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The objective of this specific project was to design and construct a new generation flying wing underwater glider, dubbed ZRay, based upon the experience developed over the past three years (2006-2008) of at-sea testing with XRay (under ONR grant N00014-04-1-0558). The new design developed during this project includes several innovations that significantly improve a Liberdade glider's persistence, passive sensing capability, and robustness.

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Final Report
Flying Wing Autonomous Underwater Glider for Basic Research in Ocean Acoustics, Signal/Array Processing, Underwater Autonomous Vehicle Technology, Oceanography, Geophysics, and Marine Biological Studies

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LONG-TERM GOALS

The long-term goal of the Liberdade flying wing underwater glider program is to develop a new class of underwater glider (the Liberdade class) optimized for long distance, long duration (persistent) flights in the ocean. Central to this objective is increasing the horizontal transport efficiency, speed, and payload capacity of underwater gliders. The approach used in this program is to exploit the high lift-to-drag ("finesse") properties of the flying wing design. A parallel, and equally important, goal is improving the sensing systems and automated decision-making capability based on the outputs of these sensor systems. In addition to providing the basis for a persistent mobile node in a future Persistent Littoral Undersea Surveillance (PLUS)-type or other wide-area surveillance system, this class of glider is ideally suited for an autonomous coastal or perimeter patrol system, or as a real-time marine mammal monitoring platform. It also provides a novel capability for data collection in support of basic ocean science.

OBJECTIVE

The objective of this specific project was to design and construct a new generation flying wing underwater glider, dubbed ZRay, based upon the experience developed over the past three years (2006-2008) of at-sea testing with XRay (under ONR grant N00014-04-1-0558). The new design developed during this project includes several innovations that significantly improve a Liberdade glider's persistence, passive sensing capability, and robustness.

APPROACH

The approach used to design ZRay was to learn all that could be learned from working at sea with XRay (in all its various incarnations) over the past three years, incorporate into ZRay those aspects and subsystems that worked well, and modify as appropriate those aspects that needed improvement. In addition, the confidence gained in the reliability of certain components (e.g., the glider's flight electronics) permitted design changes that significantly improve the functionality and capabilities of ZRay.

WORK COMPLETED

Although many of the subsystems in ZRay are identical to, or are scaled versions of, those in XRay (since many in XRay worked very well), several design innovations were made. First, the outer shape of ZRay is completely different. Rather than continue to use the McMaster's airfoil upon which the outer shapes of Stingray and XRay were based, a new airfoil in our Reynold's number regime (around one million) was chosen from the vast historical archive of airfoils that was specifically designed to operate in conjunction with camber-changing trailing-edge flaps. Unlike XRay with its nacelle around the center line, the 2D shape of this new airfoil was used consistently throughout the full span of ZRay, gradually tapering to either wingtip to provide large wing aspect ratio and with a swept-back angle of 30 deg to help move the center of pressure aft. With this new outer shape, ZRay should achieve lift-to-drag ratios exceeding 35-to-1, over twice that obtained by either Stingray or XRay. The outer shroud is designed to be made of ABS plastic (very robust) mounted to an inner strength cage made of titanium. Although the "monocoque" construction of XRay and Stingray using fiberglass and carbon-fiber composite materials for reinforcement has superior strength-to-weight ratio and has worked well in many ways, these hulls have been difficult and expensive to modify. A third innovation is to replace the spherical pressure housings containing the glider flight electronics with an oil-filled housing having a shape conformal to the interior space where the housing will be located. This change frees up a significant amount of interior space. Yet another design innovation is to incorporate small water jets into ZRay to allow for fine attitude control at or near neutral buoyancy, particularly important for orienting the leading-edge hydrophone array aperture in specific directions such as during the "knife-edge" maneuver. The water jets on the underside of the glider have been designed to also allow for glider motion and maneuvering while on the ocean surface, a capability that will be useful in a variety of ways including during recovery. To increase the passive sensing capability of ZRay, mountings for four large sensors (e.g., low frequency acoustic vector sensors or very wideband (200+ kHz) hydrophones), are incorporated into the design, one each at each wingtip and in the tail, in addition to the one presently in the nose.

As with the construction of ZRay2 under ONR grant N00014-06-1-0846, almost all of the expensive, long-lead-time items such as the lithium polymer batteries, the buoyancy foam, and the commercial off-the-shelf sensors were acquired for ZRay1 under this project. In addition, some of the components for this new glider, as well as those for ZRay2, have been fabricated. However, a significant effort also was made in testing critical aspects of the design, not just in the lab and in the Scripps saltwater tank in La Jolla, but also at sea. The results of these tests and the subsequent modifications to the new design were essential in making sure undesirable aspects of the XRay design were not repeated.

IMPACT/APPLICATIONS

Existing underwater gliders (Seaglider, Spray, and Slocum) are highly successful underwater platforms for collecting vertical profiles of water column properties to provide near real-time environmental characterization. In contrast, prop-driven AUVs are designed for level flight, a highly desirable feature when imaging the ocean bottom as required for the mine countermeasure problem. The type of mission suited for the Liberdade class of underwater glider is distinctly different than that of these other two classes of autonomous underwater vehicles; the flying wing glider has demonstrated the capability to minimize energy consumed in horizontal transport while at the same time carry large and high-data-rate payloads. This class of flying wing underwater glider is well suited for a range of Navy applications such as Long Range Persistent Surveillance, Perimeter Patrol, Deep Water Sentry with Terminal Homing and Identification, Deep Water and Coastal Perimeter Defense and Barriers, Tracking Targets, Patrolling Sonobuoy, Shallow Water ASW, Target Reconnaissance and Coastal Surveillance, and Below Surface Ocean Optics. In addition, the applications of this long range, energy efficient class of gliders for basic science and civilian resource monitoring purposes are almost limitless.

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