C445 Beacon & Node

User Guide

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1. Introduction

The Humatics Beacon is part of a system for determining the location of mobile devices, such as robots or other vehicles, so that the devices can determine and report their location. This information will be used by the robots to navigate through a variety of environments, as for example, in factories, warehouses and outdoor storage or loading areas. The location information computed by the mobile devices could also be shared with supervisory computers so that managers and operators can monitor the location of the mobile devices.

The system consists of two key components: equipment mounted on the robot and a fixed infrastructure of reference units. The reference units act much like lighthouses along the seashore, or like GPS satellites, providing reference information by which the robots can determine their positions.

More precisely, the mobile devices use an UltraWideband (UWB) radio and a distance measurement technique called Two Way Time of Flight range measurement to determine the distance from it to a UWB radio mounted in each of several fixed reference locations. By knowing the position of each reference and by measuring the distance between mobile's UWB radio and the UWB radio at each fixed reference, the mobile can calculate its position. Once the mobile has calculated its position it can report that value to the infrastructure units.

Humatics refers to these infrastructure reference units as "Beacons". Units installed on the mobile units are called "Nodes". This document describes both the Beacons and Nodes. Both consist of a C445 UWB radio mounted in a metal enclosure and both support the same UWB ranging protocols. They differ in that the software loaded on the Nodes is more sophisticated. Node software supports the localization function and other high-level functions as well. The units are provided with two input connectors. The primary connector supports Power Over Ethernet. If no Ethernet is available, then DC power can be provided through a secondary connector.

The units can be visually distinguished by the color of their radomes and by the part number prominently displayed on the identifying label. Beacons have a yellow radome and Nodes have gray ones.

The units are rated for operation in environments that require IP67.

2. System Block Diagrams

The block diagram in **Figure 1** shows the major elements of a Beacon/Node and illustrates two different ways of connecting the device to power.

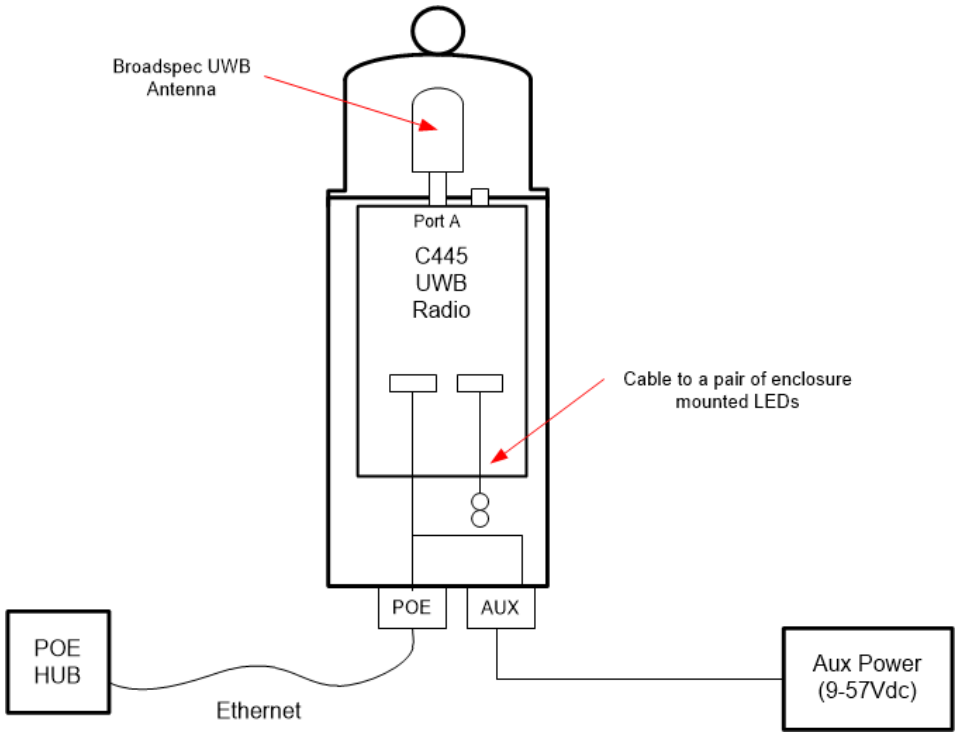


Fig. 1: Block Diagram of a Beacon

Notes:

- Normally the units will be powered through either, but not both, the POE or AUX power cables. Precautions are in place on the C445 radio to ensure that concurrently connecting the POE and Aux power will be accomplished safely.
- There are two indicating LEDs mounted on the enclosure. These LEDs are powered by the C445 Radio. One is a simple power on indicator. The second LED is a heartbeat signal which blinks at a fixed rate when the radio is operating normally. Failure to blink is an indication that the C445 has failed.

