Pandar40

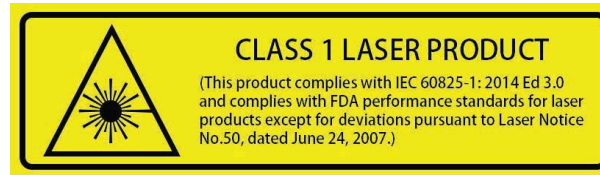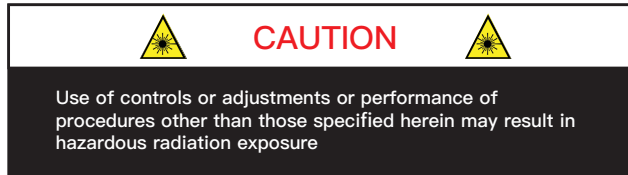## 40−Channel Mechanical LiDAR User's Manual

HESAI Wechat

Safety Notice

Please read and follow all instructions carefully and consult all relevant national and international safety regulations for your application.

■ Caution

To avoid violating the warranty and to minimize the chances of getting electrically shocked, please do not disassemble the device on your own accord. The device must not be tampered with and must not be changed in any way. There are no user–serviceable parts inside the device. For repairs and maintenance inquiries, please contact an authorized Hesai Technologies service personnel.

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

CLASS 1 LASER PRODUCT
(This product complies with IEC 60825-1: 2014 Ed 3.0 and complies with FDA performance standards for laser products except for deviations pursuant to Laser Notice No.50, dated June 24, 2007.)

■ Laser Safety Notice — Laser Class 1

The device satisfies the requirements of:
• IEC 60825–1:2014;
• 21 CFR 1040.10 and 1040.11 except for deviations pursuant to Laser Notice No.50, dated June 24, 2007;
• GB7247.1–2012

DISCLAIMER The information contained within this user's manual and the functions offered are intended to provide information about products. All reasonable efforts have been made to ensure the accuracy of the information. However, Hesai cannot be held responsible for any errors. Hesai does not warrant the accuracy and reserves the right to make changes to the catalog and its functions at any time without notice.

Contents

1 Introduction

Pandar40 is a 40–channel mechanical LiDAR. It creates 3D imaging by 360° mechanical rotating through 40 laser diodes inside the housing. Pandar40's unique channel distribution makes it more suitable for autonomous driving applications.

In addition to the specifications of Pandar40, this manual also describes the mechanical installation, data outputs format, and GPS timestamp synchronization.

This manual is undergoing constant revision and improvement, please ask Hesai for the lastest version of the user's manual.

1.1 Operational Principles

1.1.1 Distance Measurement: Time of Flight (ToF)

1. A laser diode emits a beam of ultrashort pulse laser on to the object.
2. Diffuse reflection of the laser occurs upon contact with the target object. Reflected beams are detected by the optical sensor.
3. Distance to object can be accurately measured by calculating the time between emission and receipt by the sensor.

$$d = \frac{1}{2}ct$$

d : Distance
c : Speed of light
t : Laser beam travel time

Figure 1.1 ToF Formula

1.1.2 Structure Description

40 pairs of laser emitters and receivers are attached to a rotating motor inside the LiDAR housing that perform horizontal scans in 360 degrees.
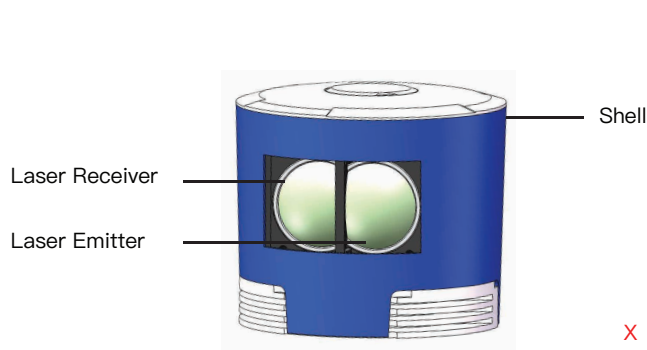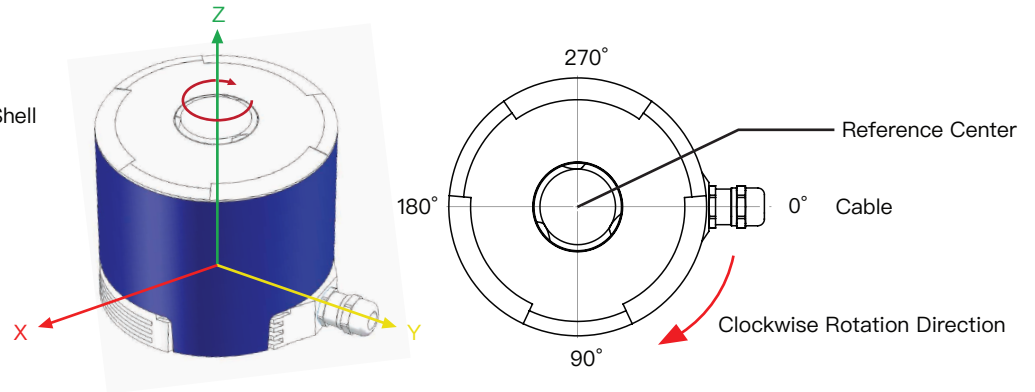
Figure 1.2 Partial Cross–Sectional Diagram

Figure 1.3 LiDAR Coordinate System and Rotation Direction

NOTE

1) Figure 1.3 shows the coordinate system and the z axis is along the rotation center of the LiDAR. The origin of the coordinate system is shown as a red dot in Figure 1.5 (side view of the LiDAR). All the LiDAR measurement data are relative to the origin after geometry transformation according to LiDAR's optical and mechanical design.

2) Because of the intrinsic angle offset of each laser channel, the zero degree is defined as the azimuth angle in the corresponding block in UDP packet when channel 12 passes y axis defined in Figure 1.3.

1.1.3 Pandar40 Channel Vertical Distribution

The vertical angular resolution is 0.33° between Channel 6 and Channel 30;
The vertical angular resolution is 1° between Channel 5 and Channel 6, Channel 30 and Channel 38;
The vertical angular resolution of the remaining channels is not evenly distributed.
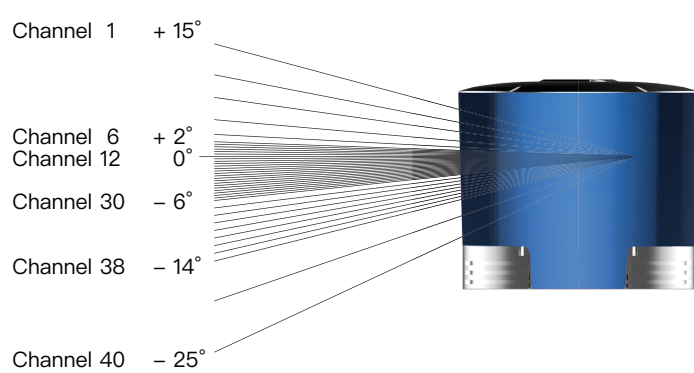Please see Appendix I for detailed channel distribution.

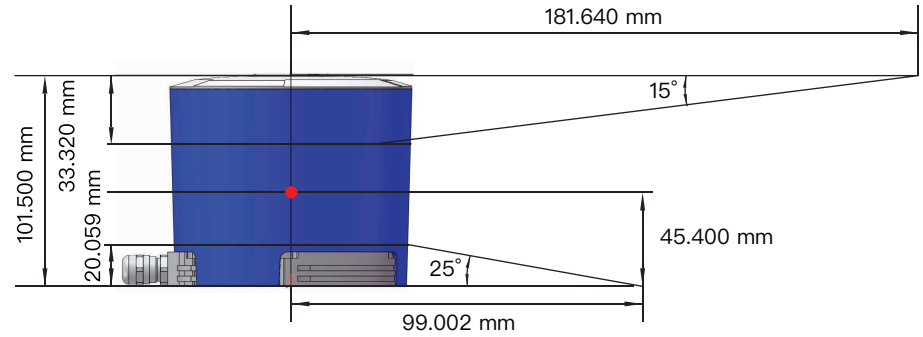Figure 1.4 Channel Vertical Distribution

Figure 1.5 Laser Firing Position

1.2　Specifications

Scanning Method	Mechanical Rotating		Angular Resolution (Vertical)	0.33° (−6° to +2°); 1° (+2° to +3°, −14° to −6°); 2° (+3° to +5°); 3° (+5° to +11°); 4° (+11° to +15°); 5° (−19° to −14°); 6° (−25° to −19°)
Channel	40			
Wavelength	905 nm			
Laser Class	Class 1 Eye Safe			
Measurement Range	0.3 m to 200 m (at 20% reflectivity)		Data Transmission Method	UDP/IP Ethernet (100 Mbps)
Data Points Generated	Single Return Mode: 720,000 points per second Dual Return Mode: 1,440,000 points per second		Operating Voltage	9 V to 48 V
			Power Consumption	18 W
Frame Rate (Configurable)	10 Hz, 20 Hz		Enclosure Level	IP67
Measurement Accuracy	±5 cm (0.3 m to 0.5 m); ±2 cm (0.5 m to 200 m)		Operating Temperature	−20℃–60℃
			Weight	1.46 kg
FOV (Horizontal)	360°		Dimensions	Height: 101.50 mm; Top Diameter: 116.00 mm; Bottom Diameter: 112.00 mm
Angular Resolution (Horizontal)	0.2° (10 Hz), 0.4° (20 Hz)			
FOV (Vertical)	40° (−25° to +15°)			

Table 1.1 Specifications of Pandar40

*Specifications are subject to change without notice.

