LASER BEAR HONEYCOMB LIDAR

User Guide

710-00632

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A listing of patents covering this product is found at the following website:
`https://www.waymo.com/legal/patents`

The Laser Bear Honeycomb™ lidar is not a consumer device.

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Introduction

At Waymo, we don't just develop lidars; we use them every day on our self-driving vehicles to navigate some of the most challenging environments and situations in the world. Now, we have an opportunity to share this technology with you.

We designed the Laser Bear Honeycomb lidar to be one of the most effective and robust lidar sensors in the world. Among its features:

Wide field of view: While some 3D lidar have a vertical field of view (FOV) of just 30°, the Honeycomb has a vertical FOV of 95°, plus a 360° horizontal FOV. This means one Honeycomb lidar can do the job of three other 3D sensors stacked on top of one another.

Multiple returns per pulse: When the Honeycomb lidar sends out a pulse of light, it doesn't just see the first object the laser beam touches. Instead, it can see up to three different objects in that laser beam's line of sight (e.g., it can see both the foliage in front of a tree branch and the tree branch itself). This gives a rich and more detailed view of the environment, and uncovers objects that might otherwise be missed.

Minimum range of zero: The Honeycomb has a minimum range of zero, meaning it can see objects immediately in front of the sensor. This enables key capabilities such as near object

detection and avoidance.

Just as the Honeycomb lidar helped launch our self-driving vehicles into the world, we hope that it unlocks new technological breakthroughs for you, too.

Lidar Details

The Laser Bear Honeycomb lidar is a time-of-flight sensor that can be used for object detection and object range determination. It is a Class 1 Scanning Laser System with a Class 3B laser. This Honeycomb lidar can be used to detect objects and measure the distance of the objects up to 56m from the lidar. The field of view can reach up to 95º vertically and 360º horizontally, though the exact field of view depends upon mounting and occlusions. The Honeycomb lidar provides rapid measurement in the vertical plane while scanning in the horizontal plane.

Safety Information

The Laser Bear Honeycomb lidar is certified as a Class 1 laser product in accordance with the requirements of the U.S. Federal Product Performance Standards for laser products. The level of laser radiation emitted from a Class 1 laser product is not considered to be hazardous during operation.

The Honeycomb lidar contains an embedded Class 3B laser which, by itself, may be hazardous. However, the Honeycomb lidar incorporates a protective housing and a scanning safeguard such that there is no exposure or human access to laser radiation above Class 1 limits during operation of the lidar.

There is a label located on the lidar warning users about exposure to Class 3B radiation if the enclosure is removed. Figure 1.1 shows the warning label. Do not operate the lidar with the outer enclosure removed or when either of the glass windows are removed or broken.

Figure 1.1 Lidar warning label

There are no user-serviceable components inside the housing. Any problems or issues discovered during periodic inspections of the assembly must be reported to the Waymo. The unit must be sent back toWaymo for servicing.

CAUTION: Use of controls or adjustments or performance of procedures other than those specified herein may result in hazardous radiation exposure.

CAUTION: Some of the Laser Bear Honeycomb lidar circuits operate above hazardous voltage levels. Do not operate the laser with the housing removed or damaged. There are no user procedures that require the housing to be removed.

CAUTION: Some of the bridge board circuits operate at 48 VDC and are exposed. Contacting the circuits with conductive objects can damage the power supply or the bridge board circuit. It is recommended that the bridge board circuit be secured and covered to prevent accidental contact with conductive surfaces or tools.

Getting Started

The tables below list the items needed to power up the Laser Bear Honeycomb lidar device.

Items included with purchase of the Laser Bear Honeycomb lidar and development kit:

Item	Description	Quantity
1	Laser Bear Honeycomb lidar (Fig 2.1)	1
2	Bridge Board (Fig. 2.2)	1
3	Bridge Cable (Fig. 2.3)	1
4	48V DC supply with barrel connector (Fig 2.4)	1
5	Mounting bracket (attached to lidar)	1

Items also required for operation (not provided with the Honeycomb lidar or development kit):

Item	Description	Quantity
6	RJ45 ethernet cable + spare ethernet port in workstation (100Mbps)	1

Item	Description	Quantity
7	X86-64 Linux Computer	1

Figure 2.1: Laser Bear Honeycomb

Figure 2.2: Bridge Board

Figure 2.3: Bridge Cable

Figure 2.4: 48V DC supply with 5.5mm x 2.5mm barrel connector

Powering up the Lidar

To power the Laser Bear Honeycomb lidar, use the following procedure while referring to Figs 3.1 and 3.2:

> **CAUTION**: input voltages above 48V ±5% could cause overheating that may result in permanent damage to the bridge board or the Honeycomb lidar, and cause a thermal event.

