

KINGFISHER USV

UNMANNED SURFACE VESSEL

USER MANUAL

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INTRODUCTION

Clearpath Robotics Kingfisher is a rugged and easy-to-use Unmanned Surface Vessel (USV) for rapid prototyping applications. In this guide, you will find information about the setup, operation, and maintenance of your Kingfisher USV.

What's Included

Included with each Kingfisher are the following:

- 1 x Clearpath Robotics Kingfisher
- 2 x 14.4V NiMH Battery Pack
- 1 x Battery Pack Charger
- 1 x Futaba hobby R/C Controller
- 1 x Carrying Sling

Each Kingfisher deployment includes:

- 1 x Clearpath Robotics VIP2400 base station
- 1 x Base Station Battery
- 1 x Battery Charger

What's Required

To simply drive Kingfisher right out of the box, use the Futaba hobby R/C controller, as described in the Getting Started section on page 9. However, the R/C controller is intended as a backup to allow powered retrieval of Kingfisher in case of a PC or network malfunction while on the water.

To realize the full potential of Kingfisher as a research and reconnaissance vessel, it will be desirable to interface with the onboard PC, using Robot Operating System (ROS). The onboard PC runs Ubuntu Linux 12.04, and ROS Fuerte.

For maximum simplicity, a development machine should be the same; however, any version of Ubuntu supported by ROS Fuerte will be adequate. If you purchased a computer option from Clearpath Robotics with Kingfisher, then the included laptop has already been configured for use with ROS.

Expansions

To expand the capabilities of Kingfisher, consider the following additional sensor packages offered by Clearpath Robotics:

- Network Camera
- RTK GPS Upgrade
- Downward-facing Single Beam Echo Sounder

Each sensor package ships from Clearpath Robotics with appropriate mounting hardware and cabling, for easy integration with Kingfisher.

THE BASICS

This section provides an overview of the key specifications of the Kingfisher platform.

Figure 2 gives a tour of key Kingfisher components.

