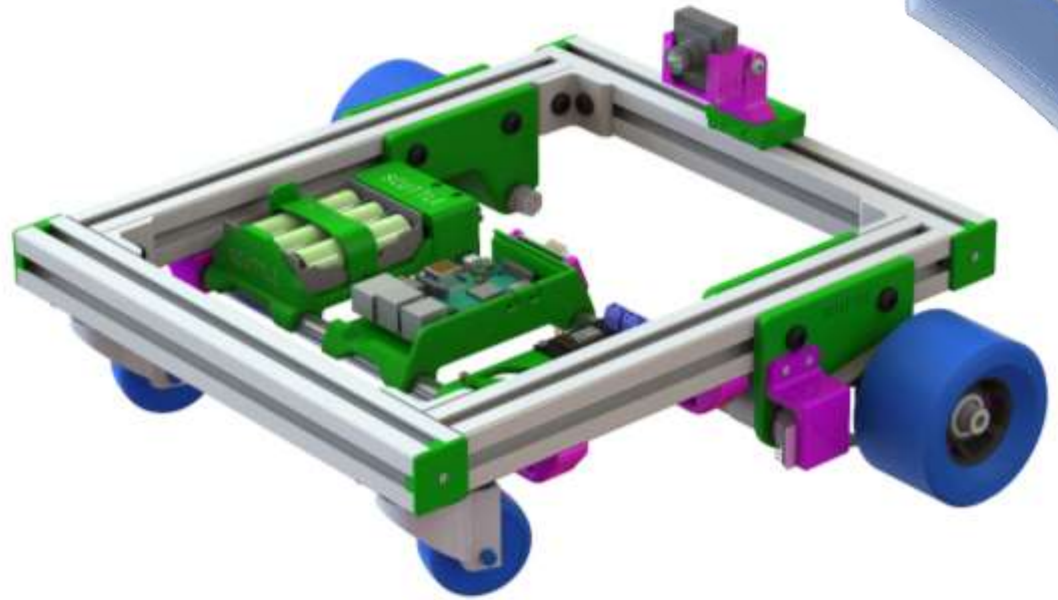
SCUTTLE
Assembly & Parts Guide

revised 2021.12.01

SCUTTLE Tech Highlights



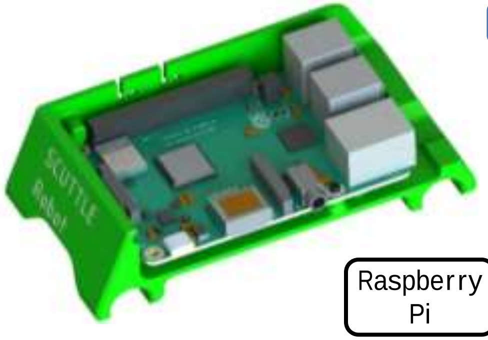
Onboard Technologies:

