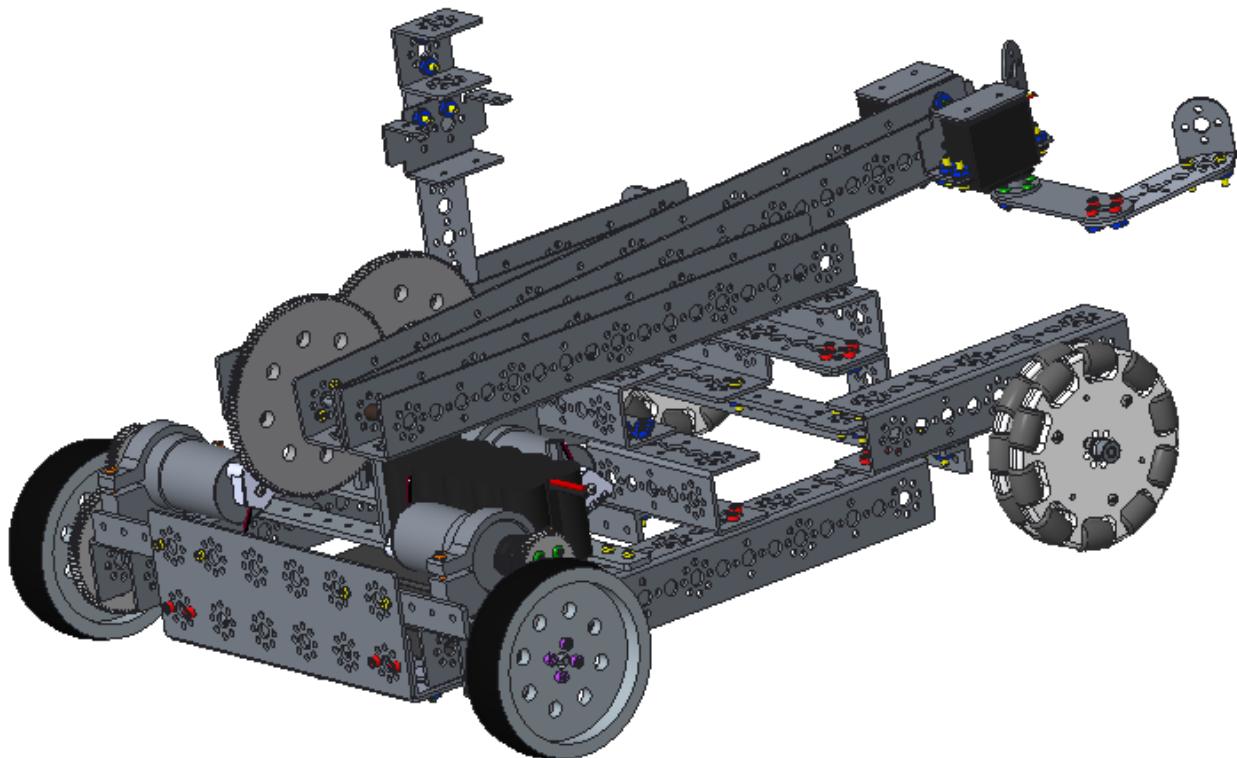


# Push ‘Bot v4b

## Build Guide

By: SSI Robotics





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Revision History	
<b>2017-08-11</b>	<b>Initial Draft Complete</b>
<b>2017-08-13</b>	<b>Initial Release</b>



## Introduction

There are three versions of the Push Bot. PBv1 (created in 2014) used the NXT and Samantha units for control and communication. PBv2 (created in 2015) was introduced cell phones to replace the NXT Mindstorm and Samantha units. Modern Robotics modules were introduced to replace the HiTechnic controllers. PBv3 (created in 2016) used the same electronics as PBv2, but had a lower center of gravity. PBv4 is being created in 2017 to introduce the Rev Robotics Expansion hub, which can be used to replace the Modern Robotics controllers. The Modern Robotics electronics are still an option, so if you are using those electronics, then refer to the building instructions for PBv2 and PBv3. Use the latest FTC SDK for programming regardless of the electronics in use.

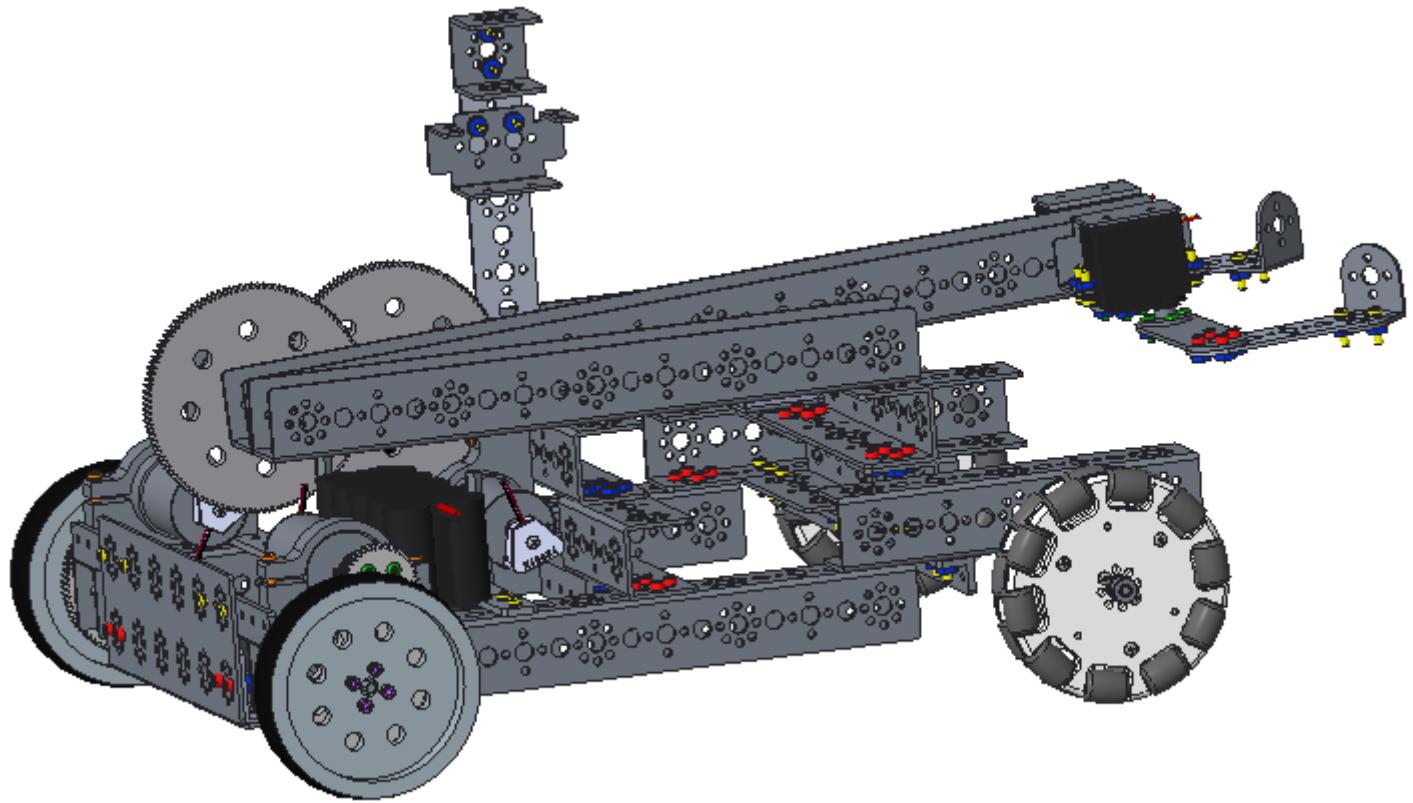
The PBv2 and PBv3 robots are being revised to use the REV expansion hub instead of the Modern Robotics modules for the 2017 season. The revised versions will be known as PBv4a (counterpart of PBv2 - reaches higher with its arm and has a higher center of gravity) and PBv4b (counterpart of PBv3 - reaches further horizontally with its arm and has a lower center of gravity).

Refer to the game rules to determine which version is desired. If the season's game has a goal that requires reaching high objects/goals, then PBv4a would be desired. If the season's game has a ramp onto which the robot must drive, then build PBv4b. This document contains the hardware and wiring instructions to build PBv4b.

