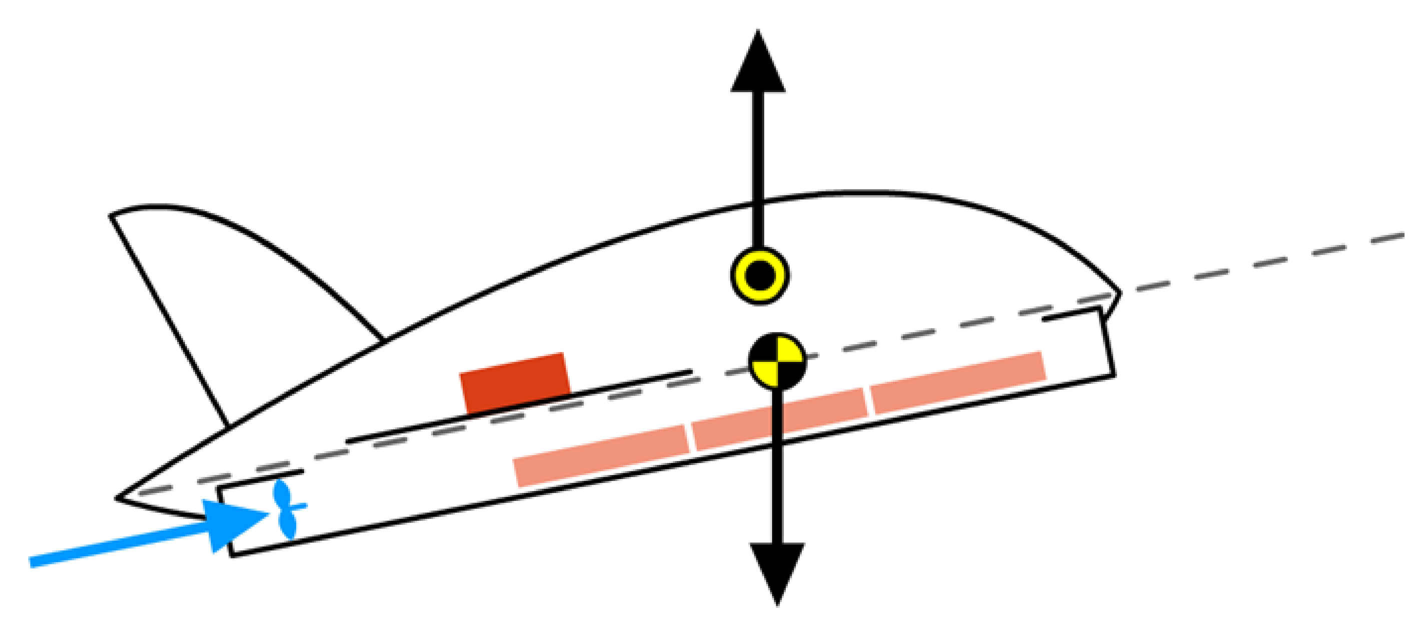
EMBRY-RIDDLE Aeronautical University

Abstract

The S.I.A.M. undergraduate research team has been working for the past two years on a submerged underwater vehicle (AUV), the Eco-Dolphin. This research project funded by IGNITE successfully completed the construction of the first Eco-Dolphin. This research project is meant to study the underwater life in areas too dangerous for humans to go. This project will be collecting data for the better understanding of the natural balance of the oceans. Upon completion of this research the Eco-Dolphins will have collected enough information to help the future development of a more advance research vehicle that will provide a better understanding of the Underwater World.



