Wave Glider® SV3v200 Product Guide

Communications and Control Interfaces for Payload Integration

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Part Number 09114

LIQUID ROBOTICS
A Boeing Company

Wave Glider® SV3v200 Product Guide: Communications and Control Interfaces for Payload Integration

Trademarks

Patents

The Wave Glider mechanism is patented under US Patent Number 7,371,136 and other patents pending. All aspects of the Wave Glider product have been developed at private expense by Liquid Robotics, Inc.

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Revision History

Document Part Number	Revision	Publication Date	Changes
09114	A	September 2017	This is the initial release of this document.

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About this Document

This document provides a detailed description of the Wave Glider SV3v200 platform, including an overview of the mechanical, electrical, communications, and software interfaces.

For in-depth developer information on the Wave Glider SV3v200 mechanical, electrical, communications, and software interfaces, contact your Liquid Robotics representative about accessing the *Wave Glider SV3v200 Interface Control Description*.

This document does not contain information on the Wave Glider Management System (WGMS) - a Liquid Robotics remote Wave Glider navigation and communications application. For information on WGMS, see the *WGMS™ User Guide* and the *WGMS™ Administrators Guide*.

Note

The term "remote application" is used in this document to refer to all remote Wave Glider navigation and communications applications, including WGMS.

Chapter 1. Overview

The Wave Glider® is an autonomous ocean-going platform for deploying custom ocean-to-surface sensor systems. This chapter describes the major components of the Wave Glider SV3v200 system and the key parameters impacting payload integration feasibility.

1.1. Wave Glider Major Components

The Wave Glider system has seven major components:

- **Float** —The Float is the component that rides on the surface of the water. It contains the batteries, control and communications electronics, and optional payloads. Three solar panels on the Float deck maintain the battery charge. The Float deck typically has additional sensing and communications devices installed. A buoy with a retrieval line can be released from the back of the float to simplify recovery. For more information see:
  - “Float Assembly” (page 4)
- **Umbilical** —The Umbilical is a high-strength streamlined connector between the Float and the Sub. The Umbilical provides electrical power to the Sub and also contains wiring for data communications between the Float and Sub. For more information see:
  - “Float to Sub Umbilical” (page 11)
- **Sub** —The Sub is always submerged well below the Float during operation. It provides the propulsion and steering for the Wave Glider system. The Sub can also be used as a platform to mount underwater sensing equipment or to attach a Towfish. Power and communications wiring connections on the Sub "Thrudder" module can accommodate these sub-surface payloads. For more information see:
  - “Sub” (page 18)
- **Towfish (optional)** —Towfish are streamlined, buoyancy neutral, sub-sea extensions of the Wave Glider system that provide mounting points, power and communications channels for a wide variety of underwater payloads. For more information see:
  - “Towfish Options” (page 26)
- **Electrical System** —Command and Control Unit (CCU) including electrical and payload communications hardware, standard power and communications connections, solar panels and batteries. For more information see:
  - Chapter 3: *Electrical Specifications*
- **Communications** —Communication methods, commands, protocols, and relays. For more information see:
  - Chapter 4: *CCU Remote Communications and Control*
- **Software** —Developing payload-specific applications that run on a System Management Computer (SMC). For more information see:
  - Chapter 5: *Software Environment*

Figure 1.1. Wave Glider System (Float, Umbilical, and Sub)

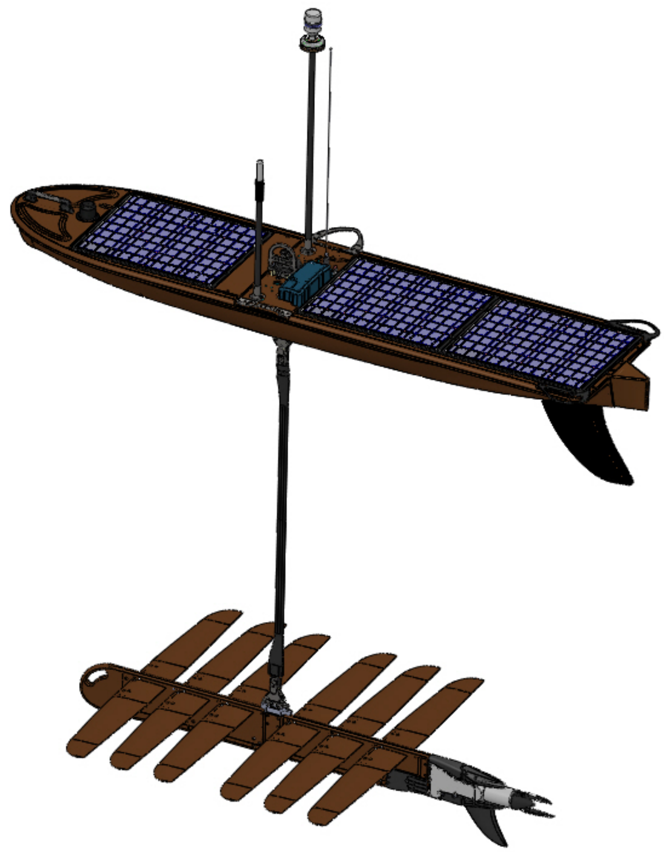
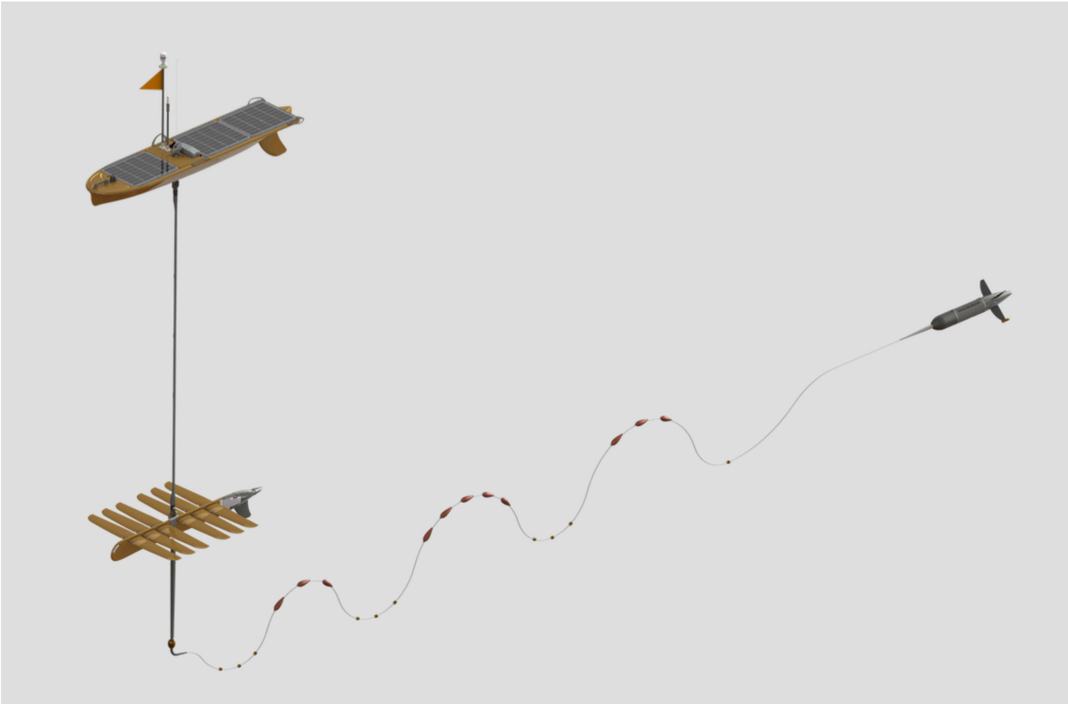


Figure 1.2. Wave Glider System (Float, Umbilical, and Sub) with Optional Tow Fish



1.2. Payload Integration

There are a few key parameters that are most likely to determine the feasibility of a payload integration project. Liquid Robotics recommends evaluating a payload integration project with respect to the following key parameters first:

- **Total weight of the payload**
- **Sizes of payload components**
- **Payload mounting requirements**
- **Payload power consumption**

For more information on payload development, contact your Liquid Robotics representative about Developer Documentation and Training.

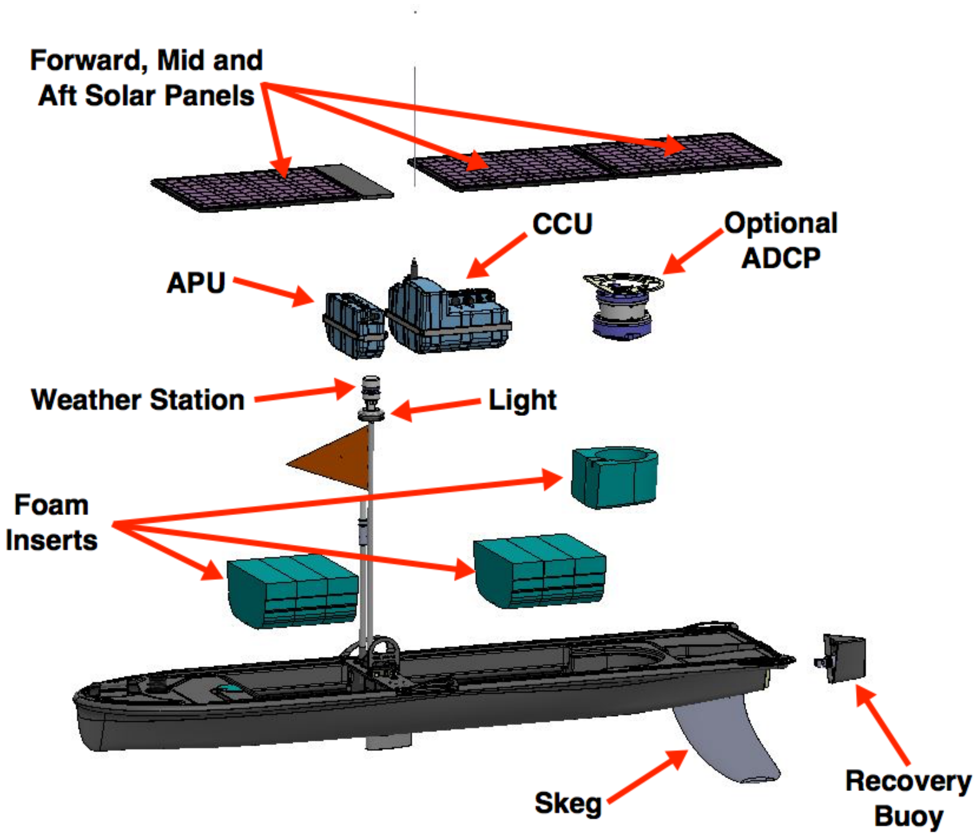
Chapter 2. Mechanical Specifications

This chapter provides mechanical specifications on the Float, CCU, Umbilical, Sub and Towfish options. The drawings in this chapter show dimensions in millimeters and [inches].

2.1. Float Assembly

The Float assembly is illustrated in Figure 2.1.

Figure 2.1. Float Assembly Exploded View

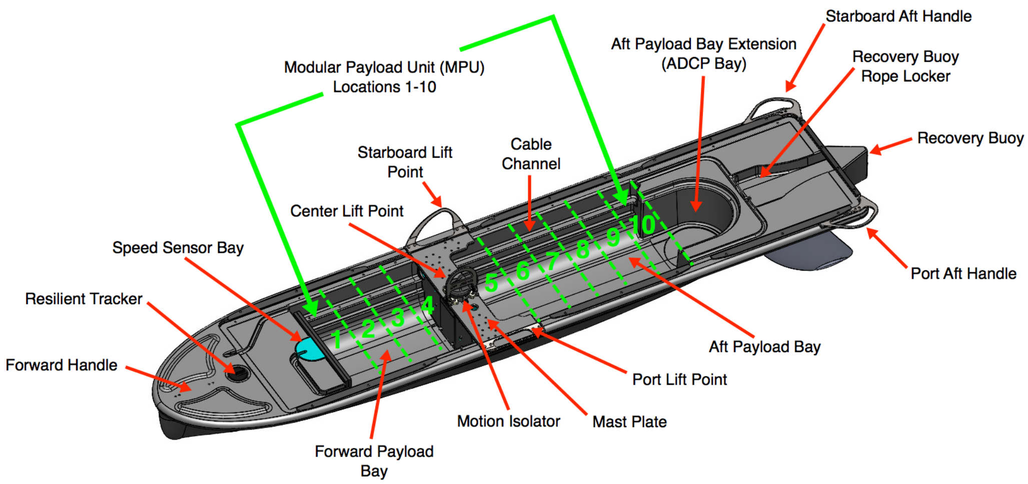


- **Command and Control Unit (CCU)** - Contains the Vehicle Management Computer, standard electronics, and standard batteries. See "Command and Control Unit (CCU)" (page 8) for more information.
- **Auxiliary Power Unit (APU)** - Contains a supplemental battery pack with the same specifications as the battery pack included in the CCU.
- **Forward, Mid, and Aft Solar Panels** - Three identical photovoltaic panels used to charge the on-board batteries.
- **Optional Acoustic Doppler Current Profiler (ADCP)** - An ADCP is used in a wide range of Wave Glider configurations. The Wave Glider Float includes an Aft Payload Bay Extension designed to accommodate an ADCP.

- **Weather Station** - Provides dynamic weather data for the Wave Glider location.
- **Marker Light** - Can be turned on and off manually from WGMS, or other Remote Applications, to improve Wave Glider visibility in low-light conditions.
- **Cover Plate** - Covers the Modular Payload Unit (MPU) between the Forward Solar Panel and the Mast Plate. In the illustration above, an Auxiliary Power Unit (APU) is located in the MPU directly beneath the Cover Plate. See Figure 2.2 for information on MPUs.
- **Recovery Buoy** - Used to recover the Wave Glider. See "Recovery Buoy and Release Mechanism" (page 6) for more information.
- **Skeg** - Stabilizes the Float in yaw.
- **Foam Inserts** - Cut into 1 MPU size sections to fill unused payload bay space. There is also a foam insert designed to fill space around an ADCP when installed in the Aft Payload Bay Extension.

The Float has some integral features that should be noted:

Figure 2.2. Float Integral Features



- **Forward Handle** - For lifting or guiding the Float in water or when it is on a wheeled stand. Not for hoisting the Wave Glider system (Float + Umbilical + Sub) out of the water. This handle is not load rated.
- **Resilient Tracker** - Provides a secondary source of GPS location information transmitted over the Iridium network, in addition to the tracker included in the CCU Dry Box.
- **Speed Sensor Bay** - Designed to accommodate a speed sensor that is included with the Wave Glider SV3v200.
- **Modular Payload Unit (MPU) Locations** - An MPU is equal to the size of the smallest modular payload dry box that Liquid Robotics offers, known as a 1-MPU. The Wave Glider Float payload bays accommodate a total of 10 MPUs, 4 in the Forward Payload Bay and 6 in the Aft Payload Bay. The CCU is a 3-MPU that typically occupies MPU locations 5, 6 and 7 directly aft of the Mast Plate.

- **Forward Payload Bay**- Located between the Speed Sensor Bay and the Mast Plate. Able to accommodate 4 MPUs.
- **Port, Starboard, and Center Lift Points** - For lifting (hoisting) the Wave Glider system (Float, Umbilical, and Sub) out of the water.
- **Motion Isolator** - Provides a shock absorbing Umbilical-to-Sub attachment.
- **Mast Plate** - Includes several threaded titanium mounting points for masts or sensors.
- **Aft Payload Bay** - Located between the Mast Plate and the Aft Payload Bay Extension. Able to accommodate 6 MPUs.
- **Aft Payload Bay Extension** - Designed to accommodate an optional Acoustic Doppler Current Profiler (ADCP) - can be used for other payloads, if an ADCP is not installed.
- **Cable Channel** - A cavity for running cables along the sides of the Forward and Aft Payload Bays.
- **Recovery Buoy** - Used to retrieve the Wave Glider during recovery. See “Recovery Buoy and Release Mechanism” (page 6) for more information.
- **Recovery Buoy Rope Locker** - Provides storage for the rope attached to the Recovery Buoy.
- **Port and Starboard Aft Handles** - For lifting or guiding the Float in water or when it is on a wheeled stand. Not for hoisting the Wave Glider system (Float + Umbilical + Sub) out of the water. These handles are not load rated.

2.2. Recovery Buoy and Release Mechanism

To facilitate recovery of the Wave Glider system, a buoy with 12.192 m [40 ft] of floating, non-fouling line attached to it can be deployed from the aft end of the Float. The line is stored in a Line Locker below the aft solar panel.

