Unit

3

Building a Protobot

In Unit 3: Building a Protobot, you build a Protobot, a robot designed to utilize the parts of the VEX Classroom Kit to teach basic assembly methods and robot wiring. After completing this unit you will have a working, ready-to-compete robot.

The concepts involved in building your Protobot have countless real-world applications. In STEM Connections, we have presented a scenario involving the design of a housecleaner robot. After completing the Think Phase and Amaze Phase in Unit 3: Building a Protobot, you will see how those concepts come into play in the real world.

Unit Objectives

After completing Unit 3: Building a Protobot, you will be able to:

- Demonstrate the engineering design process and develop and maintain an engineering notebook.
- Use Autodesk® Inventor® Professional 2009 to assemble a Protobot frame and create an animated presentation and rendered image of the frame and wheel assembly.
- Identify and use the different parts of the VEX Classroom Lab Kit to complete subassemblies in the creation of a Protobot.
- Manipulate objects and navigate a course with a VEX Protobot.

Prerequisites and Resources

Related resources for Unit 3: Building a Protobot are:

- Unit 1: Introduction to VEX and Robotics.
- Unit 2: Introduction to Autodesk® Inventor®.

Key Terms and Definitions

The following key terms are used in Unit 3: Building a Protobot:

Term	Definition
Assembly	Two or more components (parts or subassemblies) considered as a single model. An assembly typically includes multiple components positioned absolutely and relatively (as required) with constraints that define both size and position. Assembly components may include features defined in place in the assembly. Mass and material properties may be inherited from individual part files.
Brainstorming	A process where a group suggests ideas and solutions to a problem.
Build	The actual fabrication and assembly of a product.
Component	A part or subassembly placed into another assembly. Assembly components may be single parts or parts combined that operate as a unit (or subassembly). Components may be treated as parts within other assemblies.
Constraints	Rules that determine how parts in an assembly are placed relative to other parts in the assembly. Constraints remove degrees of freedom. Assembly constraints include angle, flush, mate, and tangent. Constraints may be placed between faces of features, part edges, points, inferred axes, and part work features such as planes, axes, and points.
Coordinate System	The set of magnitudes (visually represented by the X, Y, and Z axes) that determines the position of points, lines, curves, and planes in part and assembly files. By default, a grid is displayed on the active sketch plane of the coordinate system.
Design	A multistep process that includes ideation, sketching, CAD, and prototyping.
Evaluate	Compare test results to known values or establish new baselines for future results.
Grounded Component	A part or subassembly for which all six degrees of freedom were removed relative to the assembly origin. You can position the part or subassembly without reference to other parts. It is fixed in space. The first part or subassembly placed in an assembly file is grounded automatically, although the ground can later be deleted and relocated, if needed.
IAM	Autodesk Inventor filename extension for an assembly.
IPT	Autodesk Inventor filename extension for a part.
Mock-Up	A "rough" model of a product used to evaluate appearance, design, usability, and other parameters.
Paradigm	A problem or idea that serves as a model or standard. These may lead to innumerable other ideas that may or may not be considered in a design.

Term	Definition
Prototype	A full-scale working model of a product. The prototype is frequently used for testing.
Research	Thorough study and investigation of a topic.
Test	Putting a product through actual usage conditions to discover problems with the design.

Required Supplies and Software

The following supplies and software are used in Unit 3: Building a Protobot:

Supplies	Software
VEX Classroom Lab Kit	Autodesk Inventor Professional 2009
One assembled Protobot from Unit 3: Building a Protobot Build Phase	
Notebook and pen	
Work surface	
Small storage container for loose parts	
One scoring bin, approximately 12” high (Any appropriately sized container which can fit a tennis ball will do)	
At least 8' x 8' of open floor space	
One stopwatch	
Three tennis balls	

Academic Standards

The following national academic standards are supported in Unit 3: Building a Protobot.

Phase	Standard
Think	**Science (NSES)** *Form and Function* *Physical Science:* Motions and Forces PROPERTIES of objects and materials *Science and Technology*: Abilities of Technological Design **Technology (ITEA)** 3.2: Core Concepts of Technology 5.8: The Attributes of Design **Mathematics (NCTM)** *Connections* Recognize and apply mathematics in contexts outside of mathematics.
Create	**Science (NSES)** *Unifying Concepts and Processes*: Form and Function *Physical Science:* Motions and Forces *Science and Technology*: Abilities of Technological Design **Technology (ITEA)** 5.8: The Attributes of Design 5.9: Engineering Design 6.12: Use and Maintain Technological Products and Systems **Mathematics (NCTM)** *Numbers and Operations* Understand numbers, ways of representing numbers, relationships among numbers, and number systems. *Algebra Standard* Understand patterns, relations, and functions. *Geometry Standard* Use visualization, spatial reasoning, and geometric modeling to solve problems. *Measurement Standard* Understand measurable attributes of objects and the units, systems, and processes of measurement.

Phase	Standard
Build	**Science (NSES)** *Unifying Concepts and Processes*: Evidences, Models, and Explanation *Form and Function* *Physical Science:* Motions and Forces PROPERTIES of objects and materials *Science and Technology*: Abilities of Technological Design **Technology (ITEA)** 5.8: The Attributes of Design 5.9: Engineering Design 6.12: Use and Maintain Technological Products and Systems **Mathematics (NCTM)** *Communications* Organize and consolidate mathematical thinking through communication. Communicate mathematical thinking coherently and clearly to peers, teachers, and others. *Connections* Recognize and apply mathematics in contexts outside of mathematics.
Amaze	**Science (NSES)** *Unifying Concepts and Processes*: Evidences, Models, and Explanation *Form and Function* *Physical Science:* Motions and Forces *Science and Technology*: Abilities of Technological Design **Technology (ITEA)** 5.8: The Attributes of Design **Mathematics (NCTM)** *Communications* Organize and consolidate mathematical thinking through communication. Communicate mathematical thinking coherently and clearly to peers, teachers, and others. *Connections* Recognize and apply mathematics in contexts outside of mathematics.

Think Phase

Overview

This phase covers the different steps used in the engineering design process. This process has been highly refined to efficiently move products through the ideation and design phases and into production.

Objectives

After completing this phase, you will be able to:

- Demonstrate the engineering design process.
- Develop and maintain an engineering notebook.

Prerequisites and Resources

Related resources for this phase are:

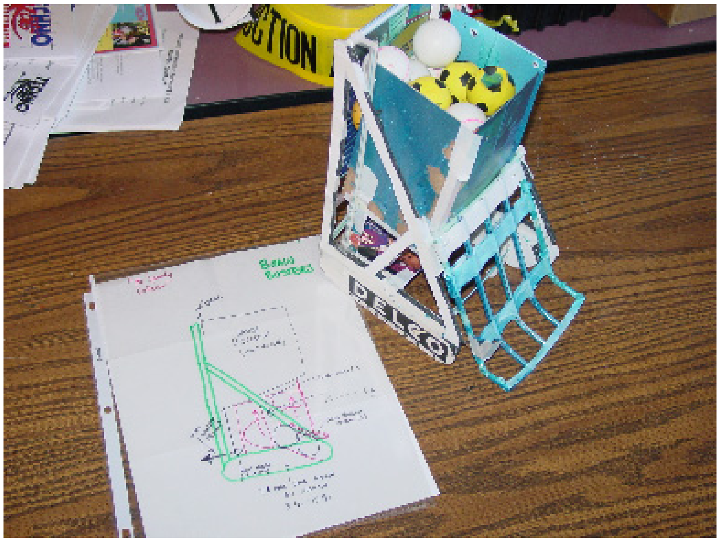
- Unit 1: Introduction to VEX and Robotics.

Required Supplies and Software

The following supplies are used in this phase:

Supplies
Notebook and pen

Research and Activity



Competition robot sketch and mock-up to validate a design
(Image from TechnoKats)

Engineering Design Process

When developing a robot design, it is wise to follow the engineering design process. This process can be as few as five steps and as many as fourteen. Essentially, the engineering design process consists of the following steps:

1. Identify a need.
2. Define the problem to be solved.
3. Gather information.
4. Conduct research.
5. Find alternative solutions.
6. Analyze the possible solutions.
7. Design, test, and evaluate the best solution.
8. Build.
9. Communicate, market, and sell the product.

Identify the Need

With any project, you need to thoroughly understand the scope and implications of the project that must be addressed. Cost, complexity, and technology demands can quickly mire down any well-intentioned project.

Many times, thinkers, designers, and engineers do not dream up an idea on their own, but are bombarded by the problems of a customer, society, or the environment that "need" to be solved to achieve a basic "need." Without a clear definition of this need, the engineering design process cannot begin. Much time and many careers have been wasted in the pursuit of an ill-defined need.

Define the Problem

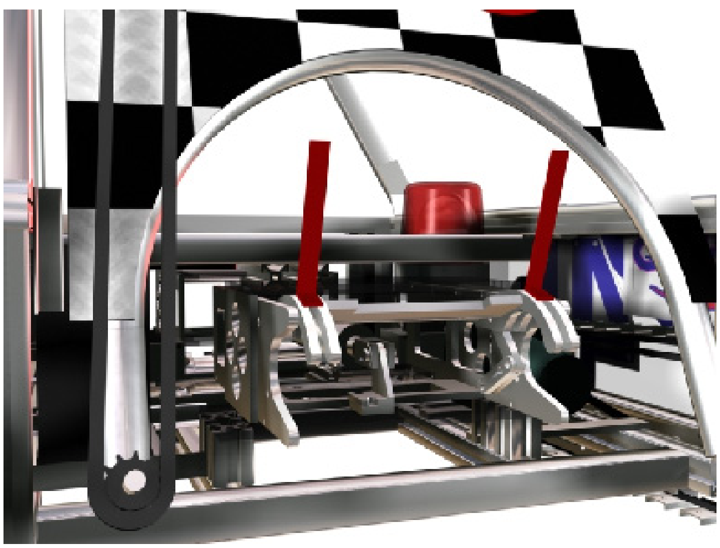
The problem is the main issue preventing the need from being fulfilled. The problem must be accurately and realistically defined in order to go about the process of solving it. If not, time and money will be wasted and the original problem may still exist with no solution.

Conduct Research and Brainstorm

Research can be an independent, lonely endeavor or a dynamic group activity. Research must be focused and incorporate new ideas and a thorough exploration of old similar ideas. Sometimes the old ideas are the best. Ever heard the saying, "Don't reinvent the wheel?" Old ideas that failed are sometimes great research gold mines; that idea may have failed due to a lack of new technology that may exist now.

No ideas are bad ideas. It is important to consider all approaches to a problem. One that did not seem feasible or make sense in the beginning might be the way to go in the end. Not too many projects go through development on the first try or on the best idea at the time. The final project usually consists of a collection of ideas; some that were considered too risky, costly, or just plain crazy. Think back to famous inventors like Edison, Benjamin Franklin, the Wright Brothers, or Leonardo da Vinci. Can you imagine them using this process? How many tries did they make before they succeeded?

Knowledge is power. Efficient methods of information collected from myriad sources are necessary to formulate a solution. The Internet is a priceless research tool, but do not forget the library, as older information may not be online. Trade publications, manuals, and company information are very useful; integrating ready-made components will keep costs to a minimum.



3D Studio MAX rendering of a virtual robot design
(Image from Luke Ward)

Design, Test, and Evaluate the Best Solution

The design phase of a product is perhaps the most challenging of the entire process. Once the idea has been fleshed out, it is time to sit down and figure out how to make it happen. Good designers are willing to be flexible when making tough decisions and willing to make trade-offs and omissions to make the design practical and possible.

The first step is to start sketching to get the ideas on paper. Sketching and drawing by hand enables you to tap your creative side. It is important to have accurate and complete sketches in order to translate the idea into hand or CAD drawings and models. This phase also allows for virtual prototyping or testing of the product in the computer. You can find potential, and sometimes costly, flaws in a design before the real world mock-up is constructed.

Mock-ups are representations of the product to test and evaluate. This process is still valuable even though computers can accomplish the same results. The only thing they cannot do is provide a real product to evaluate. After the mock-up is evaluated, the project can go to the prototyping stage.

Image courtesy of NASA

Build a Prototype

The best way to know if a design will work in real-world conditions is to build a prototype. The prototype is an accurate working model of the final design. The prototype is evaluated for cost, aesthetics, durability, ease of construction, and meeting the design criteria.

Some of the most expensive prototypes constructed are aircraft. In the early 1990s, Lockheed Martin and Northrop Grumman competed to build the next generation fighter to replace the McDonnell Douglas F-15 Eagle. Using government funds, Lockheed and Northrop Grumman both designed and built two prototype aircraft each, the YF-22s and YF-23s. These four aircraft were put through a rigorous test program with the YF-22 being selected as the winner.

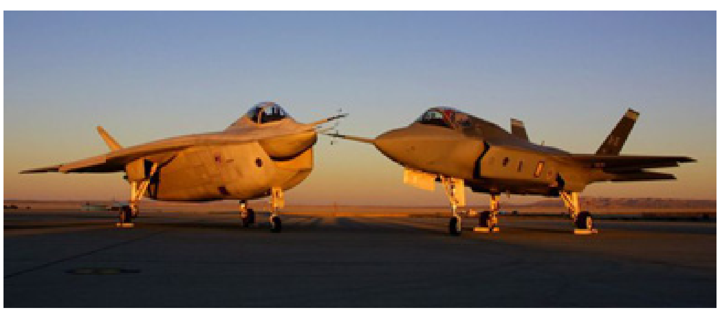


Image courtesy of the US Airforce

Refine or Redesign

If an initial design and prototype does not fully solve the problem or specifications, meet the design parameters, or stay within an acceptable cost, a designer may go "back to the drawing board" (or computer). The engineering design process has a loop to go back to the design and refine or redesign. The biggest hurdle in this refinement/redesign is money. Sometimes it is easier and less costly to settle for a slightly inferior design than spend the money to redevelop a nearly finished product.

Build

The build process is a lengthy complex process. The build process must take into consideration materials, processes, construction limitations, and cost. Companies make substantial investments in factories and the infrastructure to build their designs so the more efficiently a design has been handled, the better off the build will be.

Once the build process has begun, the company can begin to hopefully make a return on its investments in the entire design process by marketing and selling the product.

Engineering Design Process for a VEX Robot

You can apply the engineering design process to create a VEX robot in much the same way as you do for designing a new product.

Identify the Need

Most VEX robots are built for education or competition where a clear objective of solving a problem or scoring points is presented to the designer.

Define the Problem

Get a clear picture of the parameters of the problem or competition. Make a list of the objectives and rank them in order of importance. Many times a robot cannot do everything that a problem presents. It is not often that a robot can do everything well. It is important to prioritize and design a machine that can do the most things and do a few things very well.

Conduct Research and Gather Information

Explore other solutions to the same and similar problems. Look carefully at the environment in which the machine has to operate. Analyze the constraints of your project or competition carefully. Pay particular attention to specifically mentioned dimensions and measurements.

Find and Analyze Possible Solutions

Solutions must be separated according to their pros and cons. This activity is better accomplished in a group setting. Brainstorming encourages a maximum amount of input from different levels of experience and different approaches to the problem. Alternative solutions can be analyzed and cataloged according to merit and possible use.

After these ideas have been distilled to a manageable number, the numbers must be crunched to evaluate the probability and cost of a successful outcome, using the individual solutions. Larger factors come into play here, such as common sense and instinct. If it doesn't feel right, don't do it.

Come up with at least three design solutions and evaluate each of them.

Look at the number of parts that are being committed to the design. Answer these questions:

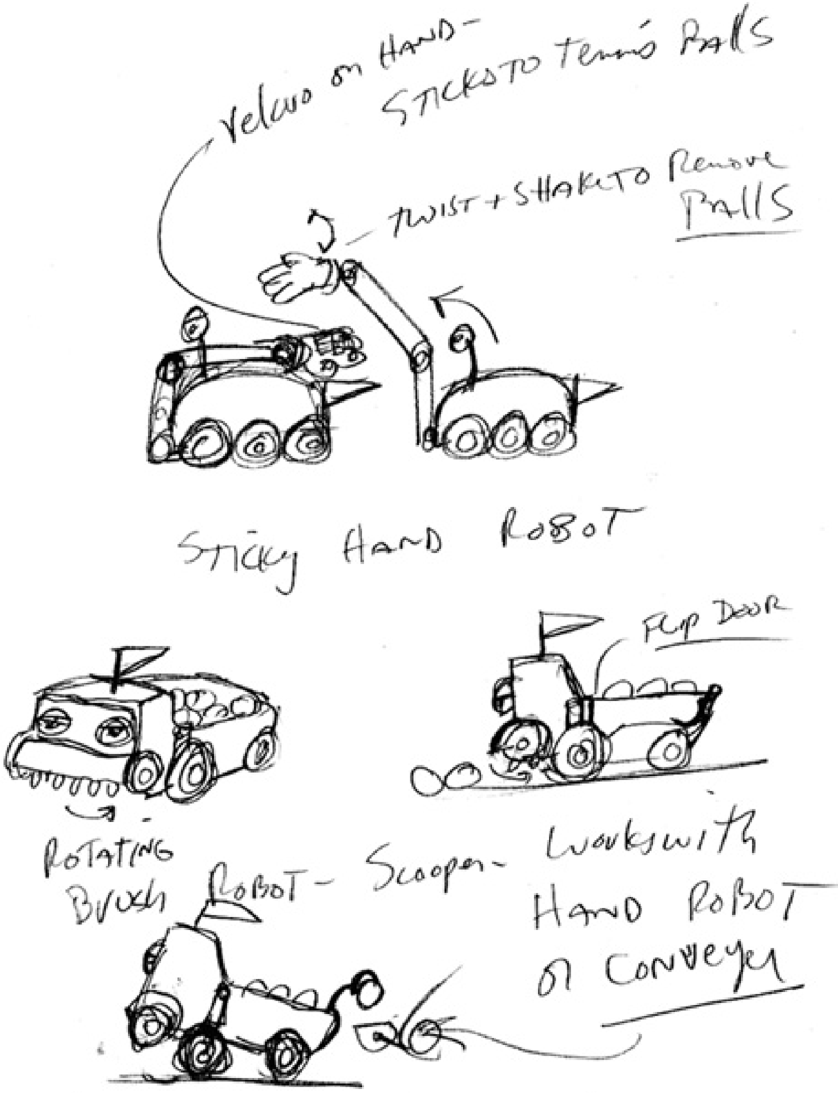
- Are there enough to make the design work?
- Will more investment be needed?
- Can the design be streamlined?
- Are there size and weight constraints?
- Will specialized tools be required?

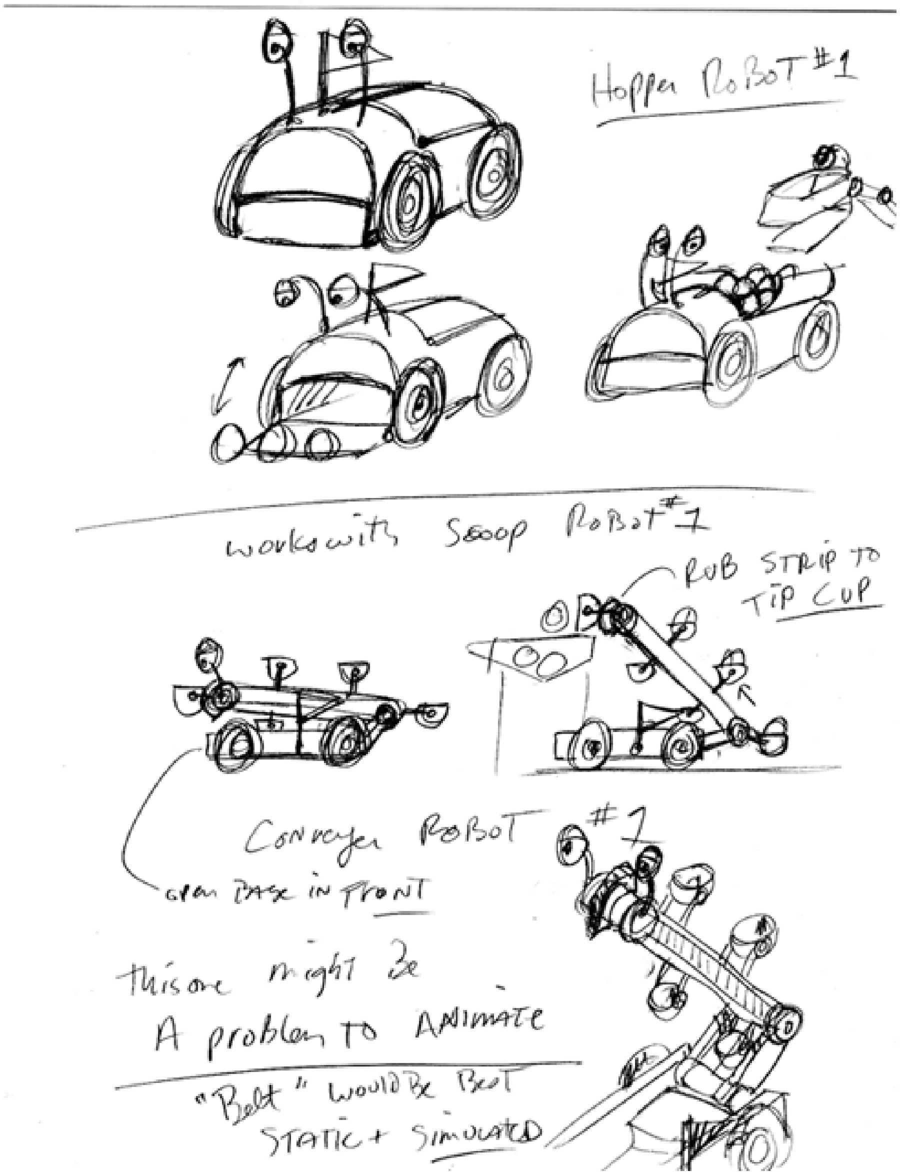
Design, Test, and Evaluate the Best Solution

With the VEX Robotics System, you can do your sketching at full scale on a large sheet of paper. You can lay out parts and then trace them. The parts of the robot are small enough to be mocked-up on a table.

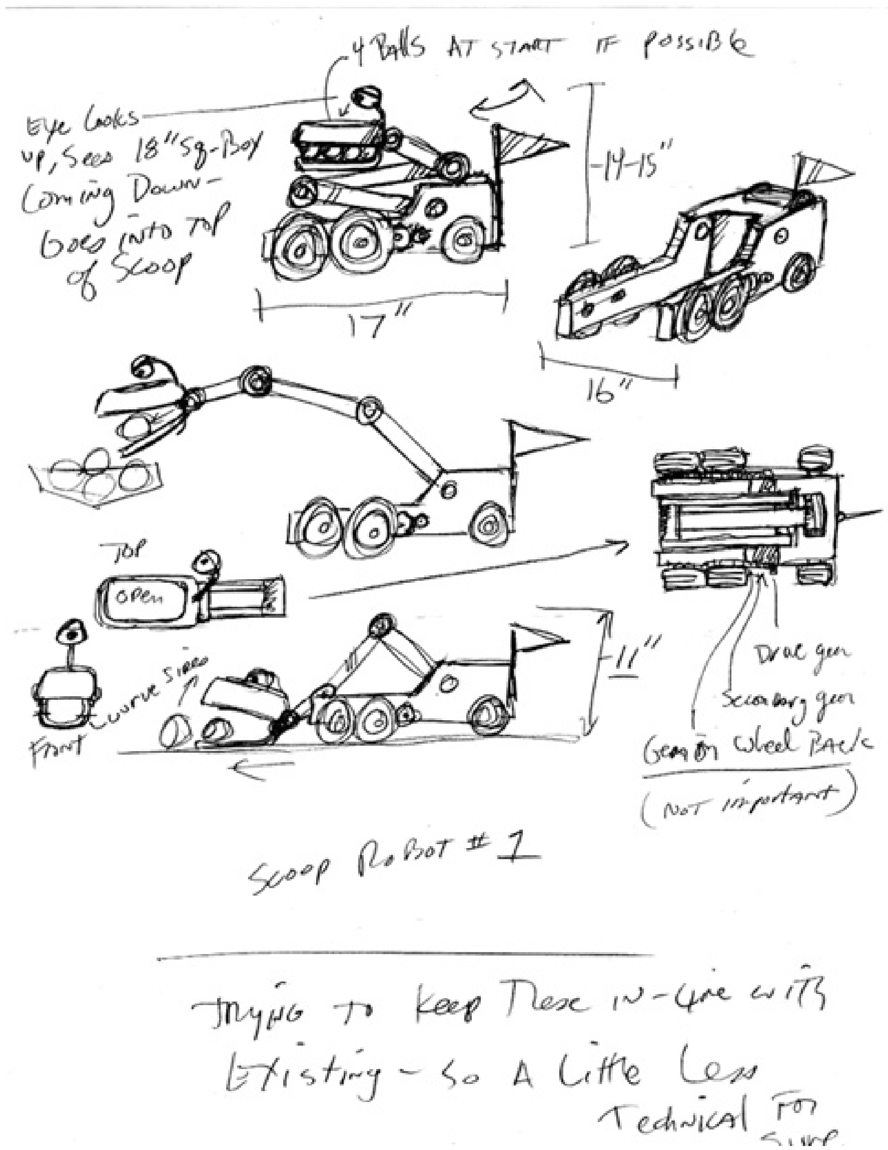
Build

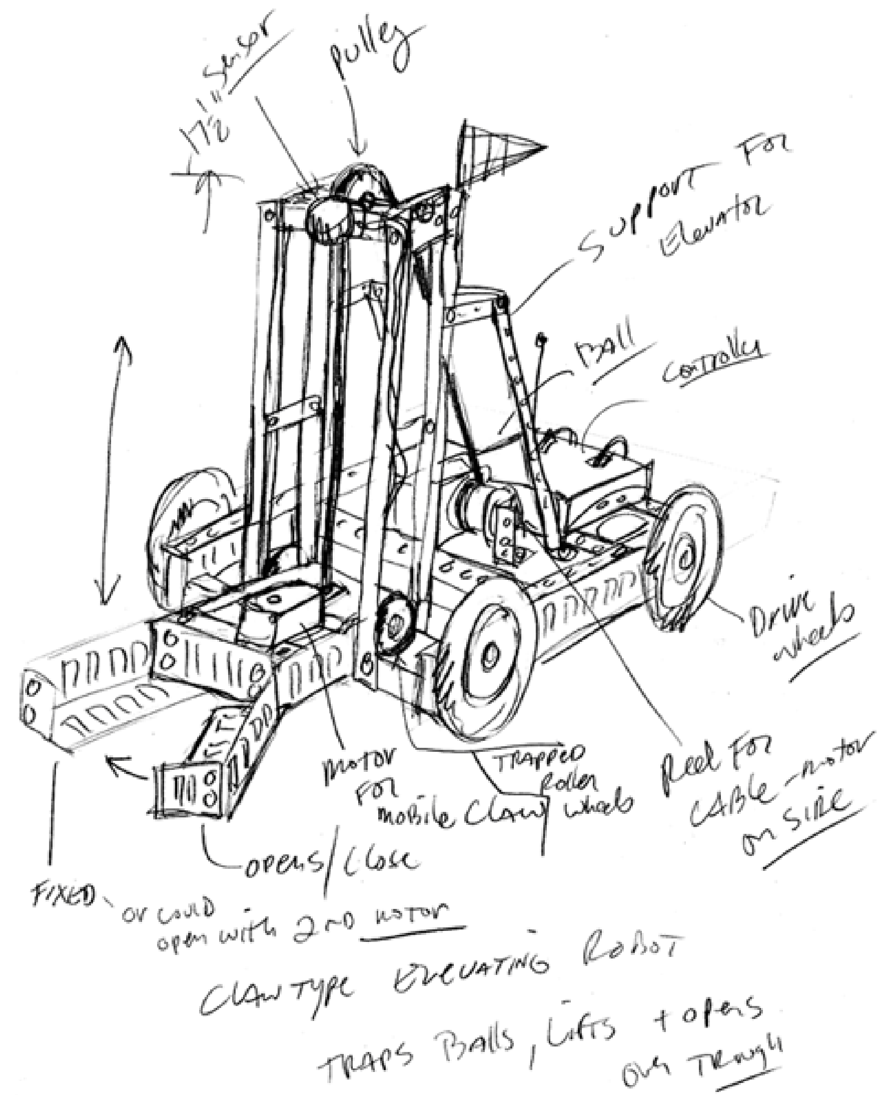
The most important part of robot building is constructing a foolproof drive base. Build it first and build it well. Test it before constructing any other parts of the machine. Add appendages and other tools to the base after they have been constructed. This modular approach to construction saves time and allows interchangeability of parts and assemblies.