Acoustic Mapping of the Sea Floor

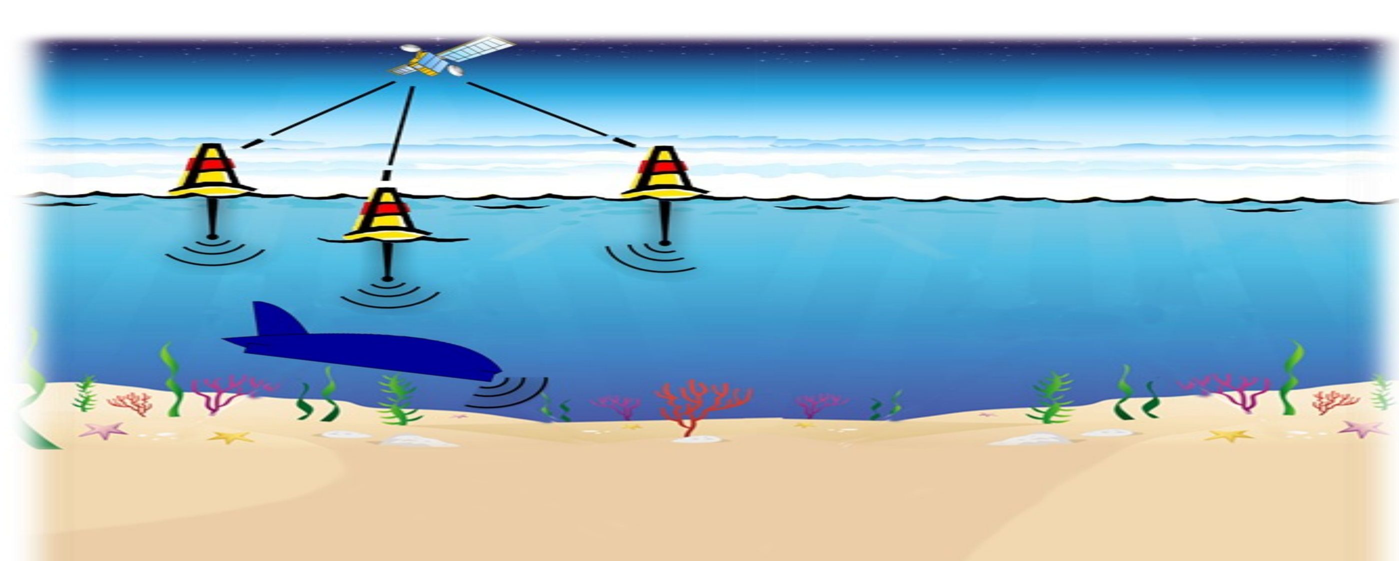


Ballast Attitude Control Unit

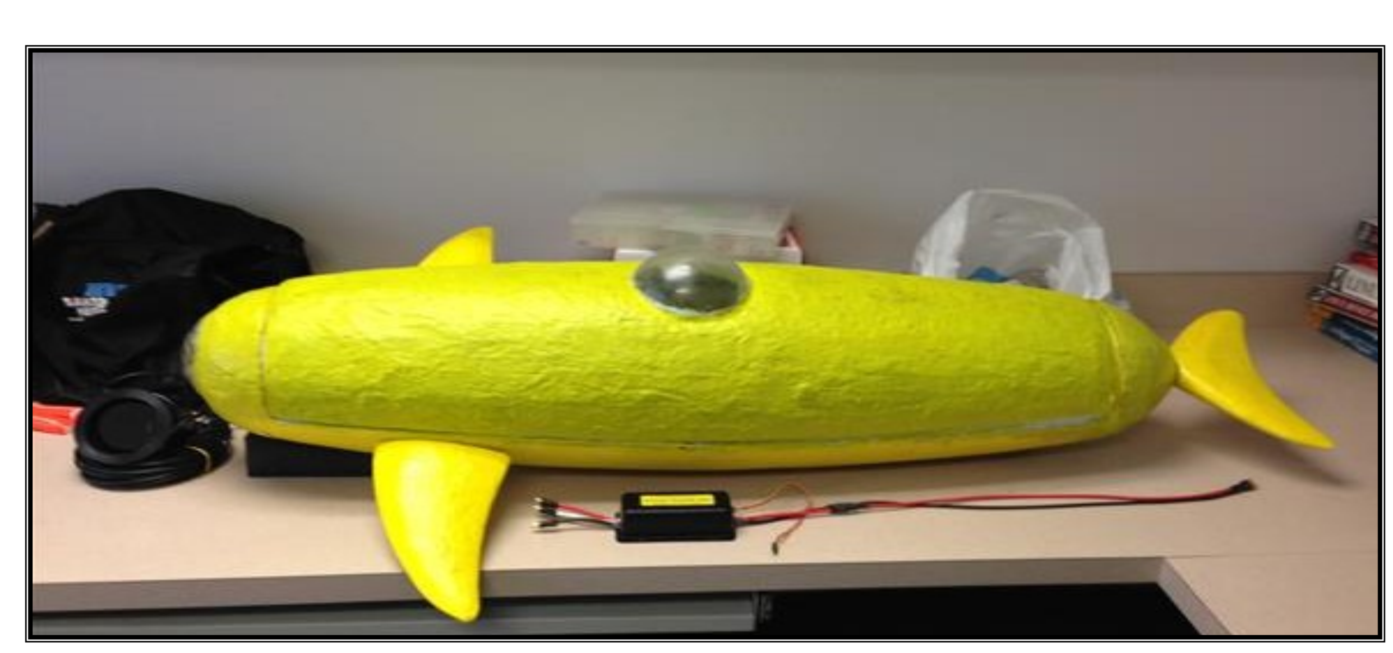
The Eco-Dolphin Ballast Attitude Control Unit has been in the construction for the fall semester of 2013. This unit will allow the Eco-Dolphin to move the heaviest component, the battery. The change on the center of gravity allows the Eco-Dolphin to climb or descent while it is under water.