2 Installation Guide
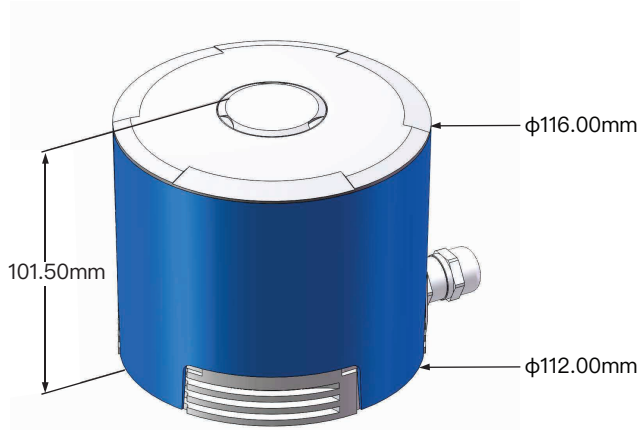
2.1 Mechanical Installation（Metric System）
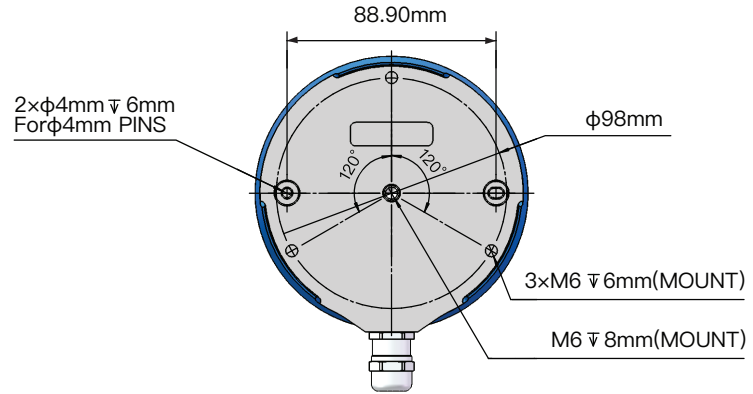

Figure 2.1 Pandar40 Side View

Figure 2.2 Pandar40 Mounting Base

■ Quick Installation

M6 screw
7~9mm over mounting base

2xΦ4PINS
5~6mm over mounting base
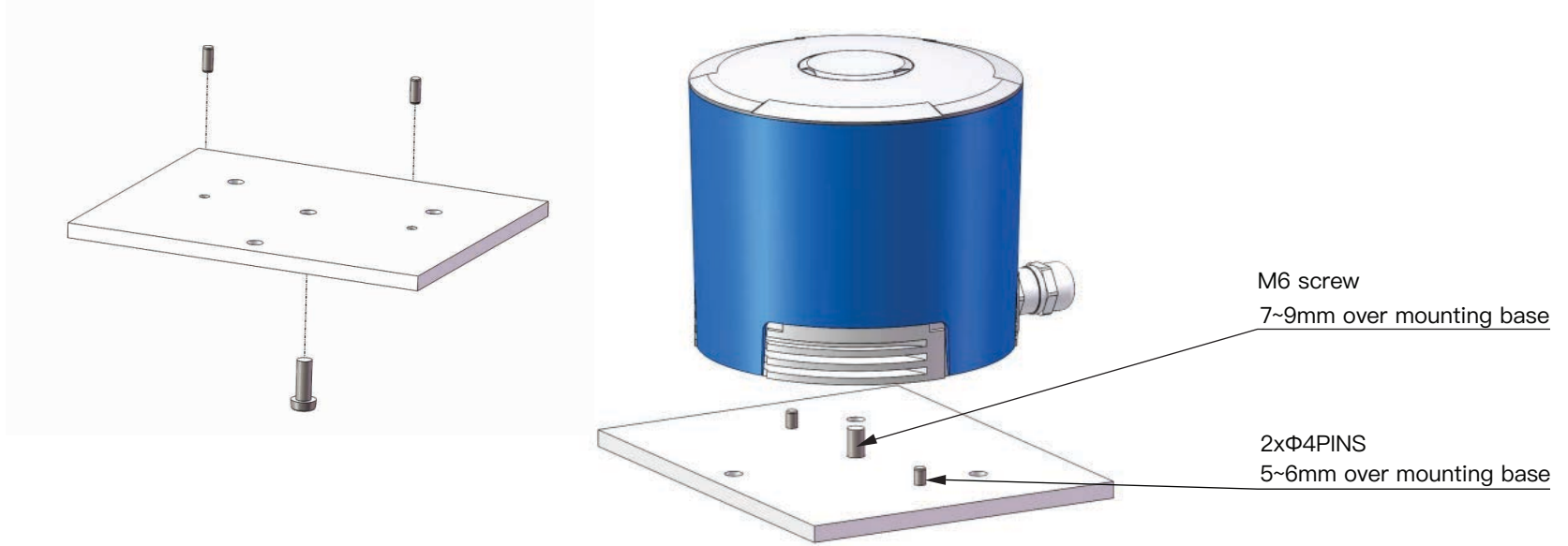
Figure 2.3 Diagram of Quick Installation

■ Stable Installation

M6 screw
7~9mm over mounting base

3xM6 screw
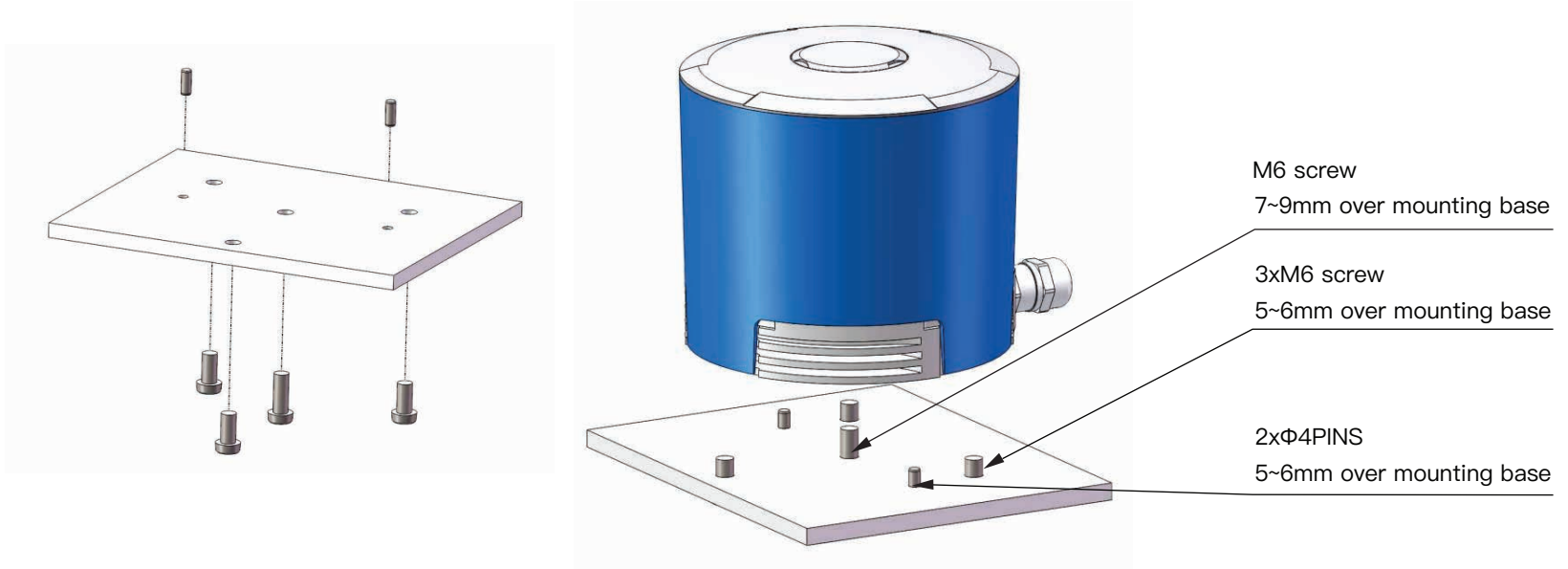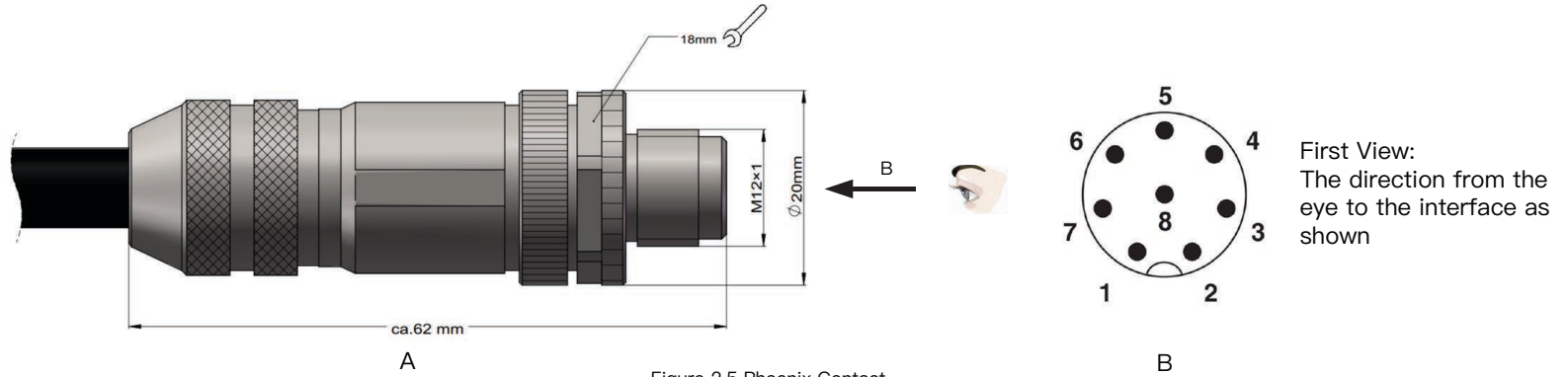5~6mm over mounting base

2xΦ4PINS
5~6mm over mounting base

Figure 2.4 Diagram of Stable Installation

2.2 Interface

Pandar40 uses Phoenix Contact (PN: SACC–M12FS–8CON–PG 9–SH) as the communication connector. The cable length from LiDAR exit to the tip of the connector is 0.3 m.

