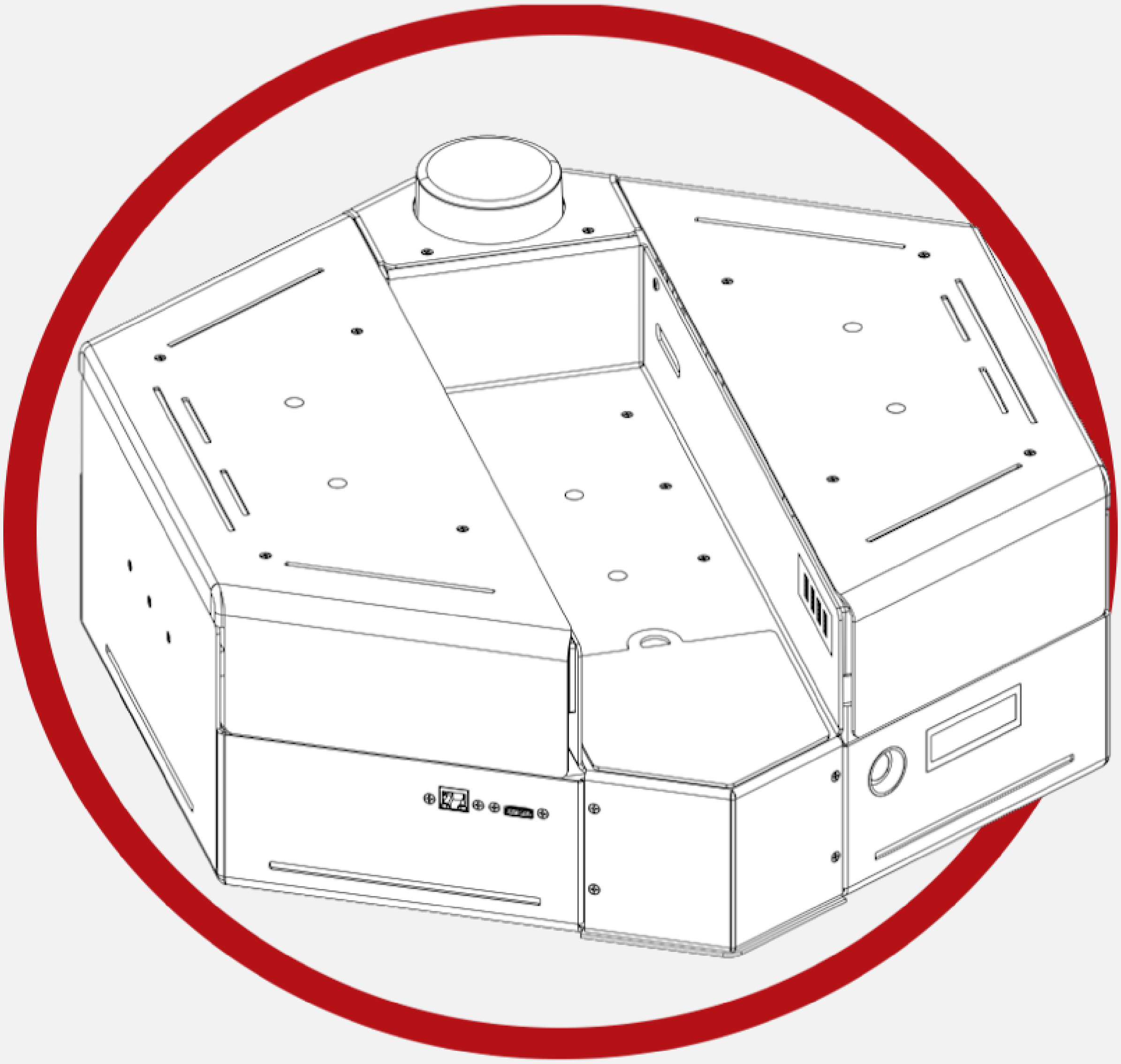

QBot Platform

System Hardware User Manual

v 1.0 — 29*th February* 2024

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Waste Electrical and Electronic Equipment (WEEE)

This symbol indicates that waste products must be disposed of separately from municipal household waste, according to Directive 2002/96/EC of the European Parliament and the Council on waste electrical and electronic equipment (WEEE). All products at the end of their life cycle must be sent to a WEEE collection and recycling center. Proper WEEE disposal reduces the environmental impact and the risk to human health due to potentially hazardous substances used in such equipment. Your cooperation in proper WEEE disposal will contribute to the effective usage of natural resources.

