

## **AUTONOMOUS MOBILE BUOY (A-M-B)**

### **COASTAL & LAGOON: autonomous monitoring and sampling**

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### **Project description, goals and objectives**

The project objective of this proposal is to develop an Autonomous Mobile Buoy to aid in establishing a permanent flexible network of environmental sensors in the Indian River Lagoon (IRL), Florida (the most diverse estuarine in continental North America) and adjacent habitats. This objective will be accomplished through interdepartmental cooperation and assistance at Florida Institute of Technology (Ocean Engineering, Meteorology, Biological & Chemical Oceanography, Environmental Science, Marine Biology, Mechanical and Electrical Engineering and Computer Science); and with local institutes and companies, for example the Harbor Branch Oceanographic Institute in Ft Pierce, Florida (Indian River Lagoon branch); Ocean Recon Inc., Bonefish and Tarpon Unlimited; the Sea Turtle Preservation Society; and federal research agencies (e.g. NSF, USGS, Fish and Wildlife Service, EPA). Vital research can be conducted throughout all coastal regions of the world through the development of advanced inexpensive student built instrumentation and autonomous/remotely operated vehicles that will be deployed, monitored, and analyzed by environmental students, scientists, engineers, and coastal management, policy and security officials.



The goal of this proposal is the final development, testing, implementation and marketing of a prototype autonomous (computer controlled) mobile buoy (A-M-B) to monitor coastal and lagoon areas, and collect ecosystem processes and changes data. The end product of the project will be to deploy a fully automated, autonomous cost-efficient modular system on which various water-based measurement instruments can be mounted, for example: turbidity, temperature, salinity, dissolved oxygen, radioactivity, hydrocarbons, chlorophyll, algae, and phytoplankton sensors, in addition to the complete array of meteorological instruments that are on the market.

The development of an automated buoy with advanced control algorithms that will allow the vehicle to perform autonomous pre-programmed surveys and sampling will be assisted by research currently underway at Florida Tech's Underwater Technology Laboratory. This research is the implementation of a unified approach to develop autonomous devices that can reside and navigate in estuaries and oceans, explore, collect data, and search for specific biological, chemical, or physical attributes observed in the ocean environment. This innovative system will lead to a completely new diverse multipurpose application of data collection in terms of marine biological, chemical and geological surveys within the coastal zone. Possible uses of the system encompass a wide variety of underwater and surface monitoring. These include, but are in no way limited to, biological and chemical surveys, harmful algal blooms (HAB), environmental assessments, wastewater management, documenting the distribution of harmful invading species, weather hazards, or long-term investigations in geomorphology, flora and fauna.

**System Architecture:**

The A-M-B prototype will be developed in two parts. The first part, which is now underway, is the development of a special buoy that is specifically for coastal and lagoon environments. The A-M-B will be able to pull up its anchor and traverse to other way-points to continuously collect data over an entire region. This buoy, without electronics, is currently being built by undergraduate students in the Ocean Engineering Design Class. The second part of the project and hopefully sponsored by the NCIIA Advanced E-Team grant will incorporate recent advances in single board computers, embedded systems and real time operation systems. The onboard computer will use an advanced control system along with a sensor array, communications package, subsurface hydrodynamic/acoustic sensors, and an aerial antenna for integrated cell phone communication (the vehicle will use autonomous Machine-to-Machine (M2M) communications based on cell-phone telemetry with a central server for real-time data transmission or interrogation by remote observers). The design will accommodate additional sensors as needed, e.g., meteorological sensors. These additional sensors, albeit not part of this preliminary work, will contribute an array of supplemental data designed to better understand the driving forces that control lagoon circulation and water quality.

**Educational technology impact for teaching or research:**

The design, construction, expansion and elaboration of the A-M-B will enlist the talents of the students from the Department of Marine and Environmental Systems (DMES), especially the Ocean Engineering Design (OCE 4541) and Computer Science (CSE 4101) senior capstone project course students, where a team of undergraduate students with the guidance of a graduate student and Dr. Stephen Wood will design, build and test the fully operational prototype buoy by the end of the 2007 summer term.

Professors from Florida Institute of Technology will provide information and guidance in building and deploying the vehicle: Ocean Engineering (Dr. Eric Thosteson: Oceanographic instrumentation & M2M communication), Marine Biology (Dr John Schenkar: Fish studies of the IRL), Meteorology (Dr. Steven Lazarus), Marine Chemistry (Dr. John Trefry) and Physical Oceanography (Dr. George Maul), Biological Physical Oceanography (Dr. Elizabeth Irlandi & Dr. Kevin Johnson), Mechanical Engineering – Control Systems & Mechatronics (Dr. Hector Gutierrez), and Computer Science (Dr. William Shoaff).

