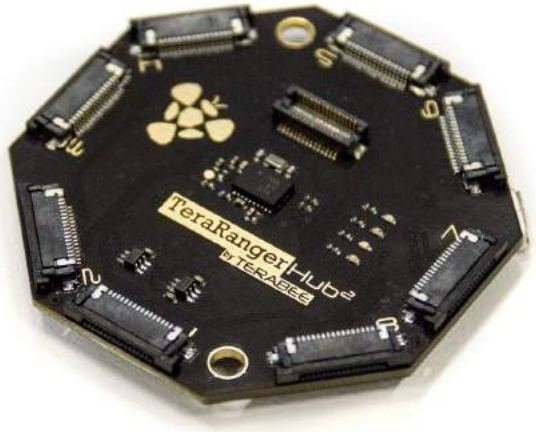
TeraRanger Hub Evo

by TERABEE

User Manual for

TeraRanger Hub Evo



Hardware revision 1.0

Firmware revision 1.0.0

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1 Introduction

The purpose of this document is to give guidelines for use and integration of the TeraRanger Hub Evo board using a USB communication interface. Instructions on how to use hub's onboard Internal Measurement Unit (IMU) are available in section 4.5

2 Mechanical Integration

2.1 Mechanical Design

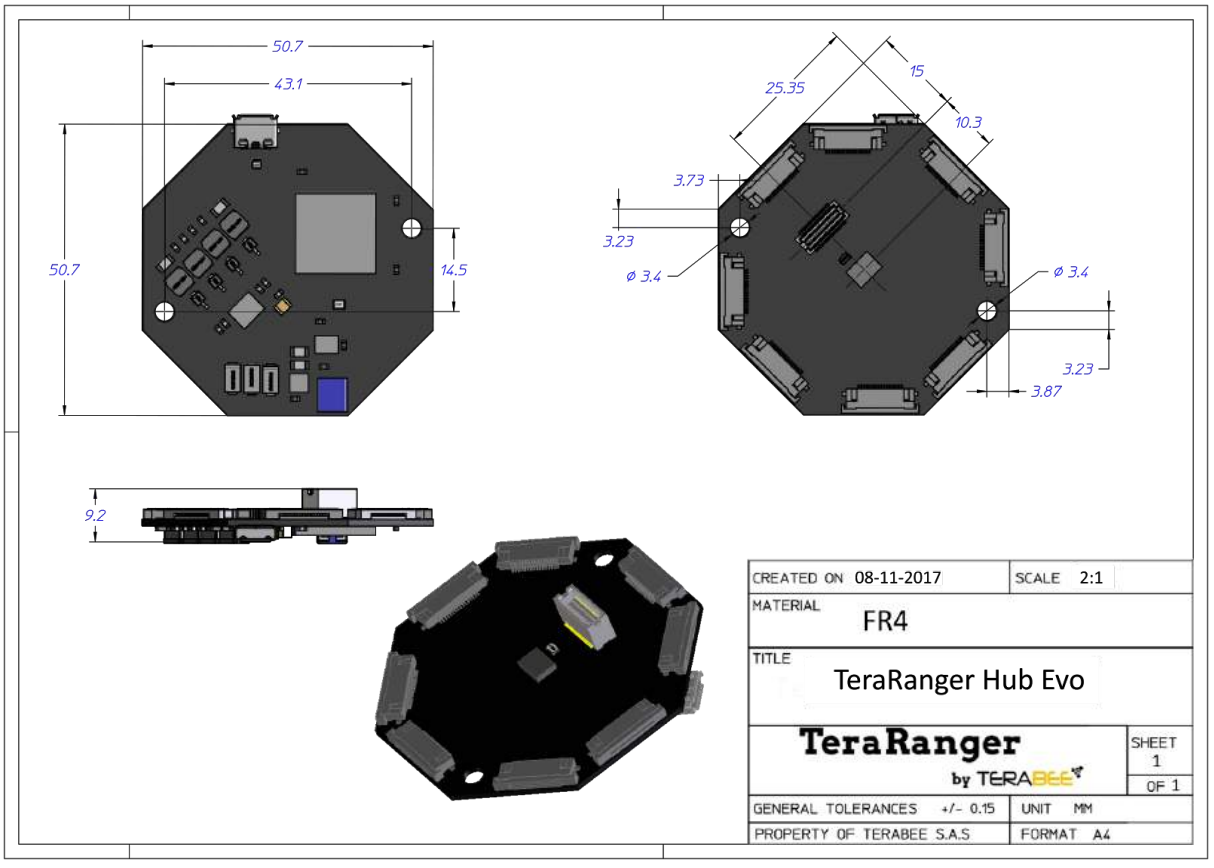

Figure 1. TeraRanger Hub Evo external dimensions

TeraRanger Hub Evo external dimensions are illustrated in Figure 1. The board provides two mounting holes, both designed for M3 screws. The straight distance between mounting holes is 45.5mm.

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2.1 Compatibility with TeraRanger Evo

Up to 8 TeraRanger Evo distance sensors can be connected to the Hub Evo board for multi-axis, multi-sensor ranging operations. TeraRanger Evo sensors use a two-part construction where the black colored optical sensor module simply clips to the yellow colored backboard for power management and communication.