Figure 2.5 Phoenix Contact

First View:
The direction from the eye to the interface as shown

Pin #	Function	Color	Voltage (V)
1	Ethernet RX–	Blue	–1V to 1V
2	Ethernet RX+	Light Blue (Blue/White)	–1V to 1V
3	Ethernet TX–	Orange	–1V to 1V
4	Ethernet TX+	Light Orange (Orange/White)	–1V to 1V
5	GPS Serial Data	White	–13V to +13V
6	GPS PPS	Yellow	3.3V/5V
7	+12V	Red	12V
8	Ground (Return)	Black	

Table 2.1 Communication Connector Description

2.3   Connecting Box (Optional Component)

Connecting box is the optional component of Pandar40. Users can choose to connect LiDAR using the connecting box. The connecting box comes equipped with a power port, a GPS port, and a standard ethernet port. The cable length from phoenix connector to the connecting box is 1.5 m.
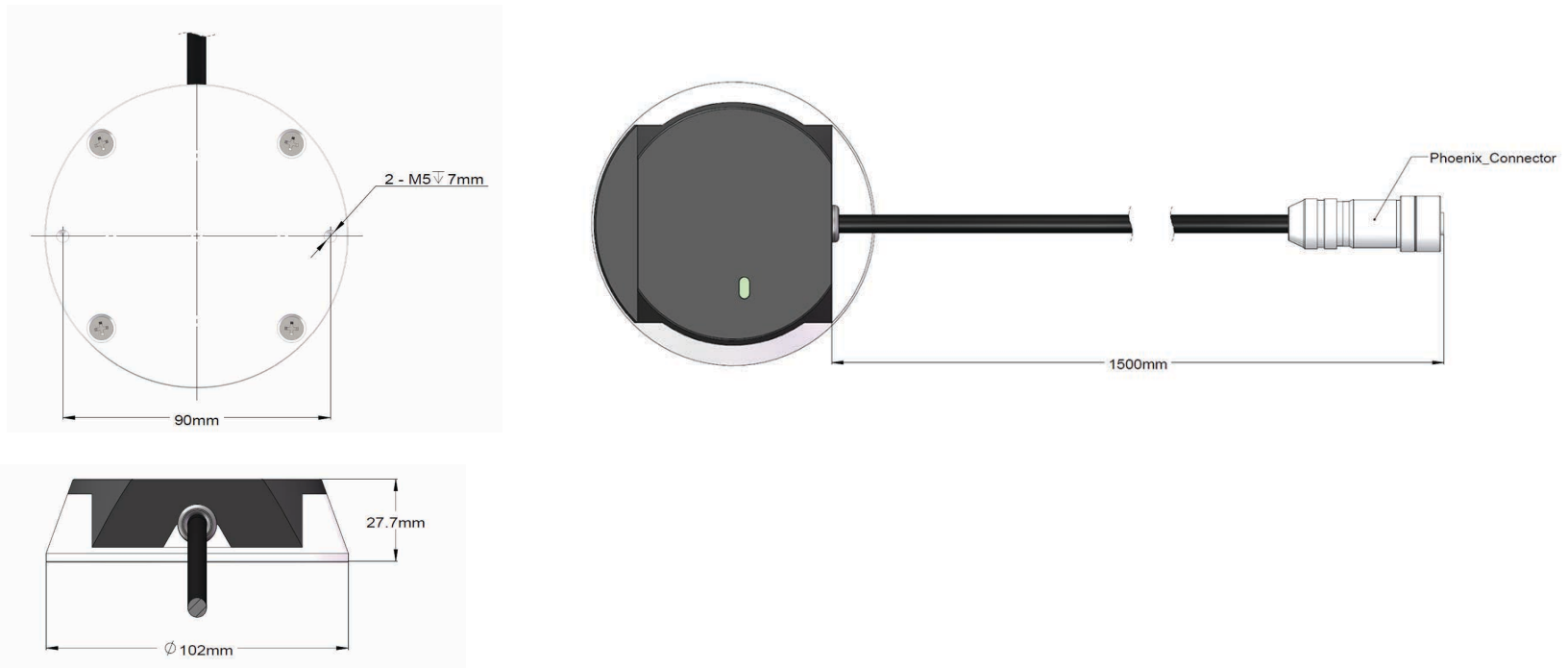

Figure 2.6 Connecting Box

2.3.1 Connecting Box Interfaces

Figure 2.7 Connecting Box Interfaces

a	Standard Ethernet Port
	RJ45, 100 Mbps Ethernet
b	Power Port
	Use DC–005 DC power adapter Input voltage ranges from 9V to 32V Power consumption is 15W
c	GPS Port
	Connector type: JST SM06B–SRSS–TB Recommended connector for external GPS module: JST SHR–06V–S–B Voltage standard: RS232 Baud rate: 9600bps

Table 2.2 Connecting Box Interfaces Description

GPS port pin number from left to right is 1 to 6, and the specific definition of each pin is shown as follows:

Pin No.	Direction	Pin Description
1	Input	PPS synchronizing signal, to receive synchronized pulses from the GPS module TTL 3.3V/5V
2	Output	5V power, to provide power for external GPS module
3	Output	GND, to ground external GPS module
4	Input	Receiving signal of serial port, to receive serial data from external GPS module, RS232 level
5	Output	GND, to ground external GPS module
6	Output	Transmitting signal of serial port, to send serial data to the external GPS module, RS232 level

Table 2.3 GPS Pin No. Description

2.3.2 How to Connect using Connecting Box

Connect the power port to the adapter.

Power port and
standard Ethernet port

Pandar40

Use an Ethernet cable to connect
the LiDAR's and computer's
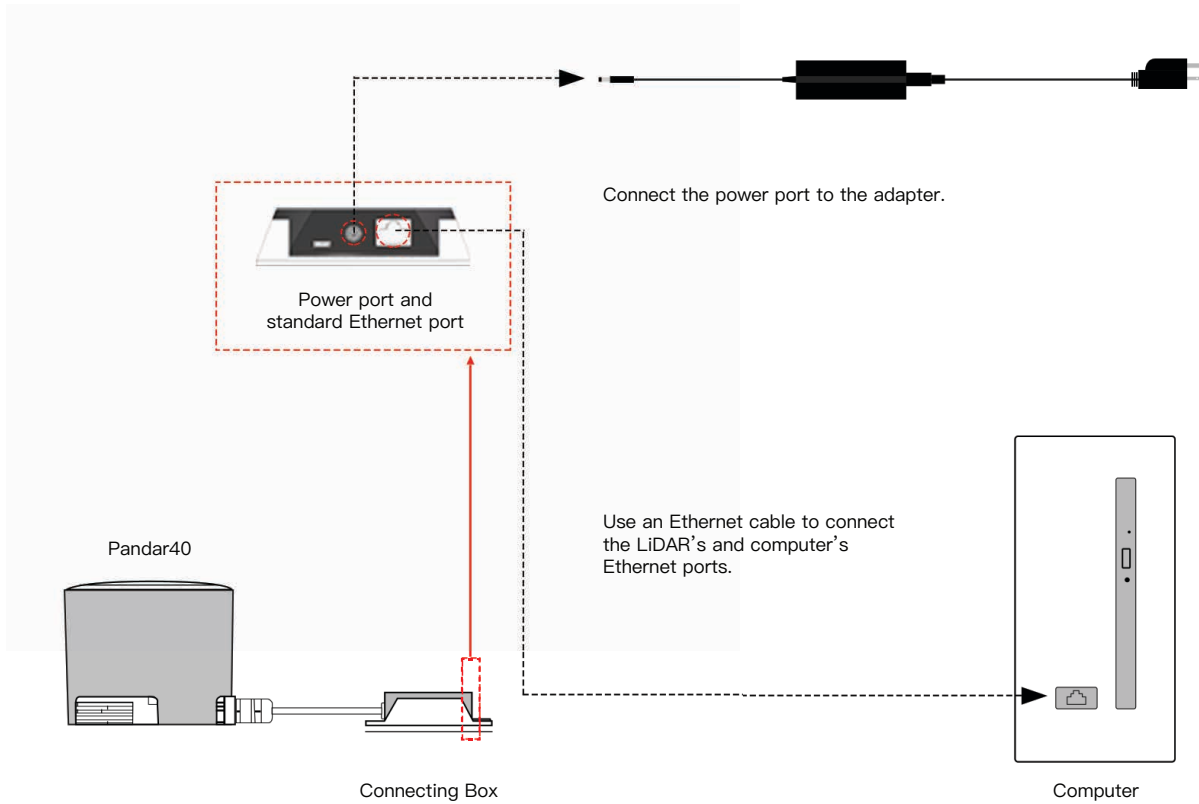Ethernet ports.

Connecting Box

Computer

Figure 2.8 How to Connect Using Connecting Box

2.4　Get Ready to Use

Pandar40 begins to scan and transmit data automatically once it is wired and powered up.
To receive the data on your PC, please set the PC IP address to 192.168.1.100 and Subnet mask to 255.255.255.0.
Point cloud data can be quickly viewed or recorded by using PandarView, the point cloud data viewer software developed by Hesai. For more on PandarView installation and usage, see Appendix III PandarView.

NOTE Pandar40 does not have a power switch. It starts to operate whenever power is applied.
NOTE Web control can be used to set up the configurable parameters of the LiDAR before using. For more on web control functions, see Chapter 4.
NOTE SDK (Software Development Kit) of our LiDAR can be found on Hesai official Github.

