

# Clearpath Robotics, Polaris GEM robotic vehicle

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User Manual, 2022



## Overview

This manual is intended to help you get started using your 2018 Polaris GEM robot. We will describe how to operate the vehicle as a robot, and will attempt to direct you to all the related documentation for the vehicle.



Front bumper—Velodyne Puck 3d lidar, and Stereolabs ZED 2i camera



Inside cab—Axis teleoperation camera near rearview mirror

Top—two GPS antenna, Wi-Fi antenna, FORT mobility antenna, and Status Light



Rear—Electronics enclosure with Velodyne Puck



Left—2X Swift Navigation Duro receivers, FORT Robotics receiver, PoE injector

Left Centre—Network switch, Wi-Fi Client, PCBA for Status Light, Relay for motion-stop

Centre Right—Computer, Audio amplifier

Right—Power supplies, Terminal blocks, Main contactor

## What's Included

- Polaris GEM robot
  - 2018 GEM e2
  - Dataspeed Drive-By-Wire conversion kit
  - Clearpath Robotics ROS computer to Nvidia 1050 graphics card
  - Manual motion-stop system
    - wireless-stop and mobility remote control
    - 5X motion-stop buttons (4 outside corners of the GEM, and on the dashboard)
  - Wi-Fi (100 Mbit/s)
  - Integrated sensors
    - 2X *Velodyne Puck* lidar, front and rear
    - *Zed 2i* stereo camera
    - *Axis P3905-R Mk II* camera
    - *Mircostrain 3DM-GX5-25* IMU (inertial measurement unit)
    - 2X *Swift Navigation Duro GPS* (Global Positioning System)
  - Status monitoring devices
    - Computer monitor and keyboard inside GEM's cab
    - Stack light and dash lights to show ROS states
    - Speakers, connected to the computer
- Clearpath Robotics Base Station
  - Wi-Fi (100 Mbit/s)
  - *Swift Navigation Duro GPS* (Global Positioning System) for RTK (Real Time Kinematics) corrections
  - Wall charger and batteries
- NEMA 5-15 extension cable, for charging the GEM
- FORT case with motion remote controller

# Specifications

Specification	Measurement
Length	2620 mm
Width	1410 mm
Height	2300 mm
Wheelbase Length	1753 mm
Wheelbase Width	1045 mm
Ground Clearance	2030 mm
Mass	650 kg
Allowable Payload	250 kg
Speed, Maximum	11.1 m/s (40 km/h)
Speed, Minimum ( ROS )	0.3 m/s
Battery	lead-acid
Range	Up to 25 km
User Power	12 V, 24 V, VBAT ( 48 - 60 V )
Communication	ROS Noetic ( Ethernet, USB, Serial, CAN )

## Key Topics

Topics	Purpose
/cmd_vel	Input to the vehicle's kinematic controller.
/vehicle/twist_odom	Odometry reported by Dataspeed kit
/piksi_position	GPS position, grouped from 3 sensors
/piksi_heading	GPS heading, grouped from 3 sensors
/piksi_position_pos_llh_cov	
/piksi_position/debug/receiver state	
/velodyne_points	point cloud lidar data

## Devices Addresses

IP address or bus	Device	Location on Robot
192.168.131.1	Robot's computer	Rear Electronics Enclosure
192.168.131.10	Axis P3905-R Mk II camera	In Cab, beside the rearview mirror
192.168.131.20	Velodyne Puck	Front Bumper
192.168.131.21	Velodyne Puck	Rear Enclosure
192.168.131.30	Swift Navigation Duro	Base Station
192.168.131.31	Swift Navigation Duro	Right side of the robot
192.168.131.32	Swift Navigation Duro	Left side of the robot
192.168.131.50	Microhard Access Point	Base Station
192.168.131.51	Microhard Client	Rear Enclosure
USB	Zed 2i	Front Bumper
USB	Microstrain 3DM-GX5-25	Rear Enclosure
USB	Wireless Keyboard	Cab
USB	FORT wireless controller	Rear Enclosure
USB	Numato Relay Board	Rear Enclosure
USB	Dataspeed Drive-By-Wire Kit	Inside Dashboard

## Turning on the GEM

1. Make sure the hidden disable switch is in the RUN position. This switch is located beside the charge port, on the hood of the vehicle.
2. Turn the ignition key to the RUN position, similar to a car.
3. Wait up to 1 minute for devices to turn on. You will hear relays clicking, and the 2 dashbard monitors starting to boot. Notice that the speedometer has a orange triangle iluminated. This triange indicates that there is a fault with the vehicle's CANbus. This is typical behaviour, since the vehicle is in a motion-stop state.
4. Once the GEM is on, check that the 5 motion-stop buttons have been released. You can check by twisting each of the 5 buttons clockwise.
5. Turn on the FORT wireless controller
6. Twist the FORT wireless controller's motion-stop button clockwise to make sure it is released.
7. You should see the orange triangle disappear from the GEMs speedometer.