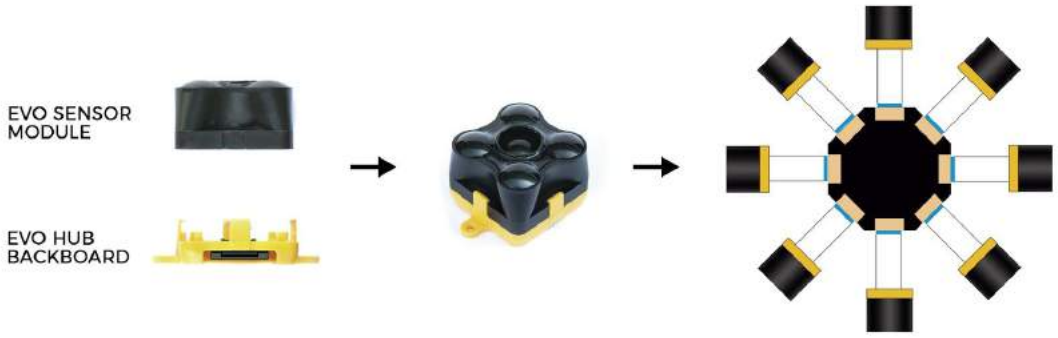

Figure 2. TeraRanger Evo Hub backboard

Please note that the **TeraRanger Evo Hub backboard** is required for connecting Evo sensors to the Hub Evo board (see Figure 2). External dimensions of the TeraRanger Evo Hub backboard are illustrated in Figure 3:

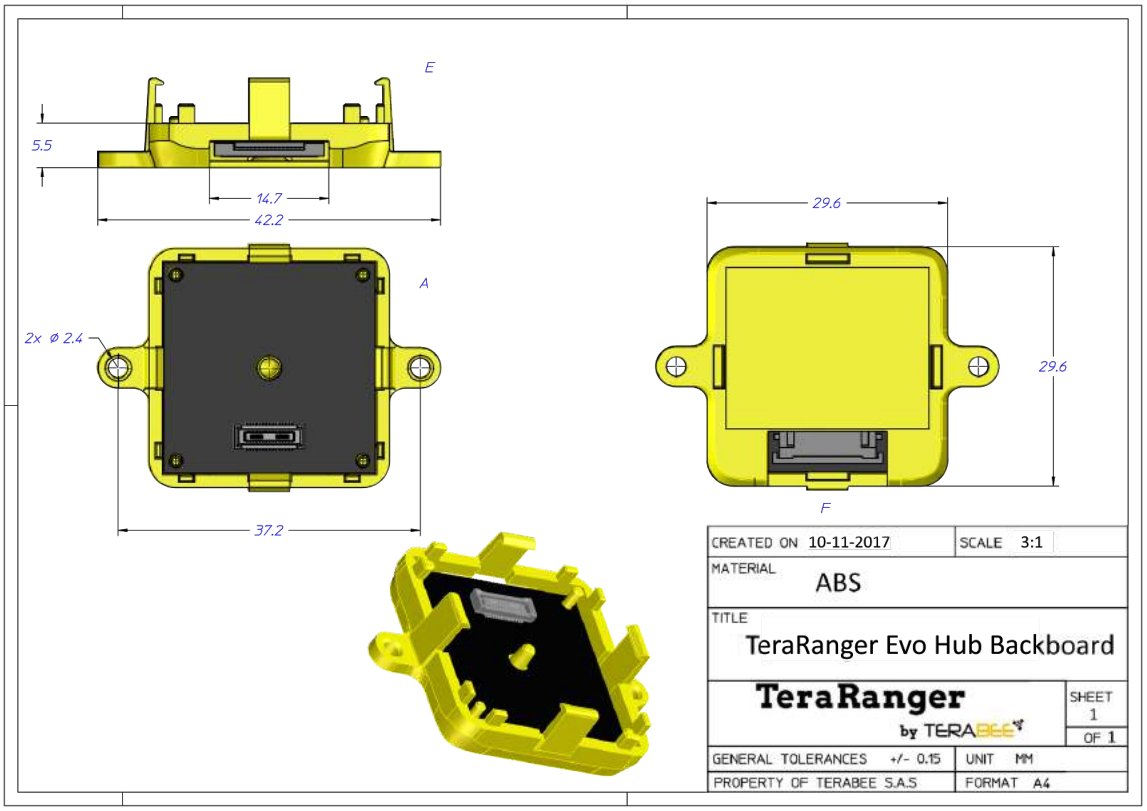

Figure 3. TeraRanger Evo Hub backboard external dimensions

2.2 Handling during system assembly

Please follow these simple steps showing how to connect 8 TeraRanger Evo sensors to the TeraRanger Hub Evo.

Step 1. Connecting the cable to the sensor

Start by plugging the flat flex cables (FFC) to the sensor's FFC connector.

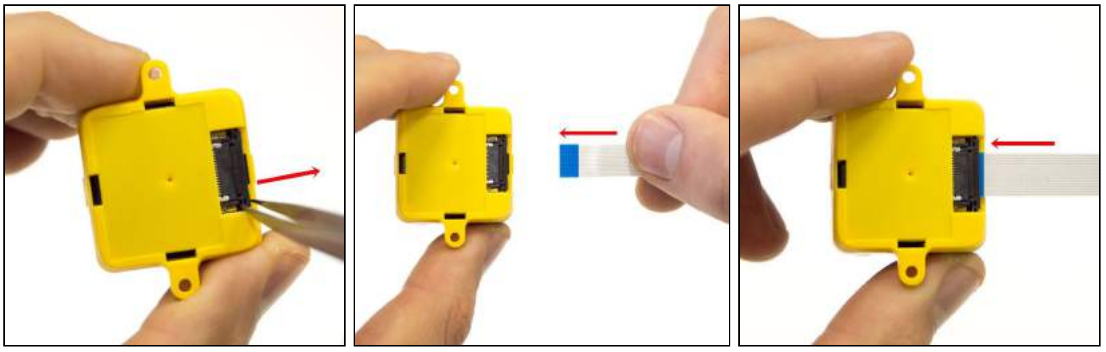

Figure 4. Open, Insert, Close (sensor)

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Note that each of the FFC connectors need to be manually opened and then closed when connecting the Flex Cables as shown in Figure 4. For easier opening you can gently pull the small locking ‘tabs’ on the sides of the connector before pulling the locking mechanism down. You may find this easier with tweezers. The locking mechanism has to be pulled out only a **millimeter or less**, not entirely! Note that, too much force can damage the sensors’ connector. Also, double check that the Flex Cable is plugged in straight so as to avoid a potential short-circuit (Figure 5).

