Glider-based Passive Acoustic Monitoring Techniques in the Southern California Region

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LONG-TERM GOALS

The long-term goal of this project is to develop technology for autonomous glider-based passive acoustic monitoring of marine mammal presence within the southern California offshore region. Gliders provide a new approach for autonomous monitoring of both the presence of marine mammals, and of other environmental parameters. They may contribute to Navy environmental compliance, as well as to basic scientific studies of marine mammals.

OBJECTIVES

Gliders provide the potential for autonomous, adaptable, and mobile monitoring over extended periods of time (weeks to months), and significant processing for detection, classification and localization of marine mammal calls. This combination of attributes ultimately may result in an operational system that provides timely information on marine mammal presence to support Naval mitigation efforts.

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14. ABSTRACT
The long-term goal of this project is to develop technology for autonomous glider-based passive acoustic monitoring of marine mammal presence within the southern California offshore region. Gliders provide a new approach for autonomous monitoring of both the presence of marine mammals, and of other environmental parameters. They may contribute to Navy environmental compliance, as well as to basic scientific studies of marine mammals

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APPROACH

Our technical approach for glider-based passive acoustic monitoring is based on miniaturization of the High-frequency Acoustic Recording Package (HARP; Wiggins and Hildebrand 2007), and development of real-time detection, classification, and localization/tracking (DCLT) algorithms that can be executed by the HARP microprocessor. Since the current generation of profiling gliders is limited in payload and battery capabilities, we are developing low-power and compact hardware for marine mammal passive acoustic monitoring, reducing the demands on the glider platform.

We are also exploring the use of glider platforms with expanded capabilities for real-time, persistent, passive acoustic monitoring such as the flying wing ZRay glider and the Wave glider. The ZRay is the world's largest underwater glider, employing a high lift-to-drag ratio wing design allowing it to travel long distances efficiently, to travel at higher speeds than oceanographic profiling gliders, and to carry a greater payload. The Wave glider is a vehicle with a surface float connected by cable to a submerged glider. Since it uses wave action for propulsion, its power requirements are moderate, and it has a large payload capability. With these characteristics, ample power and substantial payload capability, it has the potential for long-term missions involving marine mammal detection. The presence of the Wave Glider surface float, which includes Iridium data communications, allows for real-time notification of marine mammal presence.

John Hildebrand and Sean Wiggins are responsible for project management and development of marine mammal recording and detection hardware and software. Gerald D'Spain is responsible for glider development and integration with marine mammal detection capabilities. Marie Roch (SDSU Computer Science Department) is responsible for development of hardware and algorithms for real-time marine mammal detection, as well as a marine mammal call database software. Michael Porter and Paul Hursky (Heat, Light and Sound Research) are responsible for development of real-time marine mammal detection algorithms and implementation of these into digital signal processing hardware.

WORK COMPLETED

The HARP, which is typically deployed in a seafloor package or on an oceanographic mooring, was re-designed for deployment in a compact space. This involved both improvements to the hardware (lower power electronics requiring fewer batteries) and software (data compression). Based upon a desire for the acoustic subsystem to be independent of the glider, the Beagle Board computer was selected as a development platform for real-time marine mammal call detection. The BeagleBoard system uses a Texas Instruments OMAP 3530 dual-core processor, consisting of an ARM Cortex-A8 CPU in one core, and a TI TMS320C6400 series DSP chip in the other core (aka Da Vinci chip). This hardware is a recent product developed for mobile phone and other consumer electronic products, where low power consumption is a driving issue, which we plan to leverage in our marine mammal applications. Currently, we have implemented software to detect echolocation clicks in real-time on the Beagle Board based upon the Teager energy of a high-pass filtered signal (Kandia and Stylianou, 2006).

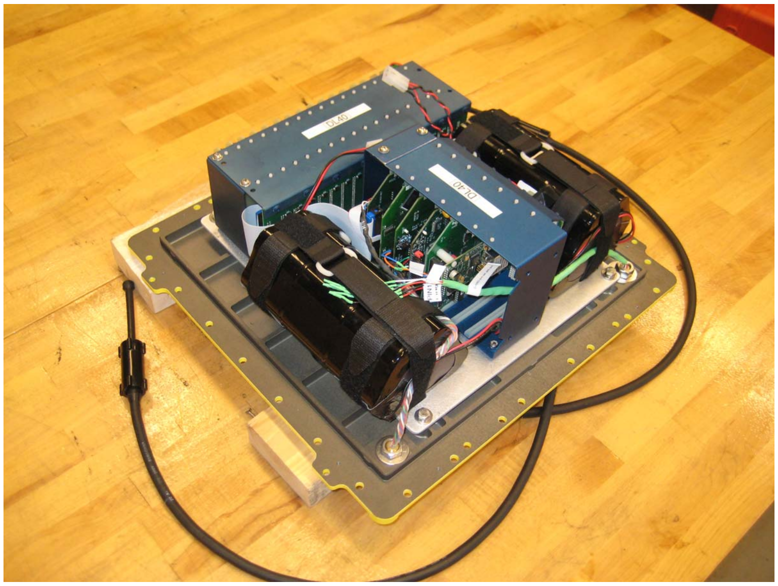

Figure 1. Compact HARP, packaged for deployment in the dry-box of the Wave glider.