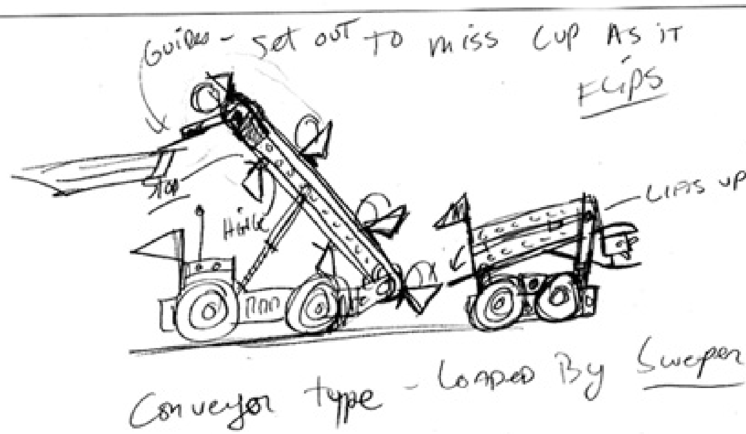


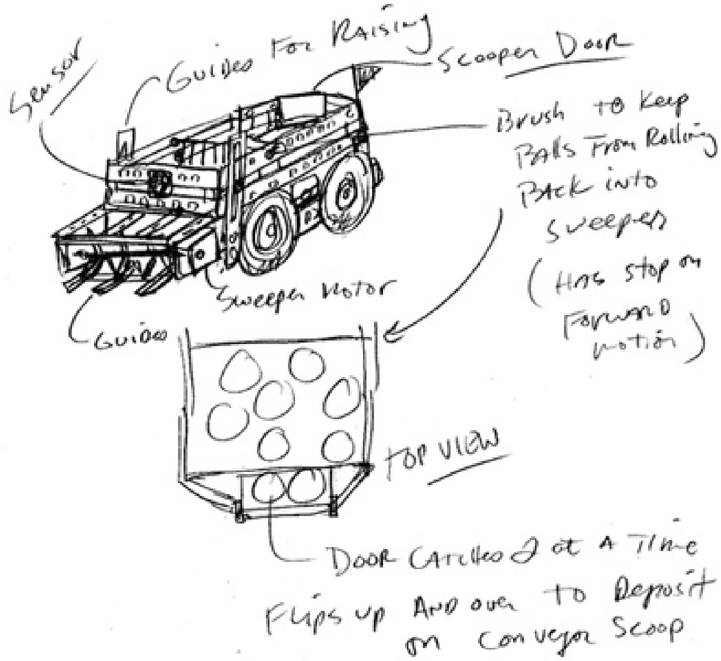

Hopper RoBoT #1
works with Scoop RoBoT #1
RUB STRIP TO TIP CUP
Conveyer RoBoT #1
open BASE IN FRONT
this one might be
A problem to ANIMATE
"Belt" would Be Best
STATIC + SIMULATED

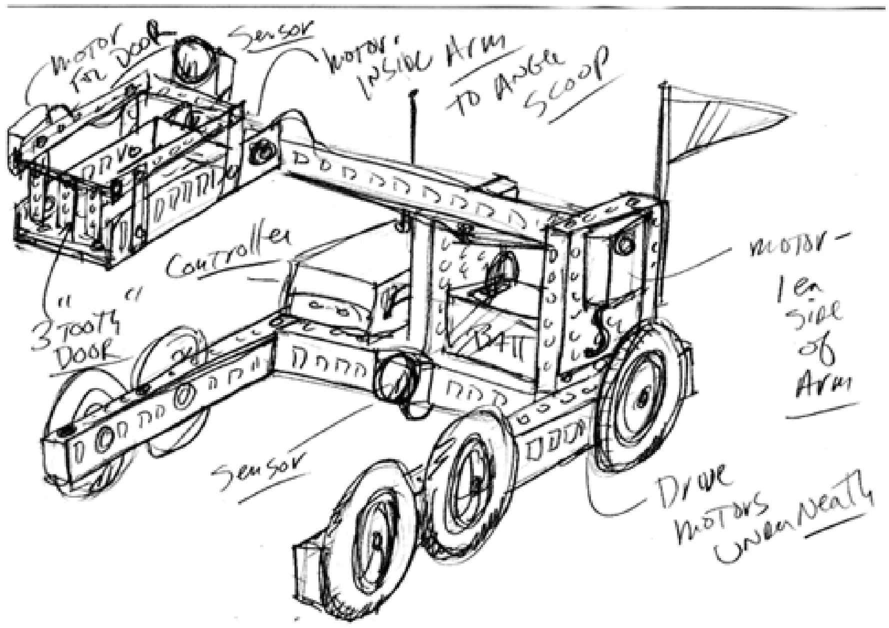

Hopper Drops To
CApture
Balls
works with STICKY HAND or
Scoop RoBoT #1


4 BALLS AT START IF POSSIBLE
Eye Looks up, Sees 18" Sq-Box Coming Down - Goes into Top of Scoop
14-15"
17"
16"
TOP
OPEN
Curve Sides
Front
11"
Drive gear
Secondary gear
Gear on Wheel Back
(NOT important)
Scoop Robot #1
Trying to Keep These in-line with Existing - So A Little Less Technical For


1½" sensor
pulley
SUPPORT FOR Elevator
BALL
controller
Drive wheels
Reel FOR CABLE-motor on SIDE
TRAPPED Roller wheels
motor FOR mobile Claw
opens/close
FIXED - or could open with 2nd motor
CLAW TYPE ELEVATING ROBOT
TRAPS Balls, Lifts + opens over Trough


Guides - set out to miss cup as it flips
Stop
Hinge
Lifts up
Conveyor type - Loaded By Sweeper

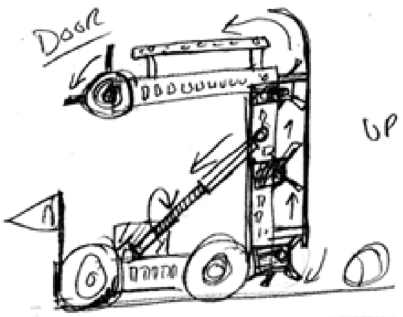

Sensor
Guides For Raising
Scooper Door
Brush to keep Balls From Rolling Back into sweeper
(Has stop on Forward motion)
Sweeper motor
Guides
Top View
Door Catches 2 at A Time
Flips up And over to Deposit on Conveyor Scoop



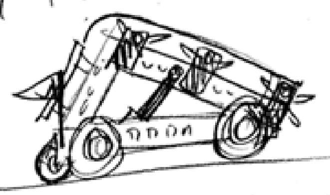
Same concept as Scoop Robot
only (1) pivot @ Base—Arm

Drops to Floor Traps Balls in
Scoop—using Door Action
Raised to Above Tray—
Scoop Tilts Door Swings

Sensor mimics Eye

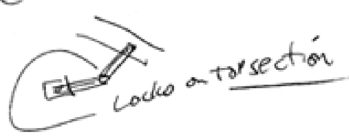


Same Basic Assemby As Actual Robot in image – Brushes, guide plates

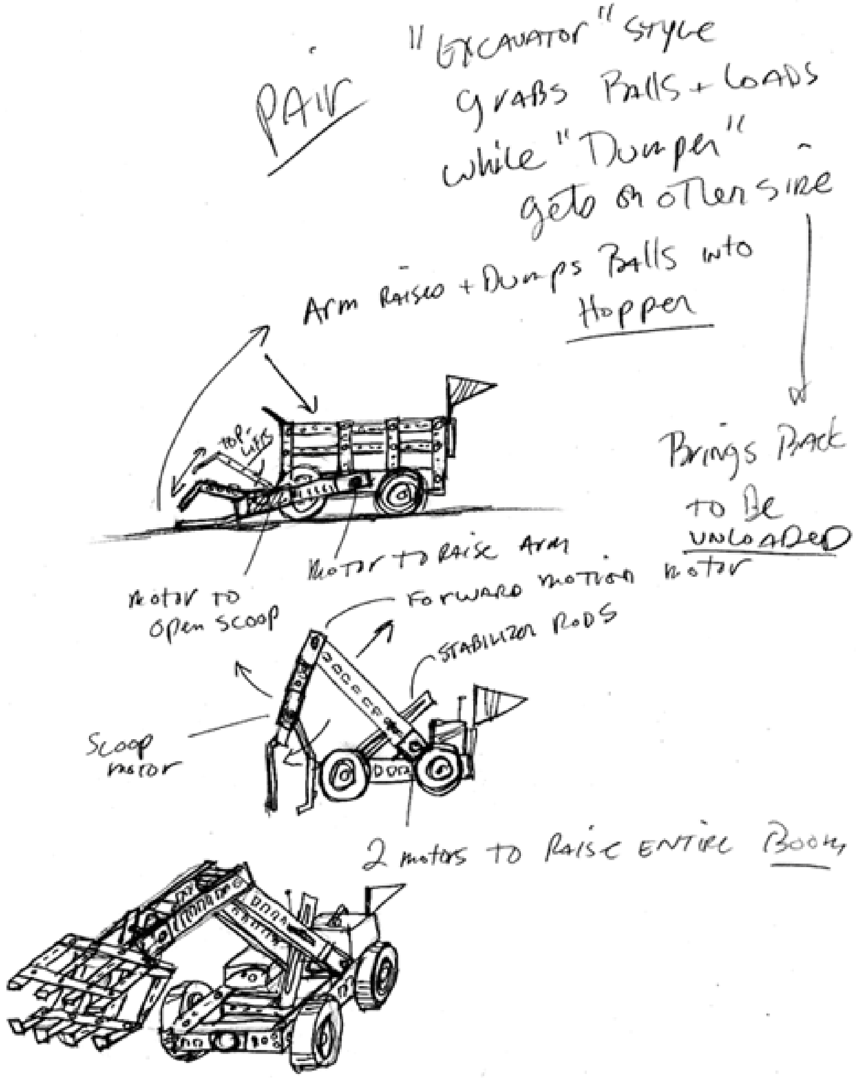


Hopper on Top

Reversed to pick up From outside And with Flipper Door At Top – Either Screw Type Lowering mech or Simple Lever Action (2 pc)



Conveyer Type Lowering Robot

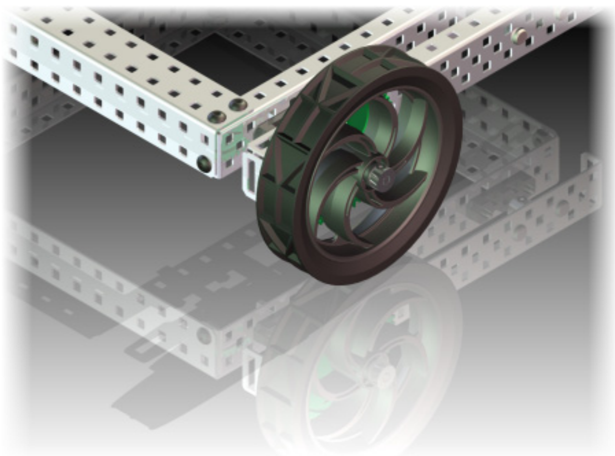

PAIR
"EXCAVATOR" STYLE
grabs Balls + Loads
while "Dumper"
gets on other side
Arm Raises + Dumps Balls into
Hopper
Brings Back
to Be
UNLOADED
Motor to Raise Arm
Motor to
Open Scoop
Forward motion motor
Stabilizer Rods
Scoop
motor
2 motors to Raise entire Boom

Create Phase

Overview

This phase describes how to place components into a Protobot frame and wheel assembly. As you create assemblies, you place component geometry that represents the robot's individual parts.

This Protobot frame and wheel assembly was created by placing components into the assembly model.



A fundamental step in assembly design is the process of adding components to the assembly. In some cases you create new components from scratch and in other cases you reuse components that have already been designed. Many designs use standard purchased components such as fasteners and bearings which you typically do not model; the parts are either included in Autodesk Inventor's Content Center or they are supplied by the part manufacturer.

Phase Objectives

After completing this phase, you will be able to:

- Describe the process of placing components in an assembly.
- Use the Place Component tool to place parts into an assembly.
- Assemble a Protobot frame.
- Create an animated presentation of a wheel assembly.
- Create a rendered image of the frame and wheel assembly.

Prerequisites and Resources

Before starting this phase, you must have:

- A working knowledge of the Windows operating system.
- Completed Unit 1: Introduction to VEX and Robotics > Getting Started with Autodesk Inventor.
- Completed Unit 2: Introduction to Autodesk Inventor > Quick Start for Autodesk Inventor.

Technical Overview

The following Autodesk Inventor tools are used in this phase:

Icon	Name	Description
	**Place Component**	Specifies one or more files to place as a component in an assembly.
	**Constraint**	Assembly constraints determine how components in the assembly fit together. As you apply constraints, you remove degrees of freedom, restricting the ways components can move.
	**Rotate Component**	Rotate an individual component in an assembly. Constraints are temporarily suppressed.
	**Create Presentation View**	Used to create a specialized assembly view. You develop the specialized views, such as exploded views, in a presentation file and then use them to create drawing views or other presentations.
	**Tweak Components**	Adjusts assembly components in an exploded view. You specify the distance and direction of movement to provide better visibility of the components and their relationships.
	**Animate**	Moves the components according to the applied tweaks.
	**Render Image**	Create a realistic image of the design, with or without an enhanced background.

Required Supplies and Software

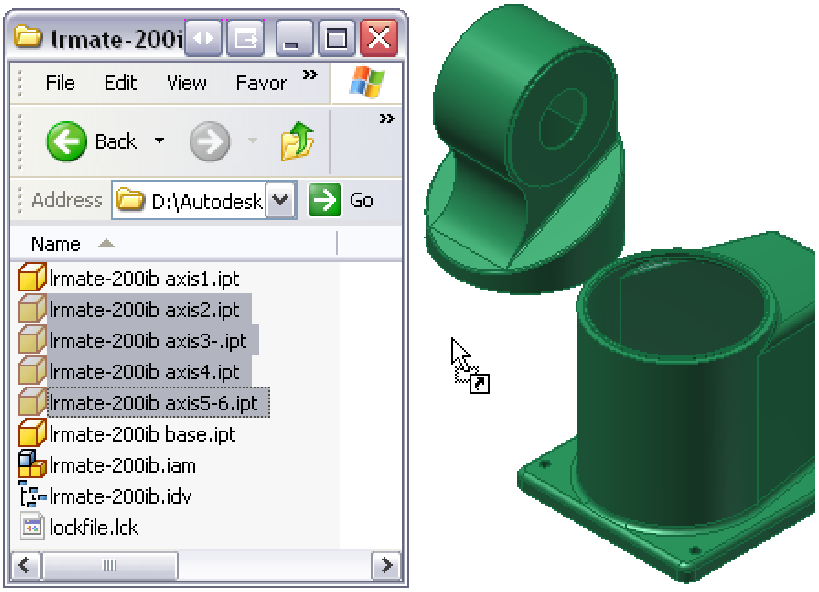
The following software is used in this phase.

Software
Autodesk Inventor Professional 2009

About Placing Components in an Assembly

When you create an assembly model, there may be components that you are not designing in the context of the assembly. You must place these components into the assembly. A typical assembly model consists of components that were created in the context of the assembly and components that were created outside of the assembly.

In the following illustration, part files are being dragged from Windows Explorer to the assembly file. This is one method you can use to place components in an assembly.



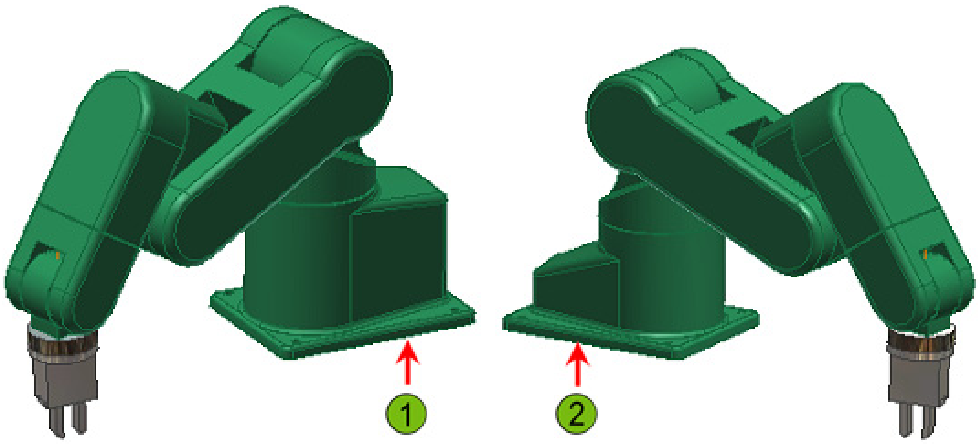
Definition of Placing Components in an Assembly

When you place components in an assembly, you add external part files or files from other sources to your assembly model. By doing so, you create a link between the assembly file and the part file. While the component's geometry is completely visible and can be manipulated and edited in the assembly environment, its definition is stored in a file that is separate from the assembly. This file link occurs, even though the component is created in the context of the assembly. All component file definitions are stored separately.

Because the component file exists outside of the assembly, it can be used in other assemblies.

Example of Placing Components in an Assembly

In the following illustration, two assembly models are shown. Advancements in motor and power supply technology enable you to redesign the base with a slightly lower height profile. The design requirements dictate that you create these two different assemblies by using as many common components as possible. As you create the second assembly, you place components also used in the first assembly. You place a copy of the base component and modify it according to the lower height profile requirements.



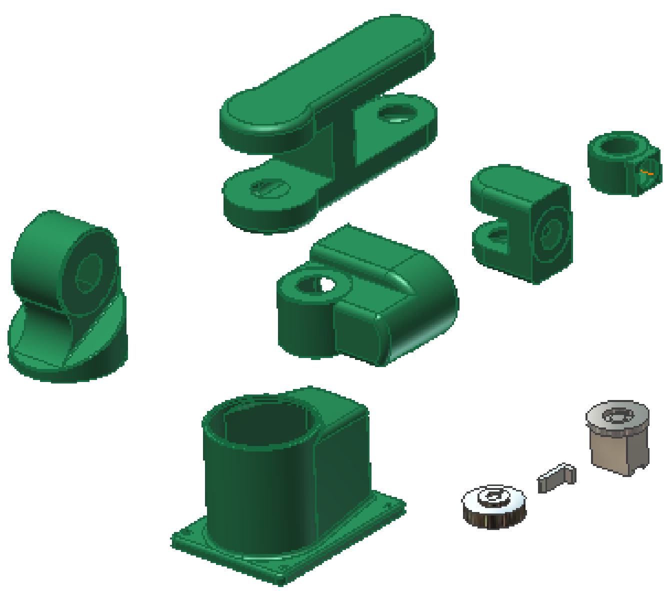
1 Original base component

2 New lower-profile base component

Placing Components in an Assembly

You use the Place Component tool to place components into the assembly.

The first component you place into the assembly is automatically placed at the assembly's origin point (0,0,0) and is grounded.



Access

Place Component

Panel Bar: **Assembly Panel**

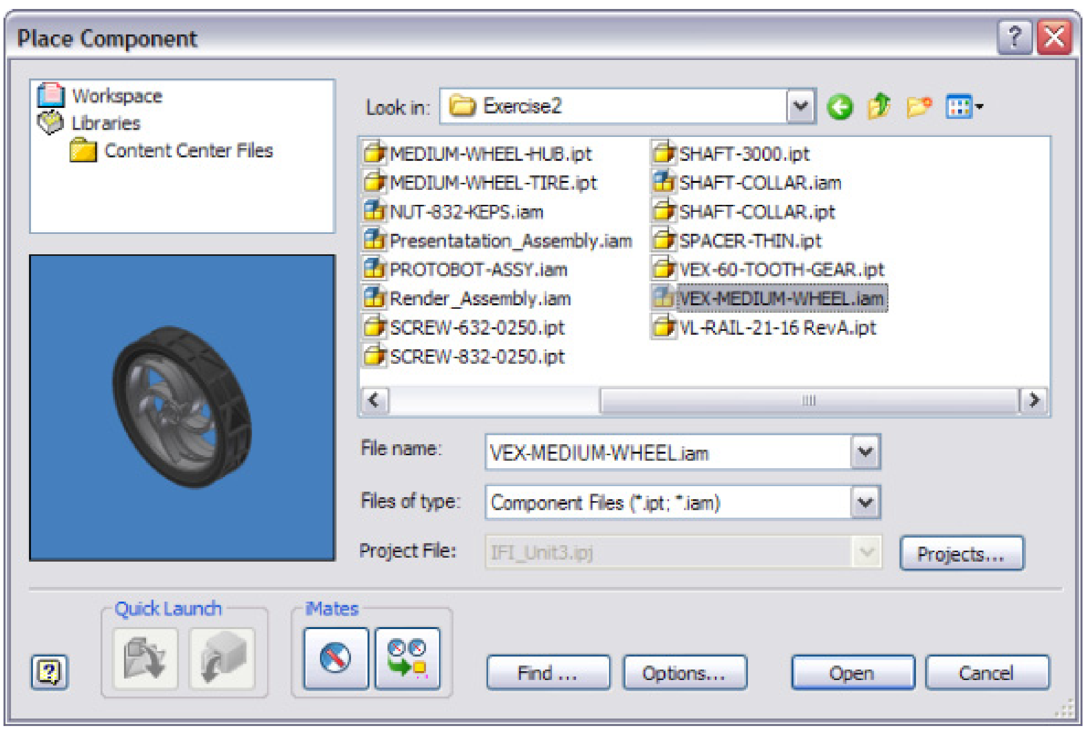
Shortcut Menu: **Place Component**

Menu: **Insert > Place Component**

Keyboard: **P**

Open Dialog Box

The Place Component dialog box is displayed when you start the Place Component tool. Select the file to place into the assembly and click Open. To place files other than Autodesk Inventor files, select the file type from the Files of Type list.



Assembly Coordinate System

Each assembly file contains an independent coordinate system. Default coordinate systems are aligned with the 0,0,0 point in the assembly and can be used as you build the assembly. When you place the first part into the assembly, the origin point of the part file is aligned with the origin point of the assembly file.

NOTE: This applies only if the first part in the assembly is placed into the assembly. These components can be repositioned if required.

Grounded Components

By default, the first part in each assembly is grounded. All degrees of freedom are removed from the component and it cannot be moved. When you apply constraints to a grounded component, the nongrounded component moves to validate the constraint, while the grounded component remains fixed in its position.

Although the first part is grounded, there is no limit to the number of grounded parts that you can have in an assembly. You can also remove the grounded property from the first part in the assembly.

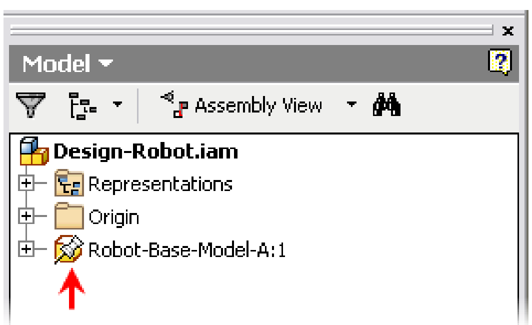
When you ground parts, you can use them to mimic real-world situations where some parts are fixed in position, while others move relative to the parts to which they have been constrained.

Grounded components are displayed in the browser with the following icon:

Procedure: Placing Components

The following steps describe how to place components into an assembly.

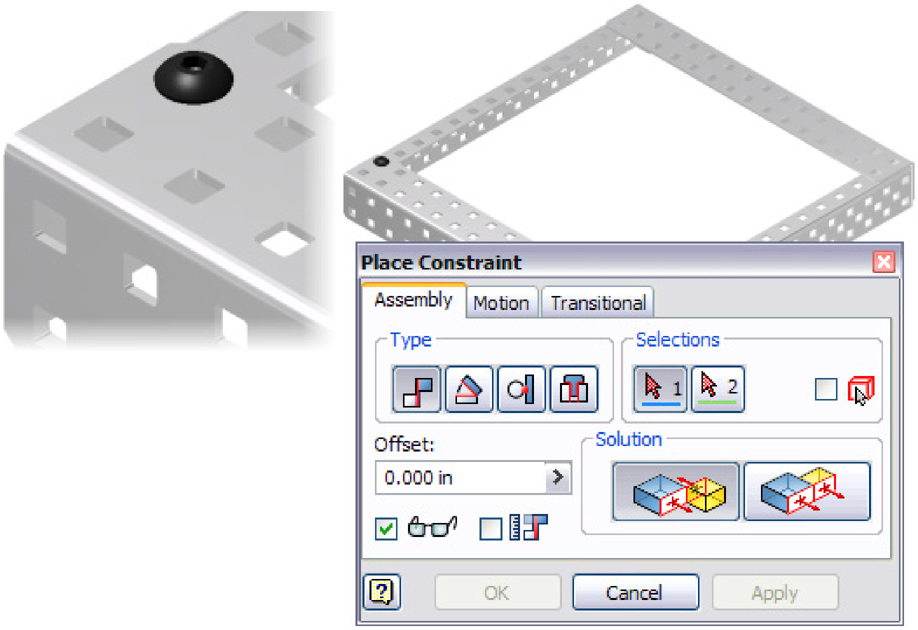
1. Open or create a new assembly file.
2. Start the Place Component tool.
3. In the Open dialog box, select the file you want to place into the assembly. Click Open.
4. The first component in the assembly is positioned automatically and is grounded, indicated by the push-pin icon. Optionally place additional components by clicking other locations in the graphics window, or press ESC to cancel.



5. Using the Place Component tool, continue to place components into the assembly.

Exercise: Assemble a Protobot Frame

In this exercise, you assemble the basic frame for the Protobot. The frame components and standard parts are already created. You apply the correct assembly constraints for the frame.

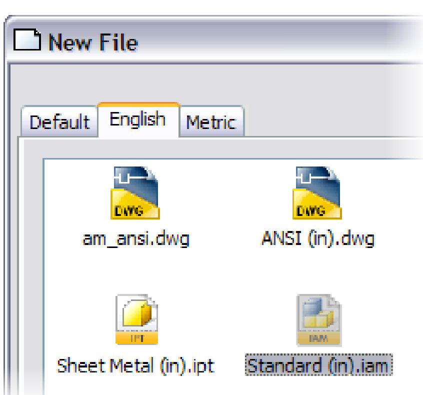


The completed exercise

Place the Frame Components

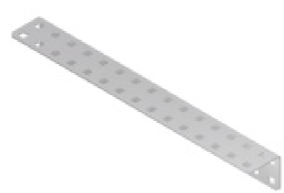
In this exercise, you assemble the basic frame for the Protobot. The frame components and standard parts are already created. You apply the correct assembly constraints for the frame.

1. Make *IFI_Unit3.ipj* the active project.
2. On the Standard toolbar, click New.
3. Click the English tab. Double-click *Standard (in).iam*. A new assembly file is created.



4. Save the file as *my_assembly*.
5. Click Place Component.

6. To place the first part:
   - Select *ANG-HH22-15-SK RevA.ipt*.
   - Click Open.
   - Right-click in the graphics window. Click Done.

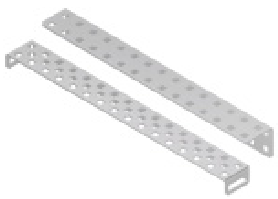


Note: The first part in the assembly is grounded. All degrees of freedom are removed. In the browser, the part has a thumbtack icon to indicate it is grounded.

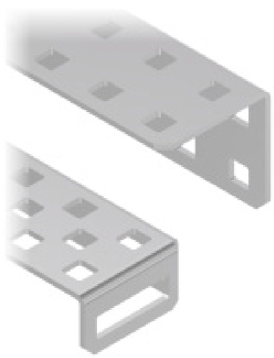
7. Click Place Component.

8. To place the second part:

- Select *VL-RAIL-21-16 RevA.ipt*.
- Click Open.
- Click to place an occurrence of the component.
- Right-click in the graphics window. Click Done.

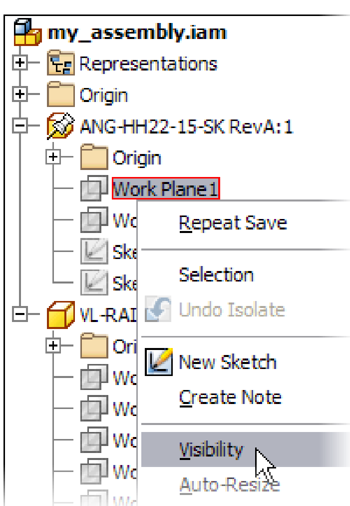


9. Zoom into the right end of the parts.

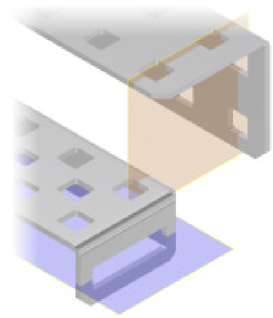


10. In the browser, expand the ANG-HH22-15-SK RevA:1 listing.

11. Right-click Work Plane1. Click Visibility to turn on visibility.



12. Repeat this workflow for Work Plane1 on VL-RAIL-21-16 Rev:1.

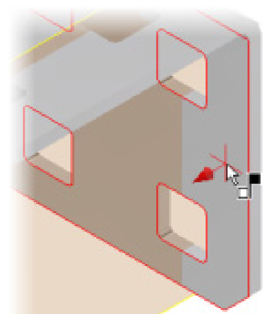


Assemble the Two Frame Components

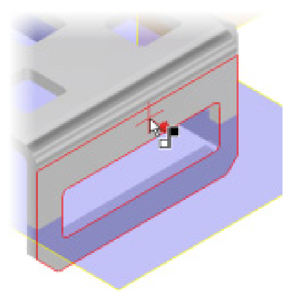
In this section of the exercise, you apply constraints to the two frame components.

1. Click Constraint.

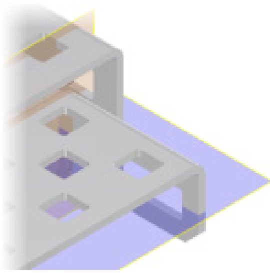
2. Select the inside face of the first part.



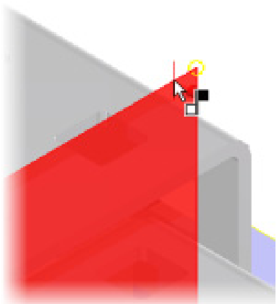
3. Select the end face of the second part.



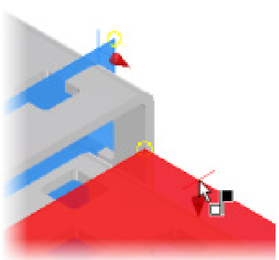
4. Click Apply.



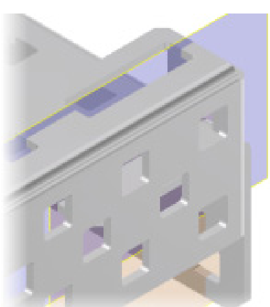
5. Select the edge of the work plane on the first part.



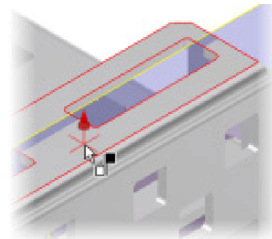
6. Select the edge of the work plane on the second part.



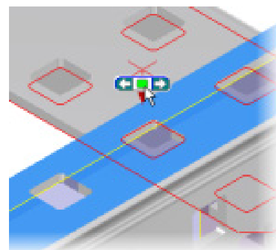
7. Click Apply.