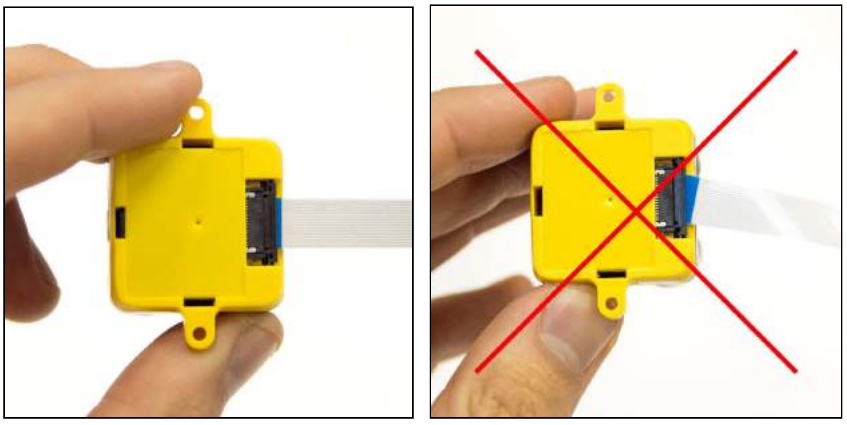

Figure 5. Left image - correct Right image - incorrect

When connecting the Flex Cable, make sure that the side with conductive tracks is facing the sensor’s backboard (yellow part) as shown in Figure 6. Connecting the wrong side of the cable can damage electronics on the hub and the sensor. Once the cable is positioned inside the connector, close the connector by smoothly pushing the locking mechanism in.

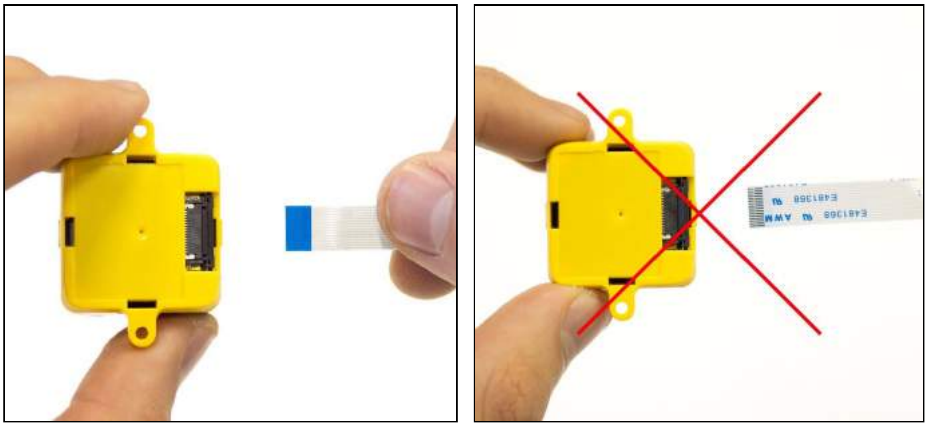

Figure 6. Left image - correct Right image - incorrect

Step 2. Connecting the sensor to the Hub Evo

Follow the instructions above to connect the cables’ other end to the FFC connector on TeraRanger Hub Evo board.

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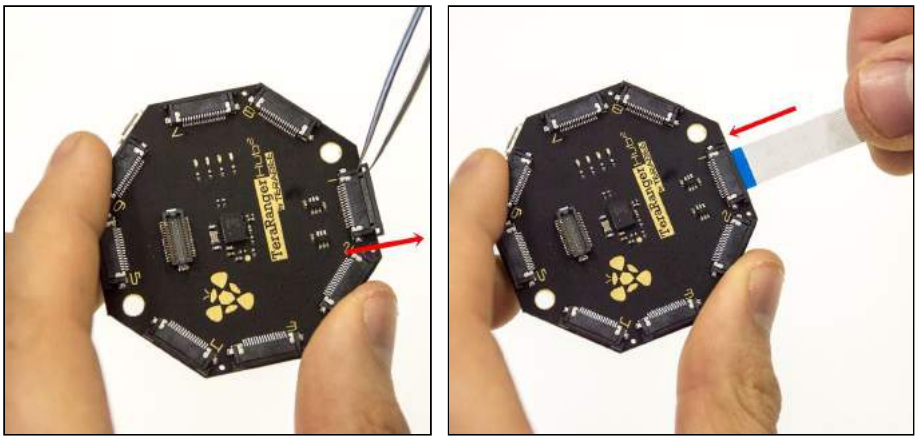


Figure 7. Open, Insert, Close (hub)

Step 3. Connecting all Evo sensors to the Hub Evo

Continue connecting the rest of the Evo sensors to the central Hub board.

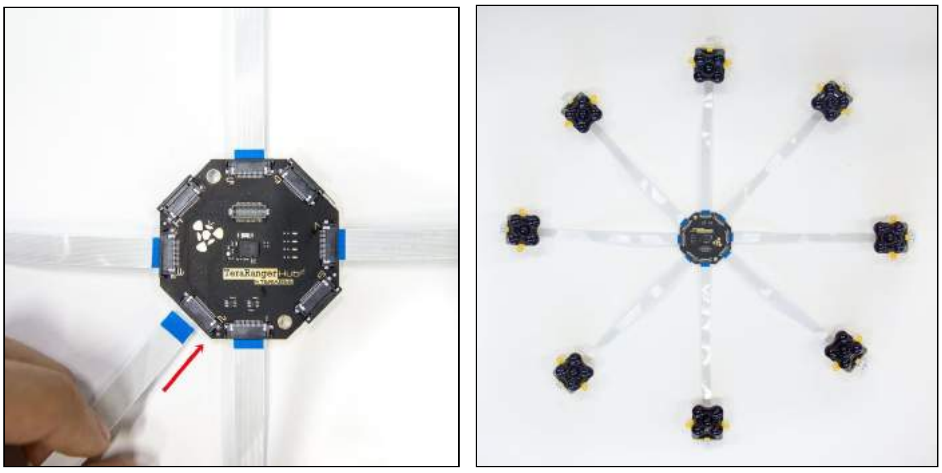


Figure 8. TeraRanger Hub Evo with 8 sensors connected

Once fully assembled, the TeraRanger Hub Evo is ready for testing on your computer. Use the micro USB cable (provided in the package) to connect the TeraRanger Hub Evo with a host computer. Instructions on how to connect the system to a host computer and use a Graphical User Interface are available in section 3.1 and 3.2.