3 LiDAR Data Structure

The communication protocol for data output of Pandar40 is Fast Ethernet UDP/IP. The output data includes point cloud data packet and GPS data packet. Each data packet consists of an ethernet header and a UDP data.
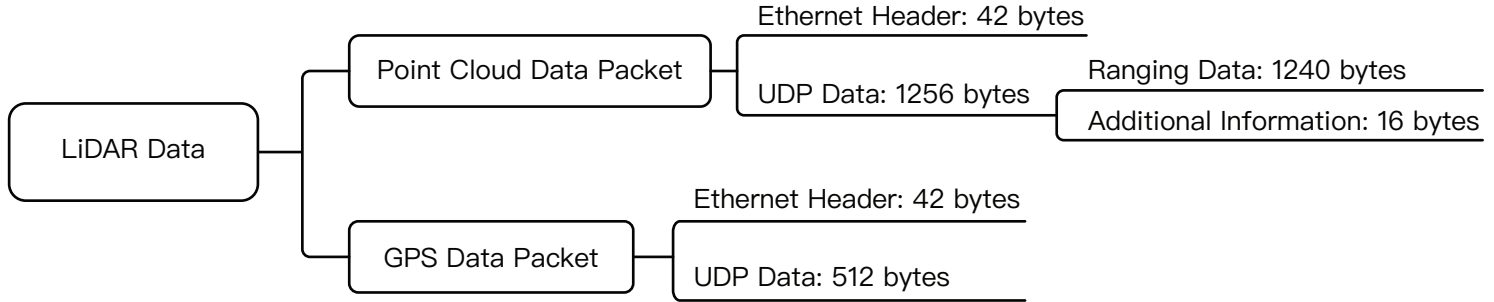

Figure 3.1 LiDAR Data Structure Illustration

3.1 Point Cloud Data Packet Ethernet Header/ UDP Data

Each Pandar40 point cloud data packet has a 42 bytes ethernet header and 1256 bytes UDP data.

3.1.1 Point Cloud Data Packet 一 Ethernet Header

Here is an example of point cloud data packet ethernet header definition:

Ethernet Header: 42 bytes		
Ethernet II MAC	12 bytes	Destination: Broadcast (0xFF: 0xFF: 0xFF: 0xFF: 0xFF: 0xFF), Source: (xx:xx:xx:xx:xx:xx)
Ethernet Data Packet Type	2 bytes	0x08, 0x00
Internet Protocol	20 bytes	Version, Header Length, Differentiated Services, Field, Total Length, Identification, Flags, Fragment Offset, Time to Live, Protocol, Header Checksum, Source IP Address, Destination IP Address
UDP Port Number	4 bytes	UDP source port (0x2710, represents 10000), destination port (0x0940, represents 2368)
UDP Length and Checksum	4 bytes	Length 2 bytes (0x04F0, represents 1264 bytes), checksum 2 bytes (0x00, represents no check)

Table 3.1 Point Cloud Data Packet Ethernet Header Definition

IP Address

The destination IP address is 0xFF FF FF FF and in broadcast form.
The default source IP address is 192.168.1.201.
Taking "Internet Protocol (20 bytes)" as an example,
it is described as Figure 3.2:

Figure 3.2 Point Cloud Data Header Internet Protocol Illustration

3.1.2 Point Cloud Data Packet– UDP Data

The UDP Data of Pandar40 has a 1256 bytes payload consisting of 1240 bytes ranging data and 16 bytes additional information.
All the multi–byte values are the unsigned type and in Little Endian format.

Ranging Data 1240 bytes (10 blocks)				
Block 1	**Block 2**	**Block 3**	· · · · · ·	**Block 10**
0xFFEE	0xFFEE	0xFFEE	· · · · · ·	0xFFEE
Azimuth Angle 1	Azimuth Angle 2	Azimuth Angle 3	· · · · · ·	Azimuth Angle 10
Channel 1 Unit 1	Channel 1 Unit 2	Channel 1 Unit 3	· · · · · ·	Channel 1 Unit 10
Channel 2 Unit 1	Channel 2 Unit 2	Channel 2 Unit 3	· · · · · ·	Channel 2 Unit 10
· · · · · ·	· · · · · ·	· · · · · ·	· · · · · ·	· · · · · ·
Channel 40 Unit 1	Channel 40 Unit 2	Channel 40 Unit 3	· · · · · ·	Channel 40 Unit 10

Table 3.2 Point Could Data UDP Data–Ranging Data

The definition of each block in ranging data is as follow:

Each Block in Ranging Data: 124 bytes	0xFFEE	2 bytes	Head, meaningless, 0xFF first	
	Azimuth Angle	2 bytes	Represents the current reference angle of the rotor Azimuth [15:0]: lower byte Azimuth_L [7:0] is in the front, upper byte Azimuth_H [15:8] is in the back Azimuth Angle=[Azimuth_H, Azimuth_L]/100˚=Azimuth/100˚	
	Channel XX Unit XX	3 bytes	2 bytes distance data	Distance Value=Range*4mm Maximum Distance Value=(2^16—1)*4mm= 262.14m
			1 byte reflectivity data	

Table 3.3 Block Definition

NOTE Under dual return mode, azimuth angle changes every two blocks. The odd number block is the last return, and the even number block is the strongest return.

Additional Information: 16 bytes		
Reserved	5 bytes	reserved data, meaningless
High Temperature Shutdown Flag	1 byte	0x01 means high temperature; 0x00 means normal operation ·　during normal operation, shutdown flag keeps being 0x00 ·　if high temperature is detected and system needs to be shut down, the shutdown flag will be set to 0x01, and the system will be shut down after 60 seconds. The flag keeps being 0x01 during the 60 seconds and shutdown period ·　after the high temperature shutdown, the Lidar temperature will decrease. When the system is not in high temperature status, the shutdown flag will be reset to 0x00 and the system can return to normal operation
Reserved	2 bytes	reserved data, meaningless
Motor Speed	2 bytes	speed_2_bytes [15:0] = speed (RPM)
GPS Timestamp	4 bytes	the firing time of the first laser in the first block, the unit is 1 μs, maximum value is 71.58 minutes
Return Mode Information	1 byte	the strongest return (0x37), the last return (0x38), dual return (0x39)
Factory Information	1 byte	0x42 (or 0x43)

Table 3.4 Point Cloud Data UDP Data–Additional Information

■ Example of UDP Data Analysis

Taking Channel 5 in block 3 of a UDP Data Packet as an example, please see Appendix I for detailed channel distribution:

1) Horizontal angle offset of the laser is −2.50°, and vertical angle of the laser is 3.00° for Channel 5 (refer to Appendix I).

2) Horizontal angle is the current reference angle of the rotor plus horizontal angle offset, so the result is (Azimuth Angle 3+(−2.5)) degree. (NOTE We define clockwise as a positive direction of the angle from top view)

3) Analyze the "Channel 5 Unit 3" from the UDP Data Packet, and the distance formed by upper 2 bytes multiplied by 4 mm is the actual distance in millimeters in the real world.

By now, the direction and distance of this point have been decided, and this obstacle point could be drawn in the polar or rectangular coordinate system. The real–time point cloud data of Pandar40 can be drawn by analyzing every data in the UDP Data Packet using the above method.

3.2 GPS Data Packet Ethernet Header/UDP Data

Each GPS Data Packet has a 42 bytes ethernet header and 512 bytes UDP Data. All the multi–byte values are the unsigned type and in Little Endian format. GPS UDP Data Packet will be triggered if there is GPS PPS signal, and the port is 10000.

3.2.1 GPS Data Packet — Ethernet Header

Ethernet Header: 42 bytes		
Ethernet II MAC	12 bytes	Destination: Broadcast (0xFF: 0xFF: 0xFF: 0xFF: 0xFF: 0xFF), Source: (xx:xx:xx:xx:xx:xx)
Ethernet Data Packet Type	2 bytes	0x08, 0x00
Internet Protocol	20 bytes	Version, Header Length, Differentiated Services, Field, Total Length, Identification, Flags, Fragment Offset, Time to Live, Protocol, Header Checksum, Source IP Address, Destination IP Address
UDP Port Number	4 bytes	UDP source port (0x2710, represents10000), destination port (0x277E, represents 10110)
UDP Length and Checksum	4 bytes	Length 2 bytes (0x208, represents 520 bytes), checksum 2 bytes (0x00, represents no check)

Table 3.5 GPS Data Packet Ethernet Header Definition

IP Address

The destination IP address is 0xFF FF FF FF and in broadcast form.
The default source IP address is 192.168.1.201.
Taking"Internet Protocol (20 bytes)" as an example,
it is described as Figure 3.3:

```
⊟ Internet Protocol, Src: 192.168.1.201 (192.168.1.201), Dst: 255.255.255.255 (255.255.255.255)
     Version: 4
     Header length: 20 bytes
  ⊞ Differentiated Services Field: 0x00 (DSCP 0x00: Default; ECN: 0x00)
     Total Length: 540
     Identification: 0x4f17 (20247)
  ⊞ Flags: 0x02 (Don't Fragment)
     Fragment offset: 0
     Time to live: 64
     Protocol: UDP (17)
  ⊞ Header checksum: 0x2749 [correct]
     Source: 192.168.1.201 (192.168.1.201)
     Destination: 255.255.255.255 (255.255.255.255)
⊞ User Datagram Protocol, Src Port: ndmp (10000), Dst Port: nmea-0183 (10110)
⊞ Data (512 bytes)
```

Figure 3.3 GPS Data Ethernet Header Internet Protocol Illustration

3.2.2 GPS Data Packet – UDP Data

Every second, one UDP data will be triggered by one GPS PPS. UDP data has 512 bytes, and the port is 10110.