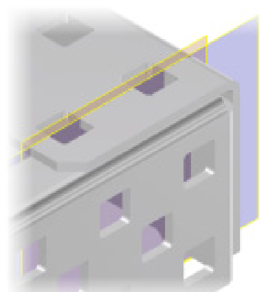
8. Select the top face on the second part.



9. Move the cursor over the top face of the first part. When the Select Other tool is displayed, click the right arrow to cycle through the faces. When the bottom face is highlighted, click the green button to select the face.



10. Click OK.



11. Save the file.

Assemble the Two Frame Components

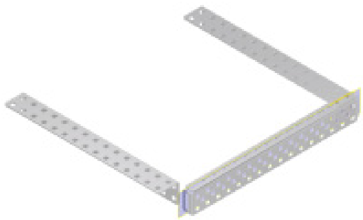
In this section of the exercise, you add the other frame components to the existing assembly.

1. On the ViewCube, click Home.

2. Click Place Component.

3. To place the third part:

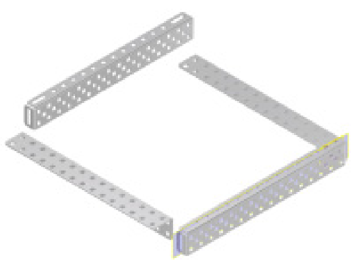
- Select *ANG-HH22-15-SK RevA.ipt*.
- Click Open.
- Click to place an occurrence of the component.
- Right-click in the graphics window. Click Done.



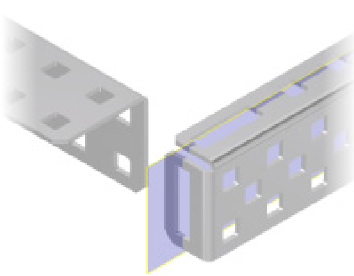
4. Click Place Component.

5. To place the fourth part:

- Select *VL-RAIL-21-16 RevA.ipt*.
- Click Open.
- Click to place an occurrence of the component.
- Right-click in the graphics window. Click Done.



6. Zoom into the end of the parts as shown.



7. In the browser, expand ANG-HH22-15-SK RevA:2.

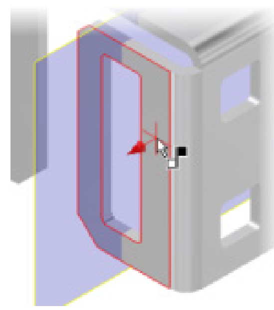
8. Right-click Work Plane1. Click Visibility to turn on visibility.

Assemble the Next Two Frame Components

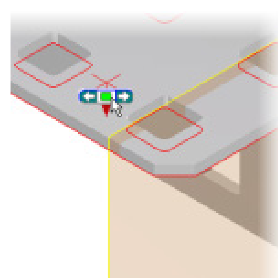
In this section of the exercise, you assemble the next two components of the frame.

1. Click Constraint.

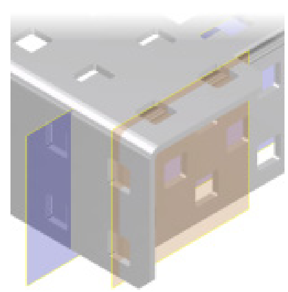
2. Select the end face of the part as shown.



3. Move the cursor over the top face of the other part. When the Select Other tool is displayed, click the right arrow to cycle through the faces. When the underside face is highlighted, click the green button to select the face.



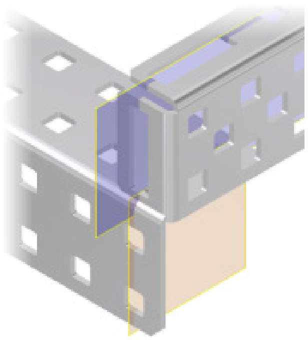
4. Click Apply.



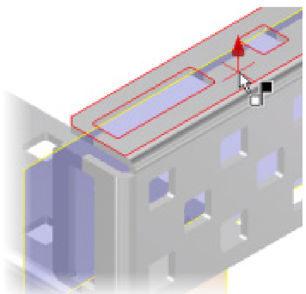
5. Select the edge of the work plane on one of the parts.

6. Select the edge of the work plane on the other part.

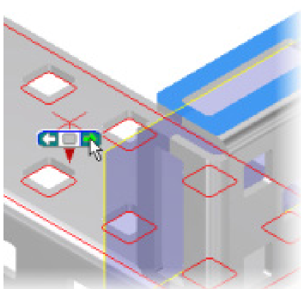
7. Click Apply.



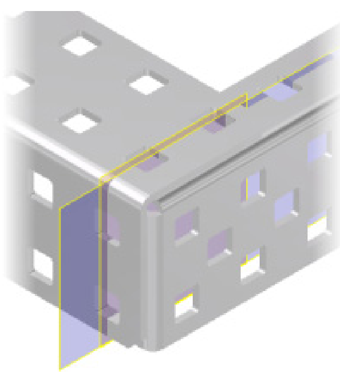
8. Select the top face on the part as shown.



9. Move the cursor over the top face of the other part. When the Select Other tool is displayed, click the right arrow to cycle through the faces. When the underside face is highlighted, click the green button to select the face.



10. Click OK.

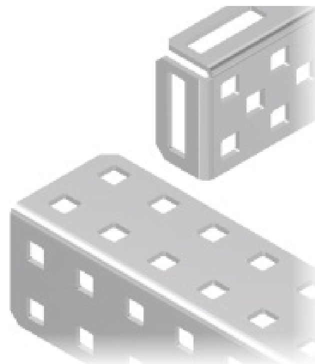


Complete the Frame

In this section of the exercise, you assemble two components of the frame.

1. Pan to the left end the part as shown.

2. Drag the other part closer as shown.

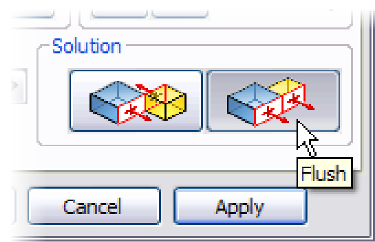


3. Turn on the visibility of Work Plane2 on ANG-HH22-15-SK RevA:2.

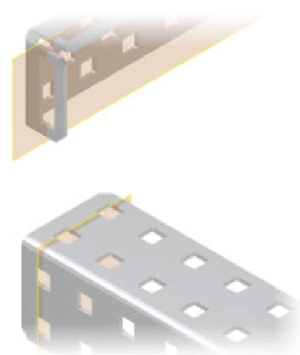
4. Turn on the visibility of Work Plane1 on VL-RAIL-21-16 RevA:2.

5. Click Constraint.

6. Under Solution, click Flush.

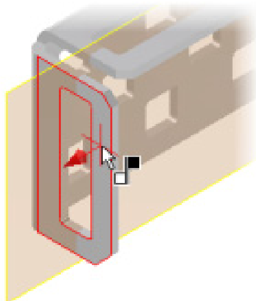


7. Select the edge of a work plane on one of the parts. Select the other work plane. Click Apply.

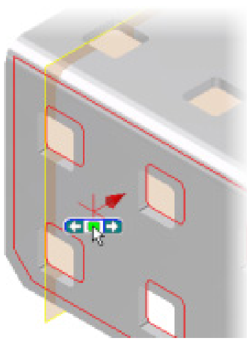


8. Under Solution, click Mate.

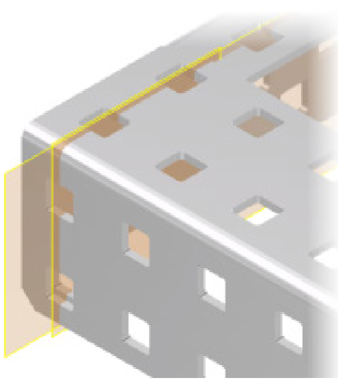
9. Select the end face of part 4.



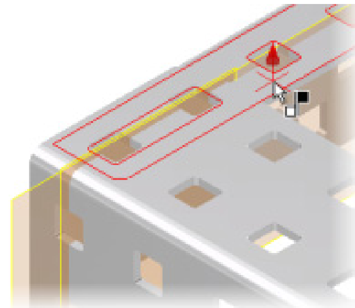
10. Move the cursor over the front face of the part as shown. When the Select Other tool is displayed, click the right arrow to cycle through the faces. When the back face is highlighted, click the green button to select the face.



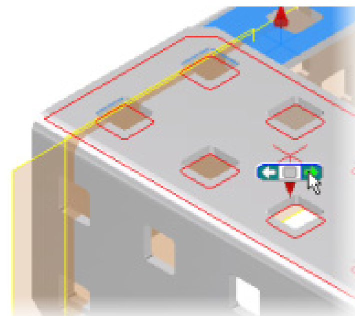
11. Click Apply.



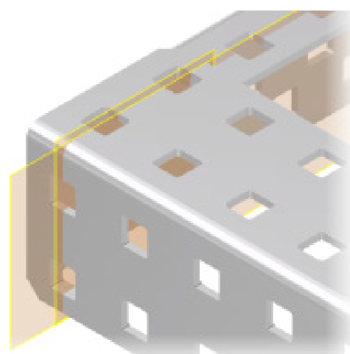
12. Select the top face of the part as shown.



13. Move the cursor over the top face of the other part. When the Select Other tool is displayed, click the right arrow to cycle through the faces. When the underside face is highlighted, click the green button to select the face.



14. Click OK.



15. Turn off the visibility of the work planes.

16. Save the file.

Place the Standard Parts

In this section of the exercise, you place the standard parts in the assembly.

The bolt and washer are Content Center parts. You should not model standard parts.

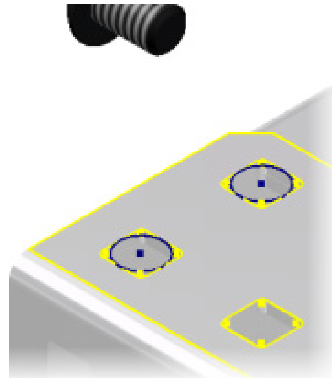
1. Click Place Component.

2. To place the bolt:

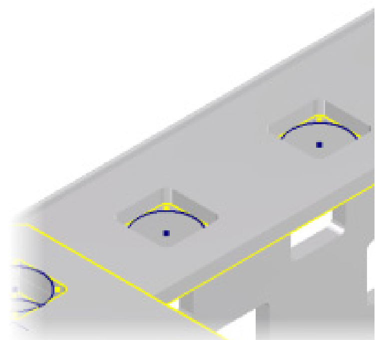
   - Select *SCREW-832-0250.ipt*.
   - Click Open.
   - Click to place an occurrence of the component.
   - Right-click in the graphics window. Click Done.

3. Use the same workflow to place *NUT-832-KEPS.iam* in the assembly.

4. In the browser, expand ANG-HH22-15-SK RevA:2. Right-click Sketch3. Click Visibility to turn on the visibility of the sketch.

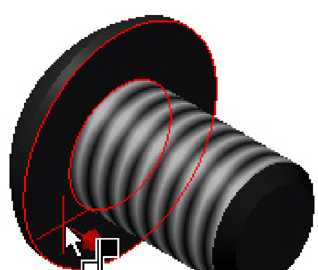


5. In the browser, expand VL-RAIL-21-16 RevA:2. Right-click Sketch2. Click Visibility to turn on the visibility of the sketch.

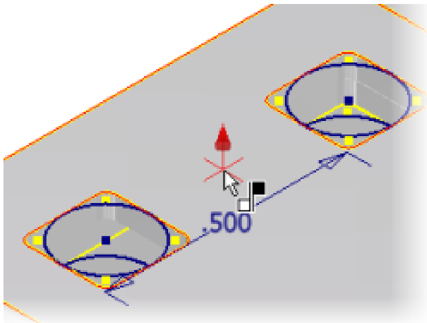


6. Click Constraint.

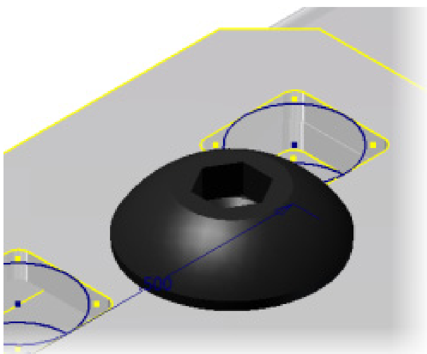
7. Select the face of the bolt.



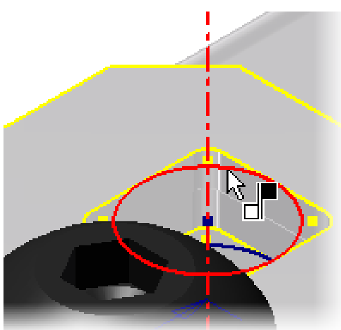
8. Select the top face of the part between the circles.



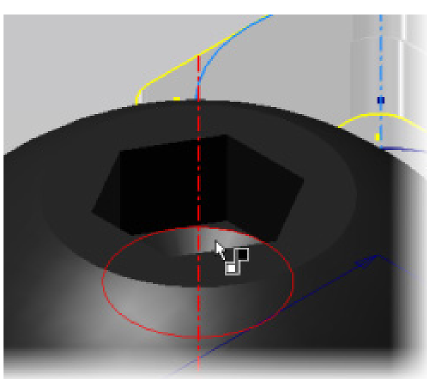
9. Click Apply. This is a *face/face* mate constraint.



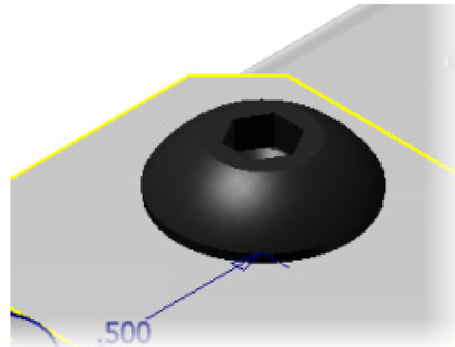
10. Select the circle.



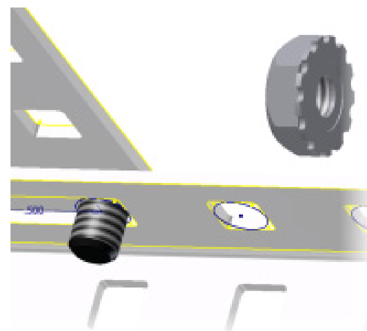
11. Move the cursor into the center of the bolt. Select the axis.



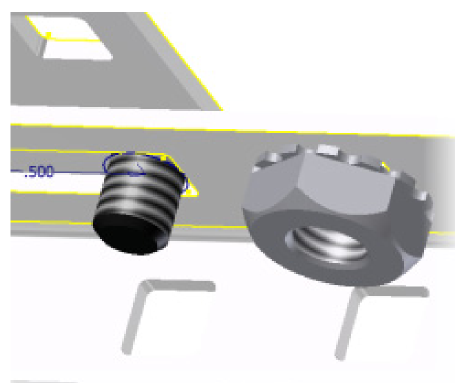
12. Click OK. This is an *axis/axis* mate constraint.



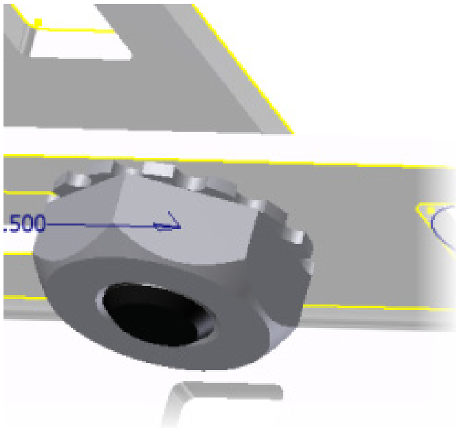
13. Rotate the assembly to view the nut and bolt as shown.



14. Using the same workflow as the previous steps, add a face/face mate constraint between the nut and the part.

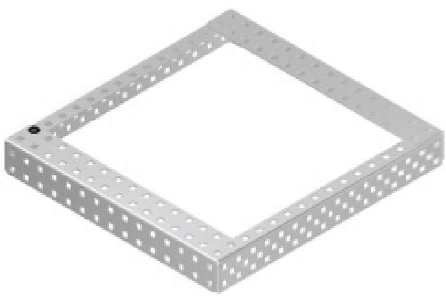


15. Add an axis/axis constraint between the nut and the bolt.



16. On the ViewCube, click Home.

17. Turn off the visibility of the sketches.



The frame requires many more nuts and bolts to complete the assembly. This workflow is suitable for a few fasteners, but a more efficient workflow would be required for many fasteners. Possible workflows are:

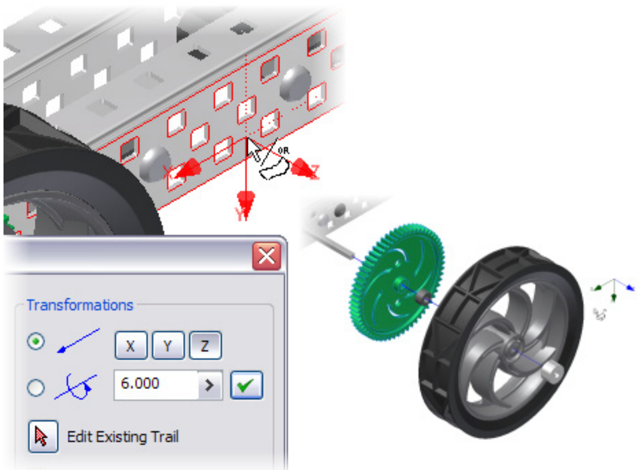
- Create a subassembly of the nut and bolt. This would reduce the work required by half.
- Identify patterns and use the Rectangular Pattern tool to place many instances of the initial nut and bolt assembly.

18. Save the file.

19. Close the file.

Exercise: Create a Presentation File

In this exercise, you create an exploded view of the wheel assembly.



The completed exercise

Create a Presentation File

In this exercise, you create an exploded view of the wheel assembly.

1. Make *IFI_Unit3.ipj* the active project.
2. On the Standard toolbar, click New.
3. Click the English tab.
4. Double-click *Standard (in).ipn*.
5. Click Create View.

6. Click Open an Existing File.

7. Double-click *Presentation_Assembly.iam*.
8. Click OK.

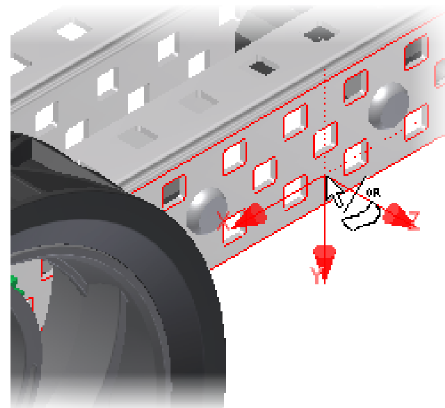
9. Save the file as *my_presentation.ipn*.

Create Tweaks

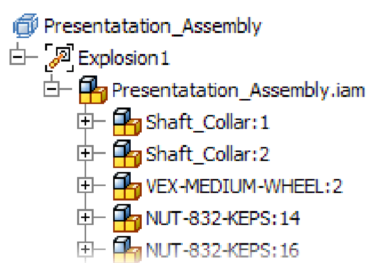
In this section of the exercise, you create tweaks for each part of the wheel assembly.

1. Click Tweak Components.

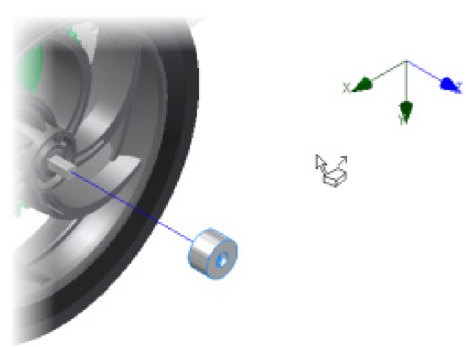
2. Select the front face of the frame. This sets the direction triad.



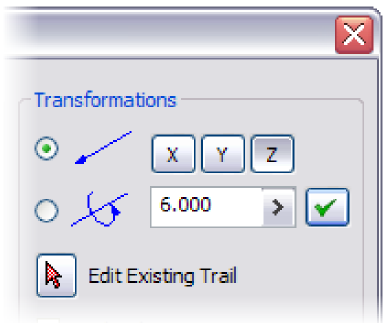
3. In the browser, expand Explosion1 > *Presentation_Assembly.iam*.



4. Select SHAFT-COLLAR:1.
5. In the graphics window, click and drag the arrowhead on the direction vector to create a tweak in the direction of the arrow.

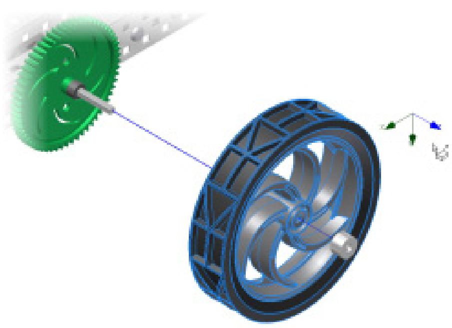


6. In the Tweak Component dialog box, enter **6**. Click the check mark.



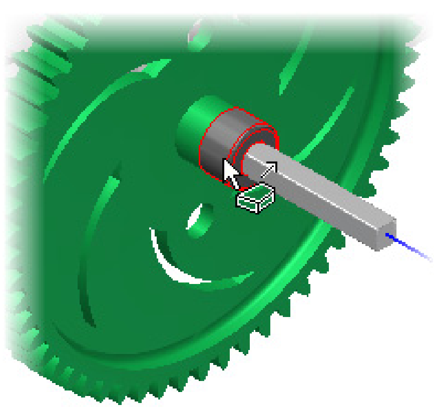
7. In the browser, select VEX-MEDIUM-WHEEL:2. This selects the wheel and clears selection from the shaft collar.

8. In the Tweak Component dialog box, enter **5**. Click the check mark.

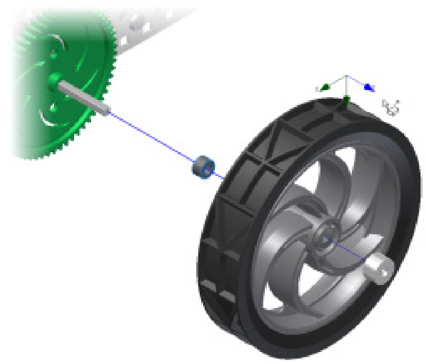


9. In the browser, hold down the CTRL key. Select VEX-MEDIUM-WHEEL:2. This clears selection from the wheel.

10. In the graphics window, select the spacer.



11. In the Tweak Component dialog box, enter **3**. Click the check mark.



12. In the browser, hold down the CTRL key, and then select VEX-MEDIUM-WHEEL:2. This clears selection from the wheel.

13. In the graphics window, select the gear.

14. In the Tweak Component dialog box, enter **2.5**. Click the check mark.

15. Click Close.

Animate the Tweaks

In this section of the exercise, you animate the tweaks on the wheel assembly.

1. Click Animate.

2. In the Animation dialog box, click Play Forward.

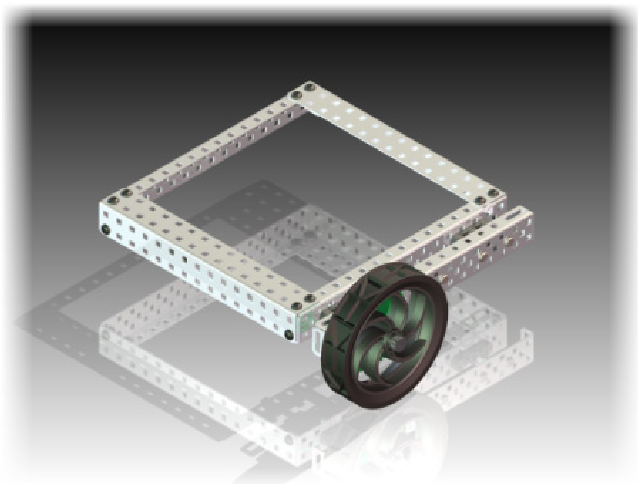
3. Click Cancel.

4. Save the file.

5. Close the file.

Exercise: Render the Protobot Assembly

In this exercise, you render the Protobot frame and wheel assembly.



The completed exercise

Render the Protobot Assembly

In this exercise, you render the frame and wheel assembly of the Protobot.

1. Make *IFI_Unit3.ipj* the active project.

2. Open *Render_Assembly.iam.*

3. Click Tools menu > Application Options.

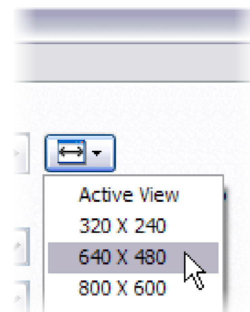
4. On the Colors tab, under Color Scheme, select Presentation. Click OK. The background color changes to white.

5. Zoom and pan so that the assembly is as large as possible in the graphics window.

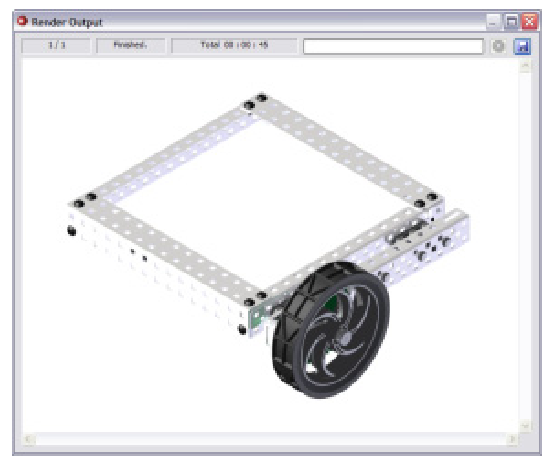
6. Click Applications menu > Inventor Studio.

7. Click Render Image.

8. From the Select Output Size list, select 640x480.

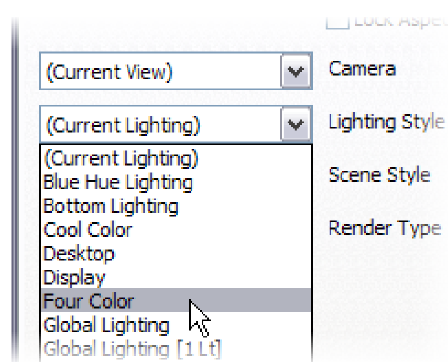


9. Click Render.

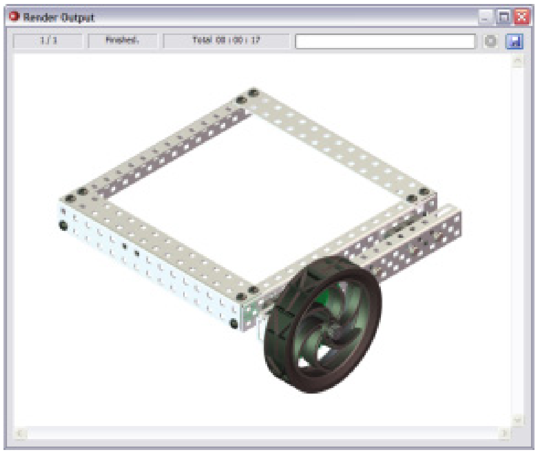


10. Close the Render Output window.

11. Under Lighting Style, select Four Color from the list.



12. Click Render.

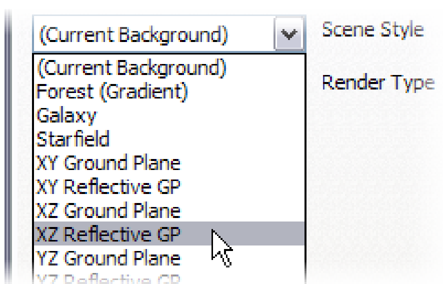


13. Close the Render Output window.

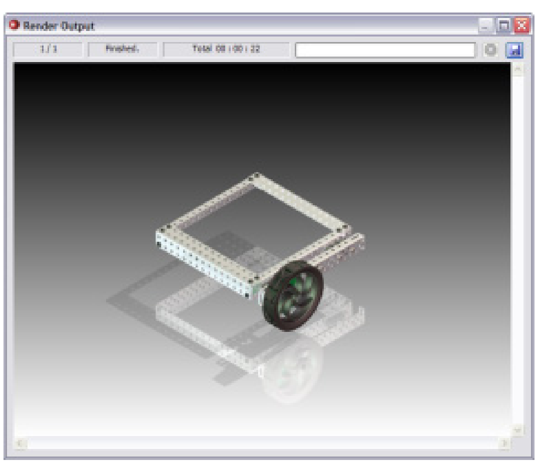
Use a Reflective Scene Style

In this section of the exercise, you render the frame and wheel assembly using a reflective ground plane.

1. Under Scene Style, select XZ Reflective GP from the list.



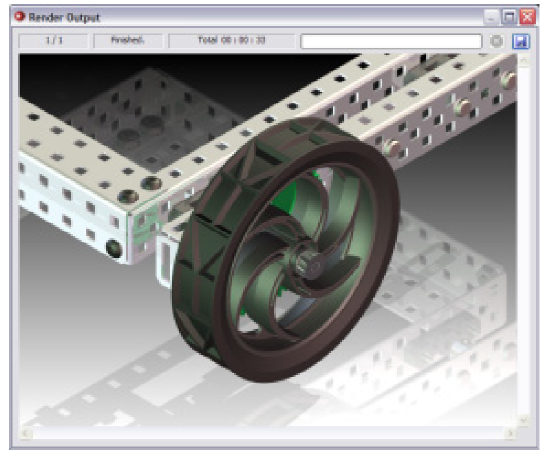
2. Click Render.



3. Close the Render Output window.

4. Zoom in to the wheel assembly.

5. Click Render.



6. Close the Render Output window.

Create an Illustration

In this section of the exercise, you render the frame and wheel assembly using the Illustration Render Type.