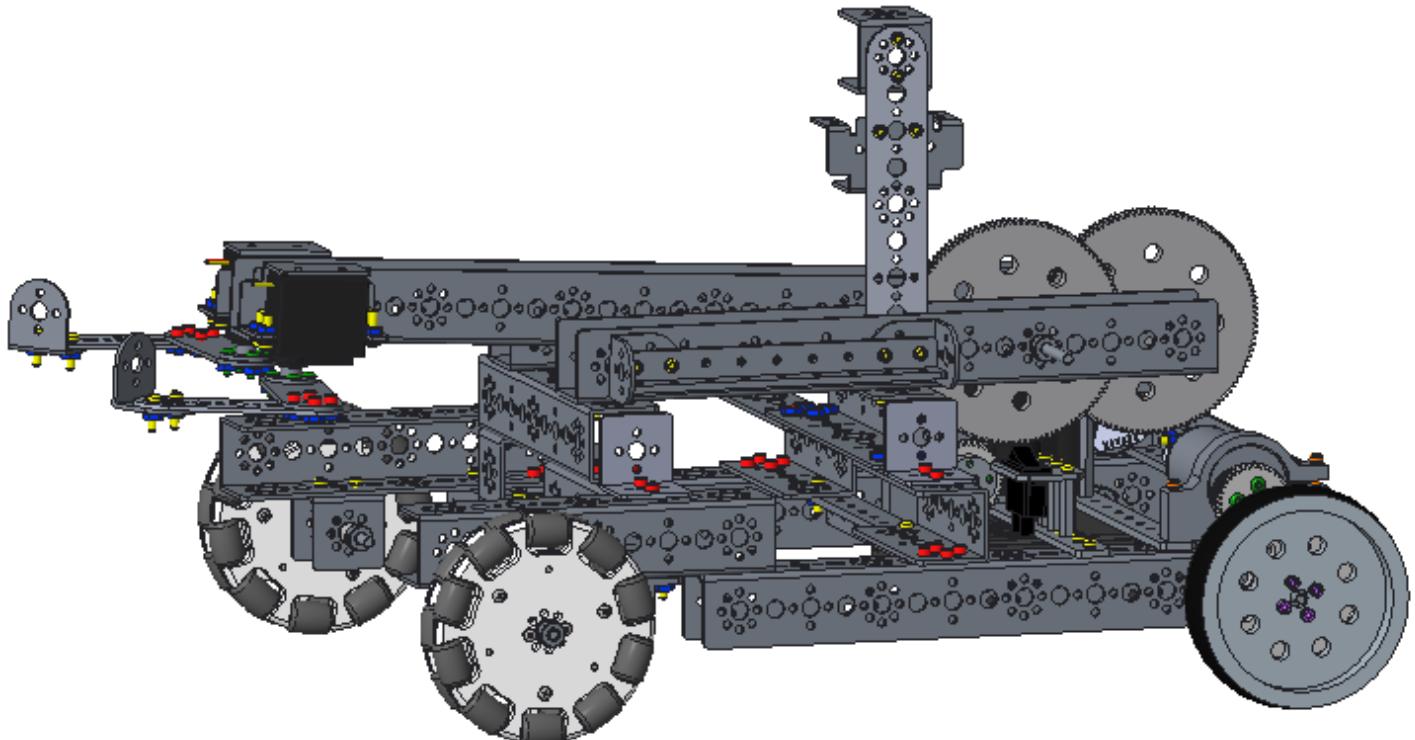
The drawings in this document were generated using Creo Parametric Computer Aided Design (CAD) software. CAD software is used to design an object on a computer. By designing on the computer first, the design can be tested (through the use of the CAD software) to ensure everything will work together before actual construction. The Creo software is available for free to FIRST teams for use in designing robots. The CAD drawings are color coded to help identify parts. Refer to the table below when performing a step to clarify and question that arises while reading this document.

CAD Coloring Legend

Pitsco Part Number	Part	Color
39098	5/16" socket head cap screw	red
39094	keps nut	blue
39111	3/8" button head cap screw	green
39097	1/2" socket head cap screw	yellow
39089 & 39090	motor mount/gear hub spacer screw	orange



The above image shows the left side of the robot.



The above image shows the right side of the robot.

## Chassis

This section will outline the construction of the chassis, which uses only the parts in the TETRIX Kit of Parts. Only the tools included in the Kit of Parts will be needed to build the robot. Make sure that set screws are installed in all of the axle hubs, motor hubs, and axle collars. If these parts are unfamiliar, then refer to the legend provided in the Kit of Parts. Make sure that all assemblies are square. It is hard to drive a crooked robot straight!

PBV4b uses drive wheels on the front of the robot, because that is where the most weight is. This weight is needed to help the wheels grip the surface better. Omni wheels are on the back of the robot, which allows the robot to turn more easily. The omni wheels can slide sideways with very little friction due to the rollers.

Note that when the arm is stowed, it appears that front and back of the robot are reversed. Keep in mind that the arm can reach further the ground on only one side - the front.

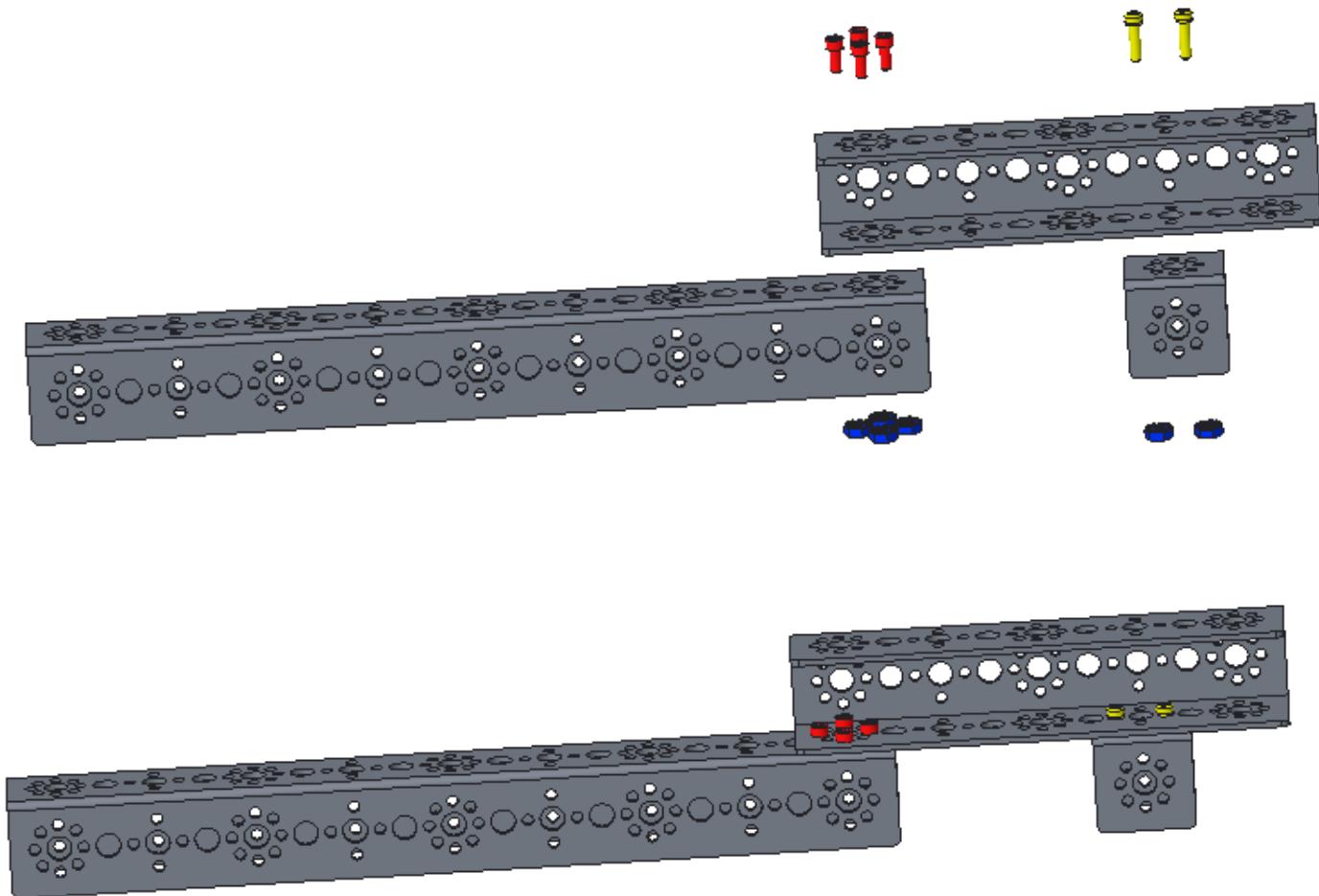
PBV4b uses two DC motors to power the drive wheels. It uses one DC motor to raise and lower the arm. The Kit of Parts includes an additional motor, which can be retained as a spare motor (in the event one of the three fail) or it can be used to power another mechanism, such as a sweeper for balls or a lifter for blocks.