GPS UDP data: 512 bytes				
GPS Time Data	18 bytes	Header	2 bytes	0xFFEE, 0xFF first
		Date	6 bytes	Year month and day in order (2 bytes each), lower byte first, ASCII code
		Time	6 bytes	Second minute and hour in order (2 bytes each), lower byte first, ASCII code
		μs Time	4 bytes	Unit is μs, lower byte first
GPRMC Data	77 bytes	ASCII code, valid till 2 bytes after '*'		
Reserved Data	411 bytes	Filled with 411 0xDF		
Location valid or not	1 byte	From GPRMC information, ASCII code, A=valid, V=invalid		
Flag of PPS lock	1 byte	1=locked, 0=unlocked		
Reserved Data	4 bytes	Reserved meaningless data		

Table 3.6 GPS Data Packet–UDP Data Definition

■ Example of GPS Data Packet UDP Data Analysis


```
⊞ User Datagram Protocol, Src Port: ndmp (10000), Dst Port: nmea-0183 (10110)
⊟ Data (512 bytes)
    Data: ffee3731323130323235353431003008a4244750524d43...

0020  ff ff 27 10 27 7e 02 08  a2 2c ff ee 37 31 32 31   ..'.'~.. .,..7121
0030  30 32 32 35 35 34 32 31  00 30 08 a4 24 47 50 52   02255421 .0..$GPR
0040  4d 43 00 2c 31 32 34 35  35 32 2e 30 30 2c 41 2c   MC.,1245 52.00,A,
0050  33 31 32 31 2e 38 36 37  37 32 2c 4e 2c 31 32 31   3121.867 72,N,121
0060  31 34 2e 36 37 33 31 38  2c 45 2c 30 2e 30 37 34   14.67318 ,E,0.074
0070  2c 2c 32 30 31 32 31 37  2c 2c 2c 44 2a 37 35 35   ,,201217 ,,,D*755
0080  35 35 35 35 35 35 35 35  35 35 35 35 35 35 35 35   55555555 55555555
0090  df df df df df df df df  df df df df df df df df   ........ ........
00a0  df df df df df df df df  df df df df df df df df   ........ ........
00b0  df df df df df df df df  df df df df df df df df   ........ ........
00c0  df df df df df df df df  df df df df df df df df   ........ ........
00d0  df df df df df df df df  df df df df df df df df   ........ ........
00e0  df df df df df df df df  df df df df df df df df   ........ ........
00f0  df df df df df df df df  df df df df df df df df   ........ ........
0100  df df df df df df df df  df df df df df df df df   ........ ........
0110  df df df df df df df df  df df df df df df df df   ........ ........
```

Figure 3.4 GPS Data Packet UDP Data Illustration

Date
Year: 0x37, 0x31, convert ASCII code to '7', '1'; means 17
Month: 0x32, 0x31, convert ASCII code to '2', '1'; means 12
Day: 0x30, 0x32, convert ASCII code to '0', '2'; means 20

Time
Second: 0x32, 0x35, convert ASCII code to '2', '5'; means 52
Minutes: 0x35 0x34 convert ASCII code to '5', '4; means 45
Hour: 0x32 0x31, convert ASCII code to '2', '1'; means 12 (UTC time)

μs Time
4 bytes, the μs time value of each GPS PPS pulse, and timestamp will be set as (minute*60+second)*1000000 μs.
The μs time of GPS PPS and the timestamp from the point cloud data have the same data source, and the unit is 1 μs.

GPRMC Data Format

The standard GPRMC data format is as follows:
$GPRMC, <01>, <02>, <03>, <04>, <05>, <06>, <07>, <08>, <09>, <10>, <11>, <12>*hh

Detailed descriptions are as follows：

<01> UTC Time, hhmmss (hour, minute, second) format

<02> Location Status, A=Valid Position, V=Invalid Position

<03> Latitude ddmm.mmmm (degree, minute) format

<04> Latitude Northern (N) or Southern (S) Hemisphere

<05> Longitude dddmm.mmmm (degree, minute) format

<06> Longitude Eastern (E) or Western (W) Hemisphere

<07> Ground Rate (000.0 to 999.9 knots)

<08> Ground Direction (000.0~359.9 degrees, referencing true north)

<09> UTC Date, ddmmyy (day, month, year) format

<10> Declination (000.0 to 180.0 degrees)

<11> Declination Direction, E (east) or W (west)

<12> Mode (only on version NMEA0183 3.00, A=Automatic Positioning, D=Differential, E=Estimation, N=Invalid Data)

The GPS interface of Pandar40 is compatible with a variety of data formats. The external GPS module GPRMC data format needs to meet the following conditions:
the data in <01> is the hour, minute, and second information; the data in <09> is the date information.

The following two formats are both admissible:
1) $GPRMC,072242,A,3027.3680,N,11423.6975,E,000.0,316.7,160617,004.1,W*67
2) $GPRMC,065829.00,A,3121.86377,N,12114.68322,E,0.027,,160617,,,A*74

4 Web Control

Web Control can be used to set Pandar40 parameters, check device info, and upgrade.
Before setting, please connect LiDAR and the computer using Ethernet cable. Set IP address to 192.168.1.100.

4.1 Open Web Control

After setting, open browser and type URL: 192.168.1.201/index.html to enter the web control homepage.
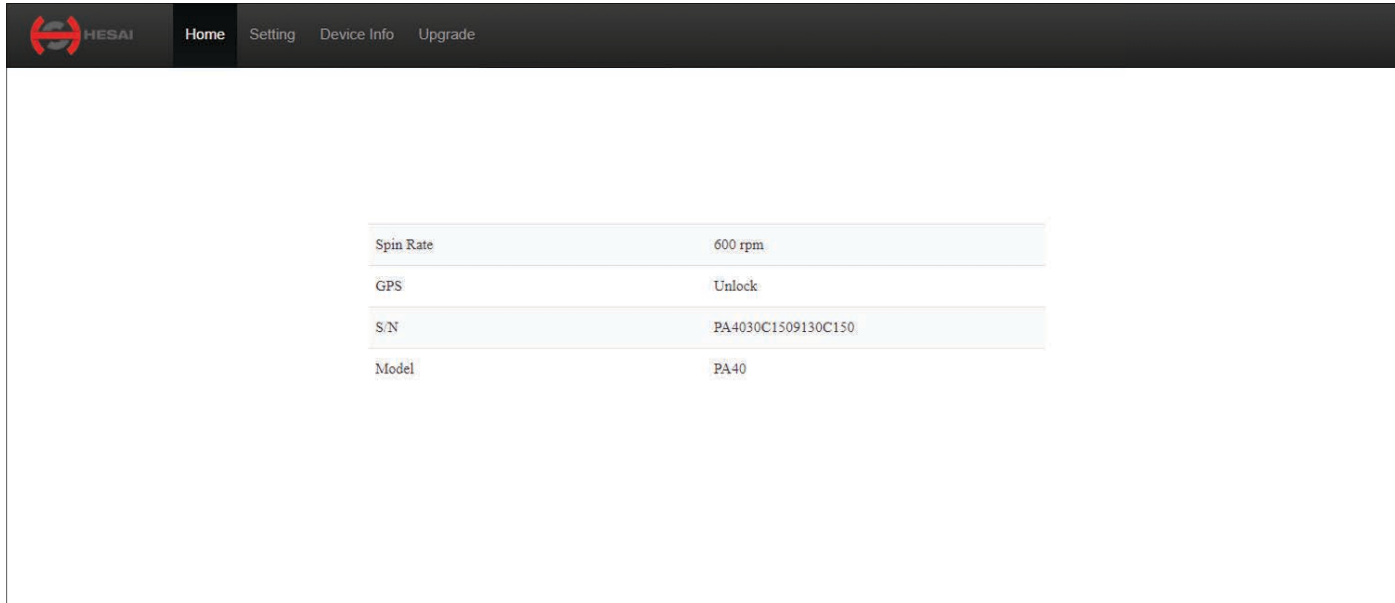
Figure 4.1 Home Page of Web Control

4.2   Setting

Figure 4.2 Setting Page of Web Control

1) Pandar40 supports both broadcast (default setting) and unicast.
   To use broadcast, please set Destination IP as 255.255.255.255. To use unicast, please set Destination IP as the same as PC IP address.

2) Users can choose the dual return type from the last return, the strongest return, and the dual return.

3) Users can choose the spinning rate from 600 rpm and 1200 rpm.

4) Users can choose the GPS sync angle. If set as 0, then the 0 degree angle is in sync with PPS.

5) Users can choose angle range less than 360° by specifying start and end angles. There will be no laser firing or data generated outside the specified angle range. If the start angle and the end angle are the same, all lasers will only fire at this particular angle.

6) Users can configure the rotation direction to clockwise or anticlockwise. The coordinate system remain the same despite the choice of rotation direction. Please refer to Figure 1.3 for more details.

4.3   Device Info

Software version, hardware version, firmware version can be viewed from device information page.