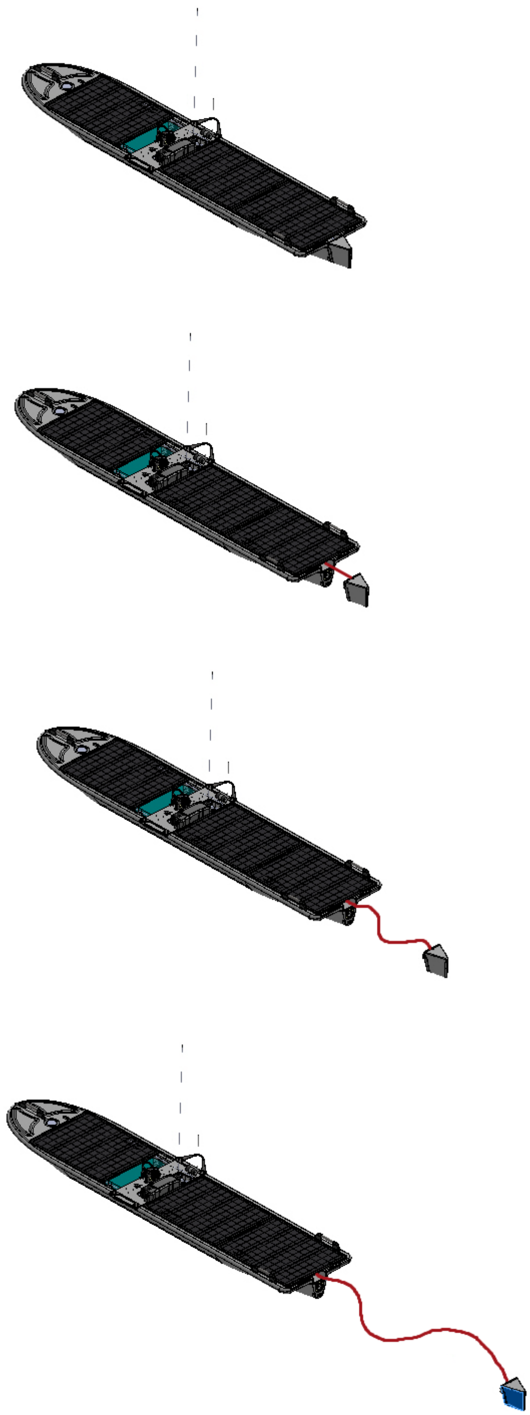
Two spring loaded latches retain the buoy by clasping a latch plate that extends from the buoy. When the release command is issued, a linear actuator forces a piston to open the latches and continue extending to push on the latch plate, until the buoy is released from the Float. The pushing force from the linear actuator will overcome any potential bio fouling.

When the buoy is released, drag on the buoy from water resistance will pull the line out of the line locker. A grappling hook can be used to capture the red and yellow colored line trailing the float, so you can bring the Wave Glider vehicle into position for hoisting.

Important

Do not use the Recovery Buoy or the red and yellow line attached to the Recovery Buoy to hoist the Wave Glider vehicle, it will not safely support the weight. Refer to the *Wave Glider® SV3v200 Launch and Recovery Guide* for more information.

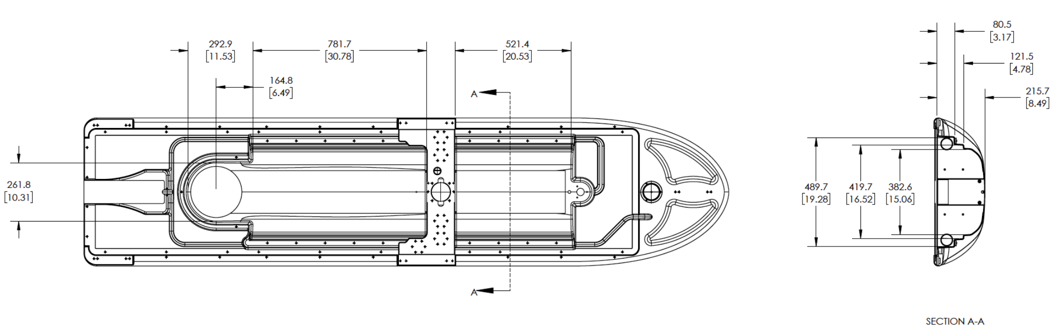
Buoy Release Sequence:



The Recovery Buoy can be manually reloaded into the Wave Glider Float in the field without tools. Also, if necessary, the Recovery Buoy can be manually released from the Float by inserting a 6" screw driver or similar object into a hole in the Recovery Buoy and pressing to release the latch.

2.3. Float Overall Dimensions

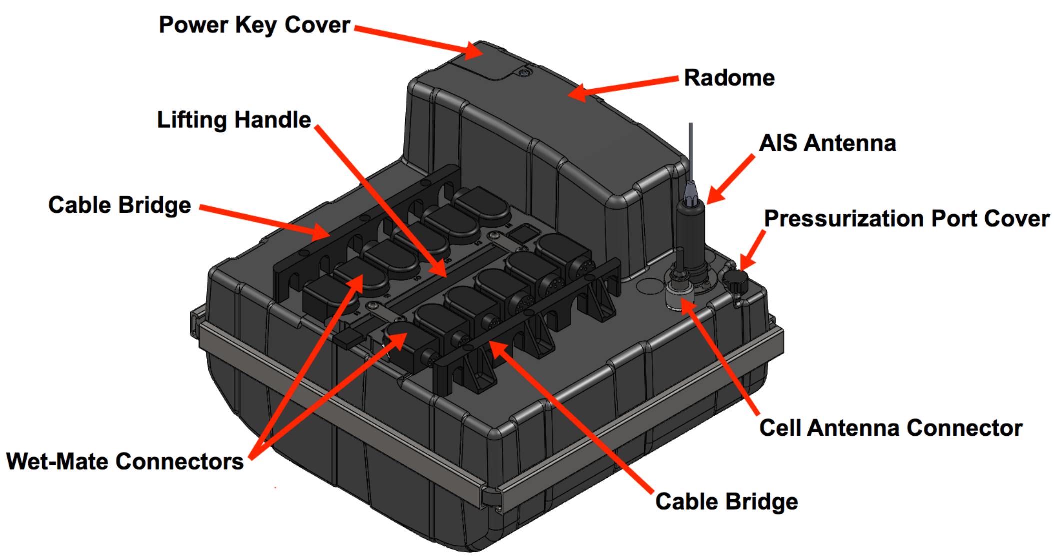
Figure 2.3. Float Overall Dimensions [inches]



2.4. Command and Control Unit (CCU)

The CCU is a factory sealed module that is mounted in the Float at the forward end of the aft payload bay, with its raised Radome tight to the mast plate. It contains the computing, control and communications electronics, and the batteries that store energy from the solar panels. Additional electronics can be added to optional Liquid Robotics Modular Payload Dry Boxes that typically interface with the CCU. **The CCU contains no customer-accessible components.**

Figure 2.4. CCU



The main external components of the CCU are:

- **Power Key Cover** - Removable cover that protects the Power Key which is the main power on/off switch for the Wave Glider electrical system. See "Power Key" (page 34)for more information.

- **Radome** - GPS, Iridium, 2.4 GHz WiFi and 5 GHz WiFi antennas are contained in the Radome.
- **AIS Antenna** - Receives Automatic Identification System reports from class A and class B vessels in the vicinity of the Wave Glider. These reports provide vessel ID, position, heading and other standard AIS data.
- **Pressurization Port Cover** - Protective cover for the dry box pressurization valve.
- **Cell Antenna Connector** - For connecting a cell antenna to be used with the cell modem in the CCU.
- **Wet-Mate Electrical Connections** - Twelve watertight electrical connectors for on-board devices, payloads, and debugging.
- **Cable Bridge** - Keeps wet-mate connectors firmly in place.
- **Lifting Handle** - Nylon strap for lifting the CCU out of the payload bay.

For information on CCU power consumption, see “ Batteries” (page 40).

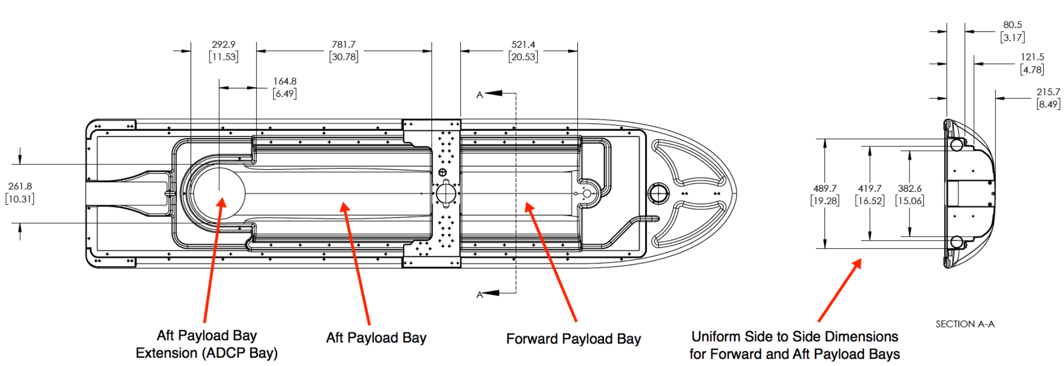
For information on CCU Communications Channels, see Chapter 4: *CCU Remote Communications and Control*.

2.5. Float Payload Bays

The Wave Glider SV3v200 Float payload bays vary in length in the forward to aft dimension, but they have uniform dimensions from side to side. This design supports the use of the Liquid Robotics Modular Payload Dry Boxes that are available in lengths of one Modular Payload Unit and three Modular Payload Units. A Modular Payload Unit (MPU) is equal to the space that an Liquid Robotics 1-MPU Payload Dry Box takes up in the payload bay (133 mm in the forward to aft dimension). The SV3v200 Forward Payload Bay has a capacity of 4 MPUs. The SV3v200 Aft Payload Bay has a capacity of 6 MPUs. For example, an Liquid Robotics 3-MPU payload dry box takes up 3-MPUs of space in an SV3v200 payload bay. The Float CCU takes up 3-MPUs, and an Auxiliary Power Unit (APU) takes up 1-MPU. See Figure 2.2 and for more information.

The Aft Payload Bay Extension (ADCP Bay) extends from the aft end of the Aft Payload Bay. This bay was designed to house a Teledyne RD Instruments acoustic Doppler current profiling sensor (ADCP), however, it is available for other uses if an ADCP is not installed.

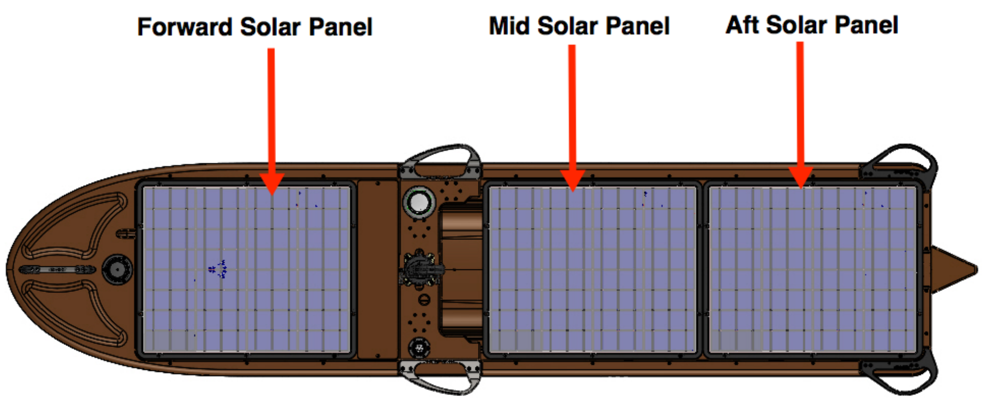
Figure 2.5. Float Payload Bay Dimensions [inches]



2.6. Solar Panels

This section describes the features of the standard Wave Glider solar panels.

Figure 2.6. Standard Solar Panels



2.6.1. Solar Panel Specifications

Table 2.1. SV3v200 Solar Panel Specifications

Panel Power	60 W
Panels per Vehicle	3
Vehicle Power	180 W
Construction	Fiberglass and foam laminate with hard points
Top Sheet	Glass

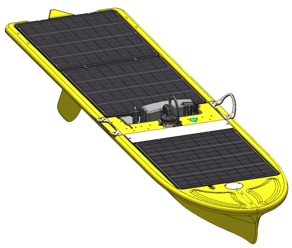
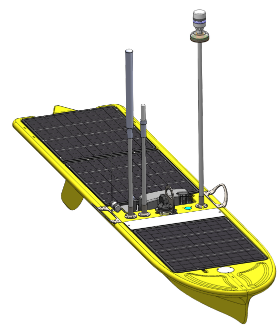
2.6.2. Shading

Shading in general comes from environmental conditions such as cloud cover, and from system components mounted on the vehicle. Shading from environmental conditions is typically temporary and is beyond our control. To optimize total power input, all sensors would have to be mounted below the solar panels to prevent shading. Since this is typically not practical, the following recommendations should be followed to minimize shading.

- If a tall object such as a mast is required, attempt to design it to be narrower than a single cell. This will not eliminate shading, but it reduces the shading impact.
- If an object is wide, attempt to design it to be as short as possible. With this design, shading is not a problem during the middle of the day.

- To maximize power harvest when there are typical shading elements on a vehicle (mid-mounted antenna masts etc.), a course that is predominantly perpendicular to the sun's rays will be best. During early morning and late evening, a North-South course line will minimize solar shadowing. In late morning and late afternoon, a NE-SW and SE-NW course line can be advantageous. During mid-afternoon, an East-West course line will result in the best solar harvest. Early morning and late afternoon solar harvest will be relatively less than mid afternoon solar harvest, regardless of the heading. For this reason, following a course to maximize solar harvest will be most effective during the hours immediately before, and immediately after, noon (Wave Glider local time). During periods of heavy cloud cover, solar shading is relatively insignificant; solar harvest is primarily limited by low ambient light intensity.

Table 2.2. Solar Panel Shading Considerations

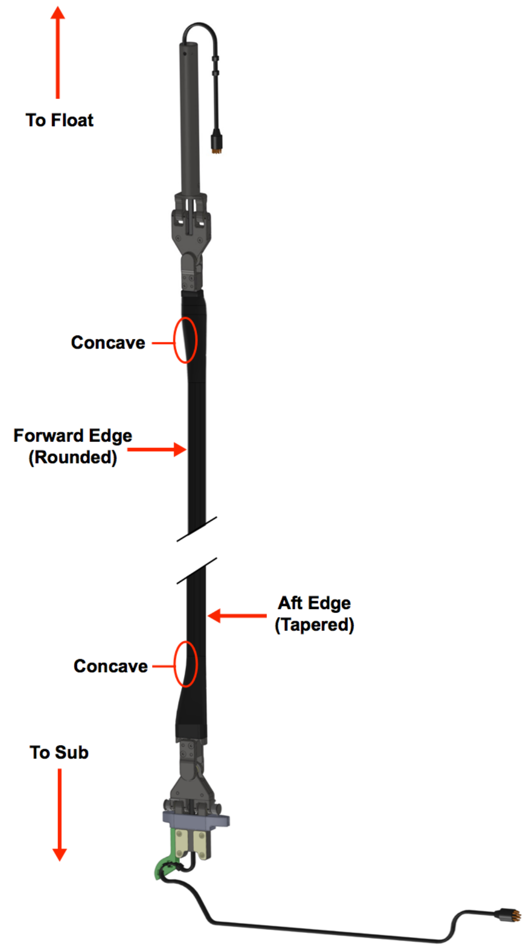
Minimal Shading Potential	Typical Shading Potential
	

2.7. Float to Sub Umbilical

The Umbilical (also referred to as the "Tether") is a flexible cable that connects the Float to the Sub. The standard SV3v200 Umbilical is 8 m [26.2467 ft] long and streamlined to reduce drag.

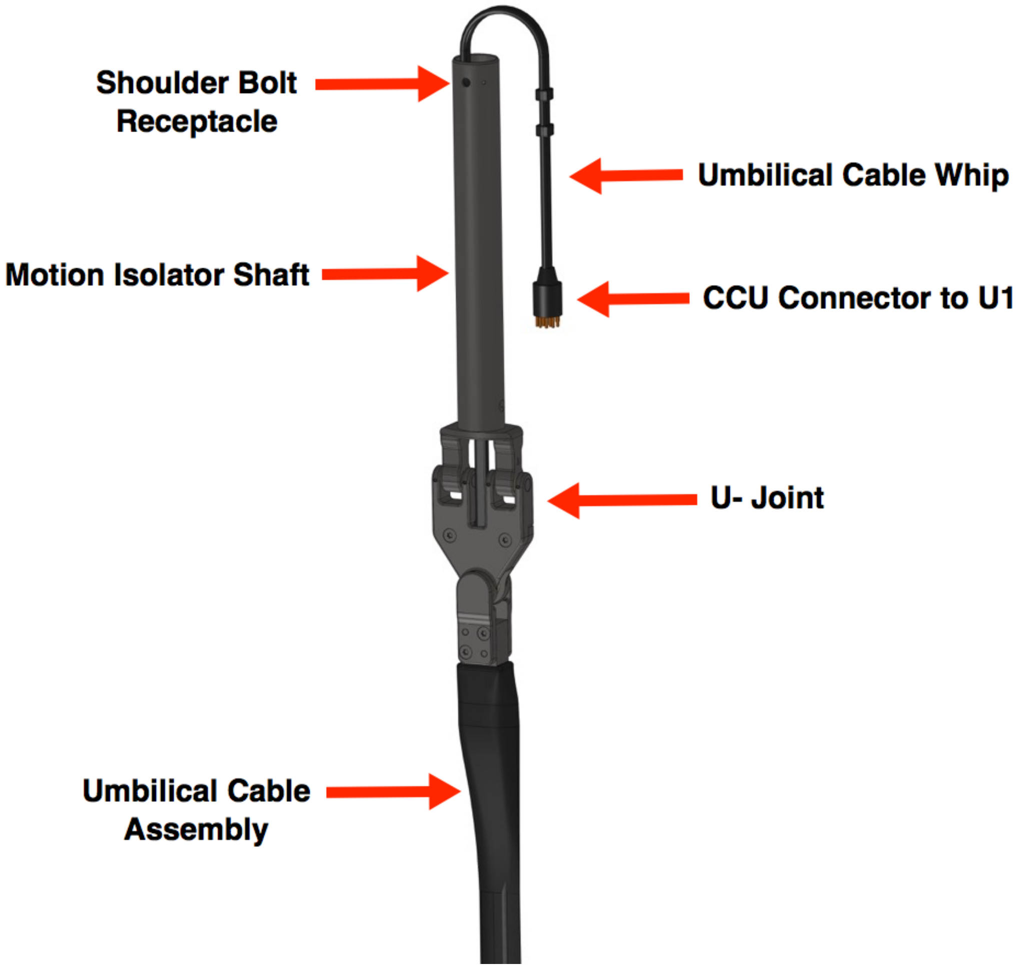
The Umbilical contains high-strength reinforcement cables designed to support the weight of the Sub and the tension the Sub exerts as it responds to wave motion. The Umbilical also contains electrical wiring for power, Thrudder control, auxiliary propulsion, and payload communications. The pin-out for the Umbilical connector to the CCU and the Umbilical connector to the Thrudder Module provide details on the wiring contained in the Umbilical.