For most of the steps in this section, the top image shows the necessary parts; the lower image shows the completed assembly.

## Constructing the Chassis

### Step 1: Left Chassis Rail

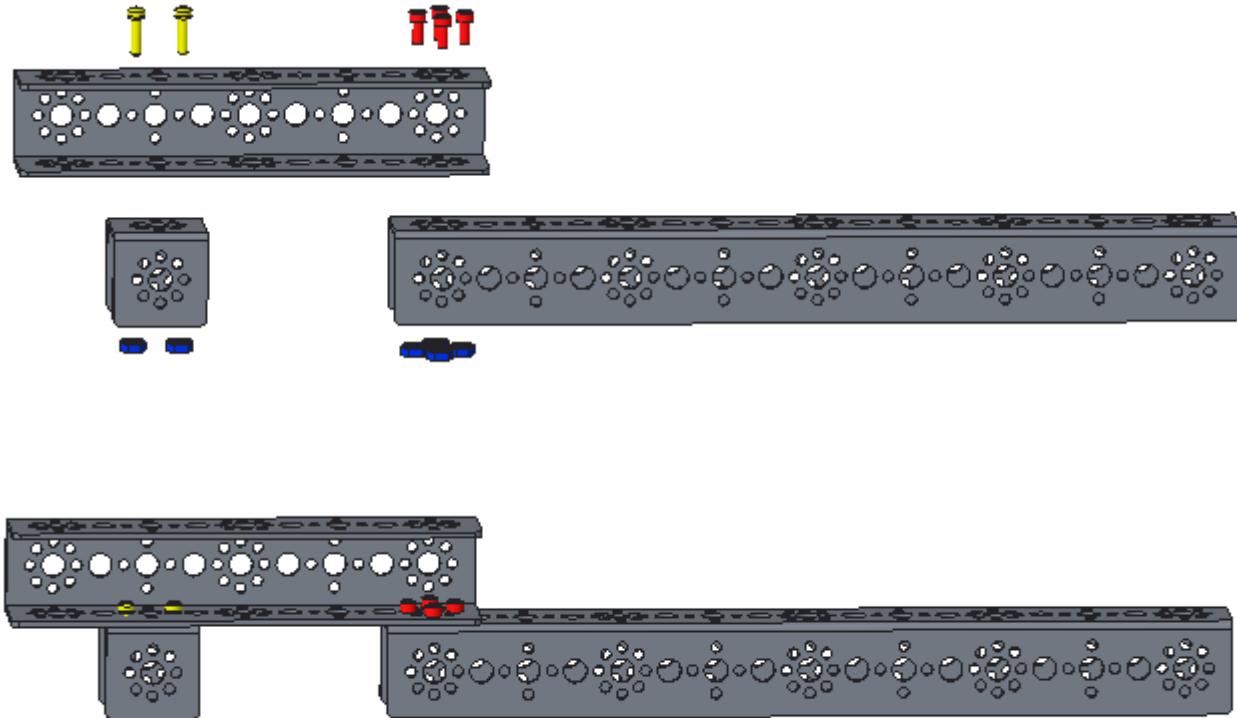
288 mm channel (1), 160 mm channel (1), 32 mm channel (1), 5/16" socket head cap screws (4), 1/2" socket head cap screws (2), keps nuts (6)



## Step 2: Right Chassis Rail

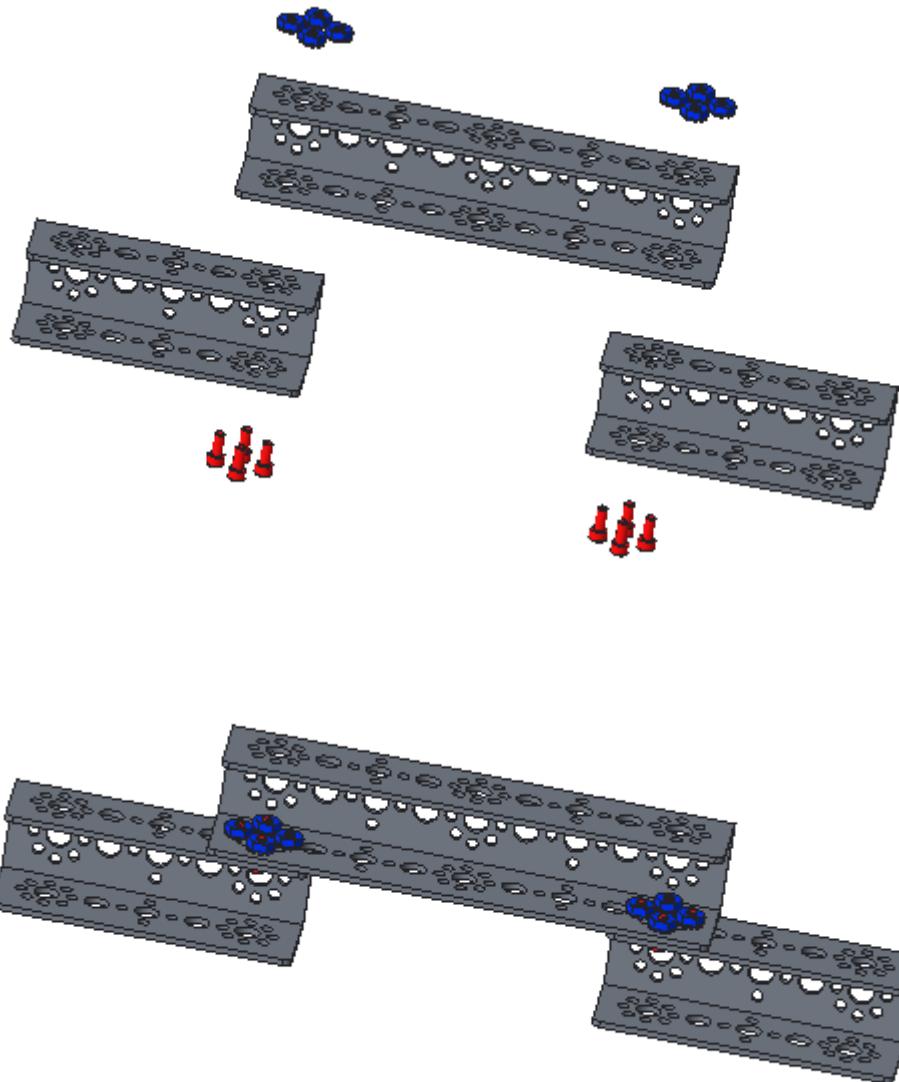
32 mm channel (1), 160 mm channel (1), 288 mm channel (1), 1/2" socket head cap screws (2), 5/16" socket head cap screws (4), keps nuts (6)

It is a mirror image of the left chassis rail assembly built in the previous step.



### Step 3: Cross Bar Assembly

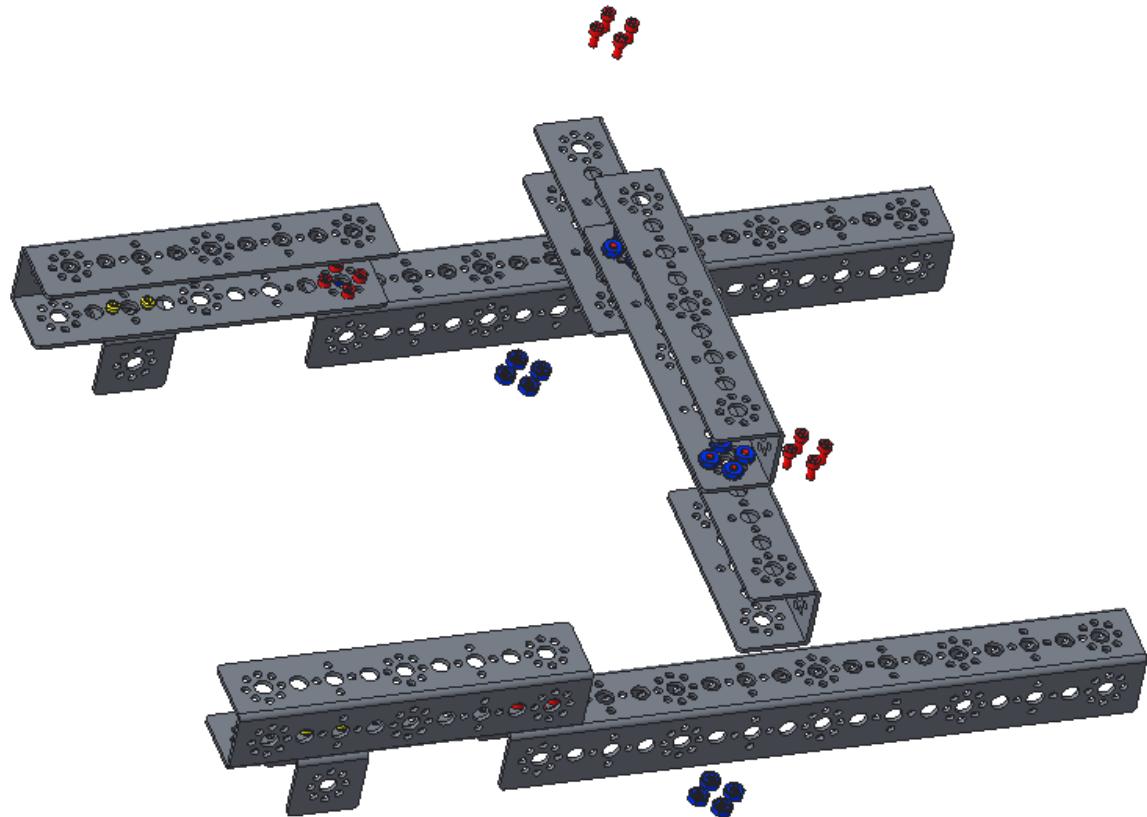
160 mm channel (1), 96 mm channels (2), 5/16" socket head cap screws (8), keps nuts (8)