720P USB Machine Vision Camera, 150 degree FOV

Panasonic Lithium Ion Cells [NCR18650B]: 3200 mAh x 3

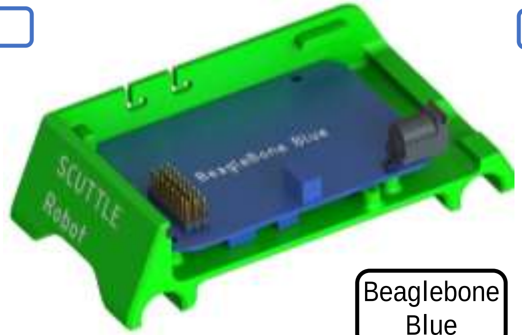
Precision-ground bearings x 4 608zz

Magnetic Contactless Encoder x 4



Raspberry Pi

OR



Beaglebone Blue

OR

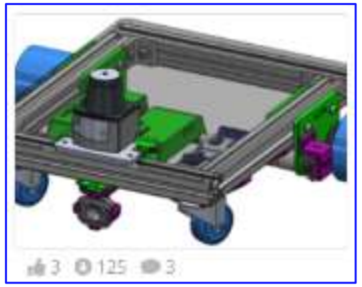
Jetson Nano

3 Options of embedded microcomputer

SCUTTLE 3D Assembly

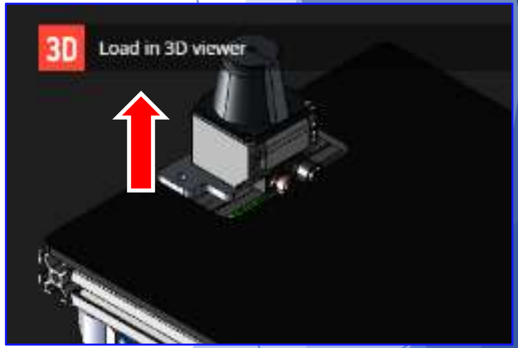
Before starting, visit our 3D model to learn about the assembly:

1 Find the latest SCUTTLE on GrabCAD

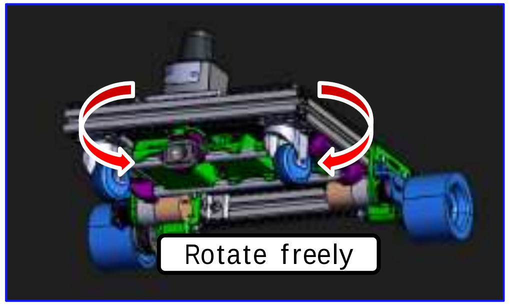


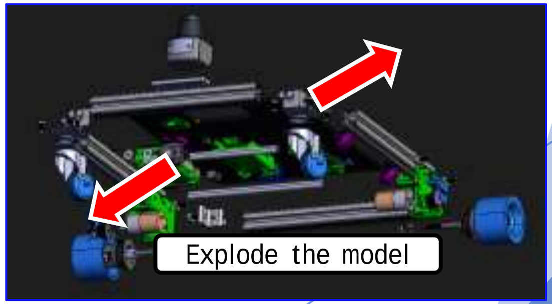
2 Go to the files and find the STEP

this is the complete model in one file

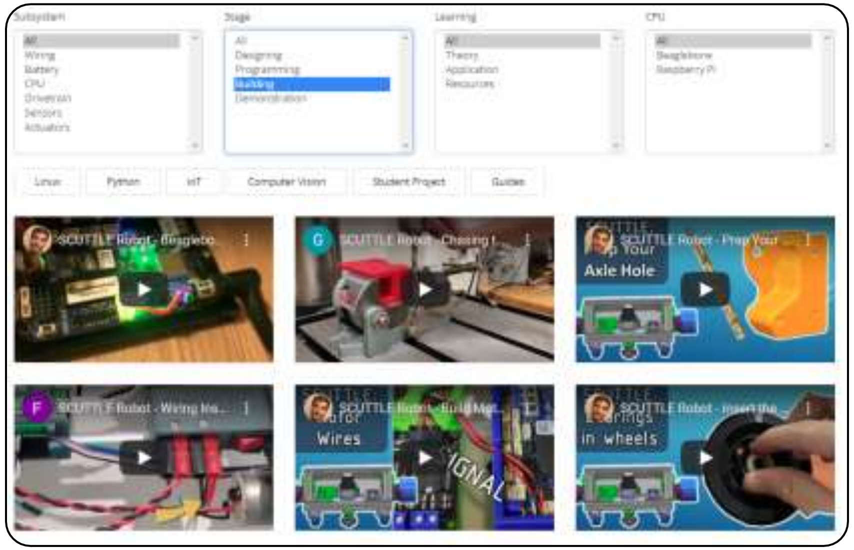


3 Explore the assembly in your web browser!





SCUTTLE Assembly



Videos Library

We recommend following our videos to build your robot. This library of 120+ videos covers building, testing, programming, and demos.