Note when using an adjustable power supply: The power supply requirement is 48V ±5%, 600mA (steady state is <300mA). Adjust your voltage and current limits accordingly.

1. Connect one end of the RJ45 ethernet cable to the bridge board and the other end to the secondary ethernet adapter on your linux computer. For best results, use a dedicated ethernet port rather than a USB interface.
2. Connect the power supply to the bridge board.
3. Connect end of the bridge cable to the bridge board. (Connector color may vary.)
4. Connect other end of the bridge cable to the Honeycomb lidar pigtail. The Honeycomb lidar will not begin movement/operation until it is configured; see Configuring Lidar Communications section.

Honeycomb1 Connections

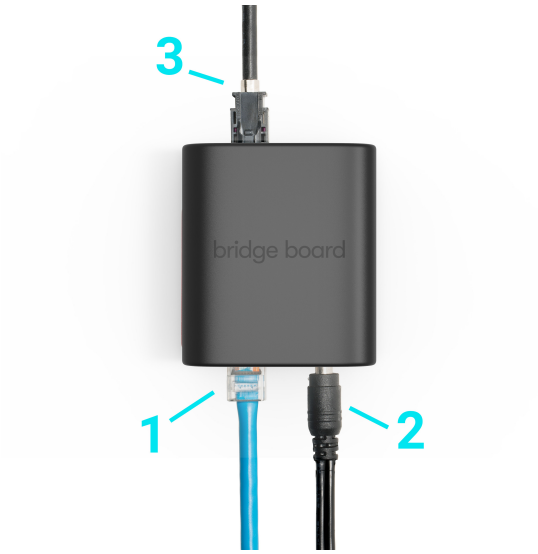


Figure 3.1 bridge board connections

Figure 3.2 lidar + development kit setup

Configuring Lidar Communications

1. Make sure ROS is installed on your linux computer to run the Honeycomb lidar. If it is not installed, go to `http://wiki.ros.org/ROS/Installation`
2. You'll need to set up a network interface to operate the Honeycomb lidar. Configure a static IP address on an unused network interface following your system's instructions.

For assistance, see the examples for ‘Command Line’ or ‘Graphical Interface,’ below. If you have a firewall, you may need to disable it or provide an exception.

Command Line: If you have the Honeycomb lidar plugged into the eth2 interface, enter the following into a terminal:

```
$ sudo ip link set eth2 up
$ sudo ip address add 192.168.2.50/24 broadcast + dev eth2
```

Graphical Interface: Alternatively, you can modify network settings as shown in Fig. 3.3.

a. Open ‘System Settings,’ click **Network**, and select **Options**.

b. Ensure that you’re using IPV4.

c. From the ‘Addresses’ drop-down menu, select **Manual**.

d. Enter your chosen IP address in the ‘Address’ text box.

e. Enter the IP address of the netmask in the ‘Netmask’ text box.

f. Click **Apply**.

Note: If your network settings default to ‘Automatic,’ you may need to repeat this process each time you turn on the Honeycomb lidar.