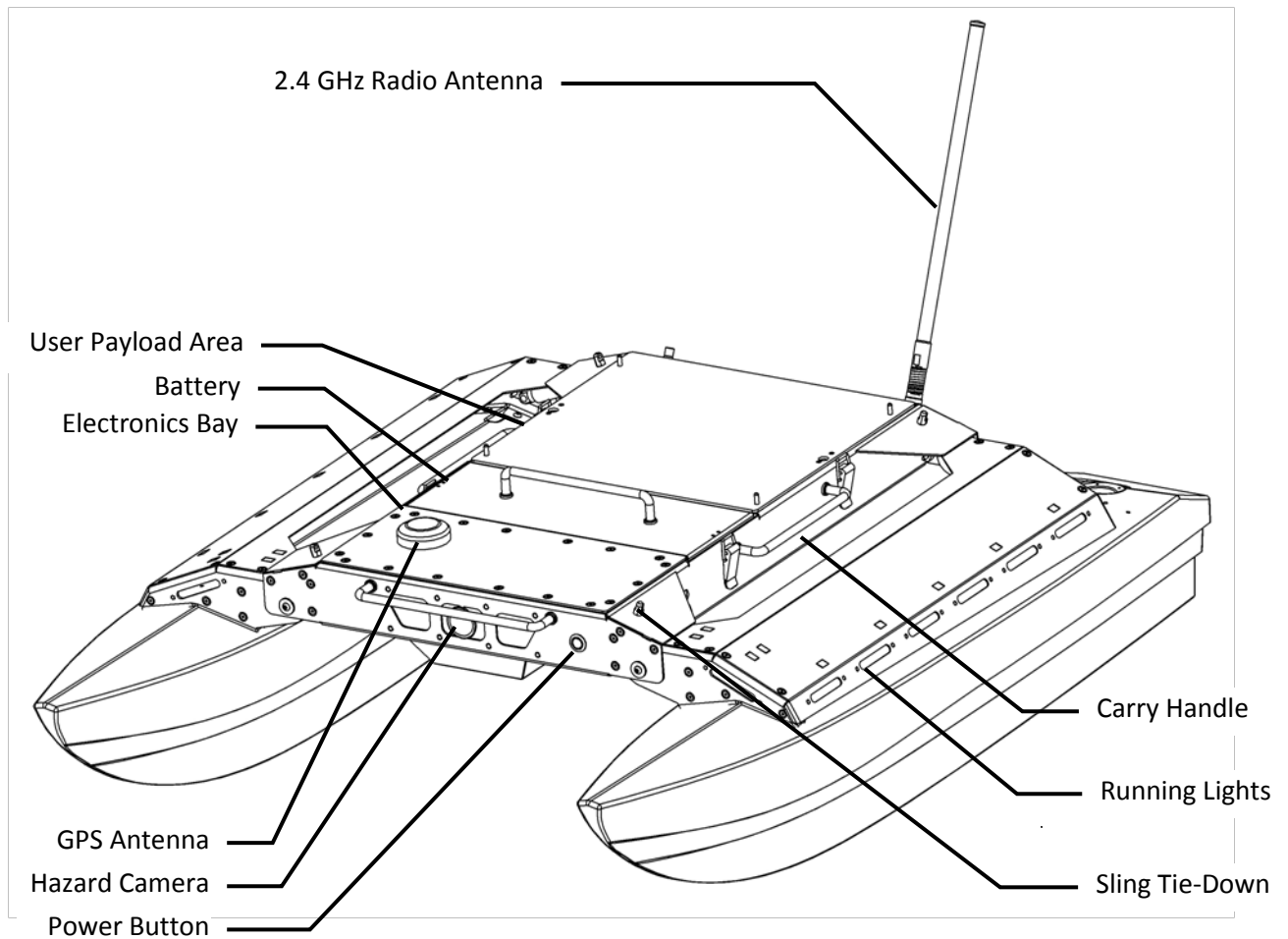


Figure 1: Kingfisher at a Glance

Hardware Architecture

Figure 3 gives an overview of the standard devices which make up Kingfisher. This diagram is provided to aid the user in understanding how Kingfisher is architected.