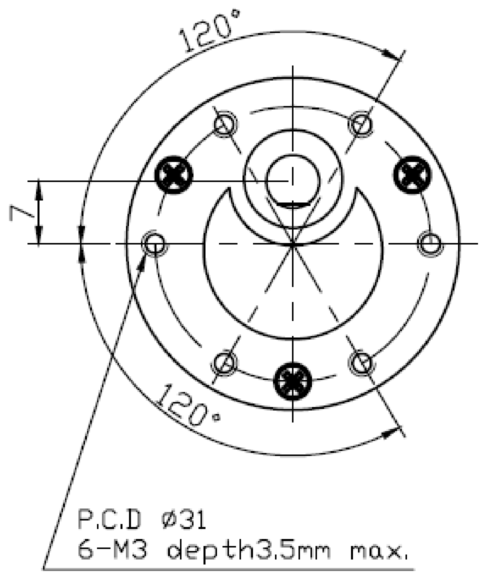
Use the CAD models & Wiring diagrams while you follow along with videos for building and modifying your SCUTTLE!

SCUTTLE Revision Numbers

Item	Naming	Compatible with previous?	Where to find	Frequency of updates	Format	Example of this kind of revision
Robot assembly, major	vX.x	✗	grabCAD	🏀	SLDASM, STEP	Changed robot construction. To use wheel brackets instead of assembly of plates.
Robot assembly, minor	vX.x	✓	grabCAD	🏀🏀	SLDASM, STEP	Many minor improvements on the modeling but not the design function
3D printed part, major	vX.x	✗	gitHub	🏀🏀	STL	Changed a bracket design to a new shape. Does not fit in place of the old part.
3D printed part, minor	vX.x	✓	gitHub	🏀🏀🏀🏀🏀	STL	Improved a bracket for printability or clearances. Still fits in old part assembly.
OTS part	None	✓	by request	🏀🏀🏀	SLDPRT, STEP	Designed a new CAD model to reflect hardware measurements
Subassembly, major	vX.x	✗	grabCAD	🏀🏀		Tested a new kind of camera and sharing the model of a new camera & custom bracket. Not changing standard components.

Motor: DC gearmotor, 200rpm

12v dc motor with gearbox



Front face drawing

Scuttle has two motors for driving the rear wheels. Each is a 12v DC motor with a gearbox that reduces the output speed to 200 RPM. The 6mm shaft is offset by 7mm from the centerline of the motor, which helps raise the clearance of the motor housing from the ground in the robot chassis. Three M3x10 screws fasten the motor to the motor plate.

The motor leads must be soldered to wires of 18 AWG or larger.

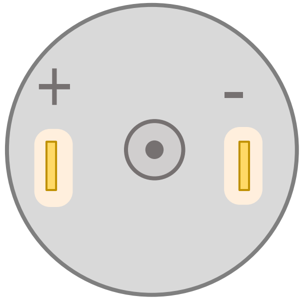
Alternates: you can find other versions of this motor with different speeds. The 250RPM version, has higher speed and lower torque.

Converting to brushless is an exciting option but it requires both hardware and software adaptations, and higher cost.

Motor Specs:

12v dc motor
with gearbox

	Value	Unit		
Speed, no-load	267	RPM		
Speed, rated	202	RPM		
Current, no-load	0.07	A		
Current, rated	0.48	A		
Current, at stall	1.60	A		
Torque, rated	0.96	Kg-cm	0.094	N-m
Torque, at stall	3.9	Kg-cm	0.38	N-m



Back side
of motor

Belt & Pulleys: HTD5 and T5

HTD Profile, 9mm wide, Readily sourced in Asia

T5 Profile, 10mm wide Readily sourced in USA

15 tooth T5 motor pulley

13 tooth HTD motor pulley

The drivetrain design has 5mm tooth pitch so users can easily 3D print pulleys with sufficient tolerance for a nice mesh. The belts have breaking strength over 500 kg force! However, the motor pulley would fail much sooner.