3. Mechanical

The mechanical drawings for the Beacon are shown below in **Figure 2**.

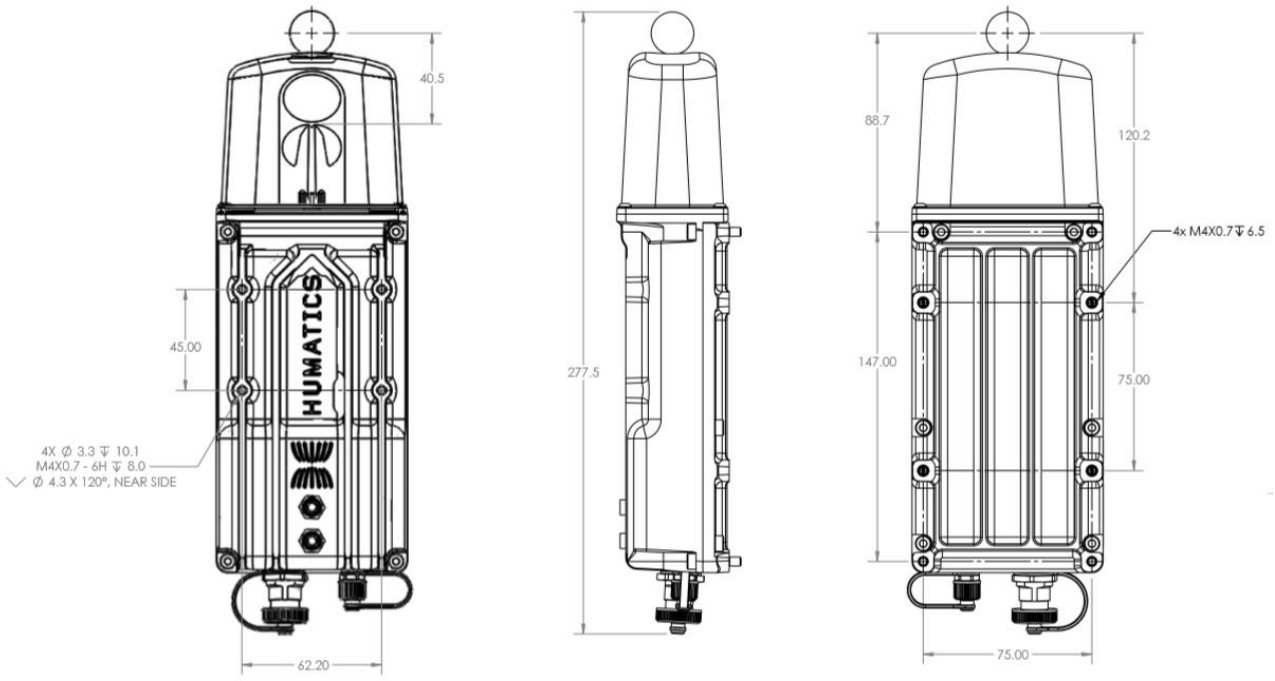


Fig. 2: Beacon Mechanical Drawings

The Beacon/Node has two connectors. As shown in **Figure 3**, the connector on the left is for Power Over Ethernet (POE) and the connector on the right is for auxiliary power for those cases where Ethernet is not available. Pin outs for the connectors are shown in **Figure 4.**