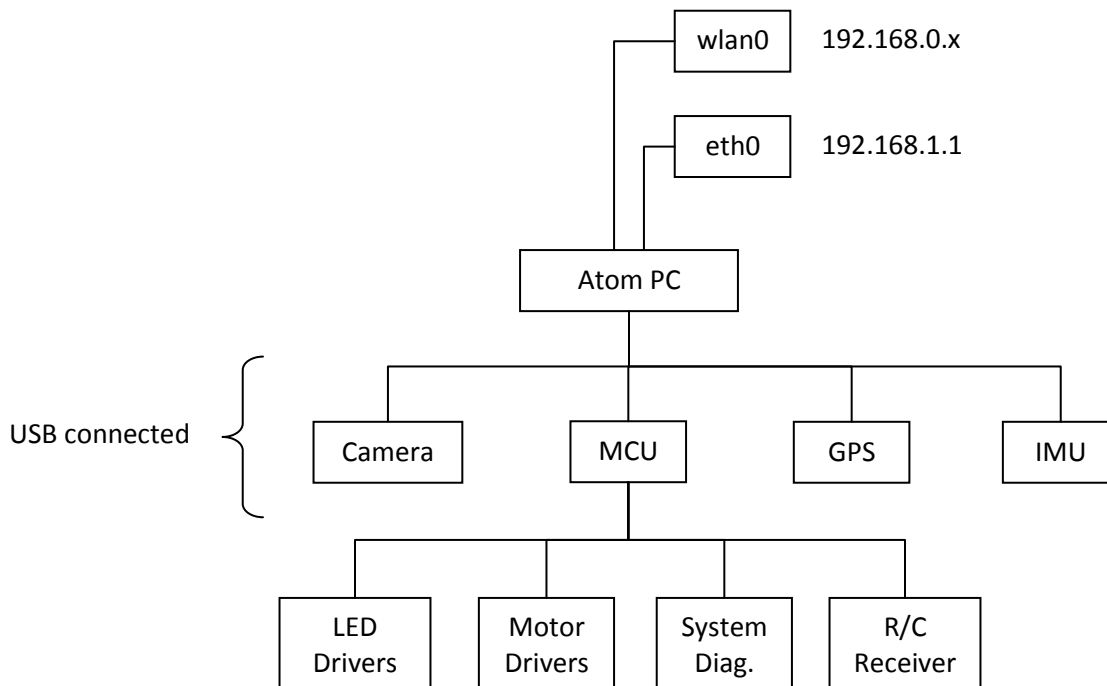


Figure 2: Kingfisher Architecture

The eth0 interface is disconnected by default, and inaccessible inside the Electronics Bay. This connector is used to host certain payloads, however, such as an IP camera or LIDAR. This interface also forms the basis of an onboard vehicle network, which hosts the vehicle’s core ROS network.

Status Indicators

The red and green running lights on the perimeter of Kingfisher indicate vehicle status based on the frequency and pattern of flashing. These patterns are described in Table 1.

Light Pattern	Description
Solid	No errors. PC and wireless are active, and a command stream is being received and processed.
Slow Single Pulse	No command. Indicates that the system is fully up, but the jet pumps are not active due to an absence of commands messages. Command messages must be sent at 10Hz or faster to maintain steady operation.
Slow Double Pulse	Wireless Error. Indicates that the onboard PC is unable to find the base station’s wireless network. If this indication is seen, check the battery level and indicator lights in the base station.
Slow Triple Pulse	Computer Error. Indicates that the microcontroller in Kingfisher cannot see the onboard PC. This is expected for about two minutes when first powering on, while the computer boots up.
Fast Single Pulse	Manual override. Indicates that manual control by the Futaba R/C controller is active, and any commands originating from the PC will be disregarded.
Fast Double Pulse	Critical Battery Pack. Indicates that the system battery level is at or below 13V. Return to shore immediately.

Table 1: Kingfisher Status Indicators

The precedence order in the table is downward—that is, the bottom-most condition which is true will be what is indicated by the lights.

R/C Controller

Kingfisher ships with a hobby R/C controller integrated as a means of backup control. The intention is always to operate with PC control, but for scenarios where the PC or network malfunctions, it is convenient to have an alternate means of retrieving Kingfisher. Please see Figure 4 for details of the RC controller.

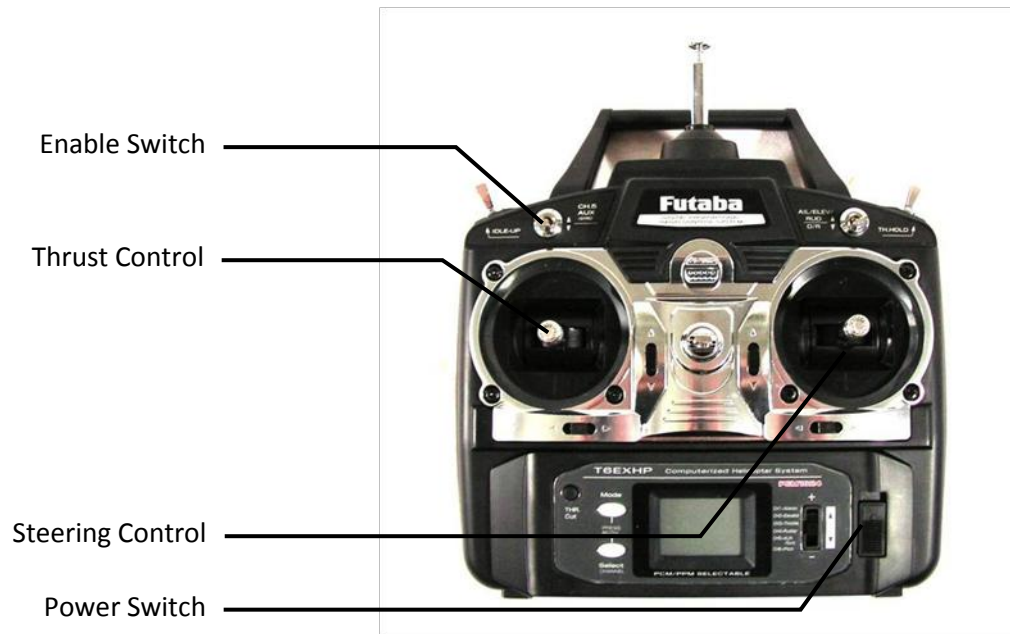


Figure 3: Kingfisher R/C Controller

The RC link is much weaker than the link which the main wireless radio has with the base station, thus one should expect Kingfisher to go out of R/C range before losing wireless connectivity. If it is desirable to remain inside R/C range, use ROS on the PC to monitor the `/sense` topic, which contains a bitfield indicating when the R/C controller is in-range and when it is in control of Kingfisher .