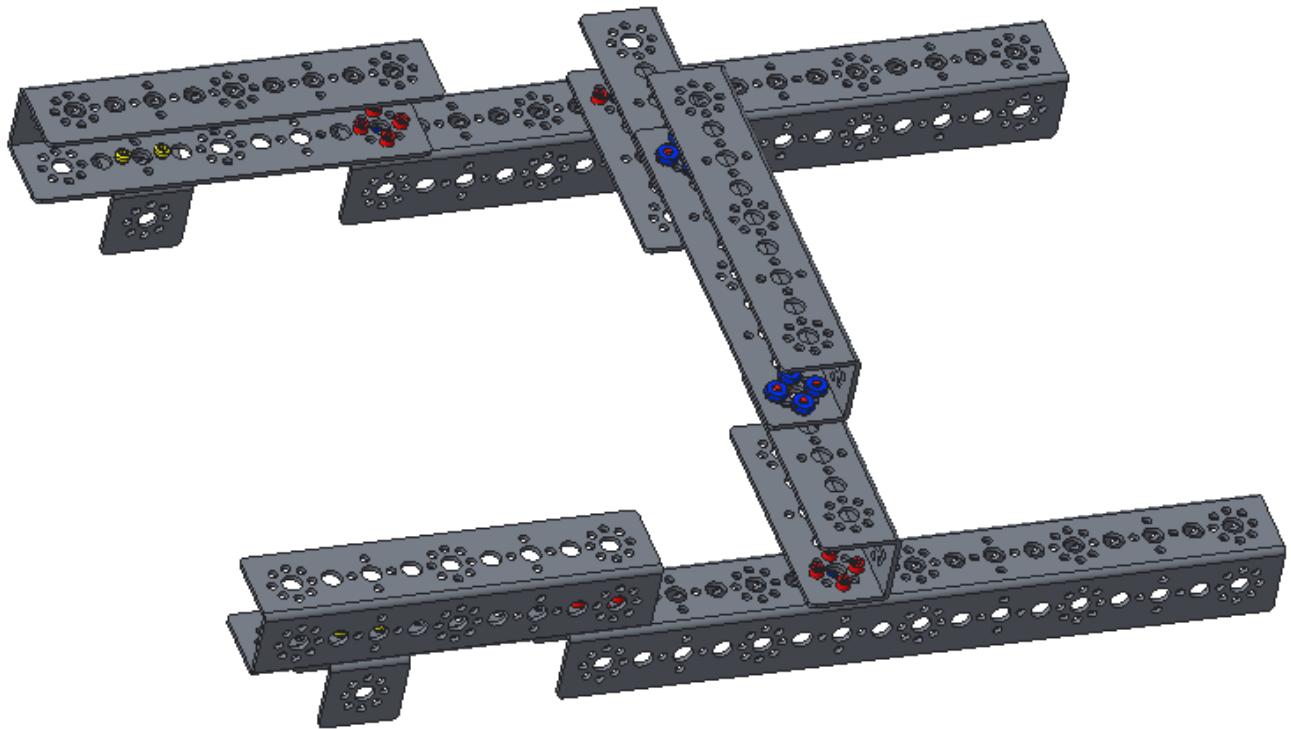


#### Step 4: Connecting the Left and Right Rail Assemblies

right rail assembly, left rail assembly, cross bar assembly, 5/16" socket head cap screws (8), keps nuts (8)

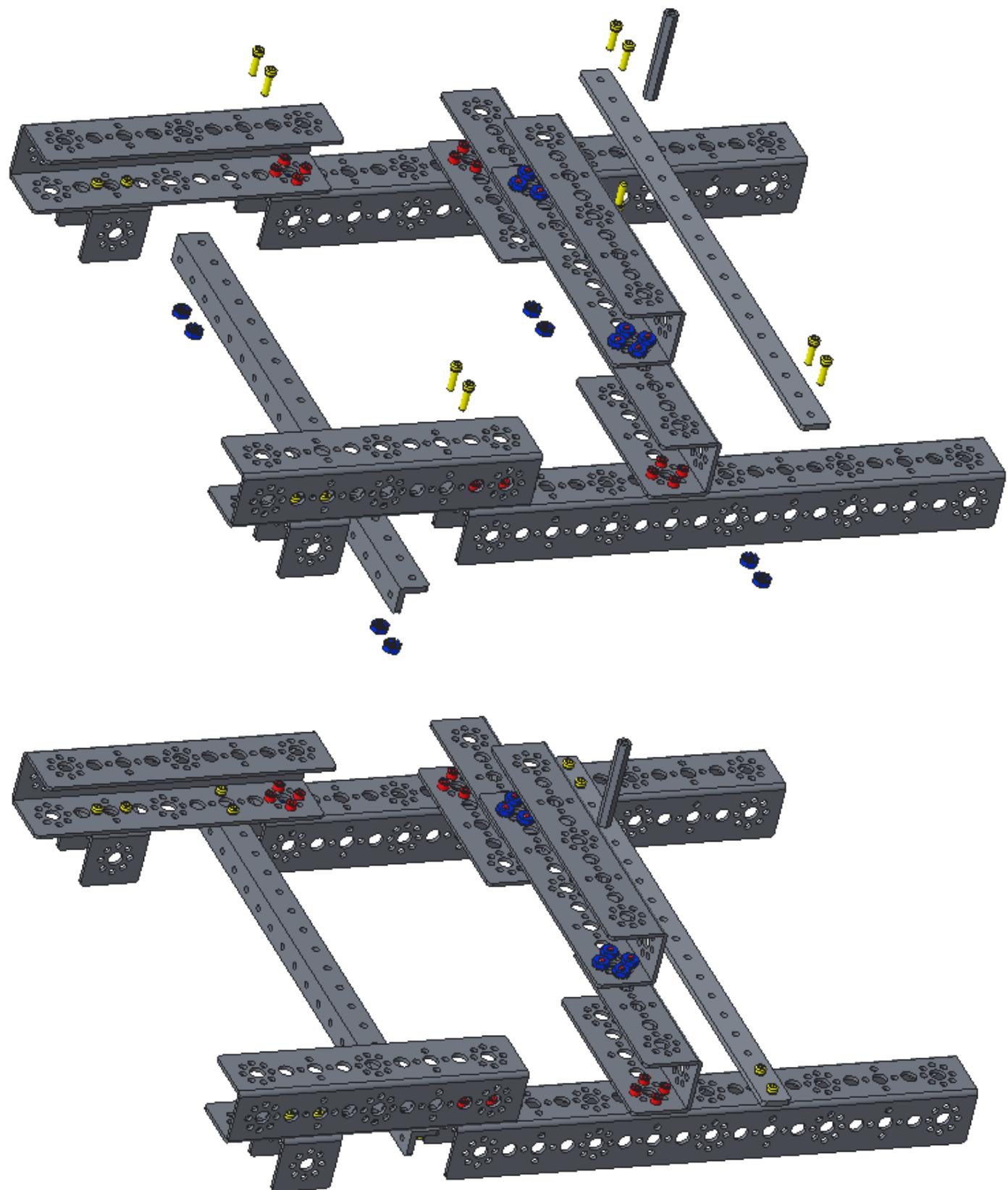
In the image, the front of the robot is on the right. The left rail assembly is on the top and the right rail assembly is on the bottom.