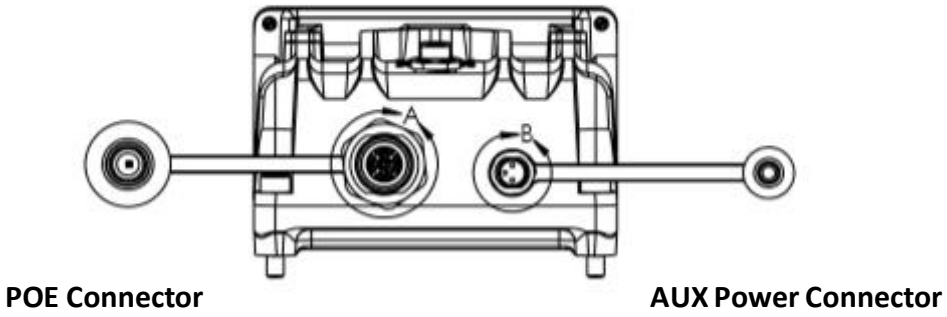
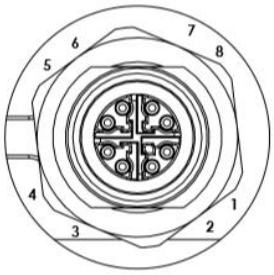


Fig. 3: Beacon/Node connectors: POE (left), Aux Power (right)



M12-8 X-CODE PIN	DESCRIPTION
1	Tx+
2	Tx-
3	Rx+
4	Rx-
5	PPS_In+
6	PPS_In-
7	PPS_Out-
8	PPS_Out+
M8-3 PIN	**DESCRIPTION**
1	-
3	Aux_Pwr_In
4	GND

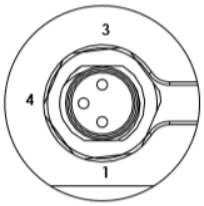


Fig. 4: Beacon/Node connectors: POE (left), Aux Power (right)

4. Technical Specifications

The technical specifications for the Beacon are provided below in **Table 1**.

Beacon Characteristics	Value
Physical Parameters	
Length:	277.5 mm (10.875 inches)
Width:	85 mm (3.3 inches)
Length:	50 mm (2.0 inches)
Weight:	0.7 kg (1.5 pounds)
Storage Temperature:	-40ºC to 85ºC
Operating Temperature range:	-40ºC to 85ºC (as reported by onboard temp sensor)
Water resistance:	Designed for IP67
Vibration:	Designed to meet most vibration specs
Environmental rating	IP67
Power	
Power Input	
Power Over Ethernet:	Complies with PoE spec. Max voltage: 57VDC
Aux Power:	Accepts input voltage from 9-57VDC
Nominal Power Consumption:	~3 Watts
Max Power Consumption:	~4 Watts when operated at 85ºC
Max Current	<1 Amp
Boot Times	
Time from power on to completion of boot:	7-11 seconds
Minimum time the power must be turned off to force the processor to reboot:	1 second
RF Characteristics	
10dB Transmit center frequency:	4.028 GHz
10 dB Transmit bandwidth:	1.35 GHz
10 dB Receive bandwidth:	1.46 GHz
Nominal System bandwidth:	3.30 to 4.76GHz
Average Transmit Power:	Max power spectral density: -41 dBm/MHz. (Equates to approximately ~50 uW or -13 dBm)
Antennas Supported:	Humatics Toroidal Dipole Antenna, ~3 dBi gain
Ranging Performance	
Ranging Techniques:	Two-Way Time-of-Flight (TW-TOF)
Max Range	Depending on the settings used and local conditions, typical maximum operating range is about 500 meters.

Table 1: Beacon Characteristics

5. Installation

5.1 Software Setup Considerations

This section describes details necessary for software setup and calibration.

- **Node ID and IP address.** Each Beacon/Node is delivered with the following default communications parameters: the Node ID is set to the C445 board serial number and the IP address is set to 192.168.100.

- **Antenna orientation matters.** The Beacon should be installed such the long axis of the unit is pointing either straight up or straight down. It should never be installing in a non-vertical fashion. See Section 5.3 for examples.

  If the Beacon is to be installed high on a wall and communicate with units on the ground, then it is best to point the wall mount Beacon radome downward. This is advisable because the Broadspec antenna beam pattern is elevated by about 20 degrees. Therefore, mounting the unit on a wall with the radome pointing upwards would point most of the RF energy away from the units on the ground. Mounting the Beacons such that they point down and the mobile units such that they are pointing up, can increase the operating range by 20-100%.

  The Radio has been calibrated assuming that both antennas are pointing in the same direction. If the antennas are pointing in opposite directions (where one is pointing up and the other pointing down) then there will be a 4 cm (~1.5 inch) error in the range measurement. This error can be compensated by setting the Beacon Ant Orientation parameter (A up or A down) such that it reflects which way the radome will be pointed.

5.2 Placement

Proper placement of the Beacon is critical to the success of the system.