The following aspects should also be taken into consideration when handling the TeraRanger Hub Evo:

- TeraRanger Evo sensors should not be connected or disconnected from the TeraRanger Hub Evo while it is powered
- Do not mount the TeraRanger Hub Evo onto hot surfaces or near other sources of heat

- Take all usual precautions for sensitive electronics such as maintaining a suitable distance from strong electric and magnetic fields, strong radio emitters, etc.
- During assembly and integration, please observe all common ESD precautions

2.3 Electrical characteristics

DC electrical characteristics

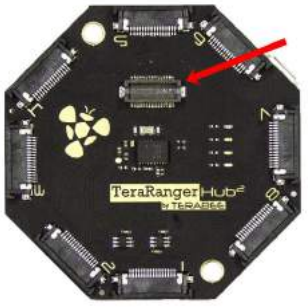
TeraRanger Hub Evo is powered by an external power source, and can not be directly powered by USB. The following table describes the amount of current and voltage needed to make the TeraRanger Hub Evo work properly.

Parameter	Minimum	Typical	Maximum
Power supply			
Voltage input (V)	12	-	24
Current consumption (mA @ 12V)	8	-	1100*

*Maximum current consumption with eight TeraRanger Evo connected and looking at long-range targets or infinity in simultaneous mode. Drops significantly in sequential mode and varies with target reflectivity and distance.

2.4 Additional interface for custom requirements

An extension connector is available on the TeraRanger Hub Evo, located in the center of the board. This connector allows you to increase the number of communication interfaces, power supplies and GPIOs, and provides the possibility to modify functionality and performance of Hub Evo. Please contact Terabee at teraranger@terabee.com for more information on additional daughter board development.



3 USB interface

3.1 Connecting the TeraRanger Hub Evo to a Host Computer

The TeraRanger Hub Evo can be easily connected to a Host Computer via the micro USB cable provided in the package. The TeraRanger Hub Evo can interact as a virtual COM port, and data can be streamed directly to terminal emulation software (Terabee advises to use HTerm for Windows and CoolTerm for MacOS).

3.1.1 Prerequisites

For usage on Windows (7, 8, 10) operating system, please download the driver from http://www.st.com/en/development-tools/stsw-stm32102.html and **follow the "ReadMe file" instructions given by the installer**. After successful installation, unplug the interface for a few seconds, and plug it back in. The virtual COM port should now be available on your PC.

3.1.2 Terminal Emulation Software

In Windows you can also use any terminal emulation software of your choosing, however we suggest you use HTerm (http://www.der-hammer.info/terminal/). Extract the downloaded zip file to the folder of your choice, open it and double click on the "HTerm.exe" document.

Connect the TeraRanger Hub Evo to your computer and select the corresponding USB port (click "R" button to refresh the port list). Select values for the following fields:

- Baud rate: 115200;
- Data Bits: 8;
- Parity: None;
- Stop Bits: 1.

For easier readings, select the "LF" option for "Newline at" tab. See Figure below for visual instructions.

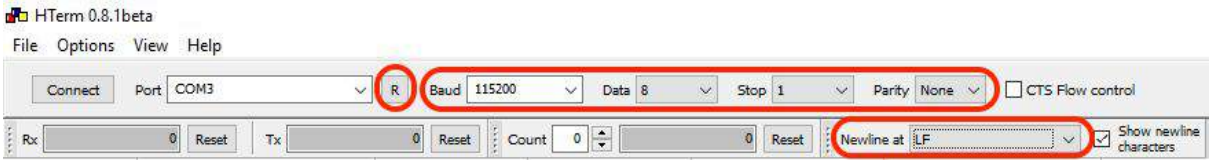


Figure 9. H-Term parameters

Once you have selected the USB port and required values, click on the "Connect" button.

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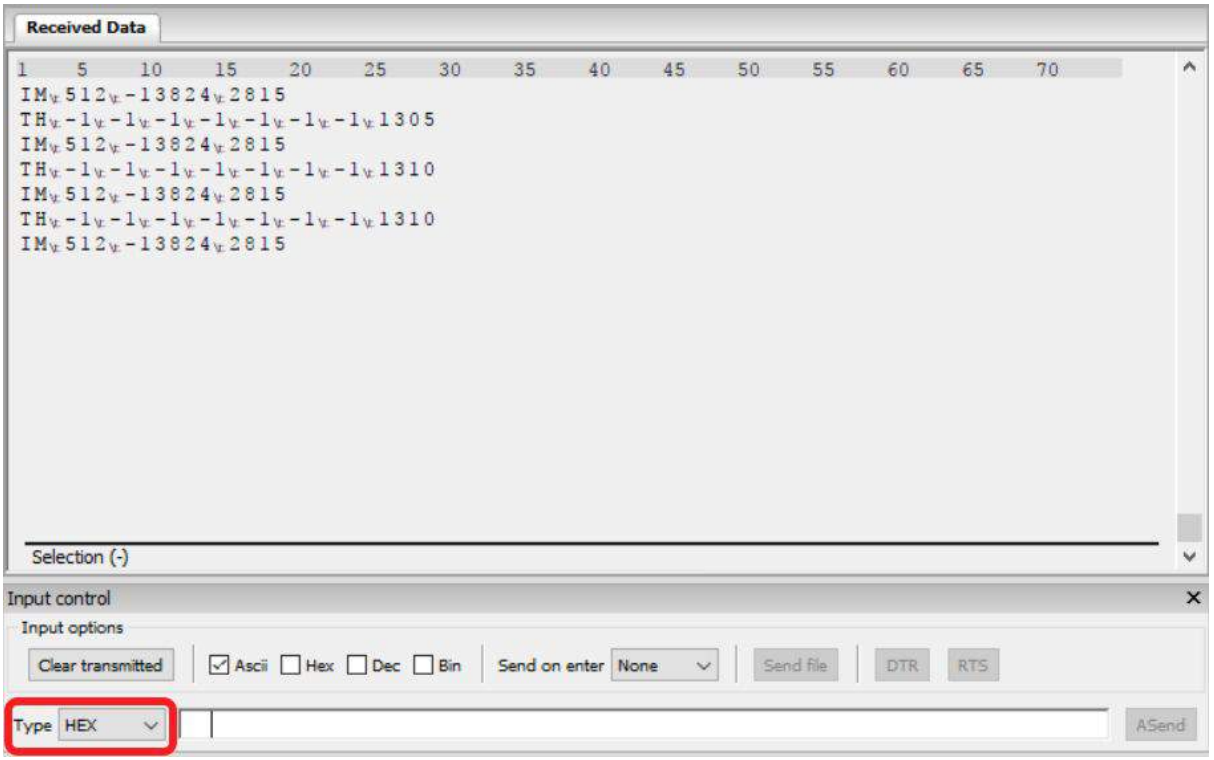