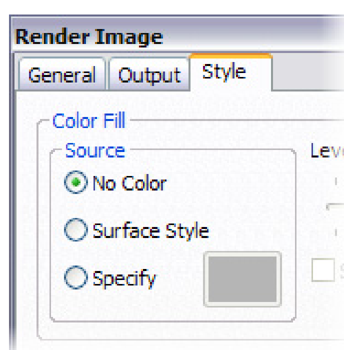
1. From the Lighting Style list, select (Current Lighting).

2. From the Scene Style list, select (Current Background).

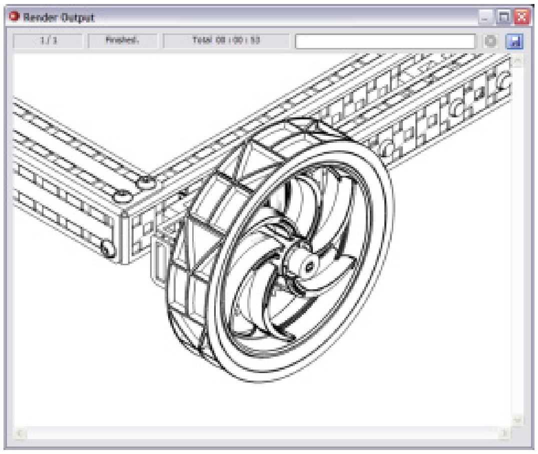
3. From the Render Type list, select Illustration.

4. Click the Style tab.

5. Under Color Fill, for Source, click No Color.



6. Click Render. The Render Output is displayed.



7. Close the Render Output window.

8. Close the Render Image dialog box.

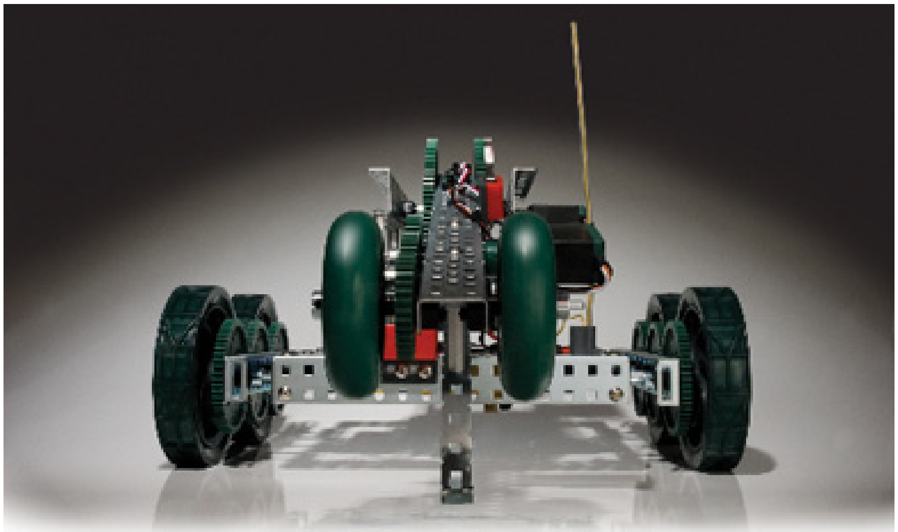
9. Save the file.

10. Close the file.

Build Phase

Overview

This phase describes the steps for building a VEX Protobot.



The Vex Protobot

Phase Objectives

After completing this phase, you will be able to:

- Identify and use the different parts of the VEX Classroom Kit.
- Identify and use VEX parts to complete subassemblies in the creation of the Protobot.
- Assemble and drive a VEX Protobot.

Prerequisites and Resources

Before starting this phase, you must have:

- Completed Unit 3: Building a Protobot > Think Phase.

Related phase resources are:

- Unit 1: Introduction to VEX and Robotics.

Required Supplies and Software

The following supplies are used in this phase:

Supplies
VEX Classroom Lab Kit
Notebook and pen
Work surface
Small storage container for loose parts

VEX Parts

The following VEX parts are used in this phase:

Quantity	Part Number	Abbreviations
4	ALL PURPOSE WHEEL	W4
1	ANTENNA HOLDER	AH
1	ANTENNA TUBE	AT
1	BAR, 25 HOLE	B25
1	BATTERY, 7.2 VOLT RECHARGEABLE	BP
2	BATTERY STRAP	BST
4	BEAM, 1/2"	B0.5
6	BEAM, 1"	B1
4	BEAM, 2"	B2
4	BEAM, 3"	B3
18	BEARING FLAT	BF
36	BEARING RIVET	BR
2	C-CHANNEL (1x2x1x15)	C15
1	C-CHANNEL (1x2x1x15)	C25
2	CHASSIS BUMPER (2x2x15), 15 HOLE	A15
4	CHASSIS RAIL, 15 HOLE	R15
3	DRIVE SHAFT, SQUARE BAR 2"	SQ2
7	DRIVE SHAFT, SQUARE BAR 3"	SQ3
1	DRIVE SHAFT, SQUARE BAR 4"	SQ4

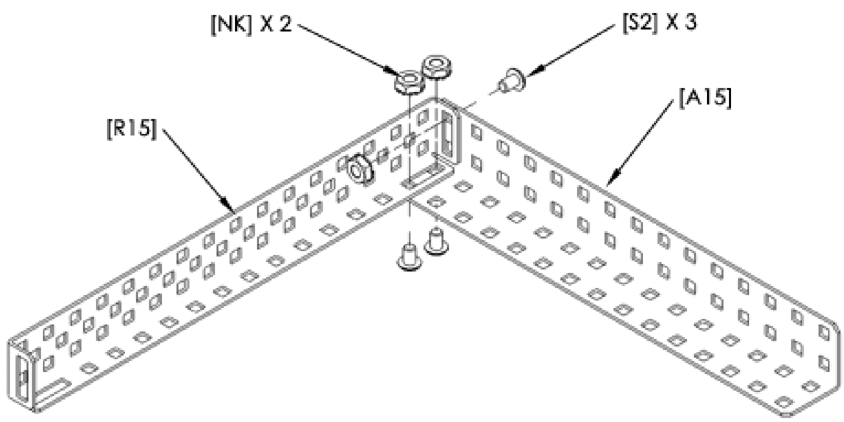
Quantity	Part Number	Abbreviations
2	GEAR, 12 TOOTH	G12
3	GEAR, 36 TOOTH	G36
6	GEAR, 60 TOOTH	G60
2	GEAR, 84 TOOTH	G84
2	LIMIT SWITCH	SWL
2	LOW FRICTION WHEEL	W2.8
1	MICROCONTROLLER	VMC
4	MOTOR with CLUTCH	MOT
31	NUT, KEPS	NK
1	PLATE, 5x15 HOLE	P15
2	PWM EXTENSION CABLE, 6"	
1	RECEIVER MODULE	RX75
8	SCREW, MOTOR #6-32 x 1/4"	SS2
46	SCREW, #8-32 x 1/4"	S2
15	SCREW, #8-32 x 3/8"	S3
4	SCREW, #8-32 x 1/2"	S4
2	SCREW, #8-32 x 3/4"	S6
21	SHAFT COLLAR	COL
2	SPACER, THICK	SP2
10	SPACER, THIN	SP1

Activity

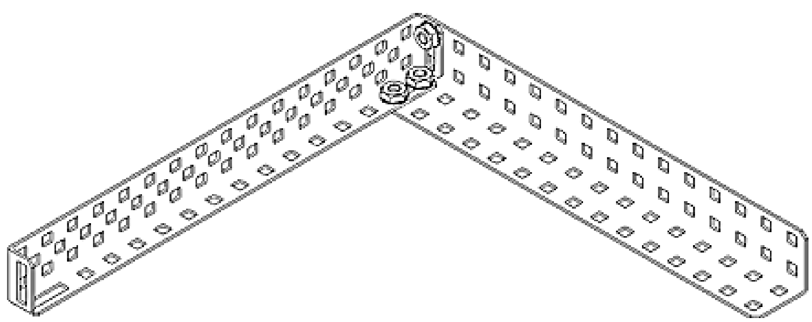
In this activity, you build a complete robot called Protobot. You start by building the base.

1. To complete the first step:

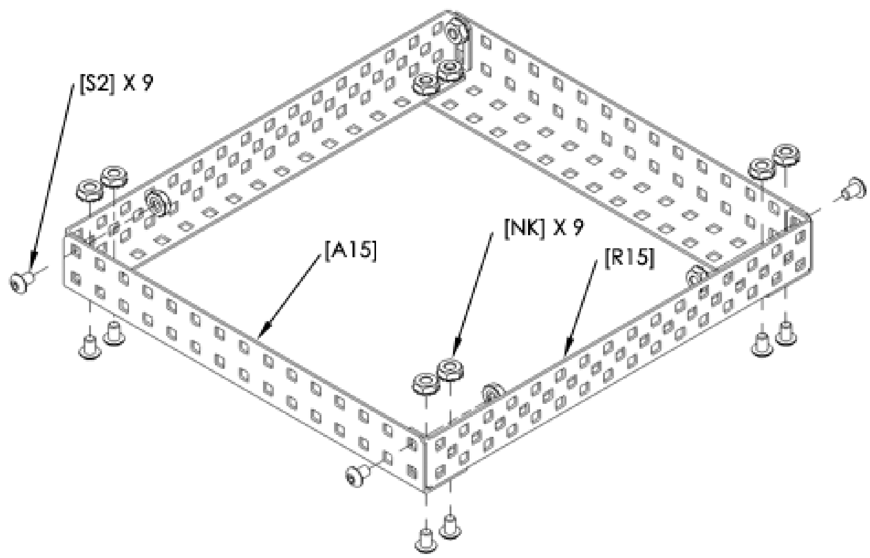
- Locate and select one Chassis Rail [R15] and one Angle [A15].
- Overlap the pieces to form a corner.
- Fasten the pieces together using three #8-32 x 1/4" screws [S2] and nuts.



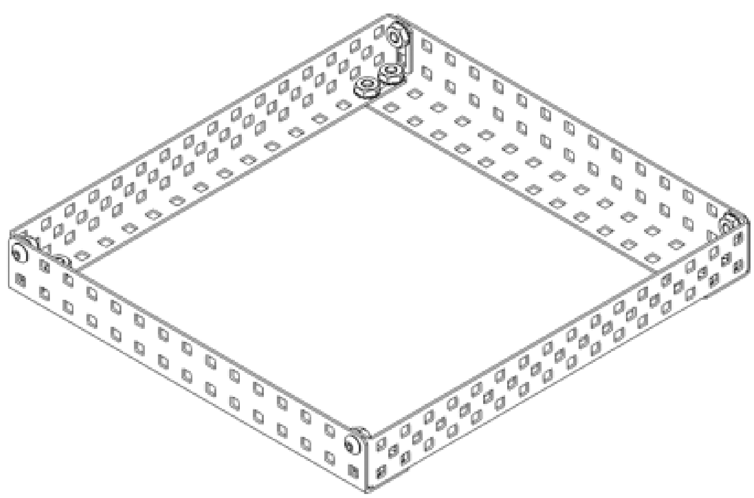
The completed model is as shown:



2. To complete the next step:
   - Locate an additional Angle and Chassis Rail from the kit.
   - Repeat step 1 to form the other three corners.

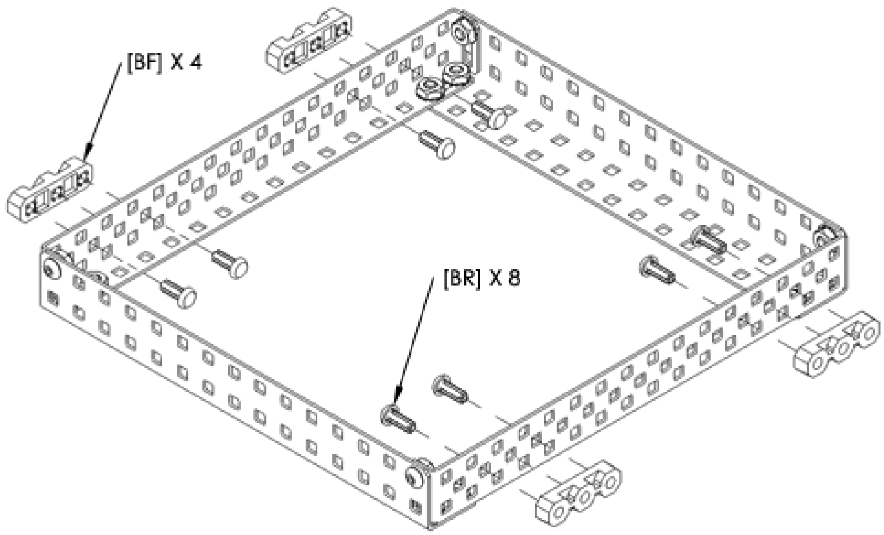


The completed model is as shown:

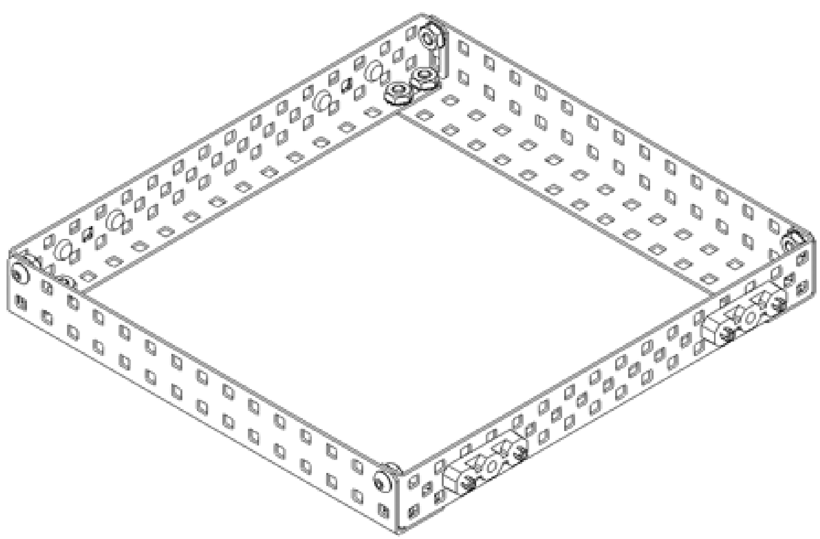


3. To complete the next step:

- Orient the frame so a Chassis Rail is facing you.
- Attach two Bearing Flats [BF] using Bearing Rivets [BR].
- Repeat on the opposite Chassis Rail.

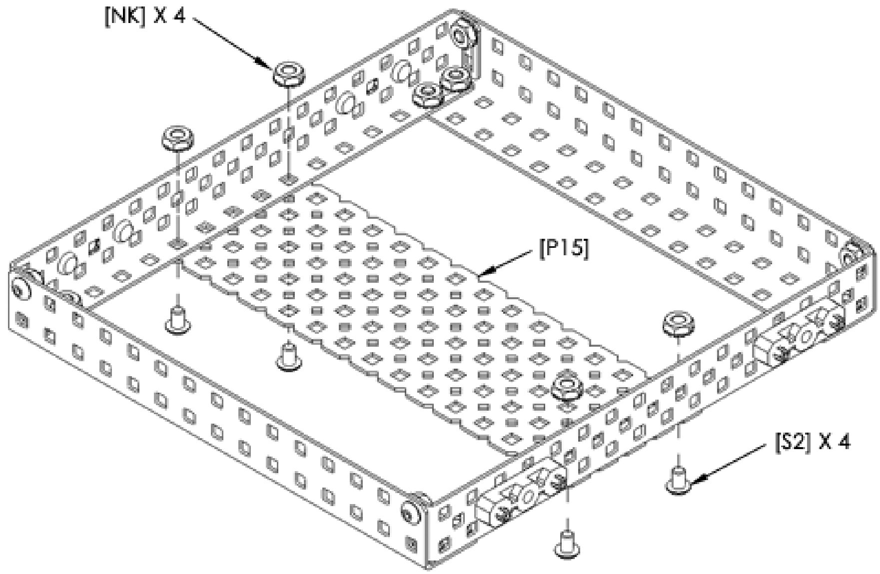


The completed model is as shown:

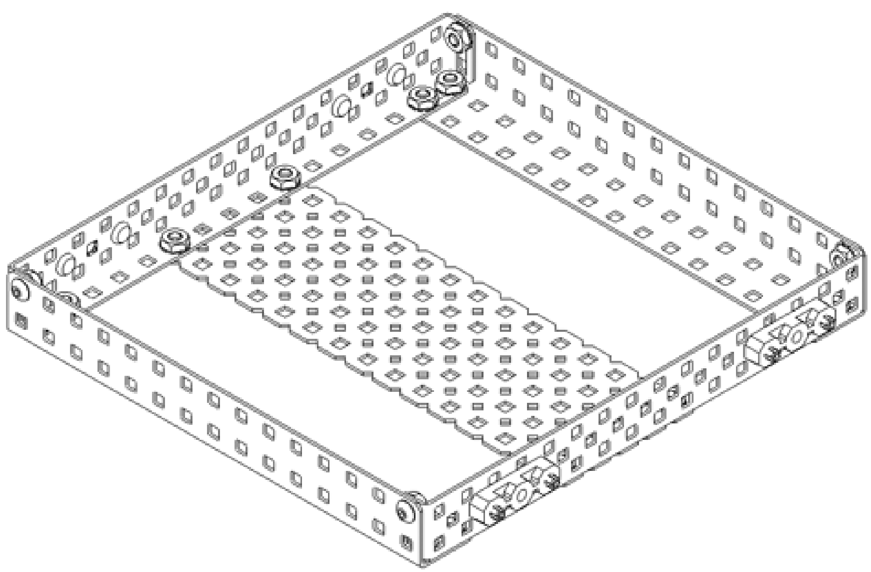


4. To complete the next step:

   - Locate and position the 5 x15 Plate [P15].
   - Attach to the frame using four screws and nuts.

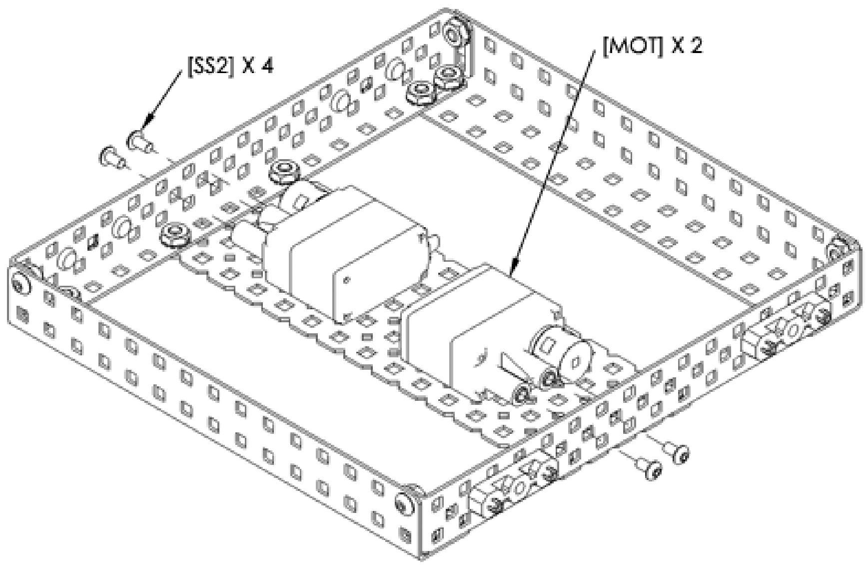


The completed model is as shown:

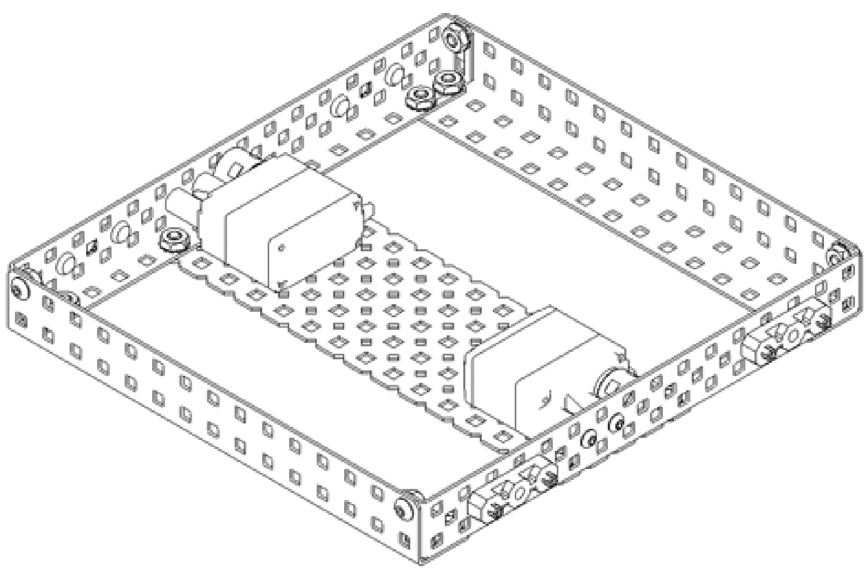


5. To complete the next step:

- Locate two Motor Modules [MOT] in the kit and four [SS2] screws. Double check to make sure you have two motors and not servo modules.
- Attach the motors as shown. Be sure to locate the motor in the middle holes in the rail.



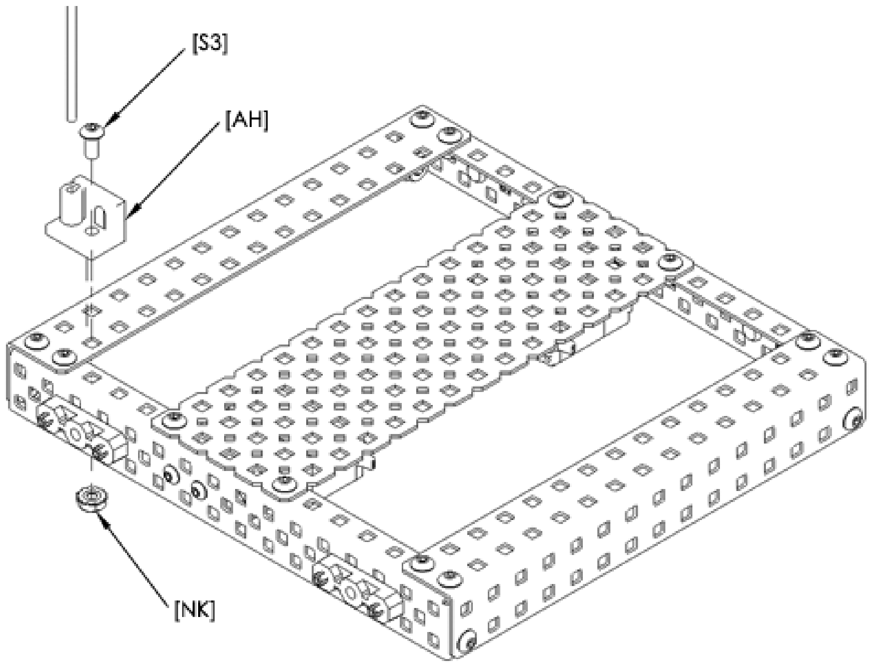
The completed model is as shown:



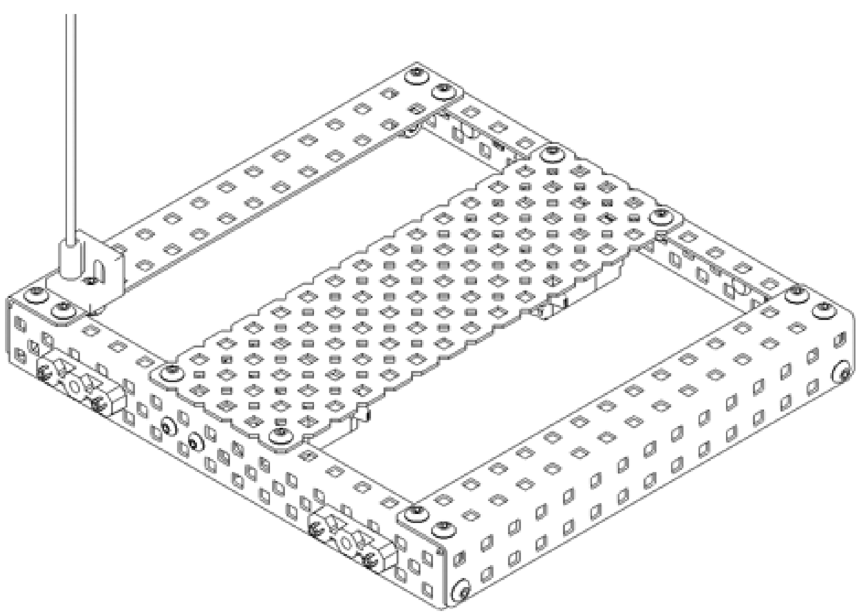
6. To complete the next step:

- Flip the entire assembly over.
- Attach the Antenna Holder [AH] using a #8-32 x 3/8" screw and nut.

The Antenna Straw shown will not be attached until the Receiver is attached later.

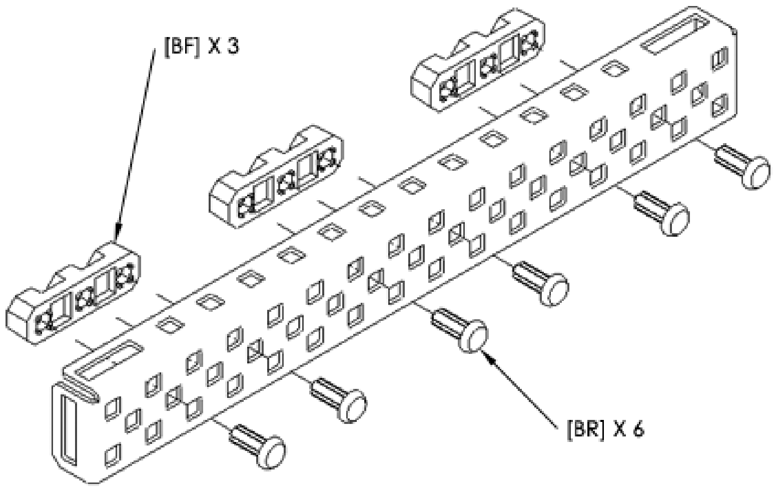


The finished model is as shown:

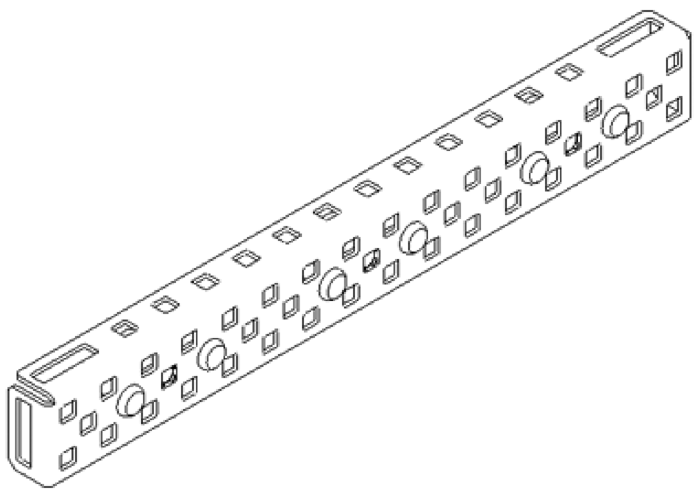


7. To complete the next step:

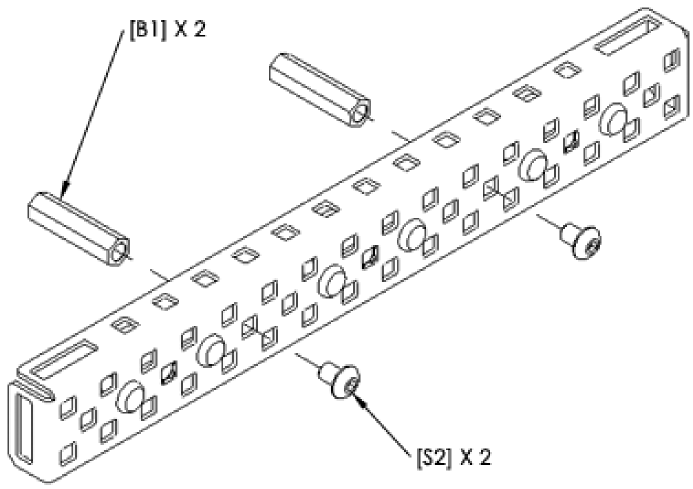
- Locate another Chassis Rail.
- Attach three Bearing Flats using the Bearing Rivets.



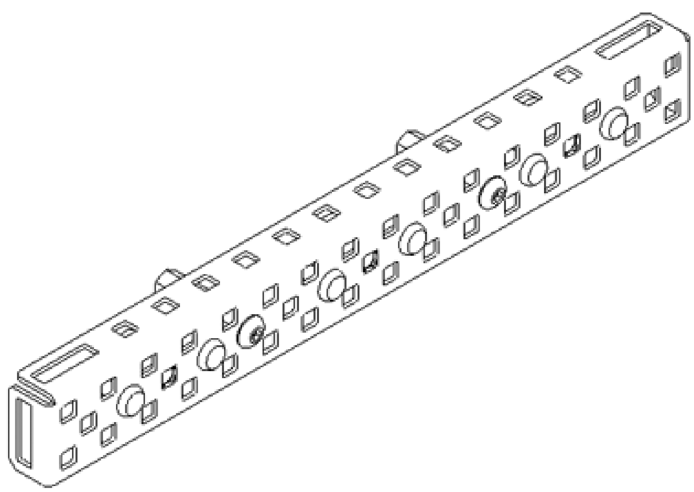
The completed model is as shown:



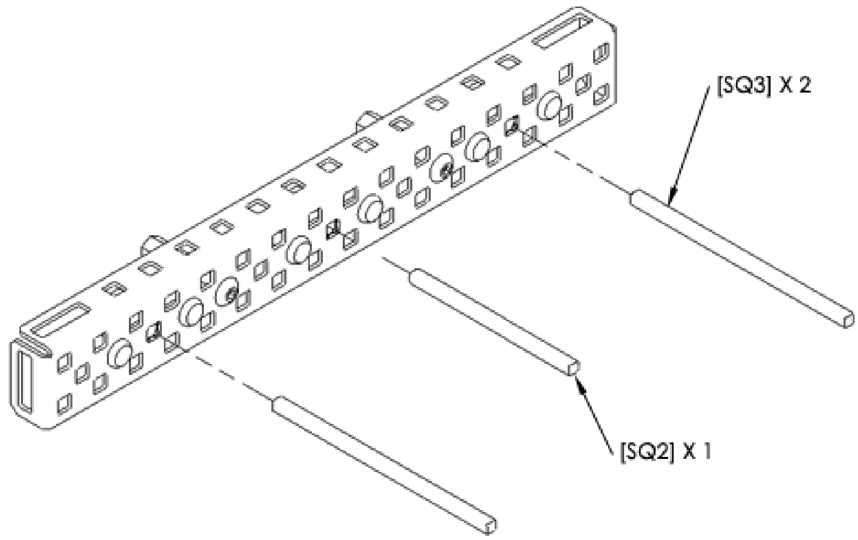
8. Attach two 1" Beams [B1] using 1/4" screws.