**Corporate Interest, contributions to the community, environment, along with integration with current scientific and technological advances:**

A larger proposal in the works at Florida Tech to establish a flexible network of environmental sensors in the Indian River Lagoon and coastal oceans would implement the A-M-B as an important integrated part of the network. Data collected by the network will be directly applicable for interdisciplinary studies on nutrient and chemical dynamics, coupled atmospheric/hydrodynamic modeling, fisheries, harmful algal blooms, sea-grass, and the development of management plans that seek to minimize or mitigate human impacts on the lagoon and coastal ecosystems. Each of these topics are of great interest to a variety of agencies, ranging from regulatory and management agencies such as the Sebastian Inlet Tax District (who presides over the waters north of Fort Pierce and south of Melbourne Florida), federal research agencies (e.g., NSF), to institutes such as Harbor Branch Oceanographic Institute in Ft Pierce, Florida (Indian River Lagoon branch does extensive sea grass and environmental studies in the Fort Pierce area of the IRL); the Sea Turtle Preservation Society (could use these platforms to monitor the many endangered juvenile sea turtles that live in the IRL all year); federal research agencies (e.g.

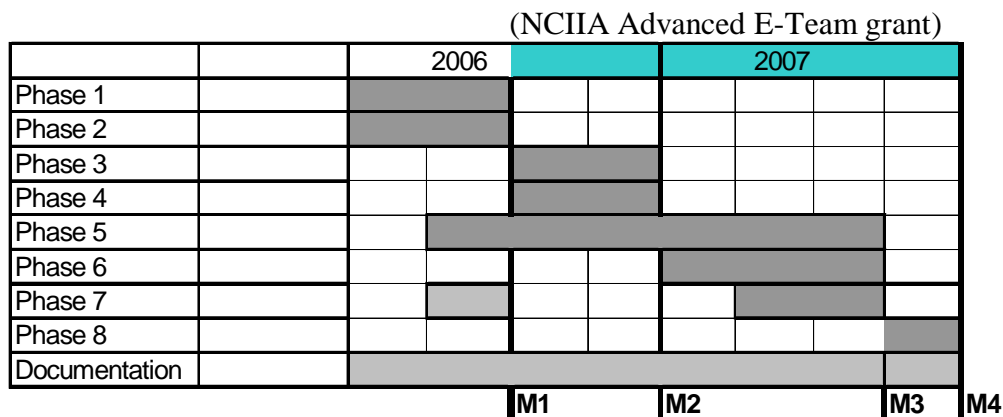
NSF, USGS, Fish and Wildlife Service, EPA); and private companies and foundations (e.g. Ocean ReCon in Fort Pierce: Dr Edith Widder - President, and Bonefish & Tarpon Unlimited who would use the vehicle for fisheries monitoring). In addition to providing support for regional interdisciplinary studies, the A-M-B and coastal network will help Florida Tech establish credibility for participation in broader coastal sensor networks. For example, the Southeast Coastal Ocean Observing System (SECOOS) along the southeast coast of the United States has a major coverage gap that extends from West Palm Beach to Jacksonville. The demonstration of Florida Tech's ability to establish a complementary environmental sensor network will provide the university with credibility to become a full partner in the much larger SECOOS program and help develop stronger collaborative relationships with other universities and agencies that are working on their own in the Indian River lagoon.

**Market Potential**

Over the past few decades, a range of monitoring strategies and techniques has been used to monitor the seas and lagoons. Recently, the role of monitoring has been expanded to include the use of autonomous vehicles to perform ocean surveys. With these vehicles it is now possible for the scientist to make complex studies on topics such as the effect of metals, pesticides and nutrients on fish abundance, reproductive success and ability to feed, or contaminants such as chemicals or biological toxins that are transported in particulate form and become incorporated into living organisms (plankton, bivalves, fishes) or deposited in bottom sediments. The scientist or environmentalist may desire to detect hazardous substances in the ocean such as the chemicals emanating from an underwater spring or detect toxic algae such as red tide. Additionally, the military's detection of mines, biologic, chemical or radioactive threats are also very important in the monitoring of the seas. Due to the acceptance of these new monitoring techniques, it is highly favorable to market an autonomous buoy system to the ocean/coastal community. Every coastal region throughout the world would want such a system. The market is extensive due to the number of ports, harbors, inlets and river outlets that need to be monitored throughout the world.

**A-M-B Work Schedule – Time plan and Milestones**

The project will be systematically completed as seen in the next figure where the eight work phases and work packages are spread over the project run time. Time line