Applications

- Biomass estimation
- Mapping ocean currents and temperatures
- Search and rescue missions
- Underwater security
- Monitoring habitat
- Detecting explosive dangers underwater
- Monitoring and mapping water pollution



GPS Navigation Combined with SONAR



Eco - Dolphin AUV

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Acknowledgment

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Multidisciplinary Development of an Autonomous Underwater Vehicle:
Cooperative Fleet for Surveillance Mission

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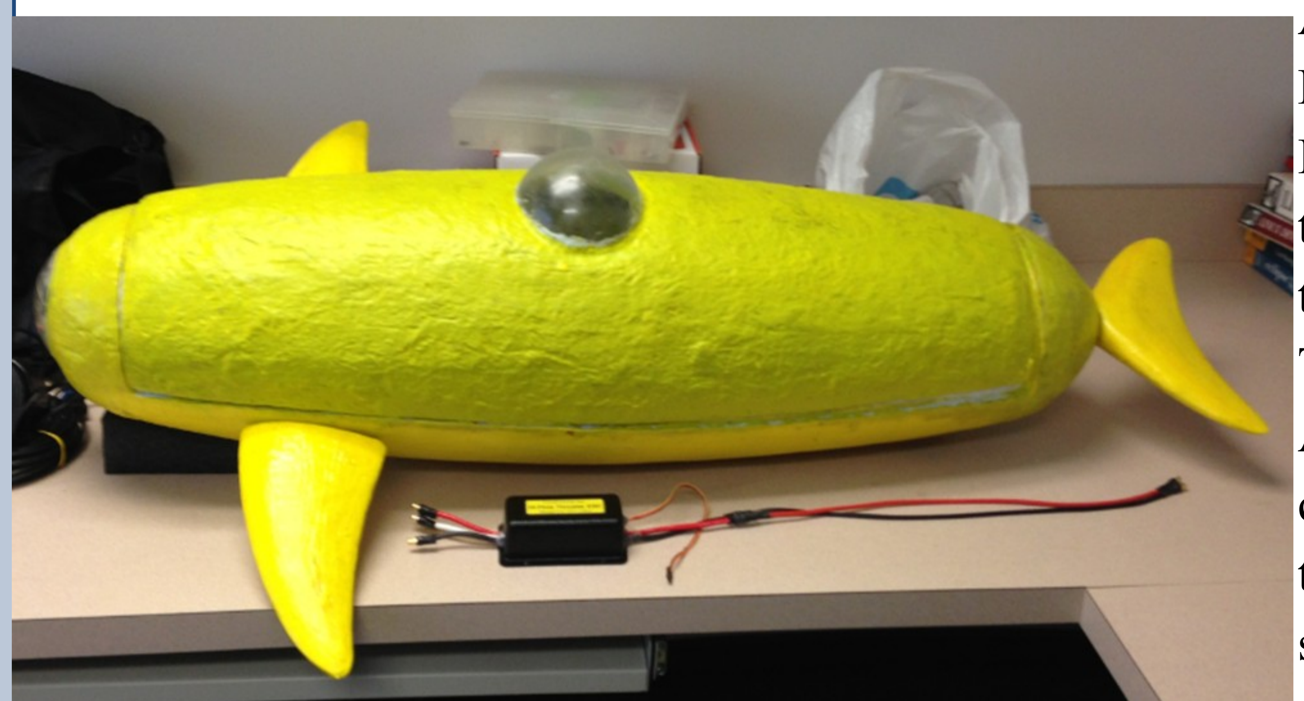
Society for Industrial Applied Mathematics