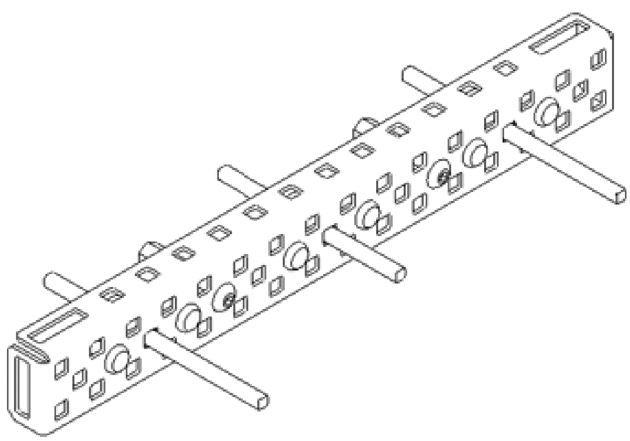
The completed model is as shown:



9. Insert two 3" shafts [SQ3] into the outer Bearing Flats. Insert one 2" shaft [SQ2] into the middle Bearing Flat.

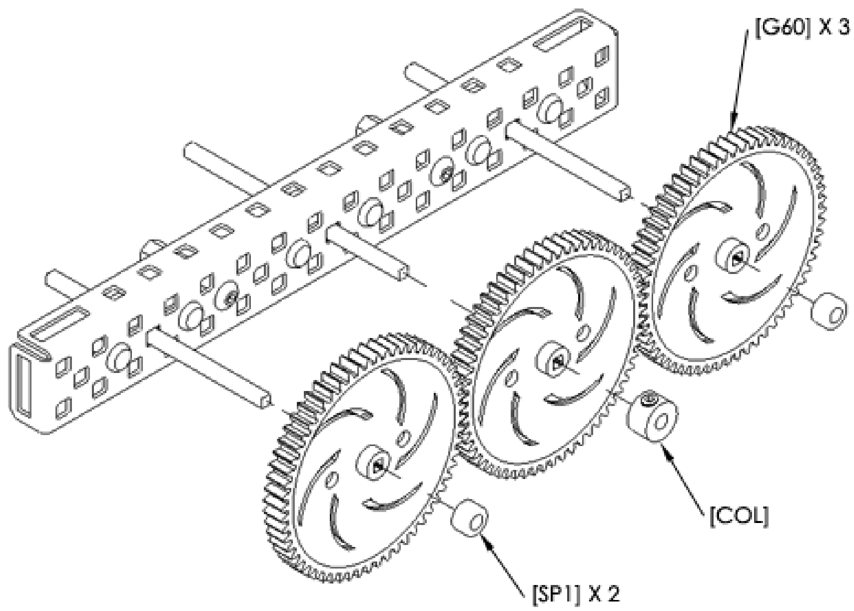


The finished model is as shown:

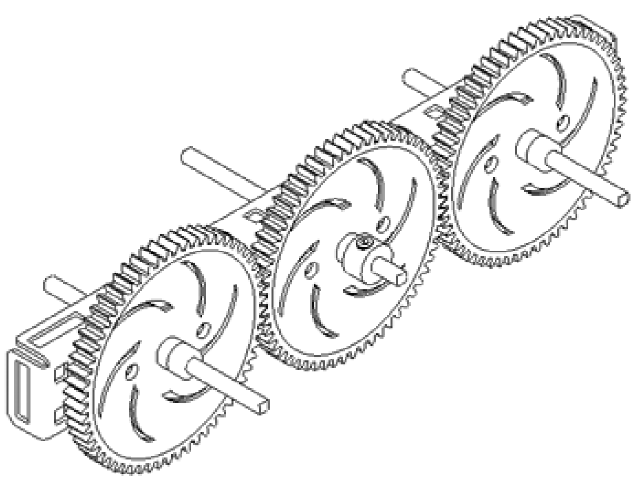


10. To complete the next step:

- Place a 60-tooth gear [G60] on each axle.
- Place a shaft collar [COL] on the middle gear and lightly tighten in position. You will need to adjust the position of the collar when you attach the shaft to the motor.
- Place a thin spacer [SP1] on the other axles.

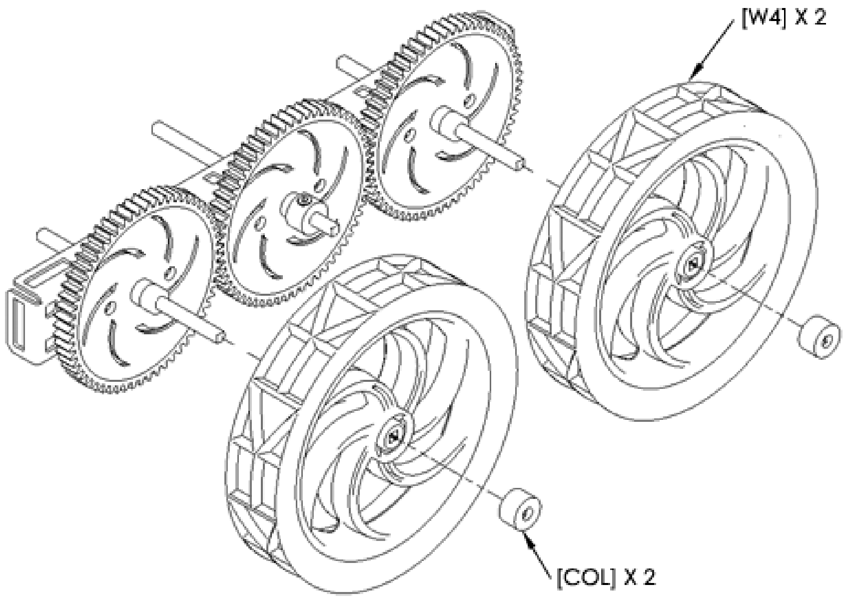


The completed model is as shown:

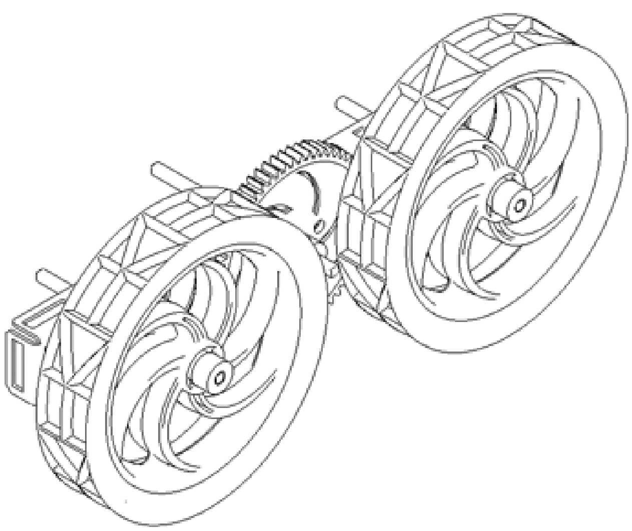


11. To complete the next step:

- Place a 4" Wheel [W4] on the two outer shafts.
- Position and tighten shaft collars to hold the wheels.

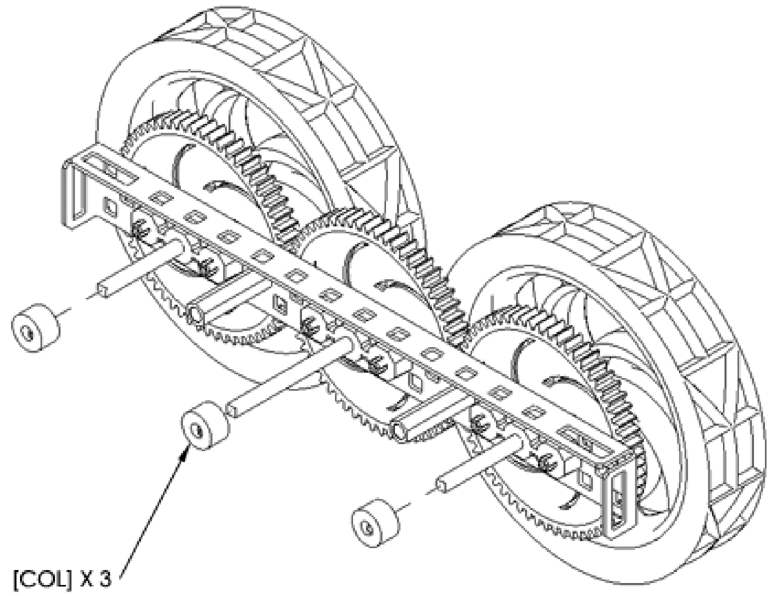


The completed model is as shown:

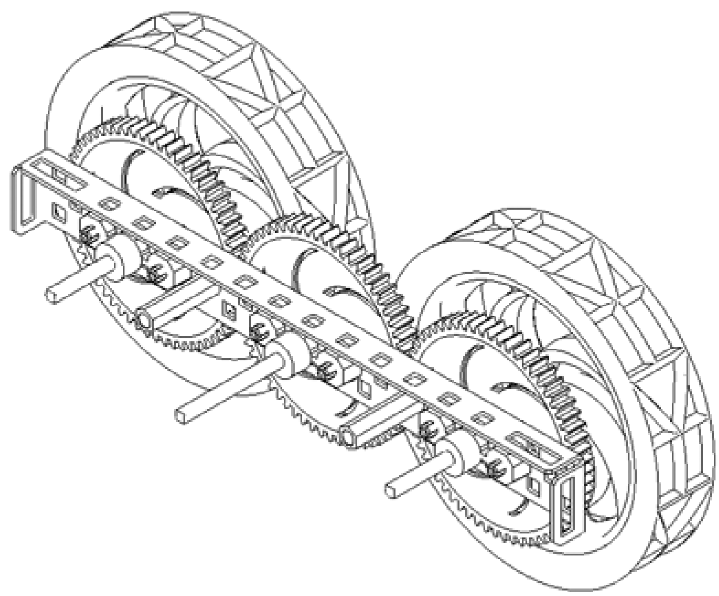


12. To complete the next step:

- Turn the assembly around and attach shaft collars. Tighten the outer two collars. Leave the middle collar loose on the shaft. You will reposition and tighten the collar when you add the wheel assembly to the base.



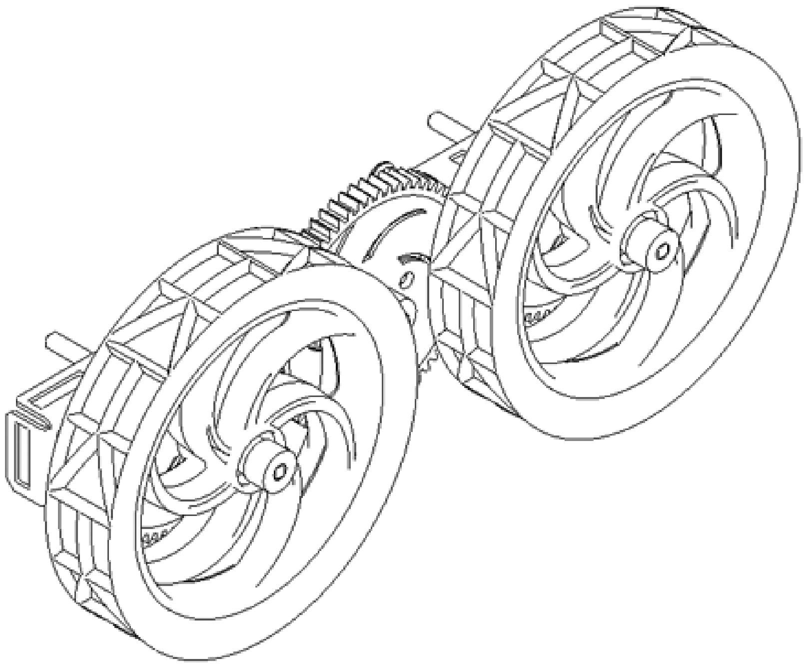
The completed model is as shown:



13. To complete the next step:

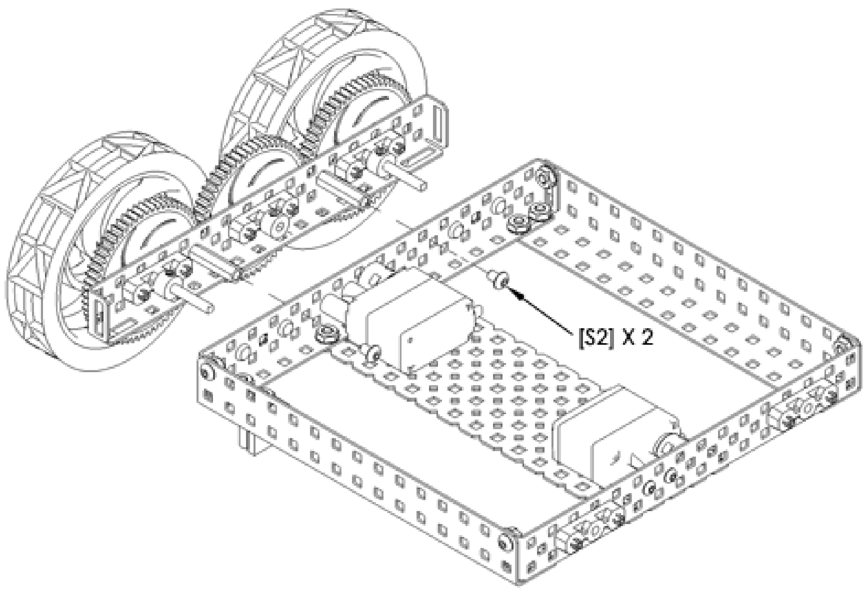
- Make an identical assembly for the other side of the robot by repeating steps 7–12.

The completed model is as shown:

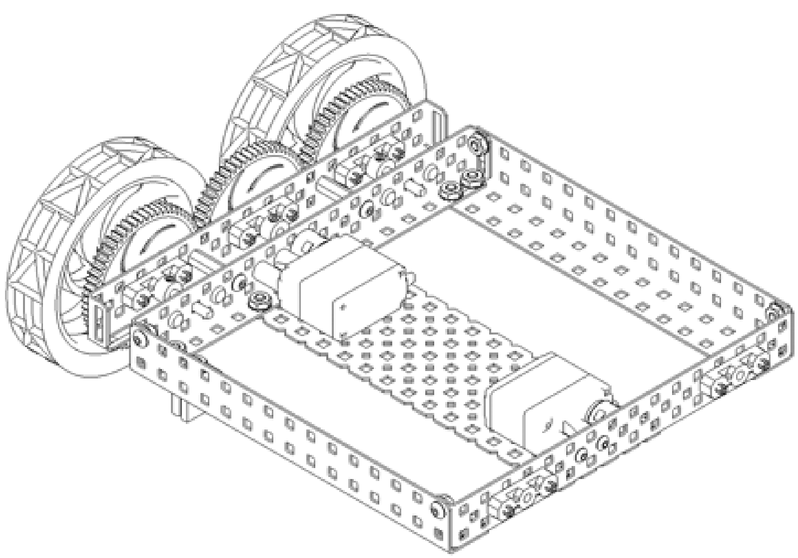


14. To complete the next step:

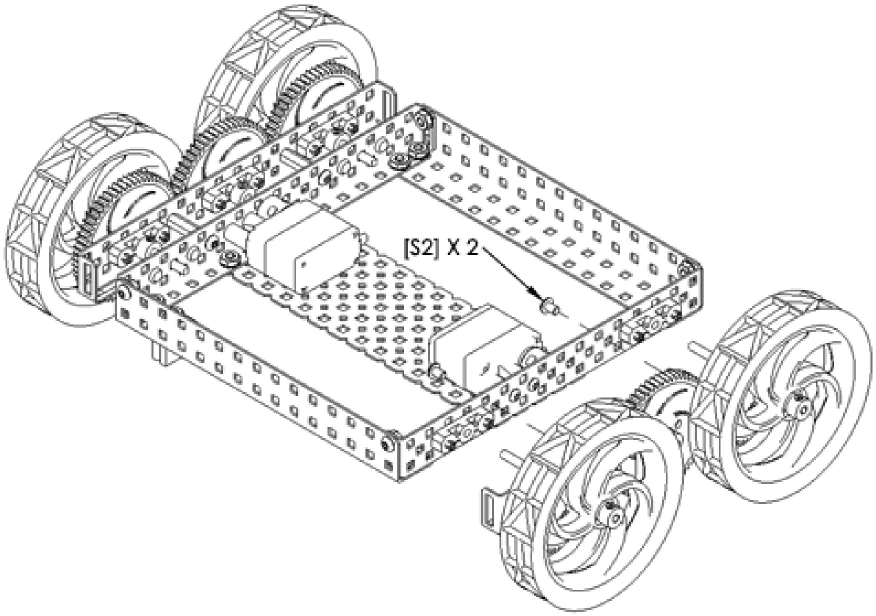
- Loosen the outer shaft collar on the middle shaft on one of the completed wheel assemblies. The inner shaft collar should already be loose.
- Align the wheel assembly with the base assembly.
- Push the two assemblies together making sure that the middle axle slides into the clutch smoothly. You may need to rotate the wheels slightly to line up the axle with the square hole in the clutch.
- Add two screws [S2] into the threaded beams on the wheel assembly.
- Tighten the shaft collars on the middle shaft.



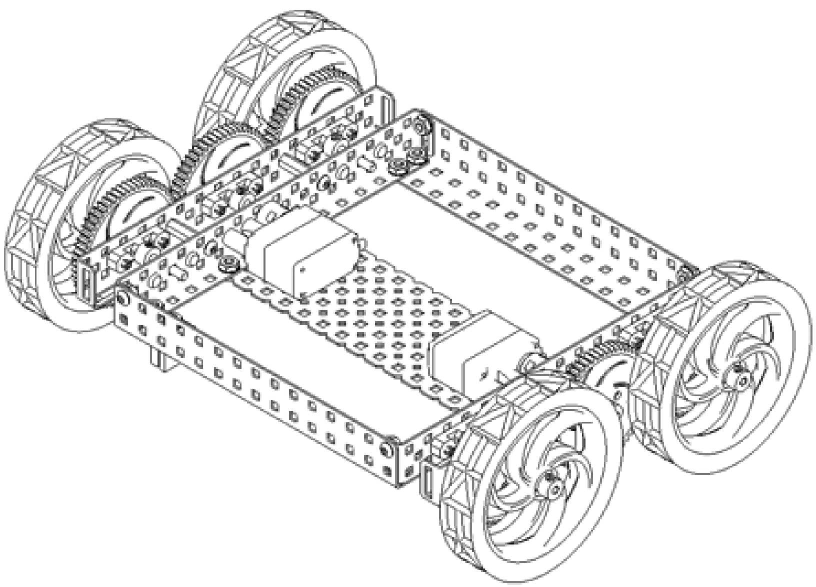
The completed model is as shown:



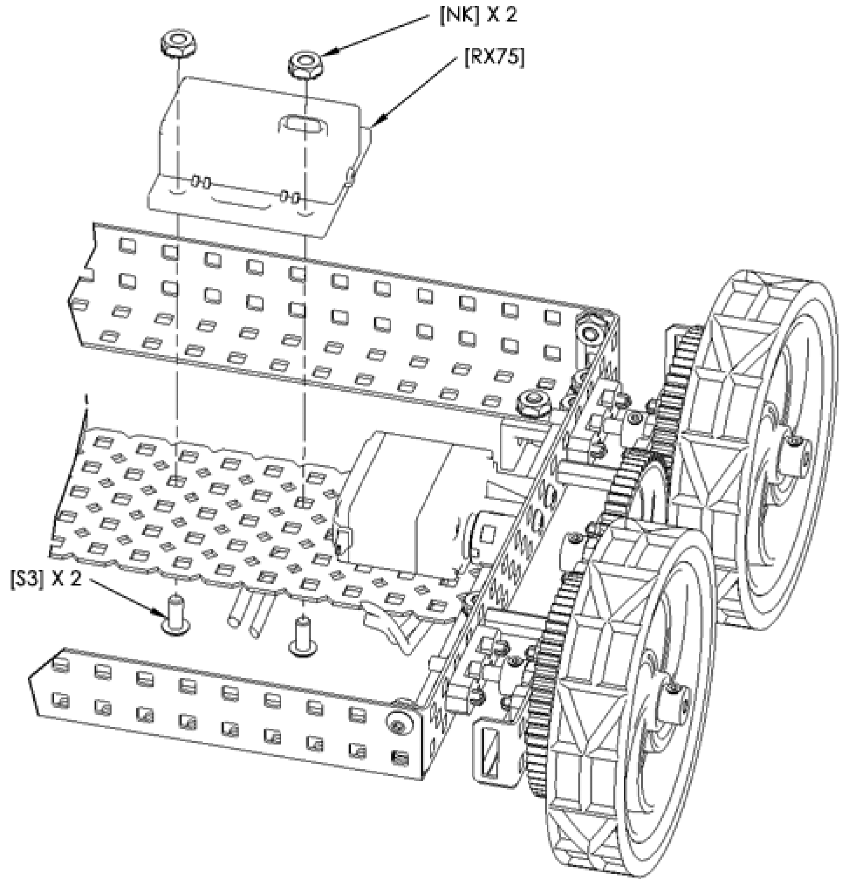
15. Repeat the wheel attachment on the other side.



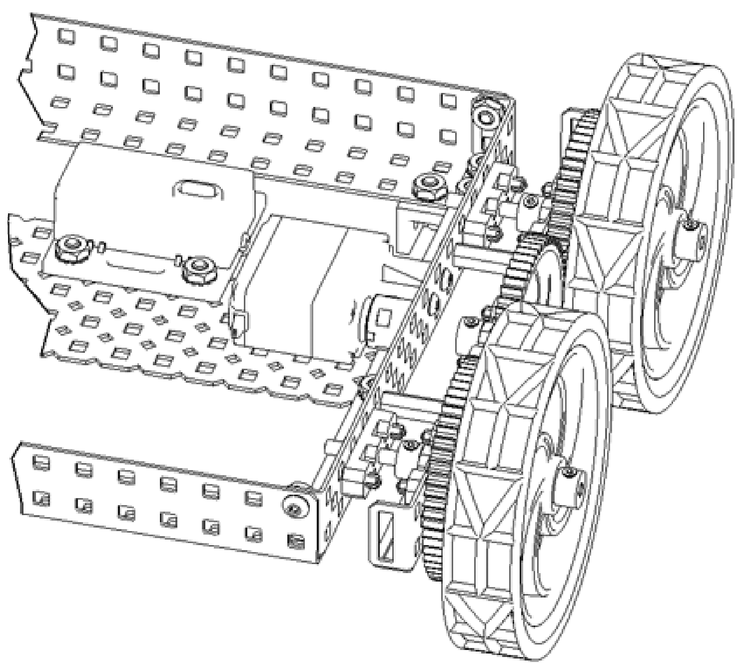
The completed model is as shown:



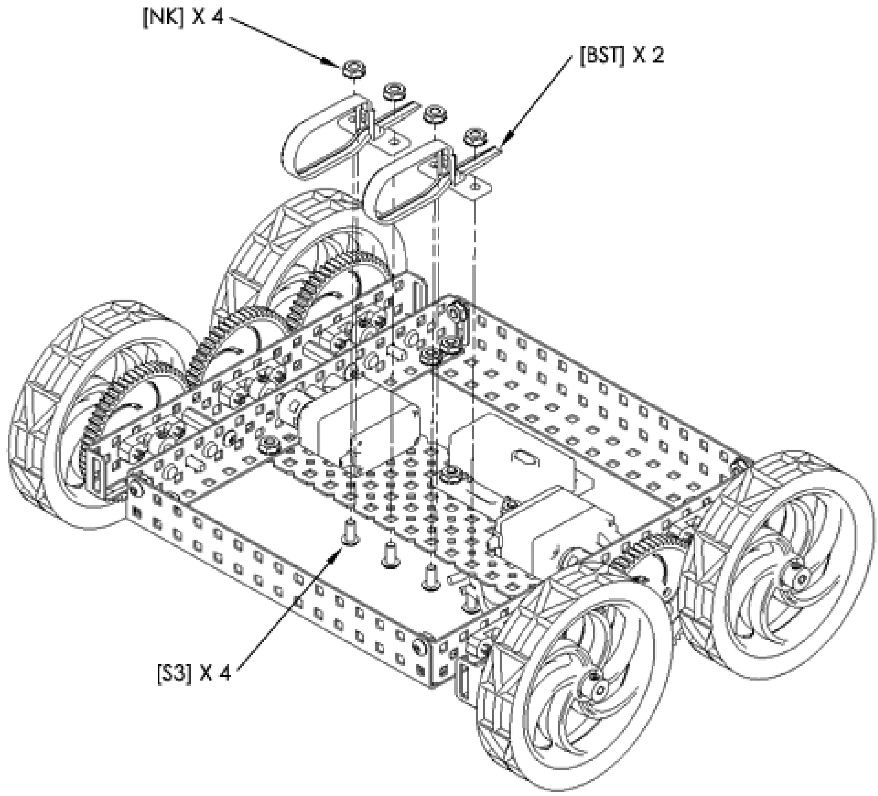
16. Attach the receiver module [RX75] with two 8-32 x 3/8" screws and nuts. Feed the antenna through the antenna tube and insert the tube into the Antenna Holder.



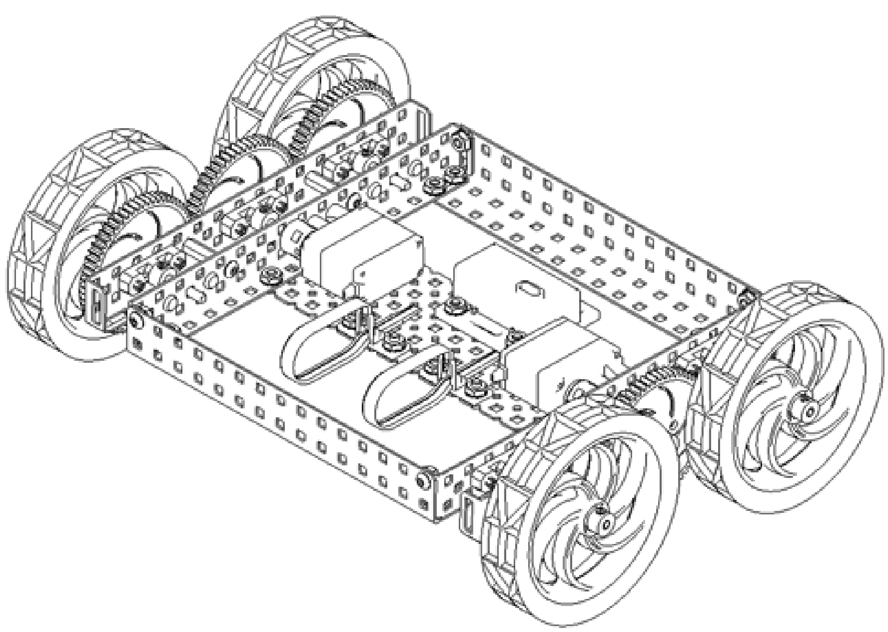
The completed model is as shown:



17. Attach two Battery Straps [BST] using four 8-32 x 3/8" screws and nuts.

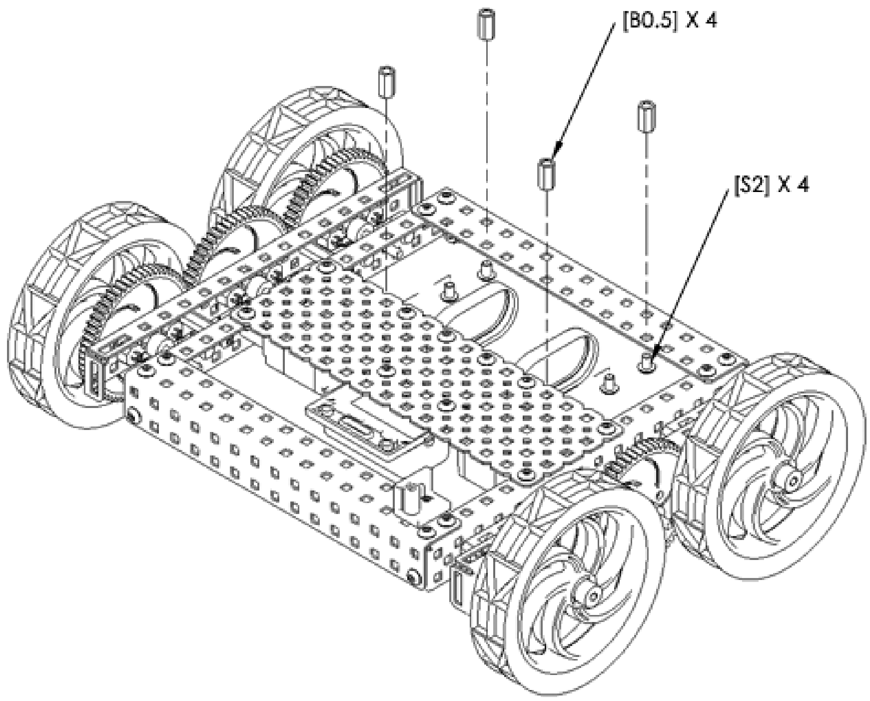


The completed model is as shown:

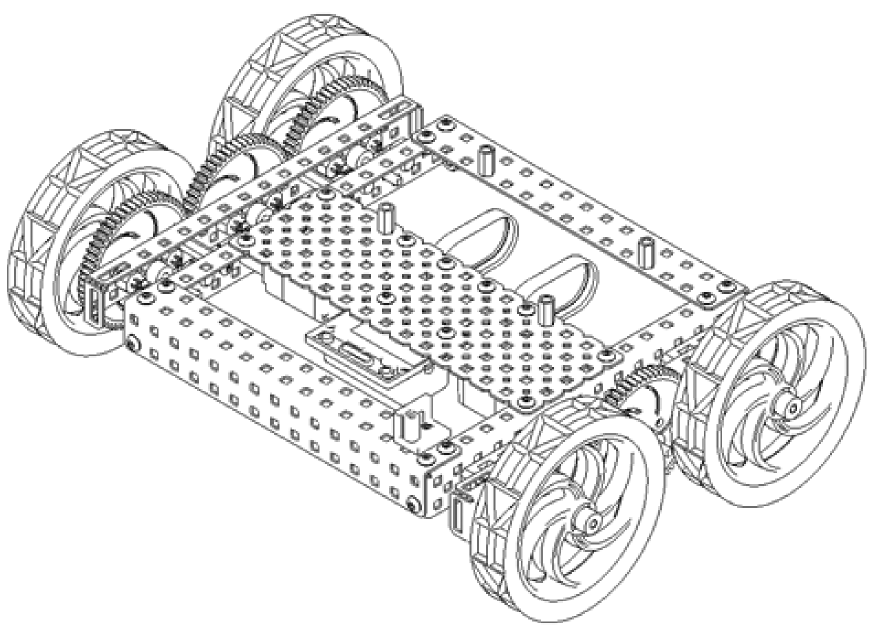


18. To complete the next step:

- Flip the assembly over.
- Attach four 1/2" beams [B0.5] in the positions shown using #8-32 x 1/4" screws [S2].