Figure 10. Communication with H-Term

To communicate with the Hub Evo via the terminal emulation software, you need to send a command in hexadecimal via the “Type” box. For this, select the “HEX” Type as illustrated in the figure above. Figure 10 shows an example of the command which allows data to be shown in TEXT mode. All commands are detailed in section 4.

In MacOS, Terabee advises the use of Coolterm for terminal emulation software.

3.2 Graphical User Interface

A free graphical user interface is available for Windows, providing an easy way to visualize the data from all the TeraRanger Evo sensors connected to the TeraRanger Hub Evo. This is useful for demonstration, testing purposes and checking some of the basic parameters of the sensors. It also provides a way to easily upgrade the firmware running on the device, should it be required.

3.2.2 Basic Operation

Make sure TeraRanger Hub Evo is connected to a USB port on your computer and to a suitable power supply. Select File > Connect. You should immediately see distance readings of TeraRanger Evo sensors displayed on the main chart.

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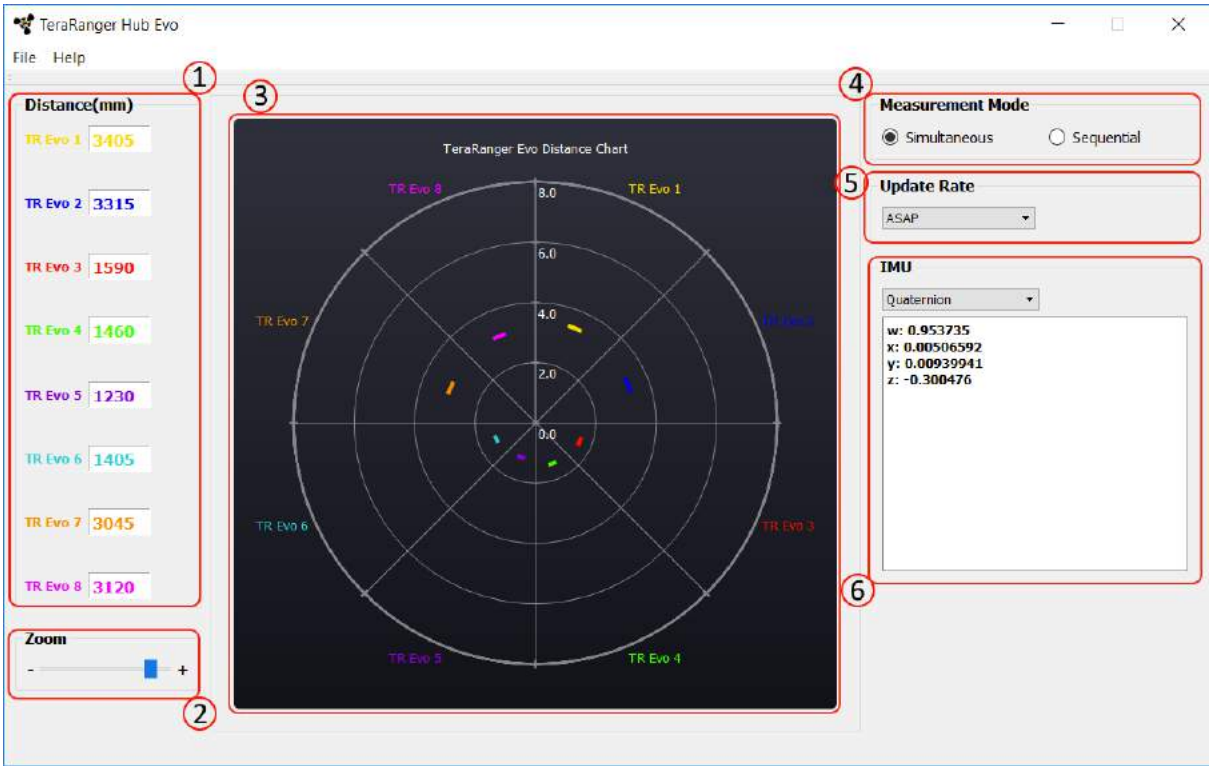

Figure 11. Graphical User Interface

#	Display	Description
1	Measurement	Provides up to 8 distance values in millimeters. Sensors are numbered as on the Hub Evo board. Example: TR Evo 3 will stream distance data connected to connector Nr 3 on Hub Evo. In case “-1” value is received, no sensor is connected or not able to measure. In case “+Inf” is received, the measurement is out of range. In case “-Inf” is received, the measurement is below minimum range.
2	Zoom	Modify scale of the main chart (#2) by just dragging the cursor to the left or right. The zoom range is [2.00m ; 60.0m]
3	Main chart	Provides real-time preview of distance measurements streamed from connected Evo sensors. The distance reading is visually represented on the chart by a small segment.
4	Mode	Switch between Sequential and Simultaneous mode.

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5	Update Rate	Select four options of sensor measurement update rate from a drop-down menu. Choose between 50Hz, 100Hz, 250Hz, or ASAP (As Soon As Possible).
6	IMU	Enable or disable the option for Inertial Measurement Unit readings. Three IMU modes are available for preview: Euler mode, Quaternion mode, Quaternion and Linear Acceleration mode.