System Specifications

Key specifications of Kingfisher are shown in Table 2.

Deployed Dimensions	1300 mm length 940 mm width 340 mm height	51.2 in length 37 in width 13.4 in height
Stowed Dimensions	1300 mm length 550 mm width 340 mm height	51.2 in length 21.6 in width 13.4 in height
Chassis Weight (no battery)	20 kg	44 lbs
Battery Weight	9 kg	20 lbs
Draft	150 mm	5.9 in
Maximum payload	10 kg	22 lbs
Speed (max)	2.0 m/s	6.6 ft/s
Operating time	6 hours typical 10 hours standby (no motion)	
Battery Pack	14.4V 40 Ah NiMH	
Battery Pack charger	Short-circuit, over-current, over-voltage, and reverse voltage protection.	
Charge time	10 hours	
User Power	12V fused at 2A	
Communication	USB, TCP/IP, RS232, RS485	
Standard sensing	Battery Voltage, GPS, IMU, Hazard Camera	

Table 2: Kingfisher USV System Specifications

SAFETY

Clearpath Robotics is committed to the safety of our users. Please be advised that Kingfisher is research equipment designed for prototyping applications and we are not able to protect operators, observers, and equipment from all possible use cases. This section provides guidelines to help ensure safety of personnel and equipment, but the ultimate responsibility lies with the operator.

General Warnings

Kingfisher USV is a rugged and high-performance vehicle. For the safety of yourself and others, conduct initial experiments in an area that is clear of obstacles and deeper than 0.6 m [24 in]. Although Kingfisher is able to operate in very shallow water, this will avoid any possibility of running aground.

Indoor swimming pools make provide an ideal environment for initial testing.

When starting out, it is recommended to favor slower speeds. Operating at speeds lower than 0.5 m/s will give the operator more time to react if things don't go quite as expected.

Electrical System

Kingfisher is powered by a single 14.4V Nickel-Metal Hydride (NiMH) Battery Pack, the same battery chemistry found in most electric RC cars and boats. Please observe the following precautions.

- Do not tamper with the plug attached to the Battery Pack.
- Do not tamper with the Battery Pack connection on Kingfisher.
- Do not operate Kingfisher without the Battery Pack clamped securely in position.
- Do not tamper with the Electronics Bay.
- Charge the Battery Pack only with chargers provided by Clearpath Robotics.
- Return the Battery Pack to Clearpath Robotics for proper disposal.



The battery pack has a rugged exterior to protect it from bumps and scrapes, but it still stores a large amount of electrochemical energy, and is inherently dangerous. Observe the above precautions carefully.

Lifting and Transport

For the safety of users and to maximize the lifetime of Kingfisher, please observe the following when manually transporting the robot:

- Kingfisher should be lifted using only the four carrying handles on the vehicle itself. Do not lift Kingfisher by the handle on the Battery Pack.
- The included Carrying Sling should be used for transporting Kingfisher medium and longer distances.
- Ensure that Kingfisher is powered off and the Battery Pack is removed, when transporting longer distances.

GETTING STARTED

You are ready to go! This section details how to get the thrusters spinning.

Before deploying into water, briefly test Kingfisher thrusters with the R/C controller and check wireless connectivity (if required).

Platform Deployment

Kingfisher has been designed for easy deployment and rapid transit to and from work sites. The hulls and thrusters stow underneath the chassis to reduce the platform's overall size during transit. Unfolding the hulls is a tool-less operation, and is to be done prior to placing the platform in the water. Please see Figure 5 and the steps following.