Figure 2.7. Umbilical Assembly Overview



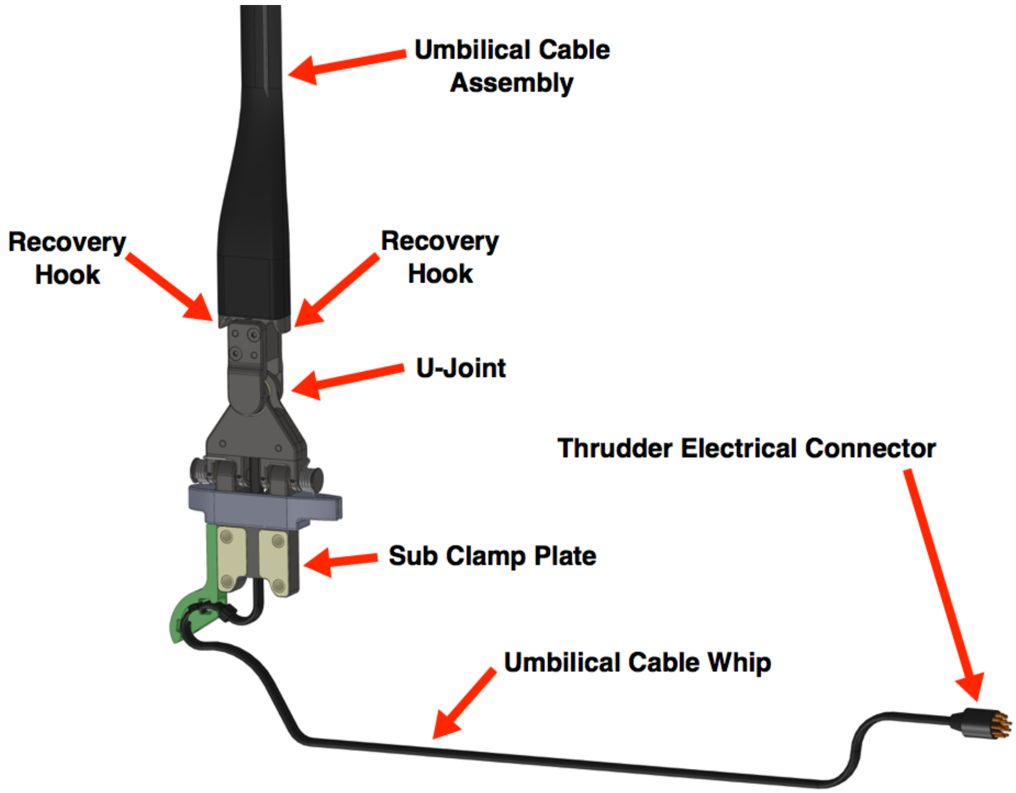
- **Forward Edge** - For streamlining, the forward edge is rounded. Note that the forward edge is also slightly concave at each end.
- **Aft Edge** - For streamlining, the aft edge is tapered.

Figure 2.8. Umbilical-to-Float Connection



- **CCU Connector** - Watertight power and communications connection between the CCU and the Umbilical.
- **Umbilical Cable Whip** - An extension of the Umbilical power and communications cable that extends from the Motion Isolator assembly to the CCU when the Umbilical is attached to the Float.
- **Shoulder Bolt Receptacle** - Where the Shoulder Bolt passes through the Motion Isolator Shaft locking it into the Motion Isolator assembly.
- **Motion Isolator Shaft** - Provides an attachment between the Float and the Umbilical when inserted into the Motion Isolator and secured with the Shoulder Bolt.
- **U-Joint** - Provides two axis of rotation to prevent stress on the Umbilical.
- **Umbilical Cable Assembly** - Attaches the Float to the Sub while providing power and communications connectivity.

Figure 2.9. Umbilical-to-Sub Connection



- **Umbilical Cable Assembly** - Attaches the Float to the Sub while providing power and communications connectivity.
- **Recovery Hooks** - Provide a positive locking feature for the Sub Recovery Mechanism.
- **U-Joint** - Provides two axis of rotation to prevent stress on the Umbilical.
- **Umbilical Cable Whip** - An extension of the Umbilical power and communications cable that extends to the Thrudder Module when the Umbilical is attached to the Sub.
- **Thrudder Electrical Connector** - Watertight power and communications connection between the Umbilical and the Thrudder Module.
- **Sub Clamp Plate** - The mechanical connection to the Sub - attaches to the Sub frame with 4 bolts.

2.7.1. Sub Recovery Mechanism

The Sub Recovery Mechanism is used to hoist the Sub out of the water. A line is attached to the ring on the Sub Recovery Mechanism, then the Sub Recovery Mechanism is slid over the Umbilical and dropped so it locks onto the Recovery Hooks at the bottom of the Umbilical. For detailed Sub Recovery instructions see the Liquid Robotics Launch and Recovery Procedures for the Wave Glider SV3v200.

Figure 2.10. Sub Recovery Mechanism

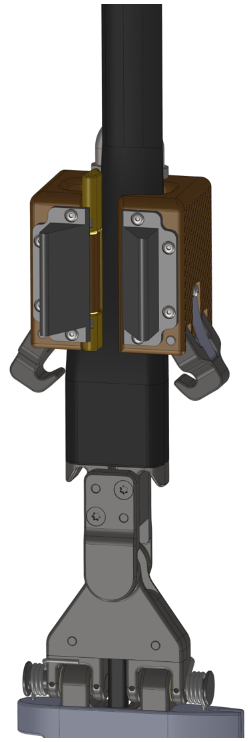
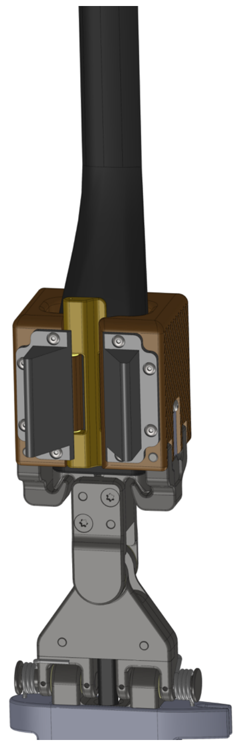


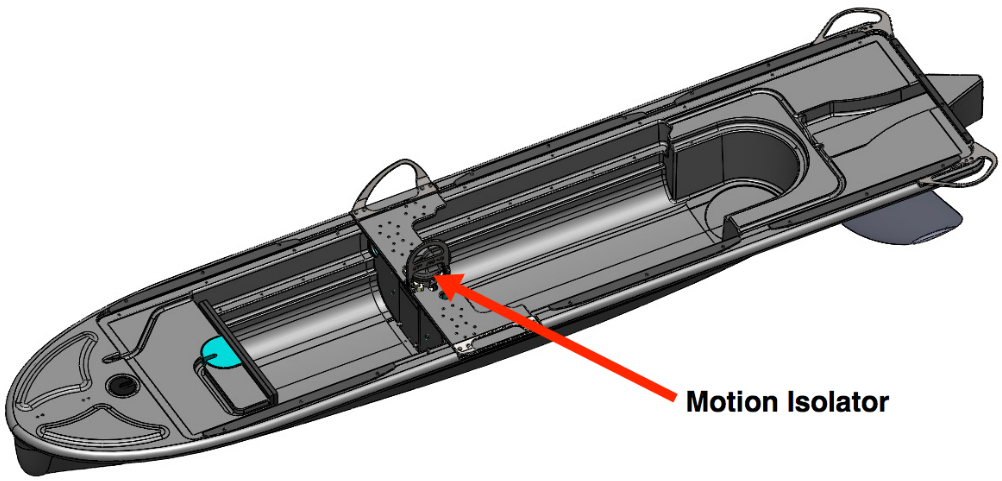
Figure 2.11. Sub Recovery Mechanism Locked Onto Recovery Hooks



2.8. Motion Isolator

The Motion Isolator provides a shock absorbing Umbilical-to-Sub attachment. The Motion Isolator assembly is located directly under the Center Lift Point on the Mast Plate of the Float.

Figure 2.12. Motion Isolator - Top View



The Motion Isolator Shaft on the Umbilical assembly inserts into the Motion Isolator assembly and is locked in place with a Shoulder Bolt that passes through the Motion Isolator Shaft. The spring in the Motion Isolator assembly absorbs shock in rough water and high seas. The Umbilical Cable Whip passes through the protective Shroud and continues on to the CCU.

Figure 2.13. Motion Isolator Extended, Cut-Away View

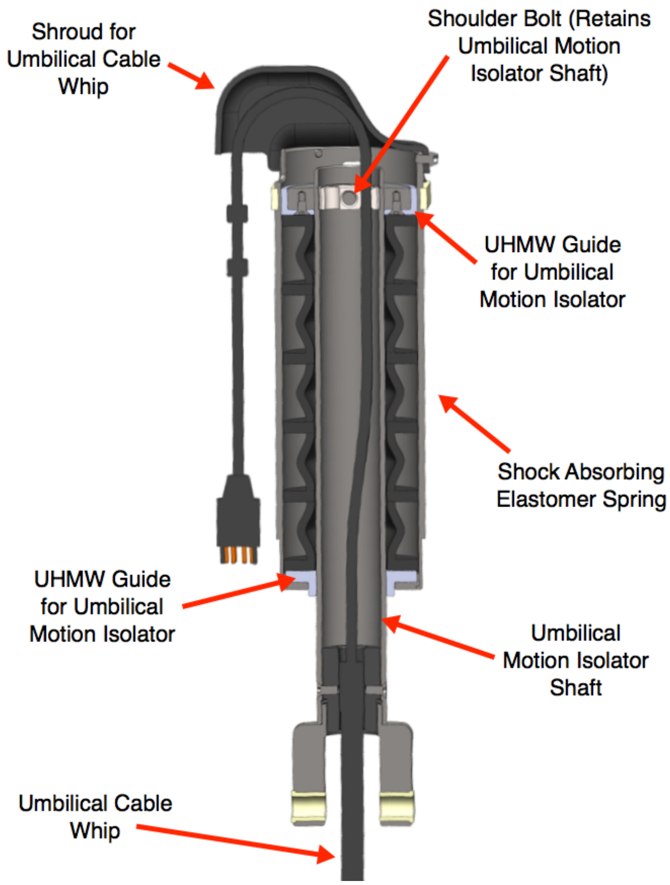
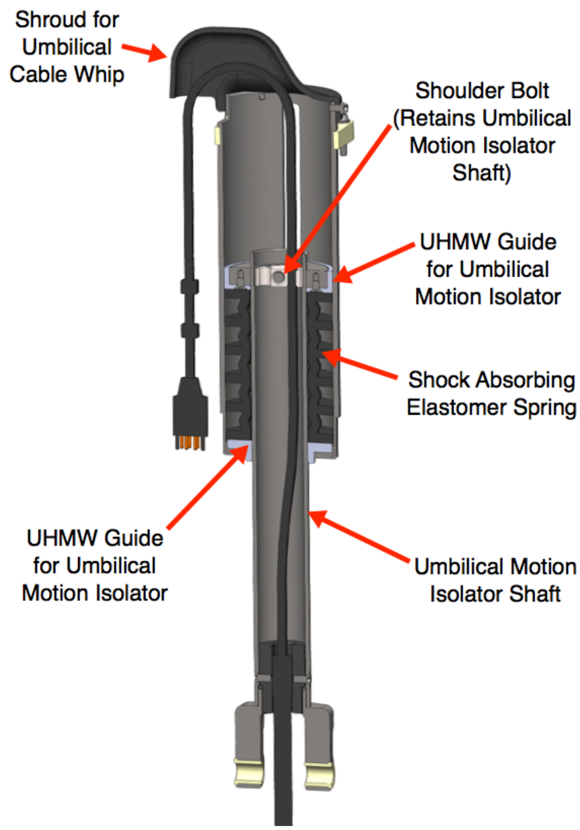


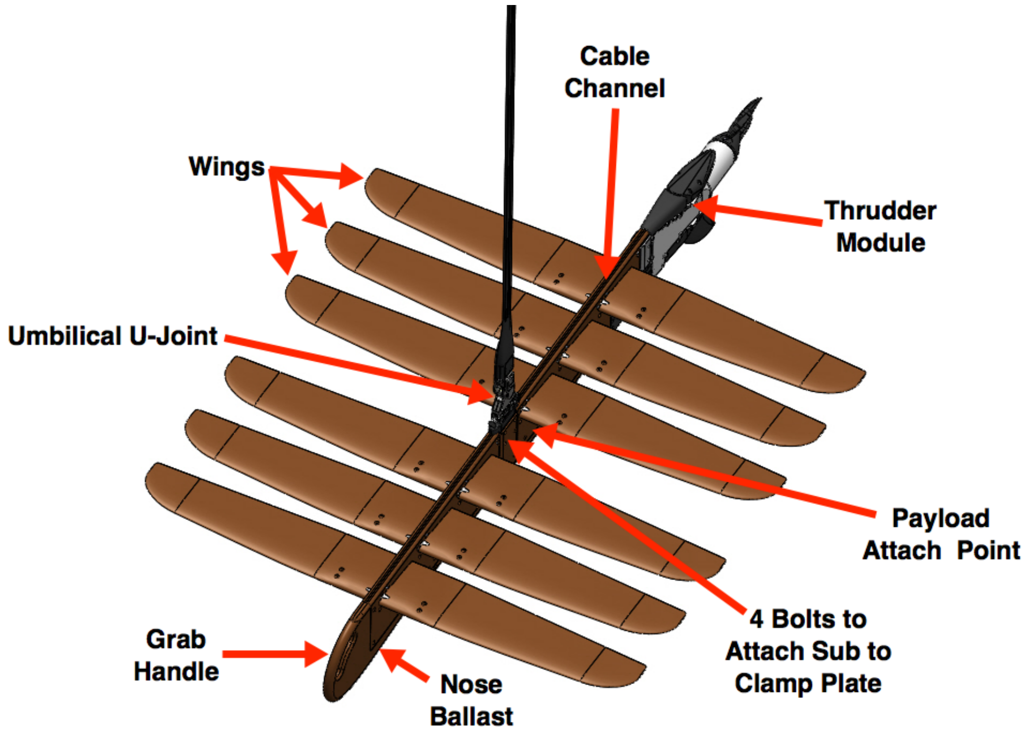
Figure 2.14. Motion Isolator Compressed, Cut-Away View



2.9. Sub

The Sub converts wave motion into forward thrust. The attached Thrudder Module steers the Wave Glider system and also provides supplemental thrust on demand with a motorized propeller. The Sub can be used to carry some underwater payloads, although use of a Towfish for these payloads is recommended. See “Towfish Options” (page 26) for more information.

Figure 2.15. Sub



- **Grab Handle** - Used for launch and retrieval.
- **Umbilical U-Joint** - Provides two axis of rotation to prevent stress on the Umbilical.
- **Nose Ballast** - Forward-located adjustable ballast. Ballast Plates can be added or removed to compensate for payload mounting that impacts the Sub center-of-gravity. Consult with Liquid Robotics before attempting to mount a payload on the Sub or adjusting the Ballast Plates.
- **Wings** - Six pairs of wings provide thrust. Each left-right pair of Wings rotates independently from the other five wing pairs, but the two wings in each left-right pair are attached and rotate in unison.
- **Cable Channel** - A fiberglass shroud provides a narrow protected channel along the top of the Sub frame. The Umbilical Cable Whip runs through the Cable Channel to get to the water-tight connector on the Thrudder Module.
- **Thrudder Module** - Factory sealed. Contains the servo motor and mechanism for pivoting the Fin and the auxiliary Thruster to steer the Wave Glider. It also contains a compass. The Thrudder Module has 3 water-tight electrical connectors for the Umbilical Cable Whip, a Sub or Towfish payload, and a connector for a remote compass.
- **Sub Clamp Plate Attachment Bolts** - 4 bolts that attach the Umbilical assembly to the Sub.
- **Payload Attach Point** - 2 bolt holes for attaching a payload. There is an adjacent electrical channel for snaking a power and communications line between the payload and the payload connector on the Thrudder Module. See “Sub Dimensions and Payload Attachment Points” (page 23) for more information.