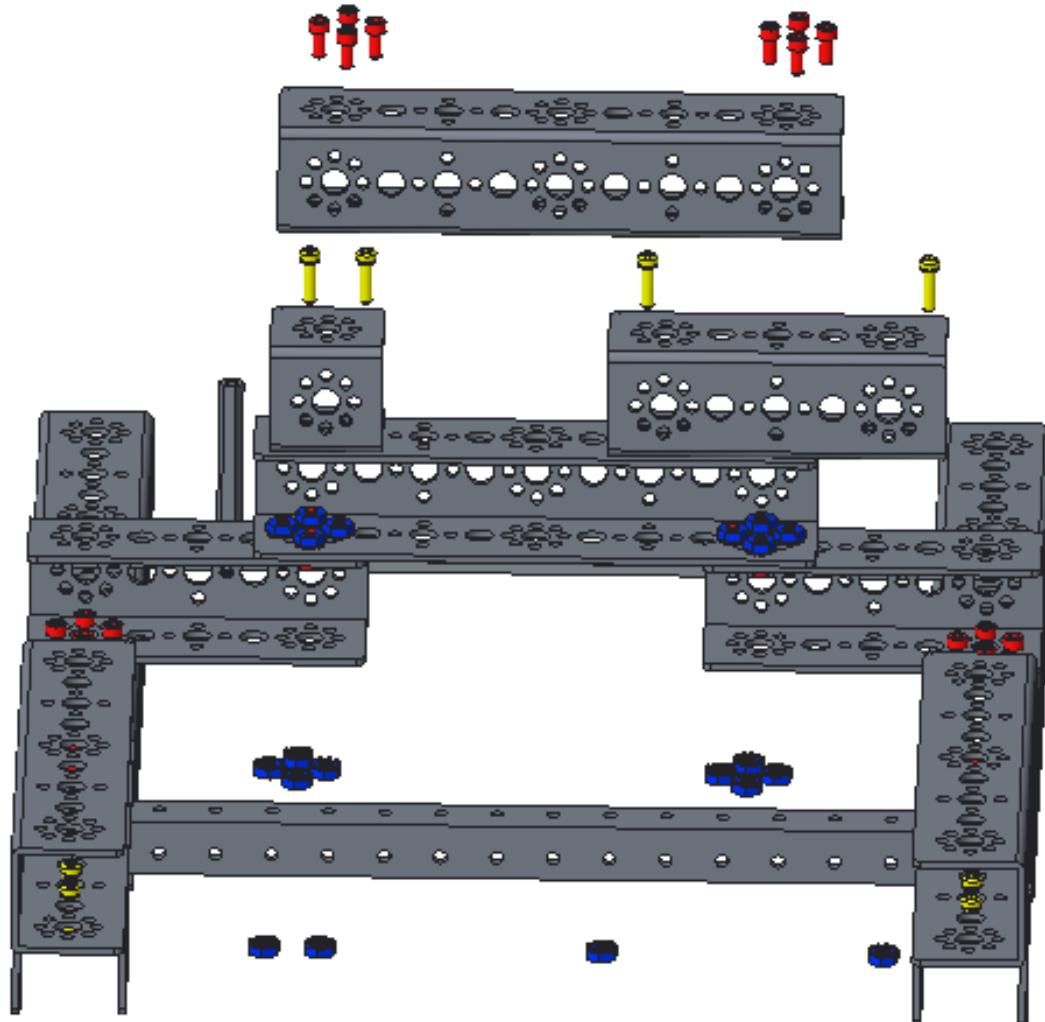
#### Step 5: Additional Cross Braces

assembly from the previous step, 288 mm angle (1), 288 mm flat bar (1), 1/2" socket head cap screws (9), 2" stand-off (1), keps nuts (8)

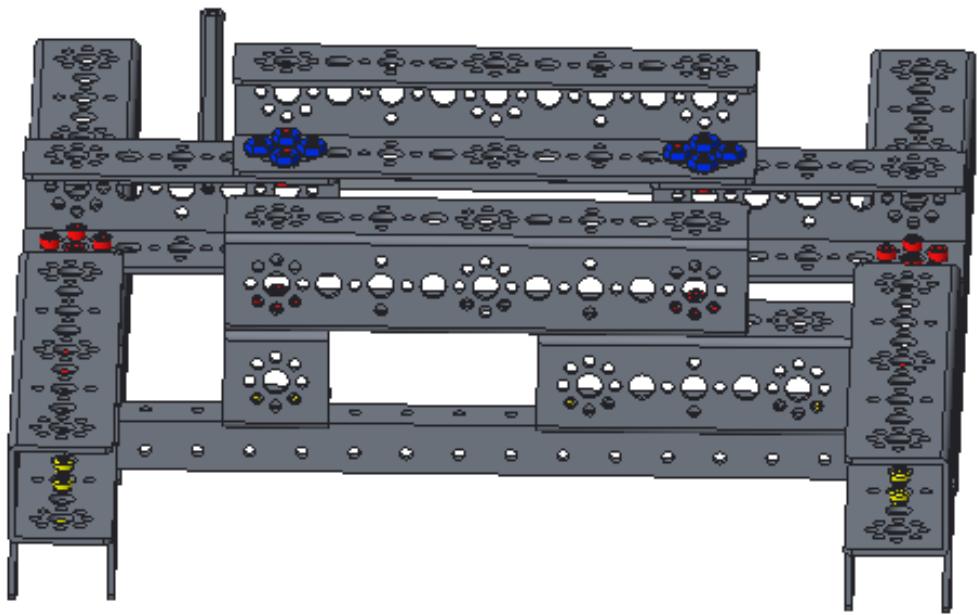


## Step 6: Tower Support

assembly from the previous step, 160 mm channel (1), 32 mm channel (1), 96 mm channel (1), 5/16" socket head cap screws (8), 1/2" socket head cap screws (4), keps nuts (12)

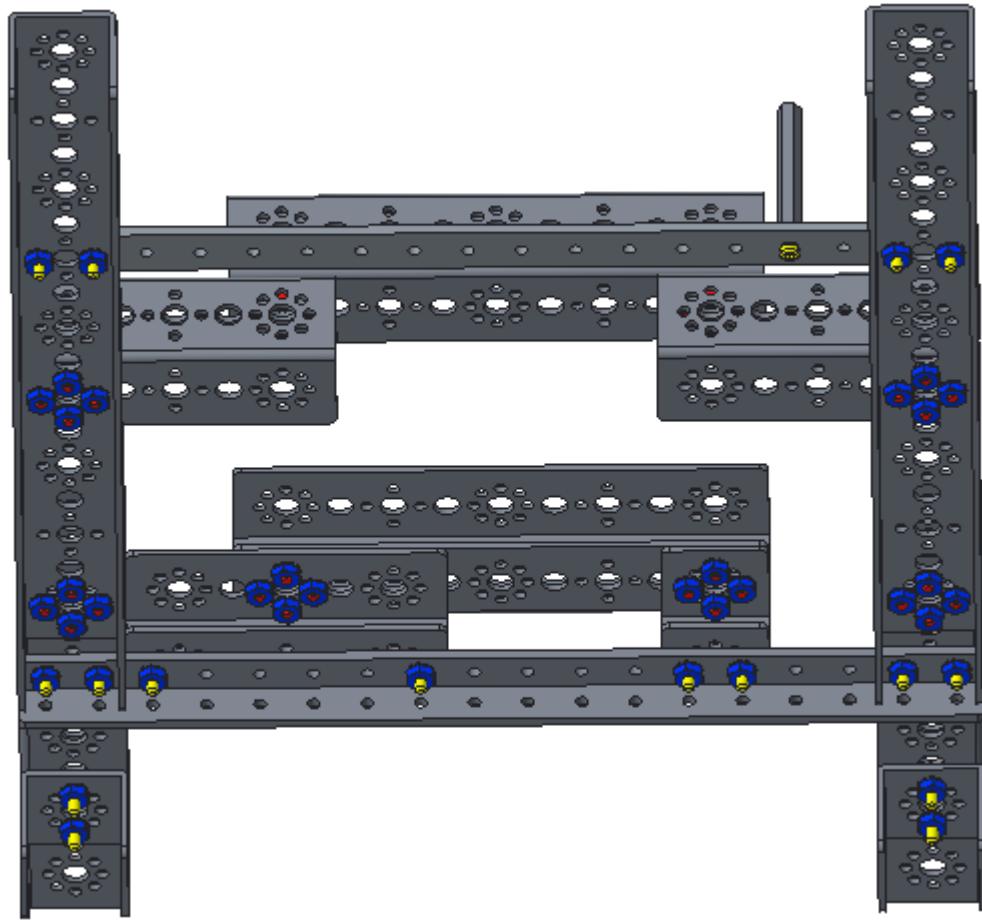


The completed assembly is on the next page.



