# Robo Rally

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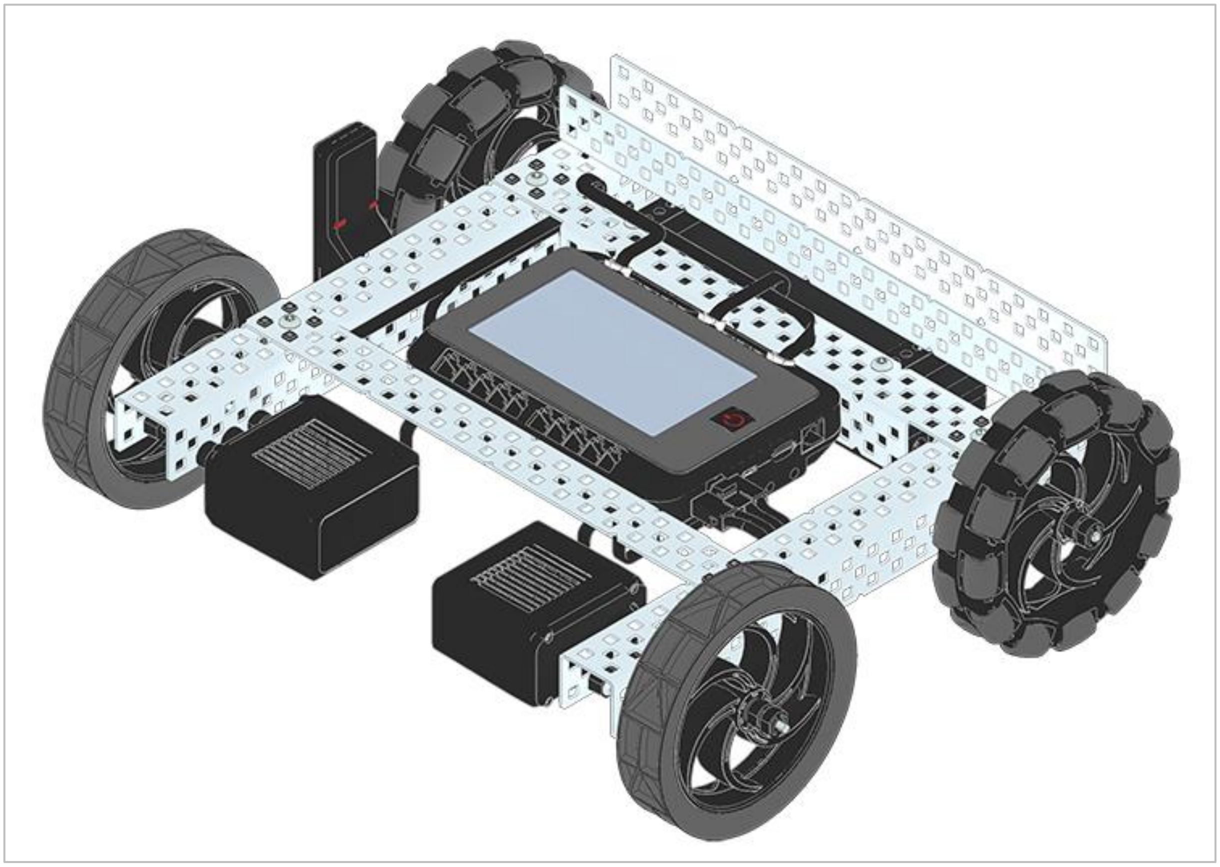
# The Completed Look of the Build



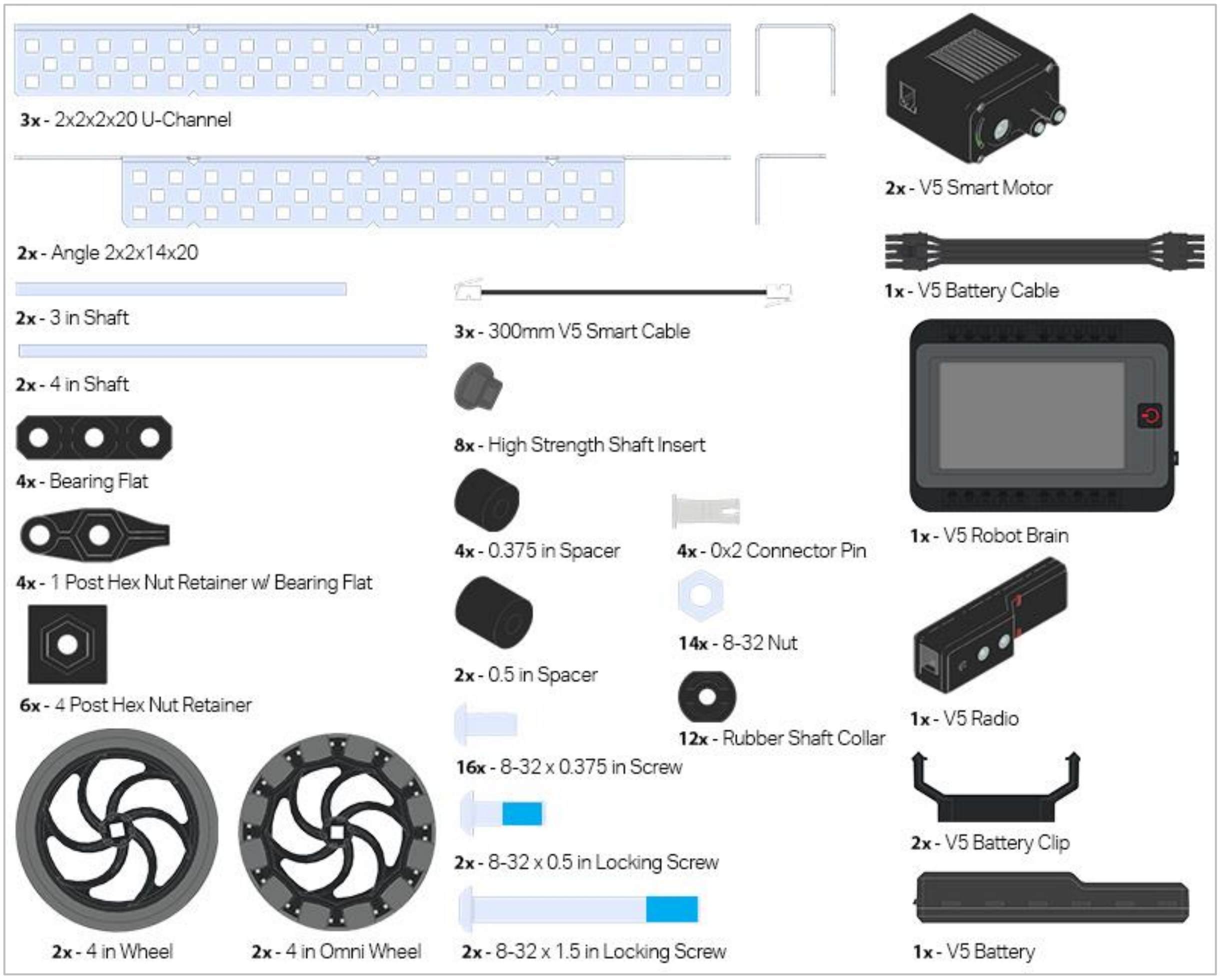
*Completed VEX V5 Speedbot*

This robot is designed so that it can be built quickly and driven around either autonomously or with the V5 Controller.