Figure 2.16. Ballast Plate Access - Side View

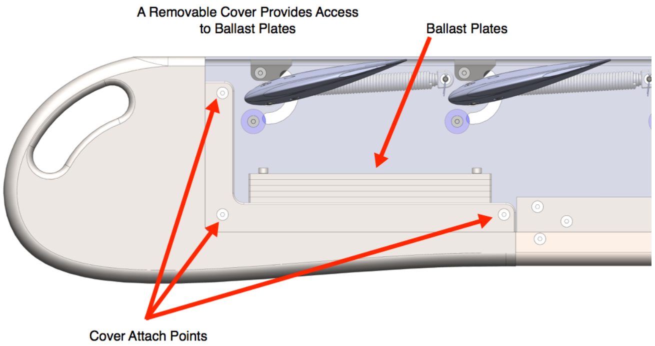


Figure 2.17. Ballast Plate Attachment

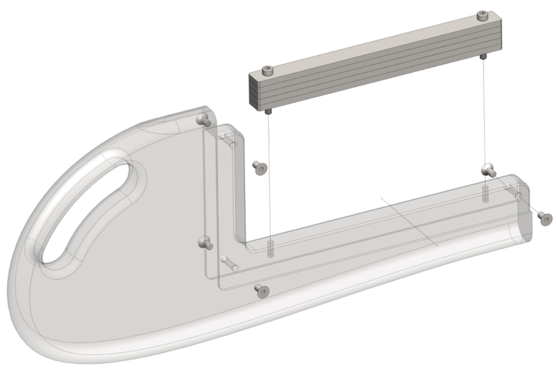


Figure 2.18. Sub with Thrudder Turned - Side View

Figure 2.19. Sub with Thrudder Turned - Top View

When the Sub is carrying payloads, streamlined fairings can be fabricated to cover the payload. An example is shown in the two figures below. The actual shape of the cover can vary depending on the type, shape and volume of the payload.

Figure 2.20. Sub Payload With Custom Fairing

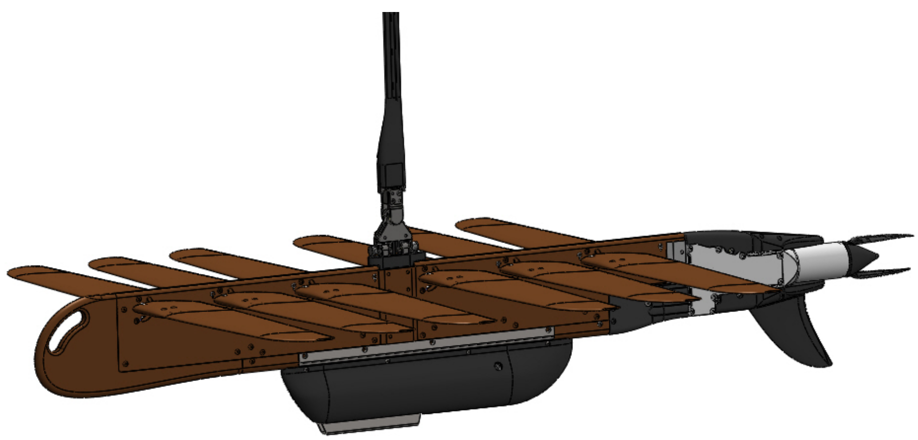
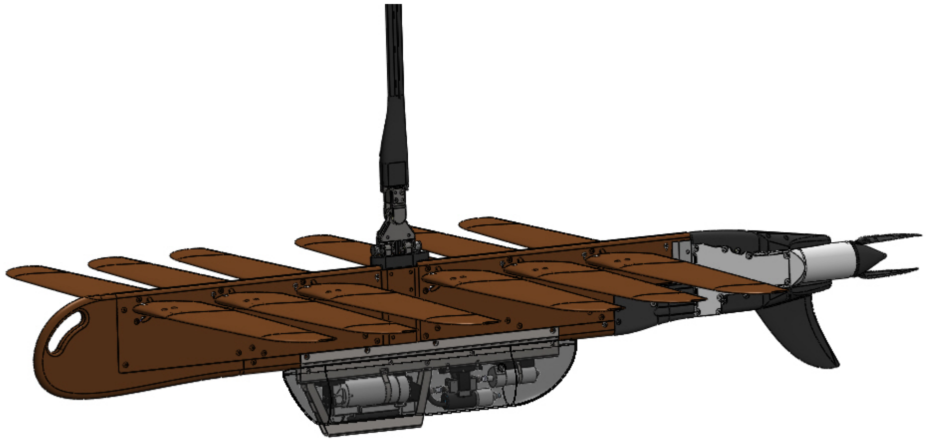


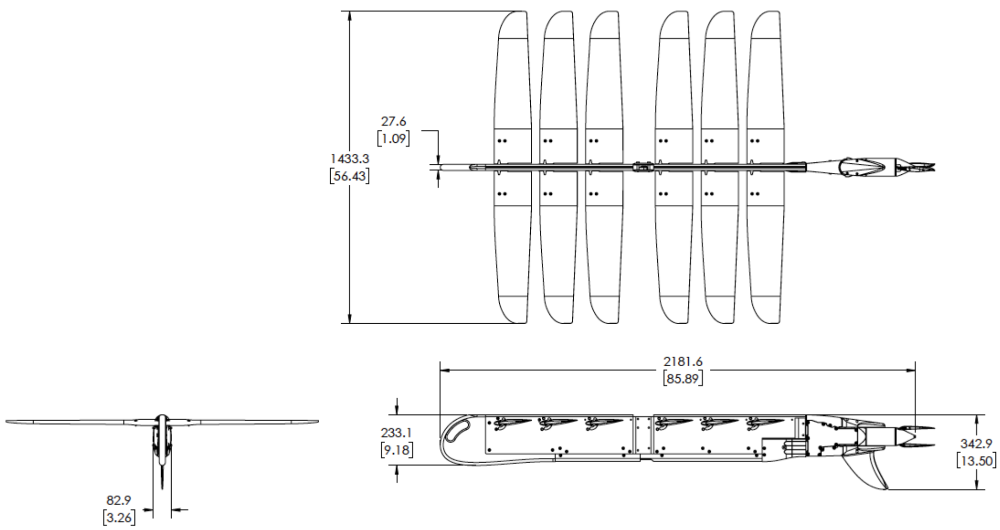
Figure 2.21. Sub Payload With Custom Fairing - Translucent



2.10. Sub Dimensions and Payload Attachment Points

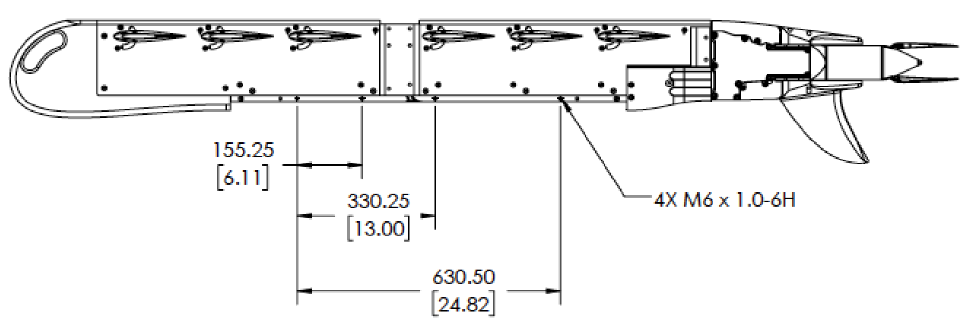
The Sub assembly overall dimensions and attachment points are detailed in the following drawings.

Figure 2.22. Sub Overall Dimensions - mm [inch]



The attachment points consist of 2 threaded holes through the Sub Frame. There is also an opening in the Sub Frame where cables can be routed through the Sub Frame to the Expansion Port on the Thrudder assembly. Typically these attachment points are used for a towing bracket where a Towfish tether is attached or for a Sub-mounted payload and the fairings that cover it.

Figure 2.23. Sub Attachment Points mm [inch]

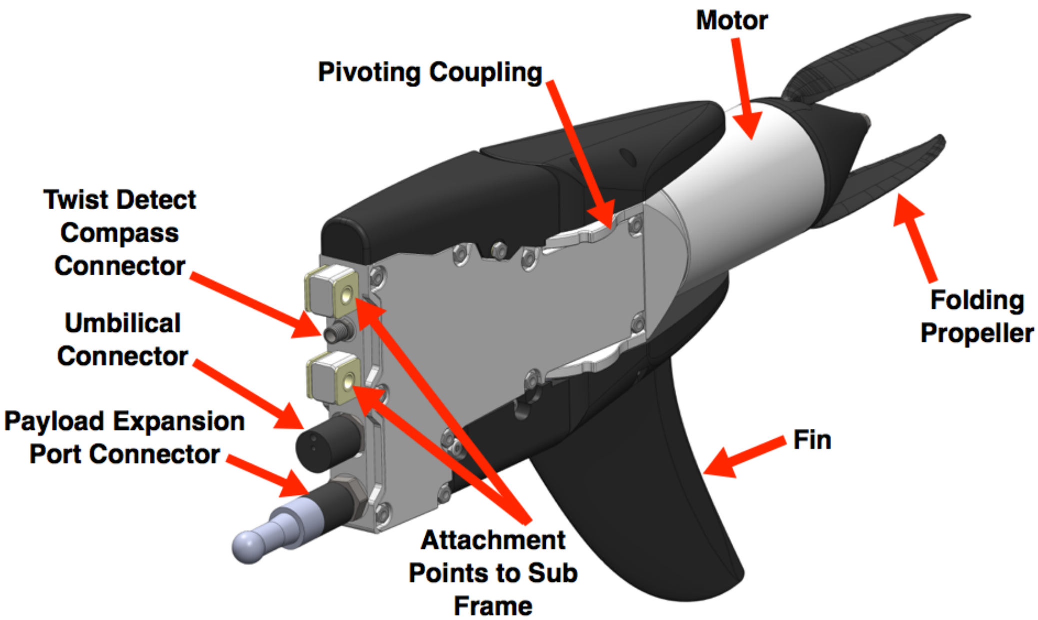


SUB ATTACHMENT POINTS (COVERS REMOVED FOR CLARITY)

2.11. Thrudder Module

The Thrudder Module is the core component in compass based navigation, a control point for Sub and Towfish payloads, and a source of auxiliary propulsion when needed. The Thrudder Module is attached to the Sub frame with two bolts. The Fin and motorized propeller are attached to the pivoting Motor Coupling to steer the Sub.

Figure 2.24. Thrudder Module



When the Thrudder Module is attached to the Sub frame, there is a fairing that encloses and protects the cables and electrical connections.

Figure 2.25. Thrudder Attachment Exploded View

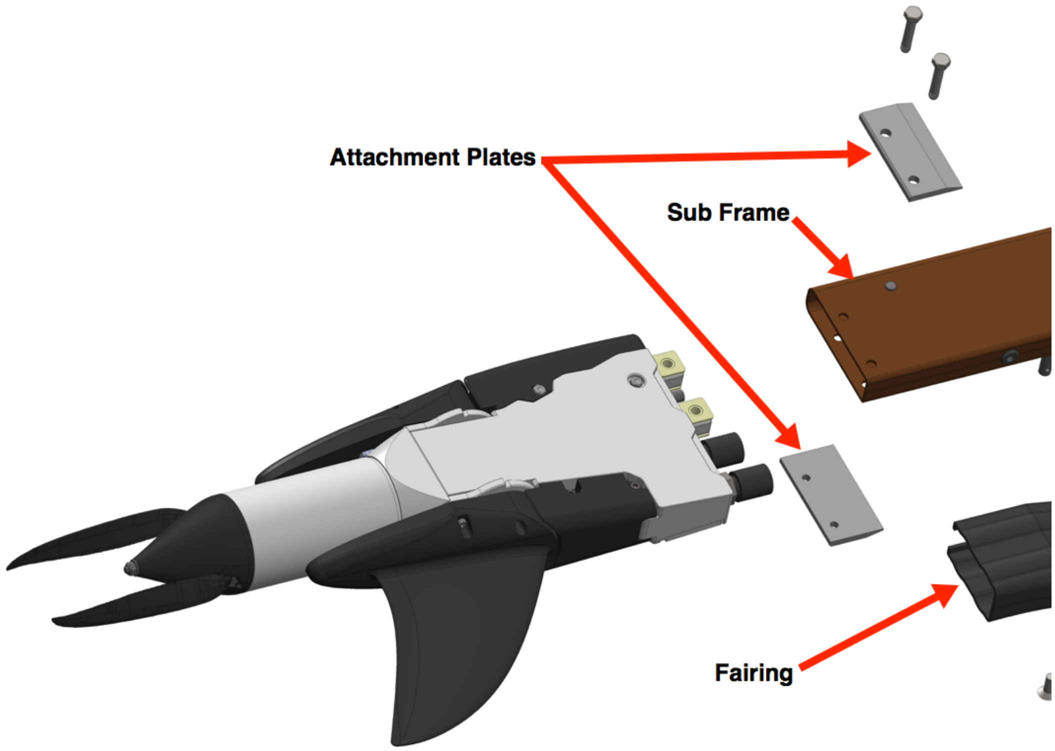
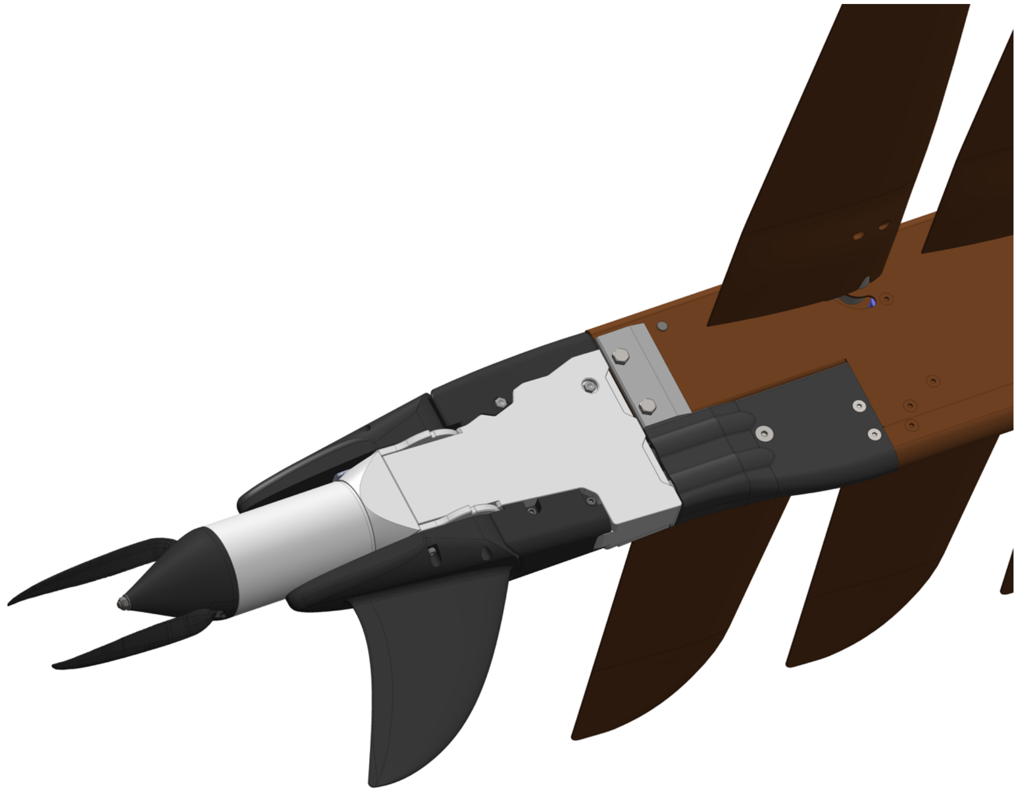


Figure 2.26. Thrudder Attached to Sub with Fairing Installed



2.12. Towfish Options

Towfish are sub-sea extensions of the Wave Glider system. A Towfish is tethered to a specific attachment point on the Sub that prevents the tow cable from interfering with the Thruster propeller. The tow cable includes wiring that provides a communication gateway for data transmissions between towfish-mounted sensors, and data gathering on the Float, or on shore. Liquid Robotics Towfish support both flooded and dry payloads and can be equipped with electronics to manage multiple sensors on the same Towfish. This section provides an overview of the Wave Glider Towfish options. For more information on Towfish sensor integration parameters, contact Liquid Robotics.

There are two standard Towfish options for the Wave Glider:

- **Gateway Towfish** For information on the Gateway Towfish see “Gateway Towfish” (page 26).
- **PAM Buoy Towfish** For information on the PAM Buoy Towfish see “PAM Buoy Towfish” (page 27).

2.12.1. Gateway Towfish

The Gateway Towfish provides a dynamically isolated location to mount an acoustic transducer and accompanying electronics for communication with sub-sea sensors. It is a streamlined, buoyancy neutral vessel that is tethered to the Sub with a shock-absorbing tow cable that has integrated power and communications wiring. The tow cable connects the Gateway Towfish electrically to the Wave Glider CCU. The CCU provides power and facilitates communications. The Towfish sends and receives data over the tow cable, through the Thrudder Module, to the CCU, where it can be stored or transmitted to shore over Iridium Satellite or cellular communications channels. If there is a Float mounted payload associated with the acoustic transducer on the Towfish, data is transmitted from the Towfish to the CCU, to the Float-mounted payload, then back to the CCU for storage or transmission to shore.

Figure 2.27. Gateway Towfish

The Gateway Towfish is designed to carry an acoustic transducer and a modem, with related electronics located in a payload dry box on the Float. Its payload bay can accept a 4.5" diameter transducer weighing up to 7 lbs. and it is designed to accept the Benthos modem or the WHOI micro-modem, with up to 3.5 lbs of total modem weight. Once the contents of the payload are installed, the Towfish must be adjusted to neutral buoyancy and level trim.