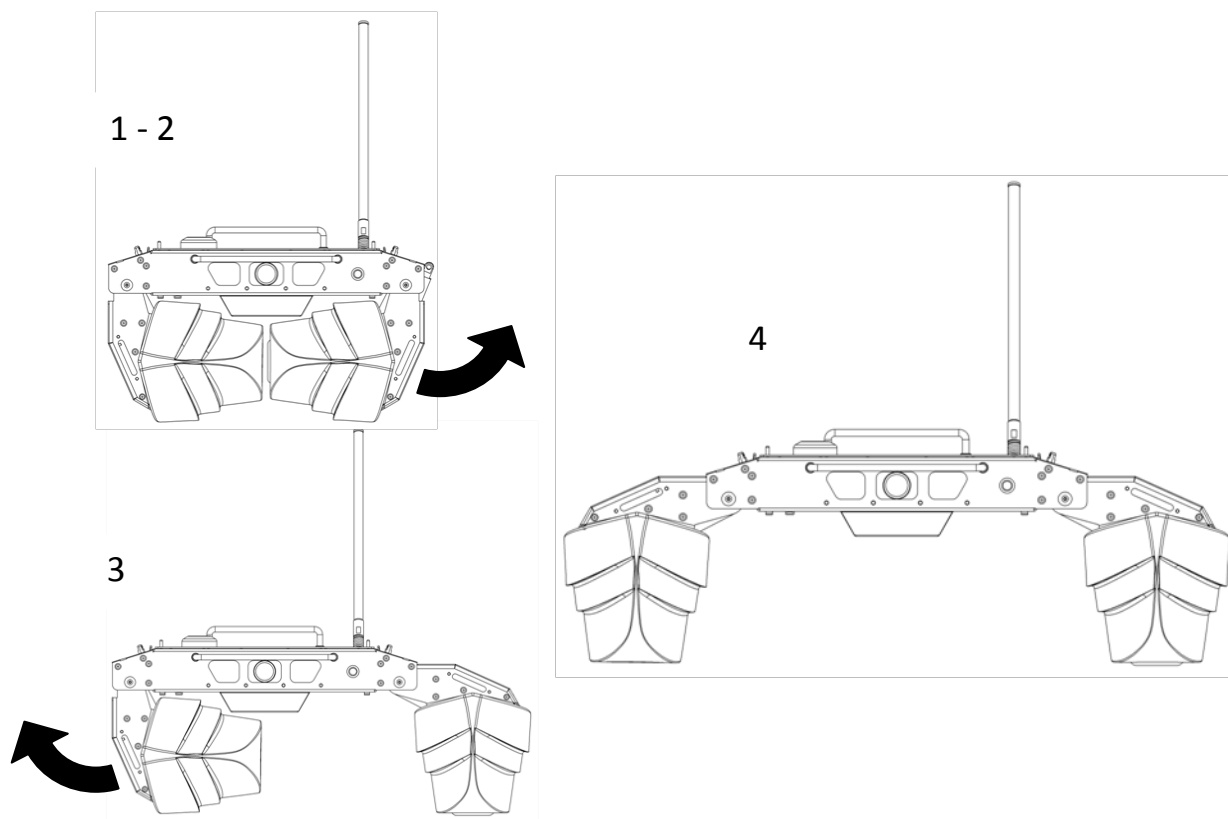


Figure 4: Kingfisher Hull Deployment

1. Place stowed Kingfisher right-side-up on the ground.
2. Hold the side handle with one hand, and using the other pull up a stowed hull to the deployment position, setting Kingfisher back down afterward.
3. Repeat this operation for the opposite hull.
4. Kingfisher is ready for battery installation and pre-launch check.

Battery Pack Installation

Kingfisher comes with a fully charged Battery Pack. For safety, it is disconnected during shipping. To reconnect the Battery Pack, please see Figure 6 and the steps following.

