Wave Glider Hardware Architecture

An Introduction for Developers

The Wave Glider ™ is an economic low-profile robotic platform for deploying custom ocean-surface sensor systems. It's an unmanned system that, once deployed, can stay on station without physical attention for up to a year. Its propulsion system converts wave motion to forward motion and allows it to remain in one location or to traverse a specified course without tethers or tows.

An intelligent command-and-control (C&C) system powered by on-board solar panels controls the Wave Glider. The C&C communicates periodically with operations on-shore or on-ship via the global Iridium satellite network. The C&C sends telemetry that includes vehicle status, on-board sensor data, and other important information. It receives commands from operators who may direct the Wave Glider and its payload of sensors to change position, course, operation, or perform other mission-specific tasks.

The Wave Glider is designed to be customized for specific purposes. It contains a core set of features that are fixed but controllable, such as the rudder and the Iridium modem. It contains other features, both standard and optional, that developers may customize to work with their payload and mission requirements—such as dry boxes designed to hold payloads. And it provides support for numerous custom features designed and built completely by developers for a specific mission.

This white paper provides an overview of the Wave Glider's hardware architecture that describes its fixed core features, its customizable features, and types of custom-built features that developers may add.

LRI # 070-01527
Version 1.0, March 23 2011

Principal Components

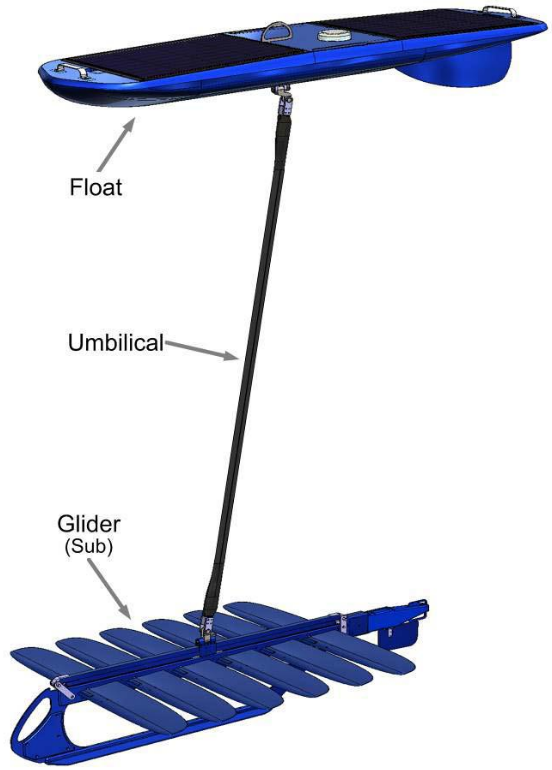

Figure 1: The Wave Glider's three principal components

A Wave Glider has three principal components:

- The *float* is a buoyant hull containing components that provide solar power, control vehicle operation, communicate with on-shore or on-ship operations, and support custom payload deployment.
- The *glider* (also called the sub) is a submerged propulsion unit that moves the vehicle forward, steers the vehicle, and supports custom underwater payload deployment.
- The *umbilical* (also called the tether) connects the float to the glider so the wave motion of the float is conveyed to the glider for conversion to propulsion. Its 7-meter (23-foot) length provides power and communication connections between the float and the glider. It has no developer-customizable parts and so isn't described further in this paper.

The Float

The external parts of the float provide buoyancy, power, and protection from the elements with storage space and mounting for payloads and the command-and-control (C&C) dry box. The internal parts provide dry spaces for the C&C and payload components as well as power storage, communication equipment, and vehicle sensors. The internal parts also provide power and communications for components.