Power requirements depend on the sensor and modem that will be used. A high voltage board (located in a Float payload dry box) may be required to power the electronics in the Towfish. Power available to the payload is dependent on Thrudder Module power limitations, as well as over-all Wave Glider system power limitations.

The Gateway Towfish has been proven in high sea states and has been successful in deep water off shore missions.

2.12.2. PAM Buoy Towfish

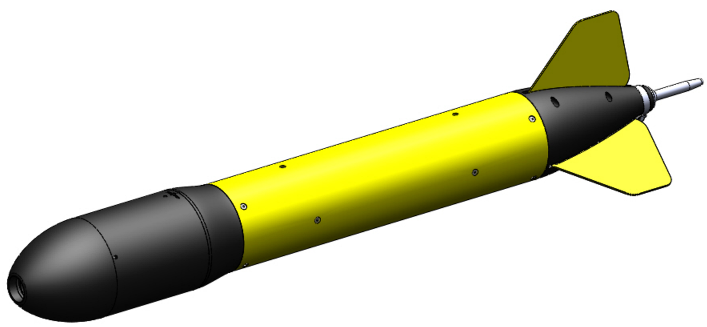
The PAM Buoy Towfish provides a simple cylindrical payload bay with modular nose and tail assemblies. It is a streamlined buoyancy neutral vessel that is tethered to the Sub with a shock-absorbing tow cable with integrated power and communications wiring. The tow cable connects the Gateway Towfish electrically to the Wave Glider CCU. The CCU provides power and facilitates communications. The Towfish sends and receives data over the tow cable, through the Thrudder Module, to the CCU, where it can be stored or transmitted to shore over Iridium Satellite or cellular communications channels. If there is a Float mounted payload associated with the acoustic transducer on the Towfish, data is transmitted from the Towfish to the CCU, to the Float-mounted payload, then back to the CCU for storage or transmission to shore.

The length of the payload bay can be adjusted based on the length of the fiberglass tube that forms the PAM Buoy Towfish body. The PAM Buoy Towfish bay is flooded, but can also carry dry payloads inside an optional sealed enclosure. Inlet and outlet scoops as well as other types of through-wall fittings can easily be integrated into the PAM Buoy Towfish.

The number of payloads the PAM Buoy Towfish can support depends on the weight, physical dimensions, and power requirements of the payloads. Power available to the payloads is dependent on Thrudder Module power limitations, as well as over-all Wave Glider system power limitations.

Once the contents of the payloads are installed, the Towfish must be adjusted to neutral buoyancy and level trim.

Figure 2.28. PAM Buoy Towfish



2.12.3. Tow Cable

The same 5.75 m (18.86 ft) long tow cable is used to connect the Gateway or PAM Buoy Towfish to the Sub. It is designed with attached floats and weights to absorb shock, protecting the towfish from the surging action of the Sub. The speed of the Wave Glider is reduced by 3 to 5% when a properly configured Towfish is attached.

Figure 2.29. Towfish with Tow Cable 3D

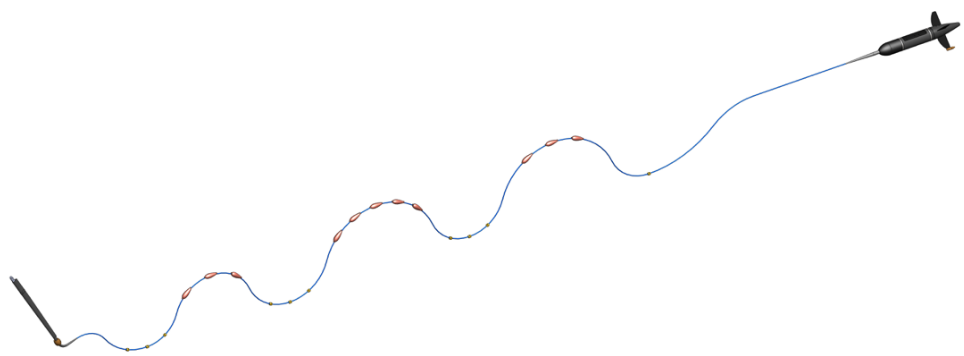
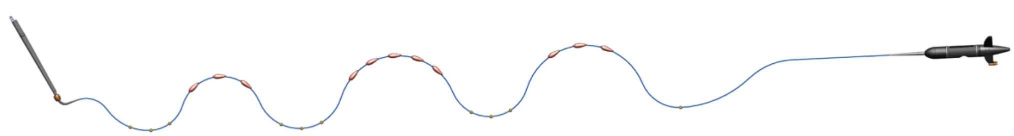


Figure 2.30. Towfish with Tow Cable Side View



Note

If you are planning shallow water operations, be aware that the Towfish flies approximately 1 to 2 meters below the sub.

2.12.4. Custom Towfish

If a Gateway or PAM Buoy Towfish cannot be adapted to your application, Liquid Robotics may be able to develop a custom Towfish to meet your needs. The following Modular Towfish and Large Payload Towfish are examples of custom Towfish Liquid Robotics has developed in the past.

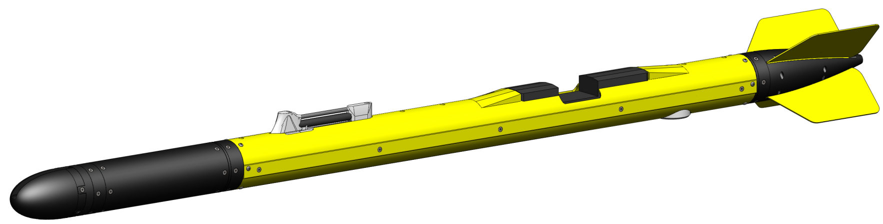
2.12.4.1. Example: Custom Modular Towfish

The Modular Towfish concept allows for multiple payloads, each with dedicated electrical power and communications provided by the on-board Sensor Management Computer that is connected to the Float CCU through the Thrudder Module and a Float payload dry box.

The number of payloads a Modular Towfish can support depends on the weight, physical dimensions, and power requirements of the payloads. Power available to the payloads is dependent on Thrudder Module power limitations, as well as over-all Wave Glider system power limitations.

Once the contents of the payloads are installed, the Towfish is adjusted to neutral buoyancy and level trim.

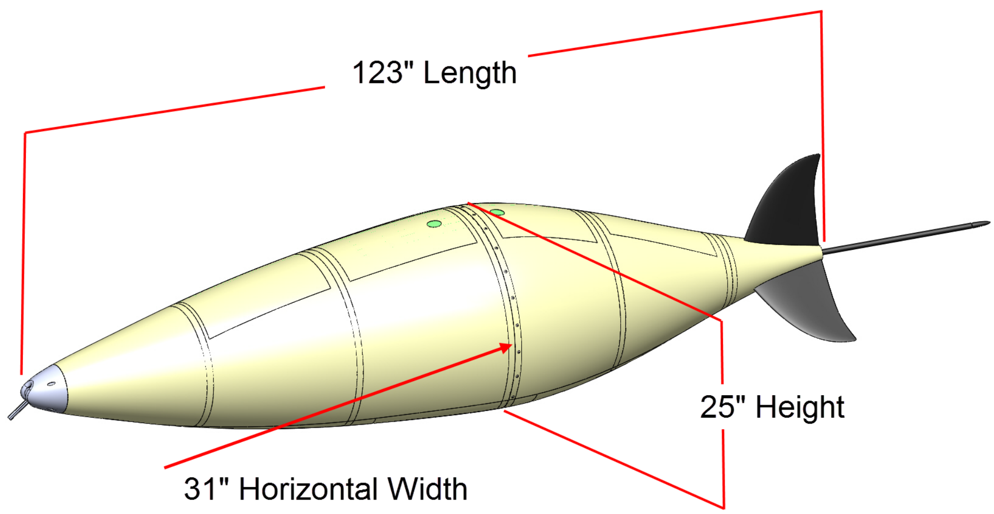
Figure 2.31. Example of a Modular Towfish



2.12.4.2. Example: Custom Large Payload Towfish

A towfish concept for very large payloads is illustrated below. This concept has been successful in initial sea trials and is included as an example of what is possible. After the payload(s) are installed, the Towfish is adjusted to neutral buoyancy and level trim.

Figure 2.32. Example of a Large Payload Towfish - Dimensions in Inches



Chapter 3. Electrical Specifications

This chapter provides information on CCU and payload physical connectivity, including all standard electrical connections, and the Wave Glider SV3v200 Adaptable Modular Power System (AMPS).

3.1. Physical Connectivity

Figure 3.1 illustrates a Wave Glider system with several Float and Sub payloads connected. This is an example of what is possible; it should not be considered a limiting factor in the overall design and implementation of a Wave Glider system. The connections between Wave Glider components shown in the diagram are described in greater detail, including pin-outs, later in this chapter.

Figure 3.1. Wave Glider CCU Connection Diagram

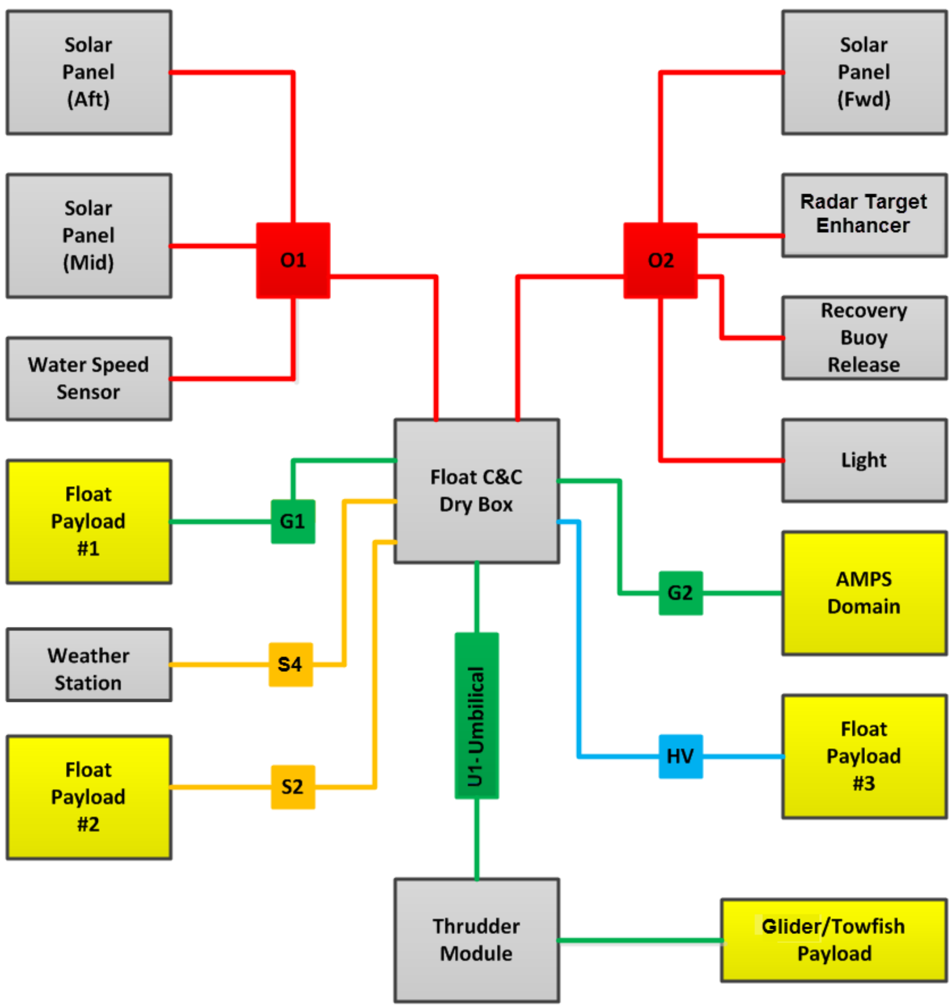


Table 3.1. Color and Label Conventions for Wave Glider Connection Diagram

Objects in Drawing	Description
Grey Boxes	These are standard Wave Glider system components.
Yellow Boxes	These are payloads.
Green Lines	These are 12-pin General Expansion Port, Umbilical, and Thrudder Module Payload connections.
Tan Lines	These are 8-pin Sensor connections.
Blue Line	This is an 6-pin High Voltage Port connection.
Red Lines	These are 16-pin O1 and O2 Octopus Cable connections that branch out to a variety of standard Wave Glider components.

3.1.1. CCU Electrical

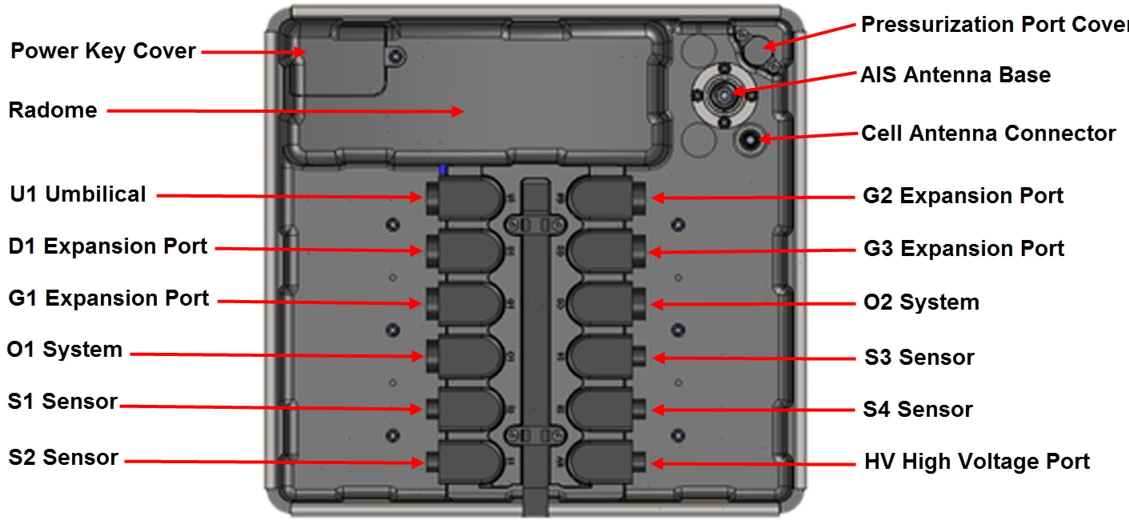
The CCU is the central hub for communications and power. This section describes the electrical interfaces to the CCU.

The CCU contains:

- Vehicle Management Computer (VMC)
- CCU AMPS Power Domain
- Iridium 9603 SBD Modem
- Primary GPS Module - UBLOX NEO-6Q
- Secondary GPS Module - integral to the CPU Module
- WiFi (2.4 & 5.0 GHz)
- Radome - Contains Iridium Antenna, Primary and Backup GPS Antennas, 2.4 GHz and 5.0 GHz WiFi Antennas.
- GSM Cell Modem
- Water Speed Sensor Interface Electronics
- Expansion Switch Matrix
- 8 Port Managed Ethernet Switch
- AIS Receiver
- Ten 98 watt hour Li-Ion Batteries
- 9 Axis Accelerometer
- Compass

The CCU manages power for sensors and other payload components, and it provides communications paths for data retrieval and Wave Glider navigation. The CCU contains no customer-serviceable components.

Figure 3.2. CCU Electrical Connections



There are three types of CCU connectors of particular interest to System Integrators, General Purpose Expansion Ports (G1, G2, G3), Sensor Ports (S1, S2, S3, S4), and the High Voltage Port (HV). The Umbilical connector (U1) and the Debug Port (D1) are dedicated expansion ports.

- **G1, G2, G3 - General Purpose Expansion Ports** - The 12-pin General Purpose Expansion Port connectors provide power, switched 10/100 Ethernet and communications channels to payloads and other AMPS domains.
- **S1, S2, S3, S4 - Sensor Connections** - The 8-pin Sensor connections provide compatibility for Wave Glider SV2 payloads to be used on Wave Glider SV3 vehicles.
- **HV - High Voltage Connection** - The 6-pin High Voltage connection provides up to 48V power for high voltage sensors, for example the ADCP, and it supports RS-232 communications with the CCU.
- **U1 - Umbilical** - The 12-pin Umbilical connector is the power and communications connection between the Float and the Sub. The Umbilical transfers power from the Float to the Thrudder Module, and from there to Sub and Towfish payloads. The Umbilical also transfers data between the CCU and Float Payloads, Sub Payloads, the Thrudder Module and a Towfish.
- **D1 - Debug Port** - The 12-pin Debug Port is reserved for Wave Glider system troubleshooting and battery charging using an AC adapter.
- **O1 - System Connection** - The 16-pin O1 System connection uses a 16-pin "Octopus" cable to connect two solar panels and a water speed sensor to the CCU.
- **O2 - System Connection** - The 16-pin O2 System connection uses a 16-pin "Octopus" cable to connect a solar panel, a radar target enhancer, a recovery buoy release mechanism, and a marker light to the CCU.

For more information on the CCU, see “Command and Control Unit (CCU)” (page 8).

3.1.2. Power Key

The power key turns the system on and off. It plugs into a 3 prong male electrical connector and is held in place with a threaded retaining nut. The system is powered on when the key is inserted. When the power key is removed, the system shuts down. When the system is shutdown, the batteries are individually disconnected and the solar panels and auxiliary power inputs are disconnected from the system.

3.2. Payload Connectivity

This section describes the physical connections between the Payload Dry Boxes and the Float CCU.

3.2.1. Payload Communication Connectivity

Figure 3.3 shows the communication paths available to Wave Glider payloads.