3.2.3 Firmware Upgrade

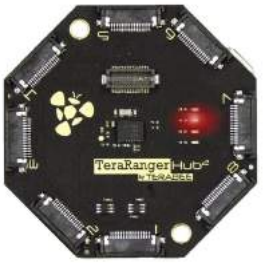
The current firmware version on your TeraRanger Hub Evo can be found by selecting *Help* > *About* in the GUI. It is possible to upgrade the firmware running on your device if a new firmware version is made available by Terabee.

Please note the Upgrade Firmware feature is only supported on Windows 7, 8 and 10. Please follow carefully the steps outlined below to avoid permanently disabling your device.

- Select *File* > *Upgrade Firmware*
- You will be presented with a dialog window asking you to confirm your choice **Beyond this point, if you press 'Yes' it will not be possible to revert to the firmware currently running on your TeraRanger Hub Evo!** Press 'No' to cancel and keep the current firmware or 'Yes' to continue
- Read the instructions in the dialog window that opens
- Press 'Select FW' and select the new firmware file with Windows File Explorer
- Press 'Upgrade' and wait until the operation finishes
- Close the Upgrade dialog window

3.4 LEDs

In total, four LEDs are mounted on TeraRanger Hub Evo to give visual feedback on the sensor performance. Table 2 lists the functionality of each LED:

LED color	**Description**	**Hub Visual**
PWR (orange)	LED continuously on whenever connected to a power supply	
LED 0 (blue)	One blink for each TeraRanger Evo Hub sensor detected by the Hub Evo. Example: if 6 sensors are connected, the blue LED will blink 6 times before sending distance data.	
LED 1 (green)	Continuous blinking indicates that distance values are being sent	
LED 2 (red)	Continuous blinking indicates an error	

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4 Communication and Modes

The current Hub Evo firmware (1.0.0) provides four parameters for optimization of Hub Evo performance. The following parameters can be configured:

1. Printout modes
2. Operating modes
3. Update rate modes
4. IMU modes

Figure 12 illustrates the logic of available parameters on Hub Evo. Please note all commands to be sent via terminal emulation software are in hexadecimal format.

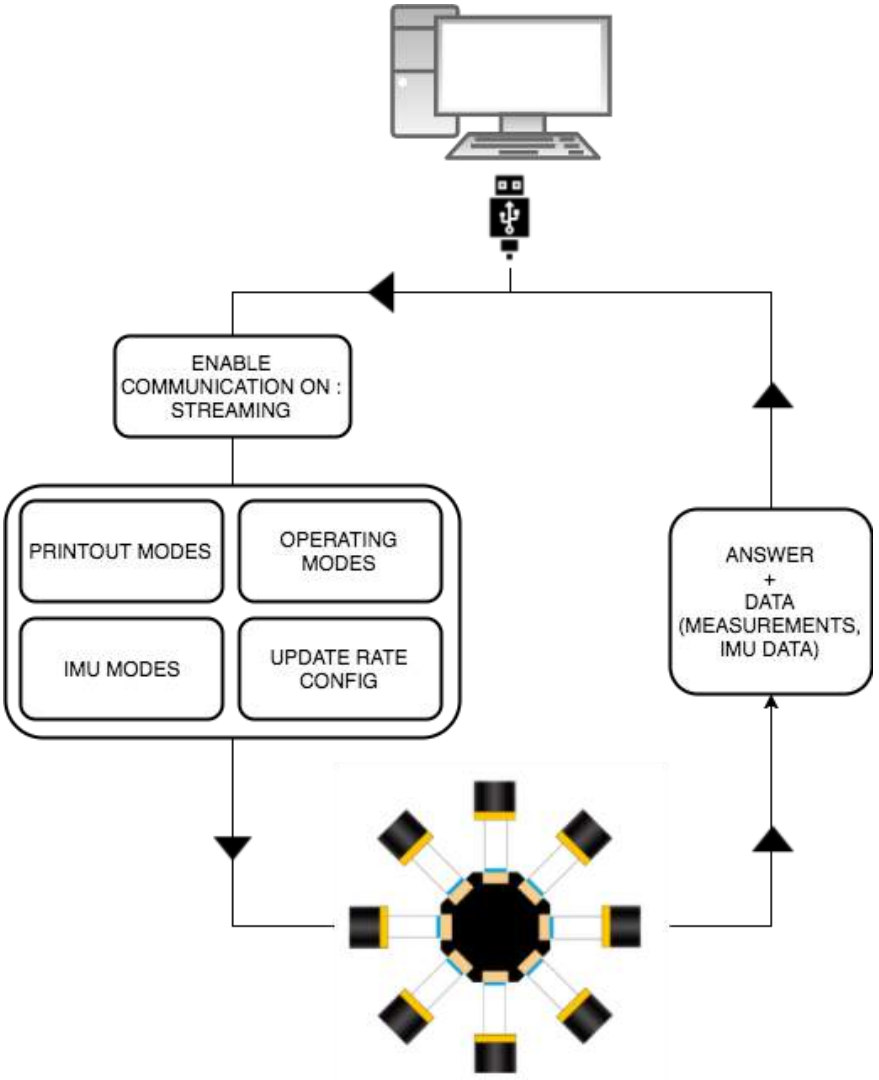

Figure 12. TeraRanger Hub Evo modes

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For each command sent to Hub Evo, a response is generated to inform the user whether the command has been validated. Command responses consist of four bytes and is a hexadecimal value. Please note that it is crucial to receive an answer to a command, before communicating the next one. For more information on response values, please read Annex 1.

4.1 Enable / Disable Hub communication

In order to enable communication with Hub Evo and send commands to modify system performance, please make sure streaming is enabled.

4.1.1 Commands

Action Type	**Mode name**	**Hex Command**
Enable/disable communication	Activate streaming	**00 52 02 01 DF**
	Deactivate streaming	**00 52 02 00 D8**

4.2 Printout modes

The current Hub Evo firmware supports two display modes via terminal emulation software: (1) Text and (2) Binary.