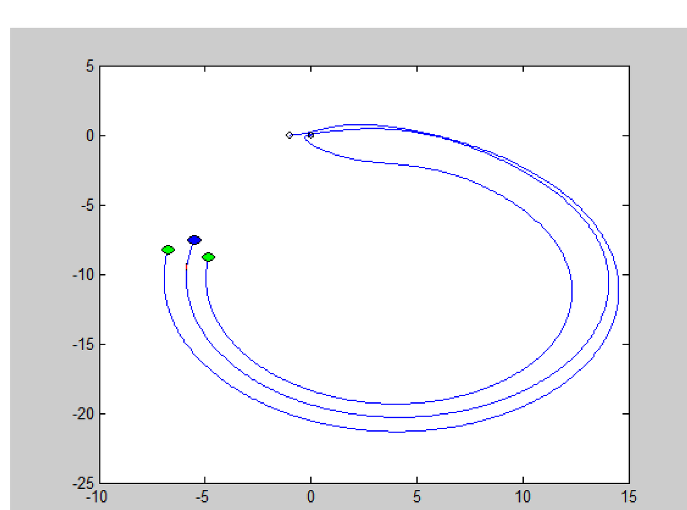
Introduction

The S.I.A.M. chapter at Embry-Riddle Aeronautical University, has been working for the past two years on a fleet of Autonomous Underwater Vehicles (AUV's), the Eco-Dolphins. The research project is funded by IGNITE, Embry-Riddle's undergraduate research office. The team has successfully completed the construction of the first Yellow Eco-Dolphin prototype (on the left). The second phase of research: Navigation and Spatial Awareness has provided the Eco-Dolphins a relay communication network to allow autonomous operations through a buoy network. The collaborative research goal is to study the underwater life in littoral waters, often too challenging for humans to travel. The current research focus is to integrate two additional successive (Blue, and Yellow) Eco-Dolphins to complete cooperative missions.

