



Autonomous Underwater Vehicle: Powered Glider

Department of Marine and Environmental Systems – Ocean Engineering

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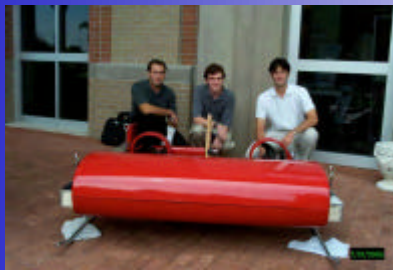


ABSTRACT

A new generation of Autonomous Underwater Gliders is currently being developed for the fields of marine biology, physical oceanography, and marine environmental studies, assessment and management at the Florida Institute of Technology, Melbourne Florida, USA. The end-product of the project will be an autonomous powered glider that collects video, acoustic, and physical data, simultaneously obtains water samples for chemical analysis through mass-spectrum analysis, and is able to gather biological specimens to improve and automate inspection and sampling of the marine environment. The powered glider will be programmed for surveying and analyzing specific phenomena. During the project several scientific surveys will be performed to test the abilities of the new autonomous underwater vehicle (AUV). For example, the assessment of marine invertebrate larvae and zooplankton (e.g. Krill - *Euphausia superba*) will be investigated from samples that are collected or photographed. All operations will be completely autonomous with the exception of the high level communication between the AUV and the support vessel. The AUV will contain a specially developed modular measurement unit containing various sensors to determine conductivity, temperature, depth, turbidity, and other sensors to detect various chemicals such as chlorophyll.

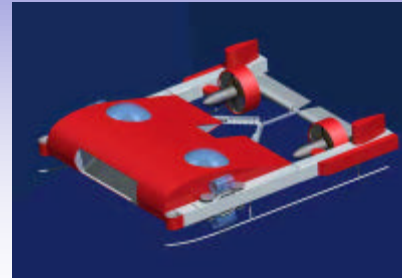
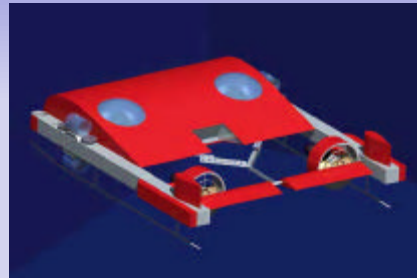
OBJECTIVES

The AUV-Glider is designed specifically for the needs of the Blue Water scientist that requires greater control over the vehicle, more space for scientific instruments and the ability to obtain water or biological samples. Scientists who perform experiments in shallower water can also use the vehicle in power-mode and/or for short duration gliding dives. 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 an AUV-Glider, pollution of ocean waters can be detected and quantified in an automated way; the AUV-Glider can take and analyze water samples to determine water quality as well as the contaminating chemicals. Thus, dangerous substances in the sea can be detected earlier and their harmful effects can be dealt with quicker. Depending on the vehicle's configuration the scientist will have the ability to take fly-by photographs of organisms in the water column or photographs of organisms collected on a mesh-screen.



Running Properties		
Property	% Running Time	Value
Max Speed (V _{max}):	30%	2.0 m/s
Endurance (powered):	10%	15 hours
Endurance (glide):	90%	135 hours

PRO-ENGINEERING RENDERINGS



Special Thanks To:

	Value	Donation
John & Barbara Rumble	\$1,000	
Syntech Technologies	\$13,100	Syntactic Foam
General Plastics	\$1,185	Modeling Foam
Vectorworks Marine	\$ 52,900	Services
F.I.T. College of Engineering	\$1,000	
F.I.T. DMES	\$1,000	
F.I.T. Underwater Tech. Lab. Parts	\$2,813	
Maaco of West Melbourne	\$400	Paint Job



General Vehicle Design

The main vehicle specifications for the AUV are:
 Dry weight: 645-lbs (293-kg)
 (without instruments and drop weight system)
 Length: 76-inches (1.93-meters)
 Width: 62.5-inches (1.59-meters)
 66.5-inches at flares(1.69-meters).
 Max. Height: 20-inches (0.58-meters)
 Displacement: 835-lbs (379-kg).
 Maximum depth: 13125-feet (4000-meters)
 Glass pressure housing depth: 19685-feet (6000-meters)



Fluid Intake Channel

At the front of the biological version of the AUV is a large intake channel that focuses all water and organisms from in front of the vehicle through the channel. Two camera systems are available to document what passes through the channel. The first camera is mounted so the photos are made from the side of the channel. The second is mounted facing directly into the channel. An optional mesh can be mounted in front of the camera to collect organisms over a specified distance. The vehicle would reverse direction to wash already documented samples from the screen using the vehicle's thrusters.

Communications

Three different communication methods are used:
 Through a low-cost 802.11b Wireless Ethernet (WLAN) card for communications between the AUV and a host PC allowing wireless communications with the AUV while at the surface. This module can be configured for one-to-one communications with another WLAN card installed in a field laptop, or with a Wireless Network Access Point, giving the AUV the ability to join a Local Area Network (LAN) and gain access to Internet resources.
 Radio through a MaxStream 9XStream-PKG-R low-speed (Host interface baud rates from 1200 to 57600 bps), half-duplex radio modem, with an extended range at sea: 7 miles (11km). Information concerning the MaxStream can be found at: [MaxStream, Inc./http://www.maxstream.net].
 Underwater acoustic modem for control and monitoring with a nominal range of 3000-m. The system is designed to enable links in noisy environments both at the surface such as bad weather and vessel noise, and underwater noises such as thruster noise, equipment etc.