First, the antenna must be positioned such that it has a clear view of everything in its operational area. To range successfully, the antenna in the Beacon must have a clear line-of-sight to the Node mounted on a mobile unit. The term clear line-of-sight needs clarification, because it does not necessarily mean optical clear line-of-sight. Optical clear line-of-sight is always preferred. However, since RF will generally diffract around thin metal (such as wire, rebar, and metal building studs) and can easily travel through sheetrock and dry wood, then a perfectly clear line-of-sight as seen by a person's eye is not necessary.

Second, RF will be blocked by metal surfaces, concrete, many types of glass as well as by people. Therefore care must be taken to insure that enough Beacons are installed such that each mobile can range successfully to at least four Beacons.

Third, to minimize unwanted reflections, take care to place the antenna at least 30 cm (12 inches) from any metal surface.

Finally, care must be taken to ensure that the C445 is operated within its temperature range of -40°C (-40°F) to +85°C (185°F). This is a very generous operating range and should allow operation of the unit almost anywhere. However, this temperature range is not the ambient temperature of the air but is instead the temperature as measured by a sensor on the C445 board located inside the Beacon. Because the unit consumes a maximum of ~4 Watts, the heat generated will raise the board temperature relative to the ambient temperature. A heat sink in the Beacon will limit this temperature rise to approximately 10°C above ambient. Therefore, the maximum allowable ambient temperature (assuming no external heating by the sun or other thermal sources) is +75°C.

5.3 Mounting and Installation

The Beacon/Node is provided with a variety of wide mounting holes and threaded screw holes thus providing a great deal of flexibility when mounting the unit. For details on the mounting holes placement, see the Section 4.

There are several items to keep in mind when mounting the unit.

- The Beacon should be installed such that it is a minimum of 30cm (12inches) from any metal.
- Because the Beacon uses a dipole antenna, the unit must be installed such that either (a) the antenna is pointing straight up to the sky and the Ethernet connector is pointing straight down to the ground, or (b) the antenna is pointing straight down to the ground and the Ethernet connector is pointing straight up to the sky. Failure to mount accordingly will result in a reduced coverage/operational area.
- When mounting the unit, it will be necessary to determine its location. There are several different techniques for locating the Beacon, but the most common method is to survey the location using a laser based Total Station. When determining location one must keep in mind that the actual range measurement is taken from the phase center of the Beacon antenna to the phase center of the Node antenna, both of which are hidden by the radome. To aide in determining location of the phase center, a laser retroreflector shaped as a ball has been mounted on the top of the radome. This ball is exactly 40.5mm from the antenna phase center. (See **Figure 5**). When using a laser system to locate the Beacon, point the laser at the ball and adjust the Z dimension by this amount.

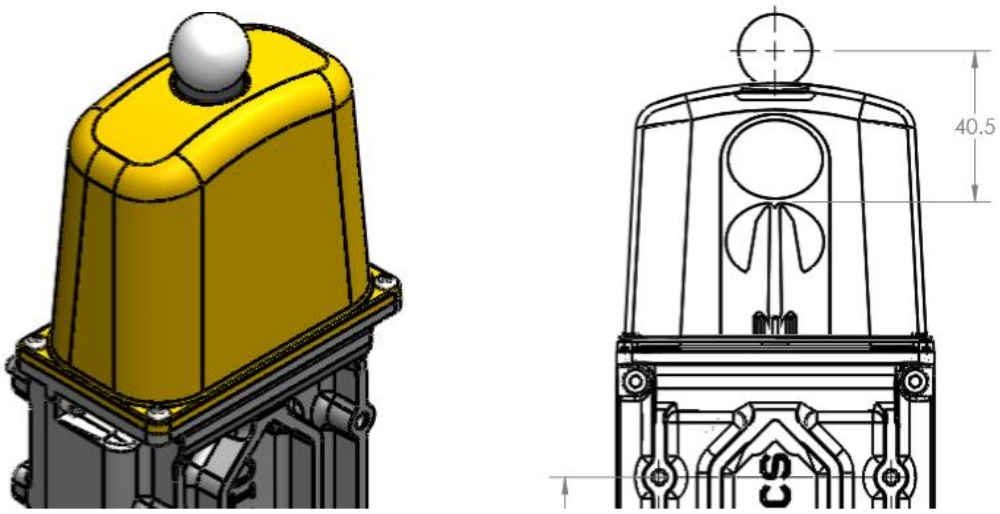


Fig. 5: Ball on radome is a Retroreflector. Its center is located 40.5mm above the antenna phase center.