Caution

This equipment is designed to be used for educational and research purposes and is not intended for use by the public. The user is responsible to ensure that the equipment will be used by technically qualified personnel only. While the end-effector board provides connections for external user devices, users are responsible for certifying any modifications or additions they make to the default configuration.

ESD Warning The QBot Platform internal components are sensitive to electrostatic discharge. Before handling the QBot Platform, ensure that you have been properly grounded.

User Warning The QBot Platform is a research device and must be operated by trained personnel with extreme caution. Please ensure that you have read this user manual and associated warnings and caution notes carefully.

Table of Contents

A. Hardware Components

The main QBot Platform components are listed in Table 1. These components are ID marked in Figures 1 through 4, which present the front, back, top, and bottom views of the QBot Platform.

ID	Component	ID	Component
1	LeiShen LiDAR M10P	**10**	User LEDs
2	Magnetic Attachment Points	**11**	Base Camera OV9281-160
3	Expandable I/O	**12**	Embedded Computer
4	10/100/1000 Base-T Ethernet jack	**13**	Drivetrain
5	4 Port - USB3.0 Hub	**14**	Caster Wheels
6	HDMI connector	**15**	LFP batteries and battery bays
7	LCD display	**16**	LFP battery connector
8	Push Button Power Switch	**17**	Intel RealSense D435 RGBD camera
9	Landing Plate	**18**	QArm Mini Cover

Table 1. QBot Platform Components

ESD Warning

The QBot Platform internal components are sensitive to electrostatic discharge. Before handling the QBot Platform, ensure that you have been properly grounded.