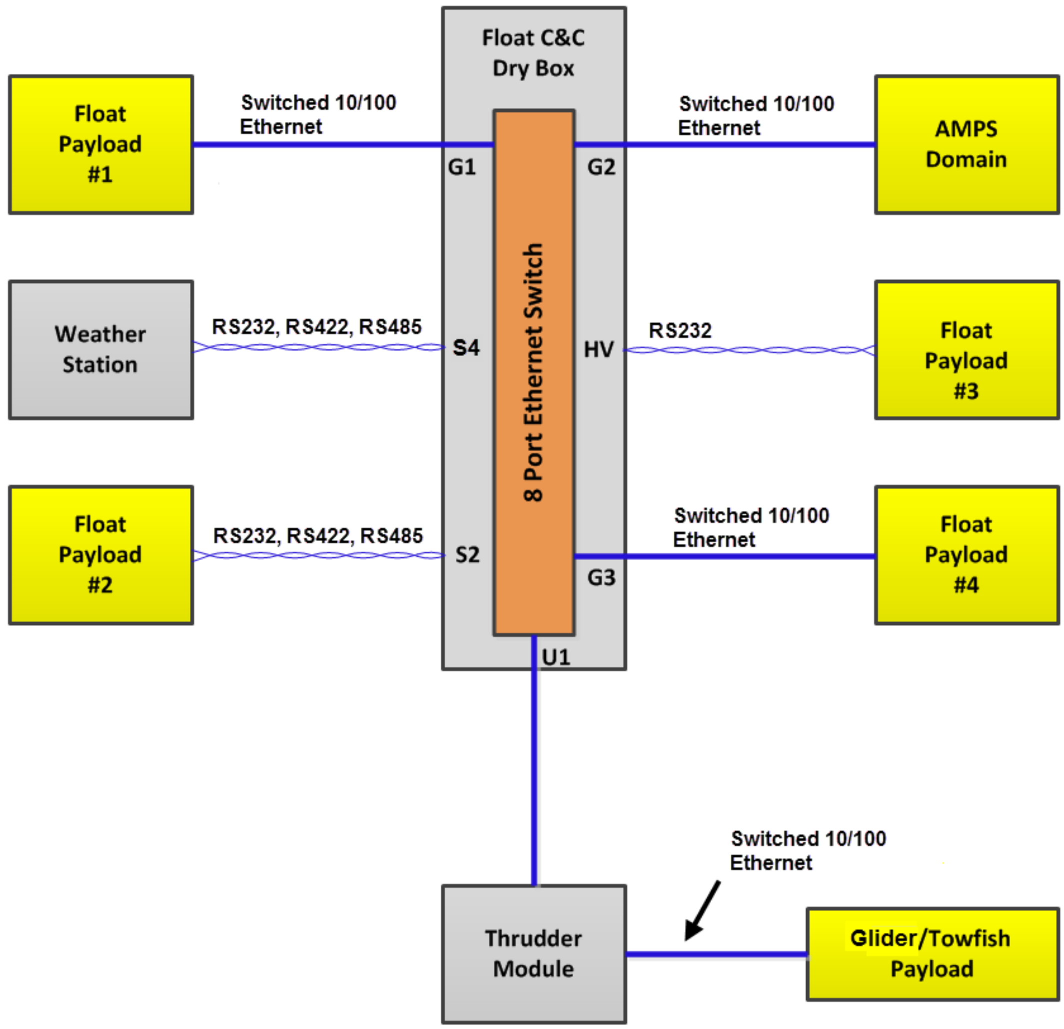
- Payloads connected to the CCU Sensor ports (S1, S2, S3, S4) can communicate directly with the CCU using RS232, RS422, or RS485 serial communications. Through the CCU, they can also communicate with other payloads, or with remote applications over the Iridium Network. Payloads that include a modem can communicate directly with remote applications.

- When the HV port is fully implemented, payloads connected to the CCU High Voltage port (HV) will be able to communicate directly with the CCU using RS232. Through the CCU, they will also be able to communicate with other payloads, or with remote applications over the Iridium Network. Payloads that include a modem will be able to communicate directly with remote applications.

- Payloads connected to the CCU General Purpose Expansion ports (G1, G2, G3) use switched 10/100 Ethernet communications. All communications sent or received by payloads connected to G ports pass through an Ethernet switch that can be configured to allow payload-to-payload communications or direct communications between payloads and the CCU. Payloads that include a modem can communicate directly with remote applications.

- Towfish or Sub payloads use switched 10/100 Ethernet communications available through the CCU Umbilical "U1" port (by way of the Thrudder module payload connector). All communications sent or received by Towfish or Sub payloads pass through the same Ethernet switch that is used by the "G" ports. The Ethernet switch can be configured to allow payload-to-payload communications or direct communications between payloads and the CCU.

Figure 3.3. Payload Communications Diagram

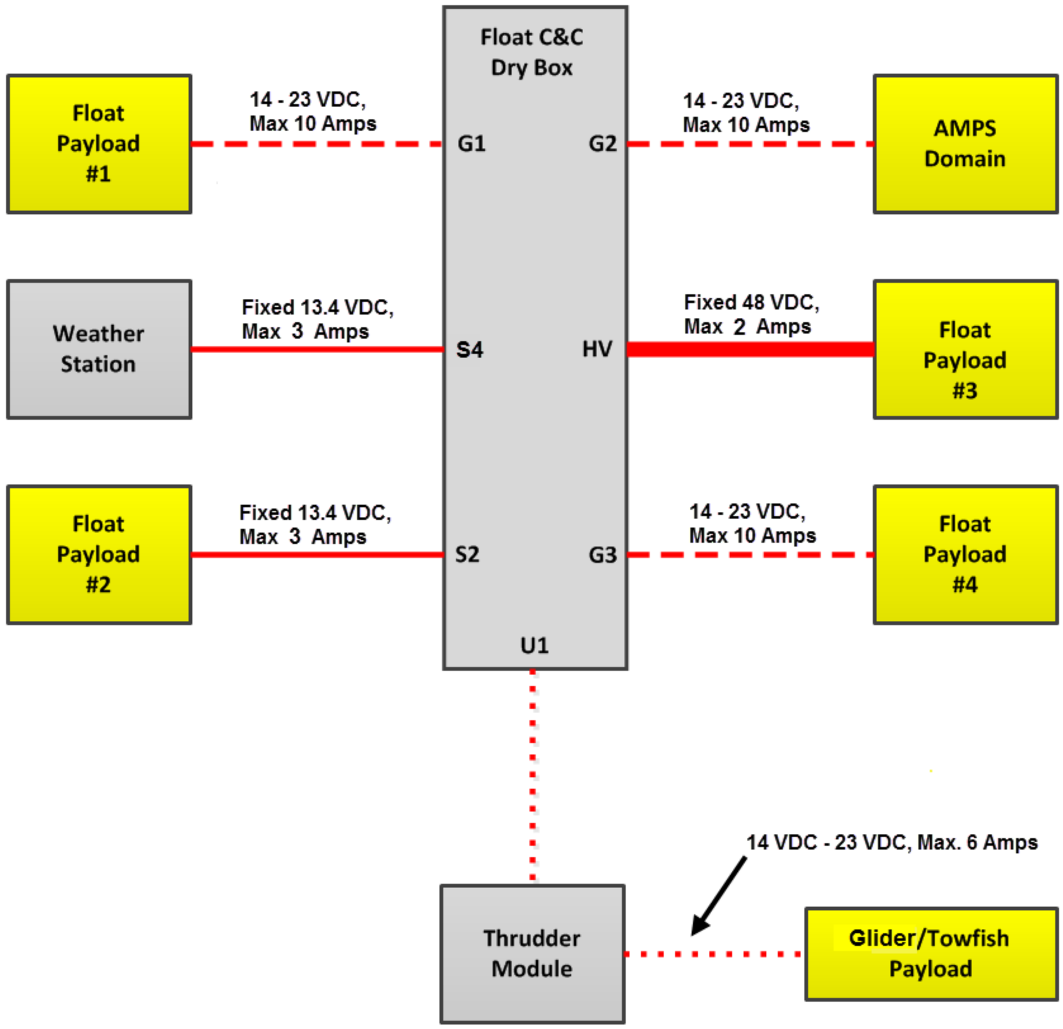


3.2.2. Payload Power Connectivity

Figure 3.4 shows power availability for Wave Glider payloads. Each of the payload connections to the CCU includes pins dedicated to powering a payload.

- Payloads connected to the CCU Sensor ports (S1, S2, S3, S4) receive a fixed 13.4 VDC power supply limited to a maximum of 3 Amps.
- Payloads connected to the CCU General Purpose Expansion ports (G1, G2, G3) receive a variable power supply ranging from 14 to 23 VDC limited to a maximum of 10 Amps.
- Payloads connected to the CCU High Voltage port (HV) receive a fixed 48 VDC power supply limited to a maximum of 2 Amps.
- Towfish or Sub payloads receive a variable power supply through the CCU Umbilical "U1" port (by way of the Thrudder module payload connector) ranging from 14 to 23 VDC and limited to a maximum of 6 Amps.

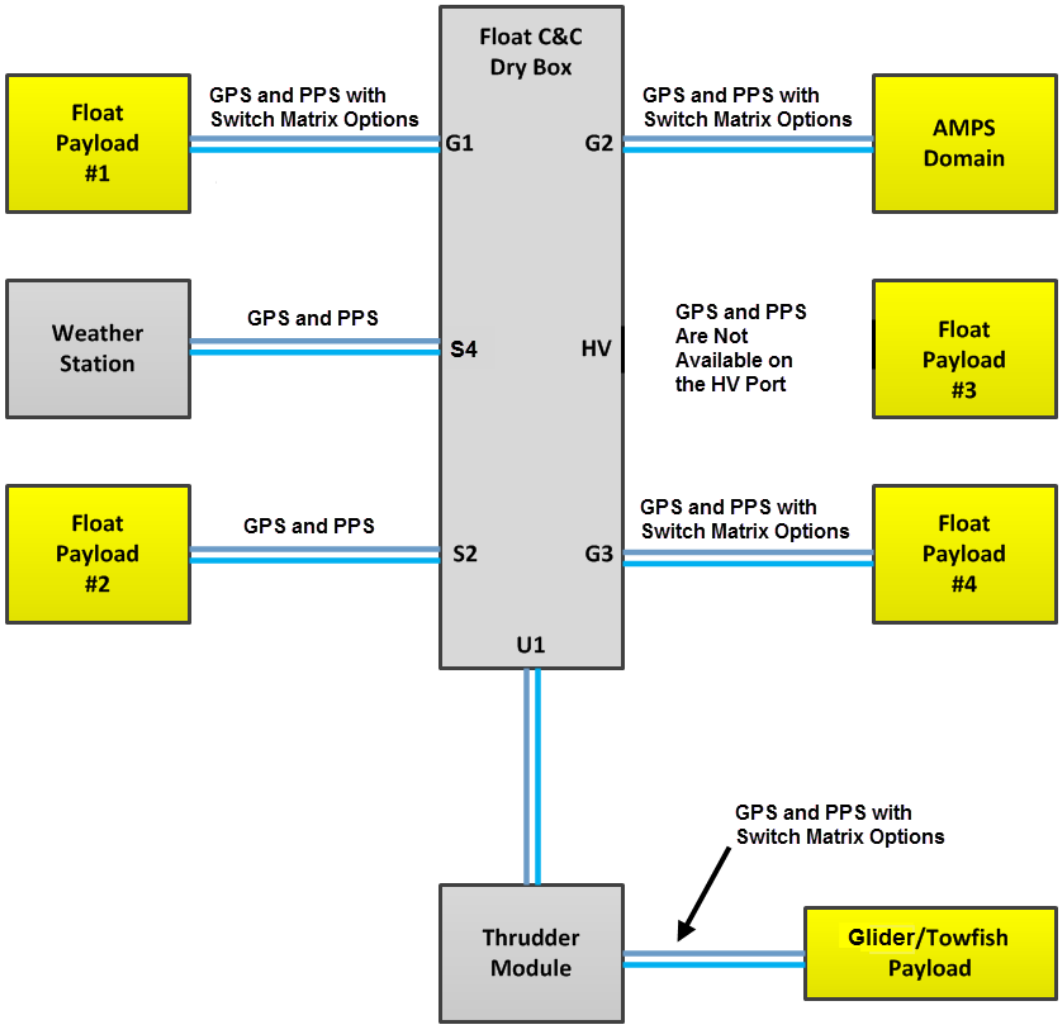
Figure 3.4. Payload Power Diagram



3.2.3. GPS and PPS Connectivity

Figure 3.5 shows GPS and PPS data availability for Wave Glider payloads. GPS and PPS data is provided through all of the CCU and Thrudder Module payload ports. For payloads connected to the G1, G2, G3, or Thrudder Module payload ports, a switch matrix makes GPS/PPS optional. If one of these payload connections is not configured (switched) to include GPS/PPS, the two lines in the connecting cable that support GPS/PPS can be used for other purposes.

Figure 3.5. GPS and PPS Diagram



3.3. Adaptable Modular Power System (AMPS)

The Adaptable Modular Power System (AMPS) enables extremely efficient power management for a wide range of possible Wave Glider configurations. By generating data on individual power producers and power consumers in prioritized power domains, AMPS facilitates optimal mission specific power management. AMPS is defined by a 3-wire power distribution system that includes hierarchical communications capability for monitoring and control.

AMPS extensibility supports:

- Scaling the number of power domains.
- Scaling power generation inputs.
- Scaling power storage capacity.

AMPS scaling is achieved through the CCU Expansion Ports. The CCU Expansion Ports are Host Expansion Ports. A Host Expansion Port is defined by having a fully isolated AMPS interface that includes electronic isolation for VPRODS, VCONS, and CAN (AMPS power and communications).

A Guest Expansion Port is defined by having a partially isolated AMPS interface where VPROD and VCONS (AMPS power lines) are fully isolated, but the CAN interface (AMPS communication network) is not isolated and is always available.

AMPS is extended by connecting a Guest Expansion Port on an AMPS domain to:

- A Host expansion port on the CCU.
- A Host expansion port on an AMPS domain that is already extended from the CCU.

When a Guest Expansion Port on an AMPS domain, for example a payload or an Liquid Robotics Auxiliary Power Unit (APU), is connected to a Host Expansion port on the CCU or on another AMPS domain, a communication channel between the newly added AMPS domain and the CCU becomes active allowing you to configure and manage the newly added AMPS domain from a remote application (for example, WGMS). If you attempt to extend AMPS by connecting a Host Expansion Port on the newly added AMPS domain to a Host Expansion Port on the CCU (or on another AMPS domain), the newly added AMPS domain will remain isolated and non-operational. Any payload that includes an AMPS domain (AMPS backplane and modules) must include a Guest Expansion Port, and will not support further expansion of AMPS unless it also has a Host Expansion Port.

The AMPS configuration on a Wave Glider vehicle includes one or more power domains. Each power domain has a set of reusable, factory installed that plug into the passive AMPS backplane, including a Power Domain Controller (PDC) module that is directed by the vehicle management computer in the CCU. There are AMPS modules for a variety of power management functions:

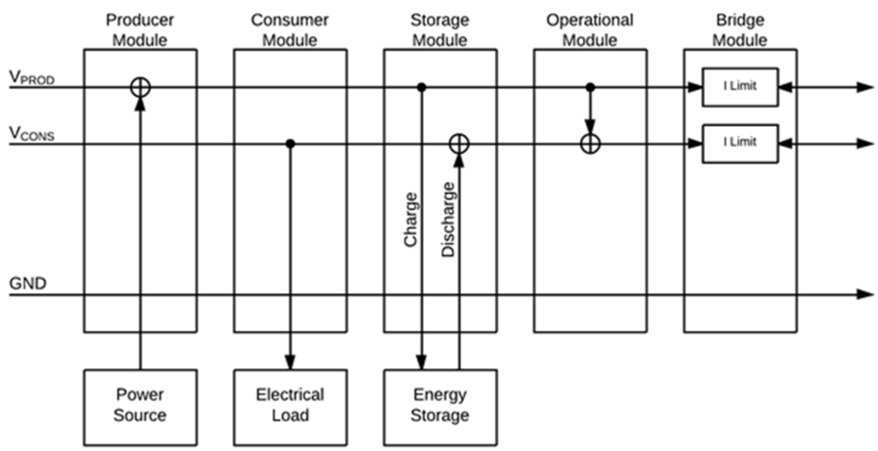
- Power Domain Controller (PDC)
- Battery Charger Module
- Solar Panel Input Module
- High Voltage Module
- Buck-Boost Regulated Output Module (BBR)
- Bridge Module
- 1 MPU Module Carrier
- 3 MPU Module Carrier
- Thrudder PDC
- SMC Carrier

A Controller Area Network (CAN) supports communications between the CCU and the PDC in each AMPS domain. AMPS provides an intelligent interface between Wave Glider power producers and power consumers, switching them on or off to regulate power based on input to the CCU from local or remote applications.

AMPS also provides data buses and power buses:

- AMPS data buses allow the PDC to send commands and receive power management data from all other AMPS modules in an AMPS domain.
- The AMPS power buses consists of a common ground circuit and two power circuits each capable of carrying up to 20A peak (240W at 12V). The two power circuits are referred to as Voltage Producer (VPROD) and Voltage Consumer (VCONS). VPROD receives all power input from the solar panels through the Solar Input modules then charges the batteries and feeds VCONS through the Battery Charger modules. VCONS receives power from the batteries through the Battery Charger modules. VCONS powers payloads through Power Consumer modules, and it also powers the VMC through the Host Power Supply module. VCONS can also feed VPROD through a Battery to Battery module.