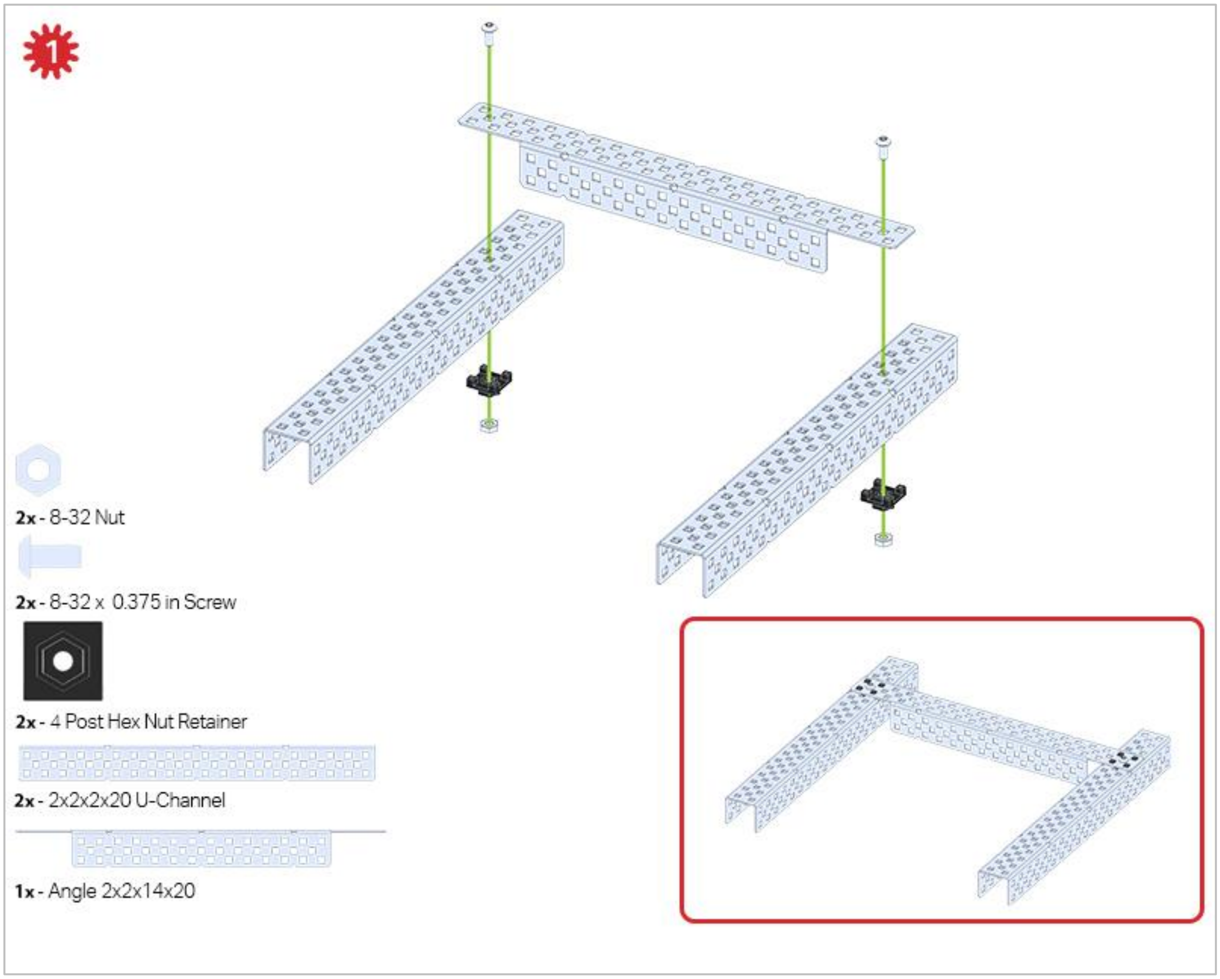
# Parts Needed

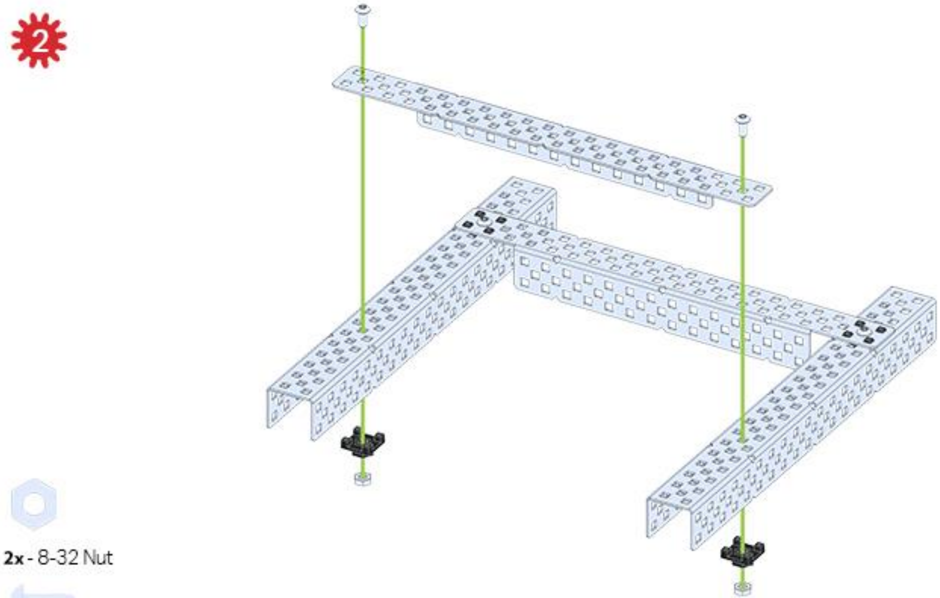
**Can be built with:**

- VEX V5 Classroom Starter Kit



# Build Instructions



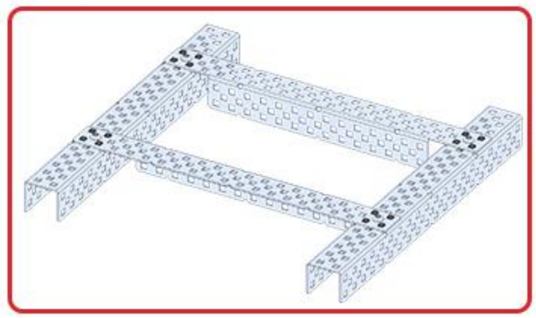


2x - 8-32 Nut

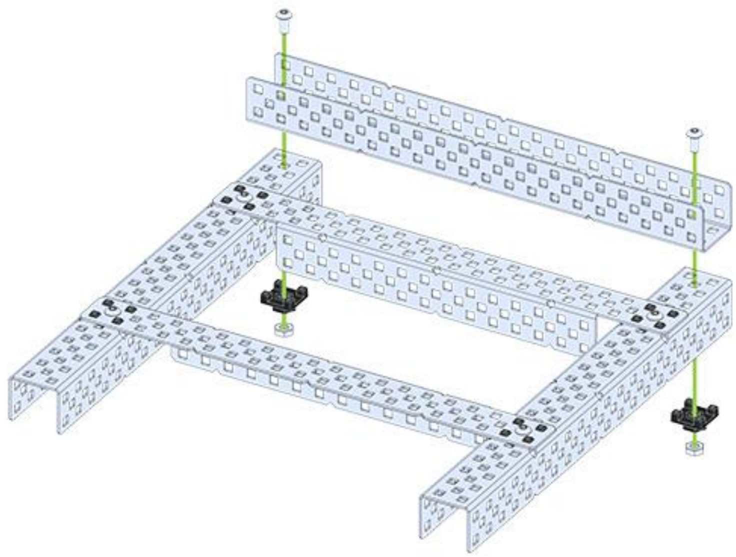
2x - 8-32 x 0.375 in Screw

2x - 4 Post Hex Nut Retainer

1x - Angle 2x2x14x20



# 3





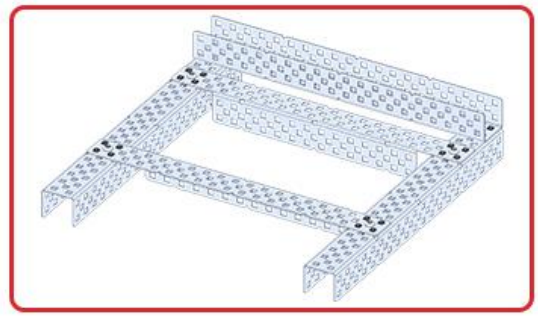
**2x** - 8-32 Nut

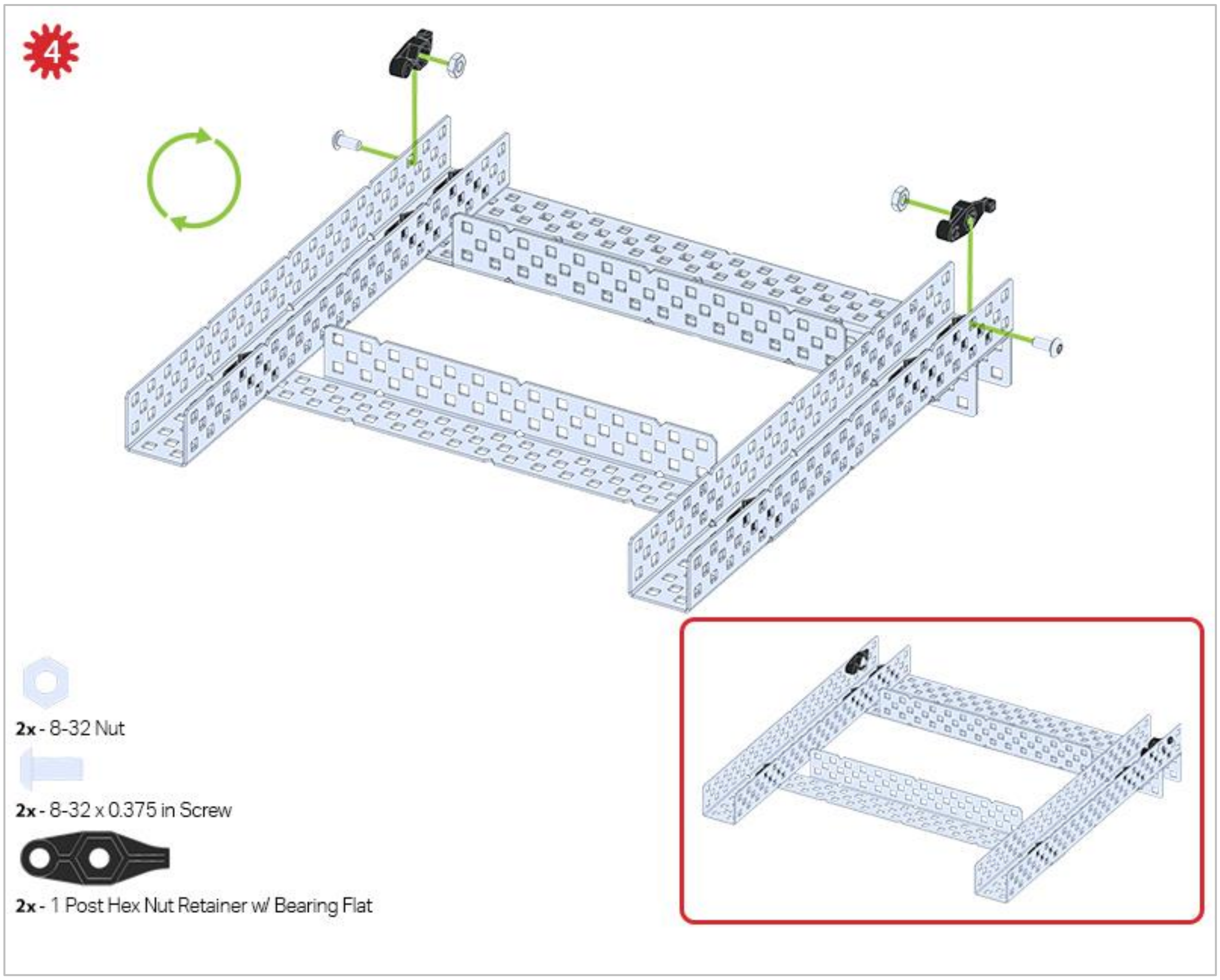


**2x** - 8-32 x 0.375 in Screw

**2x** - 4 Post Hex Nut Retainer

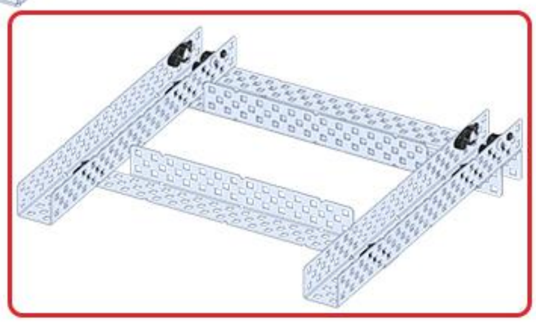
**1x** - 2x2x2x20 U-Channel






*The green icon indicates that the build needs to be flipped over (upside down).*

5



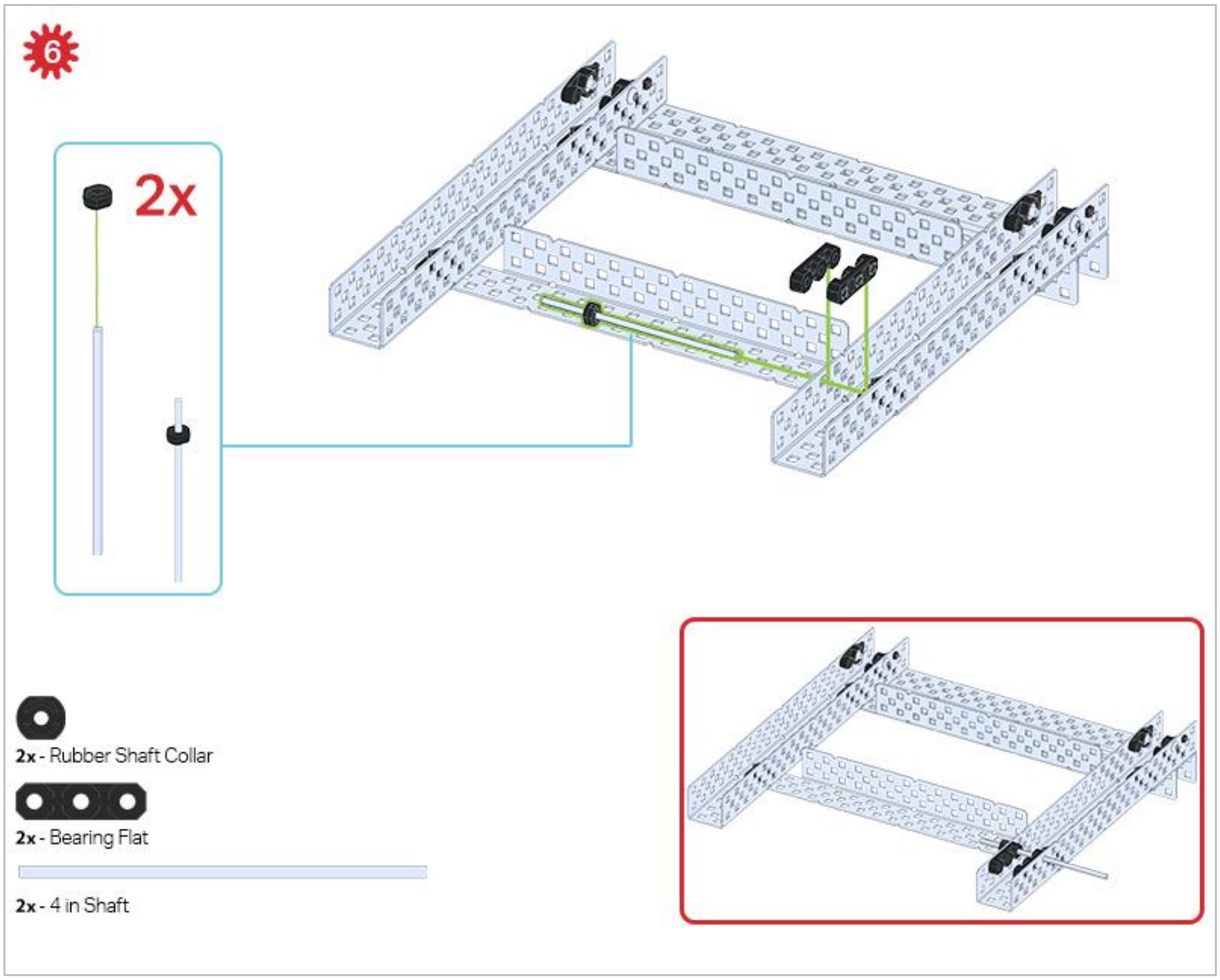


**2x** - 8-32 Nut

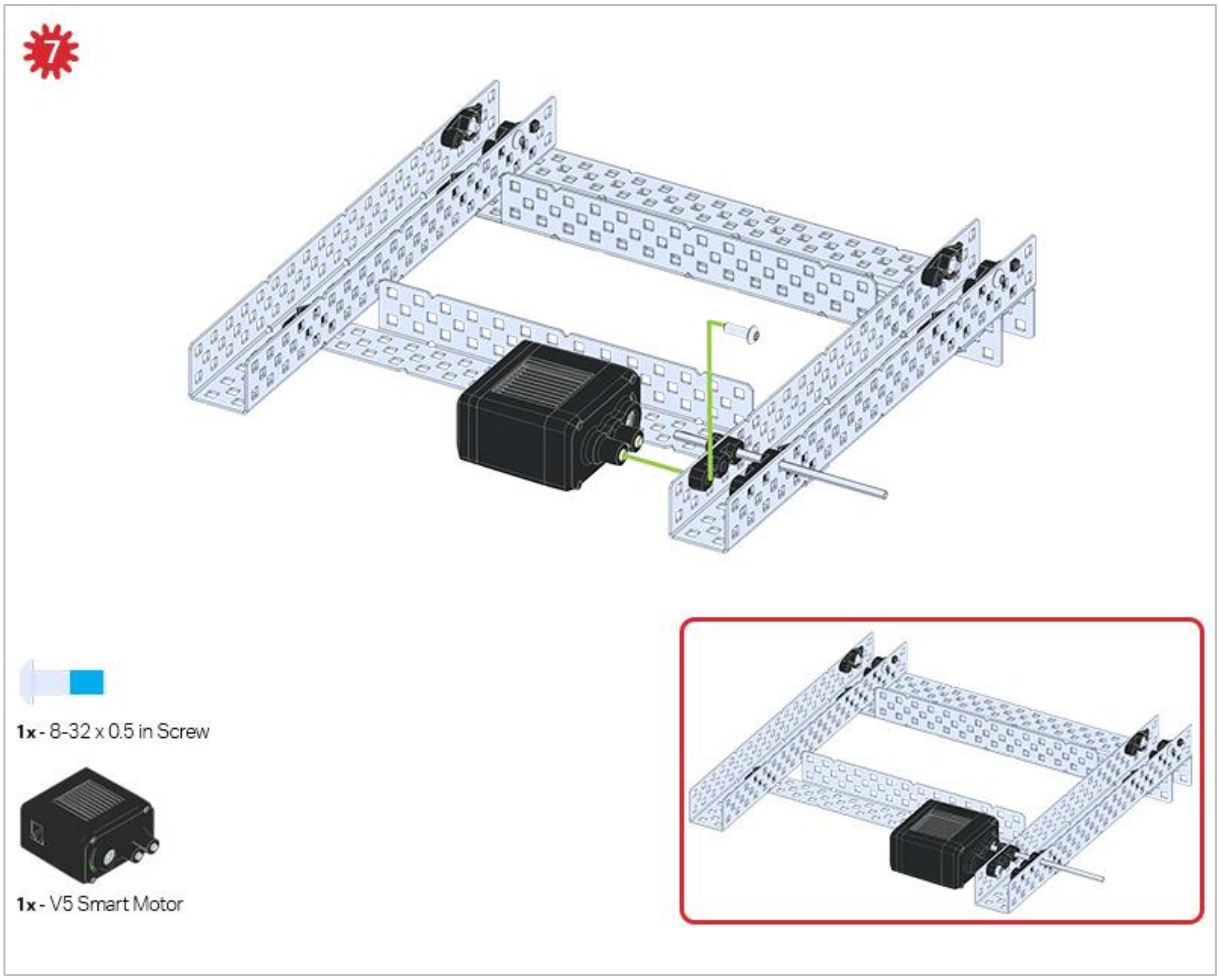


**2x** - 8-32 x 0.375 in Screw

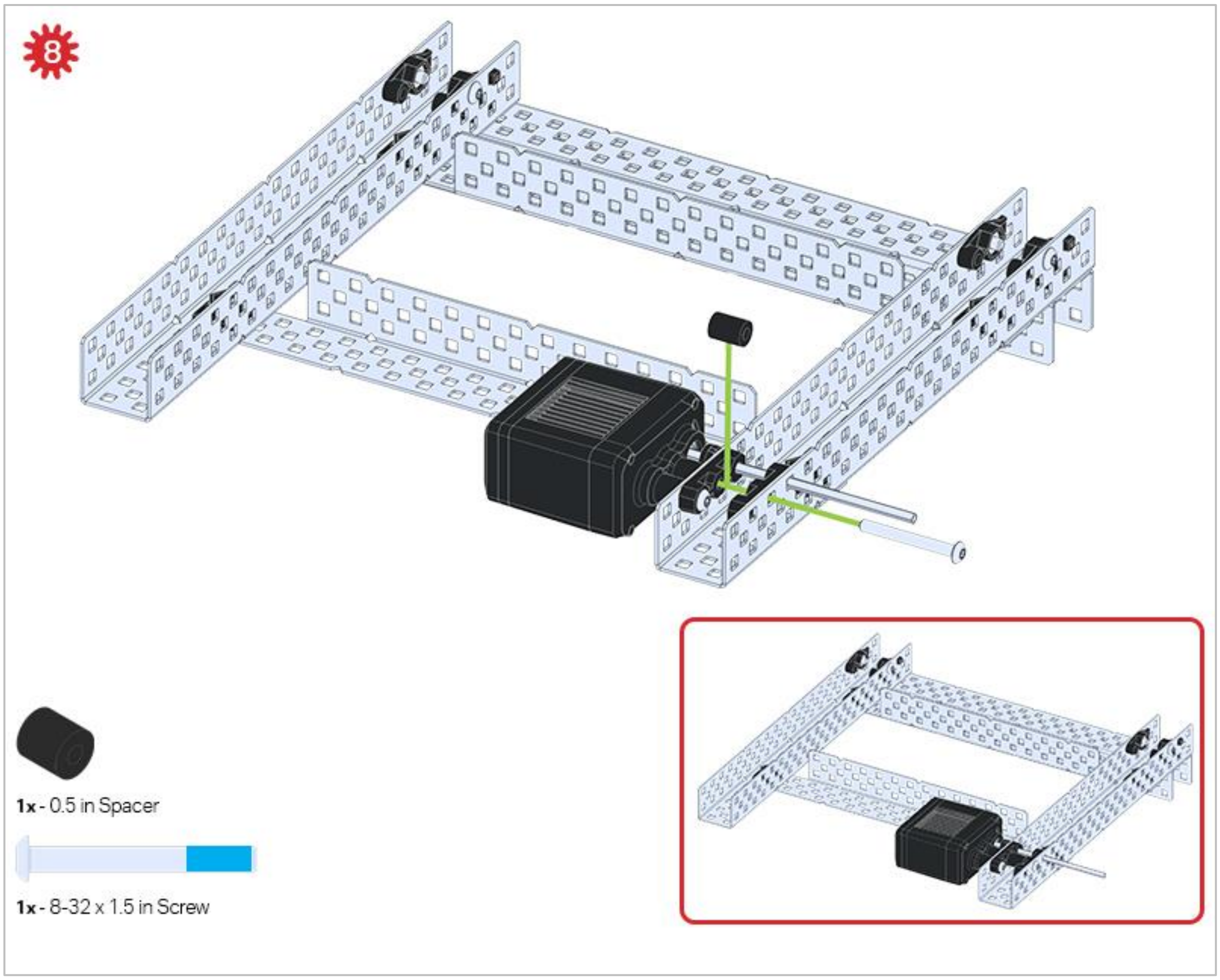
**2x** - 1 Post Hex Nut Retainer w/ Bearing Flat