In the above image, the robot is right side up and the front of the robot is at the bottom of the image.

In the below image, the robot is upside down. The front of the robot is at the bottom of the image.



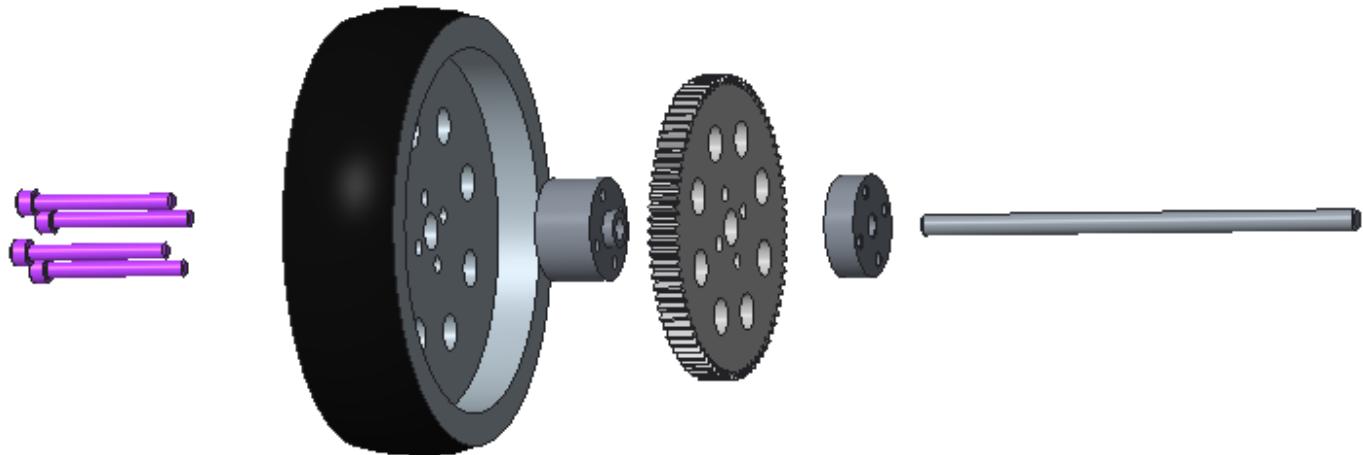
## Building Drive Wheels

Make two.

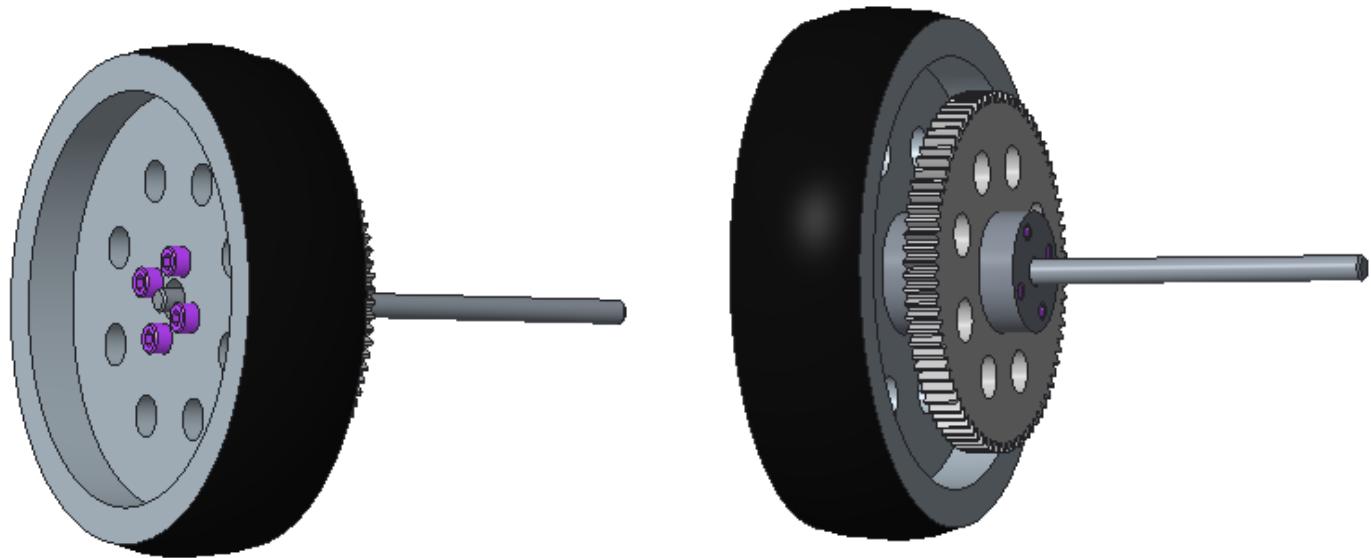
### Step 1: Drive Wheel Assembly

4" wheel (1), gear hub spacer (1) with included screws (4), 80 tooth gear (1), axle hub (1), and 100 mm axle (1)

Order from left to right: gear hub spacer screws, wheel, gear hub spacer, gear, axle hub

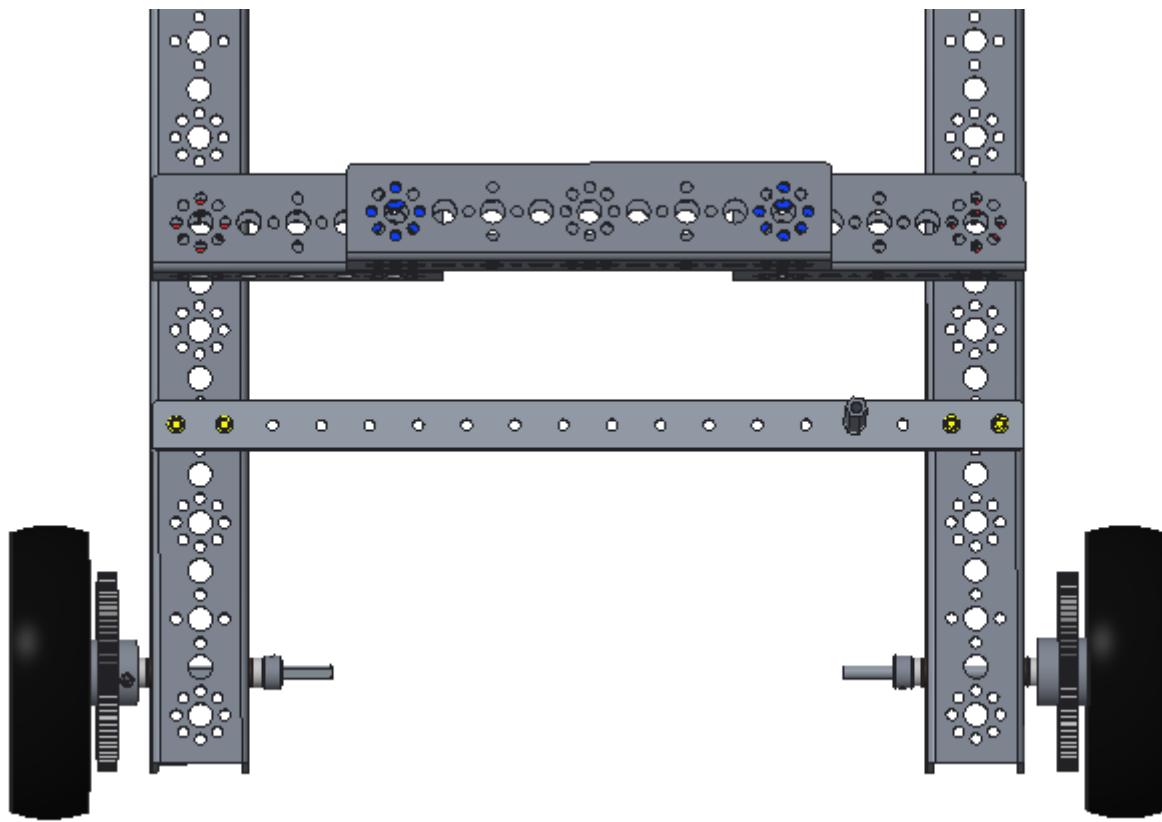
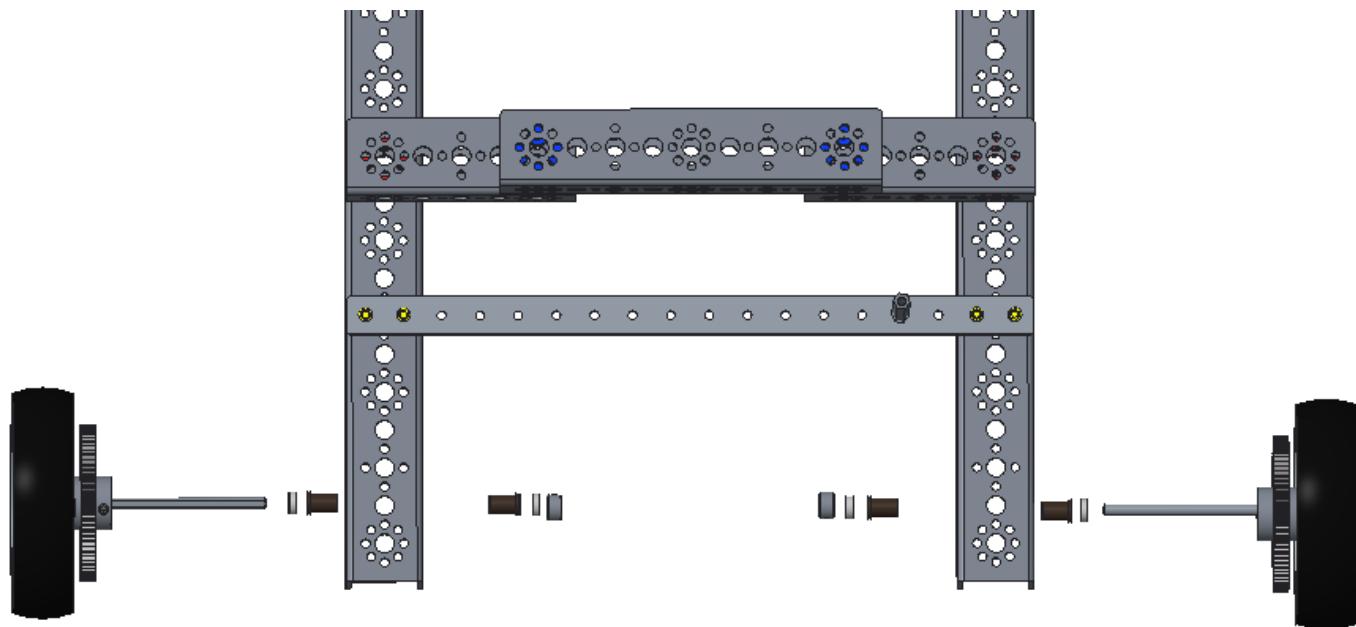