Figure 4.3 Device Info Page of Web Control

4.4 Firmware Upgrade

Please ask Hesai for the latest upgrade file if needed. Click on "Upload" button to upload the upgrade file. Please reboot the LiDAR after finishing upgrading.
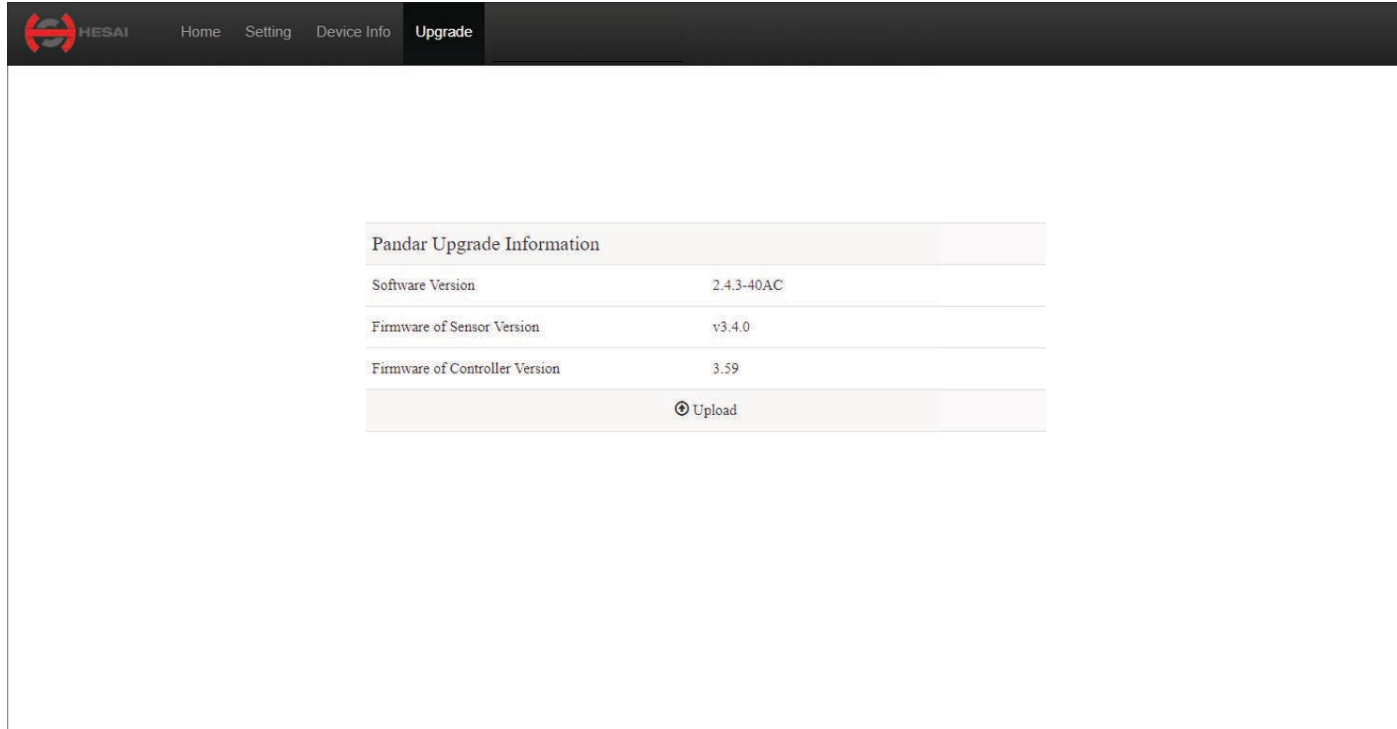
Figure4.4 Upgrade Page of Web Control

Appendix I

Pandar40 Channel Distribution

Channel Number of Laser	Horizontal Angle Offset (Azimuth)	Vertical Angle (Elevation)	Instrument Range (in meters)	Range Capability vs. Reflectivity (in meters)
Channel number in UDP Data Packet	The horizontal angle of each line is the sum of current reference angle of the rotor and the angle below. Define clockwise as positive.	The vertical angle of each line is constant, and 0° represents horizontal direction. Define upward as positive.	Instrument range capability	Range capability at objects with specific reflectivity
01 (Top Line)	–1.042	15.00	130	200@20%
02	–1.042	11.00	130	200@20%
03	–1.042	8.00	130	200@20%
04	–1.042	5.00	130	200@20%
05	–1.042	3.00	230	200@20%
06	–1.042	2.00	230	200@20%
07	3.125	1.67	230	200@20%
08	–5.208	1.33	230	200@20%
09	–1.042	1.00	230	200@10%
10	3.125	0.67	230	200@10%
11	–5.208	0.33	230	200@10%
12 (Horizontal Line)	–1.042	0.00	230	200@10%
13	3.125	–0.33	230	200@10%
14	–5.208	–0.67	230	200@10%

Channel Number of Laser	Horizontal Angle Offset (Azimuth)	Vertical Angle (Elevation)	Instrument Range (in meters)	Range Capability vs. Reflectivity (in meters)
15	–1.042	–1.00	230	200@10%
16	3.125	–1.33	230	200@10%
17	–5.208	–1.67	230	200@10%
18	–1.042	–2.00	230	200@10%
19	3.125	–2.33	230	200@20%
20	–5.208	–2.67	230	200@20%
21	–1.042	–3.00	230	200@20%
22	3.125	–3.33	230	200@20%
23	–5.208	–3.67	230	200@20%
24	–1.042	–4.00	230	200@20%
25	3.125	–4.33	230	200@20%
26	–5.208	–4.67	230	200@20%
27	–1.042	–5.00	130	200@20%
28	3.125	–5.33	130	200@20%
29	–5.208	–5.67	130	200@20%
30	–1.042	–6.00	130	200@20%
31	–1.042	–7.00	130	200@20%
32	–1.042	–8.00	130	200@20%
33	–1.042	–9.00	130	200@20%

Channel Number of Laser	Horizontal Angle Offset (Azimuth)	Vertical Angle (Elevation)	Instrument Range (in meters)	Range Capability vs. Reflectivity (in meters)
34	−1.042	−10.00	130	200@20%
35	−1.042	−11.00	130	200@20%
36	−1.042	−12.00	130	200@20%
37	−1.042	−13.00	130	200@20%
38	−1.042	−14.00	130	200@20%
39	−1.042	−19.00	130	200@20%
40 (Bottom Line)	−1.042	−25.00	130	200@20%

Table I.1 Pandar40 Channel Distribution

Appendix II

Point Cloud Data Packet Absolute Time and Laser Firing Time Calculations

Pandar40 transmits two types of UDP Data Packet, including the point cloud UDP Data Packet and the GPS UDP Data Packet, hereafter referred to as Point Cloud Data Packet and GPS Data Packet.

1   Absolute Time Calculation of Point Cloud Data Packet

LiDAR transmits a GPS Data Packet and a Point Cloud Data Packet chronologically with μs timestamps from the same data source. The μs timestamp in the Point Cloud Data Packet (GPS Timestamp) is used to calculate the packing time of this data packet.

There are two methods to calculate the absolute packing time of Point Cloud Data:
1) Retrieve the μs timestamp and the time information (UTC, decimal number) from the Point Cloud Data Packet. The absolute time of Point Cloud Data Packet can be calculated by combining 2 parts: a) the 4 bytes μs timestamp; b) the 6 bytes UTC time information (decimal number) in Point Cloud Data Packet.
2) First retrieve timestamp from the Point Cloud Data Packet, then retrieve time information (UTC) from the previous GPS Data Packet. The absolute time of Point Cloud Data Packet can be calculated by combining 2 parts: a) the 4 bytes μs timestamp; b) the UTC time information (decimal number) in previous GPS Data Packet.

NOTE
1) Because LiDAR GPS Data Packet is triggered by PPS rising edge, the corresponding GPRMC information (real absolute time) from GPS module after PPS rising edge is not available at that time.
2) The UTC time in LiDAR GPS Data Packet and following Point Cloud Data Packet can only utilize previous GPRMC information, which is 1 full second older than the absolute time of the triggering PPS rising edge. But the LiDAR can automatically adjust and the user can simply add the 4 bytes timestamp and 6 bytes UTC time to get absolute time.
3) Since every GPS Data Packet matches an internal 1Hz signal, the GPS Data Packet will be exported continuously in every second with or without GPRMC information. If GPRMC is available, UTC time in data packets are updated according to GPRMC and avoid drift of internal 1Hz signal; if GPRMC is not available, UTC time in data packets are updated according to internal 1Hz signal and keep the mechanism.

NOTE Please refer to Appendix III for the calculation of absolute time using PTP protocol.

2 Laser Firing Time Calculation

The laser firing time of every laser channel can be calculated by using the absolute time in Point Cloud Data Packet.
Assuming the Point Cloud Data Packet's absolute time is t0.

Ranging Data 1240 bytes (10 blocks)				
Block 1	**Block 2**	**Block 3**	$\cdots\cdots$	**Block 10**
0xFFEE	0xFFEE	0xFFEE	$\cdots\cdots$	0xFFEE
Azimuth Angle 1	Azimuth Angle 2	Azimuth Angle 3	$\cdots\cdots$	Azimuth Angle 10
Channel 1 Unit 1	Channel 1 Unit 2	Channel 1 Unit 3	$\cdots\cdots$	Channel 1 Unit 10
Channel 2 Unit 1	Channel 2 Unit 2	Channel 2 Unit 3	$\cdots\cdots$	Channel 2 Unit 10
$\cdots\cdots$	$\cdots\cdots$	$\cdots\cdots$	$\cdots\cdots$	$\cdots\cdots$
Channel 40 Unit 1	Channel 40 Unit 2	Channel 40 Unit 3	$\cdots\cdots$	Channel 40 Unit 10

Table II.1 Point Could Data UDP Data–Ranging Data

■ Single Return Mode

There are 10 Blocks in every Point Cloud UDP Data Packet.
In the single return mode, each block consists of 40 laser channels ranging data. The end time of the Block means all the 40 channels laser finished the firing.

The calculation of each Block's end time is as follows:

01) End time of Block10: (t0−28.58) μs;
02) End time of BlockN: (t0−28.58−55.56*(10−N)) μs;
03) End time of Block3: (t0−28.58−55.56*7) μs;

04) End time of Block2: (t0−28.58−55.56*8) μs;
05) End time of Block1: (t0−28.58−55.56*9) μs.

■ Dual Return Mode

There are 10 Blocks in every Point Cloud UDP Data Packet.

In the dual return mode, Block (1, 2) are corresponding to dual return ranging data for the same 40 channels laser firing, so they have the same firing time for each laser and the same end time for the Block. Similarly, Block (3, 4) and so on have same firing and end time.