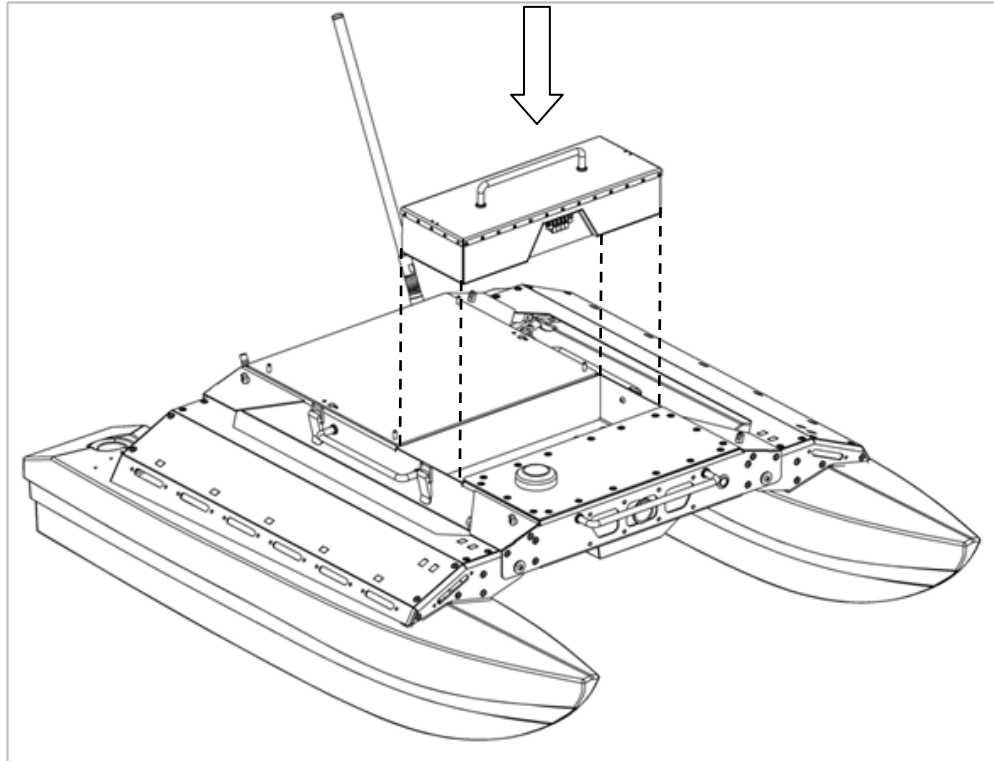


Figure 5: Kingfisher Battery Pack Installation

1. Ensure Kingfisher's main power button is in the outer "off" position.
2. Carefully lower the Battery Pack so that the plug is inserted into the mating connector in the Battery Bay. Ensure that it is firmly seated.
3. Clamp down the latches on either side of the Battery Pack's lid.

To power on Kingfisher, firmly press the main power button. It will illuminate blue, and a moment later, the running lights will come on solid for a few seconds before flashing. The motor will play a series of startup chirps to indicate ready status.



It is possible to severely damage the battery connector by attempting to insert the battery backwards. Ensure that the battery is oriented correctly before lowering it into the Battery Bay.

For R/C-only operation, the base station is unnecessary. However, if PC operation will be required, set up and power-on the base station as well: Connect the battery to the power supply pigtail, and firmly press the button located on the side of the base station module. A blue LED in the power button will come on, and the radio inside the base station box will light up.

It may take Kingfisher as long as five minutes to find the base station, but when it does, the flashing status indicator should move from **no wifi** (double slow flash) to **no command** (single slow flash).

R/C Operation

Power-on the R/C controller. Flip the enable switch (top left corner) down toward the user, which puts Kingfisher in manual override mode. This should be indicated by the Kingfisher running lights moving to short, rapid single flashes. Flipping the switch away from the user restores control to the onboard PC.

When operation of the thrusters has been verified on land, deploy Kingfisher into the water and drive it around!

If the running lights move to short double flashes, use the R/C controller to return Kingfisher to the launch location, as the batteries will be dead very soon.

For a complete list of status light codes, refer to Status Indicators on page 4.

ADVANCED OPERATION

This section provides an overview of how to use Kingfisher with the onboard PC.