The Beacon can be mounted to a wide variety of surfaces and structures. For example, the units can be installed on walls, poles, flanges, I-beams, pipes, and vehicles. The following photos illustrate some typical installations. Note the Beacon's yellow radome.

Fig. 6: Example inbuilding wall mount using standard VESA mounts. Routing of the POE cable is also shown.

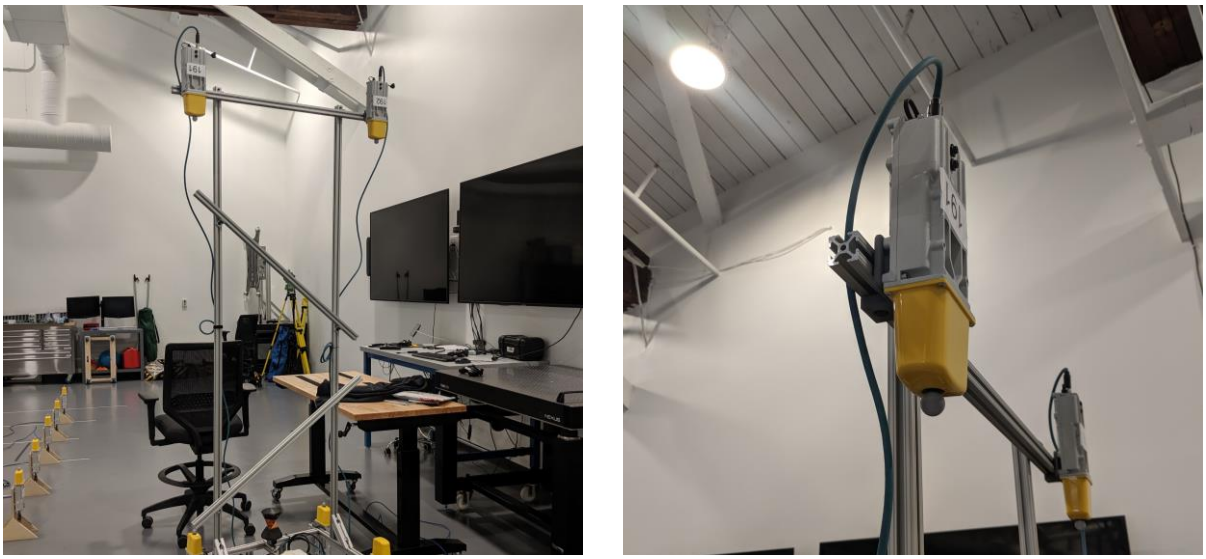


Fig. 7: Illustration of Beacon mounted to standard strut systems.