4.2.1 Commands

Action Type	**Mode name**	**Hex Command**
Modify printout mode	TEXT	**00 11 01 45**
	BINARY (default)	**00 11 02 4C**

4.2.2 Output format

Text mode	Data output: TH\txxxx\txxxx\txxxx\txxxx\txxxx\txxxx\txxxx\txxxx\r\n - Header (two characters): T (84 decimal / 0x54 hex) and H (72 decimal / 0x48 hex) - Tabulation: \t (9 decimal / 0x09 hex) - Distance reading in millimeters** (maximum 5 bytes per sensor): xxxx - Carriage return character: \r (13 decimal / 0x0D hex) - New line character: \n (10 decimal / 0x0A hex) **if a sensor is not connected or the TeraRanger Hub Evo is unable to obtain the distance measurement from the TeraRanger Evo Hub sensor, the associated distance value is replaced by the hexadecimal value "-1". If the target is too close from the TeraRanger Evo Hub sensor (below the minimum distance), the associated distance value is replaced by "-Inf". If the target is too far from the TeraRanger Evo Hub sensor (above the maximum distance), the associated distance value is replaced by "+Inf".
Binary mode	Data output (20 bytes message): TH XXXXXXXXXXXXXXXX M CRC8 - Header (two characters): T (84 decimal / 0x54 hex) and H (72 decimal / 0x48 hex) - Distance reading in millimeters** (2 bytes per sensor): XX - Mask (1 byte) Each bit of this byte correspond to one sensor connected to the hub.It gives an indication if the distance corresponding to the sensor is new (bit at 1) or old (bit at 0):M - Checksum (1 byte) of previous 19 bytes: CRC8 **if a sensor is not connected or the TeraRanger Hub Evo is unable to obtain the distance measurement from the TeraRanger Evo sensor, the associated distance value is replaced by the hexadecimal value 0x0001.

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	If the target is too close from the TeraRanger Evo Hub sensor (below the minimum distance), the associated distance value is replaced by the hexadecimal value 0x0000. If the target is too far from the TeraRanger Evo Hub sensor (above the maximum distance), the associated distance value is replaced by the hexadecimal value 0xFFFF.

4.3 Operating modes

The current Hub Evo firmware provides two operating modes: **(1) Simultaneous mode and (2) Sequential mode**. Simultaneous mode supports simultaneous sensor operation. When using this mode it is important to configure your sensors in such a way that their fields of view do not overlap and create the potential for sensor cross-talk. Sequential mode ensures that sensors connected to Hub Evo are synchronized to avoid any signal interference between operating sensors. Operating sensors in sequential mode gives more freedom for the physical placement of the sensors but can result in a decrease in overall measurement repetition rates.

4.3.1 Commands

Action Type	**Mode name**	**Hex Command**
Modify operating modes	Simultaneous mode	**00 31 01 EB**
	Sequential mode (default)	**00 31 02 E2**

4.4 Update rate modes

The current Hub Evo firmware provides the option to modify the measurement sampling rates of the sensors connected to Hub Evo. Users can select between four update rate modes: 50Hz, 100Hz, 250Hz and ASAP mode. The latter provides the best update rate possible, depending on the number of sensors connected.

4.4.1 Commands

Action Type	Update rate	Hex Command
Modify update rate	ASAP (default)	**00 52 03 01 CA**
	50 Hz	**00 52 03 02 C3**
	100 Hz	**00 52 03 03 C4**
	250 Hz	**00 52 03 04 D1**

4.5 Internal Measurement Unit (IMU) options

TeraRanger Hub Evo provides an onboard IMU, supporting users with spatial orientation data. By default the IMU is disabled. Three modes are available:

1. Euler mode,
2. Quaternion mode,
3. Quaternion and Linear Acceleration mode.

Magnetic fields and vibration can disrupt IMU calibration. In order to force a self-calibration of the IMU, move the TeraRanger Hub Evo in ways that use the full range of each axis.

Here is a non-exhaustive list of motions that help with calibration:

1. For magnetometer and gyroscope: (1) draw a figure of eight into the air, (2) make a full turn in the two directions of each axis (6 rotations in total).
2. For accelerometer: Hold the Hub Evo for a few seconds in each of the following positions; left side, right side, front side, back side, up side, down side.

For further explanation about the IMU orientation calibration, please refer to the following link: https://www.youtube.com/watch?v=Bw0WuAyGsnY

Euler mode

Euler mode provides three classic Euler angles: heading (aka yaw), roll and pitch. Please see the figure below for heading directions and roll and pitch on your Evo Hub.

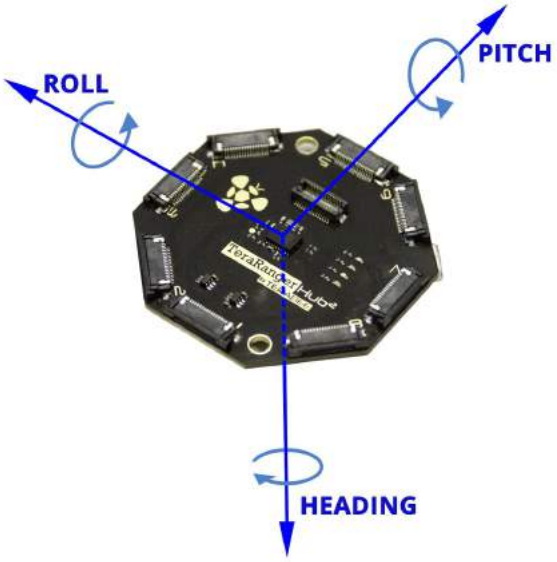

Figure 13. Roll, pitch, heading

When enabling Euler mode, the displayed values are in degrees. Please see below the corresponding scaling for each of the axes:

1. Heading angle goes from 0° to 360°, 0° meaning North
2. Pitch goes from -180° to +180°
3. Roll values are in the interval]-90°;+90°[and will loop twice.

Please note that 0° for pitch and roll angle means that the TeraRanger Evo Hub is horizontal.