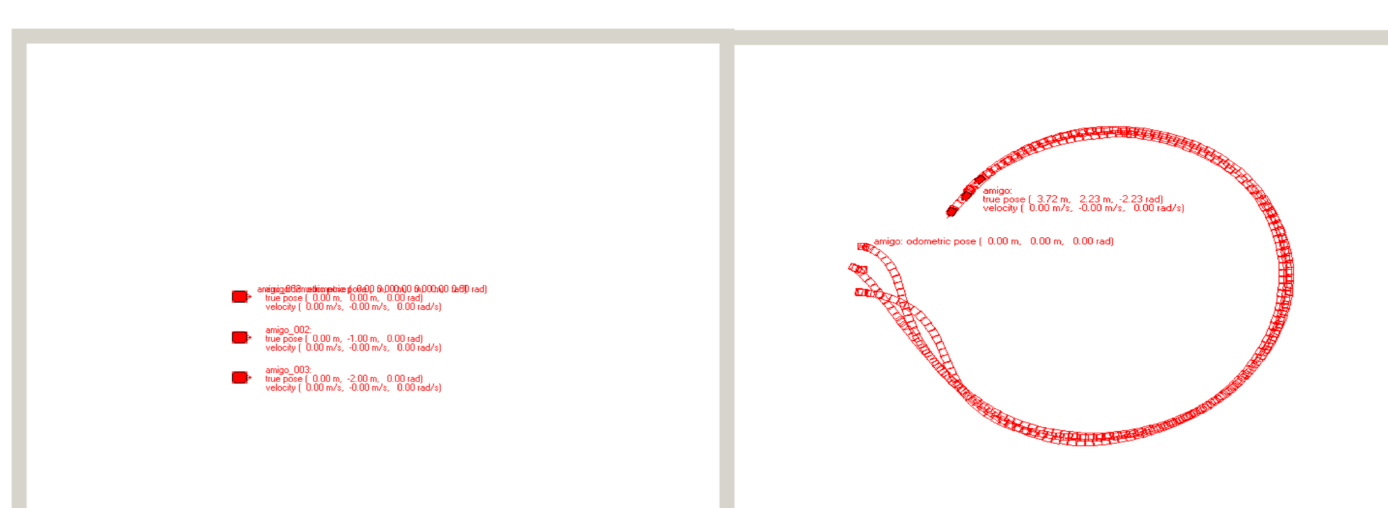


Fleet Control Simulations

Dolphin pods include a series of members that act as interdependently, to achieve the social network system. For autonomous vehicles to replicate mother-nature, the vehicles must have communication abilities. Creating a small network of AUV's mimics the pods framework, therefore allowing the group to actively interact with the environment when needed. Ungrouping should allow a more passive approach to underwater research, allowing for differing data acquisition capabilities. MATLAB software was used to provide a theoretical triangular formation, while C++ language is used in the ground robot cooperative fleet algorithm.

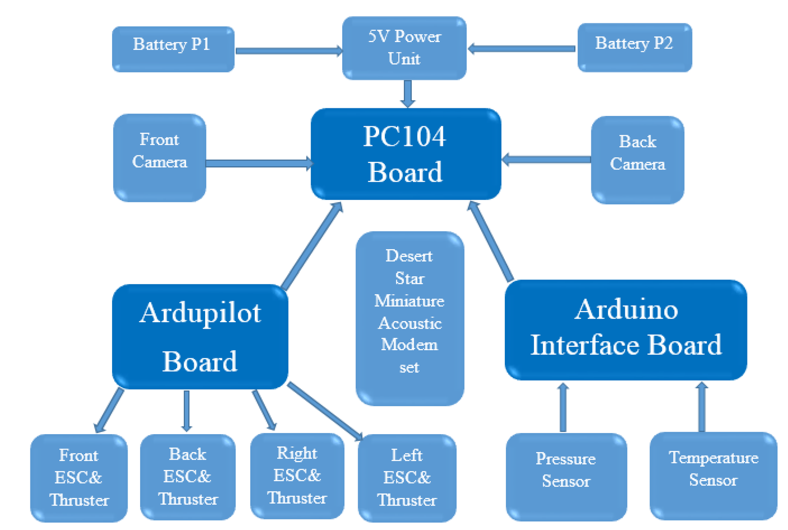


MATLAB Simulation

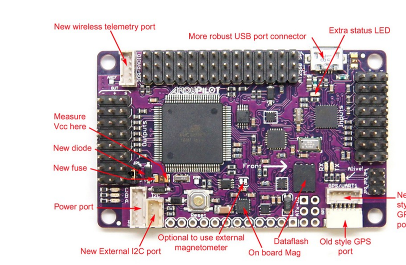


Ground Robots Simulation

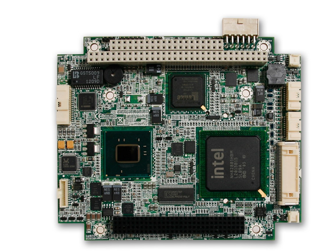
Electrical System



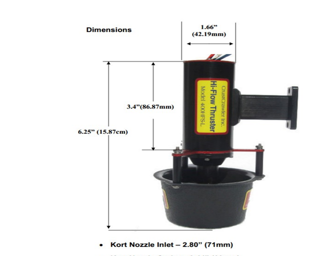
The dolphin incudes an Audopilot APM 2.5 module(2), which host an accelerometer, Gyro, pressure sensor, and IMU. All data from the Audopilot is sent to the dolphin's brain (the PC 104 board) to support the position and orientation software.