SSH Connection

To access the onboard PC using SSH, connect a base station PC to the LAN port on the base station. When a 192.168.0.0/24 IP is assigned to the base station PC, execute the following, where *nnn* is replaced by the IP of the robot (101 in single-unit deployments):

```
# ssh administrator@192.168.0.nnn
```

The default password for the administrator user is “clearpath”.

ROS Network

The onboard PC in Kingfisher uses ROS to communicate internally and externally. Because of the way ROS handles network interfaces, Kingfisher actually runs two separate ROS masters:

- **Core.** This is the internal core, which is persistent from startup, and runs against the static eth0 interface, with `ROS_MASTER_URI=http://192.168.1.1:11310`. Core runs the roserial node which communicates with the MCU, as well as drivers for the IMU, GPS, and camera.
- **Interface.** This is the external core, which is launched against the wlan0 interface when it comes up, with `ROS_MASTER_URI=http://192.168.0.nnn:11311`, where *nnn* is the IP assigned to Kingfisher by the router in the base station. Interface includes the app_manager, zeroconf announcer, and multimaster synchronization node which republishes a selection of interface topics back and forth between the two cores.

Having the robot interface broken out as a separate master shields the user from the large number of intermediate topics in the internal master, and allows driver nodes and other supervisory software to run persistently, independent of the state of the external network.

When connected by SSH to the onboard PC, both ROS masters are accessible. By default, the interface master will be seen, so `rostopic list` will produce a short list of available topics. To access the Core master, change `ROS_MASTER_URI` like so:

```
# export ROS_MASTER_URI=http://localhost:11310
```

A `rostopic list` in this shell session will now produce the much longer list of Core master topics.

Android Control

Kingfisher is compatible with the Turtlebot App Chooser app available for Android in the Google Play store, and includes support for the Teleop app:

1. On the Google Play store, search for “ROS App Chooser.” Select and install the official Willow Garage Application Chooser app.
2. Inside the App Chooser, select the “add a robot” option.
3. Enter the wifi network and password of the base station, and the ROS_MASTER_URI of the Kingfisher you wish to interact with.
4. Select the Teleop app, and you should see the direction pad and camera view on-screen.

When using the Android Teleop app, you can still interact with the vehicle ROS network via SSH or an external computer—if you subscribe to the `/cmd_vel` or `/cmd_drive` topics, you should see the command messages originating from the Android device.

External ROS Connection

To participate in the vehicle ROS network directly from a machine connected to the base station, first ensure that the machine has Ubuntu and ROS Fuerte installed. Then install the kingfisher ROS packages:

```
# sudo apt-get install ros-fuerte-clearpath-kingfisher-desktop
```

When the installation is complete, connect the user machine to the base station’s LAN port. When an IP is received in the 192.168.0.mmm range, execute the following commands to set up the ROS environment:

```
# export ROS_IP=192.168.0.mmm
# export ROS_MASTER_URI=http://192.168.0.nnn
```

Where *mmm* is the IP of the user laptop, and *nnn* is the IP of Kingfisher (typically, the IP is 192.168.0.101 for a single unit deployment).

At this point attempt to list the available topics, and try subscribing to one of them:

```
# rostopic list
# rostopic echo /sense
```

The sense topic gives the present terminal voltage of the battery, as well as the status of the R/C receiver. You can verify that you are seeing the message live by powering the R/C controller on and off, and while on, flipping the enable switch up and down.

To command the jet thrusters in Kingfisher, publish a message to one of the two following control topics:

<code>/cmd_drive</code>	Commands the thrusters to a specific percentage of maximum thrust, each side specified as a value in the range -1.0 to 1.0.
<code>/cmd_vel</code>	Commands a specific linear and angular velocity, using a standard ROS Twist message.

Future iterations of the open-source Kingfisher software may include closed-loop velocity or position control options. Contact support if these are of interest.



If you wish to connect to the Core master from the base station, this is also possible, but requires manually routing the 192.168.1.1 address from your PC to the external interface of Kingfisher. Contact Clearpath Robotics support for details and assistance with this.