A database for southern California marine mammal calls has been developed, using existing detections from our field recordings. A prototype for a network enabled meta-data database was created. The system is built upon Oracle Corporation's freely available Berkeley DB XML database, and provides fast and scalable indexing for extensible markup language (XML) documents. XML is a leading format for information interchange. Direct archive of information in XML will allow for simpler transport between various software packages. As an example, to visualize acoustic detections in Google Earth, one can query the database and rewrite the result in the Open Geospatial Consortium's keyhole markup language (KML, an XML derivative) and input the result to an Earth browser such as Google's Earth or NASA's WorldWind.

RESULTS

A significant result has been advancing the design of ZRay, the next generation flying wing underwater glider (Figure 2). This new glider has sufficient internal payload capability to allow integration of the HARP hydrophones and accompanying data acquisition system along with a multi-element hydrophone array in the leading edge of the wing. Because this design is inherently stable in flight, the need for activating its flight control systems is minimized, eliminating self noise contamination of the acoustic sensors. For passive monitoring of marine mammals with the glider, further development, testing, and implementation of an automated real-time detection, classification, and localization algorithm continued this year. The software framework required to permit decisions made by the real-time algorithm to modify the flight characteristics of the glider was created. Figure 3 shows a block diagram of the basic implementation of this combined algorithm. The equal element spacing of the leading-edge array permits a numerically efficient spatial FFT to be performed, equivalent to conventional beamforming. These methods are being tested using synthetic marine mammal vocalization data collected by the leading-edge array on the glider during at-sea testing in December, 2008. This algorithm development effort forms the basis of the Ph.D. research of Tyler Helble, a Scripps graduate student and a Department of Defense SMART fellowship recipient from the SPAWAR Systems Center, San Diego.

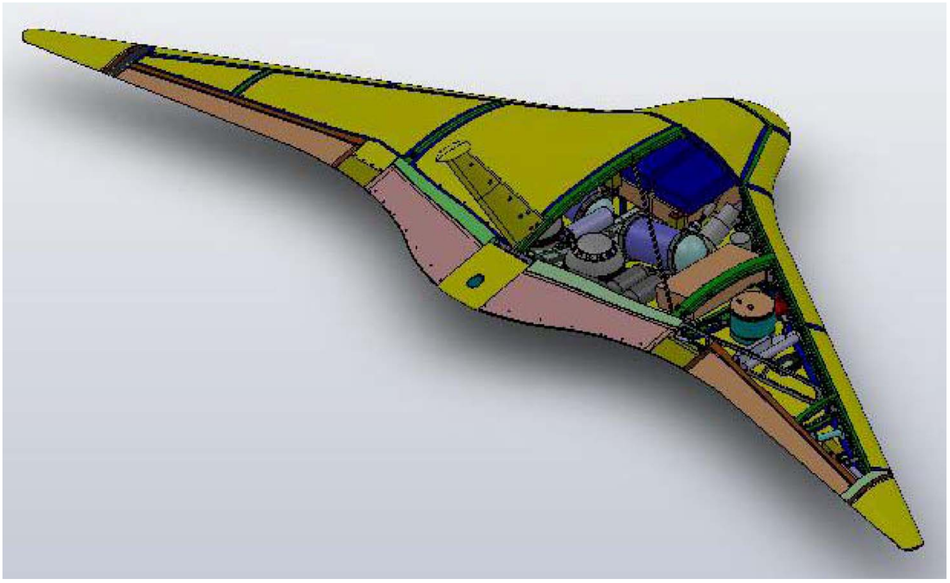

Figure 2. Mechanical design of ZRay with the upper right hatch cover removed to show internal subsystems including: one of the buoyancy engine tanks (purple cylinder with silver endcaps), two 3.3 KW-hr lithium polymer batteries (pink boxes), a data acquisition electronics pressure housing (gray sphere), and the oil-based roll control system's starboard reservoir (upright teal cylinder with pink endcap).