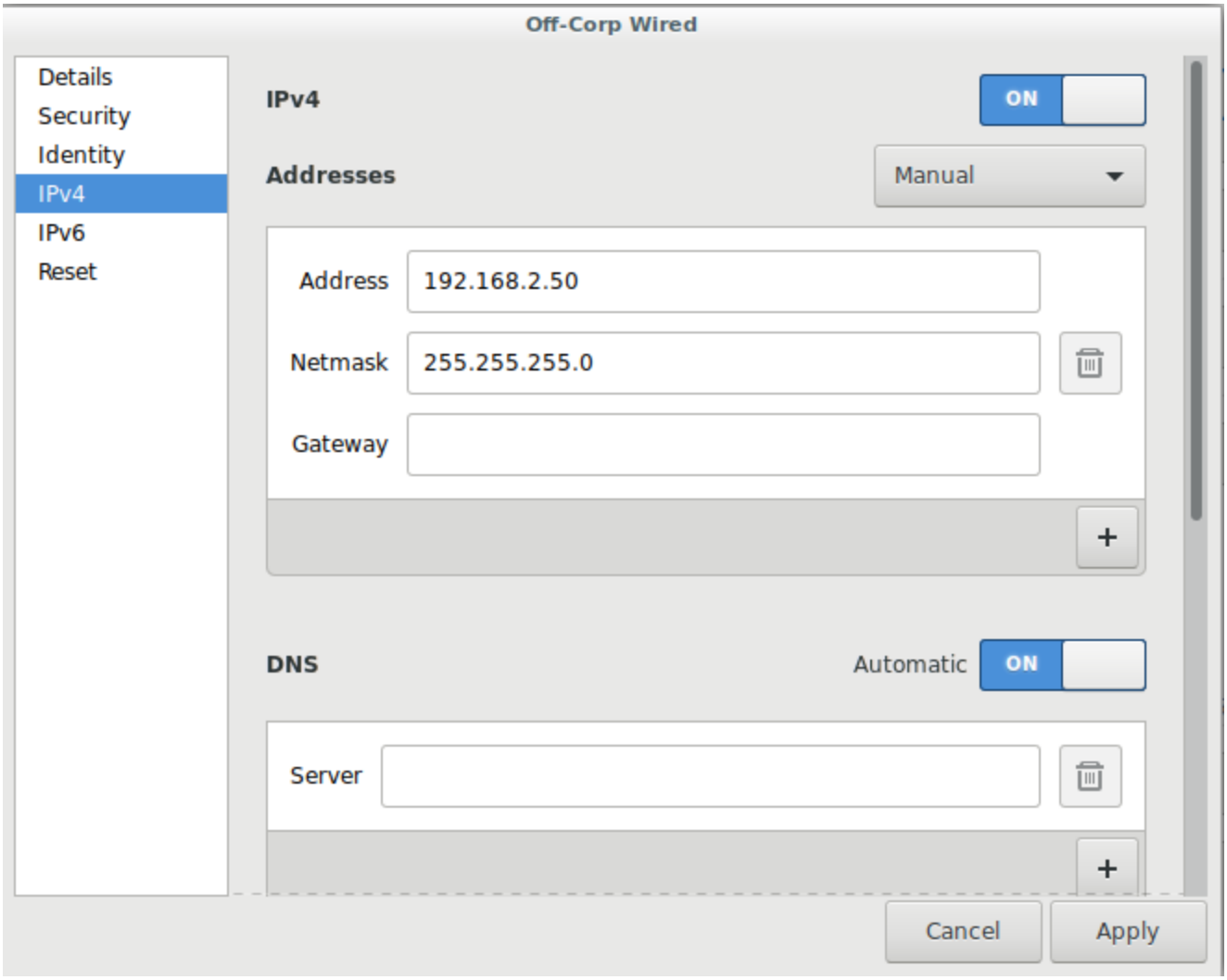


Figure 3.3 Network Settings panel

1. Go to the downloads (/honeycomb/downloads#ros_driver) page and download the latest ROS driver.
2. Open a terminal, create a directory, and untar the ROS driver file by entering the following:

```
$ mkdir ~/tmp
$ cd ~/tmp
$ tar xvf ~/Downloads/<downloaded ROS driver name>
$ cd hc-<version number>
$ export ROS_PACKAGE_PATH=$ROS_PACKAGE_PATH:$(pwd)
```

3. Launch the HC driver and rviz by entering:

```
$ roslaunch hc hc.launch
```

After approximately 30 seconds, the Honeycomb lidar begins to spin, and you should be able to view a point cloud in rviz.