Quaternion mode

To deal with matrix rotation in space, the quaternion approach simplifies the heavy math related to trigonometry and reduces the processing power requirements and optimizes the speed of operations. The Hub Evo can provide this kind of information through internal pre-processing and data fusion. For further explanation about the quaternion and the spatial rotation matrix, please refer to the following link:

https://en.wikipedia.org/wiki/Rotation_matrix#Quaternion

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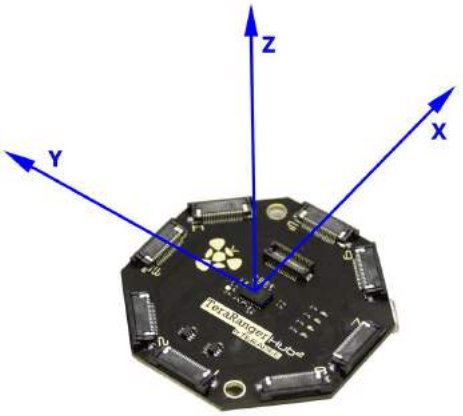

Figure 14. x, y, z axis

Please note that X axis is opposite to pitch axis, Y axis is opposite to roll axis and Z axis is opposite to Z axis (Figure 14).

Quaternions and linear acceleration

Quaternions and linear acceleration mode displays the same coefficient as the quaternion mode, however it also gives the linear acceleration of the IMU in milli-g. Please refer to figure 14.

- x acceleration refers to the x axis
- y acceleration refers to the y axis
- z acceleration refers to the z axis

Note: To convert those values to m.s-2 the conversion factor is **0.00980665**

It is important to know that there might be a constant offset (this can be visualized when the TeraRanger Hub Evo is not moving) on the acceleration values, that can be corrected by calibrating the IMU (see section 4.5).

4.5.1 Commands

Action Type	Mode name	Hex Command
Modify IMU mode	Activate Quaternion mode	**00 41 02 40**
	Activate Euler mode	**00 41 03 47**
	Activate Quaternion & Linear acceleration mode	**00 41 04 52**
	Deactivate IMU	**00 41 01 49**

4.5.2 Output format

Printout mode	IMU mode	Description
Binary	**Quaternion**	Data output (12 bytes message): IM 0x01 WW XX YY ZZ CRC8 - Header (two characters): I (73 decimal / 0x49 hex) and M (77 decimal / 0x4D hex) - Mode (1 byte) This byte indicate in which IMU mode you are. For quaternion this byte is equal to 0x01 - Orientation data in quaternion format (2 bytes per coordinate), each two bytes represent a signed 16 bit value. You need to divide those four values by 2^14. - Checksum (1 byte) of previous 11 bytes: CRC8
	Euler	Data output (10 bytes message): IM 0x02 HH RR PP CRC8 - Header (two characters): I (73 decimal / 0x49 hex) and M (77 decimal / 0x4D hex) - Mode (1 byte) This byte indicate in which IMU mode you are. For euler this byte is equal to 0x02

		- Euler angles (2 bytes per angle), each two bytes represent a signed 16 bit value. You need to divide those three values by 16 to convert them in degree. - Checksum (1 byte) of previous 9 bytes: CRC8
	Quaternion and Linear acceleration	Data output (18 bytes message): IM 0x03 WW XX YY ZZ XX YY ZZ CRC8 - Header (two characters): I (73 decimal / 0x49 hex) and M (77 decimal / 0x4D hex) - Mode (1 byte) This byte indicates in which IMU mode you are. For quaternion and linear acceleration this byte is equal to 0x03 - Orientation data in quaternion format (2 bytes per coordinate), each two bytes represent a signed 16 bit value. You need to divide those four values by 2^14. - Linear acceleration (2 bytes per axis), each two bytes represent a signed 16 bit value. Those value are expressed in mg. - Checksum (1 byte) of previous 17 bytes: CRC8

Printout mode	**IMU mode**	**Description**
Text	**Euler**	Data output: IM\t hhh\trrr\tppp\r\n - Header (two characters): I (73 decimal / 0x49 hex) and M (77 decimal / 0x4D hex) - Tabulation: \t (9 decimal / 0x09 hex) - Euler angles. You need to divide those three values by 16 to convert them in degree. - Carriage return character: \r (13 decimal / 0x0D hex) - New line character: \n (10 decimal / 0x0A hex)

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	Quaternion	Data output: IM\t www\txxx\tyyy\tzzz\r\n - Header (two characters): I (73 decimal / 0x49 hex) and M (77 decimal / 0x4D hex) - Tabulation: \t (9 decimal / 0x09 hex) - Orientation data in quaternion format.You need to divide those four values by 2^14. - Carriage return character: \r (13 decimal / 0x0D hex) - New line character: \n (10 decimal / 0x0A hex)
	Quaternion and Linear acceleration	Data output: IM\t www\txxx\tyyy\tzzz\txxx\tyyy\tzzz\r\n - Header (two characters): I (73 decimal / 0x49 hex) and M (77 decimal / 0x4D hex) - Tabulation: \t (9 decimal / 0x09 hex) - Orientation data in quaternion format.You need to divide those four values by 2^14. - Linear acceleration. Those value are expressed in mg. - Carriage return character: \r (13 decimal / 0x0D hex) - New line character: \n (10 decimal / 0x0A hex)

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Annex 1

For each command sent to Hub Evo, a response is generated to inform the user whether the command has been validated. It is important to receive a response value before proceeding with the next command. Sending commands too early may discard the one still processing. Response commands consist of four bytes and are a hexadecimal value. They contain (in order):

- a header (0x30)
- the CMD code which corresponds to the first four most significant bits of the second byte of the send command (for example for the command 0x00110145 it will be 0x01)
- an ACK (0x00) or a NACK (0xFF)
- a CRC-8 checksum of the message contents

Example:

Hex Command: **00 11 01 45**
Hex Answer: **30 01 00 F4**

To calculate the CRC-8 checksum byte, we advise you to use an online CRC-8 calculator. Here is one: http://www.sunshine2k.de/coding/javascript/crc/crc_js.html

The following table sums-up the expected responses to all the commands described in the document.

Action Type	**Valid responses**
Enable/disable communication	**30 05 00 A0**
Modify printout mode	**30 01 00 F4**
Modify operating modes	**30 03 00 DE**
Modify update rate	**30 05 00 A0**
Modify IMU mode	**30 04 00 B5**

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