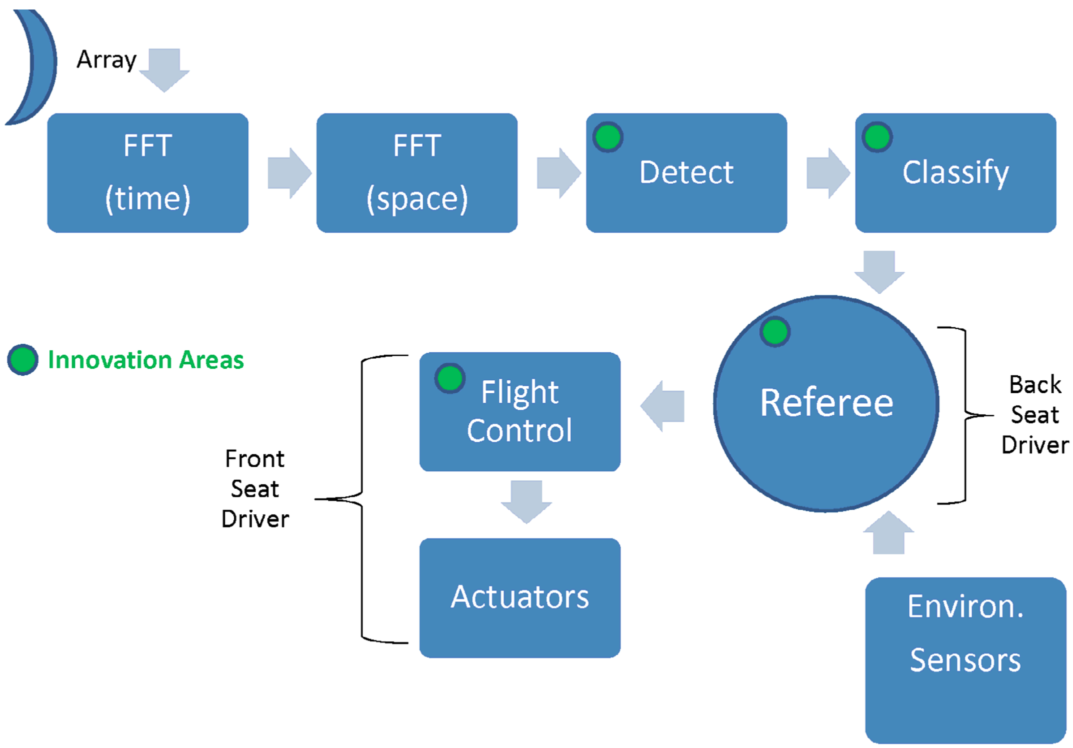

Figure 3. Information flow in the real-time DCL implementation in the ZRay.

IMPACT/APPLICATIONS

Although existing underwater gliders (Seaglider, Spray, and Slocum) are successful underwater platforms for collecting vertical profiles of water column properties, they were not designed to carry wide-band or multi-channel passive acoustic systems. In contrast, the *Liberdade* class of flying wing underwater gliders (ZRay) as well as the Wave glider are capable of carrying large and high-data-rate payloads, have sufficient physical size to provide large array aperture at low and mid frequencies, and at the same time minimize onboard energy consumed in horizontal transport. These gliders have the best potential future impact for science and/or systems applications for marine mammal studies and monitoring.

RELATED PROJECTS

Project title: Southern California Marine Mammal Studies; John Hildebrand, Principal Investigator. Sponsor: CNO N45 and the Naval Postgraduate School; Support from this project allowed for the development of HARP instrumentation and collection of the acoustic data used to create the southern California marine mammal call database.

Project title: Passive acoustic monitoring for the detection and identification of marine mammals, Marie A. Roch Principal Investigator. ONR Grant: N000140811199. This project aided in the development of algorithms for marine mammal detection and classification.

Project title: Flying wing underwater glider for persistent surveillance missions, Gerald L. D'Spain Principal Investigator. ONR Grant: N000140410558. This project supported development of large autonomous underwater gliders based on the flying wing design.

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Wiggins, S. M. and J. A. Hildebrand. 2007. High-frequency Acoustic Recording Package (HARP) for broad-band, long-term marine mammal monitoring. Pages 551-557 *International Symposium on Underwater Technology 2007 and International Workshop on Scientific Use of Submarine Cables & Related Technologies 2007.* Institute of Electrical and Electronics Engineers, Tokyo, Japan.

PUBLICATIONS

Willcox, S., J. Manley, and S. Wiggins, The Wave Glider, an Energy Harvesting Autonomous Surface Vessel: Persistent presence enables acoustic operations as a virtual buoy or mobile platform. *Sea Technology* [in press].