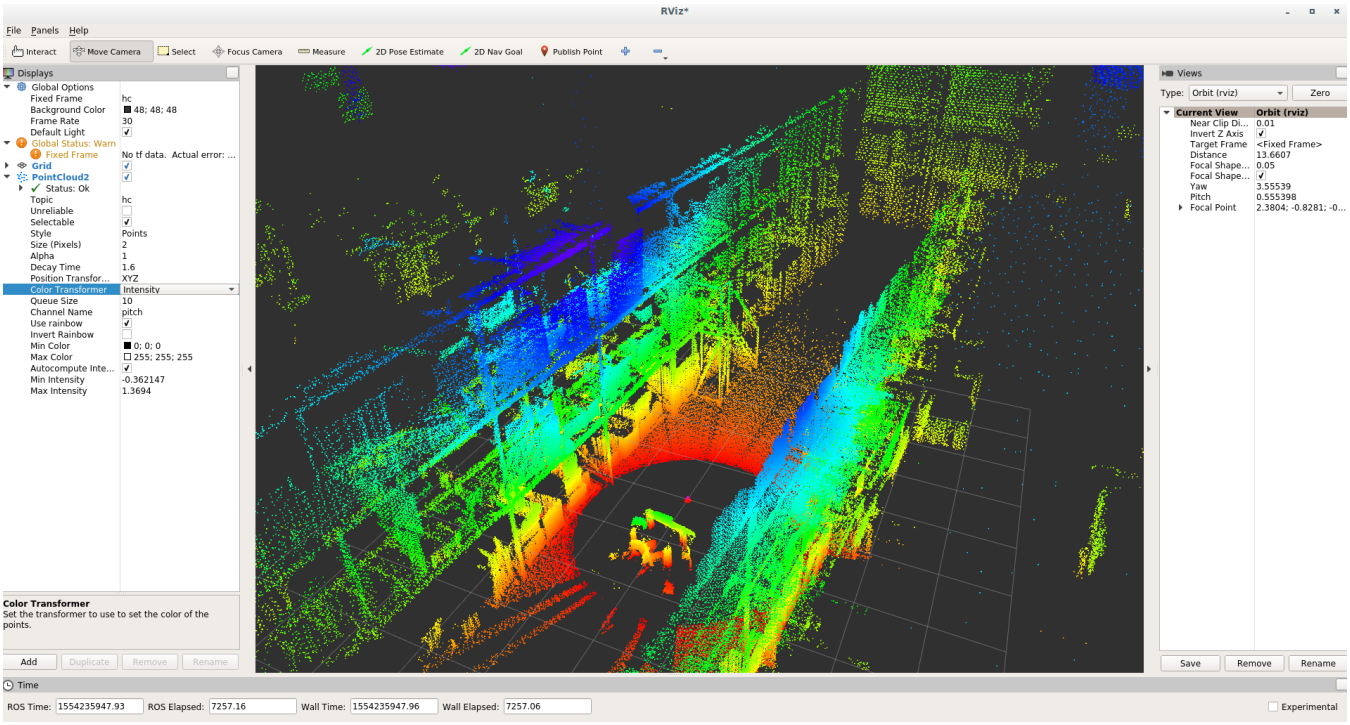


Figure 3.4 Example rviz Image

Mounting the Lidar

The Laser Bear Honeycomb lidar is intended to be a component that is incorporated into another product. It comes with a mounting bracket attached to the lidar. To install the lidar using the mounting bracket, use at least two (2) M6 screws (at least one on each side) torqued to 10 +/- 2 newton-meters. Figure 4.1 shows the mounting points. Dimensions for mounting features can be found in the Specifications section.

Note: If you want to mount the device in another manner, contact Waymo customer support at: lidar-support@waymo.com (mailto:lidar-support@waymo.com).

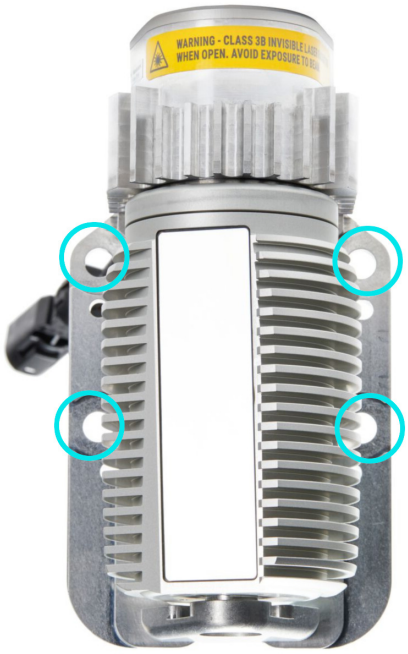


Figure 4.1 Mounting bracket holes

Calibration and Orientation

Each Laser Bear Honeycomb lidar comes with intrinsic calibration already performed on the unit. Any orientation of the Honeycomb lidar is permissible.