Extending ROS

The expected model for using Kingfisher is to launch additional nodes which interact with the standard bringup set which manage the sensors and low-level operation of Kingfisher. These could be launched on the base station PC; or, for greater reliability, they could be copied to the onboard PC and launched from there, either against the Interface or Core masters.



The section below covers a more advanced use case of Kingfisher.

The roslaunch files which are launched as part of the Core and Interface masters are generated from the `/etc/ros/forte/kingfisher/core` and `/etc/ros/forte/kingfisher/interface` directories, respectively. If there are additional nodes which the user would like launched as part of system startup, copy (or symlink) the relevant roslaunch file to one of those two folders, and restart both services:

```
sudo service kingfisher-interface stop
sudo service kingfisher-core stop
sudo service kingfisher-core start
sudo service kingfisher-interface start
```


MAINTENANCE

Kingfisher is built for rugged, long-term use. However, there are steps that can be taken to maintain and extend the life of the platform even further.

Charging

The Battery Pack which ships with Kingfisher can be charged with the following steps:

1. Remove Battery Pack from platform.
2. Connect the DC output cable from the charger to the Battery Pack terminal connector.
3. Plug the charger power cord into into the charger, and then into a wall receptacle.
4. Set the Battery Type to NiMH.
5. Press the 'Start' button, and set the charging current between 2 and 4 amperes.
6. Hold the 'Start' button for 2 seconds. The charger will play a series of beeps to indicate charging has started.
7. When the Battery Pack is fully charged, the the LCD display will flash 'FULL'. Unplug the charger from the wall, and then disconnect it from the Battery Pack.

Charging at a lower current will require more time, but will ensure that all cells within the Battery Pack are properly balanced, yielding longer runtimes and better overall battery health. It is recommended that each Battery Pack is charged at 2A after every 5 charge-discharge cycles.

Battery Pack

Kingfisher's power supply is a sealed 14.4 V nickel metal hydride (NiMH), providing 40 ampere-hours of charge. To maximize the lifetime of the Battery Pack, recharge immediately after use, and keep charged to prevent loss in capacity.

Battery Pack should never be used or stored in an environment exceeding 40 degrees Celsius (104 °F), and should always be charged at temperatures above freezing.

Electronics Bay

Kingfisher's electronics are enclosed in a sealed compartment. These do not require maintenance, and the bay should not be opened by the user unless instructed to do so by Clearpath Robotics.

TIPS AND TROUBLESHOOTING

This section lists a few possible issues which may be encountered in the course of using Kingfisher.

Observation	Issue & Resolution
No power LED	System is unpowered. Ensure power button is pressed, and check that battery is properly seated in battery bay. It is unlikely that the battery would be so discharged as to be unable to illuminate the LED, but you could also confirm with a multimeter that the battery has a terminal voltage of at least 14V.
Running lights indicate error status	System is in error. Please refer to Status Indicators on page 4 to determine the status being indicated, and contact support for further assistance.
Can't ping onboard PC	Network problem. Ensure that Kingfisher is indicating successful connection to the base station, and that the user laptop is also successfully connected (ie, able to ping 192.168.0.1).
Unable to list ROS topics	ROS network problem. Ensure that the user laptop has a working ROS installation, including the Kingfisher workspace. Ensure that ROS_MASTER_URI is correctly pointing to the Kingfisher IP, and that ROS_IP is set to the user laptop's IP.
Unable to echo ROS topics	ROS environment problem. Ensure that the user laptop is able to ping Kingfisher, and that ROS_MASTER_URI and ROS_IP are set correctly.

If you're having some trouble that you don't see here, or the suggested solution isn't working out, please get in touch so we can help you with it (see next page for contact details).



For more details on setting up multiple machines to work together in ROS, please see the following pages on the ROS wiki:

- <http://www.ros.org/wiki/ROS/NetworkSetup>
- <http://www.ros.org/wiki/ROS/Tutorials/MultipleMachines>

A. SERVICE AND SUPPORT

Clearpath Robotics is committed to your success and satisfaction. We are located in Waterloo, Ontario, and can accept phone calls from 9AM to 5PM Monday to Friday, at our toll-free number, or emails at any time.

1-800-301-3863
support@clearpathrobotics.com