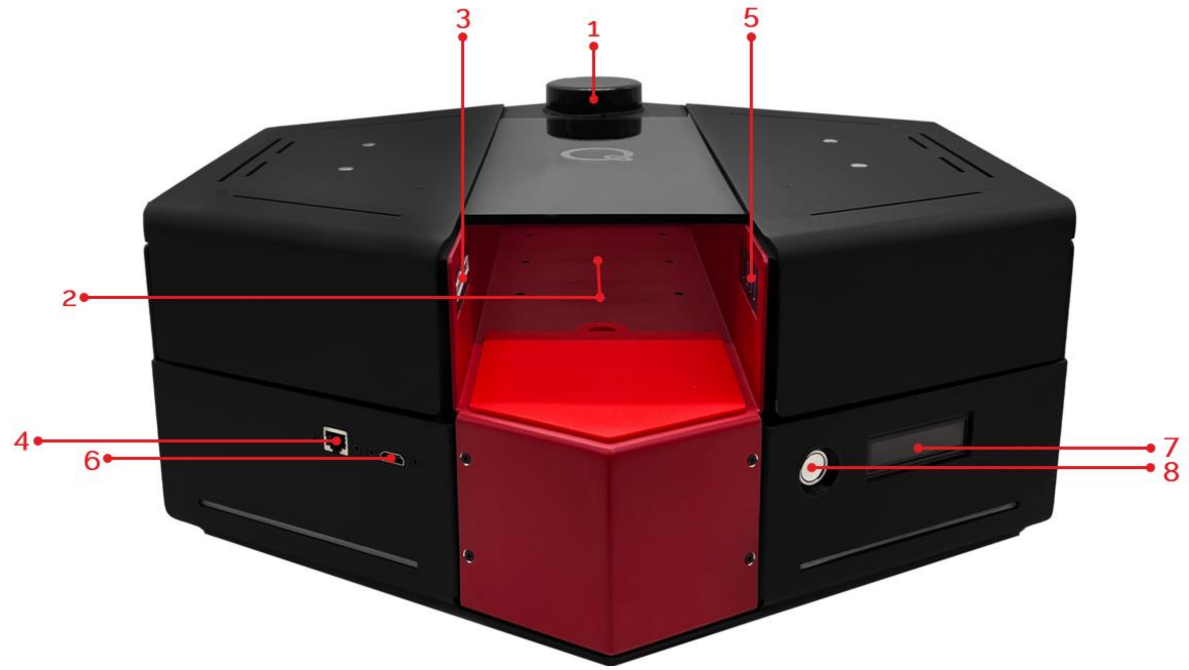

Figure 1: Back view

Figure 2: Front view

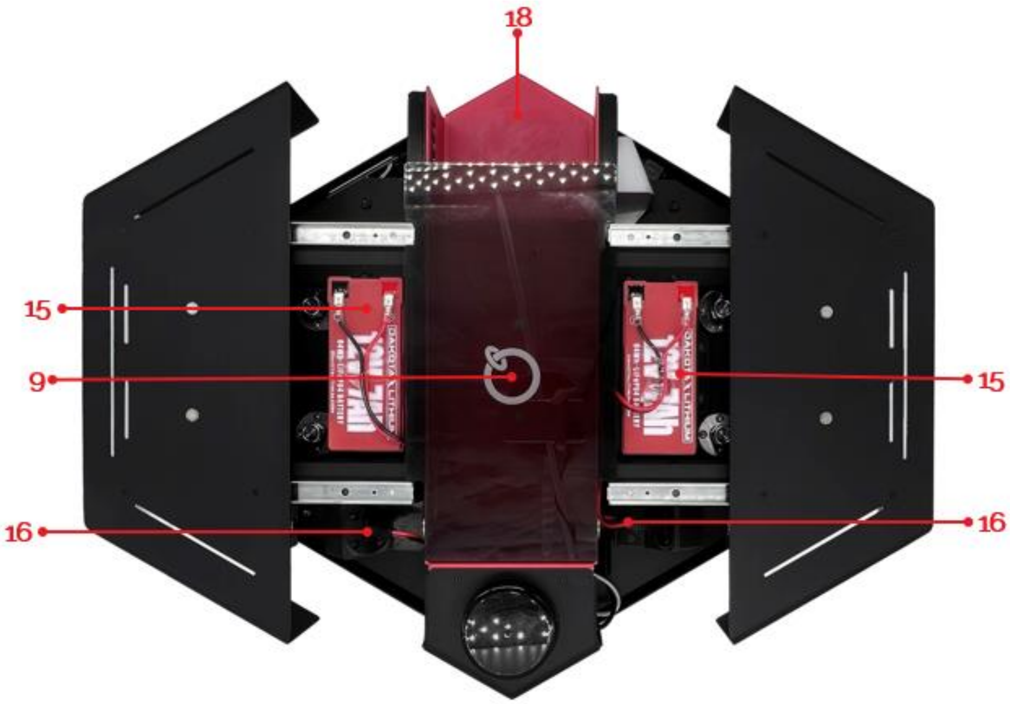

Figure 3: Top view

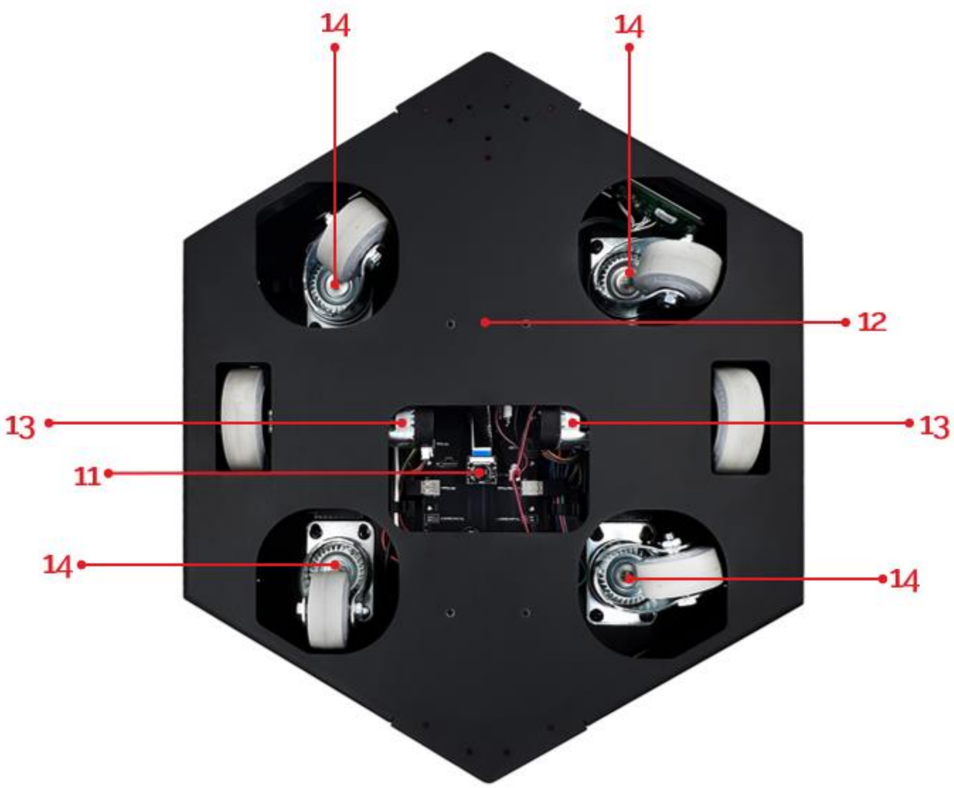

Figure 4: Bottom view

i. Embedded Computer

The QBot Platform is powered by an NVIDIA Jetson Orin Nano with 4GB RAM on an AverMedia D131-L carrier board. Please see the datasheets available in the ancillary materials directory.

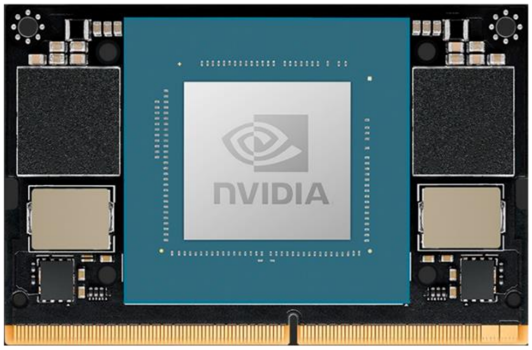

Figure 5. Raspberry Pi4 – 4GB

The NVIDIA module includes a 6-core ARM Cortex-A78AE v8.2 64-bit CPU with 4GB 64-bit LPDDR5 memory as well as a 512-core NVIDIA Ampere architecture GPU. The carrier board provides numerous peripheral inputs/outputs to the user that are exposed at the QBot Platform's body surface for user interfacing. A heat sink and fan are also provided to cool the NVIDIA module appropriately. See section A.ix. for more details on available peripherals.

ii. LiDAR

The QBot Platform comes equipped with a Leishen LiDAR M10P as shown below. This 2D planar LiDAR supports 1680 points per sample for a revolution at 10 samples per second and has a sensing range of up to 10m. The scanning frame rate and corresponding samples per revolution are summarized in Table 2 below. More information on this LiDAR can be found in the attached datasheets. The LiDAR is Class I and eye-safe, with a wavelength of 905nm. The recommended operation parameters have been shown in Table 2.

Figure 6. Leishen LiDAR M10P

Frequency (Hz)	Samples per revolution	Angular Resolution (degrees)
10 Hz	1680	0.214°