Maintenance

There are no maintenance actions that need to be taken on the Laser Bear Honeycomb lidar except periodic inspections and cleaning of the external window.

Inspection

The Laser Bear Honeycomb lidar should be inspected periodically for an accumulation of dirt, dust, mud, or other debris that could degrade the performance of the lidar. Users should wipe away any dirt in accordance with the cleaning instructions below. If any visible damage to the glass windows or restriction of free motion is noticed, the lidar must be sent back to Waymo for repair.

WARNING: Do not operate the lidar if there are cracks or visible damage on the glass windows, the windows are missing or loose, or the enclosure does not rotate freely when the laser is not powered.

Cleaning

The Laser Bear Honeycomb lidar should be cleaned approximately once per month, or if dirt, dust, mud, or other debris accumulates on the lens of the unit. If you notice internal reflections, this may indicate that the lidar requires cleaning. To clean the Honeycomb lidar, you will need two items:

- Professional optical surface cleaner (for example Edmund lens cleaner)
- Clean microfiber cloth

1. Spray optical surface cleaner on one clean unused corner of the microfiber cloth.

   CAUTION: Damage to the external window can occur if a dirty microfiber cloth is used to clean the external window.

2. Starting at the top of the Honeycomb lidar external window, wipe toward the bottom of the window in one motion with light pressure.

   CAUTION: Do not wipe up and down. Only wipe down and away from the window.

   CAUTION: Do not use excessive force.

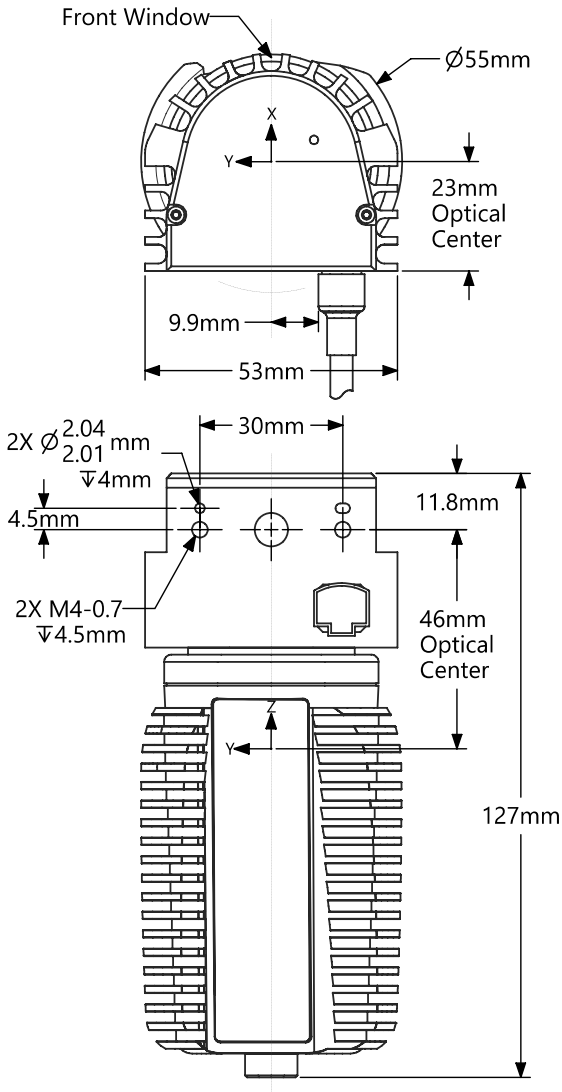
3. Use a clean, dry portion of the microfiber cloth to wipe off excess lens cleaner.
4. Repeat steps 1-3 as needed until window is completely clean.