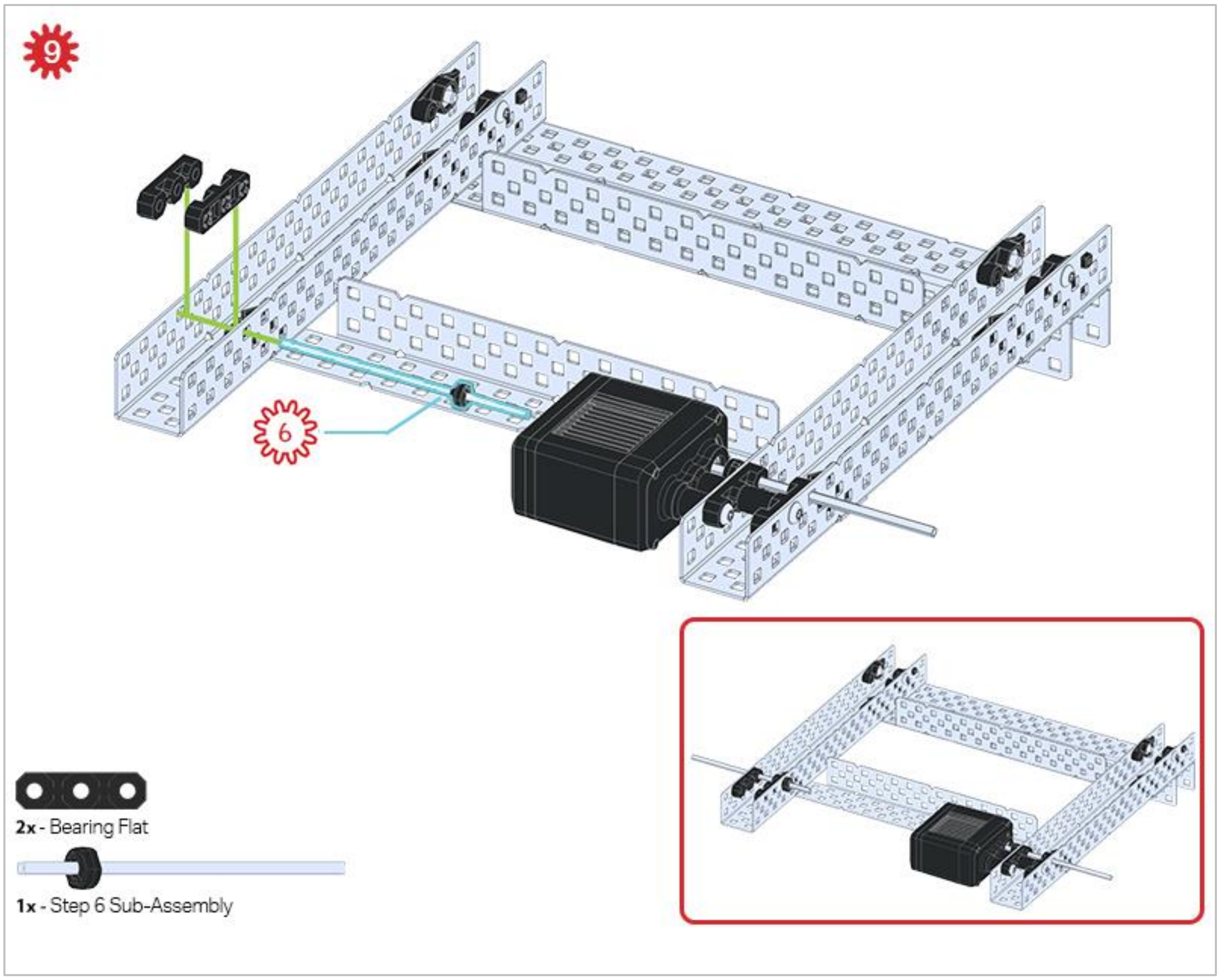


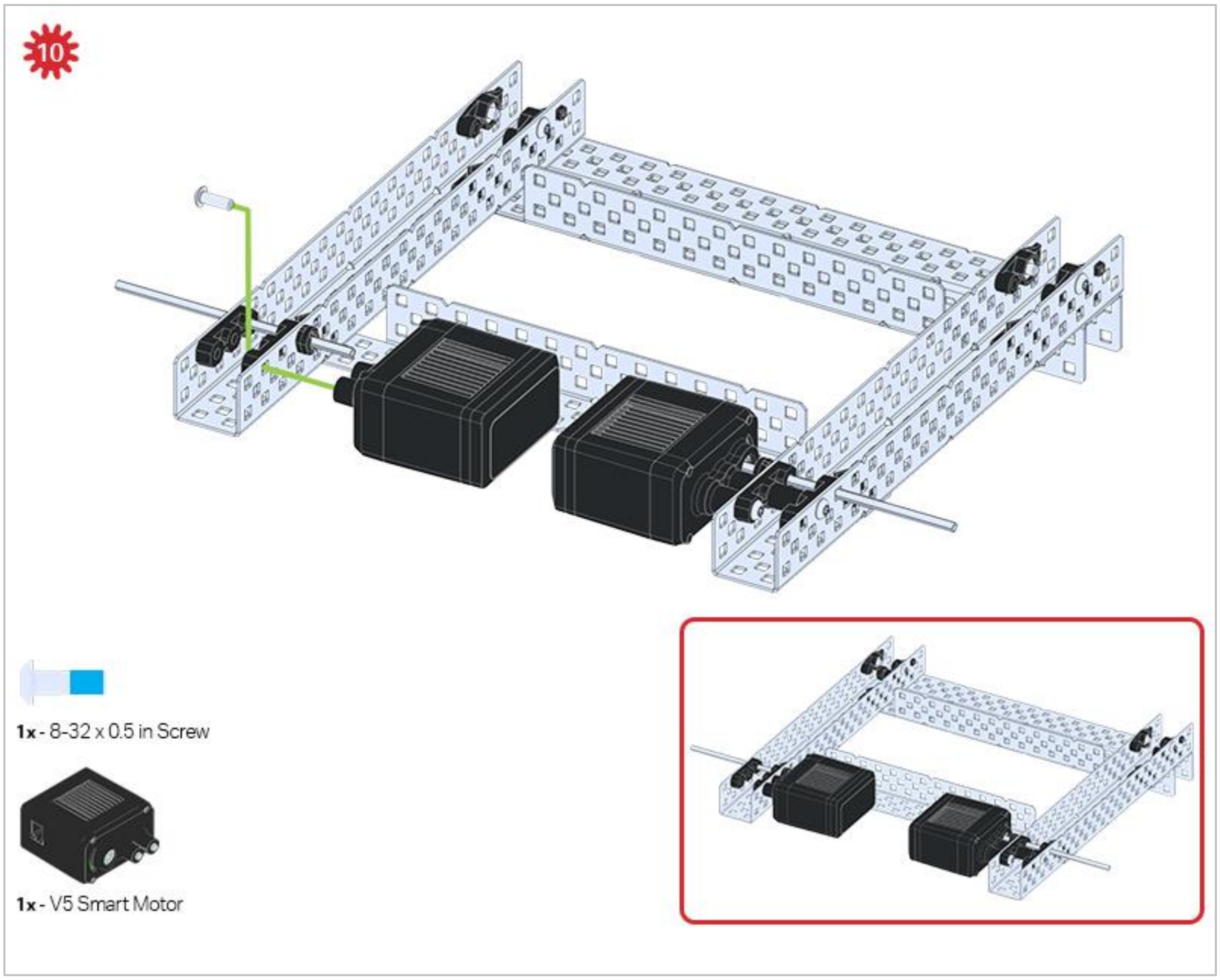

*Only one of the two sub-assemblies made in this step is used right now. The other will be used later in step 9.*




*Make sure your Smart Motors are oriented in the correct direction (screw holes facing the outside of the build and the shaft hole towards the inside).*

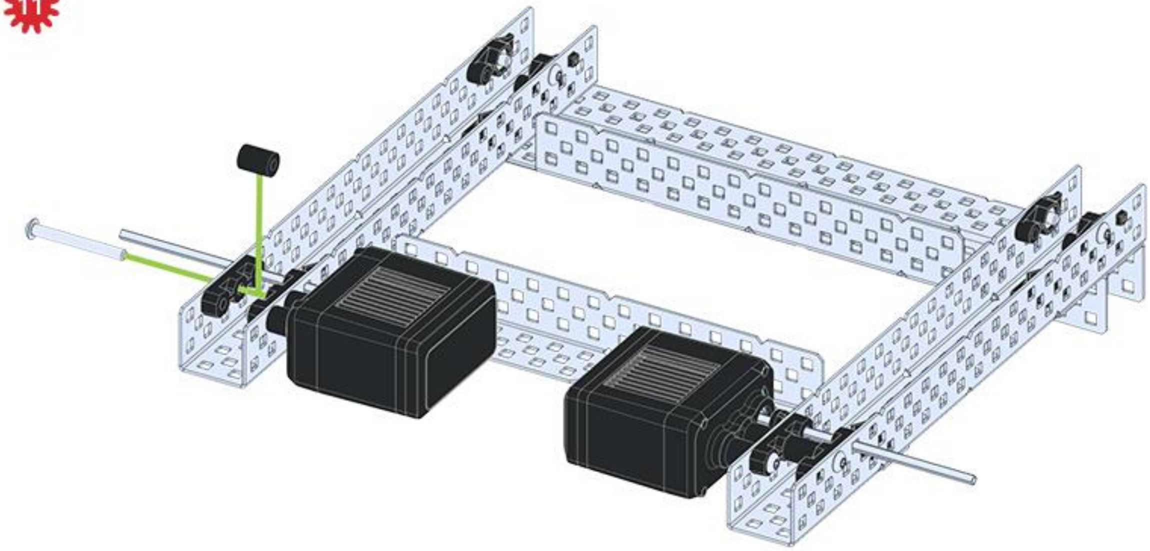

8
**1x** - 0.5 in Spacer
**1x** - 8-32 x 1.5 in Screw


9
6
2x - Bearing Flat
1x - Step 6 Sub-Assembly



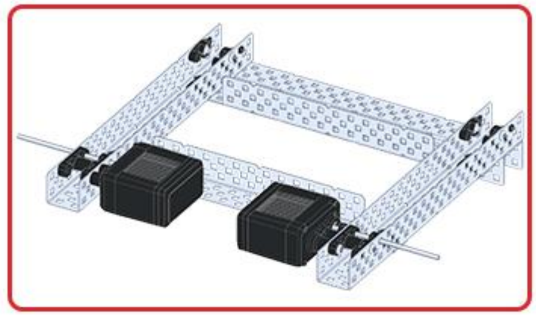

*Make sure your Smart Motors are oriented in the correct direction (screw holes facing the outside of the build and the shaft hole towards the inside).*

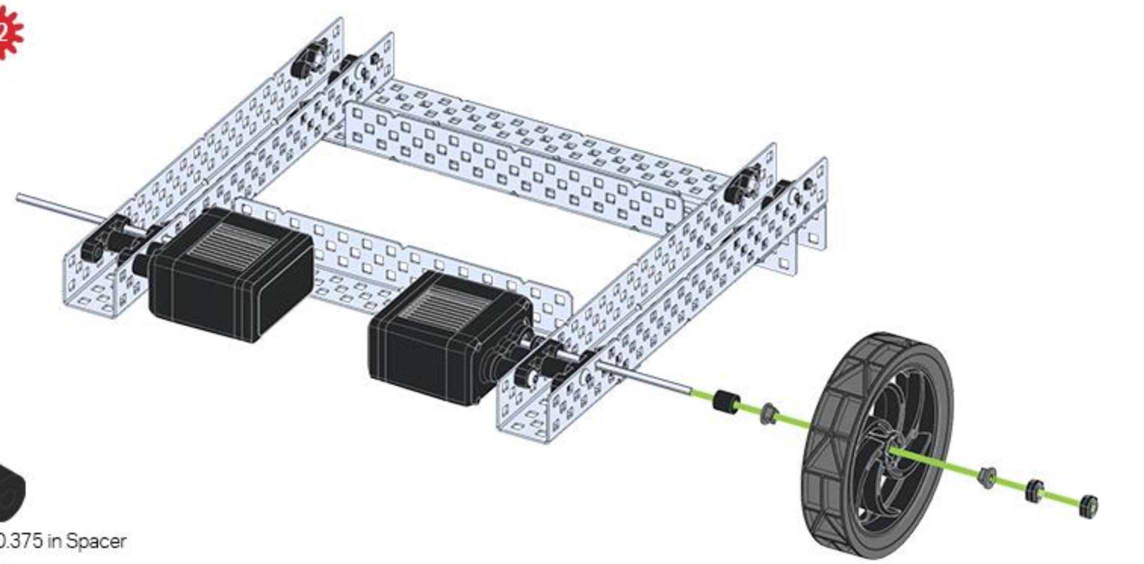
11



1x - 0.5 in Spacer

1x - 8-32 x 1.5 in Screw



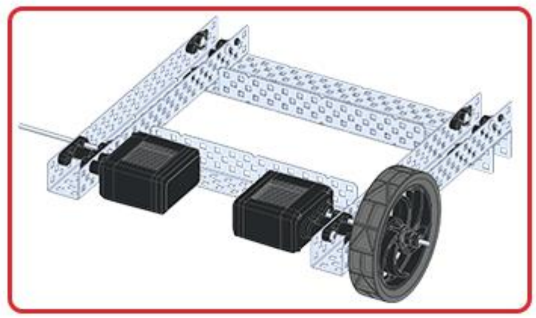



**1x** - 0.375 in Spacer

**2x** - Rubber Shaft Collar

**1x** - 4 in Wheel

**2x** - High Strength Shaft Insert



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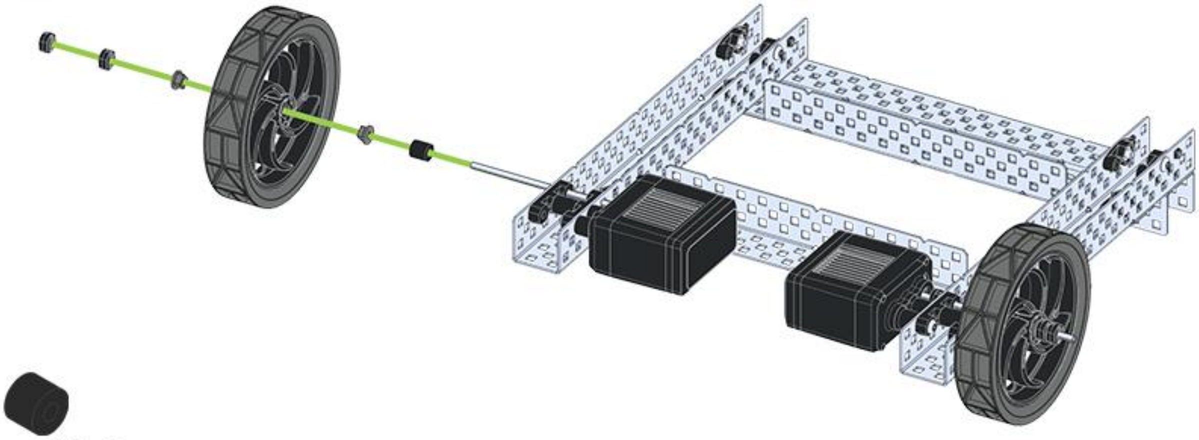
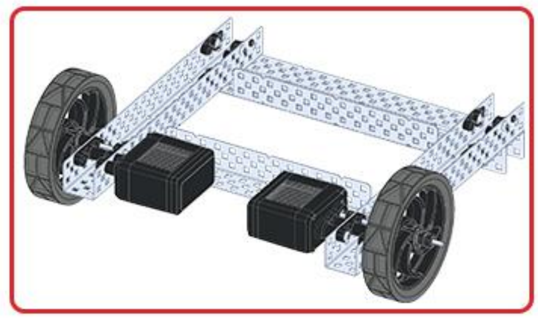


**1x** - 0.375 in Spacer

**2x** - Rubber Shaft Collar

**1x** - 4 in Wheel

**2x** - High Strength Shaft Insert



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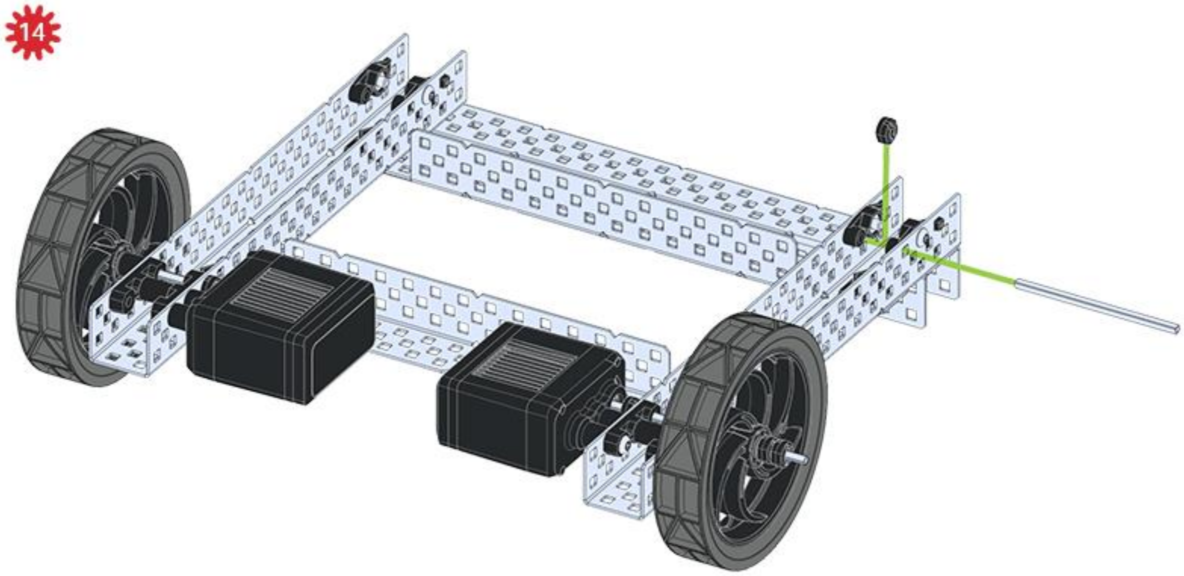
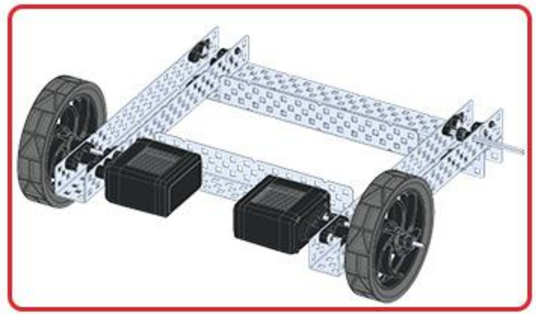


**1x** - Rubber Shaft Collar

**1x** - 3 in Shaft



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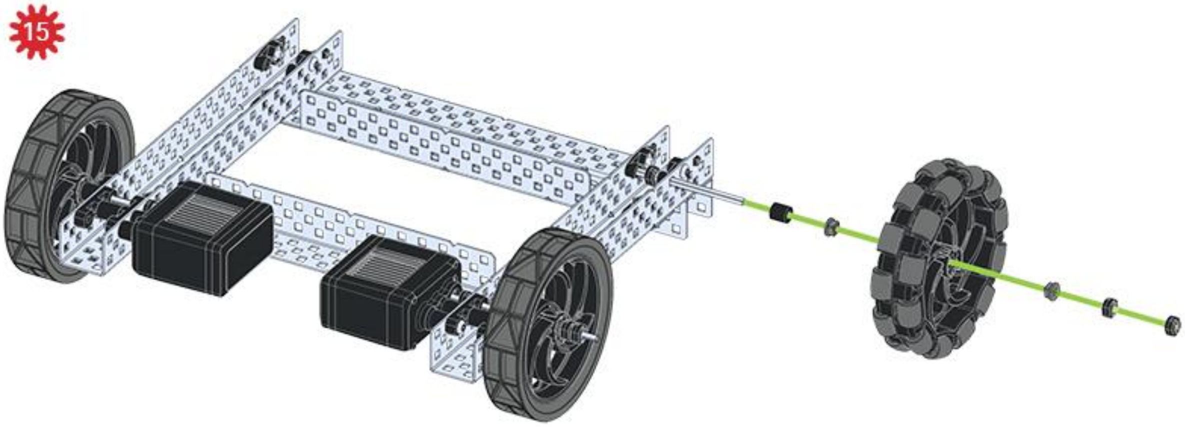
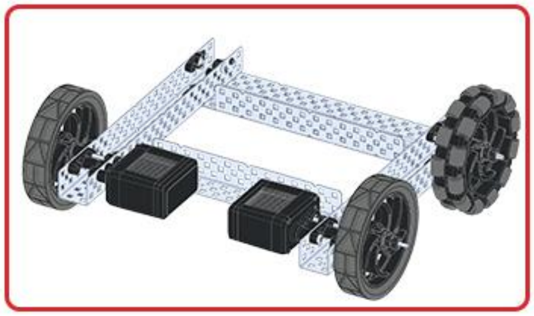