The above image shows only one wheel. Make two.



## Step 2: Add Drive Wheels to the Frame

assemblies from the previous step (2), 1/8" axle spacers (4), axle collars (2), 11 mm bronze bushings (4)



## Adding Omni Wheels

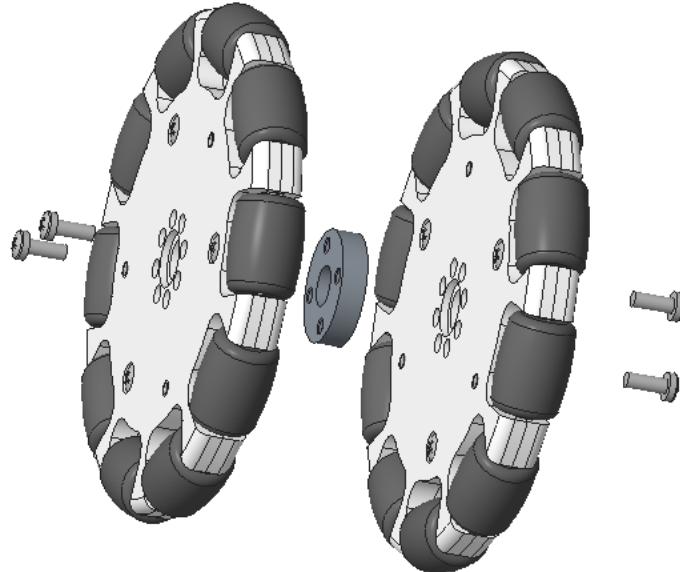
Make two.

### Step 1: Omni Wheel Assembly

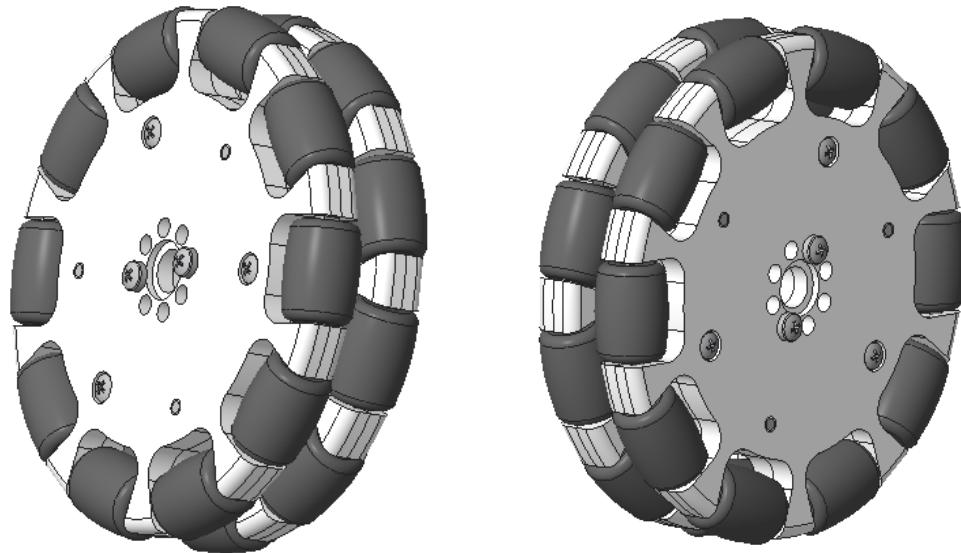
4" omni wheel halves (2), joining ring (1) with included screws (4)

Assemble according to the instructions that come in the omni wheel pack.

Note the screws on one wheel are in opposite holes from the screws on the other wheel.



The above images shows only one wheel assembly. Make two.

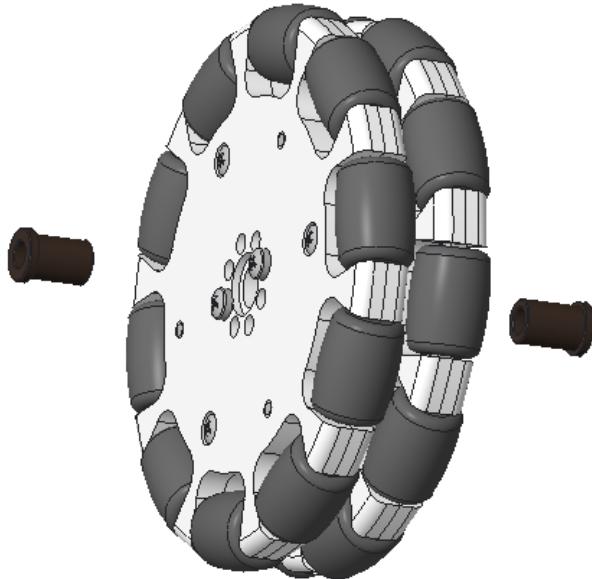


## Step 2: Add Bronze Bushings

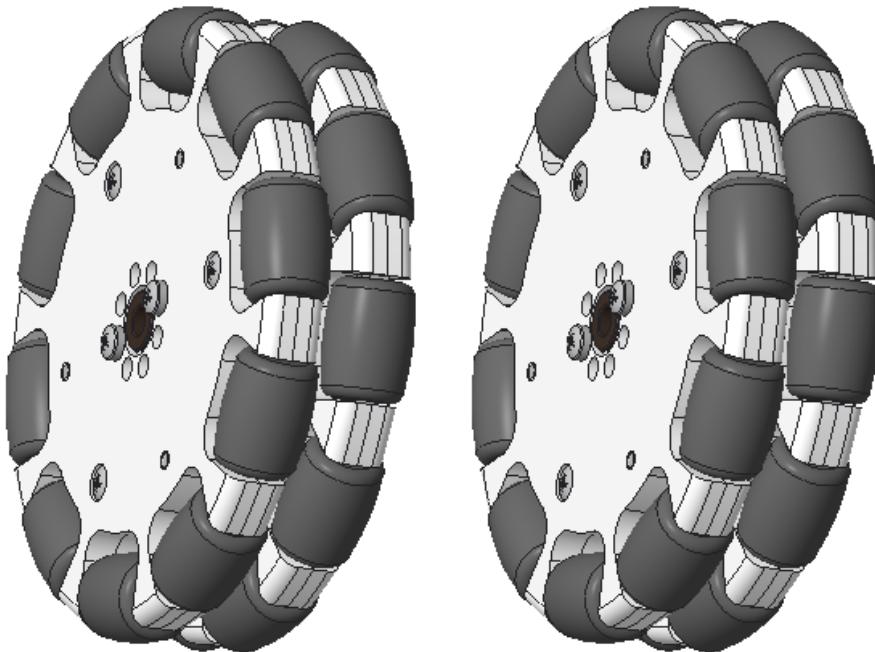
assemblies from the previous step (2), 11 mm bronze bushings (4)