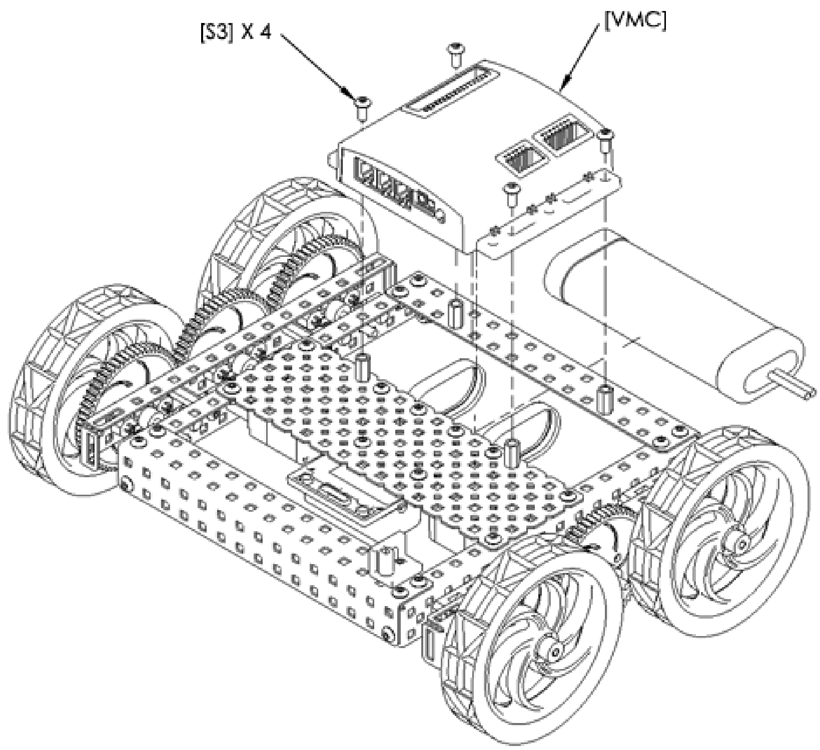


The completed model is as shown:

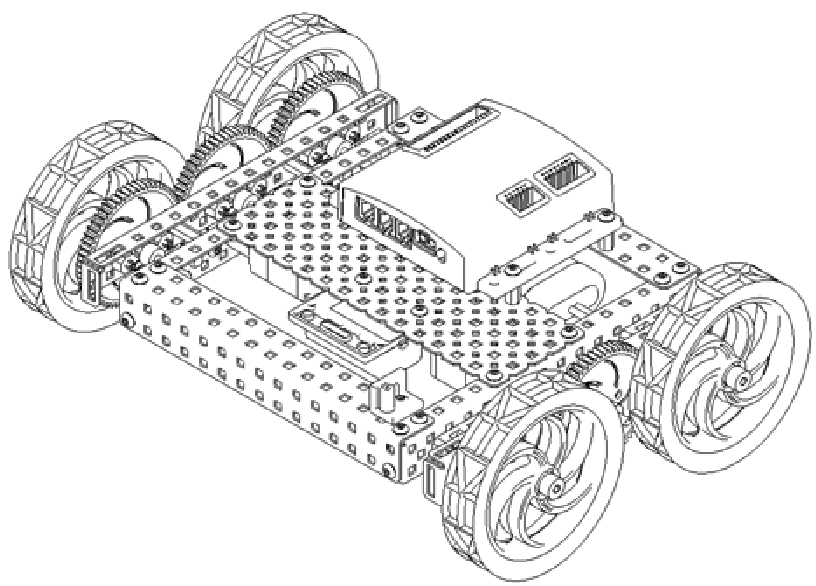


19. To complete the final step:

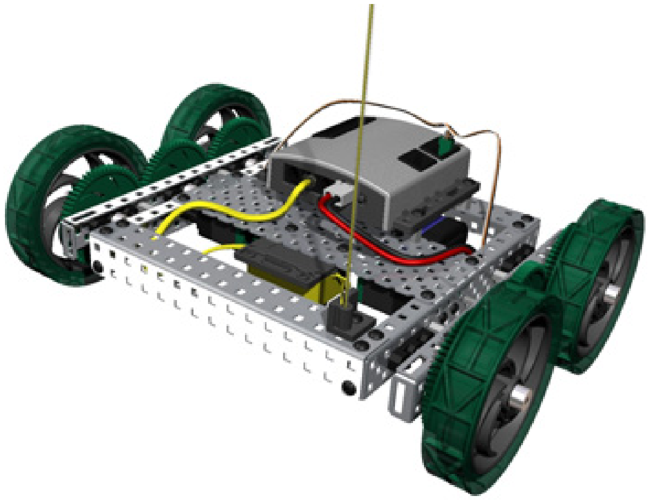
- Fasten the Microcontroller [VMC] to the tops of the threaded beams using #8-32 x 3/8" screws [S3].
- Plug the right and left drive motors into motor ports 2 and 3 respectively (not shown).
- Attach the yellow receiver wire to the receiver and the "Rx1" jack on the Microcontroller (not shown).
- Install a 7.2V battery into the straps and plug it into the controller (cable not shown).



The completed model is as shown:



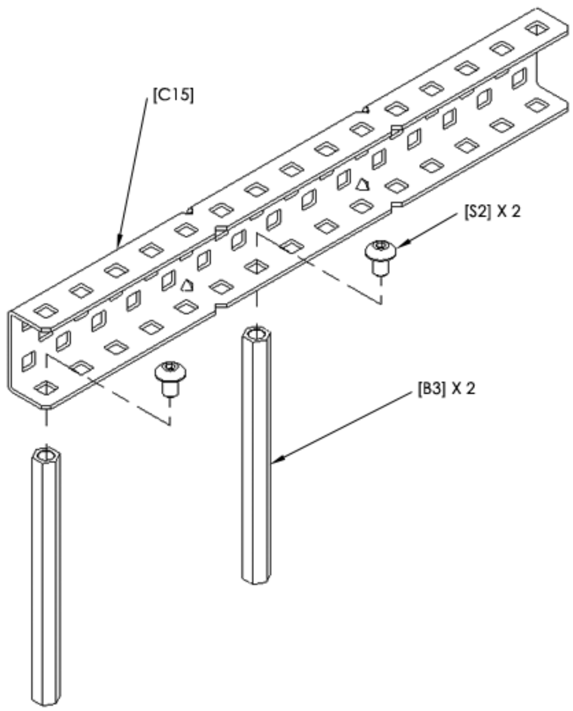
20. You are ready to drive!



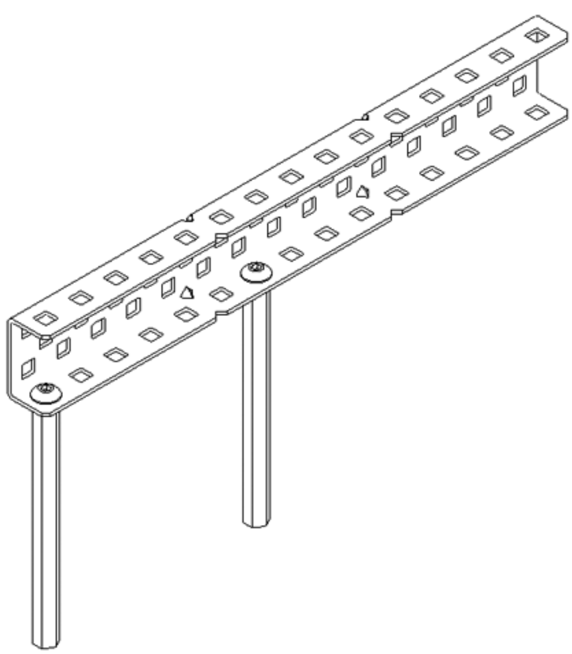
Protobot Stand Assembly Instructions

1. To complete the first step:

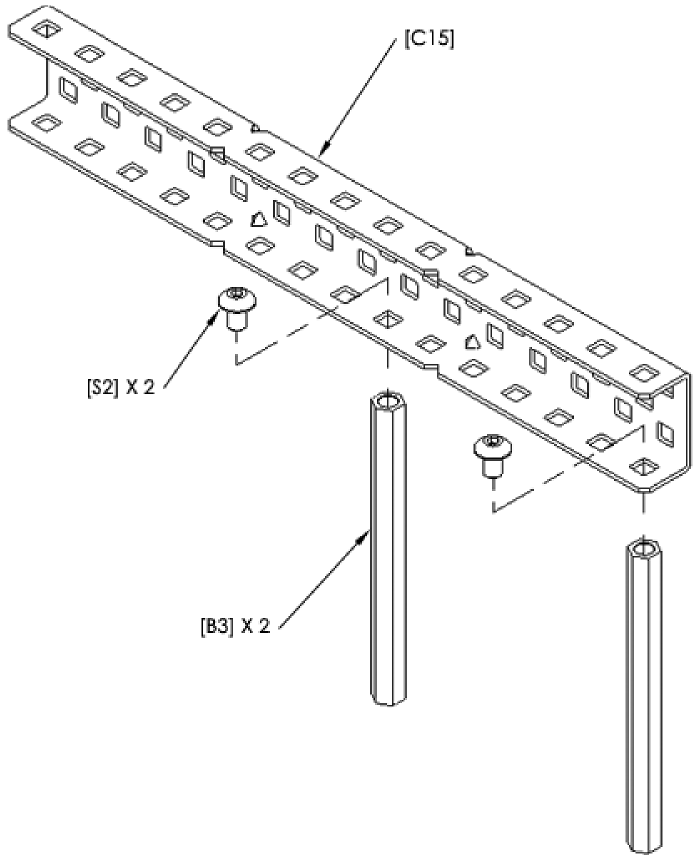
- Locate the appropriate C-channel [C15] from the kit.
- Attach two 3" beams [B3] to the C-channel with screws [S2].



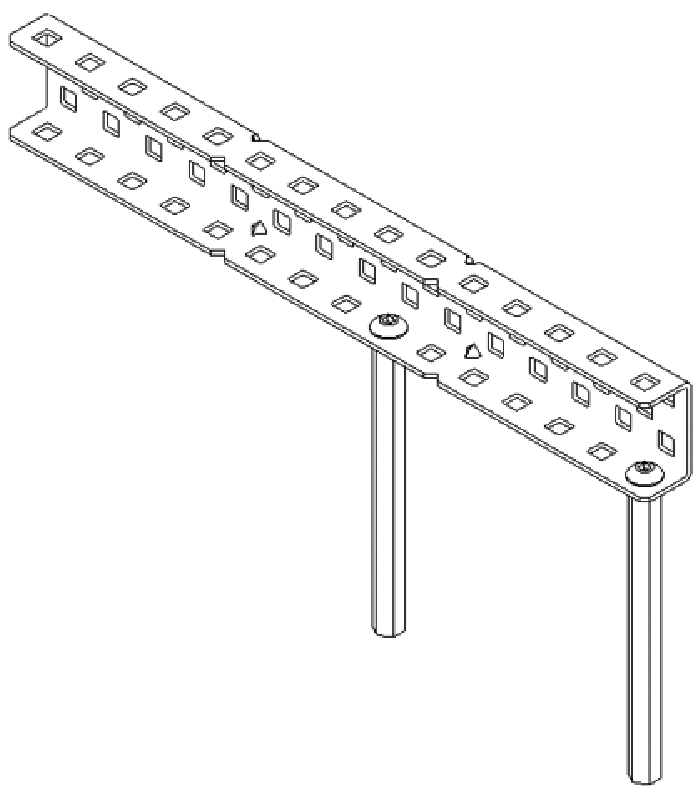
The completed model is as shown:



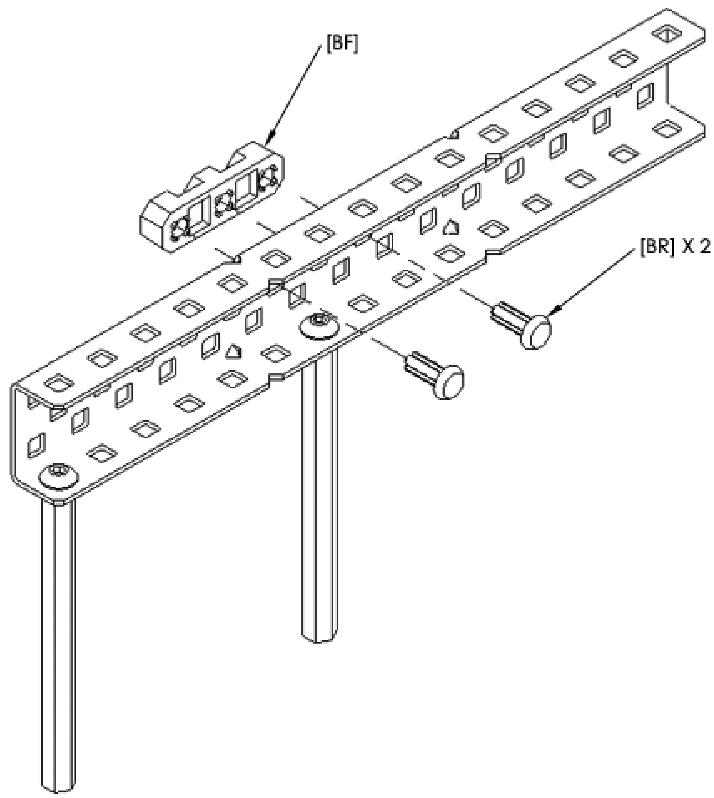
2. Repeat step 1 but complete a mirror-image assembly.



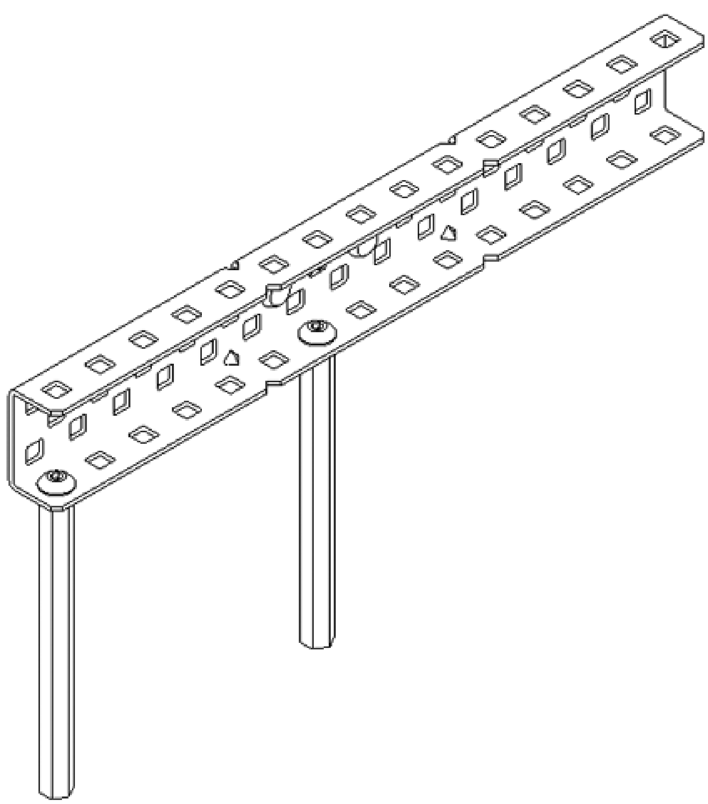
The completed model is as shown:



3. Attach a Bearing Flat [BF] to the C-channel assembly from step 1. Be sure to use the matching assembly for this step, and to place the heads of the rivets on the inside of the C-channel.

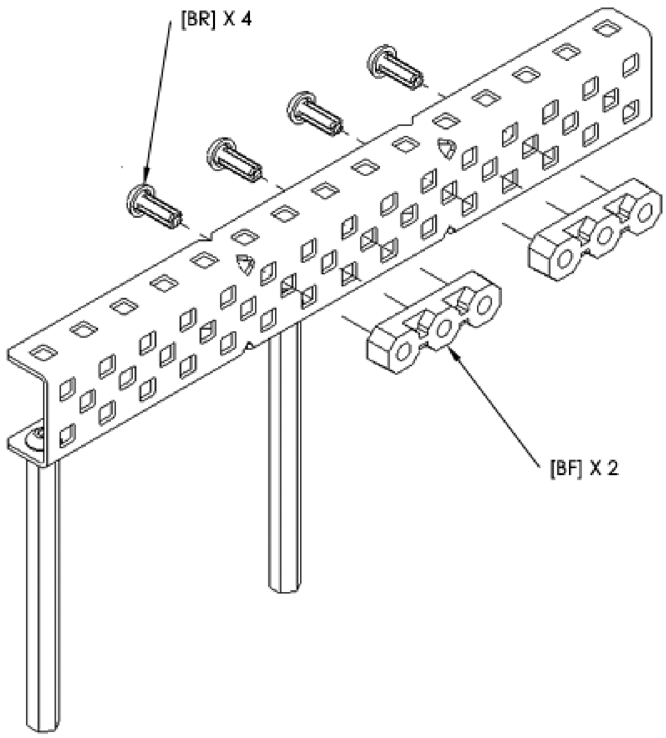


The completed model is as shown:

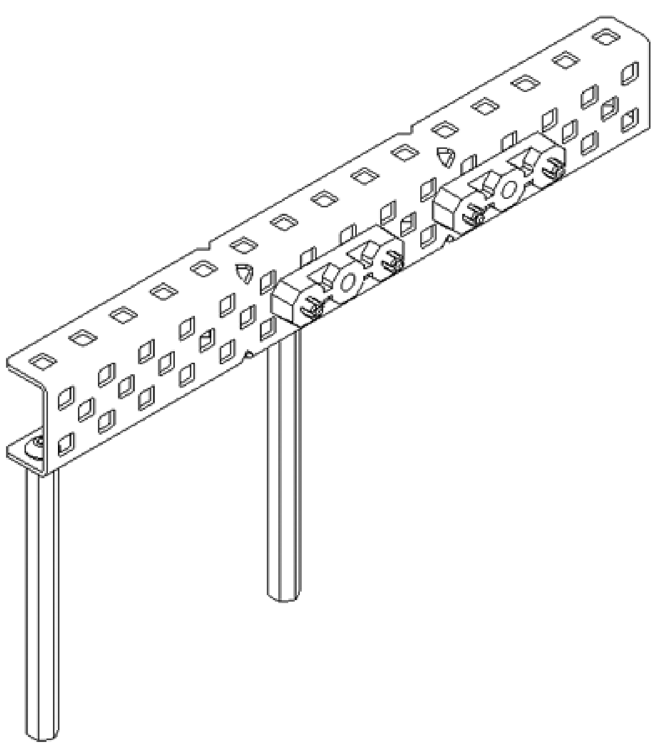


4. To complete the next step:

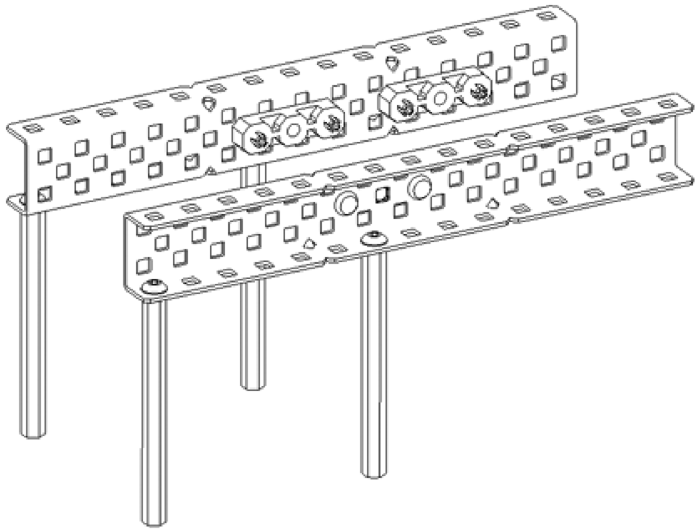
- Attach a Bearing Flat in the same position on the C-channel assembly completed in step 2.
- Attach an additional Bearing Flat to the same C-channel in the position shown.



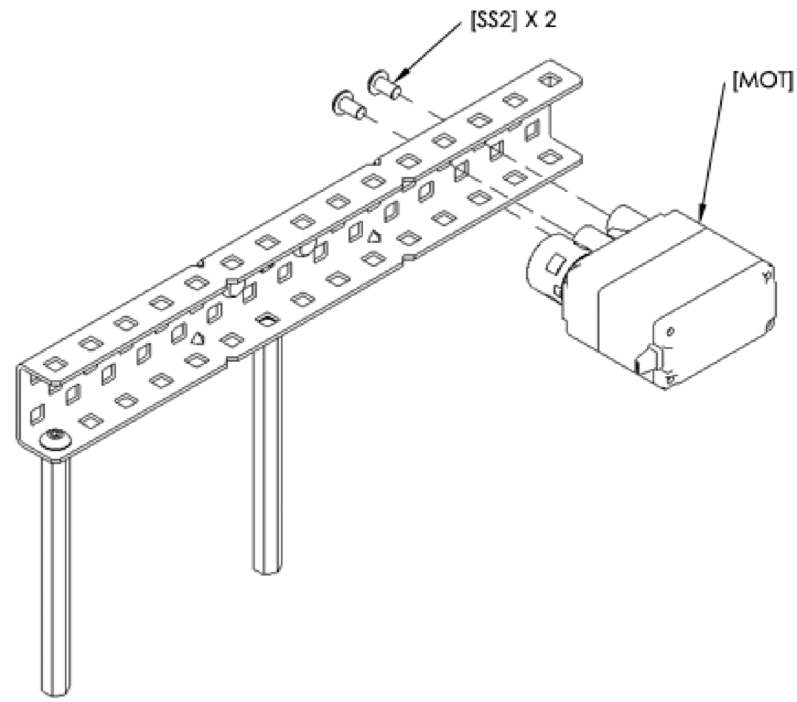
The completed model is as shown:



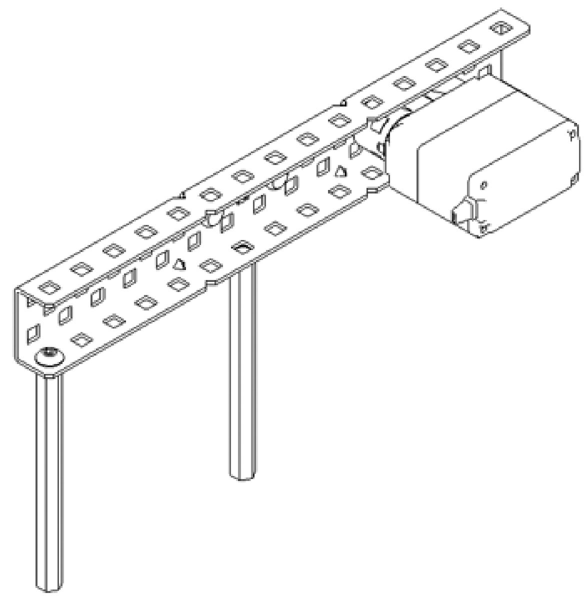
5. Both stand sides should appear as shown when positioned in this manner.



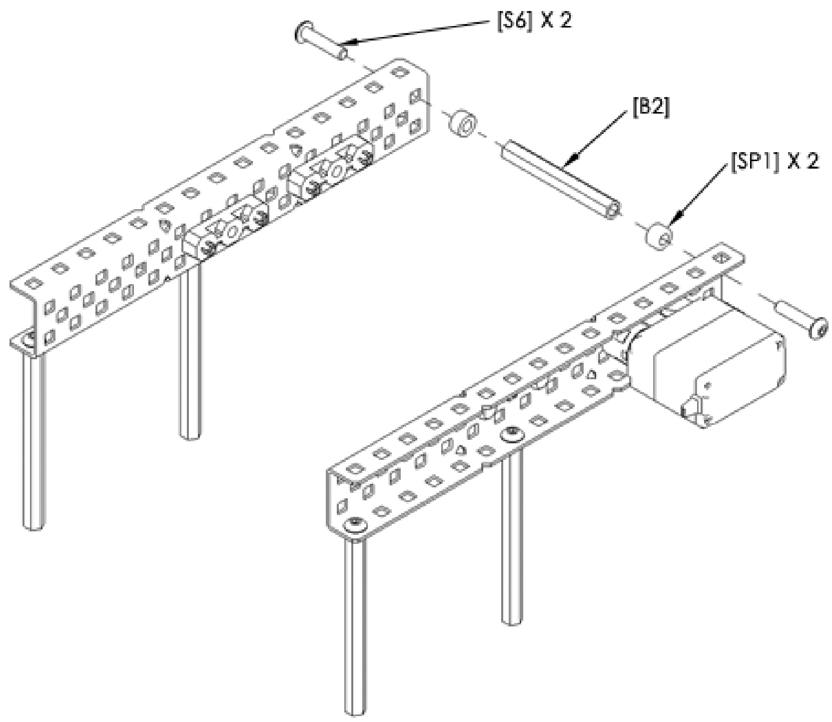
6. Attach a Motor [MOT] to the near C-channel assembly so that the clutch lines up with the center hole in the opposite side's bearing flat.



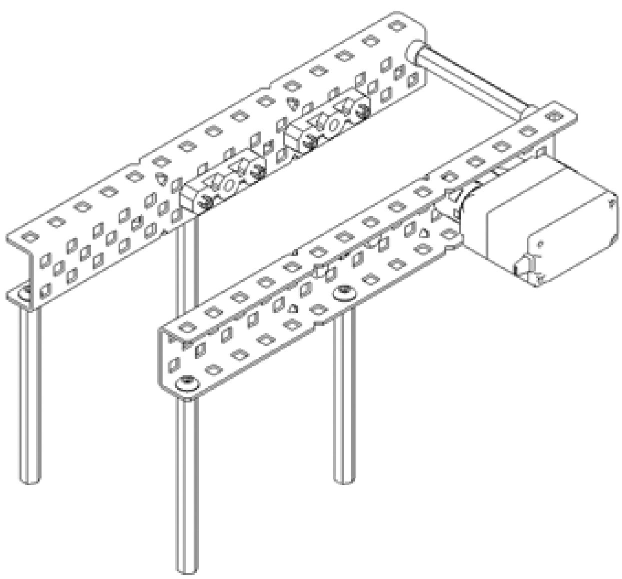
The completed model is as shown:



7. Place and attach a 2" beam [B2] and two thin spacers [SP1] to the end of the stand assembly as shown. Be sure to attach the beam in the top holes of the C-channel.

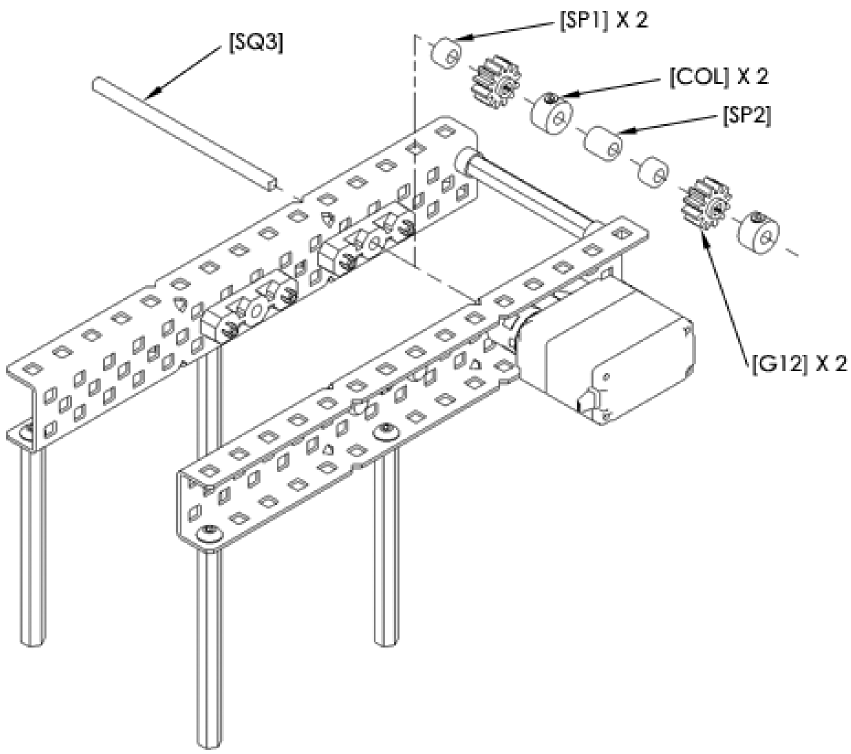


The completed model is as shown:



8. To complete the next step:

- Feed a 3" shaft [SQ3] through the bearing hole opposite the motor.
- Thread a thin spacer [SP1], a 12-tooth gear [G12], a collar [COL], a thick spacer [SP2], a thin spacer [SP1], a 12-tooth gear [G12], and one more collar [COL] on the axle as it is pushed into the motor clutch.
- Seat the shaft into the clutch and tighten the collars.