The calculation of each Block's end time is as follows:

01) End time of Block10: (t0–28.58) μs;

02) End time of Block9: (t0–28.58) μs;

03) End time of Block8: (t0–28.58–55.56*1) μs;

04) End time of Block7: (t0–28.58–55.56*1) μs;

05) End time of Block6: (t0–28.58–55.56*2) μs;

06) End time of Block5: (t0–28.58–55.56*2) μs;

07) End time of Block4: (t0–28.58–55.56*3) μs;

08) End time of Block3: (t0–28.58–55.56*3) μs;

09) End time of Block2: (t0–28.58–55.56*4) μs;

10) End time of Block1: (t0–28.58–55.56*4) μs;

Through the Block's end time, it is possible to calculate the laser firing time for every channel in the Block.

Take Block 6 for example, assuming Block 6's end time is t6, then:

01) Laser ID 4's firing time: (t6–3.62) μs;

02) Laser ID 40's firing time: (t6–3.62) μs;

03) Laser ID 36's firing time: (t6–4.92) μs;

04) Laser ID 28's firing time: (t6–6.23) μs;

05) Laser ID 12's firing time: (t6–8.19) μs;

06) Laser ID 16's firing time: (t6–8.19) μs;

07) Laser ID 32's firing time: (t6–9.5) μs;

08) Laser ID 24's firing time: (t6–11.47) μs;

09) Laser ID 29's firing time: (t6–12.77) μs;

10) Laser ID 17's firing time: (t6–14.74) μs;

11) Laser ID 3's firing time: (t6–16.04) μs;

12) Laser ID 39's firing time: (t6–16.04) μs;

13) Laser ID 35's firing time: (t6–17.35) μs;

14) Laser ID 25's firing time: (t6–18.65) μs;

15) Laser ID 9's firing time: (t6–20.62) μs;

16) Laser ID 13's firing time: (t6–20.62) μs;

17) Laser ID 31's firing time: (t6–21.92) μs;

18) Laser ID 21's firing time: (t6–23.89) μs;

19) Laser ID 26's firing time: (t6–25.19) μs;

20) Laser ID 14's firing time: (t6–27.16) μs;

21) Laser ID 2's firing time: (t6−28.47) μs；
22) Laser ID 38's firing time: (t6−28.47) μs；
23) Laser ID 34's firing time: (t6−29.77) μs；
24) Laser ID 6's firing time: (t6−31.74) μs；
25) Laser ID 22's firing time: (t6−31.74) μs；
26) Laser ID 10's firing time: (t6−33.71) μs；
27) Laser ID 30's firing time: (t6−35.01) μs；
28) Laser ID 18's firing time: (t6−36.98) μs；
29) Laser ID 23's firing time: (t6−38.95) μs；
30) Laser ID 11's firing time: (t6−40.91) μs；

31) Laser ID 1's firing time: (t6−42.22) μs；
32) Laser ID 37's firing time: (t6−42.22) μs；
33) Laser ID 33's firing time: (t6−43.52) μs；
34) Laser ID 5's firing time: (t6−45.49) μs；
35) Laser ID 19's firing time: (t6−45.49) μs；
36) Laser ID 7's firing time: (t6−47.46) μs；
37) Laser ID 27's firing time: (t6−48.76) μs；
38) Laser ID 15's firing time: (t6−50.73) μs；
39) Laser ID 20's firing time: (t6−52.7) μs；
40) Laser ID 8's firing time: (t6−54.67) μs；

Appendix III

PandarView

PandarView is a software that is used to play and record the point cloud data. Installations are available on platforms: Windows 7x64/Windows 8x64/Windows 10x64/Ubuntu–16.04. The installation package can be found in the provided USB disk in the LiDAR box.

1 PandarView Installation

Please install the PandarView and set the computer static IP address to 192.168. 1.100 before running.

■ Installation

System	Installation Files	Installation Steps	Finish Installation
Windows	PandarView_Windows_V1.5.5.msi python-2.7.13.msi	1. Double–click on python_2.7.13 2. Double–click on PandarView_v1.5.5_Windows (install with default settings)	Pandar.exe shortcut will show on the desktop after installation:
Ubuntu–16.04	PandarView_Installer_V1.5.5.tar.gz	1. Enter the following command at the terminal: sudo apt–get install qt4–default libboost–all–dev. 2. Unzip the installation file 3. Run PandarView_Installer.bin	

Table VI.1 PandarView Installation Steps

■ IP Configuration

Ubuntu–16.04:
The IP address can be configured on the terminal by using the ifconfig command:
~$ sudo ifconfig enp0s20f0u2 192.168.1.100
Replace enp0s20f0u2 with the local network port name.

Windows:
① Open the Network Sharing Center, click on "Ethernet".
② In the "Ethernet Status" interface, click on "Properties" to proceed to the next interface.
③ Double–click on "Internet Protocol Version 4 (TCP/IPv4)".
④ Configure the IP address to 192.168.1.100 and the subnet mask to 255.255.255.0, then click "OK" to finish configuration.

2 PandarView Instructions

■ Check Live Data

Run PandarView, click on ⚡ and select your LiDAR model to begin receiving data over Ethernet.
Windows: Double–click shortcut "Pandar" 🔴 and you will see an initial interface.
Ubuntu–16.04: Double–click the shortcut on the desktop (if you set "Run executable text files when they are opened"), or open the terminal, enter:
~/Desktop/PandarView to open the software.
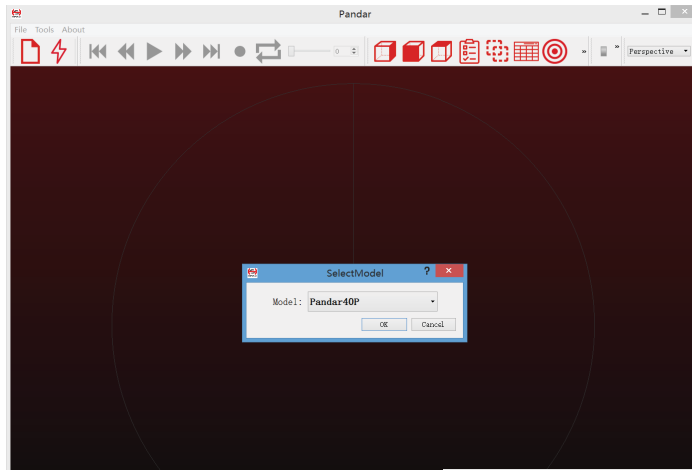
Figure III.2 Select LiDAR Model

■ Record Pcap Files

In real–time play mode, click on the icon ● to pop up the "Choose Output File" window. Click on "Save" to begin recording a pcap file.
After recording, click on ● again to stop recording the pcap file.
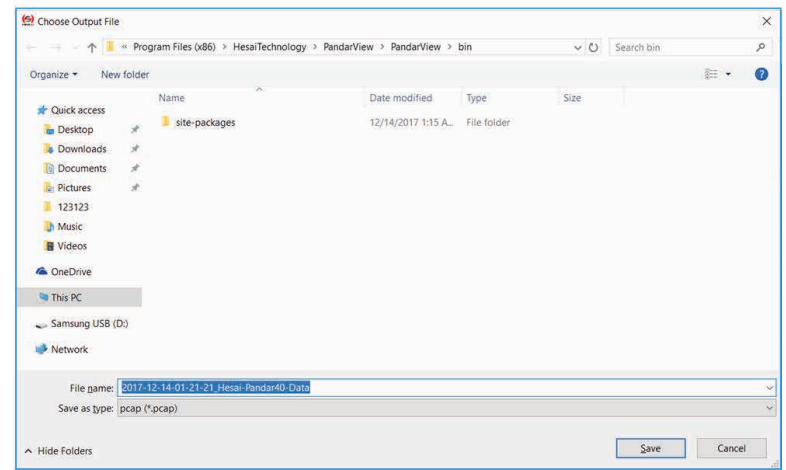
Figure III.3 Choose Output File Window

■ Play Pcap Files

Click on the icon ▯ to open the "Choose Open File" window. Select the pcap file and click on the icon [Open] .
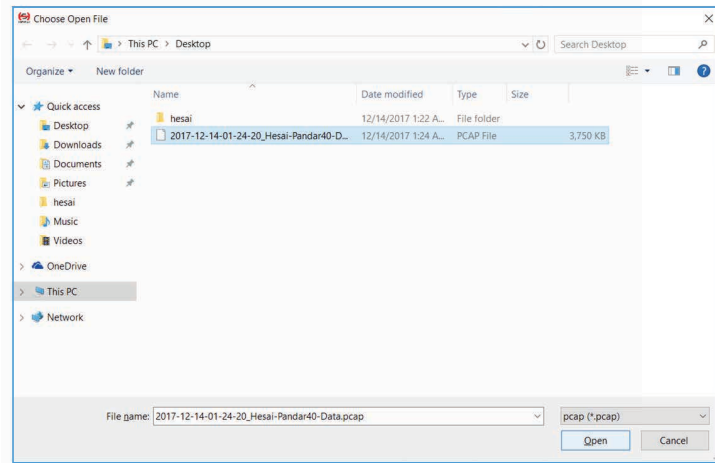
Figure III.4 Choose Open File Window

Click on ▶ to play the pcap file and visualize point cloud data.
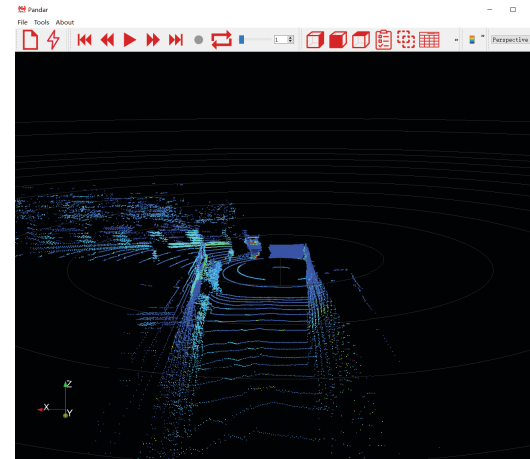
Figure III.5 Ready to Play the Pcap File

■ Import Correction File
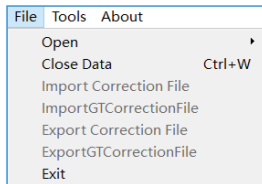
Figure III.6 File Menu

Each LiDAR comes with a correction file (CSV) in the provided USB disk.