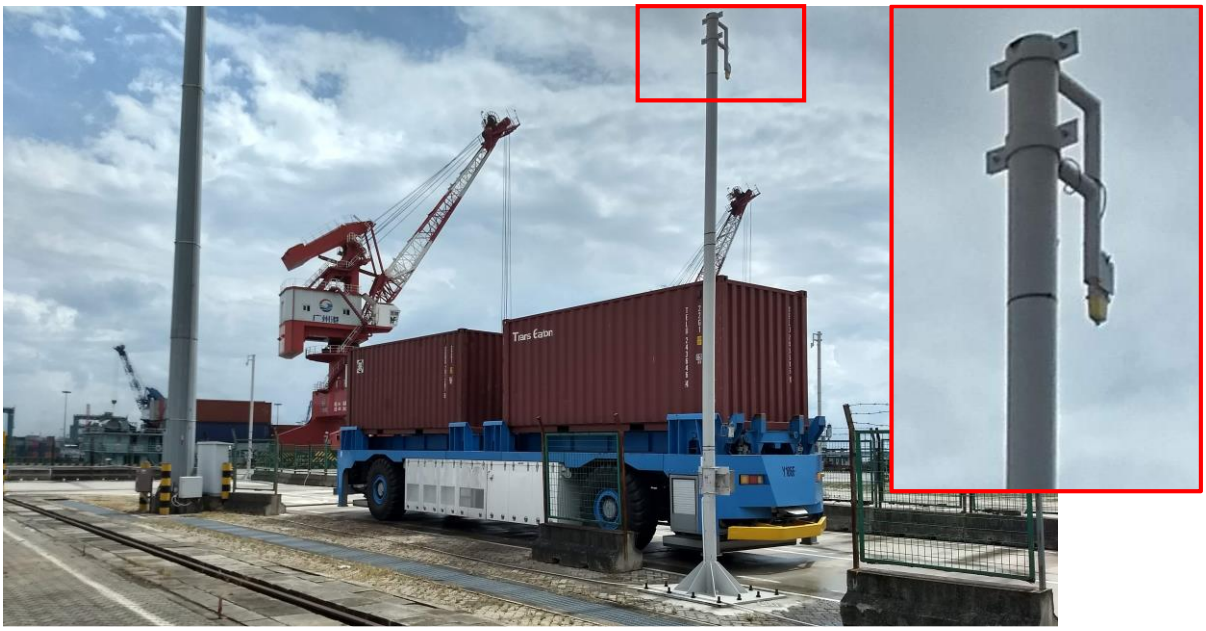


Fig. 8: Illustration of Beacon mounted to pole.

Nodes are more difficult to mount because there are typically more physical or practical limitations as to where they can be installed on the vehicle in question. While the same rules about separation distance from metal still apply, in practice, there will be times when the installation location is less than ideal. The following photos illustrate typical Node mounting arrangements. Note the Node's gray radome.

Fig. 9: Beacon mounted on beam above rear corner of vehicle (left) detail (right).

Fig. 10: Vehicle mounted on customer support plate.

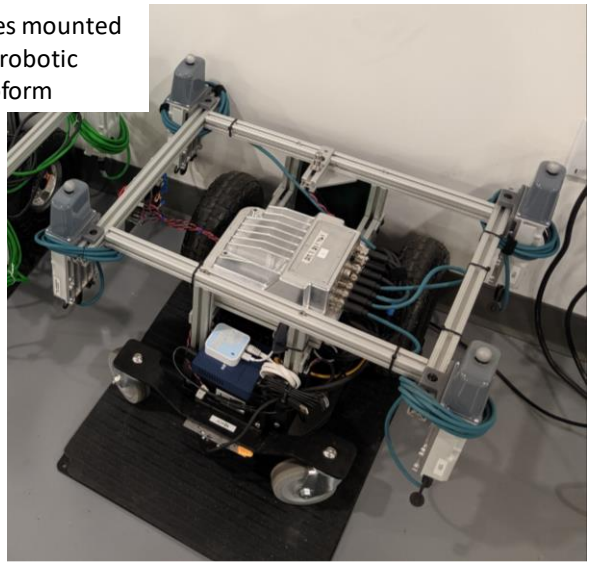


Fig. 11: Nodes mounted on a small robot

5.4 Hookup

Connection to the Beacon is either through a standard, Power Over Ethernet (POE) M12 cable or through an Auxiliary M8 two wire power only cable. The M12 POE connection is illustrated in **Figure 12**.

Fig. 12: Illustration of POE cable to Beacon connection.

6. Regulatory

The Beacon is certified to meet the U.S. Federal Communications Commission (FCC) Part 15 subpart F regulations, sections 15.517 (Technical requirements for indoor UWB systems), 15.519 (Technical requirements for handheld UWB systems) and 15.521 (Technical requirements applicable for to all UWB devices.

15.517 and 15.519 define the constraints associated with where and how the units can be installed and used.

To be compliant with 15.517, the UWB devices (Beacons and Nodes) can only be used indoors. Any fixed infrastructure devices (Beacons) must not only be installed indoors, but it cannot be intentionally positioned such that it can perform an outside function. The regulations specially state

> *"emissions from equipment operated shall not be intentionally directed outside of the building in which the equipment is located, such as through a window or a doorway, to perform an outside function, such as the detection of persons about to enter a building."*

Furthermore, the regulations require that the following language be included in this manual.

> *"This equipment may only be operated indoors. Operation outdoors is in violation of 47 U.S.C. 301 and could subject the operator to serious legal penalties."*

To be compliant with 15.519, the UWB devices can be used outdoors or indoors but cannot be used in conjunction with fixed infrastructure and must be compliant with the 10 second rule.

Note that there are other applications which are specifically forbidden, such as use of the devices in toys or in fixed outdoor installations. See FCC Parts 15.519 and 15.521 for more details.