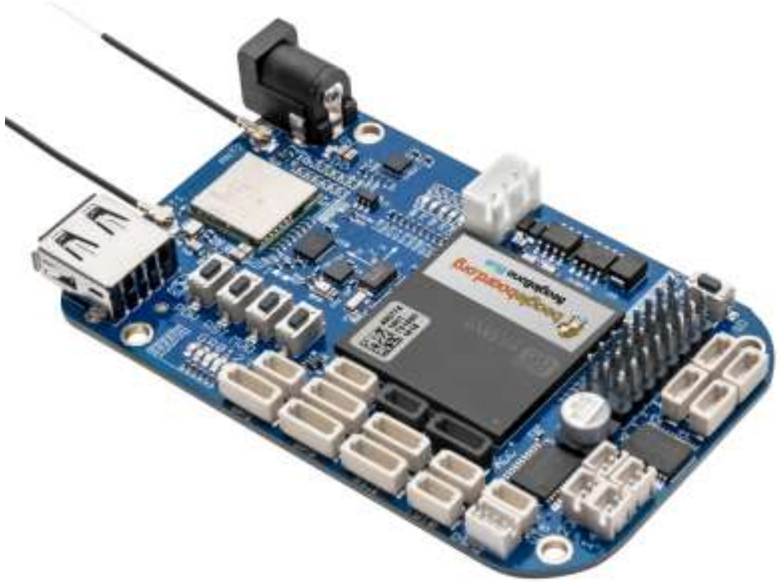
There are two variants of the assembly (as of 2021.10) but you can customize pulleys any way you want. Increasing the wheel pulley size increases torque and reduces speed. Go crazy and build a 200kg-ready “Muscle SCUTTLE” by combining metal gears, bigger motor, and custom ratios.

Alternates: Belt types and pulley pairs.

Belt Design	Common mfr	Reinforcement	Material	Tooth Shape
HTD-5	Continental	Fiberglass	Rubber	Round
T5	Continental	Steel	Urethane	Trapezoid

Motor Pulley	Wheel Pulley	Ratio	Belt Length (mm)	Width (mm)
15	25	**0.500**	245	9
13	25	**0.520**	225	10

Embedded Computer – Beaglebone Blue



Beaglebone Blue

The beaglebone Blue is an embedded Linux computer with extra robotics features such as built in motor drivers and dual WiFi modules, power management and servo ports.

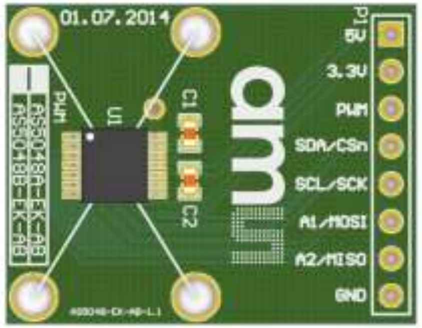
More resources:
Beaglebone Blue [Wiki]
Beaglebone Blue [Specification Sheet]
Beaglebone Blue [Schematic]
Summary [Video] in 1 Minute

Alternates: you can also use Raspberry Pi or other single board computer (SBC).

Other modules will require separate purchase of:

- Power regulator
- 2nd Wifi Dongle
- Servo driver (if used)

Encoders



ASM AS5048B
Encoder PCB

Two AMS AS5048B encoders are required for SCUTTLE, with one at each motor pulley.

Some details:

- It’s actually an angular position sensor. It returns degrees, from 0 to 360.
- It communicates over I2C. The left-hand encoder is addressed as 0x40 and the Right-hand encoder is addressed as 0x41, assigned by address pins.
- They measure the rotation of the motor pulley, and the software adjusts for (approx 1:2) wheel:motor turn ratio
- The sensor is paired with a diametrically opposed magnet, mounted at the end of the motor shaft.

Resources for the encoder:
AMS AS5048B Datasheet

The encoder addresses are set by soldering and wiring according to our wiring diagrams.

	Pin A0	Pin A1	Resulting i2c address
Left Encoder	LOW	HIGH	0x41
Right Encoder	LOW	LOW	0x40

Dual Motor Driver

Motor Driver
based on MC33886

A number of motor driver options are available. The standard choice is HW-231 motor driver which uses the NXP MC3386 H-Bridge. The ground is connected directly to the battery pack and it accepts two input pin pairs as PWM channels.

Resources for the motor driver are here:

- MC3386 [Datasheet]

Alternate: the ever-common L298N will also work for driving the motors, but it will not drive enough current for full output of our motors. It's an option if you're just learning and want to save money.