Table 2. Achievable frame rates and samples per revolution for the Leishen LiDAR M10P

This LiDAR uses a 6-pin serial connector, that is connected to the Raspberry Pi via an OTS USB-to-serial connector.

iii. Intel RealSense D435 Camera

The QBot Platform comes equipped with an Intel RealSense D435 RGB-D camera. It includes an IR projector and two IR imagers, making this unit a stereo tracking solution. The FOVs have been summarized in Table 3. The camera can provide RGB, Infrared (left and right) and depth streams of data at a variety of frame rates and resolutions, with the most common ones summarized in Table 4. For typical resolutions requested, it provides the maximum frame rate as well as the maximum resolution supported at that frame rate. More information can be found here.

Figure 7. Intel RealSense D435 RGBD camera

Camera	Horizontal	Vertical	Diagonal
RGB	$69.4^\circ \pm 3^\circ$	$42.5^\circ \pm 3^\circ$	$77^\circ \pm 3^\circ$
Depth	$87^\circ \pm 3^\circ$	$58^\circ \pm 1^\circ$	$95^\circ \pm 3^\circ$

Table 3: Field of Views (FOV)

RGB		Depth	
Typical (max) Resolution	**Max Frame Rate**	**Typical (Max) Resolution**	**Max Frame Rate**
640 x 480 (960 x 540)	60	848 x 100	100
1280 x 720 (1920 x 1080)	30	640 x 480 (848 x 480)	90
-	-	1280 x 720	30

Table 4: Intel RealSense resolutions and frame rates

iv. Downward Facing Global Shutter CSI Camera

The QBot Platform provides a grayscale global-shutter CSI camera (Figure 4 item 11 and Figure 8) underneath the robot at a slight offset towards the front of the robot for line following. The camera has a lens providing up to 160° Diagonal-FOV. See Table 5 for more information.