Navigation and Absolute Positioning

The navigation process uses a Spartan Electronics SP3000D digital compass, depth gage and speed vector/altitude generated by a Doppler Velocity Log (DVL) for dead reckoning. Like any integrating process, dead reckoning accumulates errors and requires periodic fixes to cancel resulting drift. This is done by GPS during surface navigation. When the AUV is underwater, fixes can be sent to the vehicle by an inverted Long Base Line system from the ship and one or more floating location buoys that broadcast their position acoustically, allowing the vehicle to determine its absolute position relative to the buoys and the ship. The vehicle can be monitored from the ship via the acoustic communication link between the ship and the AUV. Collision control is through two UA-2 altimeters from J.W. Fishers Mfg., Inc. The altimeters have the pulse generation and return detection circuitry ported into the transducer and return the information to the computer via a RS232 connection. The UA-2 altimeters provide height over ground and the distance to an object in front of the vehicle up to 100 feet (30 meters) at 200 kHz. An inertial measurement unit (IMU) will measure the vehicle's acceleration and will determine the vehicle's position while underwater. The position will be verified when the vehicle is on the surface by GPS.

Control System and Supervision

The whole system is managed by a control and supervision system that was developed using classical Windows-based tools that allow easy integration and operation of different computers (potentially two or three computers with Windows-XP embedded operating system). The control of the vehicle will be a combination of a traditional feedback system for standard grid pattern surveys and an under-developed neural-network control system for chemical or physical trace mapping.

General Vehicle Design - Unlike torpedo-shaped survey AUVs, the structure of the AUV-Glider has a rectangular frame that is approximately 1.5 by 2-meters square.

The vehicle is designed for easy assembly, disassembly, and with easy access to the batteries and the two 17-inch diameter, 3/8-inch-thick vehicle control system and the scientific pressure housings. The objective was to use cost-effective solutions to keep overall budget of the AUV reasonable. The version shown in figure 3 is for marine biologists and oceanographers that need samples and photographs of organisms in the water column. Other designs (e.g., for physical oceanography, marine chemistry or military operations) would be readily interchangeable.

Battery and Power Management - The battery system is composed of 2 different packs each made up of multiple state-of-the-art lithium-ion SAFT 3.5-Volt, 41.5-Amp-Hour cells for propulsion, instruments and computers. The batteries were chosen for their ease of operation, longevity, and recharging cycles, which greatly extend the vehicles operating range when compared with any other type of battery. It has been calculated that the vehicle will have a 150 hour endurance time assuming 90% of the time is in glide mode and 10% under power.

Propulsion - The vehicle is equipped with two 12-volt longitudinal thrusters capable of producing 35 to 55-lbs of thrust each with an individual manufacturer-rated maximum of 45-Amp draw (28-Amp tested maximum), and two 12-Volt dc-brushless vertical thrusters mounted on the forward two corners of the frame. Each vertical thruster is capable of producing 20-lbs of thrust with an individual maximum 1.5-Amp draw.

Longitudinal thrusters: asynchronous 3-phased, oil-filled design. The estimated motor run time is based on the manufacturer's published data (i.e., 0.85 * (Battery Amp Hour Rating) = (Hours of Running Time) * (Motor Amp Rating)).
 Optimum Running Speed of 2-knots.
 Estimated Power usage for the two thrusters at 2-knots, 12-Volts and 5-Amps = 50-Watts for each thruster.

Vertical thrusters: Elcom ST N2312, coil-type 3-phase wye-wound, low speed, low operating voltage and high torque (Kt=5.30), 12-Volt DC-brushless motors from DC-brushless thrusters, are typically run up to 75% thrust and draw a total of 1.0-Amp for very short periods of time (e.g., one minute in order to raise the vehicle's bow/front from the ground in cases where the vehicle has landed).

Active Buoyancy Control

Active buoyancy control is used to make the vehicle's buoyancy either slightly positive or negative allowing the vehicle to silently, without power, glide up and down the water column in a zigzag or yo-yo pattern. The speed of the ascent or descent in glide mode is in respect to the buoyancy and glide angle and whether the vehicle is under power. The vehicle can be under power at anytime, but energy consumption is high since the motors use more energy than any individual system on the AUV. A buoyancy control system has been a difficult design task for depths deeper than 3000 meters on an AUV due to the extreme pressure at those depths. Consequently, the design and development of a deepwater buoyancy system is a primary component of a glider AUV to obtain the maximum number of glide cycles. For rapid prototyping of the vehicle a simple drop system was configured to drop weights for positive buoyancy and to drop flotation for negative buoyancy until the actual buoyancy system is perfected.

Active Trim Control

Active trim control is used to stabilize the vehicle's trim. For example, as specimens are collected, or when the buoyancy system has an unbalanced configuration (e.g., too much positive or negative buoyancy on one side) or when something foreign is tangled with the vehicle such as seaweed, the active trim control would attempt to align the vehicle. This control is handled by the rear control rudders and flaps. An automatic trim system using liquid mercury is under investigation that is similar to the trim systems on airplanes.

Technical Overview Vehicle System Design