In the play mode, click on "File" in the upper left corner. Choose "Import Correction File" in the drop-down menu, select and open the correction file to display the calibrated point cloud.

■ Play Buttons

Button	Description					
I◄◄	Jump to beginning of the file.					
◄◄	1. While paused, click to view point cloud data from previous frame. 2. While playing, rewind (click again for different speeds, such as 2x, 3x, 1/2x, 1/4x, 1x speeds).	◄◄ 2X	◄◄ 3X	◄◄ 1/2X	◄◄ 1/4X	◄◄
►	1. After the point cloud file has finished loading, click on ► to play. 2. While playing, click on ❚❚ to pause.					
►►	1. While paused, click to view point cloud data in next frame. 2. While playing, forward (click again for different speeds, such as 2x, 3x, 1/2x, 1/4x, 1x speeds).	►► 2X	►► 3X	►► 1/2X	►► 1/4X	►►
►►I	Jump to end of the file.					
●	While playing pcap file, the recording button will be gray and unclickable.					
⇄	While playing pcap file, click on this button to loop playback, else playback will stop at the end of file.					
—————◻ 3210 ⬍	Progress bar: drag to control playback speed, or enter frame number to jump to the desired frame.					

Table III.2 Play Buttons Description

3 PandarView Features

■ View Direction Selection

Click on the following buttons to view the point cloud data from different directions.

Right POV   Front POV   Top POV

Figure III.7 View Direction Selection
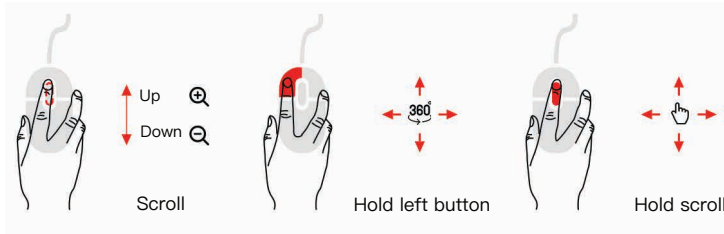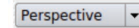
■ Mouse Shortcuts

Figure III.8 Mouse Shortcuts

01. Slide scroll wheel to magnify/minimize
02. Drag while holding left button to adjust view angle
03. Drag while holding scroll wheel to pan

■ 3D Projection Mode Switching

PandarView enables switching between two types of 3D projection methods (Orthogonal Projection and Perspective Projection) through the drop-down menu.

In Orthogonal Projection view, click on [ruler icon] , thereafter while holding "Control" on the keyboard, select a point and hold down the left mouse button in order to create a spatial distance reference, in units of meters. Click on [ruler icon] again to cancel the distance reference.

■ Distance Reference Circle
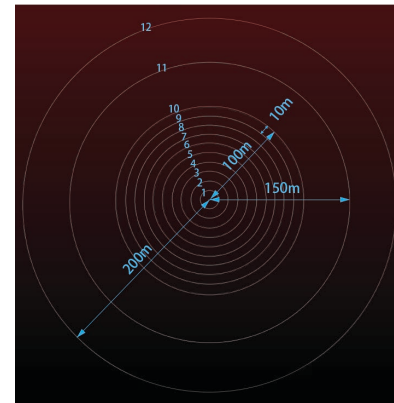
Click on ◎ to show/hide 12 gray distance reference circles. The corresponding actual distances are as shown above. The lower left axis shows the current viewing position. Click "Tools" to open "Grid Properties", where you can change the color and width of the circles.

Figure III.9 Distance Reference Circle

Point Cloud Data Selection

Users can click on ☑ to display or hide point cloud data from any selected laser channels. Clicking on this icon will pop up the following interface. Click on ☑ again to close the interface.

	Channel	Elevation	Azimuth
☐	1	15	-1.042
☐	2	11	-1.042
☐	3	8	-1.042
☐	4	5	-1.042
☐	5	3	-1.042
☐	6	2	-1.042
☐	7	1.67	3.125
☐	8	1.33	-5.208
☐	9	1	-1.042
☐	10	0.67	3.125
☐	11	0.33	-5.208

☐ Enable/Disable all

Figure III.10 Channel Display

Click on the left–side checkboxes to show/hide any given channel's display. Check the "Enable/Disable all" option in the bottom left corner to show/hide all channels at once.

Click on ⬚ to select visible points. Users can hold down the left button to box a certain area for selection. The selected points will be highlighted. Click on ▦ to view detailed data of the selected point cloud. Click on ⬚ again, select an area outside of the point cloud data to deselect.

Showing Data ▾ Attribute: Point Data ▾ Precision: 3 ▣ F

	Point ID	Points	azimuth	distance_m	elevation	intens
0	70526	0.084...	176.760	41.736	1.670	18
1	70566	0.084...	176.760	41.736	1.670	18
2	72202	0.080...	180.930	41.584	8.000	3
3	72205	0.081...	180.930	41.328	2.000	3
4	72242	0.080...	180.930	41.584	8.000	3
5	72245	0.081...	180.930	41.328	2.000	3
6	72282	-0.070...	181.140	41.292	8.000	12
7	72283	-0.069...	181.140	40.268	5.000	37
8	72284	-0.069...	181.140	40.428	3.000	2
9	72322	-0.070...	181.140	41.292	8.000	12

Figure III.11 Detailed Data of Selected Point Cloud

The main data shown about the points are their id, x, y and z values, angle, distance, reflectivity, corresponding channel id and timestamp (μs) information.

■ **Click 🚀 to compensate the azimuth error caused by the delay of laser activation.**

■ **Color Schemes**
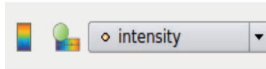
By clicking on 📊 , users can see the current color scheme in the lower right corner. The drop–down list is used to choose different color schemes. The default color scheme of point cloud is drawing according to the intensity. Users can choose azimuth, distance, laser_id, or timestamp as the color scheme as well.
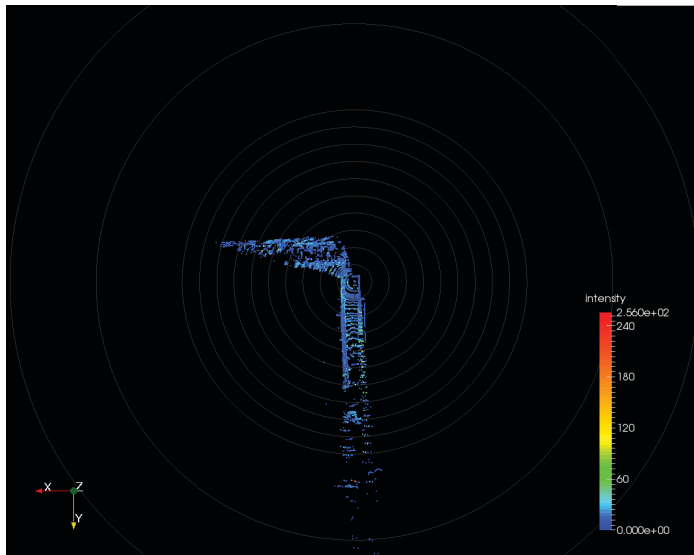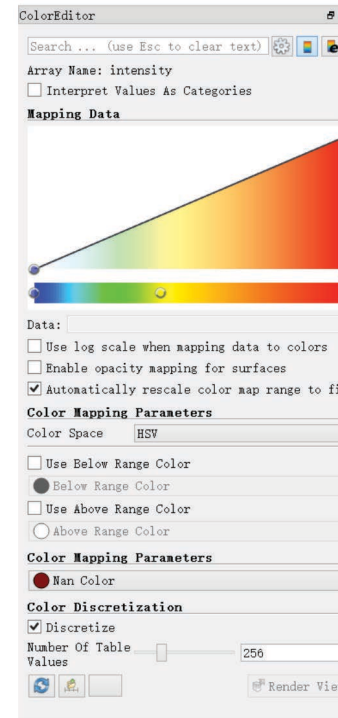

Figure III.12 Current Color Scheme

Click on 📊 to open "Color Editor", where users can customize colors. Click the button again to close the color editor.

Figure III.13 Color Editor

■ PandarView Software Version

Click "About" in the upper left corner to check the software version.

Figure III.14 PandarView Softeware Version

Appendix IV

FCC Statement

FCC ID: 2ASO2PANDAR

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) this device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

NOTE Any changes or modifications not expressly approved by the grantee of this device could void the user's authority to operate the equipment.

Appendix V

Support and Contact

■ Technical Support

If you have any problems, and cannot find the solution in this manual please contact us:

E–mail: service@hesaitech.com

Website: www.hesaitech.com

GitHub: https://github.com/HesaiTechnology

NOTE If you have any questions about the open source we provide on GitHub, please leave your questions under corresponding projects.

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2) The defect is caused by abuse or misuse of the product or by environmental conditions that are not in conformance with the recommended operating condition of the product.
3) Repairs or product modifications, alterations and disassemble have been carried out by unauthorized personals.
4) The unit was stolen, lost or discarded.
5) The damage to the unit is caused by the event of force majeure, including but not limited: abnormal voltage, water or fire, natural disaster or transport accident.

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