## Motion Stops

The motion-stops on the GEM and wireless FORT remote are connected to the Dataspeed kit. The Dataspeed kit will disconnect the motor controller when any of the motion-stop buttons are pressed. The vehicle will coast to a stop.

NOTE: The vehicle does not have a fail-safe brake. The vehicle has a low friction drivetrain, so it will not slow down quickly from a motion-stop event. The intention of the motion-stop system is to prevent the vehicle from driving from ROS commands while you are working near it.

There are 5 motion-stop buttons on the vehicle, and 1 stop button on the FORT controller. All 6 buttons will need to be released, and have the FORT controller on, or the GEM will not drive.

## Checking the brake fluid

The vehicle stops using hydraulic brakes, similar to a car. This system required a full reservoir of DOT 4 brake fluid to function properly.

**⚠️ WARNING:** This system will not stop the vehicle if it does not have enough fluid, or if there is a large leak in any of the brake lines.

Before using the vehicle:

1. Check the fluid level. You can see the reservoir through the front-left wheel well. Add fluid if necessary.  
(Note that you will need to remove the hood to add fluid)
2. Check that the brake pedal is firm, and does not contact the floor when you press on the pedal.
3. Check that the brake lights turn on when you press the brake pedal.



Brake reservoir, with yellow fluid, visible behind the front-left spring

## Charging the vehicle

There is an access cover on the front hood, near the windshield. Connect a NEMA5-15 extension cord between a 110 VAC outlet and the vehicle.

**⚠️ WARNING:** Use a functioning GFCI outlet, or the included GFCI extension cord to prevent shocks or electrocution.



Hood—NEMA5-15 jack, Thumb screws for removing the hood, Hidden ignition disable switch

## Removing the hood

1. Remove the two thumbscrews shown in the picture above.
2. Pull the hood towards the front of the vehicle. You can grab the hood near the two headlights.
3. This will remove the hood's 6 clips from their rubber-grommets on the vehicle.

## Hidden disable switch

The switch is visible in the picture above. This switch is in series with the standard ignition switch on the steering column. This switch needs to be flipped up, or the vehicle will not turn on.

## Driving the vehicle manually

1. Turn on the GEM, release the motion-stop buttons, and turn on the FORT wireless controller.
2. There is a switch on the dashboard labeled *F-N-R*. Press the *F* state to put the vehicle in *Forward* drive.
3. You can now drive the GEM similarly to other road vehicles, using the:
  - Steering Wheel
  - Accelerator Pedal
  - Brake Pedal

NOTE: the GEM can be registered as a legal road vehicle on Ontario Canada. Clearpath Robotics has not gone through the process to register and insure this vehicle in Ontario. You should review your local rules for this class of vehicle, and ensure that you can operate it at your workplace.

## Driving the GEM with the FORT controller

The FORT controller appears on the Ubuntu computer as a joystick, similar to a Playstation or Xbox controller. You can see that the device's data in `/dev/js0`. Clearpath Robotics has configured the computer to publish this data to the `joystick` rostopic. This is then republished as a `cmd_vel` rostopic.

There are a list of dependencies for the vehicle to drive using the FORT controller:

1. The GEM must be turned on.
2. All motion-stop buttons need to be released.
3. The FORT controller must be turned on.
4. The Dataspeed kit needs to be operating and connected to the vehicle.
5. The ROS computer must be operating, and connected to the Dataspeed kit.
6. The ROS computer needs to have launched properly, and translating correctly:

joystick -> joystick rostopic -> cmd\_vel rostopic -> Dataspeed topics

Assuming these dependencies are met; you can drive the vehicle by:

1. Holding the FORT Robotics controller.
2. Make sure the controller is on, and the motion-stop button is released.
3. Read the screen to make sure the controller is not paused. You may need to press the pause button || and 1.
4. Hold 2 to place the vehicle in *drive-by-wire* mode. You will hear the vehicle press the brake pedal when ROS has taken control.
5. Press and hold 1. This is the motion-enable / deadman button. You will need to hold this button for ROS to recognize controller input as valid.
6. While holding 1, use the left joystick to drive the vehicle. Note that reverse commands may seem unintuitive. This is because ROS is not commanding left and right, it is commanding positive or negative yaw.

 **WARNING:** motion-stops or losing radio signal will cause the vehicle to go into a stop-state. This state means the vehicle will coast at its current velocity. Care should be taken so this does not cause the vehicle to strike anyone or anything.

## Turning on the Base Station



Base Station with GPS

The Base Station is required for connecting to the robot's computer remotely. The base station includes a wireless Access Point that is the primary DHCP server for the robot. The robot can connect to all its static IP devices while the Base Station is off, but you cannot connect a computer with a DHCP address unless the Base Station is on.

You can power the Base Staion using either a battery or the wall adaptor. You can change between battery and wall power by opening the Base Station and swapping the red-and-black cables. After connecting the battery or wall-adaptor, you can turn on the Base Station by pressing the silver button on the outside of the case. The silver button should illuminate blue.