Note: these resolutions are typically used for capture and processing. Consider reducing frame rates to 30Hz or lower when displaying images from remote targets such as the QBot Platform for Wi-Fi considerations. Image compression can also serve as a useful tool to reduce bandwidth impact.

Figure 8: Downward Facing CSI camera

Resolution	Max Frame Rate (FPS)
1280 x 800	120 fps
1280 x 720	130 fps
640 x 380	180 fps
640 x 400	210 fps

Table 5. Achievable frame rates and FOVs for CSI camera

v. Drivetrain

The QBot Platform comes equipped with two motors. The motor parameters are listed in Table 6. There are firmware velocity controllers implemented for both motors accepting velocity commands, with an option to bypass them for PWM commands. There is also firmware level protection implemented for Stall as well as Overcurrent.

The motors commands can be either duty cycles in PWM mode (-1 to 1) or velocity commands in velocity mode (rad/s). In PWM mode, a fixed duty cycle command will apply lower motor voltages as the battery life decays.

Symbol	Description	Value
R_m	Terminal resistance	0.923 Ω
k_t	Torque constant	0.1397 Nm / A
k_m	Motor back-emf constant	0.1397 V/(rad/s)

Table 6: Drive motor parameters

Stall protection

If the PWM duty cycle commands are greater than 10% (0.1) and the motor velocity is under 43 counts/sec (approximately $\pi/4$ rad/s), then a stall warning will be issued in the Digital channels through the HIL driver. If the stall warning is consistently held for 5 seconds, a stall error is triggered and both motor PWMs are disabled for safety, with the LCD showing a `Motor error: STALL` message. Ensure that the QBot Platform is not stuck behind any obstacles and can move freely and re-enable the motors.

Note: Any examples supplied with the QBot Platform do not move the robot at speeds under $\pi/4$ rad/s per wheel. This corresponds to an approximate body forward velocity of 3 cm/s and a body turn velocity of $\pi/20$ rad/s.

Overcurrent protection

Onboard overcurrent protection from the firmware will ensure that either motor enters an Overcurrent state if the following conditions are met,

1. current draw of 4 Amps continuously for 6 seconds
2. current draw of 6 Amps continuously for 4 seconds
3. current draw of 8 Amps continuously for 3 seconds
4. current draw of 10 Amps continuously for 2.4 seconds
5. current draw of 12 Amps continuously for 2 seconds

Once in the Overcurrent state, the LCD will show a `Motor error: OVERCURRENT` message and both motors PWMs are disabled for safety. Ensure that the QBot Platform can freely move and consider reducing the payload based on the desired trajectory/commands and re-enable the motors.

Encoder

The QBot Platform includes two pre-gear encoders used to measure the angular position of each drive motor. The encoders provide 17 counts per revolution with a gear ratio of 5:1 reducing speed and increasing torque. At the output shaft, this provides 85 counts per revolution in normal mode or 340 counts per revolution in quadrature mode.

A hardware encoder-based speed measurement is also available from the firmware on the Other channels in the HIL driver (channels 14000 and 14001). This is based on the time between encoder edges, and is considered a 'hardware velocity', available in counts/s. A version of this velocity in rad/s is also available in the other channels in the HIL driver (channels 3003 and 3004)

The motor and encoder's datasheet can be found in the supplementary manuals attached here.

vi. Battery

The QBot Platform uses a 12V 7Ah battery (84Wh) LiFeP04 battery (Figure 9a). The battery can be charged using the provided Optimate lithium battery charger (Figure 9b). For more information, see the User Manual - Power document. We have included a firmware limit for the battery to protect the robot and battery for long term use. Current draws for various components have been listed in Table 7. For example, if both the LEDs are set to red ($0.33\ A$) and the robot is driving continuously while streaming both cameras and the LiDAR, the total current draw should be $3.50\ A$, which yields an estimate operation time of $2\ hrs$ for a $7Ah$ battery per battery.