Service

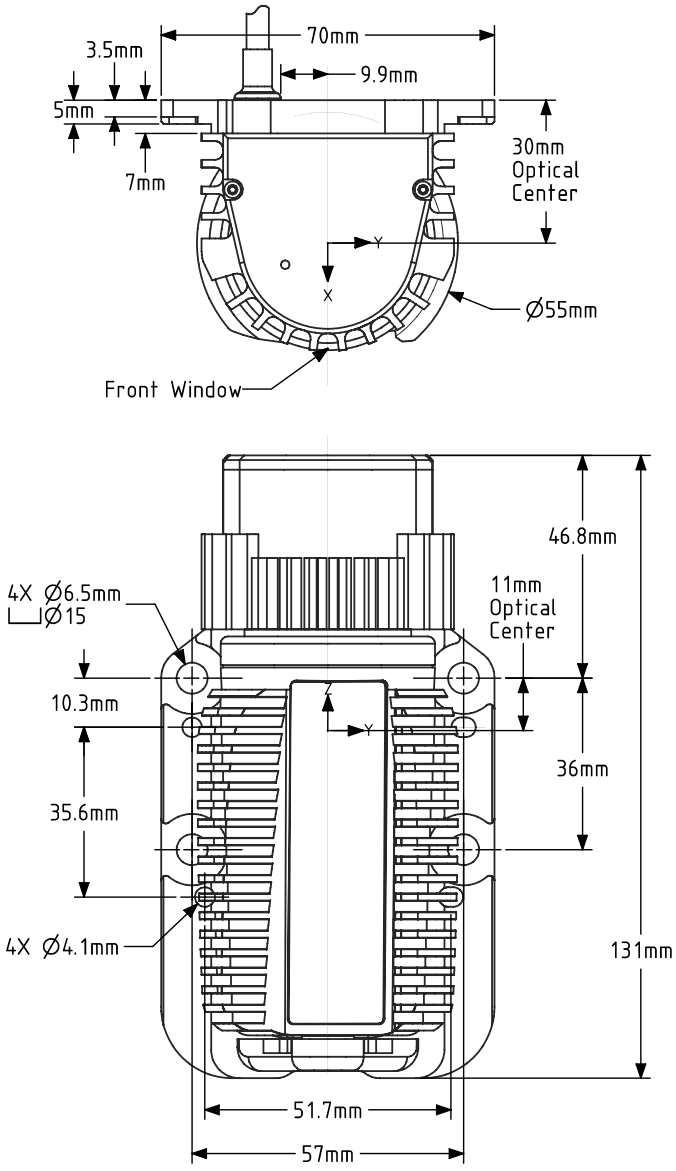
There are no user-serviceable components inside the Honeycomb lidar. Any problems or issues discovered during the periodic inspections must be logged and reported, and the lidar must be sent back to the manufacturer for servicing.

Specifications

Dimensions



Honeycomb 1 dimensions



Honeycomb 1 dimensions with bracket

Sensor

Maximum Range	50m (80% reflectivity); 20m (10% reflectivity)
Minimum Range	0m
Range Accuracy	±2cm (typical)
Horizontal FoV	360° without bracket / 210° with bracket
Horizontal Resolution	1.2° at 5Hz update rate, 3.6° at 15Hz

Vertical FoV	95° (21° up, 74° down)
Vertical Resolution	0.76° (best)
Angular Accuracy	±0.3°
Points per second	Up to ~200k (variable)
Returns per pulse	Up to three
Vertical scans per second	1500 per side
Horizontal scans per second	5-15Hz

Mechanical

Operational temperature range	-40°C to 75°C
Storage temperature range	-40°C to 105°C
Maximum operational relative humidity	93% (non-condensing)
Ingress protection	IP67 (lidar only; does not cover bridge board, power supply, or included cables)

Laser

Class 1	per IEC 60825-1:2014
Wavelength	905nm

Physical

Weight	353 grams; 420 grams with bracket
Dimensions without bracket	53mm width / 55mm depth / 127mm height
Dimensions with a bracket	70mm width / 57mm depth / 131mm height

Electrical

Input voltage	48V, ±5%, 12-48V with upcoming bridge board
Steady state power consumption	<10W

Startup power	<30W for up to five seconds
Communication Interface	100Mbps Ethernet via BroadR-Reach or RJ-45 connection

Drivers

OS for drivers	Linux (x86-64 & ARM64)
API	ROS, C++

Data Provided

- Cartesian coordinates
- Spherical coordinates
- Intensity
- Timestamp
- Normals
- Pulse width
- Beam side
- Return index

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For questions, comments, or orders, email us at:
lidar-support@waymo.com (mailto:lidar-support@waymo.com)

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