Important Features:

- Board is available from array of unbranded distributors with genuine FETs.
- Drives up to 5A per channel, continuously.
- Up to 10KHz PWM frequency
- 5.0 to 40.0v operation

Battery Pack

Version 2 Battery Pack with Cover Removed

The battery pack is a 3-cell lithium ion pack with a nominal voltage of 11.1v (3.7v per cell) combined with a few off-the-shelf parts and a 3D printed case. The capacity is 3400 mAh (we verified!) And they have enough capacity to drive SCUTTLE for several hours.

With additional actuators, a significant payload, or demanding sensors such as the SICK LIDAR, it is advised to add more capacity to the robot. The cells must not be drained below 2.8 volts each to prevent damage.

Resources for the battery pack are here:

- Panasonic NCR18650B datasheet
- Battery Cell handling and protection youtube video
- Instructions: Battery Cell supplemental info
    - shows more on assembly.

Alternate: our next favorite cell is undergoing testing and it's the LG HE4. We discovered it by this comparison video. It has a lower cost and nearly-equal performance.

LIDAR (optional)

SICK TiM561 LIDAR

SCUTTLE has been enhanced with a lidar manufactured by SICK sensor company. This lidar performs laser-based ranging in 270 degree plane at 0.33 degree resolution, 15 times per second! The USB interface is used to communicate to the microprocessor and the power is directly provided by the 11.1v battery pack.

Resources for the LIDAR unit are here:

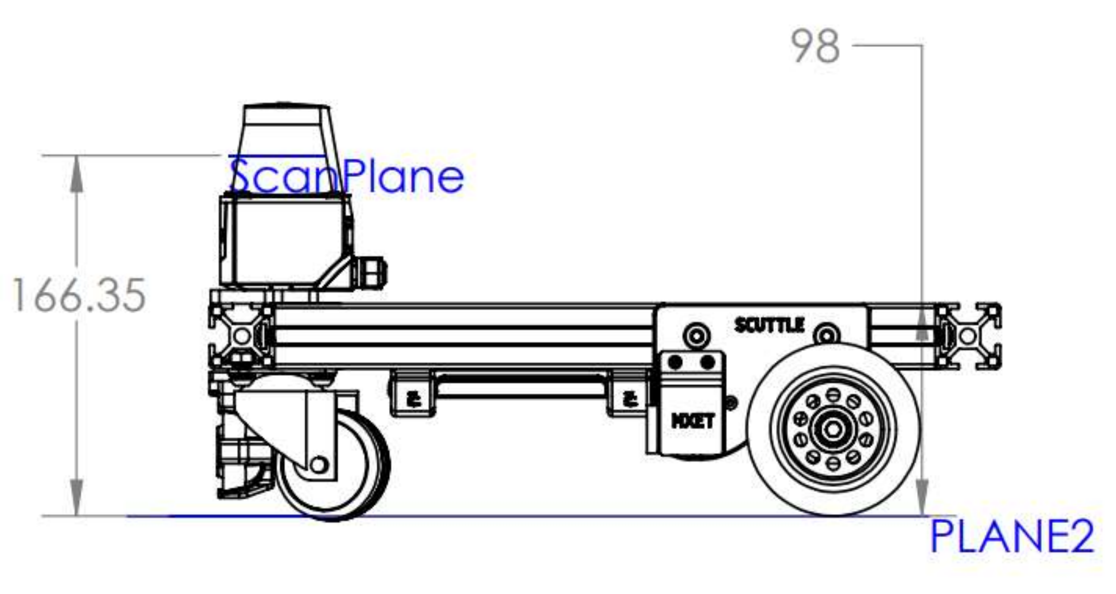
- Pysicktim python library on Github
- Operating instructions from SICK
- Technical information from SICK