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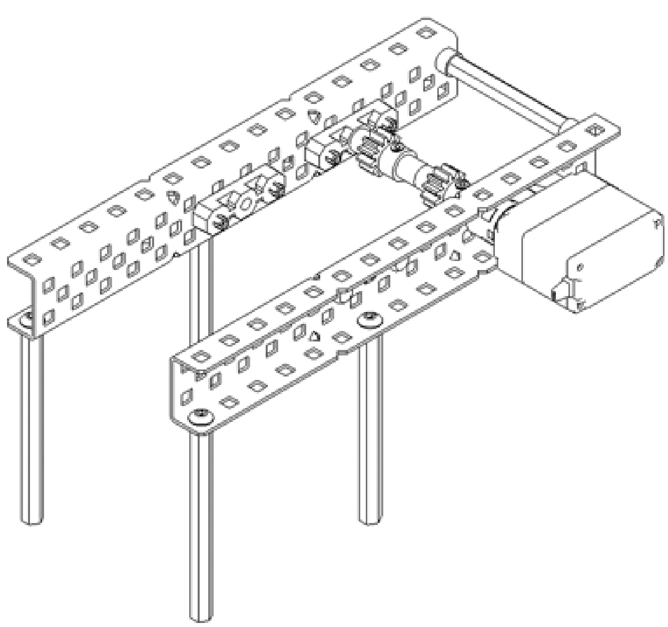
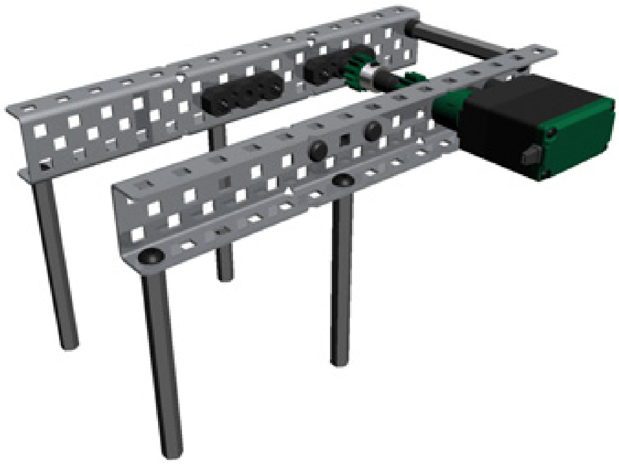


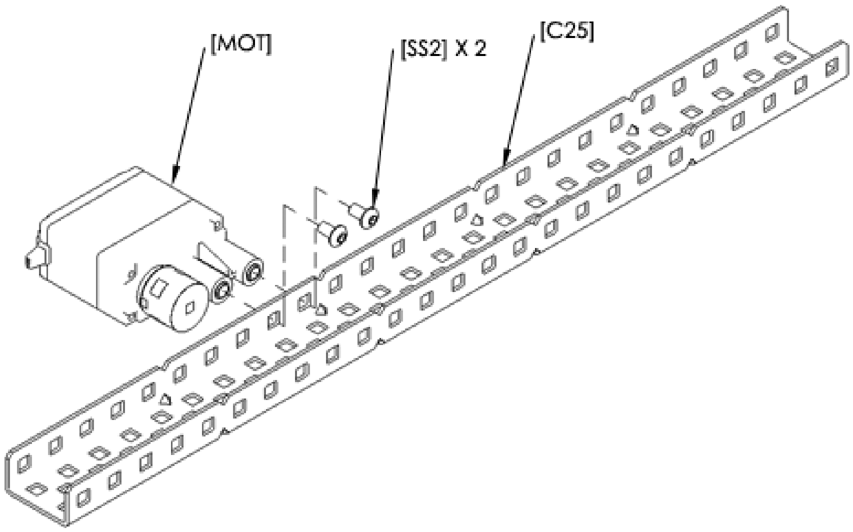
9. The stand assembly is now complete.



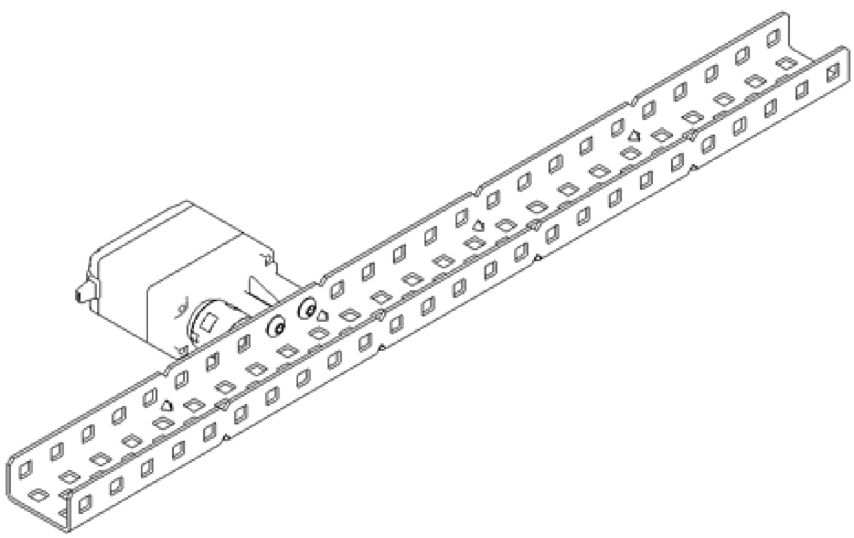
Protobot Arm Assembly Instructions

1. To complete the first step:

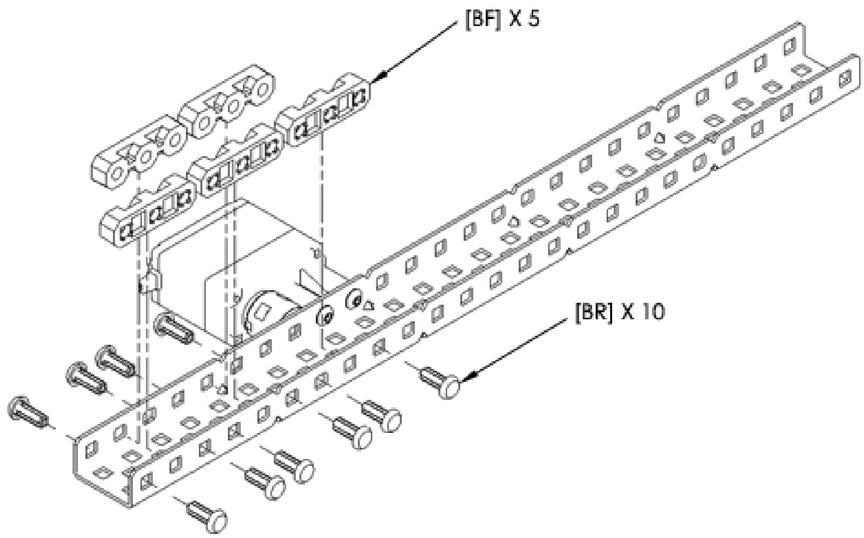
- Locate a 1 x 2 x 1 x 25 C-channel [C25].
- Attach a Motor [MOT] as shown.



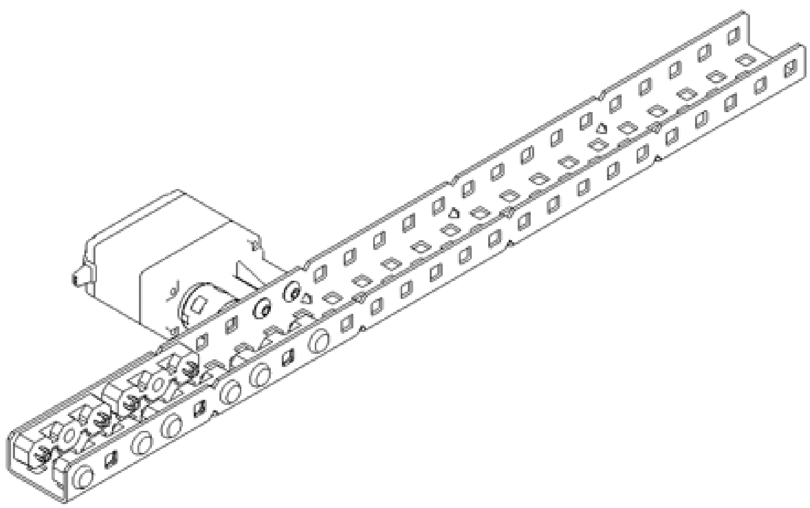
The completed model is as shown:



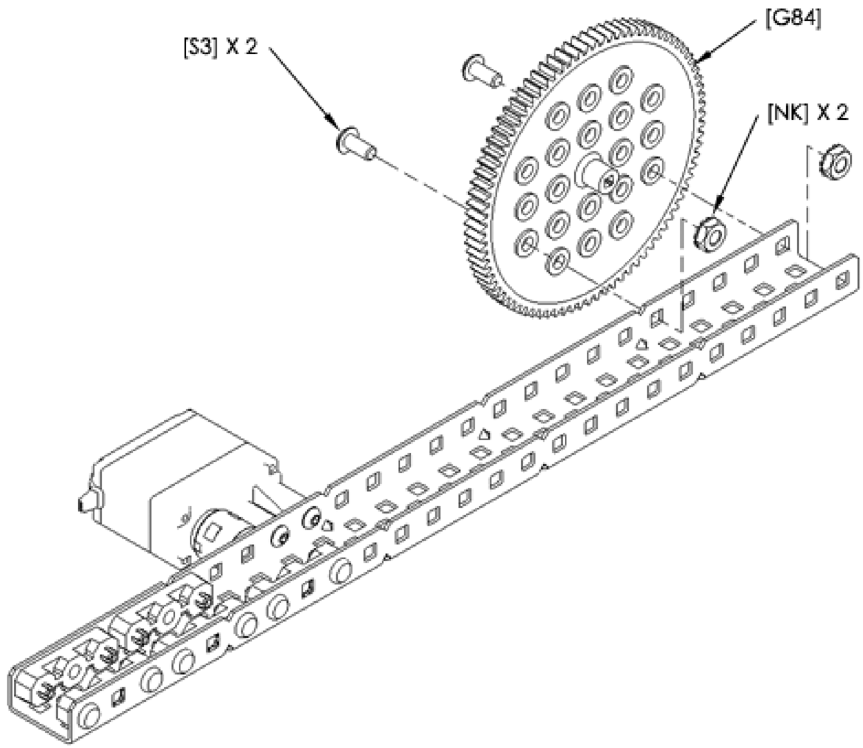
2. Use Bearing Rivets [BR] to attach five Bearing Flats [BF] in the positions shown.



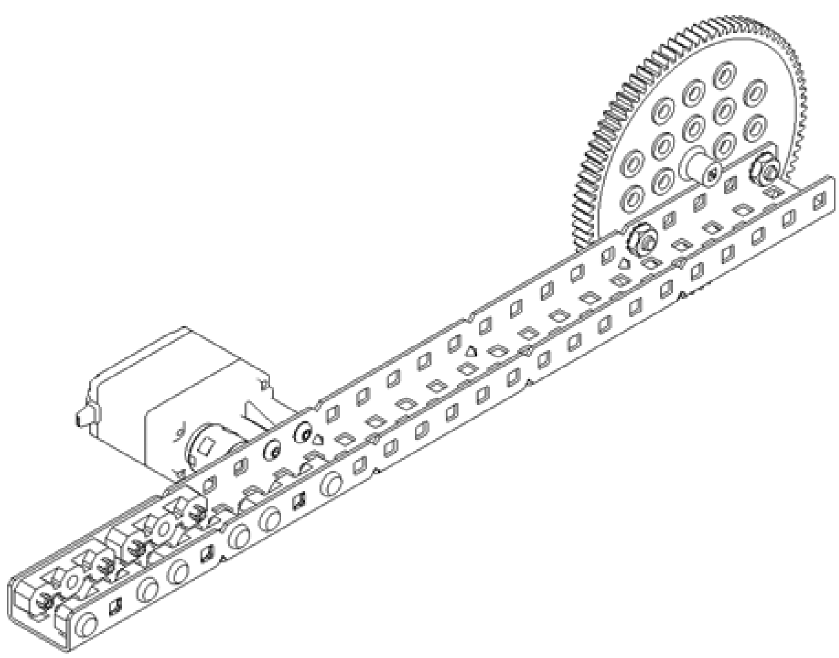
The completed model is as shown:



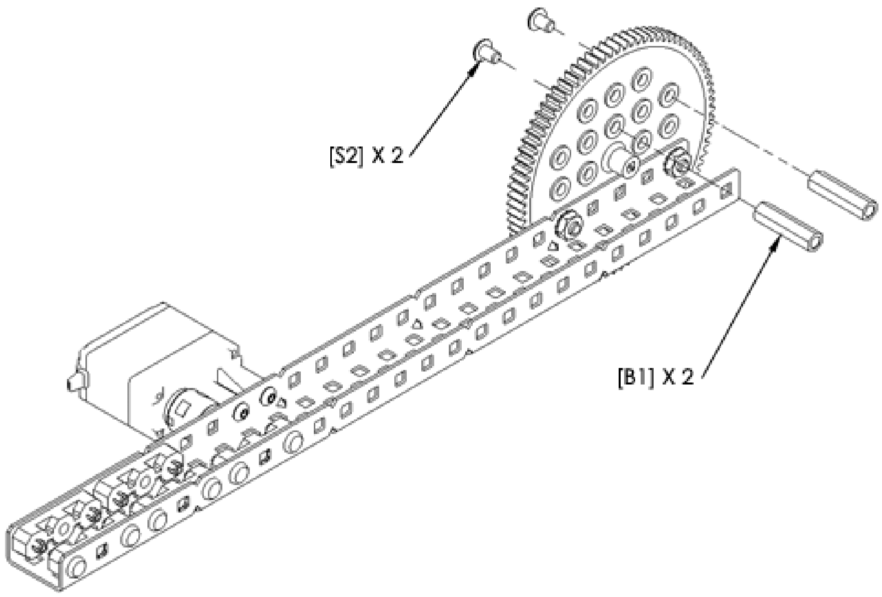
3. Attach an 84-tooth gear [G84] to the end of the C-channel using two screws [S3] and nuts. Be sure to position the gear off-center, fastening it through the holes shown.



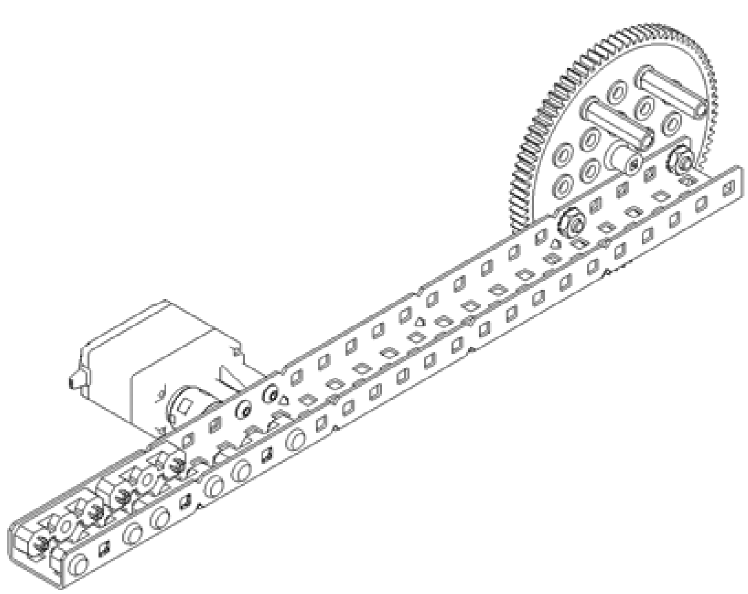
The completed model is as shown:



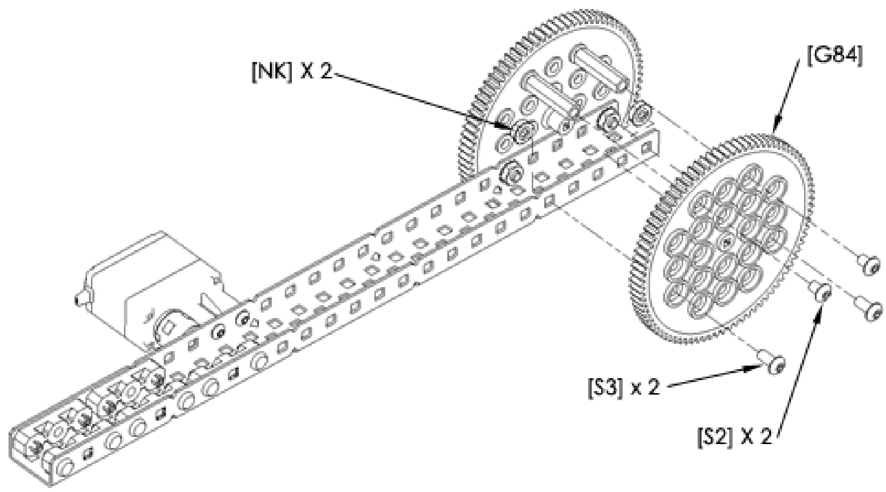
4. Attach two 1" beams [B1] in the positions shown using two screws [S2].



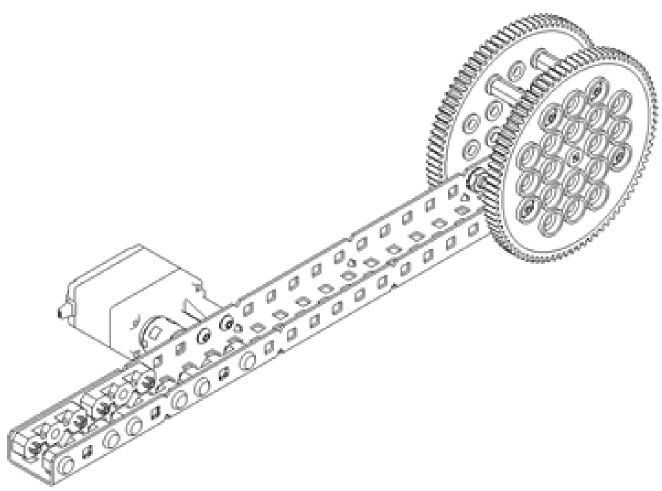
The completed model is as shown:



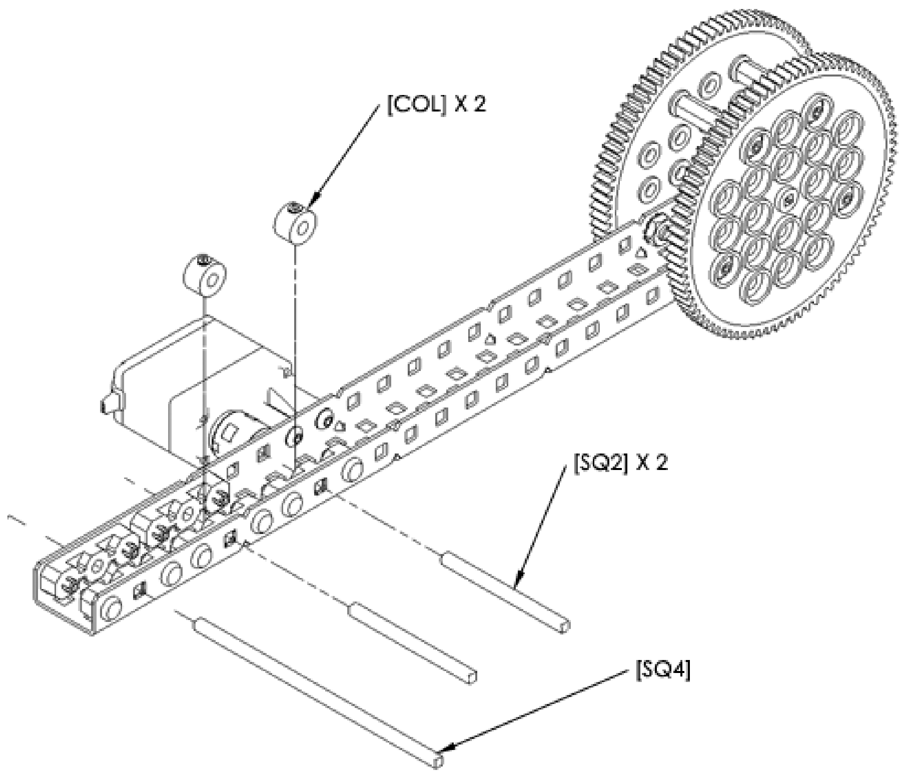
5. Attach another 84-tooth gear on the opposite side of the arm using the same fasteners.



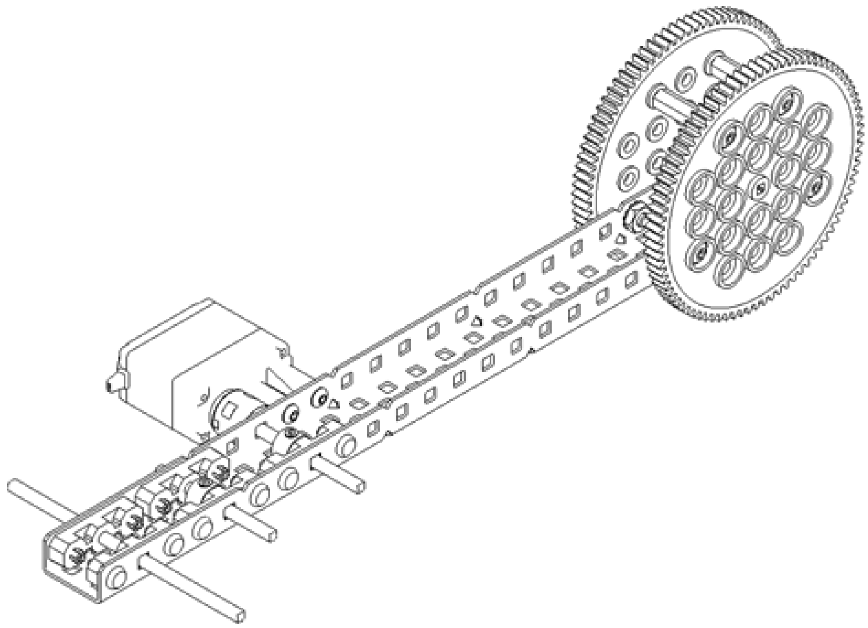
The completed model is as shown:



6. Place one 4" shaft [SQ4] through the end bearing blocks and two 2" shafts [SQ2] through the center of the other two blocks. When inserting the 2" shafts, place a collar [COL] between the bearing blocks on the inside of the C-channel. Do not tighten! Be sure to firmly seat the driven axle into the clutch.

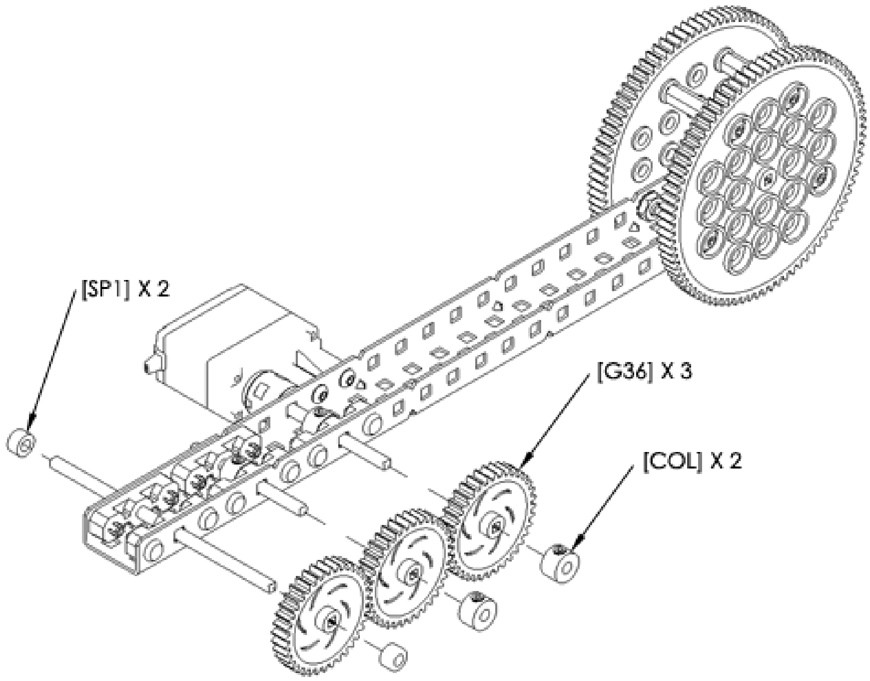


The completed model is as shown:

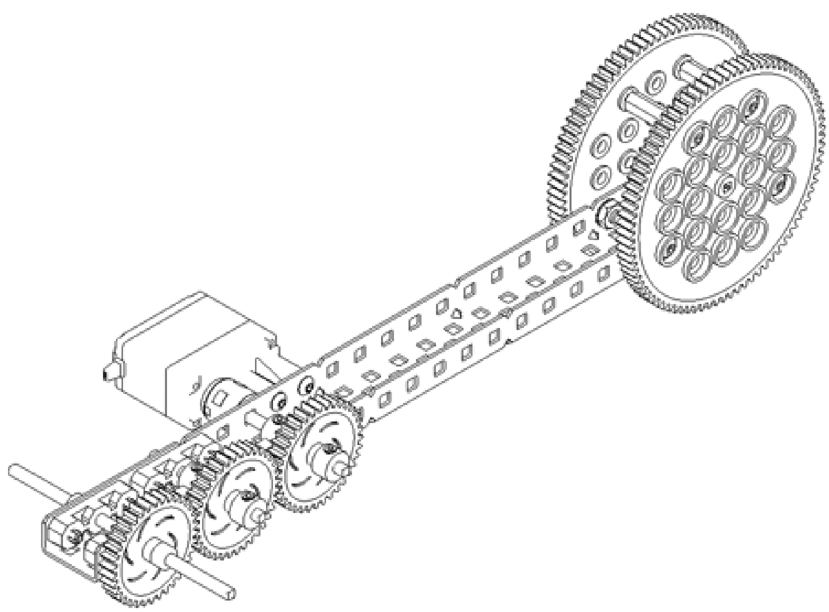


7. To complete the next step:

- Fit three 36-tooth gears [G36] to the shafts.
- Place two thin spacers [SP1] on each side of the end shaft.
- Place two collars [COL] to the outside of the other two gears.
- Tighten the collars, allowing for smooth movement of the gears.

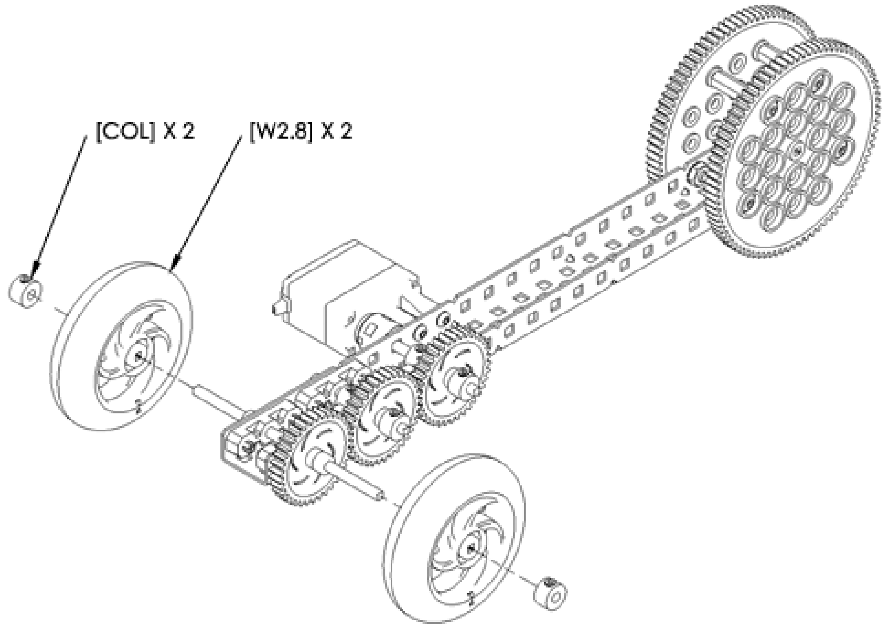


The completed model is as shown:

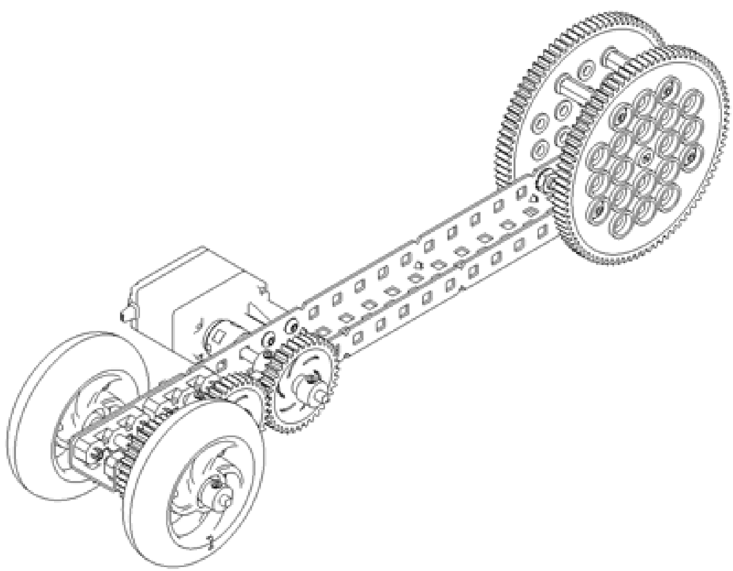


8. To complete the next step:

- Place two low-friction wheels on the end shaft.
- Place collars on the axle shaft and tighten.