**1x** - 0.375 in Spacer

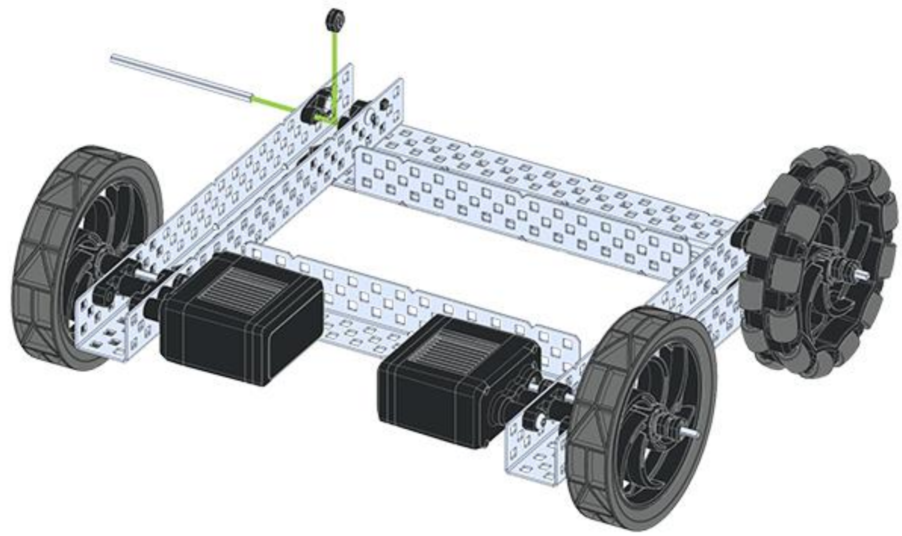
**2x** - Rubber Shaft Collar

**1x** - 4 in Omni Wheel

**2x** - High Strength Shaft Insert

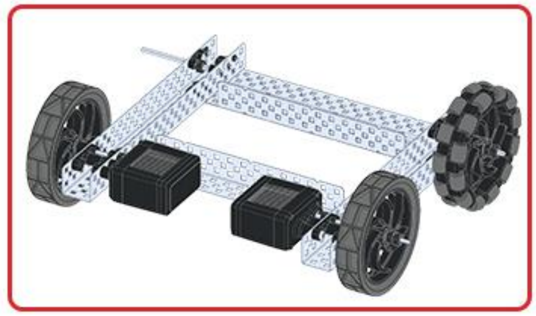


16



**1x** - Rubber Shaft Collar

**1x** - 3 in Shaft



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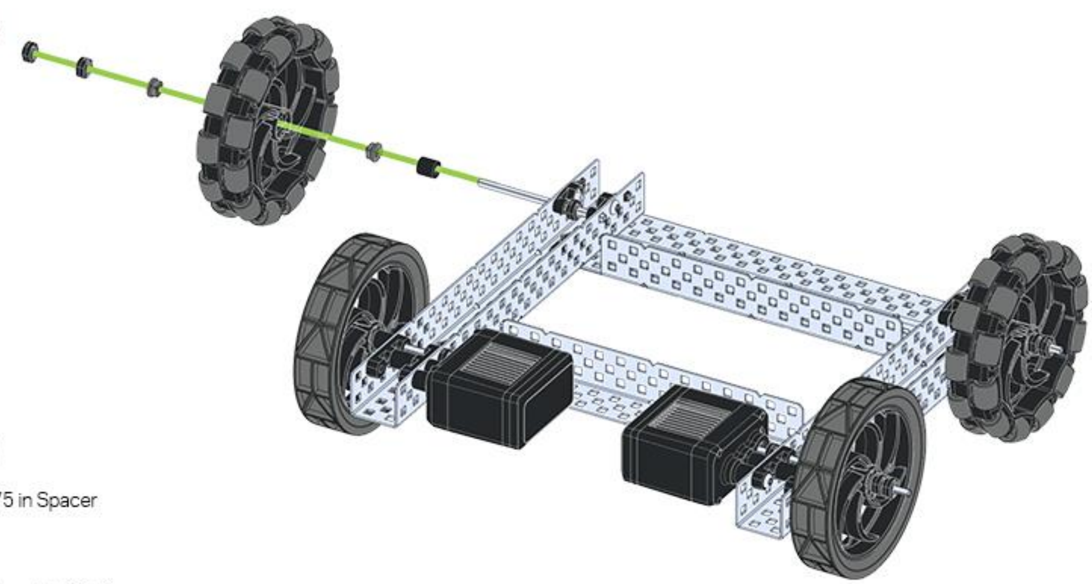
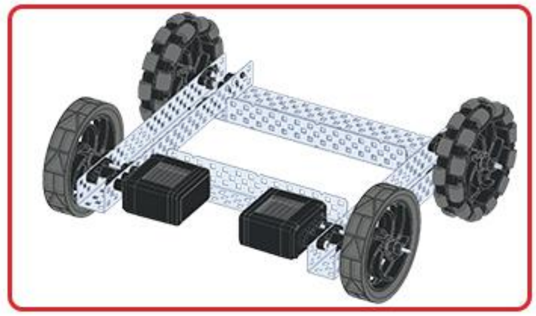