Figure 3.6. AMPS Power Bus



3.4. Batteries

The CCU contains a battery pack that supplies power to the core system and payloads as needed to supplement input from the solar panels. The CCU battery pack consists of ten 98 watt hour Lithium Ion batteries capable of storing up to 980 watt hours of energy. Optional Auxiliary Power Units (APUs) and stand-alone battery packs (for payload integration) are also available. An APU is a self-contained AMPS power domain. A stand-alone battery pack can be integrated into a payload power domain. Each APU or stand-alone battery pack also contains ten 98 watt hour Lithium Ion batteries capable of storing up to 980 watt hours of energy. AMPS allows energy sharing between the core electronics and the various payloads connected to the system.

3.4.1. Battery Power Input

The Float CCU is expecting a solar panel or similar type power source to provide energy to recharge the batteries. To minimize losses, the main path to charge the batteries is unregulated. For this reason, the power input to the batteries must fall within the specified ranges. There is also an auxiliary charging input available through the CCU Debug Port (D1).

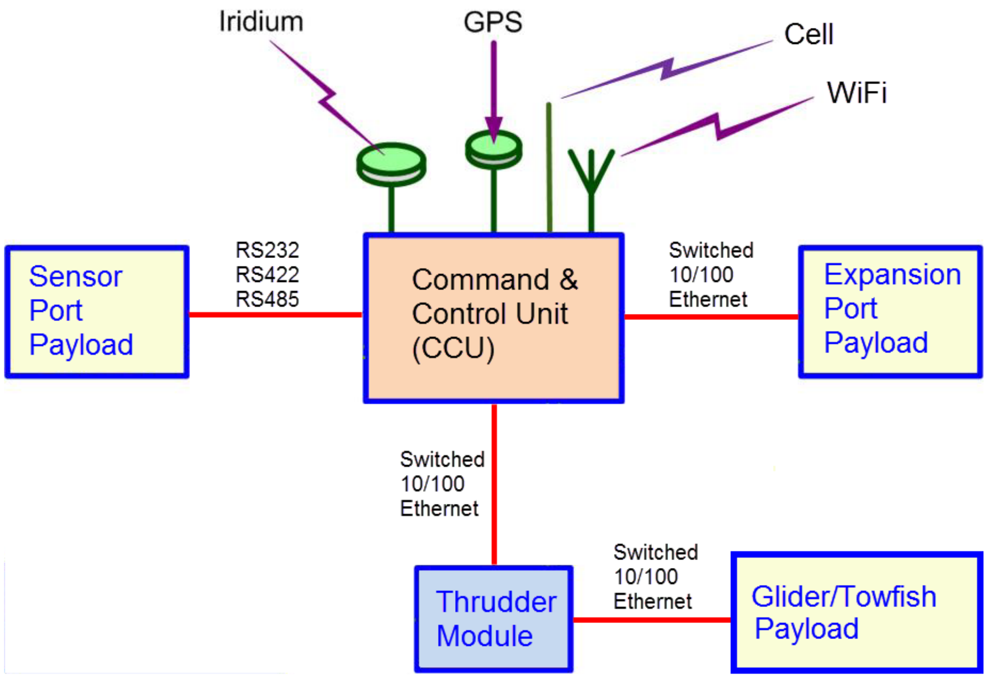
Power input is imparted onto the Vprod bus. The charge controllers on the CCU battery packand on each APU battery pack will influence the power distribution. If all of the batterypacksin the system are at approximately the same state of charge, the charging will be somewhatevenly distributed. If some battery packs are less charged than others, the charging currentwill be biased toward the less charged battery packs. Power discharge from battery packsis similarly distributed with the battery packs that have the most charge contributing more to Vcons than the battery packs that have less charge. This battery pack charging and discharging behavior is the same for APUs that are daisy-chained together, and for APUs that are directly connected to an expansion port.

A power report for each battery in the CCU battery pack, and for each battery in any APUs that are installed on the Wave Glider SV3, is automatically returned shoreside every hour and is accessible in WGMS.

Chapter 4. CCU Remote Communications and Control

Wave Glider vehicle command, telemetry and polling communications are managed by a computer contained in the Command & Control Unit (referred to as the "CCU"). The CCU handles communications between the Wave Glider and remote applications.

Figure 4.1. Wave Glider Remote Communications



This chapter includes information on:

- CCU Communication Functions
- CCU Communication Methods
- CCU Communication Data Types

4.1. CCU Communications Functions

This section provides an overview of the following CCU communications functions:

- Telemetry and Polling
- Command Processing
- Command and Message Responses

4.1.1. Telemetry and Polling

All communications with the CCU are initiated by the CCU. The CCU initiates communications when it transmits telemetry and polling to remote applications.

The CCU automatically sends telemetry data over specified communications channels at regular, user-configurable, intervals. Telemetry data includes the position and general status of the vehicle, as well as any alarms. There are different telemetry data types, and each type can be sent out on a different schedule.

The CCU also sends periodic polling messages to the payloads at regular, user-configurable intervals to check the status of the payload. Payloads must respond and can also indicate availability of data or commands for the CCU.

4.1.2. Command Processing

Commands issued from remote applications are queued. When the CCU initiates any communication with the remote application to the remote application (for example, telemetry, polling data, mailbox check, ACKs), the CCU downloads and executes queued commands.

There are more than 50 Wave Glider commands. Wave Glider commands typically fall into one of the following functional categories:

- Make some change to the vehicle (for example, move rudder, turn a light on).
- Set system parameters (for example, telemetry rates).
- Request vehicle systems status (for example, battery level).
- Communicate with a payload.
- Define a course (for example, set/delete course Waypoints).
- Follow a course (for example, hold position, follow a set of Waypoints).

4.1.3. Command and Message Responses

When a command or payload message is received by the CCU, it will respond in one of two ways:

- Acknowledge (ACK) responses that let the requesting system know that the command or message was received and understood. The ACK response may also contain requested status information.
- Not-Acknowledge (NAK) responses that indicate the command or message was received but is in error, and could not be processed. The NAK response also indicates the general nature of the error.

If there is an additional command queued, it is downloaded to the vehicle, executed, and an ACK or NAK response is transmitted to remote applications. This process continues until there are no more commands in the queue.

If the communication channel is interrupted there may be multiple CCU data packets queued-up on the vehicle. When communication resumes, remote applications will see multiple incoming data packets. All communications are asynchronous, delayed, and in no consistent order. Any software designed for real-time processing of vehicle responses needs to consider this characteristic of communications with the CCU.

4.2. CCU Communications Channels

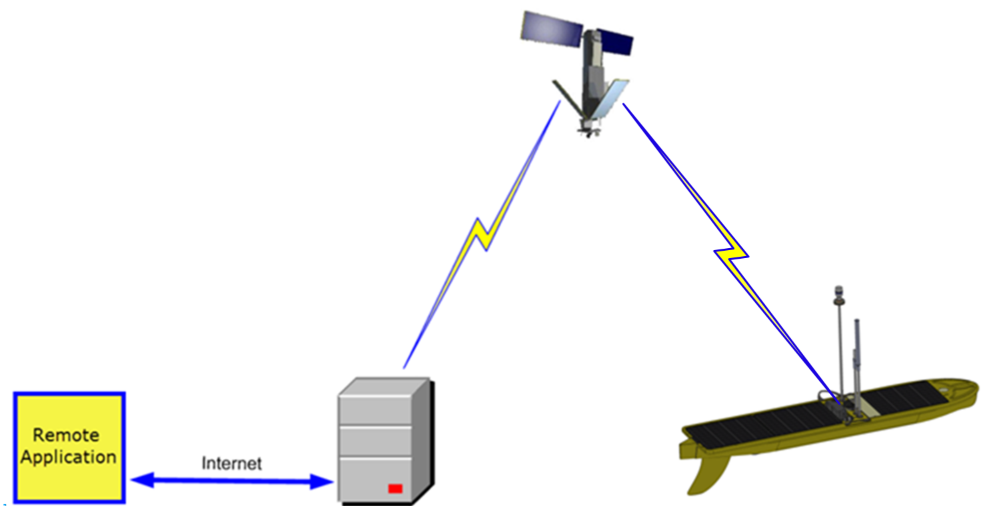
The standard CCU communications channels are:

- "Iridium Relay Link" (page 43)
- Cellular communications - The Wave Glider SV3v200 CCU includes a cell modem that can be used for communications within cell range. The commands for turning the cell modem ON or OFF are available in the **WGMS SV3v200 Commands Window** from the **cellModem** device in the **Devices** menu.
- WiFi - The Wave Glider SV3v200 CCU includes a WiFi modem that can communicate directly with a WiFi enabled device. The commands for turning the WiFi modem ON or OFF are available in the **WGMS SV3v200 Commands Window** from the **wirelessAccessPoint** service in the **Services** menu.

4.2.1. Iridium Relay Link

The Iridium satellite network is an "always on" system with 100% global coverage. It is the primary communications link for the Wave Glider. The Wave Glider is typically linked to remote applications through an Internet connection to the Iridium satellite system. This is the standard means of controlling and monitoring the vehicle.

Figure 4.2. Vehicle to Remote Applications Iridium Communications



A Wave Glider's Iridium modem sends and receives data over the Iridium satellite network using Iridium Short Burst Data (SBD) packet sessions. Iridium satellites exchange data with Iridium network servers in the Iridium data center. Iridium network servers use TCP/IP to exchange data with remote applications using the Liquid Robotics Iridium Relay.

Communication sessions are initiated by the Wave Glider CCU. The CCU periodically sends telemetry data packets to remote applications over the Iridium link. The time span between telemetry messages is user-configurable. Command data packets from remote applications are sent to the Iridium network servers, where they are queued until the Wave Glider initiates a communication session. After telemetry data is sent from the vehicle CCU to remote applications, any commands sent from remote applications are downloaded to the vehicle CCU.

When a command data packet has been processed by the CCU, it responds to all connected remote applications with an ACK (acknowledge) data packet containing the requested data. If the command requests some action by the vehicle (for example, moving the rudder), that action is also executed.

If the command data packet sent to the Wave Glider CCU is in some way incorrect, the vehicle responds with a NAK (not-acknowledged) data packet that indicates the nature of the error.

Note

When a command is issued from a remote application over Iridium, there is a delay before the command is implemented on the Wave Glider. The duration of the delay depends on how frequently the Wave Glider CCU sends telemetry data, as well as the amount of telemetry data being transmitted. Iridium command data is queued until the Wave Glider CCU initiates a communication session. Iridium command data is not processed by the CCU until vehicle-initiated communications (telemetry intervals or ACK/NAK responses) are completed.

4.2.1.1. Short-Burst Data

The Iridium "Short-Burst-Data" (SBD) protocol is used for Iridium (Direct IP). SBD allows for economical transmission of relatively small data packets. Iridium refers to messages from the modem as "mobile-originated" (MO) and messages to the modem as "mobile-terminated" (MT).

The Iridium Short-Burst-Data format supports packets of limited size, depending on the modem used and the direction of the packet:

- Iridium 9601/2/3 modems can send messages (MO) of up to 340 bytes and receive messages (MT) of up to 270 bytes.
- Iridium 9522B and 9523 modems can send messages (MO) of up to 1960 bytes and receive message (MT) of up to 1890 bytes.

4.2.1.2. Iridium Message Buffering

Iridium service may occasionally be interrupted for up to several minutes. In this case, the CCU electronics will buffer any responses and telemetry, and then send out multiple responses and telemetry when service is resumed.

The message buffer is 16 responses deep. Once the 16-message limit is reached, any additional messages will be added to the buffer, and the oldest message discarded. Thus, for very long Iridium disruptions, some data may be lost.

4.3. CCU Communications Security

WGMS initiates the authentication process, requiring the Wave Glider to authenticate itself. The authentication process requires the exchange of the symmetric AES256 session key, then the Wave Glider and WGMS can exchange messages using a secure session.

4.4. CCU Communications Components

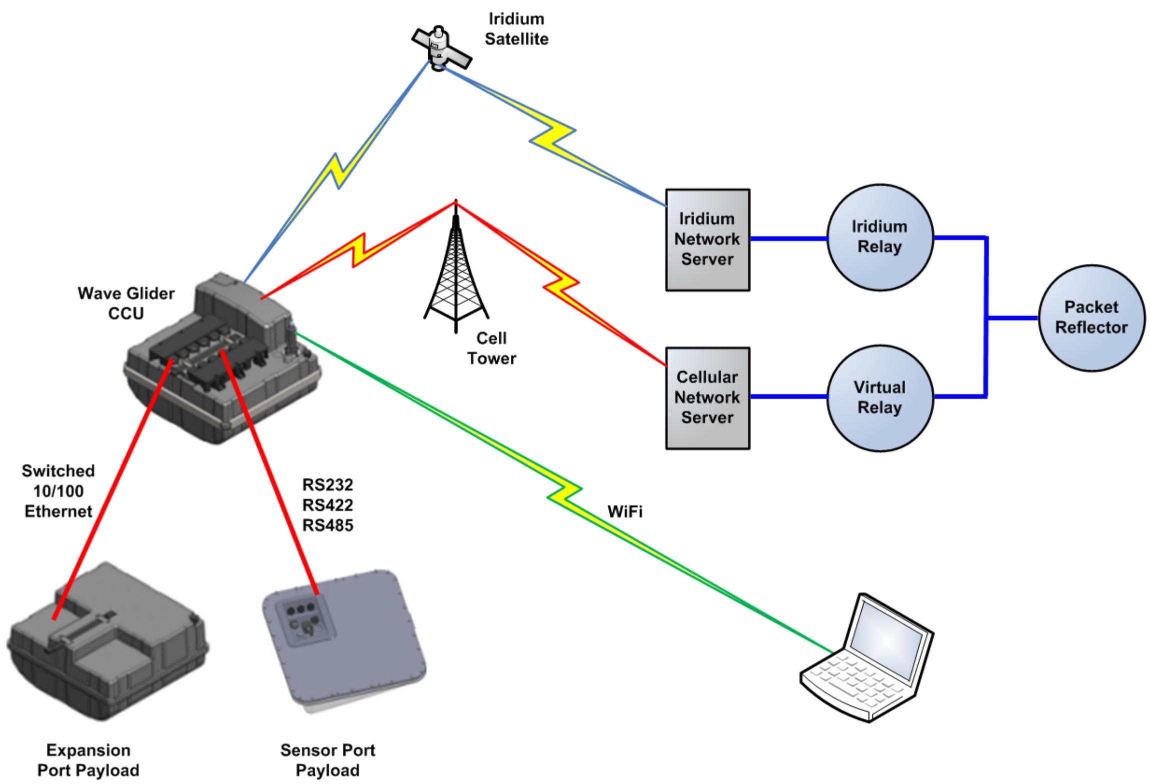
Figure 4.3 illustrates Iridium Relay, Cellular and WiFi communications configurations.

- Blue circles are user configurable Liquid Robotics-supplied components All of these components are co-located in a Liquid Robotics data center.
- Blue lines represent TCP/IP communications.

Specific deployments use a subset of the modules represented by the illustration, for example:

- Iridium Relay communications depend on an internet connection between the Iridium Relay and an Iridium network server. The connection between the Iridium network server and the CCU is over the Iridium satellite network.
- Cellular communications depend on an internet connection between the Virtual Relay and a cellular network server. The connection between the cellular network server and the CCU is over a cellular network.
- WiFi communications do not require an Internet connection. Data is transmitted directly between the CCU and a WiFi enabled device.

Figure 4.3. CCU Communications Components



The following sections describe the basic communications components of the Wave Glider system.

4.4.1. Communication Relays

Relays mask the variations between the underlying communications technologies by converting the communication interface they control to remote application compatible TCP/IP packets, or by converting TCP/IP packets from remote applications to a format that is compatible with a specific communication interface. Specific duties may include fragmenting and reassembling packets, managing queues and driving the physical interface.

Communication relays can be one of two types:

- Iridium Relay
- Virtual Relay

4.4.1.1. Iridium Relay

For most deployed Wave Gliders, the primary mode of communication is through the use of Short Burst Data (SBD) packets sent over the Iridium satellite constellation. Actual satellite communications with the vehicle are accomplished through a group of servers maintained by Iridium Communications, Inc. remote applications depends on the Iridium Relay to communicate with the Iridium Servers over the Internet, using TCP/IP. If necessary, data transfer can be done using Email, but at a lower data rate.

It is sometimes beneficial to communicate with the vehicle through means other than the Iridium Relay. Considerations can include Internet availability, bandwidth, cost, latency, privacy, security and distance. For example, in a payload development scenario inside a building, the Wave Glider's Iridium satellite antenna might not be able to see the sky, necessitating the use of WiFi.

4.4.1.2. Virtual Relay

A Liquid Robotics Virtual Relay Server is required when you want to establish a direct radio communications link between one or more Wave Gliders and one or more instances of a remote application. Examples of Wave Glider radio communications methods that require the Virtual Relay Server include: Cellular, Iridium RUDICS, and BGAN. Typically a Virtual Relay Server and a Packet Reflector are installed on a PC along with a remote application instance. A Virtual Relay Client is installed (on a SMC) on each Wave Glider vehicle. The Virtual Relay Server consists of a Virtual Relay Service that runs in the background, and a Virtual Relay Application that you use to configure and manage the Virtual Relay Service. When the Virtual Relay Service is started, it will continue running any time your PC is running, until you deliberately stop the service using the Stop Service function in the Virtual Relay Application. Regardless of the radio communications method, the TCP/IP protocol is used for data transmissions between a remote application and a vehicle. The Liquid Robotics Virtual Relay protocol rides on top of the TCP/IP protocol to support encryption and to ensure messages are received by their specified recipients. Communications between the Virtual Relay Server and a remote application are transmitted through a Packet Reflector in an Liquid Robotics Data Packet format over TCP/IP.