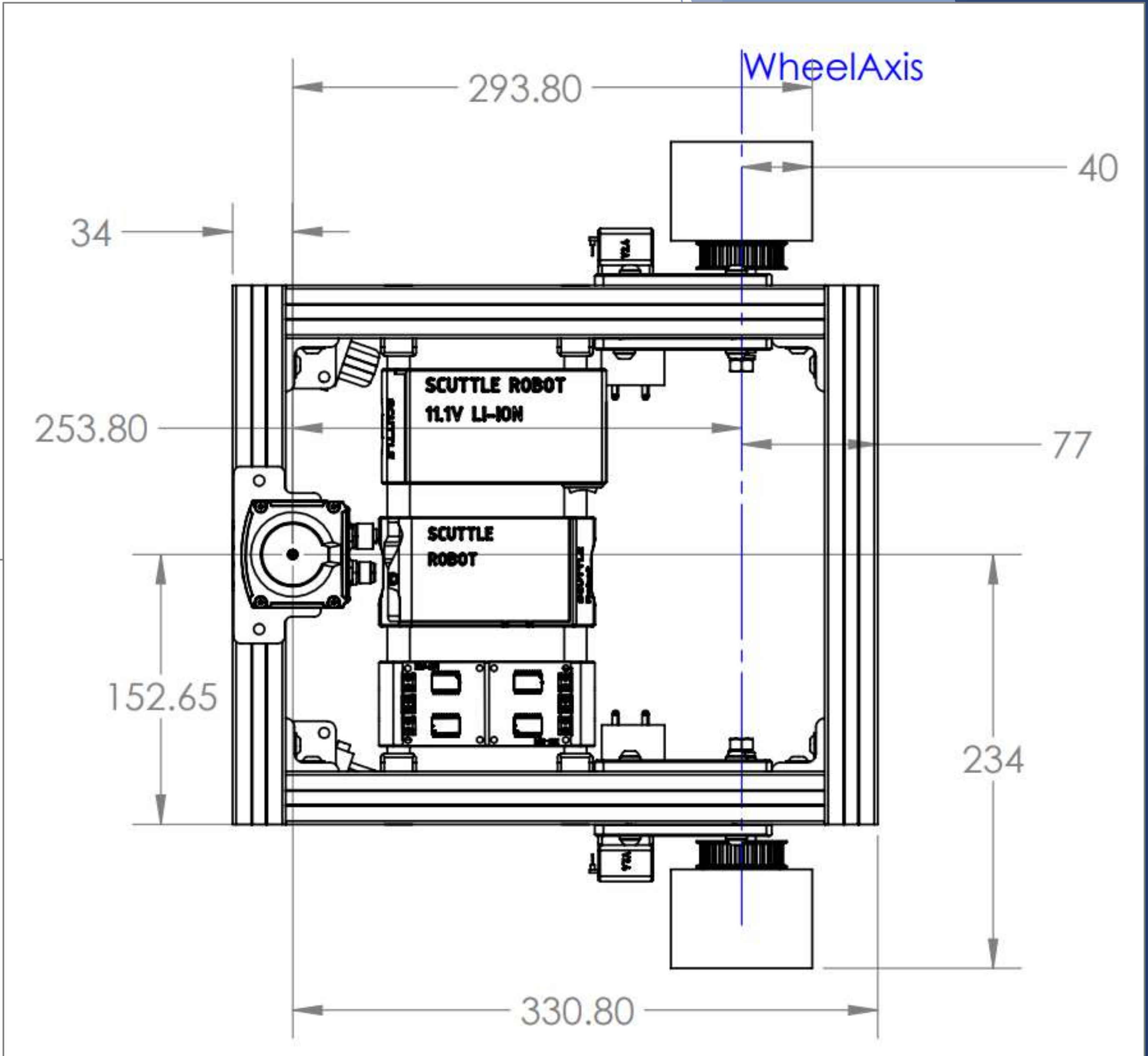
Important links:
Datasheet from SICK
User Manual from SICK
Software maintained by SICK on GitHub
Software library applying TiM561 to Python (pysicktim)

LIDAR (continued)