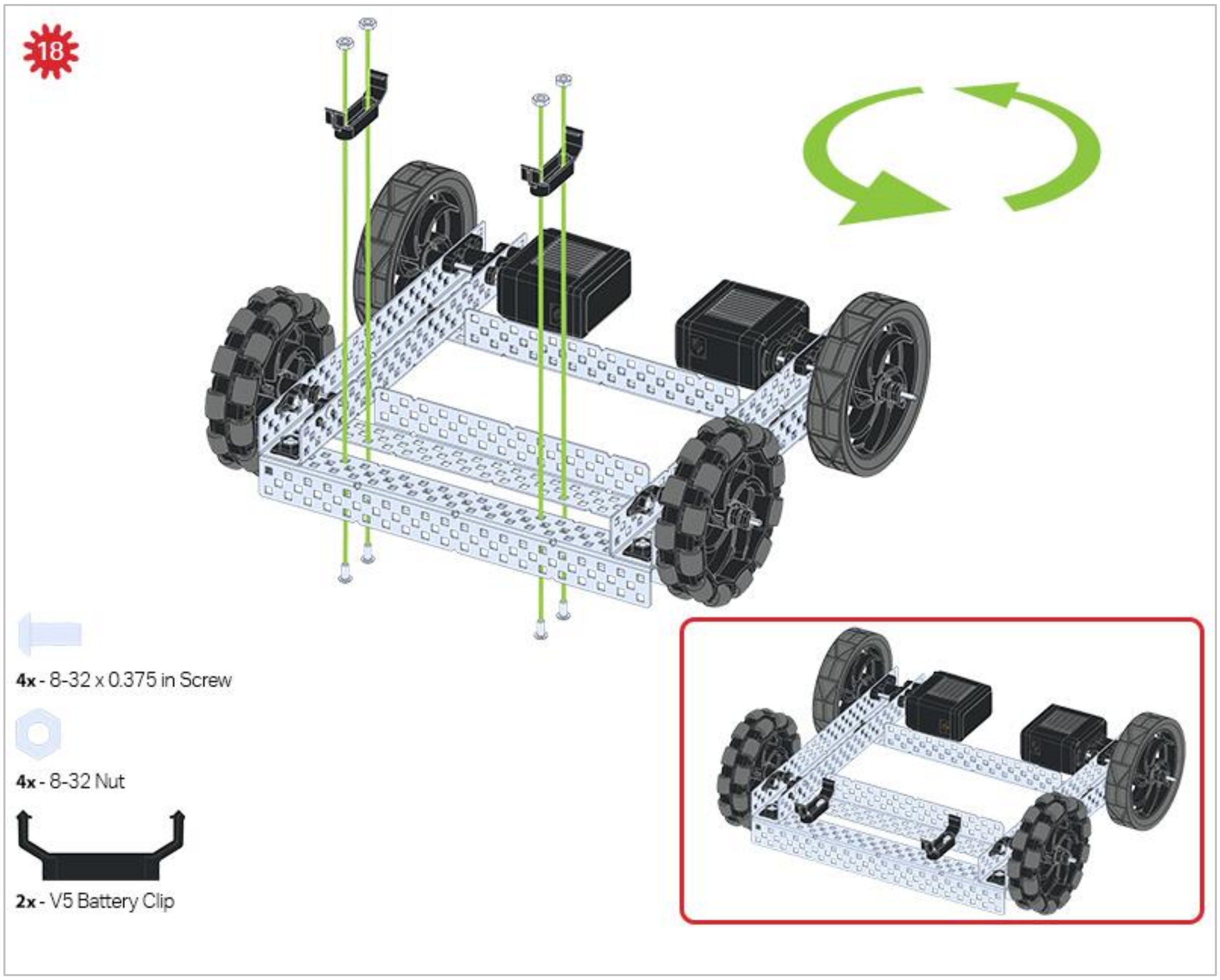
**1x** - 0.375 in Spacer

**2x** - Rubber Shaft Collar

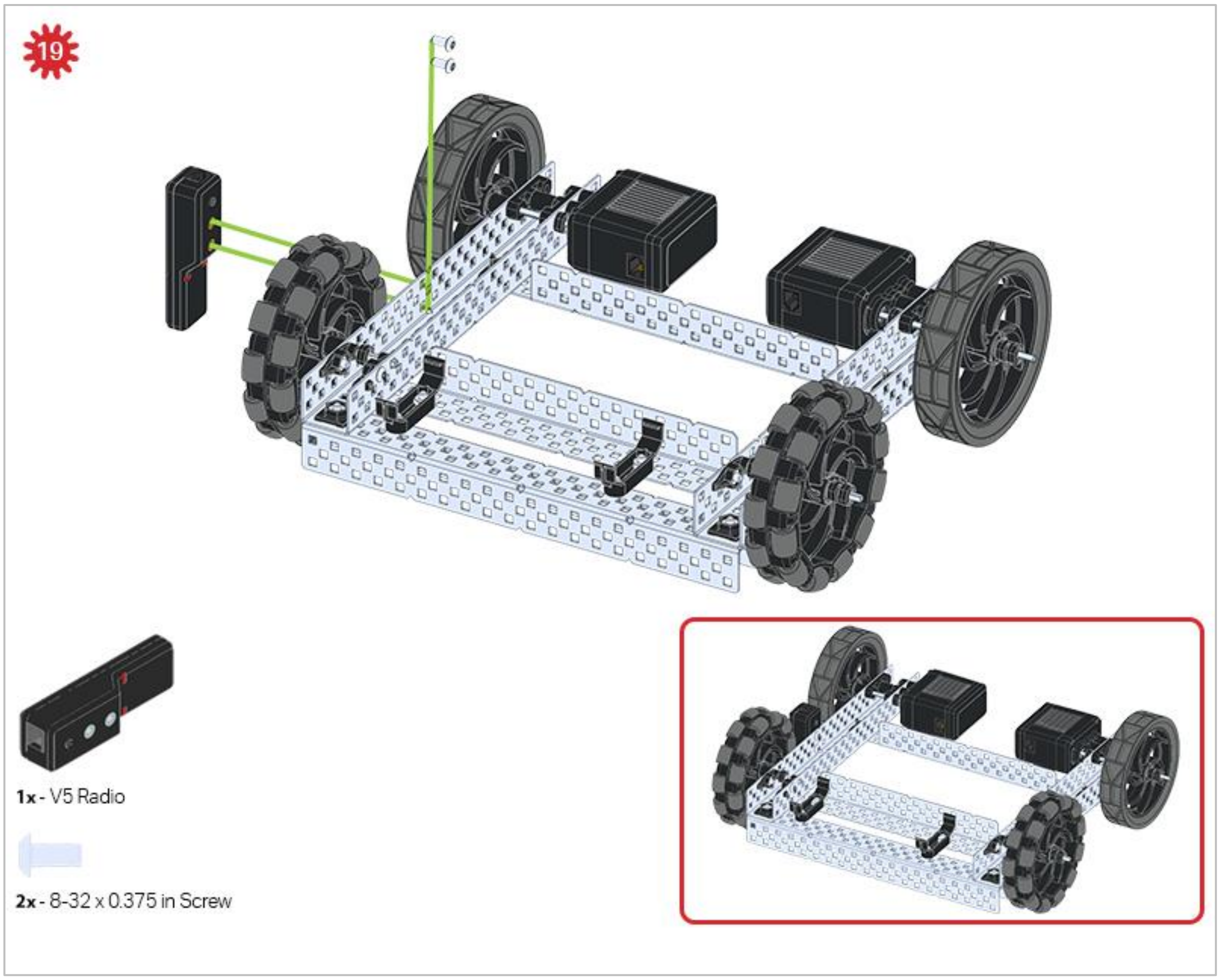
**1x** - 4 in Omni Wheel

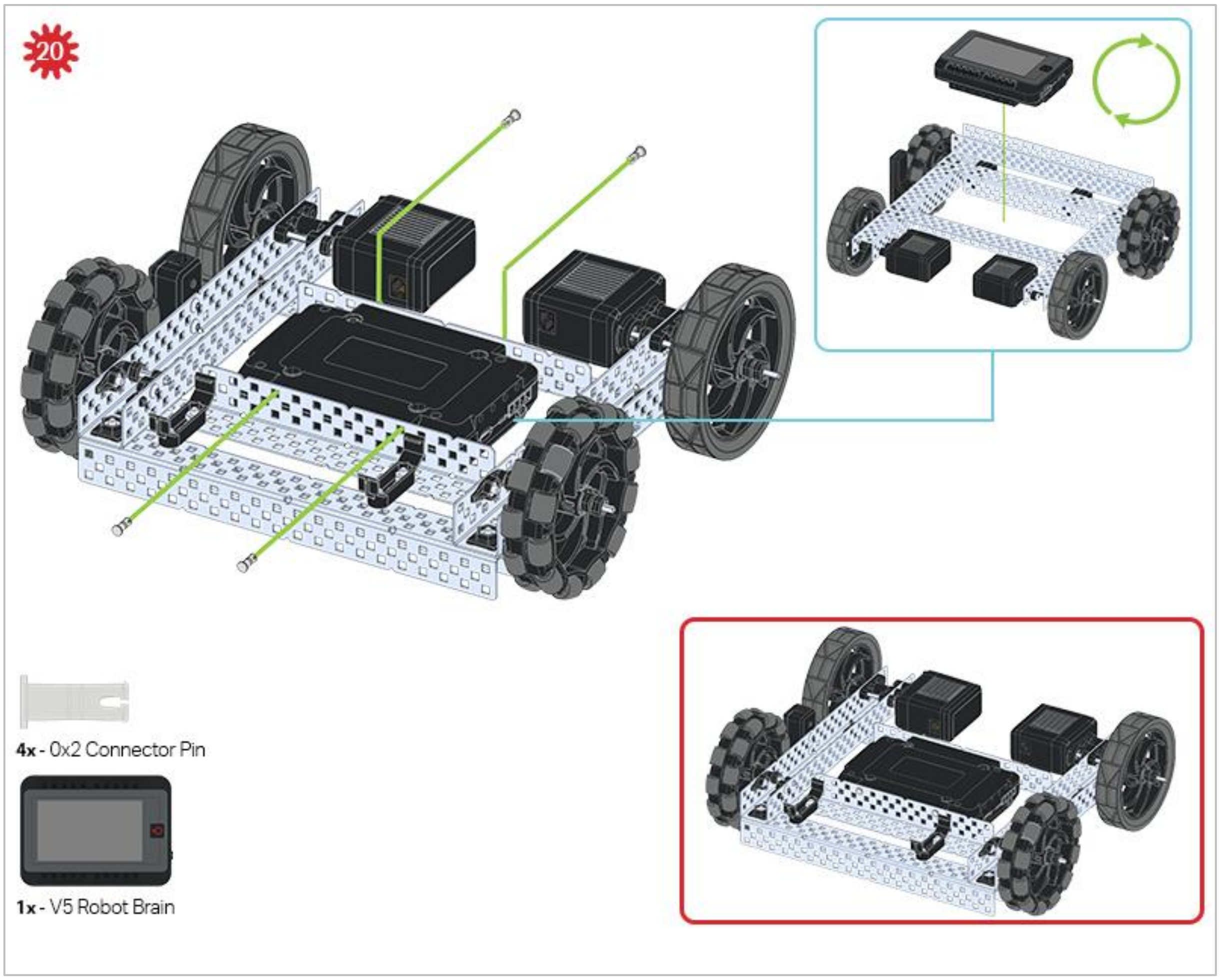
**2x** - High Strength Shaft Insert





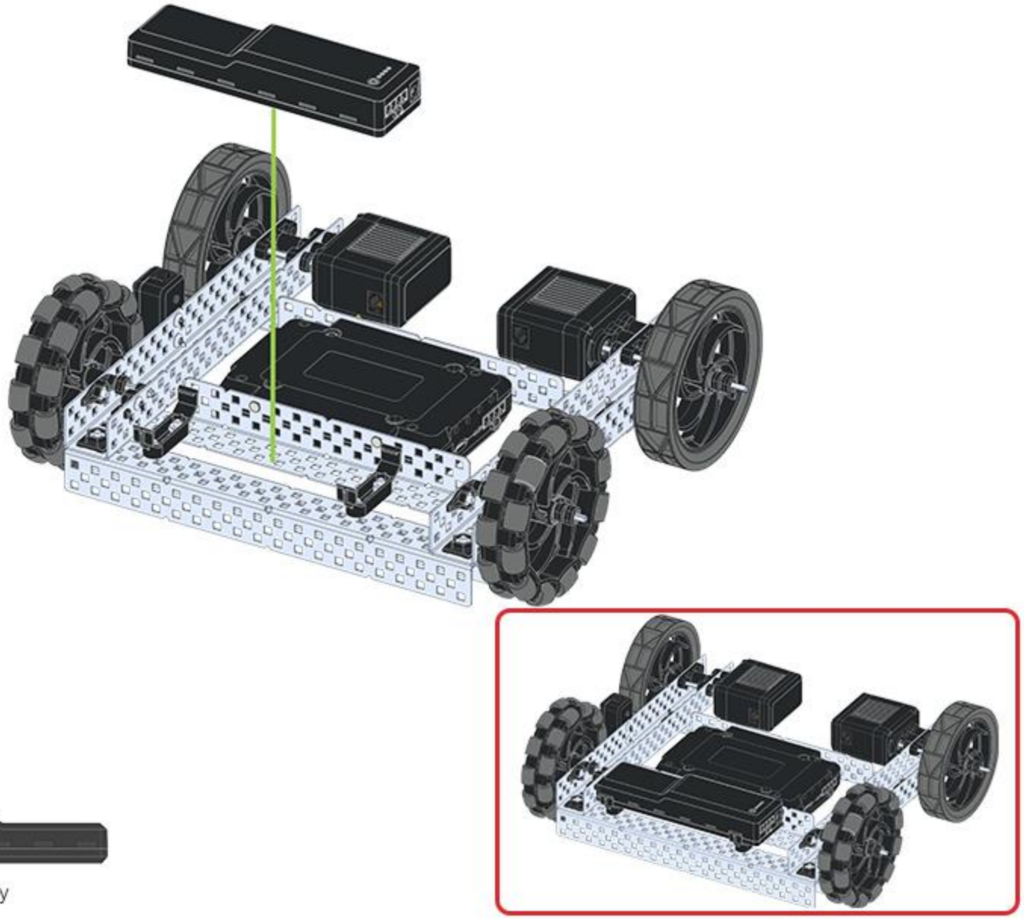

*The green icon indicates that the build needs to be rotated (180 degrees).*


19
1x - V5 Radio
2x - 8-32 x 0.375 in Screw

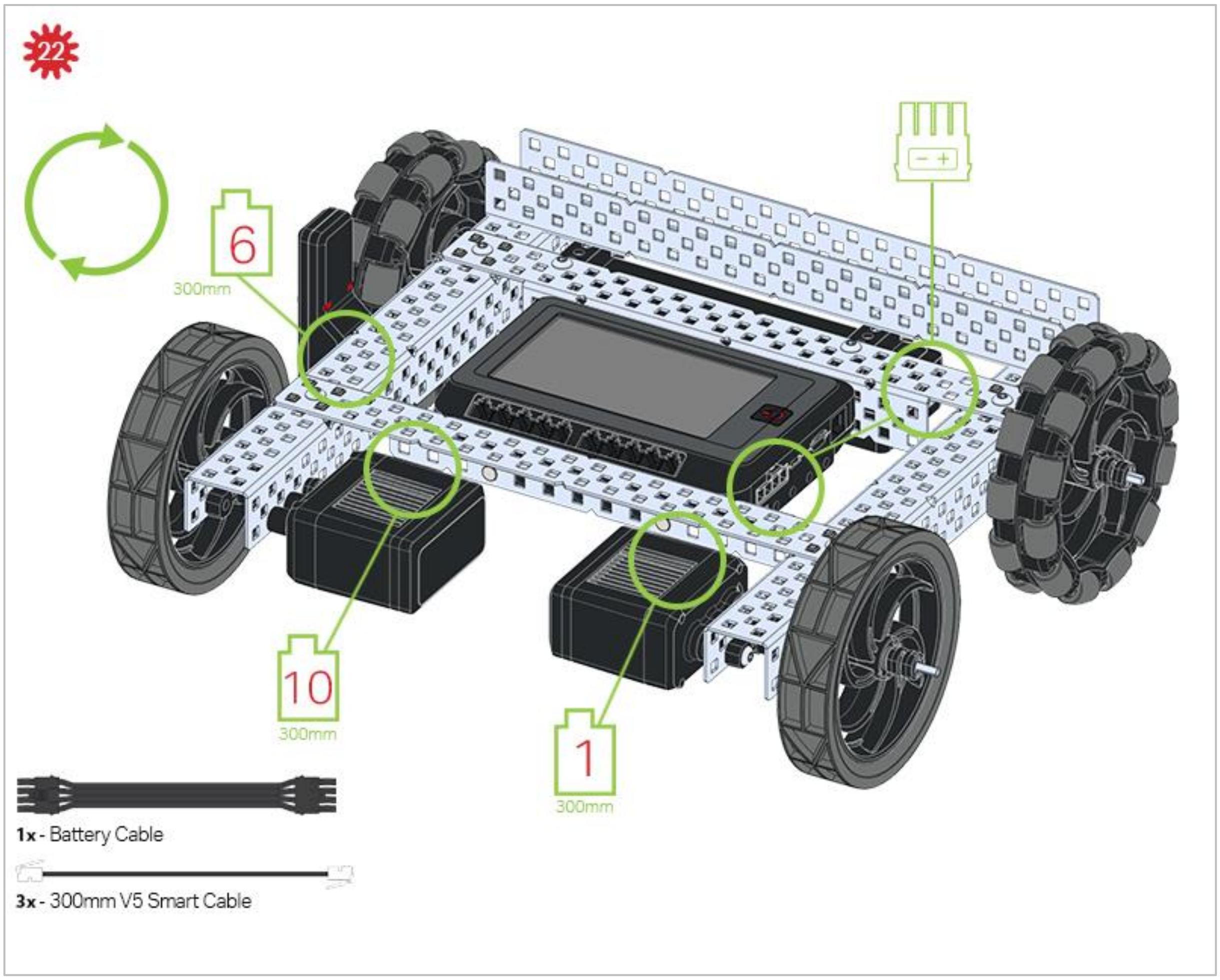



*The blue call out shows what the orientation of the Robot Brain should be if the build were flipped right side up. Make sure the 3 wire ports on the Robot Brain are facing the V5 Radio!*

21



**1x** - V5 Robot Battery




*The green call outs indicate which port on the Robot Brain to plug each device into using their respective cable.*

## Build Instruction Tips

Check the Appendix for info on how to use the new Hex Nut Retainers.

# Exploration

The VEX V5 Speedbot is meant to get you comfortable working with the system as quickly as possible. Now that the build is finished, experiment and see what it can do. Then answer these questions in your engineering notebook.

- What types of activities could this Speedbot be used for in the real-world?
- If this Speedbot was 5 times larger, how would that change in size revise what the robot is capable of doing? What advantages would there be with a bigger robot?
- If this Speedbot was 5 times smaller, how would that change in size revise what the robot is capable of doing? What advantages would there be with a smaller robot?

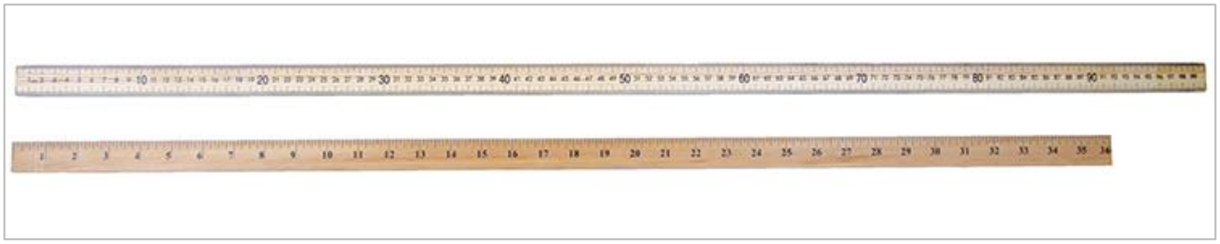
Test your build, observe how it functions,
and fuel your logic and reasoning skills
through imaginative, creative play.

# Converting Units

**Vocabulary**

The following mathematical vocabulary will be used throughout this STEM Lab:

- Proportion: When two ratios are equal.
- Ratio: A mathematical comparison of two values.
- Unit Ratio: A ratio with a denominator of 1.
- Conversion Factor: An expression for the equal exchange between units.
- Unit Conversion: The process of converting a measurement in one set of units to the same measurement in another set of units.
- Scale: The relationship or ratio between a set distance on a map, model or drawing and the corresponding measurement on the actual object.
- Scale Drawing: The drawing of an object that is proportional.



*A meter stick and yard stick side by side*

## Changing Units Without Changing Measurements

Sometimes, different designers may use different sets of units. For example, much of the world uses metric units like meters and centimeters, but a few places in the world uses imperial units like feet and inches. If we have different ways of measuring things, we could easily get the wrong measurements!

When converting between measurements, it is helpful to use conversion factors. Here are some examples:

- 1 meter = 100 centimeters = 1000 millimeters
- 1 inch = 2.54 centimeters = 25.4 millimeters = 0.0254 meters
- 1 yard = 3 feet = 36 inches = 914.4 millimeters
- 1 kilogram = 1000 grams

- 1 liter = .001 cubic meters

How many inches is 5 meters? Use the conversion factor 1 inch = 0.0254 meters.

$$5\ meters = \frac{5\ m}{1}$$

↑ Re-write 5 meters as $\frac{5}{1}$ to make cancelation easier.

---

$$\frac{5\ m}{1} \bullet \frac{1\ inch}{0.0254\ m}$$

↑ Multiply by the conversion factor of 1 inch = 0.0254 meters. It is important to understand that the conversion factor is equivalent to 1 and multiplying by it does not change any quantities.

---

$$\frac{5\ \cancel{m}}{1} \bullet \frac{1\ inch}{0.0254\ \cancel{m}} = \frac{5\ inches}{0.0254}$$

↑ Notice here that the units of meters cancel since we have meters in the numerator and denominator. Thus, we are just left with the unit of inches. Fraction multiplication is carried out by multiplying straight across in the numerator and denominator.

---

$$\frac{5\ inches}{0.0254} = \frac{196.85\ inches}{1} = 196.85\ inches$$

↑ Converting back to a unit ratio using division, we see that 5 meters converts to 196.85 inches.

---

$$\frac{196.85\ inches}{1} \bullet \frac{1\ foot}{12\ inches} = \frac{196.85\ feet}{12} = 16.4\ feet$$

↑ Converting further shows that 5 meters = 196.85 inches =16.4 feet.

How many centimeters is 36 inches? Use the conversion factor 1 in = 2.54 cm.

$$36\ inches = \frac{36\ in}{1}$$

↑ Re-write 36 inches as $\frac{36}{1}$ to make cancelation easier.

---

$$\frac{36\ in}{1} \bullet \frac{2.54\ cm}{1\ in}$$

↑ Multiply by the conversion factor of 2.54 centimeters = 1 inch. It is important to understand that the conversion factor is equivalent to 1 and multiplying by it does not change any quantities.

---

$$\frac{36\ \cancel{in}}{1} \bullet \frac{2.54\ cm}{1\ \cancel{in}} = \frac{91.44\ cm}{1}$$

↑ Notice here that the units of inches cancel since we have inches in the numerator and denominator. Thus, we are just left with the unit of centimeters. Fraction multiplication is carried out by multiplying straight across in the numerator and denominator.

---

$$\frac{91.44\ cm}{1} = 91.44\ centimeters$$

↑ We see that 36 inches converts to 91.44 cm.

# Understanding Scale

*Using scale is an important skill to learn.*

## What is "Scale"

Scale is the relationship or ratio between a set distance on a map or drawing and its corresponding distances in real life. Materials that use scale, such as blueprints, are often considered more valuable because they allow the user to perceive distance visually, therefore making them more effective models. Being able to convert measurements when working with scale is important for careers that incorporate maps, blueprints, and architectural models. Professionals such as architects, engineers, military soldiers, and set designers all use scale in some fashion in their industry.

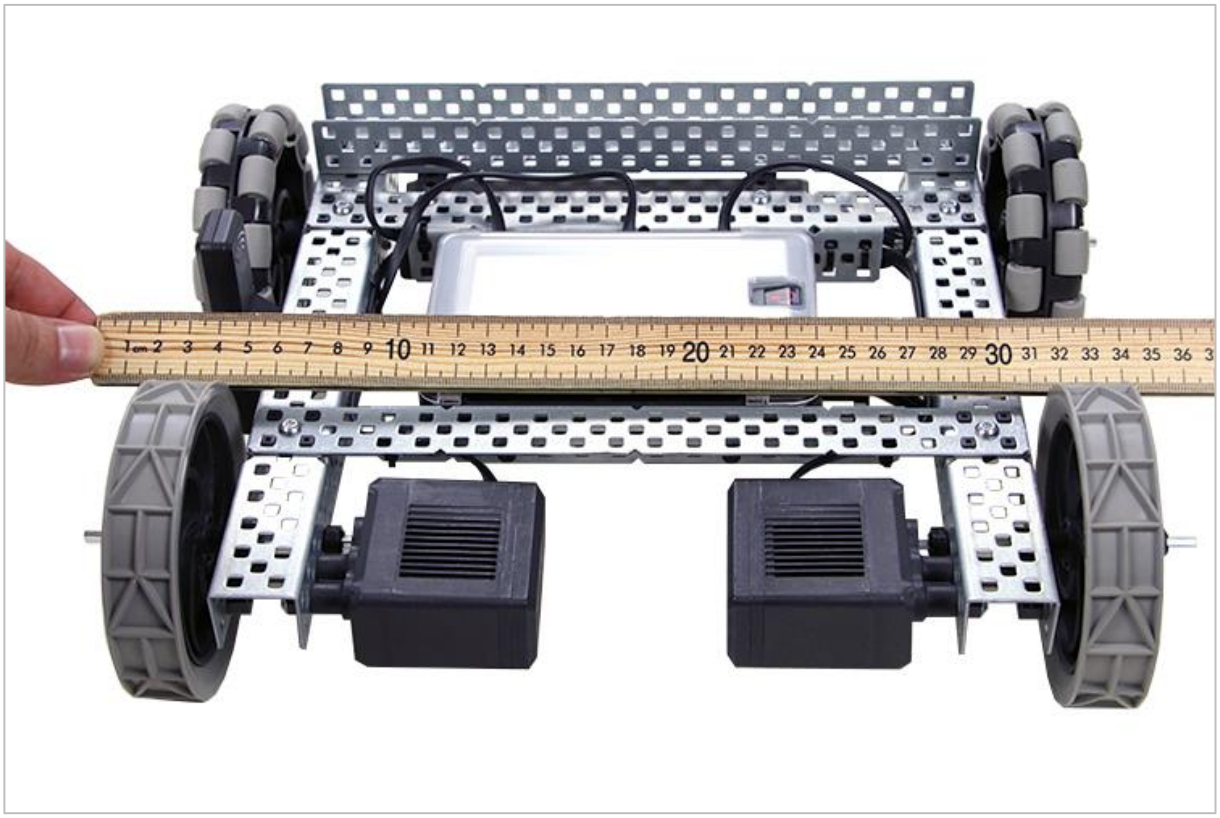
Developing a detailed sketch as a plan is an important step in the engineering design process. When we make a scaled copy of an object, the original and the copy must have the same proportions. To present how much an object has actually been scaled down (or up), we often use ratios. These ratios are displayed on the scaled copy so that the real-life object can be represented correctly. For example, a scale on a drawing may be represented as 1 cm = 20 m. This lets a team know that for every 1 cm on the sketch, the real-life measurement is 20 m. So, if a wall is represented on the sketch as 4 cm, the real-life wall needs to be 80 m. When engineers construct things like highways or buildings, the scaled plans are checked continuously to make sure the proportions are always correct. Breaking the real-life model down into sections and checking that the proportions are correct while completing each section is one way teams work to make sure that they are keeping to scale. Mistakes can cause a loss of substantial time, money and materials, so keeping with the accuracy of the scale is essential.