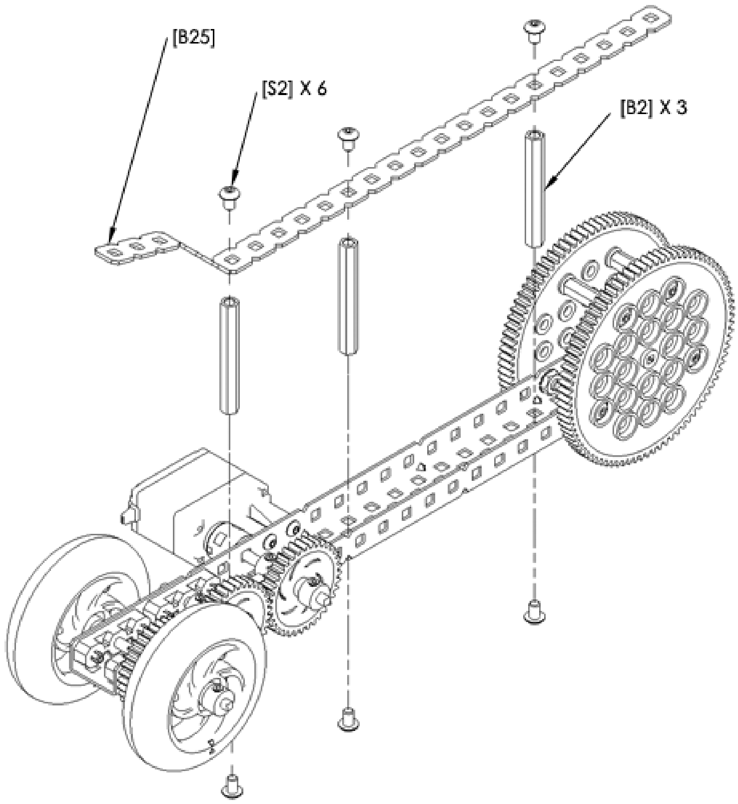


The completed model is as shown:

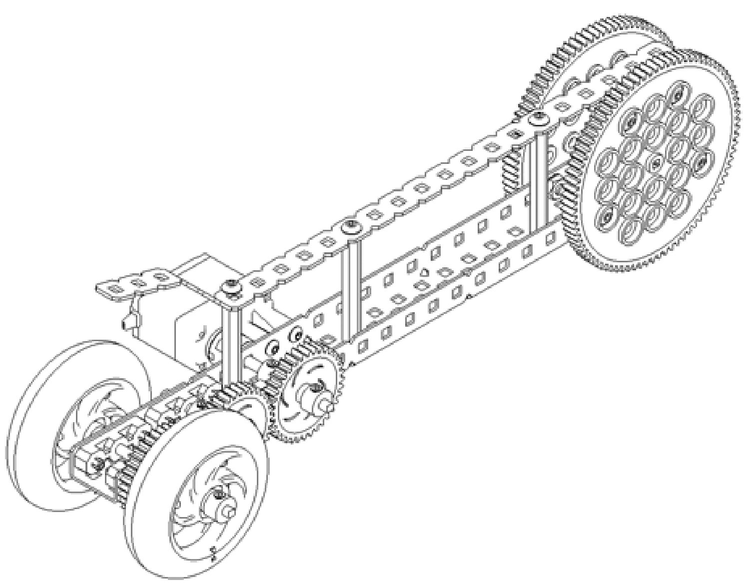


9. To complete the next step:

- Attach three 2" beams [B2] in the position shown using three screws [S2].
- Bend a 25-hole bar [B25] at the locations shown and attach to the beams using screws [S2].
- The angle of the bends will be modified later to adjust for the size of the scoring component.

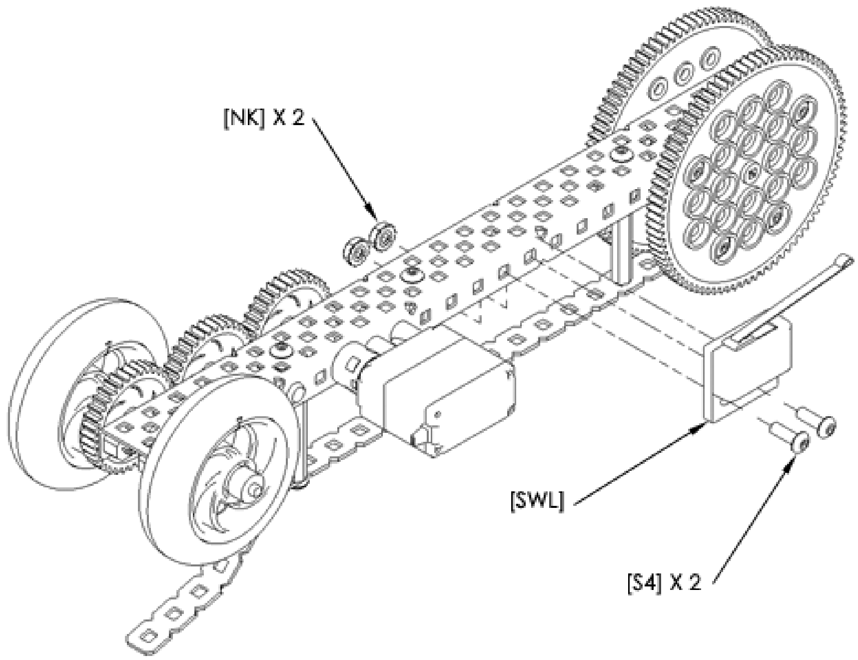


The completed model is as shown:

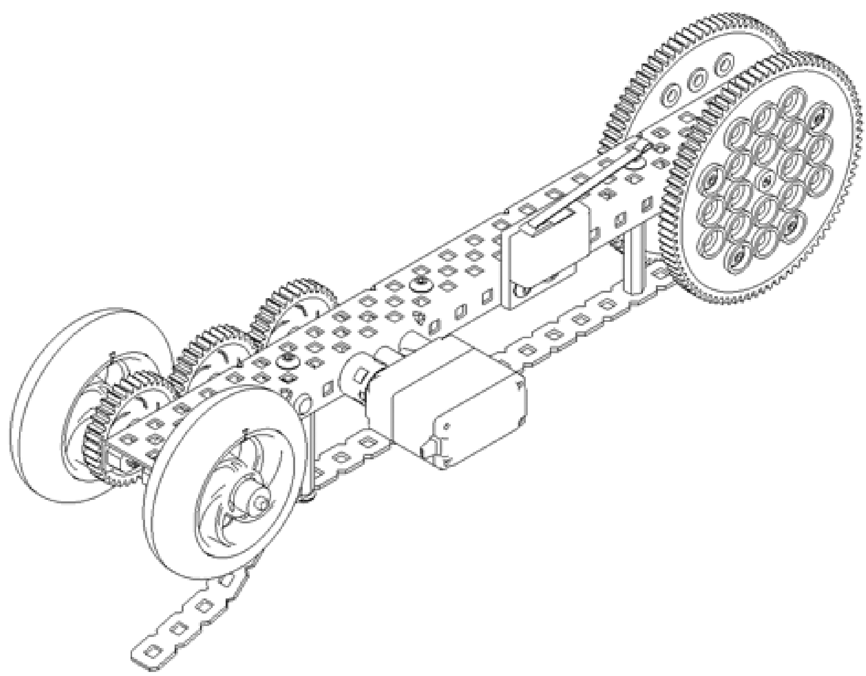


10. To complete the final step:

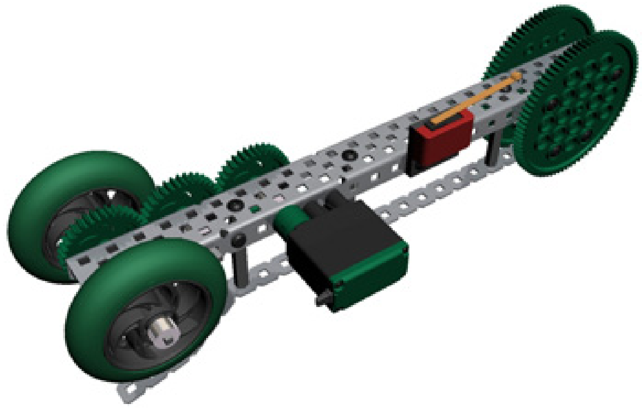
- Flip the assembly over.
- Attach a limit switch [SWL] in the position and orientation shown. This will be used to stop the arm's rotation in order to prevent damage to the motor.



The completed model is as shown:



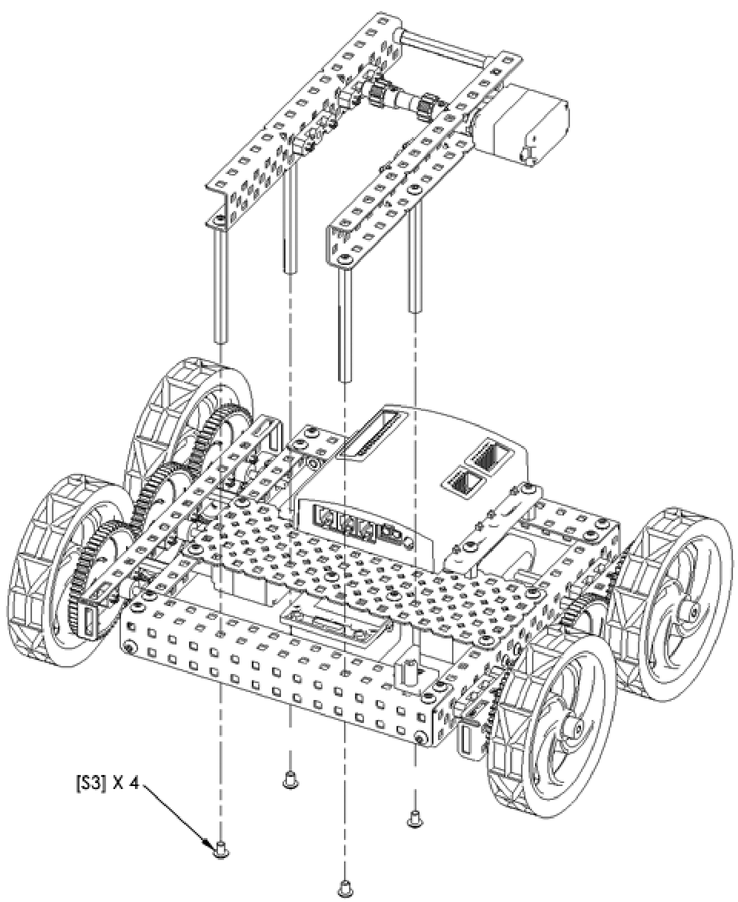
11. The completed arm assembly.



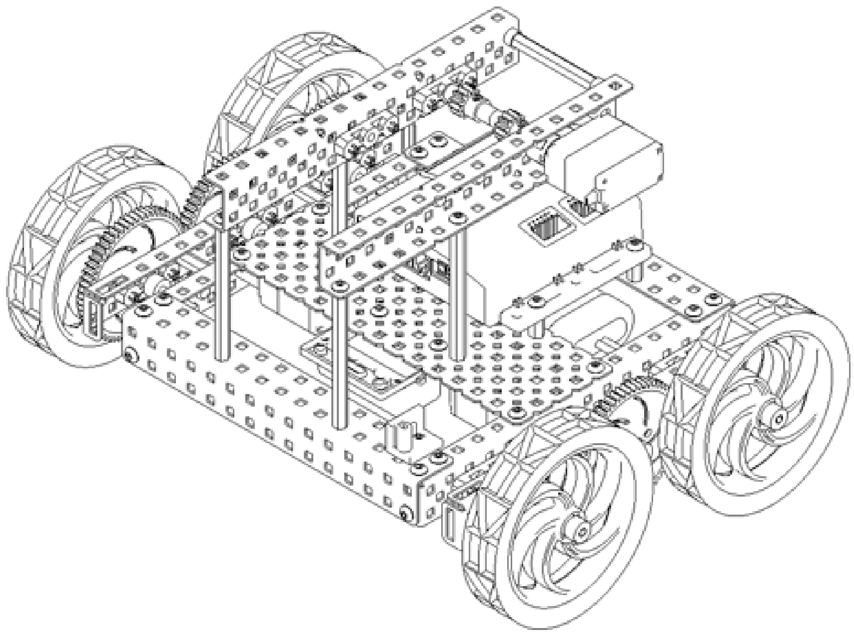
Protobot Final Assembly Instructions

1. To complete the first step:

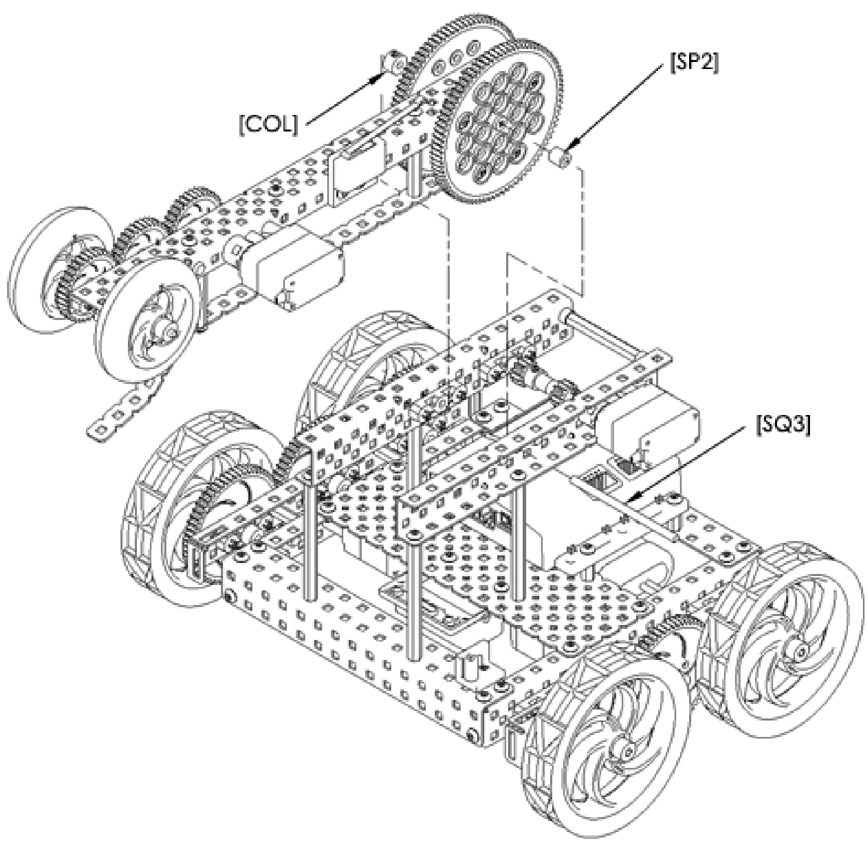
- Get your completed drive base.
- Position the completed stand above the base.
- Attach the stand to the base using four #8-32 x 1/4" screws [S2].



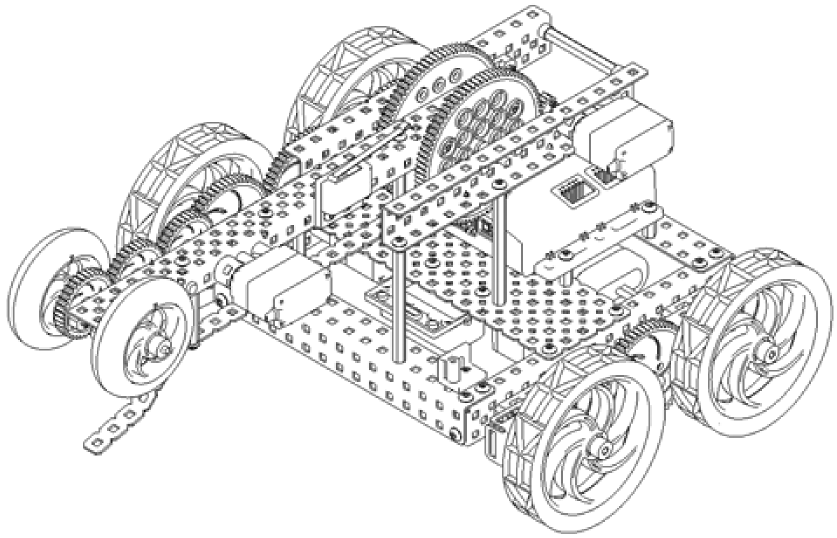
The completed model is as shown:



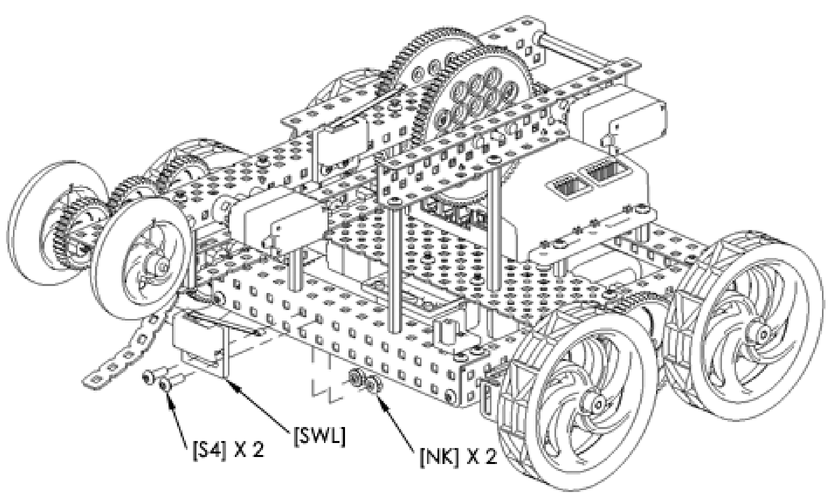
2. To complete the next step:
   - Position the completed arm assembly between the C-channels of the stand.
   - Thread a 3" shaft [SQ3] through the 84-tooth gear's center using a spacer [SP2] and a collar [COL] as shown.



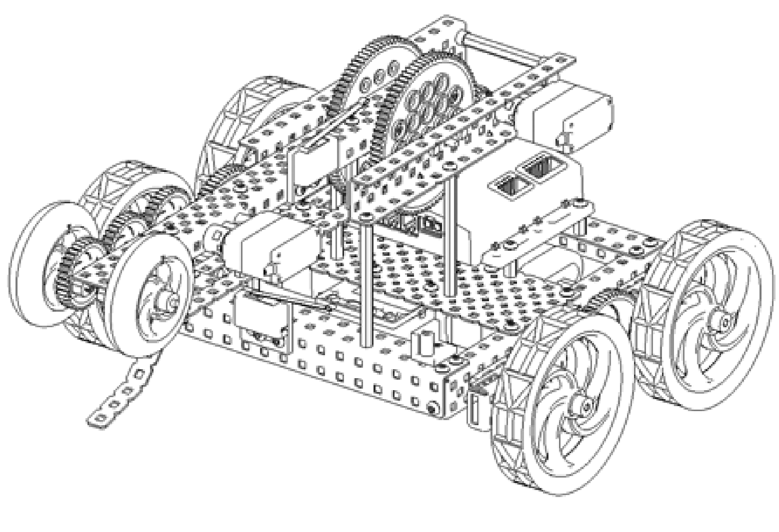
The completed model is as shown:



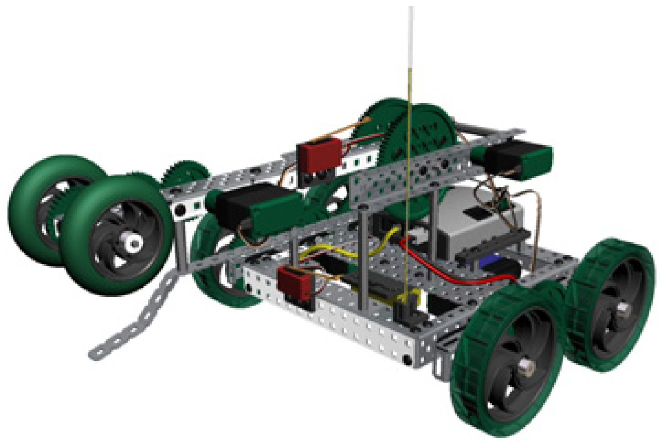
3. Attach another Limit Switch to the bumper on the front of the robot as shown.



The completed model is as shown:



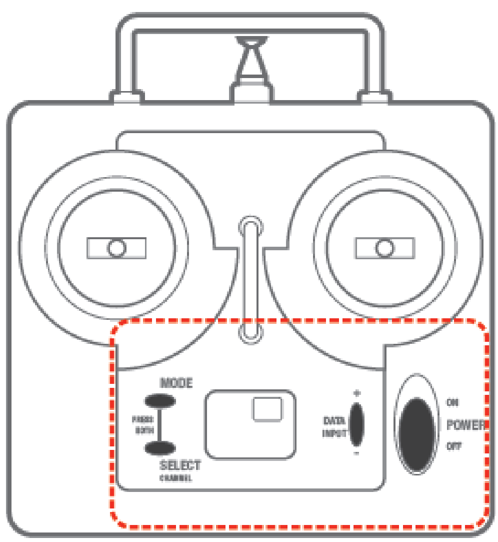
4. The final step is to connect the PWM connectors into the appropriate ports on the Microcontroller as follows:
   - Arm Rotation motor to Motor Port 6.
   - Roller Motor to Motor Port 5.
   - Arm Mounted Limit Switch to Analog/Digital Port 5.
   - Chassis Mounted Limit Switch to Analog/Digital Port 6.
5. Your Protobot is ready to roll!



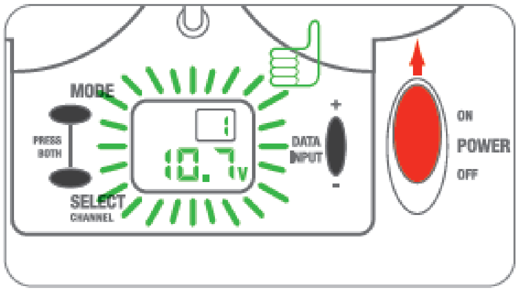
Configure the Transmitter

You now configure the Transmitter so the directional controls on channel 1 are in standard mode. See the VEX Inventor's Guide for detailed information on configuring the transmitter.

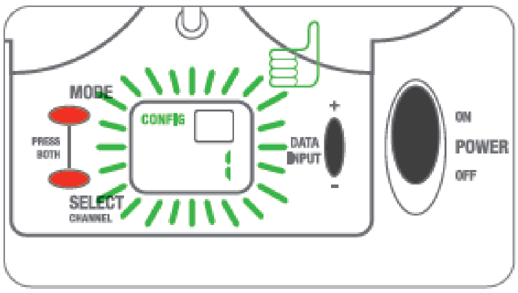
1. Turn on the Transmitter.



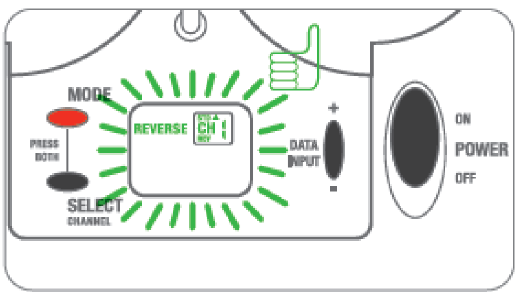
2. Check the voltage. If the voltage is less than 8.9 volts, recharge the batteries in the transmitter.



3. Press and hold the MODE and SELECT buttons simultaneously until the CONFIG menu is displayed.

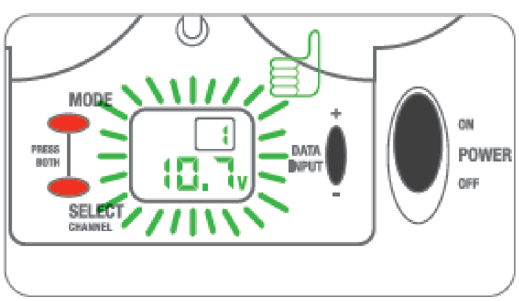


4. Press the MODE button once to display the REVERSE menu.



5. Channel 1 should be in standard direction mode (the arrow is next to STD). If it is in reverse direction mode (the arrow is displayed next to REV), press the DATA INPUT plus key.

6. Press and hold the MODE and SELECT buttons simultaneously until the voltage is displayed.



7. Turn on the Microcontroller and go for a drive!

Amaze Phase

Overview

In this phase, students test their second VEX robot, Protobot.

Phase Objectives

After completing this phase, you will be able to:

- Navigate a course with a VEX Protobot.
- Manipulate objects with a VEX Protobot.

Prerequisites

Before starting this phase, you must have:

- Completed Unit 3: Building a Protobot > Think Phase.
- Completed Unit 3: Building a Protobot > Build Phase.
- Have one assembled Protobot from Unit 3: Building a Protobot > Build Phase.

Related resources for this phase are:

- Unit 1: Introduction to VEX and Robotics.

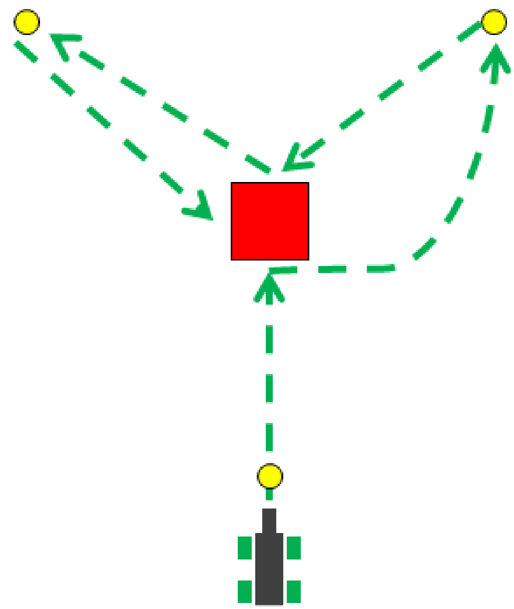
Required Supplies and Software

The following supplies are used in this phase:

Supplies
One assembled Protobot from Unit 3: Building a Protobot > Build Phase
Notebook and pen
One scoring bin, approximately 12" high (Any appropriately sized container which can fit a tennis ball will do)
At least 8' x 8' of open floor space
One stopwatch
Three tennis balls

Evaluation

In this challenge, you will attempt to use Protobot to place three tennis balls in a container as quickly as possible.

Instructions	Figure 1
1. Choose an appropriate sized container for use as your scoring bin. 2. Place your scoring bin in the center of your open floor space. See figure 1. 3. Place the tennis balls in evenly spaced intervals around the scoring bin. See figure 1. 4. Place the Protobot behind one of the tennis balls. 5. Turn the Protobot and its transmitter on. 6. Start the stopwatch to time your challenge. 7. Use the Protobot arm to pick up the closest tennis ball. This requires moving the arm, followed by activating the Protobot "roller claw." 8. Drive towards the scoring bin. Notice that the Protobot is harder to balance now that it is carrying a ball. 9. When in reach of the scoring bin, drop the tennis ball into the bin. 10. Drive to the second tennis ball, and repeat the process until all three balls are scored. 11. Record your time in your Engineering Notebook. 12. Try again to see if you can improve your time or compete with a classmate to see who can complete the Amaze challenge the fastest. 13. For an additional challenge, try using taller or smaller scoring bins.	

Engineering Notebook

Record all your times from the challenge in a chart in your engineering notebook. Highlight your fastest and slowest times and calculate your average time to score the three balls. Did your times improve or become slower as you repeated the challenge? Discuss why and brainstorm ideas for different challenges or games that can be played using the Protobot.

Presentation

- Create a game or challenge to be played with the Protobot and explain it to the class. The game can involve one or multiple Protobots.
- Using the Protobot, demonstrate your game or challenge to the class.

STEM Connections

Background

You are told that you cannot leave the house to meet your friends until you clean up your very messy room. Since your room is always a mess, you have decided to develop a robot that can clean up and organize your clutter.

Science

A key component of the invention process is the use of the *scientific method*. This method involves a process of creating and answering scientific questions through observation, conducting experiments, and analyzing the results of those experiments. To design a successful housecleaner robot, develop your responses to the following components of the scientific method:

1. What questions do you need to ask to determine the functional characteristics of your housecleaner robot?
2. What background research can you do to maximize the potential of creating a successful design?
3. What is your hypothesis for this design activity?
4. What experiment(s) can you set up to test your hypothesis?
5. How will you analyze the results of your experiments and how will those conclusions influence your final design?
6. How can you use Autodesk Inventor Professional software and the VEX Classroom Lab Kit to communicate these results?

Technology

To clean a room, a robot must be able to move in many different ways. For example, to pick objects up, it can use a gripper similar to the one on the Protobot.

1. What other parts can help your robot clean efficiently?
2. Brainstorm the different movements the robot needs to perform to clean a room, and consider what parts can accomplish these movements.

Engineering

Think about your own room at home. For your robot to put everything where it belongs, you need to answer the following questions.

1. How much weight does the robot need to be able to lift?
2. How high does it need to reach?
3. Think about the parts you brainstormed in the previous Engineering question. Did you miss any?
4. Do you think that you can fit all the parts you need on one robot?
5. Describe the engineering design process you can use to make a prototype housecleaner robot.

Math

Your housecleaner robot can become an international hit! You might want to tell people how quickly it cleans up a typical room of a certain size, using different units of measurement.

1. If a model room is 8.5 feet by 12 feet, how many square feet of floor is there?
2. What are the length and width of the same room to the nearest tenth of a meter? (Take a meter to be 3.28 feet.)
3. How many square meters of floor are there?
4. What do you think of the claim that a square meter is 3.28 square feet?