APM 2.5



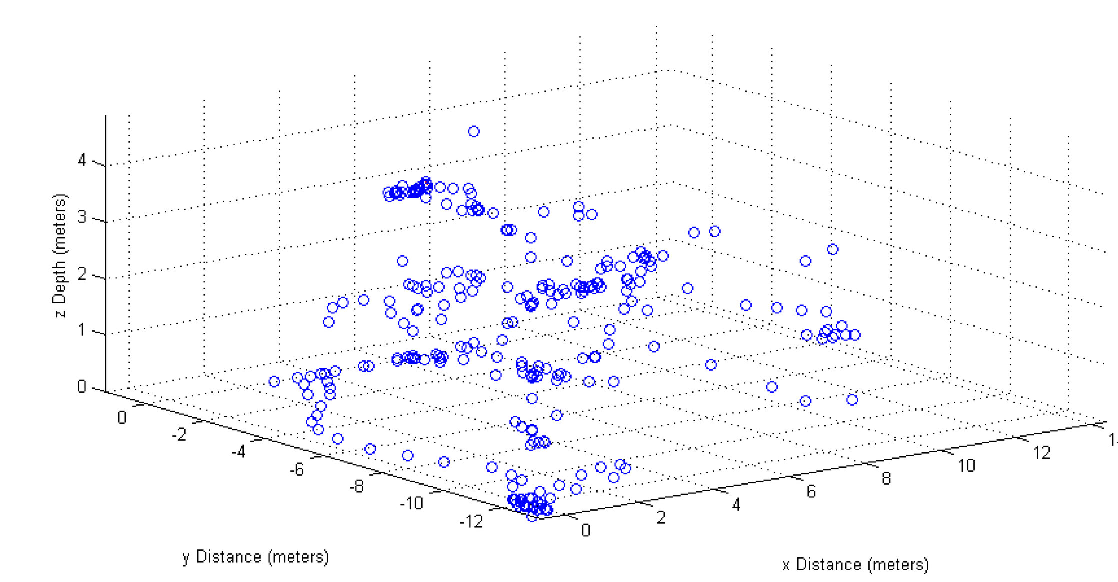
PC 104



High-Flow Thruster

Results

The Universities Non-Linear Wave Lab is used to test the Mechanical components of the buoy system for fit, forum and function. The image shown to the right shows the location of the submersible in the campus swimming pool, during summer testing procedures. Much like conventional global positioning systems, which use at least three satellites to locate an object. The designed sonar navigation system uses at least three buoys to give the position of the Eco-Dolphin while submerged.



Conclusion

The Yellow eco-Dolphin prototype was used to test the thruster design and electrical systems layout. The ground station was capable of tracking the location of the Eco-Dolphins while submerged on research mission through the use of the navigational buoys. The team has finished the first step, two-dimensional algorithms and is dedicated to producing three-dimensional underwater application. Potential applications for the cooperative Eco-Dolphin fleet include mapping ocean current and temperature, harbor security system, pollution mapping, gravitational waves and rip currents(1). Research was conducted using Analysis, Computation and Experimentation (ACE) approach to conclude the results.

Reference

1. Avion, The. The Avion newspaper. *The Avion.* [Online] October 30, 2012. [Cited: January 19, 2014.] http://theavion.com/page/50/.
2. Arducopter. Arducopter. 19th March 2013. 20th Feb. 2014 <code.google.com/p/arducopter/wiki/APM25board_Overview>.

Acknowledgments

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Embry-Riddle Aeronautical University Student Government Association
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Embry-Riddle Aeronautical University Honors Program
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Supporting

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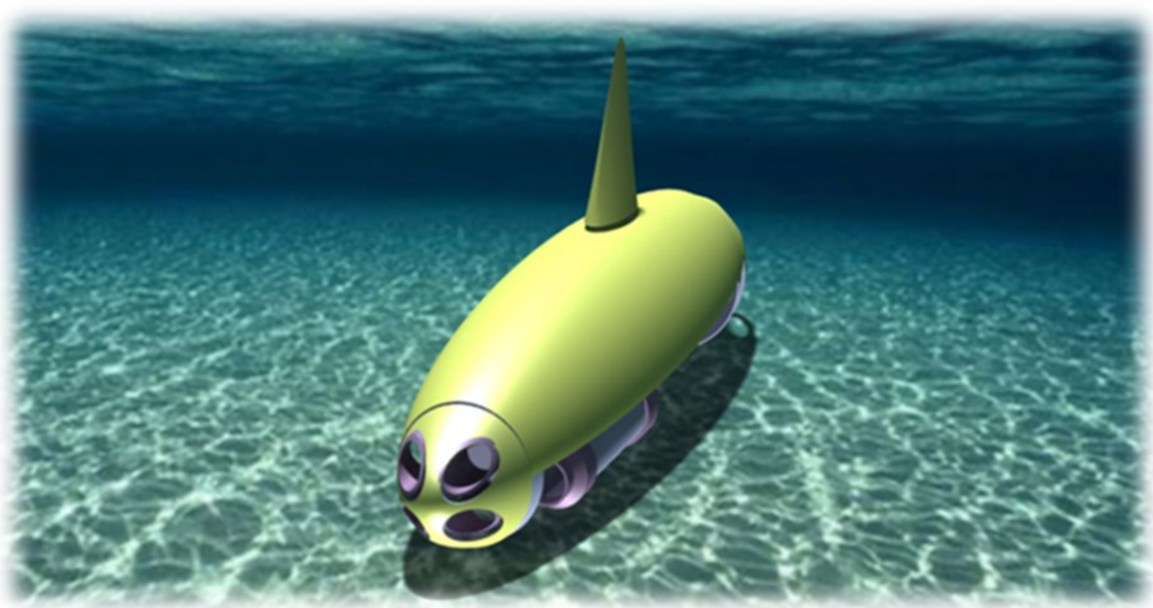
At Embry-Riddle Aeronautical University:

Cooperative Fleet for Autonomous Underwater Vehicle Research

EMBRY-RIDDLE Aeronautical University



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Society for Industrial Applied Mathematics (SIAM) at Embry-Riddle Aeronautical

Universities represents our chapter of the national organization. We base our organization on the ability to apply mathematics to research opportunities involving members in personal development, while benefiting the local community. Our mission is cooperation between Software, Technology, Engineering and Mathematics (STEM) which includes member from every department of the university. Our research combines classroom theory and industrial applications.

The Eco-Dolphin Network plan is to incorporate three autonomous vehicles on a social platform. The universities ideal location is situated between the ocean and elaborate waterways and caves that spiral the state. The research targets the study of internal propulsion methods that eliminate the impact on the precious environment.

Junzhen Shao, Jonathan Jaworski, Francisco Pastrana, Zakaria Daud, Kevin Leong, Shane Williams, Dynamite Obinna and Stacey Joseph-Ellison

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Introduction

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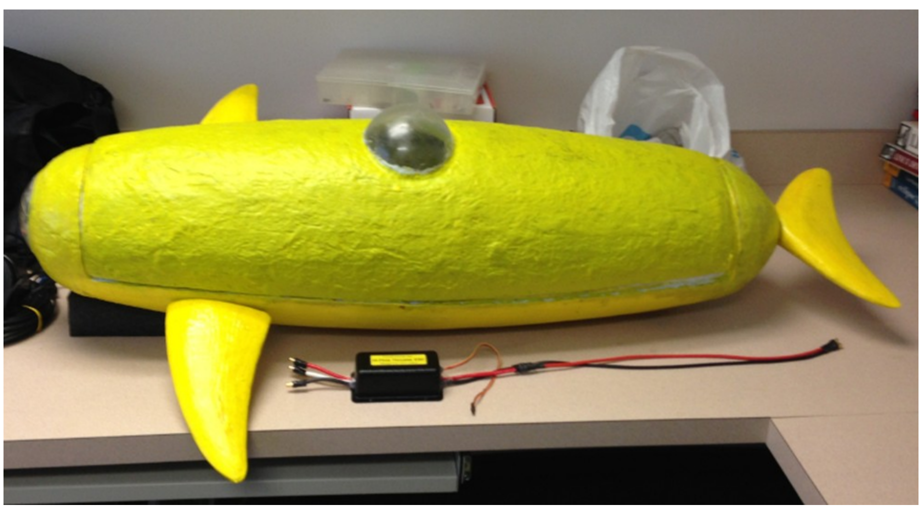

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Members need the support of our Partners to fund research goals.

All financial support and donations are welcome.

Applied Product Manufacturing Partner ($25,000 or greater)

Exclusive right to decretive design scheme, and place Company logo upon three Eco-Dolphin platforms

Initiation to littoral water testing event

Ability to peer mentor the Organization

Logo placement on social network

Logo placement on organization apparel

Mathematical Modeling Partner ($5,000-$24,999)

Logo placement on social network

Large logo placement on Organization apparel

Large logo placement on Eco-Dolphins

Computer Aided Design Partner (up to $4,999)

Logo placement on social network

Logo placement on organization apparel

Logo placement on Eco-Dolphins

For more Information please contact:

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