# Designing and Scaling a Race Course

**Hardware/Software Required:**

| Quantity | Hardware/others Items |
| --- | --- |
| 1 | Engineering Notebook |
| 1 | Roll of Tape |
| 1 | VEX V5 Speedbot with a charged battery. |
| 1 | VEX V5 Controller |
| 1 | Meter Stick or Ruler |

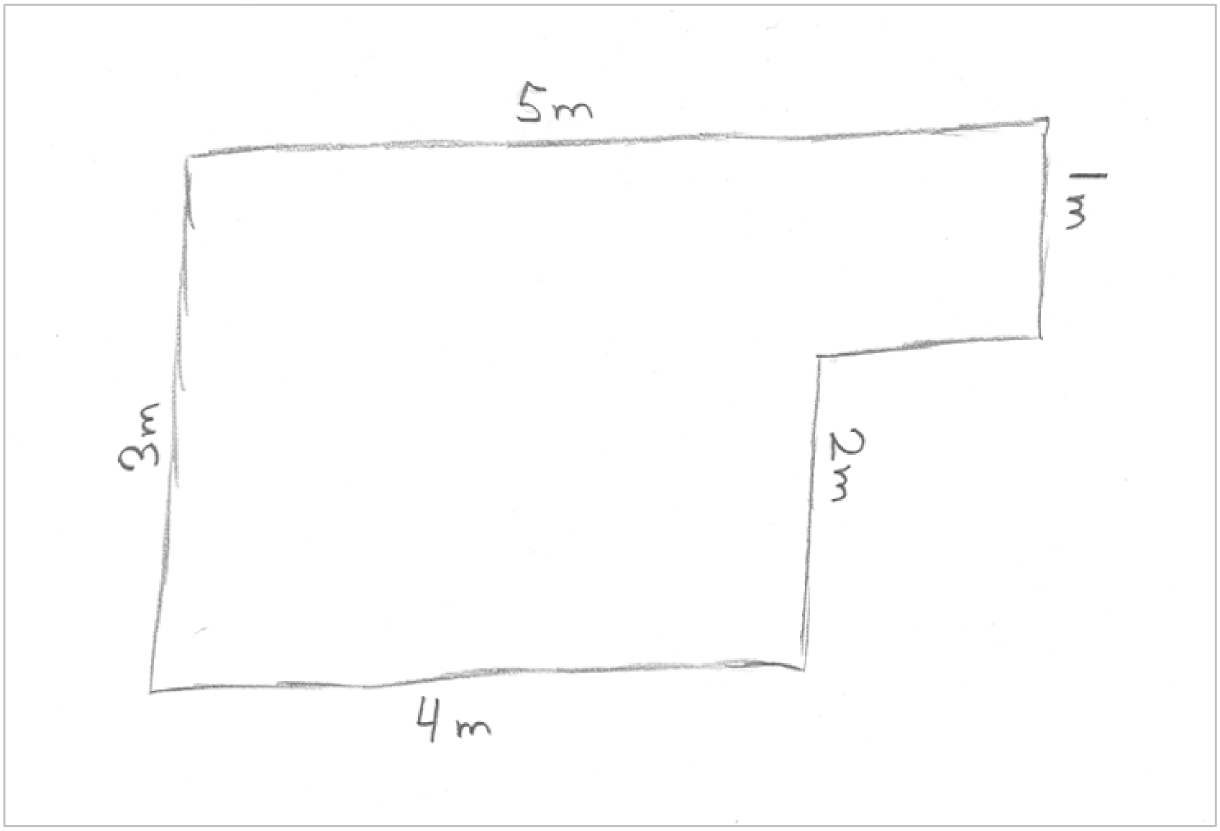
## 1. Measuring Your Robot



*Measuring the width of the VEX V5 Speedbot*

Measure the length and width of the VEX V5 Speedbot using a meter stick or ruler and write its dimensions in your engineering notebook.

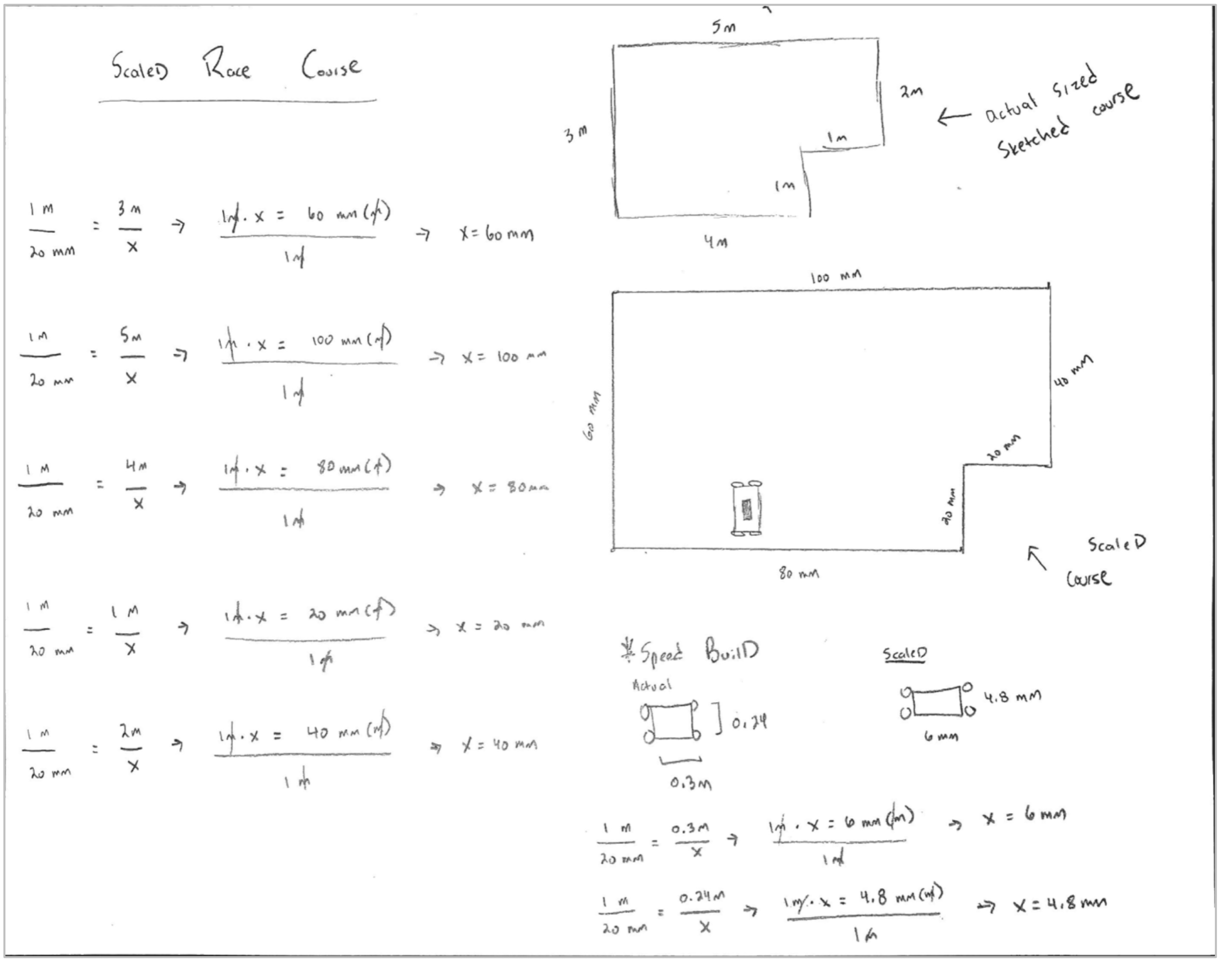
## 2. Sketching and Measuring the Area




*Example sketch of an area with measurements*

Draw a simple sketch of the available area for your race course design in your engineering notebook. Using a meter stick or ruler, measure the dimensions of the area and record them on the sketch of the area in your engineering notebook.

## 3. Creating a Scaled Version




*Example of a scaled area sketch*

In your engineering notebook, create a scaled version of the area you sketched using your recorded measurements. Before starting, decide the scale at which you would like to recreate the area in meters. For example, 20 millimeters on the sketch may be 1 meter in the area you have available for your race course, like in the example above.

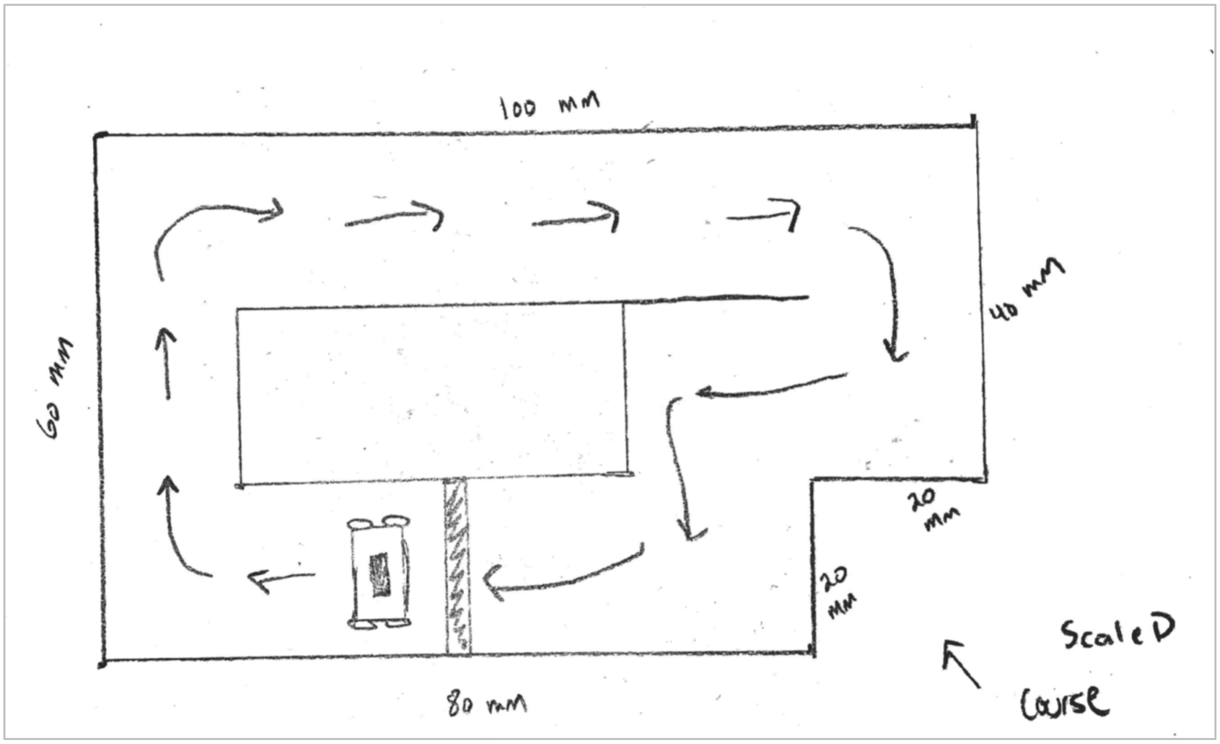
You should consider the size of your sketch when choosing the scale. Too large of a scale may not fit on the paper that you are using.

Add a scaled version of the VEX V5 Speedbot to your sketch to help visualize its scaled size in comparison to the scaled area you have created.

Respond to the questions below in your engineering notebook:

- How did you determine the scale to you use in your sketch?
- How did the dimensions of your robot influence your scale?

## 4. Designing Your Course

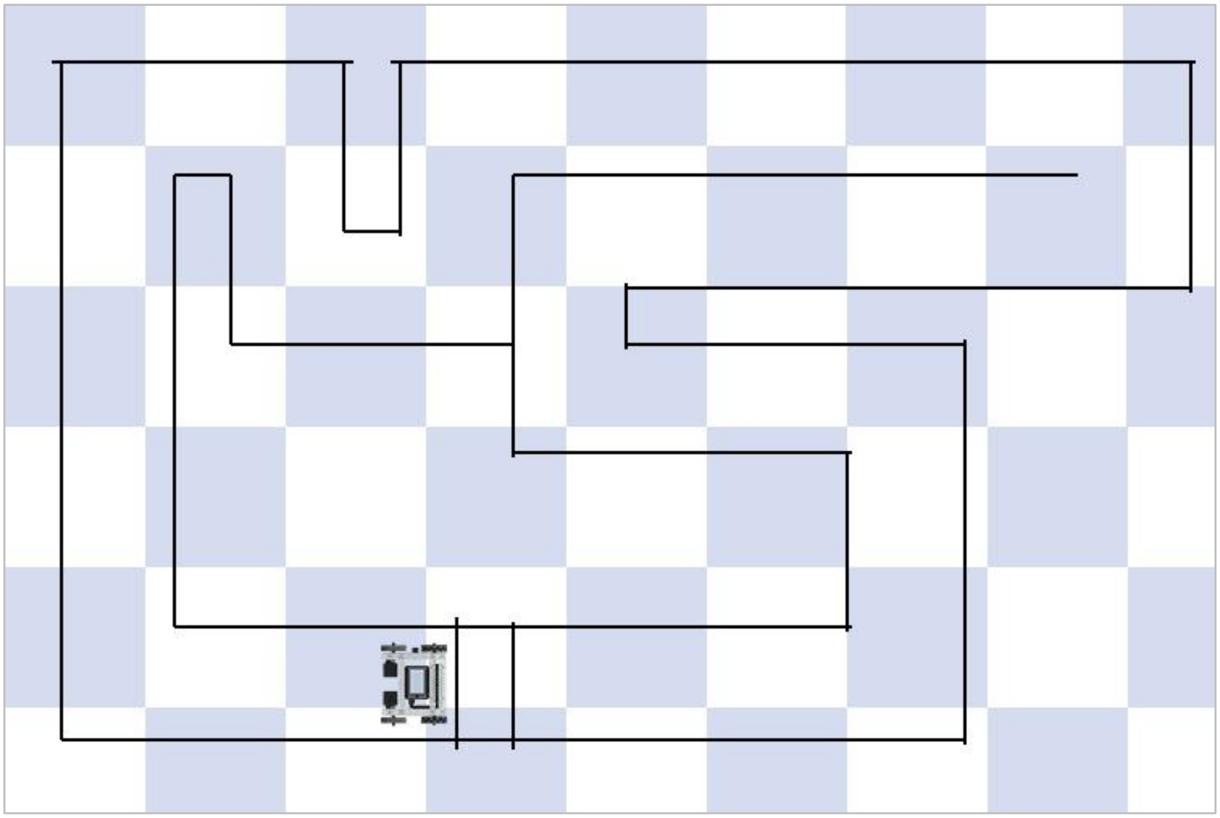



*A race course sketched within the scaled area*

Sketch a race course within the scaled area that you made in your engineering notebook. Keep in mind the size of the VEX V5 Speedbot and how it is represented in the scale that you used. The robot should be able to navigate the course without leaving the sides of the race course.

Try to be as creative as possible with your course by adding multiple turns and straightaways. Use arrows or other symbols to indicate the direction the robot on the race course should travel in. In addition, indicate the location of the starting and finishing lines using a symbol or lines.

## 5. Create Your Course



*Example of a full size race course*

Using tape and the scaled sketch of your race course, create a full size version of the course in the area you originally measured. Pay close attention to the scale that you chose for your drawing and use a meter stick or ruler to ensure the full size version of your course matches the dimensions of the scaled version you created in your engineering notebook.

Respond to the questions below in your engineering notebook:

- What was the most difficult part when creating a full sized version of the course from your scaled version? Why?
- What strategies did you use to determine if your measurements were accurate? How did you come up with them?

## 6. Test Your Course

*VEX V5 Speedbot that is about to test the newly built Race Course!*

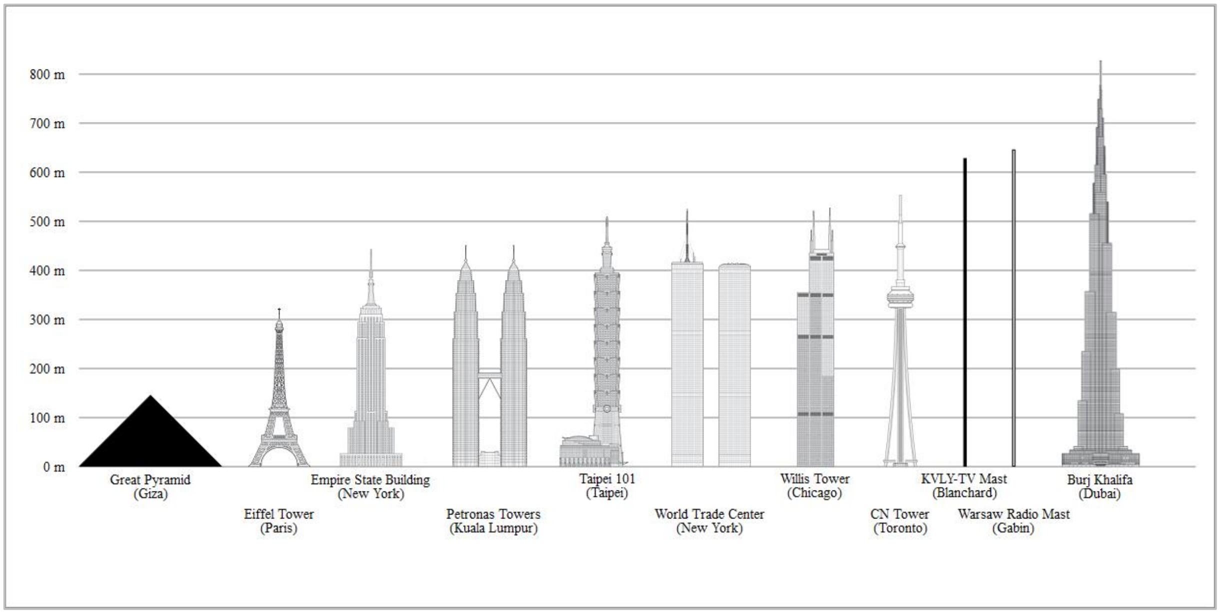
Time to test the course! Do the scaled measurements on the Race Course work? Let's find out!