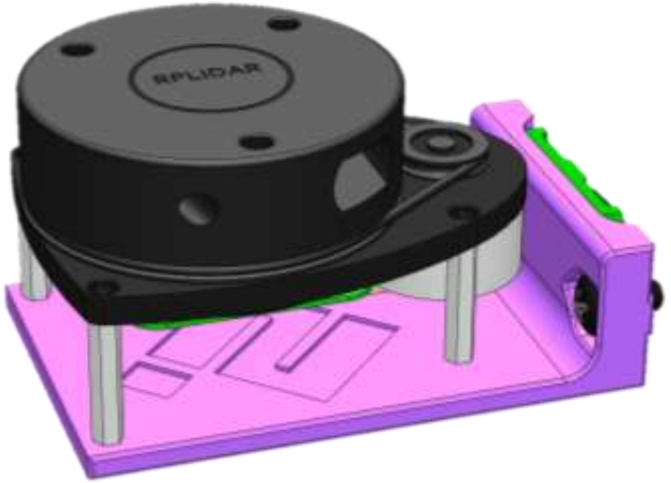
SICK TiM561 LIDAR

Dimensions and basic mounting configuration shown.





LIDAR (optional)



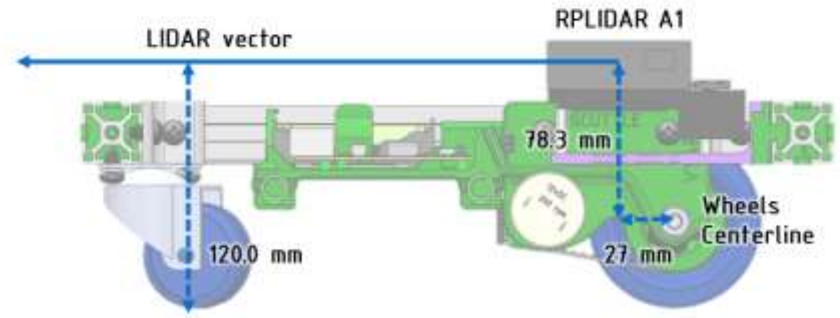
RPLIDAR A1 with Bracket

This selection of LIDAR is economical and tested using Python and ROS. Slamtec offers a free desktop GUI for testing the lidar off the robot. As of 2021 this unit sells for around $99 on amazon.

Resources for the LIDAR unit are here:

- Printable bracket CAD design
- 2D Drawing from Slamtec
- ROS Package from SLAMTEC on Github

Lidar Placement with LidarBrkt_v1.0



Key Parameters:
Power Consumption: 1.5 watts (tested by us)
Range: 12 m radially, 2D plane
Rotation: 5.5 rpm
Resolution: 1 degree

USB Camera

M720 model USB Camera

As of 2020, the camera is an industrial wide-angle USB unit. The steel box-shaped housing makes it easy to design custom adaptations for Computer Vision tasks. The specs:

Resolution: 720P
Field of view: 150 degrees
Microphone: built-in

Resources for the HD-3000 Camera are here:

- LifeCam HD-3000 datasheet
- Adapt this camera to see infrared by performing the modifications on the next slide.

Alternate options have been successfully tested including Logitech C270 & WyzeCam with webcam firmware. Some will work with no changes to software, and some will require minor changes

USB Camera (previous)

Microsoft Webcam

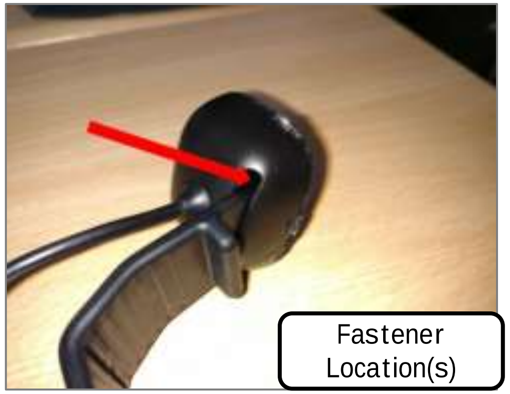
The previous integrated USB camera is a Microsoft LifeCam HD-3000. On the robot, we remove the camera's mounting bracket and inserted the camera into a 3D printed bracket.