Please carefully review the safety guidelines for using Lithium Iron Phosphate batteries listed after Table 7 before using the product.

a. 12V 7Ah 84Wh LiFeP04 battery

b. Optimate lithium battery charger

Figure 9. LiFeP04 battery and charger provided with the QBot Platform

Component	Approx. Current Draw
RealSense camera	$0.700\ A$
Leishen M10P LiDAR	$0.400\ A$
Downward camera	$0.150\ A$
LEDs (per channel per side, e.g. x6 multiplier for white)	$0.165\ A$
Electronics current	$0.500\ A$
Both motors running at nominal speeds 0.7 m/s	$1.410\ A$

Table 7. Current draws for various components of the QBot Platform

⚠ **Caution**: Before using any batteries, chargers/balancers, or power supplies, users must first read the manuals packaged with their equipment. Quanser supplies these guidelines for charging batteries, but it is the users' responsibility to ensure they are operating their equipment safely and correctly. Quanser is not responsible for any damages resulting from use of batteries, power supplies, chargers, or balancers.

⚠ **Caution**: Prior to using the QBot Platform, visually check the battery for bloating or damage. If the battery exhibits bloating **DO NOT USE** it. Visual bloating of the battery is dangerous - discard it in accordance with your country's relevant recycling and disposal laws

⚠ **Caution**: Do not charge the battery under direct sunlight.

⚠ **Caution**: Keep LiFeP04 batteries away from children and animals.

⚠ **Caution**: Never charge a LiFeP04 battery or battery charger that has been punctured or damaged in a crash. After a crash, inspect the battery or charger for signs of damage. Protect your LiFeP04 batteries from accidental damage during storage and transportation. Do not put batteries in pockets or bags can encounter sharp or metallic objects.

⚠ **Caution**: Do not use batteries unless supplied by Quanser. If you require additional batteries, please contact Quanser.

⚠ **Caution**: A LiFeP04 battery left deep-discharged for an extended period may develop permanent damage in one or more cells. Such batteries may heat up excessively while charging. Always monitor battery temperature during the first hour, then hourly there-after. If at any time the battery is uncomfortably hot to touch or you notice any unusual signs, disconnect the charger immediately.

Caution: Do NOT attempt to disassemble, modify, or repair the LifeP04 battery.

Note: When discarding a LiFeP04 battery, discard it in accordance with your country's relevant recycling and disposal laws.

vii. IMU

The QBot Platform includes a 6-axis IMU. There is a 16-bit accelerometer and gyroscope. The spec sheet for the part is attached here.

viii. Dimensions

Index	Item	Value
1	Length	$0.575\ m$
2	Width	$0.500\ m$
3	Height (with lidar)	$0.215\ m$
4	Wheelbase Width (tire center to center)	$0.393\ m$
5	Tire diameter	$0.0889\ m$

Table 8. QBot Platform dimensions

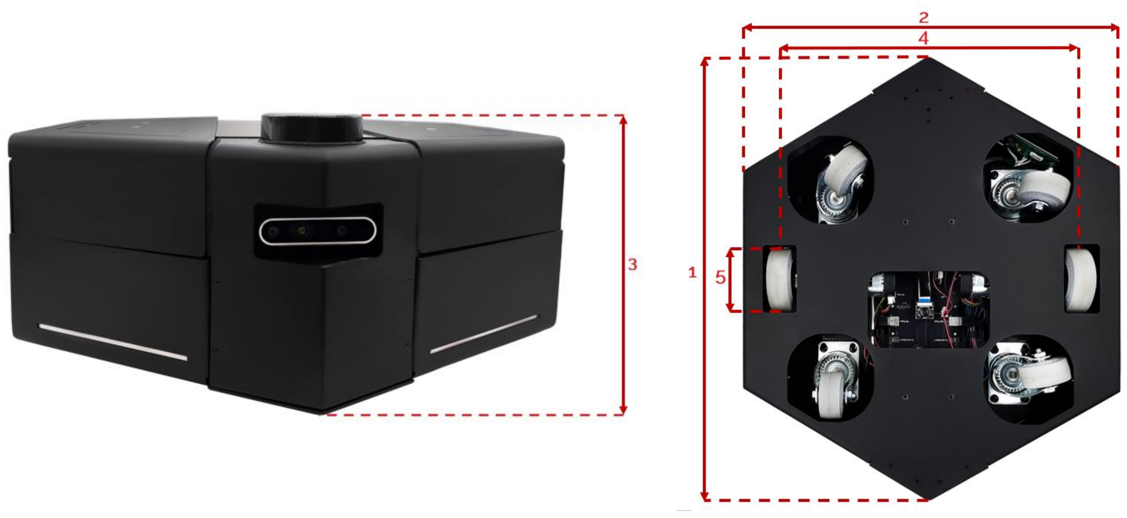

Figure 10. QBot Dimensions

ix. Peripherals

The QBot Platform features accessible ports, including HDMI and Ethernet, the 40-pin GPIO interface from the embedded computer, and a powered USB hub for additional peripheral connections. The top face of the QBot includes slots for convenient attachment of fiducial markers or custom solutions, while a centrally located slot hole on the side of the QBot Platform facilitates the neat routing of wires and cables.