4.4.2. Standard Modems

The CCU on the Wave Glider vehicle includes an Iridium SBD modem to enable direct communications with the Iridium satellite network and a cell modem for communications with cellular networks. Similarly, for remote applications to communicate with Wave Glider vehicles in the absence of an Internet connection, the CCU includes a WiFi modem for direct communications between a Wave Glider and a WiFi enabled device.

4.4.3. Iridium Network Servers and Satellites

Iridium network servers are maintained in Iridium Communications, Inc. data centers. Iridium network servers relay data across the Iridium satellite network to complete communications between Wave Glider vehicles and remote applications. The Iridium satellite constellation can be accessed from the Internet over a TCP/IP link to an Iridium network server, or directly using an Iridium SBD modem.

4.5. GPS

The GPS constellation location signals are essential to vehicle operation. Most commands for Wave Glider positioning are based on Latitude and Longitude values. Telemetry and other status responses from the vehicle contain the Lat/Long location based on GPS data.

Figure 4.4. GPS Satellite Constellation

GPS fixes are typically obtained every 1 seconds. However, there can be short periods (usually less than a minute) when no signal is received.

4.6. Navigation

Navigation of the vehicle is typically achieved by referencing Waypoints. Each Waypoint is defined by three values:

1. The Waypoint number - a user-assigned integer value from 1 to 254. No two Waypoints can have the same number.
2. A Latitude value - defined with a precision of arc-minutes / 10,000.
3. A Longitude value - defined with a precision of arc-minutes / 10,000.

The basic Navigation Modes of a vehicle are:

- Move to a Waypoint and maintain station there.
- Move from a start Waypoint through a sequence of Waypoints to an ending Waypoint.
- Continually move through a series of Waypoints, in a cyclic fashion.
- Maintain a constant heading.
- Hold a fixed rudder position.

4.6.1. Navigation Modes

Once a set of one or more waypoints have been defined, the vehicle is instructed to proceed in one of several navigation modes.

The navigation **Mode Names** and their associated **Values** are shown in the table below. The value is used in commands to specify the desired navigation mode. Vehicles return the navigation mode value in the telemetry as part of the command acknowledgement (ACK).

Table 4.1. Navigation Modes

Mode Name	Value
NAV_MODE_UNDEFINED	0x00
NAV_COURSE_LOOP	0x01
NAV_COURSE_HOLD	0x02
NAV_CUSTOM_LOOP	0x03
NAV_CUSTOM_HOLD	0x04
NAV_CUSTOM_HEADING	0x10
NAV_RUDDER_POSITION	0x20
NAV_TARGET_WAYPOINT	0x40
NAV_HOLD_POSITION	0x41
NAV_MODE_UNDEFINED_ALT_GPS	0x80
NAV_COURSE_LOOP_ALT_GPS	0x81
NAV_COURSE_HOLD_ALT_GPS	0x82
NAV_CUSTOM_LOOP_ALT_GPS	0x83
NAV_CUSTOM_HOLD_ALT_GPS	0x84
NAV_COURSE_LOOP_PID	0x0A
NAV_COURSE_HOLD_PID	0x0B
NAV_CUSTOM_LOOP_PID	0x0C
NAV_CUSTOM_HOLD_PID	0x0D
NAV_COURSE_LOOP_PID_ALT_GPS	0x8A
NAV_COURSE_HOLD_PID_ALT_GPS	0x8B
NAV_CUSTOM_LOOP_PID_ALT_GPS	0x8C
NAV_CUSTOM_HOLD_PID_ALT_GPS	0x8D
NAV_CUSTOM_HEADING_ALT_GPS	0x90
NAV_RUDDER_POSITION_ALT_GPS	0xA0
NAV_TARGET_WAYPOINT_ALT_GPS	0xC0
NAV_HOLD_POSITION_ALT_GPS	0xC1

Chapter 5. Software Environment

This chapter provides information on the following payload development topics:

- "Regulus" (page 49)
- "SV3v200 Manifests" (page 49)

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5.1. Regulus

Regulus is a Wave Glider SV3v200 management application that runs on Linux on the Vehicle Management Computer (VMC) in the Command and Control Unit (CCU). Regulus controls all Wave Glider SV3v200 operations, including navigation and management of telemetry and data.

Regulus also manages Wave Glider SV3v200 communications for most payloads, with the exception of payloads that have been developed to provide exclusive independent communications channels.

A Regulus Stub that includes the Iridium Relay and Virtual Relay modules runs at the remote end of the communications channels (on ship or onshore). The Regulus Stub manages security keys and communications channels. Regulus can be configured to automatically select the lowest cost available communications channel for each data and command transmission.

5.2. SV3v200 Manifests

Regulus generates two JSON files referred to as manifests. The manifests contain extensive information on the Vehicle.

The Configuration Manifest provides a detailed accounting of the Vehicle configuration including base Wave Glider components, Liquid Robotics factory options, and integrated payload devices that are registered with Regulus and connected to CCU Expansion Ports. For information on CCU Expansion Ports, see Chapter 3: *Electrical Specifications*.

The Commands Manifest lists the commands that are supported by the Vehicle, including commands specific to payload devices that are registered with Regulus and connected to CCU Expansion Ports.

Both manifests can be retrieved on command manually, or automatically, by remote applications. For example, when Regulus notifies WGMS that new manifests have been published, WGMS can automatically retrieve the manifests based on criteria contained in the Regulus notification that indicates a significant (non-trivial) change has occurred.

The manifest files are transmitted compressed, and then decompressed to a JSON format by the remote application.

The two manifests can be parsed by remote applications (for example, WGMS) to populate a UI with vehicle specific commands and data.

Chapter 6. Troubleshooting

This chapter focuses on problems commonly encountered during **on-shore** Wave Glider payload development. Refer to the *Wave Glider User Manual* for troubleshooting on-water operational problems.

6.1. Overview

On-shore troubleshooting falls into two general categories:

1. Fixing non-functioning systems

2. Diagnosing and correcting error conditions

6.1.1. Iridium Interface

In general, most development and systems integration will be done using the WiFi interface. However, it can be helpful to also have the Iridium interface available as an alternate method of communication for troubleshooting.

6.1.2. General Checks

Since the vehicle is fully electric, many problems can be traced back to connectors and/or batteries. The first checks for any problem should be:

1. Check that the CCU is powered ON. For more information see “Power Key” (page 34).

2. If the problem appears to be a connectivity issue, check that the electrical connectors are tight. It is possible that a hold down sleeve is cross-threaded or otherwise jammed so a connector is not fully seated. If you're not sure, undo and re-install the connector.

3. Make sure that the electrical cables are plugged into the correct connectors:

   - The Expansion Port connectors are all the same. Cross-connecting should not cause damage, but data communications will be incorrect.

   - The Sensor Port connectors are all the same. Cross-connecting should not cause damage, but data communications will be incorrect.

4. Use WiFi, Cell or Iridium to get the Power Status and verify that the System voltage is at least 14 Volts. If not, the batteries need re-charging.

6.1.3. Re-Booting

Generally, re-booting the CCU is a solution of last resort. Re-booting may temporarily fix the problem, but not address the root cause.

If you have Admin privileges, you can issue the Float Reboot command.

A “hard” re-boot can be initiated by powering the vehicle OFF (remove the Power Key), waiting 20 seconds, and then turning the vehicle back ON (insert the Power Key).

6.1.4. Contacting Liquid Robotics

If you've tried the suggested solutions and the problem persists, make note of the vehicle identification data and contact Liquid Robotics as described in “Contacting Liquid Robotics, Inc.” (page 56).

6.2. Problems and Responses

6.2.1. No Iridium Connection

The Iridium connection is initiated by the vehicle at each Telemetry interval. The interval can be set for an especially long time (as much as 24 hours). Also, if the batteries are low, the vehicle may revert to the "Low Battery" telemetry rate, which is typically longer than the standard rate (to conserve battery power).

Also, Iridium communications require a clear view of the sky to operate. Being near a window is generally not adequate.

Responses:

1. Check that the vehicle power is ON.
2. Check that the Iridium antenna (in the CCU Radome) has a clear view of the sky.
3. Confirm that the vehicle you are attempting to communicate with is the same vehicle you have selected in the remote application.
4. Refresh the remote application Web Page.
5. Use Cell or WiFi communications (if available) to get the IMEI and verify that it is the correct IMEI for the vehicle.
6. Use the remote application to check the strength of the last-sent Telemetry data. The Iridium Signal Strength ranges from 0 to 5. A Level of zero may indicate an Iridium signal problem.

6.2.2. No GPS Reception.

Like Iridium communications, the GPS requires a view of the sky, although it can sometimes get an adequate fix near a large window.

Responses:

1. Check that the vehicle power is ON.
2. Check that the GPS antenna (in the CCU Radome) has a reasonably clear view of the sky.

6.2.3. No Float Payload Power From CCU

When the system is powered up (or re-booted), power to the payloads is turned OFF. The power needs to be explicitly turned ON. Also, the maximum current that can be supplied to any payload is limited. Any attempt to use more current will result in power to that payload being shut off.

Responses:

1. Check that the payload is connected to the correct connector on the CCU.
2. Check the connectors on CCU and Payload Dry Boxes.
3. Check for an over-current alarm.
4. Check the power status for low batteries.

6.2.4. No Sub Payload or Towfish Payload Power From CCU

As with the Float payloads, Sub and Towfish payload power is Off when the vehicle power is turned On. Also the maximum current that can be supplied to both the Thrudder and the Sub/Towfish payloads combined is 6 Amps.

Responses:

1. Verify that rudder can move. If not, check both the Float and Rudder Module Umbilical connectors. Also check the Umbilical for cracks or tears.
2. Check for an over-current alarm.
3. Check the power status for low batteries.

6.2.5. No CCU-to-Payload RS-232 Communications

Lack of RS-232 communications can be caused by a problem with the CCU electronics, the Payload electronics, and/or the connection between them. If communications were previously established, but no longer work, the best response is to try re-booting the system. The responses below assume that communication has never been established using a specific payload.

Responses:

1. Check for correct cable connection to CCU.
2. Check that CCU has turned on power to the Payload.
3. Check for an over-current alarm.
4. Check payload electronics UART.

6.2.6. Float Continuously Re-Boots

This indicates a serious electronics problem. Contact Liquid Robotics.

6.2.7. Sub Continuously Re-Boots

This indicates a serious electronics problem. Contact Liquid Robotics.

6.3. Interpreting CCU Alarms

The Alarm indicator bits are returned in the first two bytes of the Telemetry Type 0x06 data packet. The interpretation for each Alarm bit is:

0 → No alarm

1 → Alarm set

Table 6.1. CCU Alarms

Alarm	Byte	bit	For More Information
Sub Leak Alarm	0	0	See "Sub Leak Alarm (Byte 0 | bit 0)" (page 53)
Float Leak Alarm	0	1	See "Float Leak Alarm (Byte 0 | bit 1)" (page 53)
Sub-to-Float Comms Alarm	0	2	See "Sub-to-Float Comms Alarm (Byte 0 | bit 2)" (page 54)
Payload Alarm	0	3	See "Payload Alarm (Byte 0 | bit 3)" (page 54)
Float Battery Low Alarm	0	4	See "Float Battery Low Alarm (Byte 0 | bit 4)" (page 54)
Umbilical Fault Alarm	0	5	See "Umbilical Fault Alarm (Byte 0 | bit 5)" (page 54)
GPS Not Functioning	0	7	See "GPS Not Functioning (Byte 0 | bit 7)" (page 54)
Sub Reboot Alarm	1	1	See "Sub Reboot Alarm (Byte 1 | bit 1)" (page 55)
Float-to-Sub Comms Error	1	2	See "Float-to-Sub Comms Error (Byte 1 | bit 2)" (page 55)
Float Temperature Threshold Exceeded	1	4	See "Float Temperature Threshold Exceeded (Byte 1 | bit 4)" (page 55)
Float Pressure Threshold Exceeded	1	5	See "Float Pressure Threshold Exceeded (Byte 1 | bit 5)" (page 55)
EPROM Error	1	6	See "EPROM Error (Byte 1 | bit 6)" (page 56)
Float Reboot Alarm	1	7	See "Float Reboot Alarm (Byte 1 | bit 7)" (page 56)

The alarms are described below:

6.3.1. Sub Leak Alarm (Byte 0 | bit 0)

Water leak was detected in the Thrudder Module. This should never occur unless the vehicle is in the water. The Thrudder Module is factory-sealed and not field-repairable.

Responses:

1. If the Sub is under water, retrieve the vehicle as soon as possible.
2. If the Sub is not under water, try re-booting. If the alarm persists, there is likely an electronics error.

6.3.2. Float Leak Alarm (Byte 0 | bit 1)

Water leak was detected in the CCU. This should never occur unless the vehicle is in the water. The CCU is factory-sealed and not field-repairable.

Responses:

1. If the Float is in the water, retrieve the vehicle as soon as possible.

2. If the Float is out of the water, try re-booting. If the alarm persists, there is likely an electronics problem in the CCU.

6.3.3. Sub-to-Float Comms Alarm (Byte 0 | bit 2)

The CCU computer detected a data comm error from the Sub.

Responses:

1. Check the electrical connectors on the CCU and the Thrudder Module.
2. Check the Umbilical for cracks or tears.>
3. Try re-booting. If the error occurs again, contact Liquid Robotics.

6.3.4. Payload Alarm (Byte 0 | bit 3)

General problem with a payload. It may be a communications, electrical or environmental issue.

Responses:

1. Check the connectors between the CCU and each MPU dry box.
2. Verify that the payload is not drawing more than the maximum allowed current.
3. Try re-booting. If the alarm occurs again, contact Liquid Robotics.

6.3.5. Float Battery Low Alarm (Byte 0 | bit 4)

CCU battery level is below the specified "Float Low_Battery Power".

Responses:

1. Power off the vehicle and re-charge the batteries.
2. If the alarm persists after re-charging, contact Liquid Robotics.

6.3.6. Umbilical Fault Alarm (Byte 0 | bit 5)

There is an integrity problem (a leak or broken conductor) on the Umbilical.

Responses:

1. If the vehicle is in the water, retrieve as soon as possible.
2. If the vehicle is out of the water, check the Umbilical for holes or tears.
3. Try re-booting. If the alarm persists, there is likely an electronics error.

6.3.7. GPS Not Functioning (Byte 0 | bit 7)

The vehicle has not received a valid GPS fix for two minutes.

Responses:

1. Verify that the CCU radome has a clear view of the sky.
2. Try a re-boot, then wait for at least 2 minutes.

6.3.8. Sub Reboot Alarm (Byte 1 | bit 1)

A serious error occurred on the Thrudder Module computer, causing a re-boot.

Responses:

1. Check for a "Sub Leak Alarm" or a "Sub-to-Float Comms Alarm".
2. Try powering OFF, then ON. If the error occurs again, contact Liquid Robotics.

6.3.9. Float-to-Sub Comms Error (Byte 1 | bit 2)

The Sub computer detected a data comm error from the CCU computer.

Responses:

1. Check the electrical connectors on the CCU and the Thrudder Module.
2. Check the Umbilical for cracks or tears.
3. Try re-booting. If the error occurs again, contact Liquid Robotics.

6.3.10. Float Temperature Threshold Exceeded (Byte 1 | bit 4)

The temperature in the CCU is above the "Float Temperature Threshold". If the Float is not exposed to high outdoor temperatures, this indicates an electronics or battery problem.

Responses:

1. Immediately power the vehicle OFF.
2. Check the outside air temperature. If the CCU interior is noticeably warmer than outside, there may be a serious internal problem. Call Liquid Robotics and do not re-power the unit.

6.3.11. Float Pressure Threshold Exceeded (Byte 1 | bit 5)

The pressure in the CCU is above or below the "Float Pressure Threshold" values.

Responses:

1. Remove the valve cover on the top of the CCU, and check the pressure. Adjust as necessary.
2. If the pressure values are within the acceptable range, re-boot and see if the alarm goes off.

6.3.12. EPROM Error (Byte 1 | bit 6)

During boot-up, the system transfers data from the EEPROM to Flash memory, using error checking. This alarm is activated if there is an error in the data transfer.

Responses:

1. Try re-booting. If the error occurs again, contact Liquid Robotics.

6.3.13. Float Reboot Alarm (Byte 1 | bit 7)

An error occurred on the CCU computer, causing a re-boot.

Responses:

1. If the error occurs continually, contact Liquid Robotics.

6.4. Contacting Liquid Robotics, Inc.

If you cannot determine or correct the cause of a problem, contact the Liquid Robotics Support Organization.

To expedite resolving the problem, make a brief list beforehand with the following information:

1. Wave Glider Model Number
2. Any special or added payloads on the vehicle
3. Time/date when the problem occurred
4. Location of vehicle when problem occurred
5. Initial indication of problem
6. Any other indications or unusual readings
7. Attempts at corrective actions and their results

The Liquid Robotics Customer Support organization is available 24/7.

Telephone:

(US) 888-574-4574

(International) 1-408-636-4205

Email: support@liquidr.com