External Components

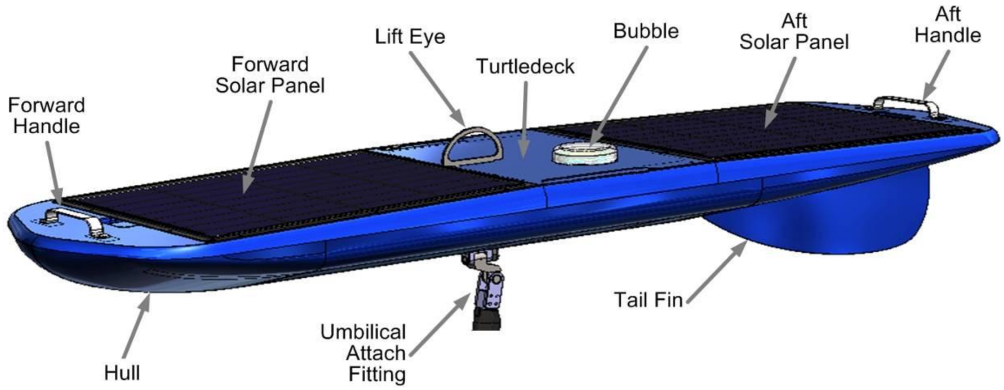

Figure 2: The float's external components

The external float provides these fixed components that can be controlled but not customized:

- The *hull* is made of a carbon-fiber composite with a tail fin for stability, handles and lift eyes for hoisting the vehicle out of the water, a turtle deck to cover and protect the C&C module, and an attachment for the umbilical.
- The *solar panels* fore and aft generate electricity.

Developers can add their own custom components to the outside of the float:

- A forward attachment bolted alongside or in front of the forward solar panel (a camera, for example). This attachment typically connects to a payload in the fore dry box (described later).
- An aft attachment bolted alongside or behind the aft solar panel, similar to the forward attachment, but typically connecting to a payload in the aft dry box (also described later).
- A mid-section attachment bolted to the turtle deck above the C&C module, typically antennas for additional communication channels, but possibly many other things.
- A payload on a cable extending from the stern of the float, integrated with a payload in the aft dry box.

Internal Components

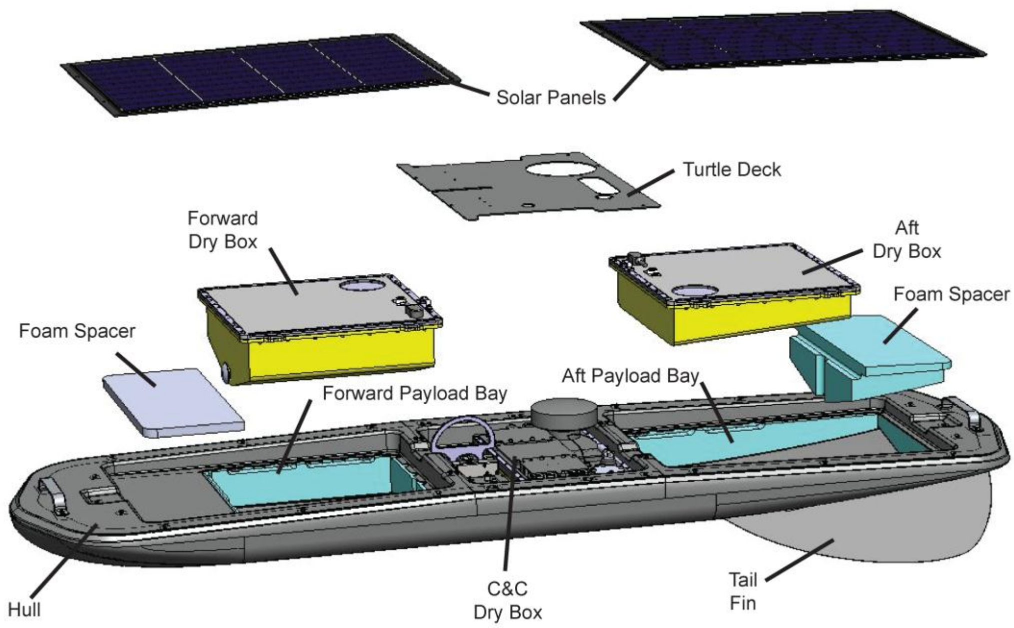

Figure 3: The float's internal components

The float contains the C&C dry box, fore and aft payload bays that may contain payload dry boxes, optional fore and aft payload dry boxes that fit in the payload bays, and connections to share power and communication among the C&C and payloads.