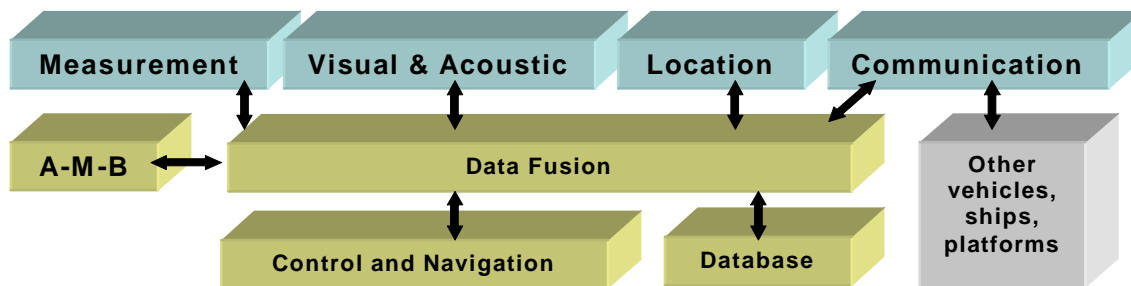


*Graphic representation of the time plan*

- Phase 1**      Conceptualization of the vehicle with selection of the required sensors and actuators.
- Phase 2**      Design, build and test basic buoy hull
- Phase 3**      Development of various models such as the control strategy for the vehicle. Verification of the results with help from simulations.
- Phase 4**      Development of methods to automatically plan the optimum, collision free trajectories respective to the trajectories of previously defined waypoints.
- Phase 5**      Building the vehicle with all of the primary components and instruments.
- Phase 6**      Construct the necessary computer and micro-controllers in the vehicle with an optimum distribution of computer resources. Implement and test the developed program algorithms and methods for navigating, controlling and planning the vehicle's trajectory.
- Phase 7**      Verifying and testing the vehicle.
- Phase 8**      Promoting and Commercializing vehicle
- Documentation** The documentation of each part of the project runs over the entire running life span of the project. At the end of the second project year will account for the depiction of the work accomplished leading to the final vehicle documentation.

The following phases are for the successful conclusion of the individual milestones:

- Phases 1 and 2 for **M1 (July 26<sup>th</sup>, 2006)** “Definition of the entire system and construction of basic buoy.” NCIIA Advanced E-Team grant would take effect after **M1** to support later-stage development of the AMB and its commercialization
- Phases 3 and 4 for **M2 (December 15)** “Analysis and Simulation”
- Phases 5, 6 and 7 for **M3 (July 25<sup>th</sup>, 2007)** “Individual systems for the integration in a complete demonstration”
- Phases 8 for **M4 (December 14<sup>th</sup>, 2007) Project Completion**



*View of the sub-projects: A-M-B, Measurement, Visual & Acoustic, Location, Communication, Data Fusion, Control & Navigation, Database*

### Equipment & Resources:

The development of the A-M-B will use the Underwater Technology Laboratory for all design, development and analysis using the various test machines and software in the lab: oscilloscopes, frequency generators, power supplies, solder stations, microchip programmers, computers and software (e.g., C++, MatLab, LabView, ProSurf, ProEngineering). This lab is under the directorship of the PI.

The Florida Institute of Technology's 60ft ocean and estuarine research vessel "Delphinus" will be used for testing and transporting the A-M-B, which will coincide with the student Marine Field Project's cruises that are made every summer.

One final resource that will be used to construct the A-M-B is the university's machine shop. The shop is always open to faculty and student use and is equipped with two CNC mill machines, CNC lathe, 4 normal mill machines, 3 normal lathes plus welding capabilities and various other cutting and boring machines.

**Budget:**

Electronics, vehicle computers, collision control acoustic sonar and software, conductivity-temperature-depth (an inexpensive highly accurate instrument underdevelopment at Florida Tech), turbidity and basic meteorological sensors and machine-to-machine communication package (also being developed by undergraduates at Florida Tech). **\$ 10,000**

<b>Undergraduate support</b>	<b>\$/hr</b>	<b>hrs/week</b>	<b>weeks</b>	<b>Total/Year</b>
2 Students	\$7.00	20	35	<b>\$9,800</b>

**Total Cost: \$19,800**

**Team Members:**

Dr. Stephen Wood – PI, Adam Outlaw - Graduate Student Advisor, Michelle Rees and Zachary Pfeiffer – Undergraduates leading the team, and an undetermined group of 4 students from the Ocean Engineering design class (OCE 4541) or Ocean Engineering System's design class (OCE 4542) that the PI teaches.

**Summary**

The objective of this project is to develop a new technology to survey and monitor the coastal and lagoon environment in a cost effective manner where the end product will be an autonomous vehicle combining survey capabilities, simultaneous water sampling and environmental data gathering capacities that are not available on other systems.

The overall project consists of three consecutive phases: 1) Autonomous Mobile Buoy design, development, and testing; 2) the technological phase for development and integration of all scientific components into a functional tool and 3) the scientific phase for testing and demonstration through a series of surveys that addresses a variety of marine ecosystems.

The A-M-B is to be designed specifically for the needs of the coastal/lagoon scientist that requires greater control over the vehicle, and more space for scientific instruments. The more information the scientist is able to accumulate the better he or she will be able to determine the health of the ocean ecosystem and document the specific ecosystem parameters. Using A-M-B, pollution of ocean/lagoon waters can be detected and quantified in an automated way; The A-M-B can take and analyze water samples to determine water quality as well as the contaminating chemicals. Thus, dangerous substances can be detected earlier and their harmful effects can be dealt with quicker.

For more information and current status of the A-M-B project see:  
[http://my.fit.edu/~swood/OCE4541\\_pg1.html](http://my.fit.edu/~swood/OCE4541_pg1.html)