Note: In figure 11c, the bottom left pin is pin #1

a. Powered USB Hub

b. Ethernet Port

c. GPIO pins from Embedded Computer

d. HDMI Port

Figure 11: Designated locations on the QBot Platform intended for the attachment of peripherals.

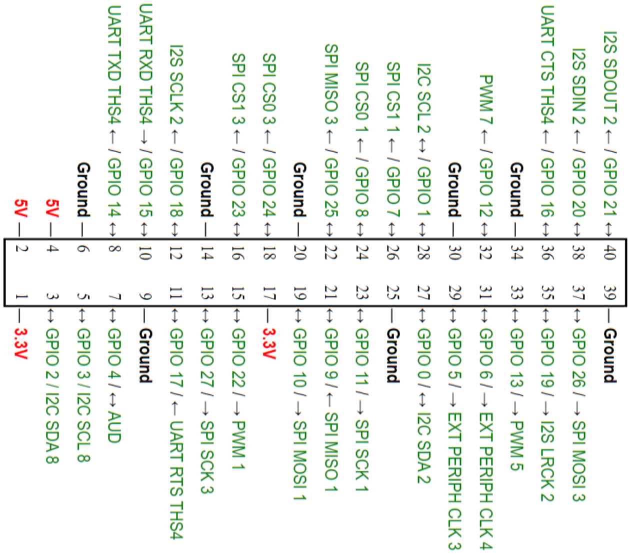

Figure 12: 40-pin GPIO configuration

vi. Landing Plate

Each QBot Platform comes with its own landing plate. The landing plate can be removed or installed depending on your use. To install the landing plate simply open the wings and place down your landing plate snuggly around the rails and close the wings again. See Figure 13.

Figure 13: QBot Platform Landing Plate Installation Steps

B. Environment Setup

Each QBot Platform Bundle comes with a set of mats and walls for education and research purposes. In case you have not acquired the QBot Platform Bundle, each QBot Platform comes with a testing mat as shown in Figure 14. This mat is to be used as a guideline for building your own setup. The recommended setup is shown in Figure 15. The QBot Platform Bundle also contains walls (see Figure 16) for setting up a perimeter around the mats in challenging environments for the LiDAR (larger then 12 m in diameter or containing dark objects).