The Command & Control (C&C) Dry Box

The C&C dry box contains fixed features that may be controlled but not customized:

- The *C&C computer* controls vehicle navigation, handles communications with shore or ship operations, manages data flow among float payloads, reads internal C&C sensors, and carries out other control activities. It responds to commands given to it internally by vehicle payloads and externally by operations on shore or ship.
- The *power management system* stored power from the solar panels and provides regulated power to the rest of the Wave Glider electronics.
- *External communication equipment* receives data from and transmits data to off-vehicle sources. This equipment includes a GPS receiver to fix vehicle position and time of day, an Iridium modem to communicate off-vehicle through the Iridium satellite network, an XBee transceiver to communicate off-vehicle through a close-proximity wireless network, and an AIS modem to receive and (if desired) transmit ship IDs.
- The *bubble* contains antennas for Iridium, XBee, and GPS.

- *Internal sensors* report C&C interior dry box conditions. They include a thermometer, an optional air pressure sensor, a compass to report float orientation, and an inertial measurement unit (IMU) to report acceleration and incline.
- *External electrical connectors* to provide plug-ins for power and communications cables to the solar panels, the glider (via the umbilical), and vehicle payloads on both the float and the glider.

Payload Dry Boxes

Liquid Robotics can provide optional payload dry boxes, one to fit the fore payload bay, another to fit the aft payload bay. These payload dry boxes are designed to be customized for the payloads they contain. Developers may also create their own custom dry boxes for deployment in the payload bays or attachment elsewhere. Each of these dry boxes can get power and can communicate through connections with the C&C (described later).

Each Liquid Robotics dry box has a housing that contains the payload and a lid to seal the housing and make it watertight. The lid has a connector for a cable to the C&C that carries power and provides communication. The lid may also have optional removable connector blanks for adding other watertight connectors for developer-supplied accessories such as an antenna, a sensor, or others. The lid has a built-in pressure valve for pressurizing the dry box and checking its watertight seal before deployment.

Float Connections

Liquid Robotics can supply watertight cables with submersible connections that plug into payload dry boxes and the C&C dry box. These cables provide power and data connections among components. Another watertight cable provides power and data connections from the C&C to the glider. Watertight cables also connect the solar panels' power output to the C&C to power the batteries there.

The cables between dry boxes contain lines that perform different functions:

- An RS-232 bus provides serial digital communication among intelligent components of payload dry boxes and the C&C.
- Power lines provide battery power to dry box components.
- A custom communications bus is a line pair unused by the Wave Glider system that payloads can use to convey any kind of signal, analog or digital, that they care to use. The custom communications bus passes through the C&C without intervention or monitoring by the C&C computer to other payloads, including the glider payload.

Power and communications lines terminating in a payload dry box can go straight to a developer's custom equipment. They may also connect to Liquid Robotics equipment designed to provide an easy interface to custom payload equipment:

- An optional payload integration board (PIB) contains a developer-programmable central processing unit (CPU) with data store. The PIB can transmit data to the C&C and from there to other payloads through the RS-232 bus. It may also use the custom communications bus as a developer sees fit. A payload dry box may have one or more PIBs that are daisy chained together if there are more than one.

- Optional personality modules plug into a PIB, which can support up to three of the modules. Each module connects a payload device (a sensor or an actuator, for example) to the PIB. A module provides power and data connections to each device.