You can check that the base station is running by going to your development computer, and looking for :

- The Wi-Fi SSID: `cpr-base-station`
- The Wi-Fi password is `clearpath`

Afer connecting, you can check our desktop's IP address by entering `ip a`. You should see an address like `192.168.131.xxx`.

You should be able to ping devices like the robot's computer by entering `ping 192.168.131.1`.

## Logging into the ROS computer

1. Make sure the robot is on.
2. Turn on the computer monitor in the cab.
3. Remove the wireless keyboard from the cab's right footwell, and turn the keyboard's switch to GREEN
4. Enter the computer's username and password. The defaults from factory are:
  - username: *administrator*
  - password: *clearpath*
5. Once logged in, open a terminal. Take note of the computer's hostname. You should see something like `administrator@cpr-wat-79`. The text after the @ symbol is the computers hostname, in this case it is `cpr-wat79`.

## Connecting to the ROS computer from a development desktop

1. Connect your development desktop to the Base Station's SSID
  - SSID: *cpr-base-station*
  - password: *clearpath*
2. Add this information to your development desktop's `/etc/hosts` file:

```
<robot computer's hostname> 192.168.131.1
```

for example:

```
cpr-wat79 192.168.131.1
```

Close the file by entering `ctrl + x', selecting save by typing *Y*.

3. Then in a terminal, enter `ping <robot computer's hostname>`, such as `ping cpr-wat79`. You should see responses, indicating that your desktop computer can contact the robot's computer through hostname.
4. Make sure your desktop computer has ROS Noetic installed. You can follow the instructions on [ros.org](https://www.ros.org/).
5. Connect your desktop computer's ROS session to the robot's Master by entering `export ROS_MASTER_URI http://administrator@cpr-wat79:11311`, substituting in your correct hostname for `cpr-wat79`.
6. You should be able to see all the robot's rostopics on your desktop computer. You can test this by running `rostopic list` on your desktop computer.
7. You should also log into the robot's computer, and add your desktop computer's hostname to the robot's `/etc/hosts` file. This is necessary if your plan to exchange data between computers with ROS, or using tools like Rviz.

## Adding ROS packages to your development desktop

TODO

## Using the robot with OutdoorNav

TODO

## Using the robot with other navigation packages

TODO

## Autonomy considerations for an Ackermann drive vehicle

TODO

## Turning off sensors for better network performance

This robot connects to the Base Station over a 100 Mbit/s Wi-Fi radio. This connection speed is not sufficient to transfer the large amount of data from cameras like an Axis P3905-R Mk II, RealSense D435, or a Stereolabs ZED 2. You could choose to reduce the amount of data by reducing the rostopic frequency.

Environment variables to turn these devices on and off can be found in [~/wat79\\_outdoornav\\_env.sh](#).

## Where to find documentation

This manual is intended to be used by an experienced ROS developer. AS such, we have tried to keep the manual brief by only covering common setup problems, and redirecting you to existing tutorials and documentation relevant to this robot.

Contact our Support team at [support@clearpathrobotics.com](mailto:support@clearpathrobotics.com) if you need any further information.

1. Polaris GEM e2 manual, 2016 - 2021: [https://cdn.polarisportal.com/servicemanagement-public/OwnerManuals/LEV/9928180r04\\_standard.pdf](https://cdn.polarisportal.com/servicemanagement-public/OwnerManuals/LEV/9928180r04_standard.pdf)
2. Dataspeed drive by wire kit:
  - o [https://bitbucket.org/DataspeedInc/dbw\\_polaris\\_ros](https://bitbucket.org/DataspeedInc/dbw_polaris_ros)
  - o [https://bitbucket.org/DataspeedInc/dataspeed\\_ulc\\_ros](https://bitbucket.org/DataspeedInc/dataspeed_ulc_ros)
  - o An alternative driver, that has not been tested by Clearpath Robotics, [https://github.com/VT-ASIM-LAB/dataspeed\\_can\\_driver](https://github.com/VT-ASIM-LAB/dataspeed_can_driver)
3. Clearpath Robotics, OutdoorNav UI manual,  
<https://clearpathrobotics.com/assets/manuals/outdoornav/index.html>
4. Clearpath Robotics, OutdoorNav API,  
[https://clearpathrobotics.com/assets/manuals/outdoornav/api\\_details.html](https://clearpathrobotics.com/assets/manuals/outdoornav/api_details.html)

## Support

Clearpath is committed to your success. Please get in touch with us and we will do our best to get you rolling again quickly: [support@clearpathrobotics.com](mailto:support@clearpathrobotics.com).

To get in touch with a salesperson regarding Clearpath Robotics products, please email [sales@clearpathrobotics.com](mailto:sales@clearpathrobotics.com).

If you have an issue that is specifically about ROS and is something which may be of interest to the broader community, consider asking it on <https://answers.ros.org>. If you do not get a satisfactory response, please ping us and include a link to your question as posted there. If appropriate, we will answer in the ROS Answers context for the benefit of the community.