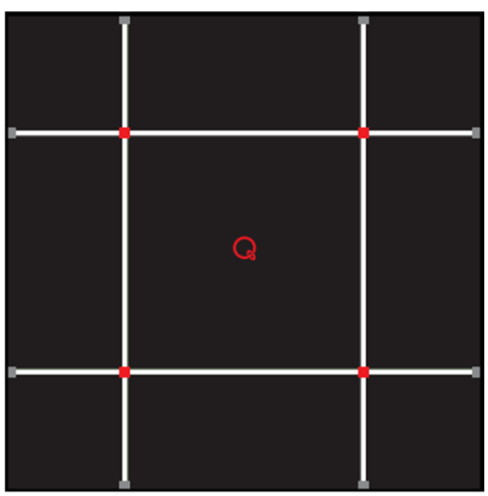

Figure 14: Testing Mat

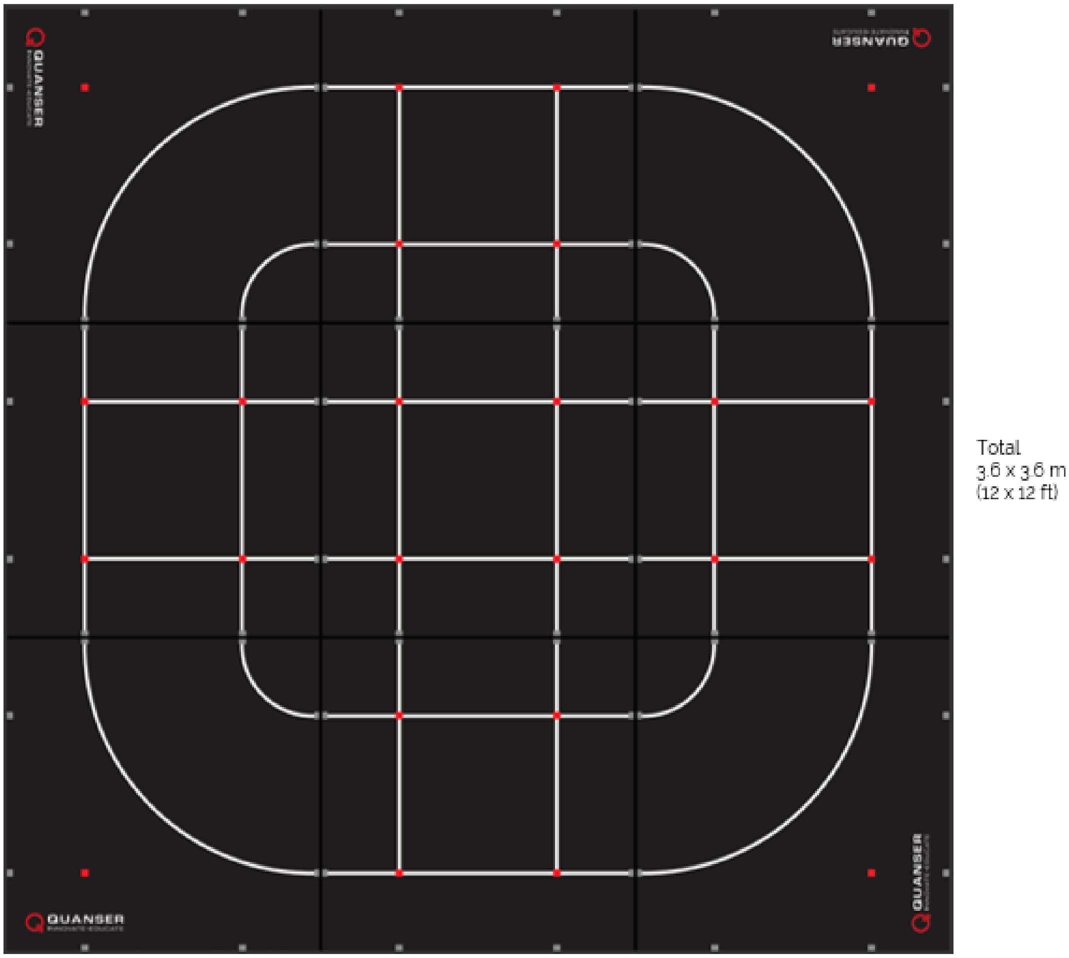

Figure 15: Recommend Mat Layout for the QBot Platform Bundle with dimensions.

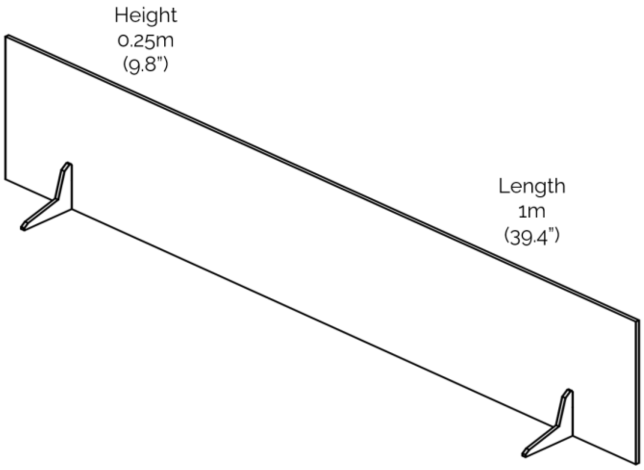

Figure 16: QBot System walls with dimensions

C. Electrical Considerations

ESD warning	The QBot Platform internal components are sensitive to electrostatic discharge. Before handling the QBot Platform, ensure that you have been properly grounded.
Caution	Maximum recommended total current draw from the power pins on user header from the embedded computer are: - 2 A for 5V - 500 mA for 3.3V
Caution	The QBot Platform has a max payload of 20 kg. Do not sit or stand on the robot.
Caution	The QBot Platform is not waterproof.

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