The Glider

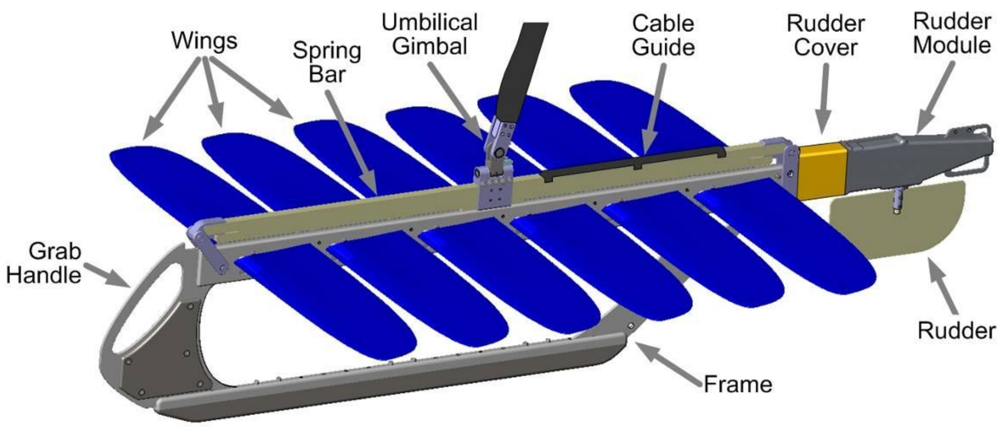

Figure 4: The glider's components

The glider, tethered seven meters below the float, provides propulsion and steers the Wave Glider. It provides these fixed features:

- The *frame* has an umbilical gimbal that attaches to the umbilical, a spring to absorb shock coming through the umbilical, a grab handle to help remove the glider from the water, nose and bottom ballasts to adjust buoyancy and trim, and payload attachment points for bolting on an underwater payload.

- *Wings* pivot up and down with wave motion to propel the glider and pull the float with it. The wings are strictly mechanical; the C&C has no control over them. Whenever there's wave motion, the wings propel the Wave Glider.

- An electronically-controlled *rudder module* with a rudder that steers the glider. The rudder module is connected to the C&C via a power and communications cable. The module contains a servo motor that responds to C&C commands to steer the vehicle.

The glider also provides opportunities to add custom features:

- A custom *underwater payload dry box* that a developer can create from scratch for underwater sensor activities. It can mount at various points on the glider, but can't interfere with the wings or rudder and can't add too much drag.

- An optional *payload connector cable* from the rudder module can connect a custom underwater payload dry box to the C&C. This cable provides power from the C&C and the custom communications bus for optional communication with other payloads.

It does not contain an RS-232 bus, so a payload using this cable depends on communication with other payloads to pass data on to the C&C.

- A custom *trailing wire* from below the keel of the glider can act as a sensor or transmitter.

Developer Options

The preceding hardware overview shows numerous developer options to customize a Wave Glider's hardware for a specific mission. Some options are best built from scratch as custom additions to the Wave Glider, others are adaptations of components supplied by Liquid Robotics to make deployment easier. This section recaps those options.

Custom Options

The contents of a payload are the most obvious custom equipment required when adapting a Wave Glider for a mission. They include sensors, activators, and other components used to carry out a mission. These components are usually stored in a dry box to protect them from the elements.

Dry boxes might be located in the float's two payload dry box bays or (if small and unobtrusive enough) attached externally to hull attachments located fore, aft, and amidships. The float may also tow a streamlined dry box from the stern. Underwater payloads can use a custom underwater dry box attached to the glider.

Dry boxes may be created completely from scratch to fit mission requirements, or they can be a modified Liquid Robotics dry box. Custom dry boxes will usually need to provide their own connections to the C&C module for power, for transmitting data to operations on shore or ship, and for conveying commands for C&C execution.

Payloads located in dry boxes may also need their own external sensors or antennas. These payloads need to provide their own dry box connectors for their external devices. Developers can mount those devices using fore, amidships, and aft attachments on the hull, or can trail them from the stern of the float or the keel of the glider.

Adapted Options

Many developers opt to use Liquid-Robotics-supplied components that are easily adapted to a mission's purposes without a lot of custom work. Liquid Robotics dry boxes are designed to fit the fore and aft dry box bays in the float hull. They provide a payload connector to the C&C, and may also supply removable connector blanks that can be replaced with custom connectors to outside sensors, antennas, and other equipment. Liquid Robotics can provide cables to make standard connections from payloads to the C&C.

Optional payload integration boards (PIBs) inside a Liquid Robotics dry box make it easy to attach payload components through personality modules so components have power and data connections to the C&C. PIBs are programmable to execute mission tasks designed by developers.

Payloads that have special data communication requirements among themselves can use the custom communication lines provided in Liquid Robotics connections to the C&C. Developers can implement whatever communication standard they require using these lines.

Liquid Robotics' support for custom-built components provides maximum flexibility for mission support; its customizable equipment makes it faster, easier, and more economical to set up a mission on the Wave Glider.