Resources for the HD-3000 Camera are here:

- LifeCam HD-3000 datasheet
- Adapt this camera to see infrared by performing the modifications on the next slide.

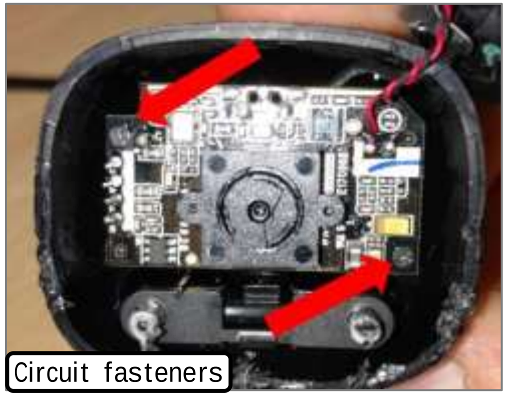
Alternate options have been successfully tested including Logitech C270 & WyzeCam with webcam firmware. Some will work with no changes to software, and some will require minor changes

USB Camera – Infrared Conversion



Fastener Location(s)

Pry here



Circuit fasteners

1.
After removing the IR filter, you can still use the camera to process visible light. The vision program in this manual is executed with no IR filter. It is the only way to see the beacon containing IR LED's. Remove the two screws on either side of the flexible tab in the first picture. You must rotate the tab to the left to access the right, and vice versa.

2.
The camera front shell can be removed with a light prying force, near the arrows.

Next, unscrew the circuit board (two screws).

3.
• Use a small PH1 screwdriver. Do not get any dust on the sensor. With all the cables still attached the board should be in a facing-down position.
• Get a sharp knife or pointed tool. The IR filter is on the sensor facing side of the lens. It reflects red. Be careful: it's glass and brittle. Cut from the edges of the filter towards and through the plastic ring. This way you will have some gaps to jam your knife in and pry the IR filter out more or less in one piece.
• Pry the filter out. Be careful not to scratch the underlying lens.
• Reassemble Lens and board, but don't close the case yet.
•Adjust the lens. When you look at the assembled lens you will notice it looks a bit like a triangular screw. And that's what it is. Get some pliers and gently, carefully adjust the lens to make up for the changed focal length. Don't scratch the lens with the pliers. Open a webcam app and look at an object at 1-2 meters distance. Turn the lens a little each way until you find the right direction, then continue until you see the best focus.

4.
Removing the Flexible Grip
This grip will need to be removed to mount the camera on the robot. The figure below shows the parts which hold the grip inside the camera.
1. Spring clip
2. Pin
3. Flex grip
In order to remove the flex grip, you'll open the camera, remove the circuit board (two screws) which holds the camera sensor, and then use a small flat screwdriver to remove the silver clip (part no.1) which will allow the pin (2) to fall out and then the grip (3) to be removed.

Pin components of the flexible grip.

Ultrasonic Sensor

HC-SR04 Ultrasonic Ranging Sensor

The ultrasonic sensor is for range-finding. It’s an optional item to support autonomous driving and obstacle avoidance.

There are versions of this board which require 5v (more common) or only 3.3v (less common). If your board requires 5.0v then power will need to be drawn directly from the power port on the beaglebone.

Resources for the HC-SR04 are here:

HC-SR04 [Datasheet]

Alternate options include IR rangefinders or full-on LIDAR. Both have been successfully tested.

Power Connector

Anderson Powerpole Connector Housing

Our Anderson Powerpole (APP) power connector is rapidly gaining popularity. It's carefully chosen with these metrics in mind:

- Easy for students to crimp, no soldering
- High Current (15, 30, and 45A)
- Modular, for expansion
- Affordable

Many power electronics, such as radio-controlled cars are using gold-plated barrel connectors. You can use any connector that supports sufficient current but this is our favorite.

Spade "Quick Connect" Connector

Spade Quick Connect Terminal

This spade connector may be the most common of all connectors inside in appliances and automotive circuits. These are best suited for connections that are not frequently plugged and unplugged.

- Low cost
- High Current (for AC or DC)
- Tin plated brass resists corrosion
- Nylon insulation for safety