Follow the following procedure:

1. Ensure both the Robot Brain and Controller are turned on.
2. Pair the V5 Controller to the V5 Robot Brain.
3. Place your Speedbot at the start line on your Race Course.
4. Review how to drive the robot using the Controller.
5. Run the Drive Program to drive the Speedbot through the Race Course.
6. Make note of any places in the Race Course that should be adjusted for size in your engineering notebook.
7. After you have driven the robot around the Race Course a few times to test the size, sketch the Race Course again with the improved sizes.
8. Re-scale the Race Course, document the changes made and why in your engineering notebook, and test it again!

Become a 21st century problem solver
by applying the core skills and concepts
you learned to other problems.

# Scaling in Architecture



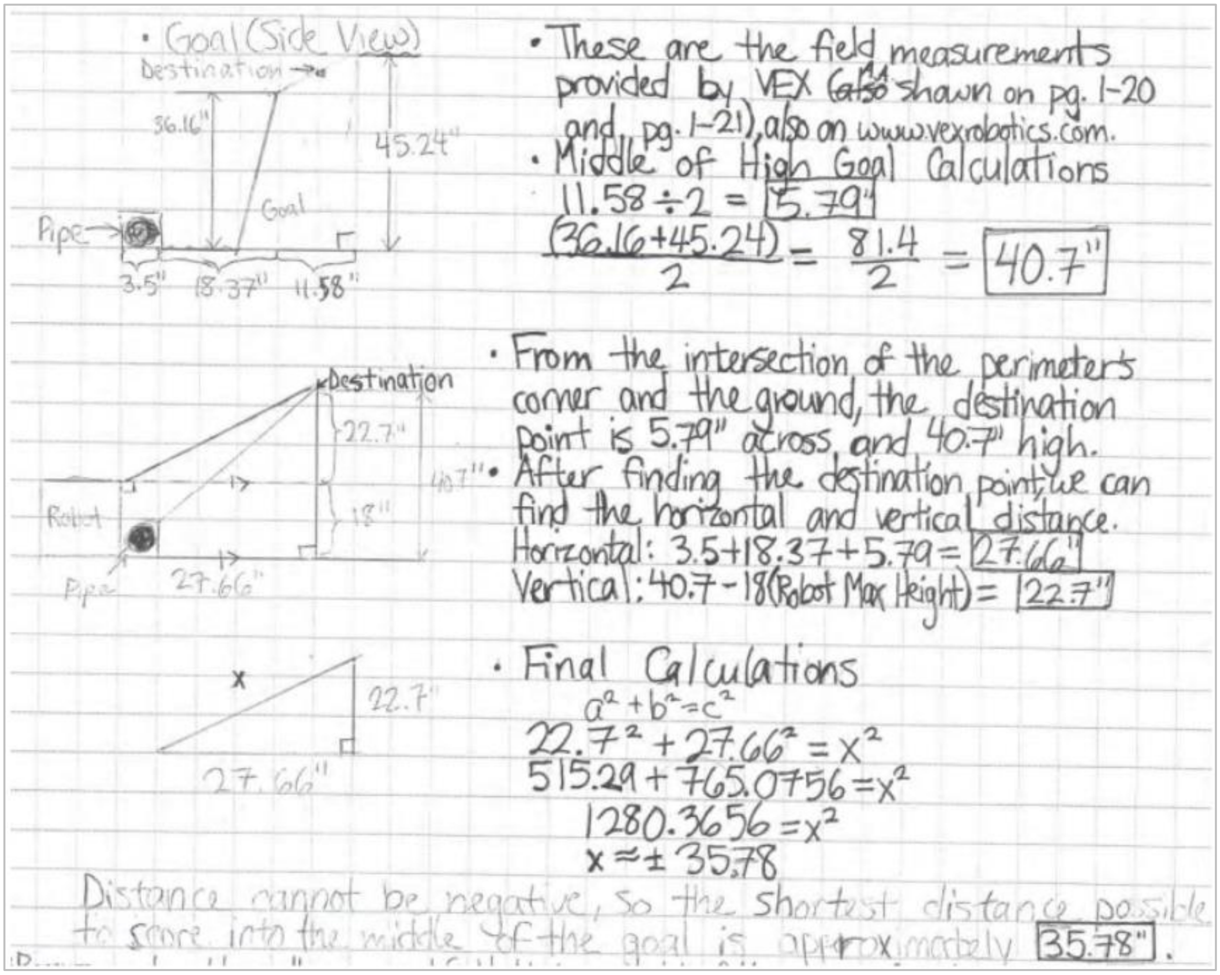

*BurjKhalifaHeight.svg: *BurjDubaiHeight.svg: Rama derivative work: Astronaut (talk) derivative work: WelcometoJurassicPark (talk), Scaling and drawings from https://commons.wikimedia.org/wiki/File:BurjKhalifaHeight.svg and http://www.skyscrapercenter.com All rights reserved. [CC BY-SA 3.0]*

An architect is a person who designs buildings or other structures. Architects need to draw scaled-down blueprints or images in order to design structures that are appropriate in size, height, etc. Could you imagine only having a small piece of land to build a building on, and it did not fit? Especially in areas that are limited on the amount of space they can use such as clustered cities. Architects scale their blueprints to size so that they fully understand how much material they need as well as make sure everything will fit properly.

There have been many famous architects throughout history. Some well-known structures include the Parthenon in Athens, Greece, and the Burj Khalifa in Dubai, which has been the tallest building in the world since 2009 at a total height of 829.8 m. However, the Jeddah Tower in Saudi Arabia scheduled to open in 2020 will become the world's tallest skyscraper. Intricate planning and calculations were required for such vast and complex structures to be built properly.

Scaling structures in the form of blueprints and sketches not only allows the designer to plan accordingly. Scaling also allows structures and buildings to be compared to each other. The image above required scaling in order to compare the relative sizes of the structures next to each other. Each actual size of 100 m is represented by approximately 10 mm on the drawing. You can view the ratio of drawing size/actual size as 10 mm/ 100 m.

# The Advantage of "Robot Math"




*A team applies math to plan a route in their engineering notebook.*

## The Advantage of "Robot Math"

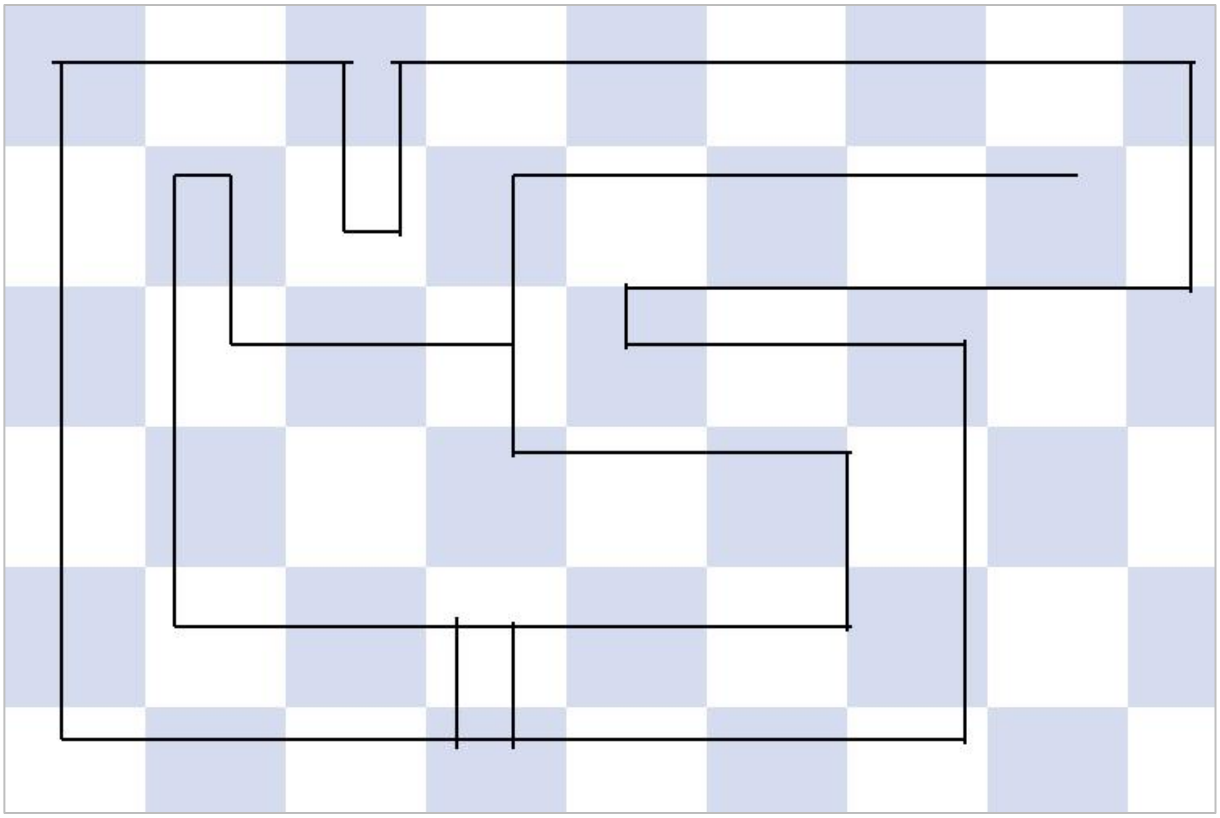
Robotics teams that effectively use math concepts, like proportional reasoning and scale, usually have the upper hand in competitions. When these teams form alliances with others during the competition, they can quickly make changes, like mapping out a new path or determining the correct motor rotation values for their autonomous programs. Knowing the math behind the changes can save valuable time. Teams then use that time to make other physical or program changes to their robots that can increase their chances of winning. Using "robot math" like proportional reasoning and scale can definitely maximize a team's performance.

In the image above, the team is using the actual measurements of the field that VEX provided to calculate the distances between different locations on the field. They then calculate the shortest distance from a particular location to the planned destination. These are particularly important calculations for moving the robot accurately during the autonomous program.

SPARK
RETHINK

Is there a more efficient way to come to the same conclusion? Take what you've learned and try to improve it.

# Prepare for the Robo Rally Challenge



*A sample Robo Rally course*

## Challenge Preparation

In this challenge, you need to drive your robot through your race course combined with another group's course! To successfully complete the challenge, teams must also create a correctly scaled map of the new combined course using the dimensions and scales from both groups.

To complete the challenge you will need:

- Multiple boxes, 3-ring binders, tape, or other objects to outline the course
- Meter stick or ruler
- Timer or stopwatch
- Engineering notebook to record values and complete calculations

- Engineering notebook to create a new scaled map of the course

# Improve Your Build

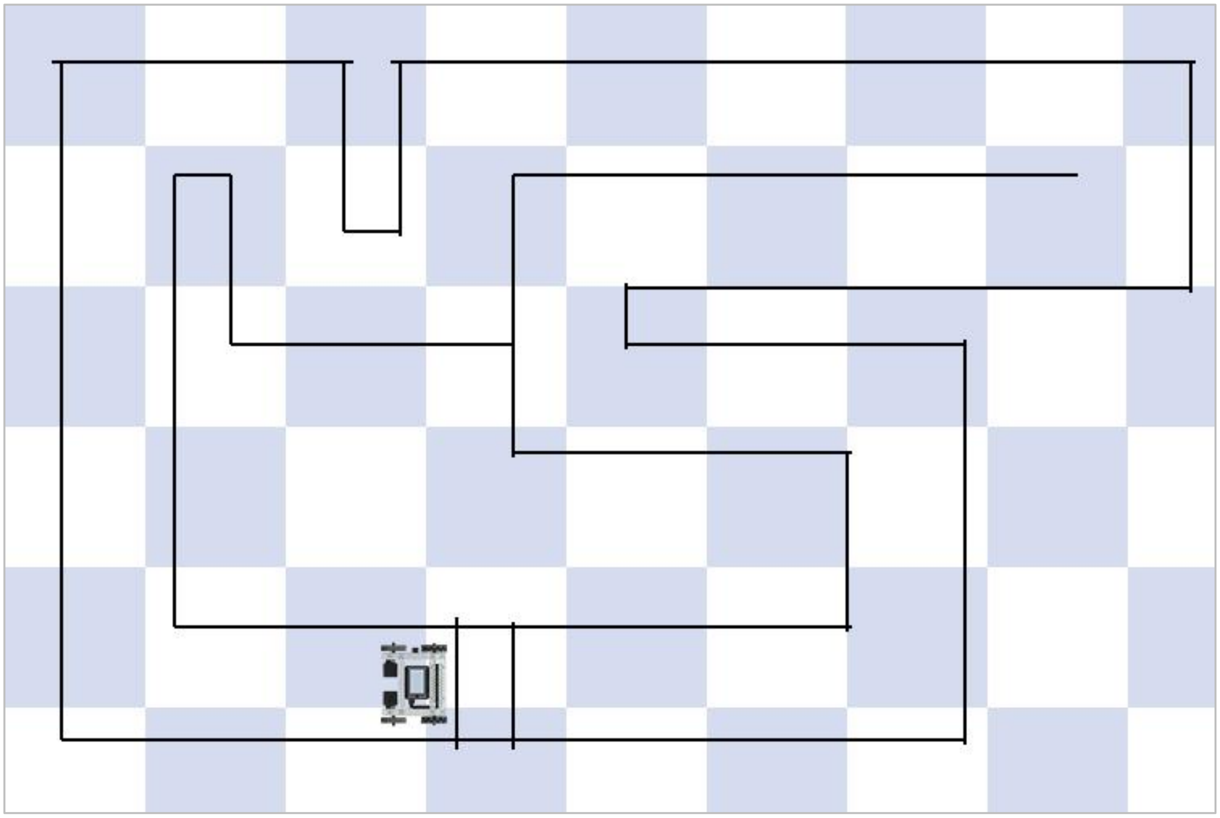
Answer the following questions in your engineering notebook as you think about the challenge.

- Was your course scaled the same as the other teams? If not, what units/scale were you using compared to them and how will you get them all in the same units?
- What areas of the course should you keep in mind as you are altering/combining them?

Think about the questions below. Record your thoughts and observations in your engineering notebook.

- Why is it important to ensure the scale and units are the same for both teams?
- If you changed the scale in your sketch to represent a larger difference in scale, how would that effect the overall challenge?

# Robo Rally Challenge



*VEX V5 Speedbot in the Robo Rally Challenge*

## Robo Rally Challenge

In this challenge, you need to drive your robot through your race course combined with another individual or team's course! To successfully complete the challenge, teams must also create a correctly scaled map of the new combined course using the dimensions and scales from both students or teams. Each team from the combined course will have a Driver that will navigate the robot through the course. The team with the Driver who completes the course the fastest, wins!

Challenge rules:

- The robot must begin and end at the finish line.
- Both teams will use the Drive Program on the Robot Brain.
- As one team member drives the robot, others should ensure the robot is not hitting the sides of the course or losing control.

- You may drive the robot through the race course one time as a practice round before time is recorded.
- The dimensions of both courses must be in the same units and scale.
- Each team must complete a new correctly scaled map, with measurements, based on the values of the combined race courses.
- Whichever team completes the same course in the shorter amount of time - wins!
- Have fun!

SPARK

KNOW

Understand the core concepts and how to apply them to different situations. This review process will fuel motivation to learn.

# Review

1. **Scale is the relationship or ratio between a set distance on a map or drawing and**
    - its deviated distances in real life.
    - its corresponding distances in real life.
    - its differing distances on the paper.
    - its offset distances on paper.