More specifically:

> *This device complies with 47 CFR 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.*

Furthermore:

> *The user is cautioned that changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.*

The label certifying Beacon Safety and FCC compliance is shown below in **Figure 13.**

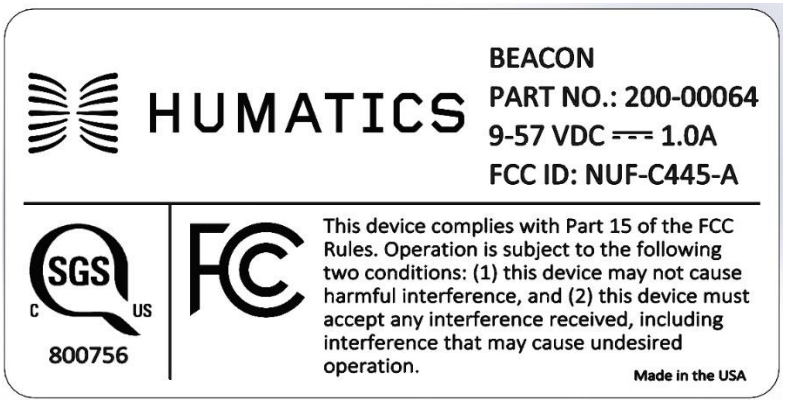


Fig. 13: Beacon Safety and FCC ID certification label

The label certifying Node Safety and FCC compliance is shown below in **Figure 14.**

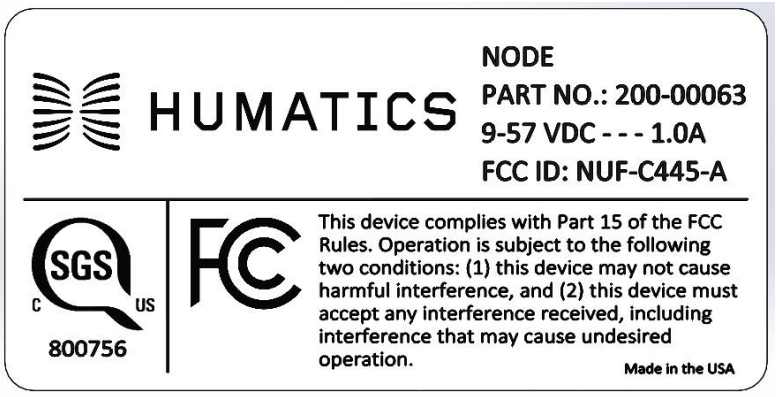


Fig. 14: Node Safety and FCC ID certification label

This label is located on the outside of the Beacon as shown in **Figure 14.**

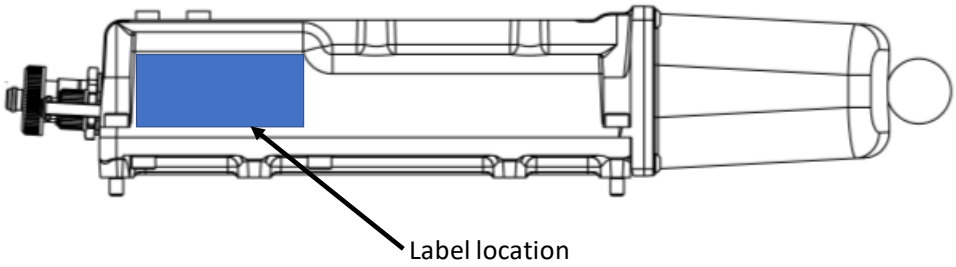


Fig. 15: Location of certification label

7. Safety Certification

The Beacon has been tested and is compliant with the following safety standard:

> STANDARD FOR SAFETY Electrical Equipment for Measurement, Control, and Laboratory Use; Part 1: General Requirements (UL 61010-1 Third Edition, Dated May 11, 2012.)

The certification labels for the Beacon and Node are shown above in **Figures 13 and 14**.

In addition, please be aware of the following 61010-1 advisements:

- If the equipment is used in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired.
- The power supply (9-57VDC) should be an approved SELV power source and the maximum available current is limited inherently or by impedance so that it cannot exceed 2.6A.

8. Maintenance and Service

The Beacon is not field serviceable. If it is malfunctioning it should be replaced and returned to the factory or to a factory trained technician.