2. **True or False: When we make a scaled representation of an object, the original and the copy do not have the same proportions.**
    - True
    - False

3. **Ronda made a scale drawing of a race track in her engineering notebook. The scale she used was 1 cm = 250 km. The first portion of her track is 3 cm. How long is the actual track?**
    - 500 km
    - 850 km
    - 450 km
    - 750 km

4. **True or False: Scaling objects also allows you to properly compare them to one another.**
    - True
    - False

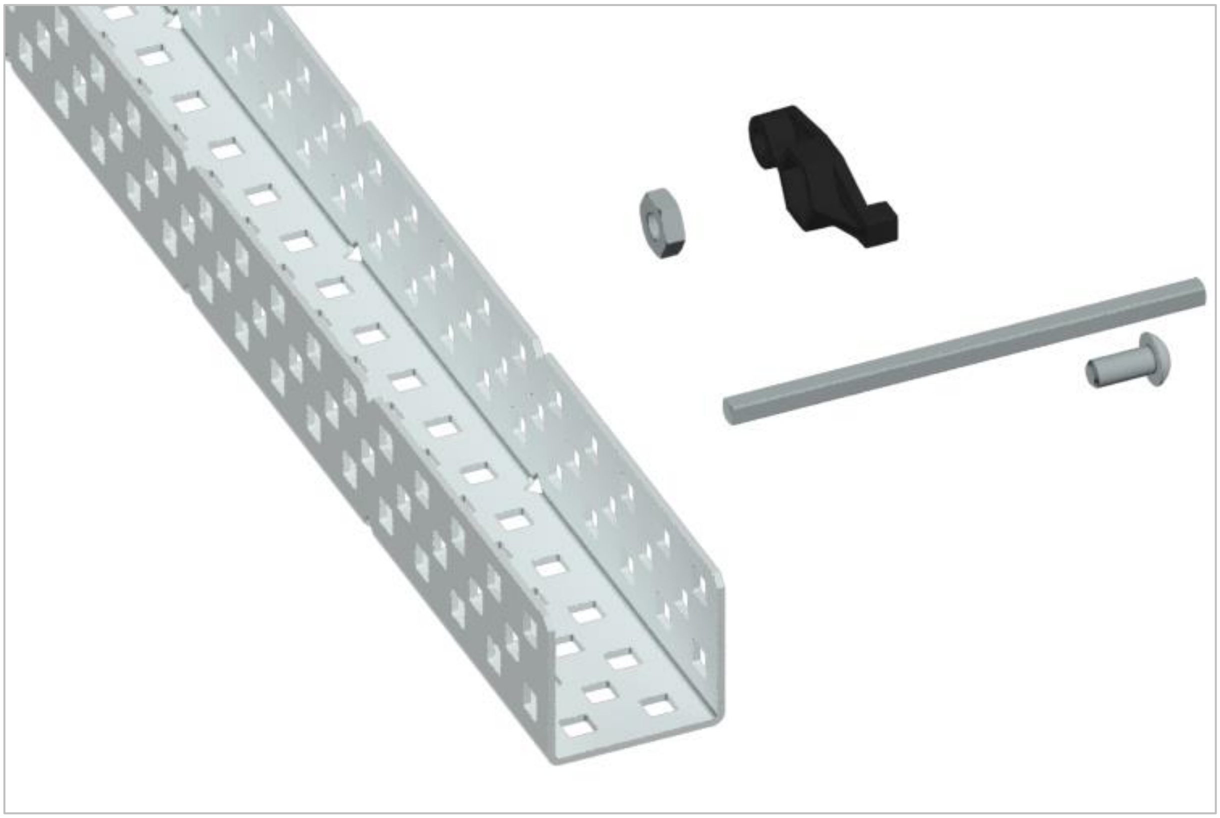
5. **Erin is going to build a model car based off of her brother's car. Her brother's car is 5 meters in length. If Erin wants her model car to have a ratio of 10 mm for every meter, how long will her model car be?**
    - 50 mm

- 500 mm
- 5 mm
- 5000 mm

# APPENDIX

Additional information, resources, and materials.

# Using the 1 Post Hex Nut Retainer w/ Bearing Flat



*1 Post Hex Nut Retainer w/ Bearing Flat*

## Using the 1 Post Hex Nut Retainer w/ Bearing Flat

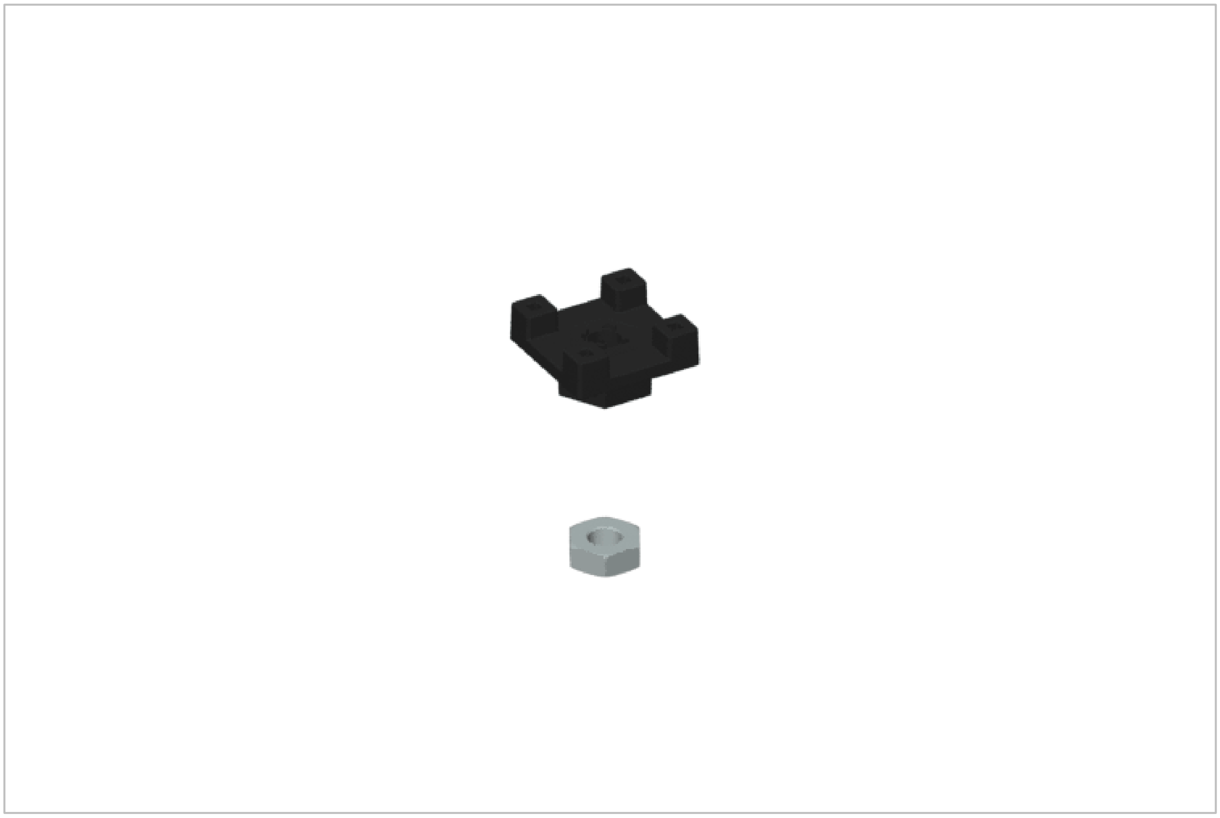
The 1 Post Hex Nut Retainer w/ Bearing Flat allows shafts to spin smoothly through holes in structural components. When mounted, it provides two points of contact on structural components for stability. One end of the retainer contains a post sized to securely fit in the square hole of a structural component. The center hole of the retainer is sized and slotted to securely fit a hex nut, allowing a 8-32 screw to easily be tightened without the need for a wrench or pliers. The hole on the end of the Retainer is intended for shafts or screws to pass through.

To make use of the retainer:

- Align it on a VEX structural component such that the end hole is in the desired location, and the center and end sections are also backed by the structural component.

- Insert the square post extruding from the retainer into the structural component to help keep it in place.
- Insert a hex nut into the center section of the retainer so that it is flush with the rest of the component.
- Align any additional structural components to the back of the main structural component, if applicable.
- Use an 8-32 screw of appropriate length to secure the structural component(s) to the retainer through the center hole and hex nut.

# Using the 4 Post Hex Nut Retainer



*4 Post Hex Nut Retainer*

## Using the 4 Post Hex Nut Retainer

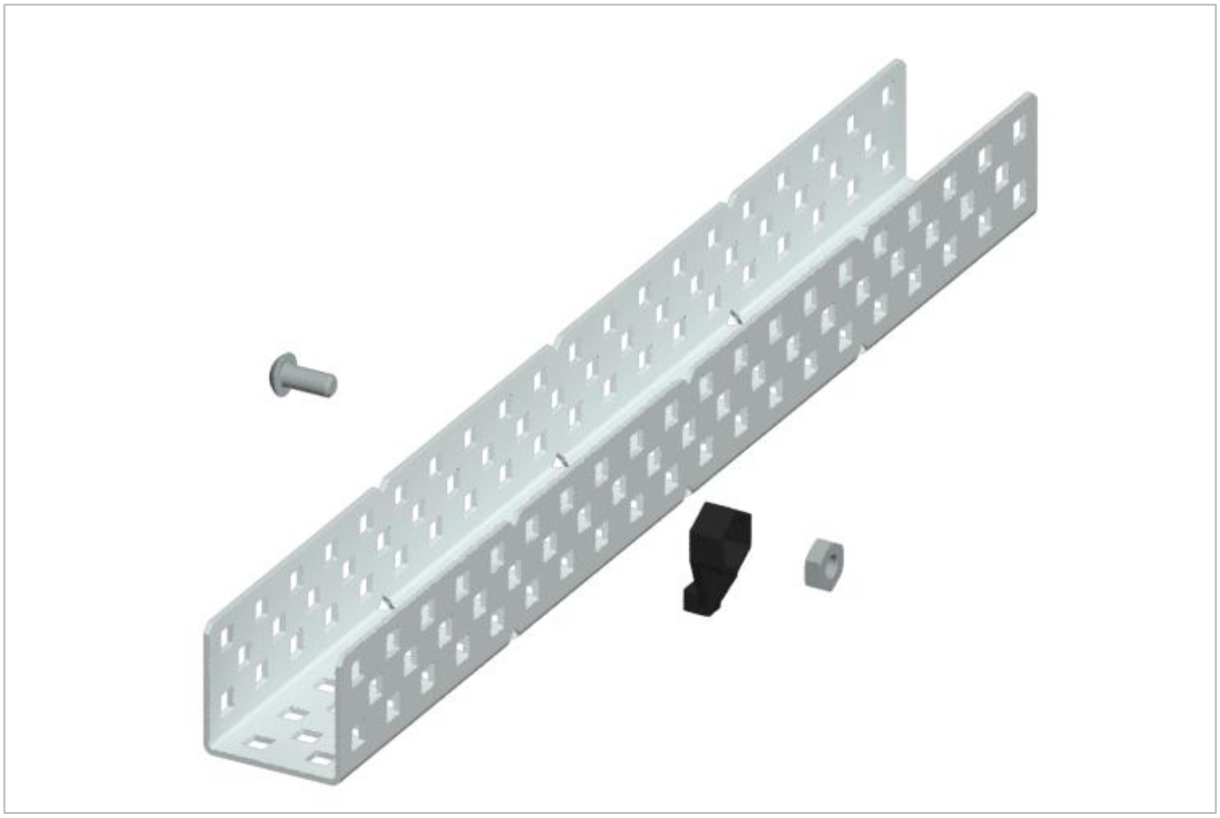
The 4 Post Hex Nut Retainer provides five points of contact for creating a strong connection between two structural components using one screw and nut. Each corner of the retainer contains a post sized to securely fit in a square hole within a structural component. The center of the retainer is sized and slotted to securely fit a hex nut, allowing a 8-32 screw to easily be tightened without the need for a wrench or pliers.

To make use of the retainer:

- Align it on a VEX structural component such that the center hole is in the desired location, and each corner is also backed by the structural component.
- Insert the square posts extruding from the retainer into the structural component to help keep it in place.
- Insert a hex nut into the center section of the retainer so that it is flush with the rest of the component.

- Align any additional structural components to the back of the main structural component, if applicable.
- Use an 8-32 screw of appropriate length to secure the structural component(s) to the retainer through the center hole and hex nut.

# Using the 1 Post Hex Nut Retainer



*1 Post Hex Nut Retainer*

## Using the 1 Post Hex Nut Retainer

The 1 Post Hex Nut Retainer provides two points of contact for connecting a structural component to another piece using one screw and nut. One end of the retainer contains a post sized to securely fit in the square hole of a structural component. The other end of the retainer is sized and slotted to securely fit a hex nut, allowing a 8-32 screw to easily be tightened without the need for a wrench or pliers.

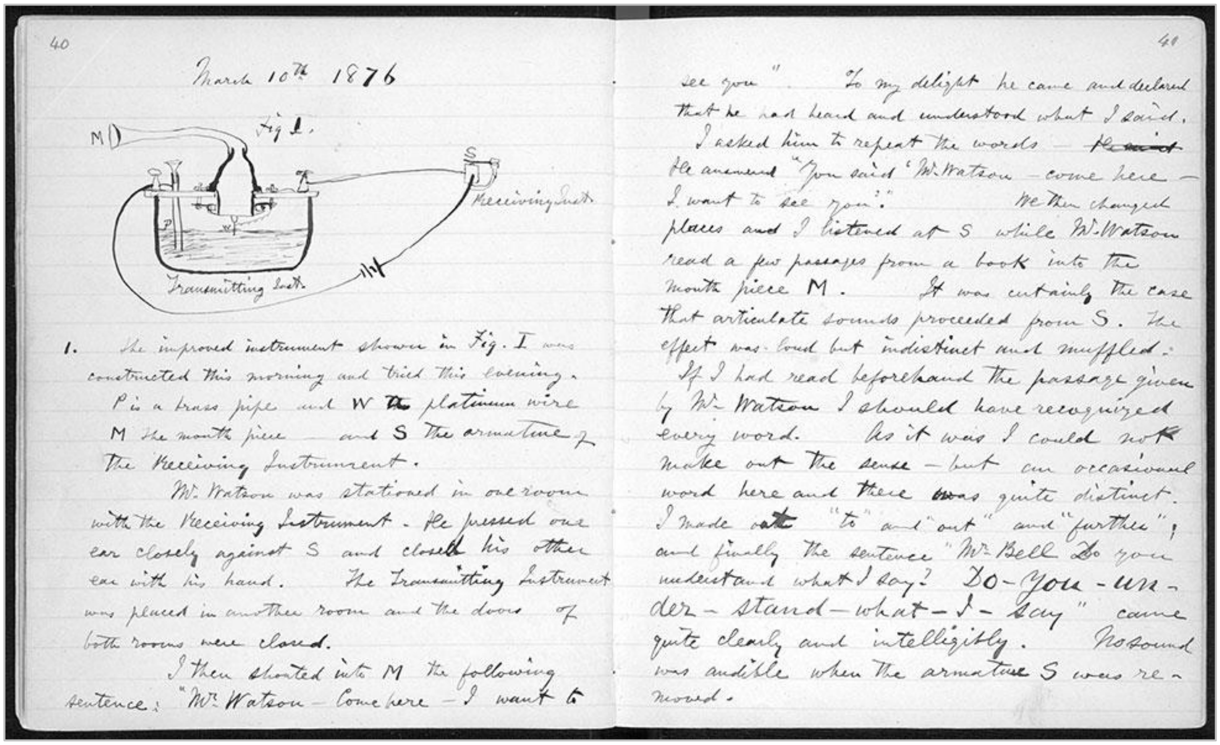
To make use of the retainer:

- Align it on a VEX structural component such that both ends are backed by the structural component and positioned to secure the second piece.
- Insert the square post extruding from the retainer into the structural component to help keep it in place.
- If the retainer is being used to secure two structural components, insert a hex nut into the other end of the retainer so that it is flush with the rest of the component. If used to secure

a different type of component, such as a standoff, it may be appropriate to insert the screw through this side.

- Align any additional components to the back of the main structural component, if applicable.
- If the retainer is being used to connect two structural components, use an 8-32 screw of appropriate length to secure the structural components through the hole and hex nut. If used to connect a different type of component, such as a standoff, secure it directly or with a hex nut.

# Engineering Notebooks


40

March 10th 1876

Fig. I.

M

S

Receiving Instr.

P

W

Transmitting Instr.

1\. The improved instrument shown in Fig. I was constructed this morning and tried this evening.
P is a brass pipe and W ~~the~~ the platinum wire
M the mouth piece and S the armature of the Receiving Instrument.

Mr. Watson was stationed in one room with the Receiving Instrument. He pressed one ear closely against S and closed his other ear with his hand. The Transmitting Instrument was placed in another room and the doors of both rooms were closed.

I then shouted into M the following sentence: "Mr. Watson — Come here — I want to see you". To my delight he came and declared that he had heard and understood what I said.

I asked him to repeat the words — ~~He said~~ He answered "You said 'Mr. Watson — come here — I want to see you.'" We then changed places and I listened at S while Mr. Watson read a few passages from a book into the mouth piece M. It was certainly the case that articulate sounds proceeded from S. The effect was loud but indistinct and muffled.

If I had read beforehand the passage given by Mr. Watson I should have recognized every word. As it was I could not make out the sense — but an occasional word here and there was quite distinct. I made out "to" and "out" and "further"; and finally the sentence "Mr. Bell Do you understand what I say? Do-you-un-der-stand-what-I-say" came quite clearly and intelligibly. No sound was audible when the armature S was removed.

41

*Alexander Graham Bell's notebook entry from a successful experiment with his first telephone*

## An Engineering Notebook Documents your Work

Not only do you use an engineering notebook to organize and document your work, it is also a place to reflect on activities and projects. When working in a team, each team member will maintain their own journal to help with collaboration.

Your engineering notebook should have the following:

- An entry for each day or session that you worked on the solution
- Entries that are chronological, with each entry dated
- Clear, neat, and concise writing and organization
- Labels so that a reader understands all of your notes and how they fit into your iterative design process

An entry might include:

- Brainstorming ideas
- Sketches or pictures of prototypes

- Pseudocode and flowcharts for planning
- Any worked calculations or algorithms used
- Answers to guiding questions
- Notes about observations and/or conducted tests
- Notes about and reflections on your different iterations