Sometimes the bronze bushings are hard to insert. To make this easier, put a bronze bushing on a wheel assembly from the drive wheel assembly section. Slide the omni wheel down the axle and press it against the wheel assembly. A video is available that shows this trick. Visit

<https://www.facebook.com/322705934572847/videos/506108019565970/>.



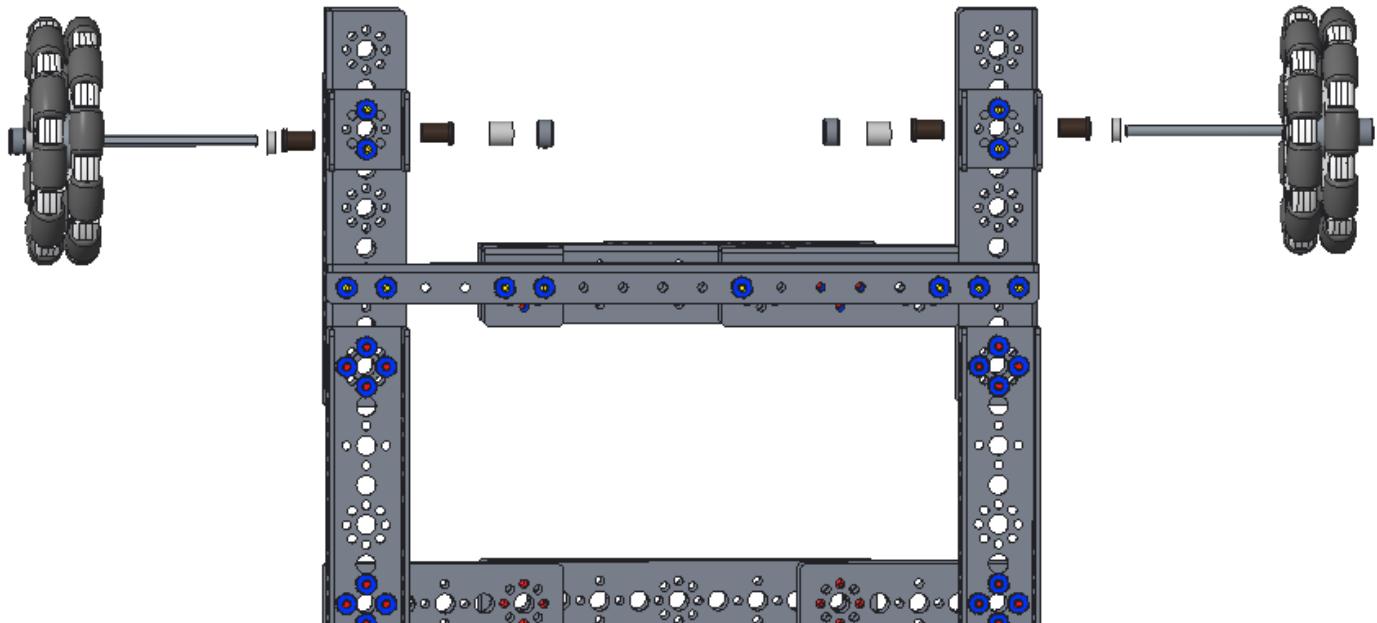
The above image shows only one wheel assembly. Perform this step on both assemblies.



### Step 3: Attach Omni Wheels to Chassis

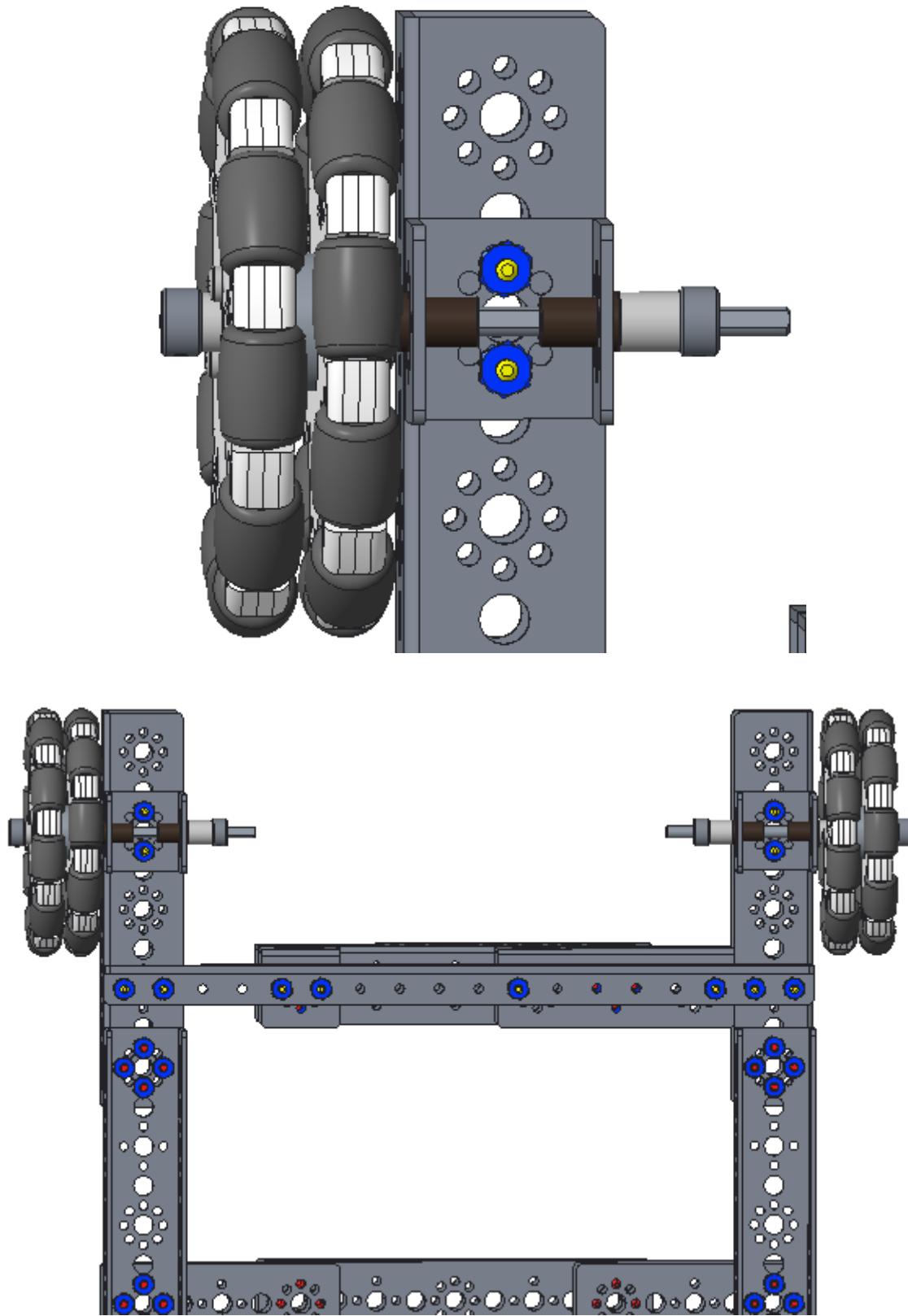
chassis, omni wheel assemblies (2), 1/8" axle spacers (4), 3/8" axle spacers (2), axle set collars (4), 11 mm bronze bushings (4), 100 mm axles (2)

Order from the outside in: axle set collar, 1/8" axle spacer, omni wheel assembly, 1/8" axle spacer, 11 mm bronze bushing, channel, 11 mm bronze bushing, 3/8" spacer, axle set collar



The front of the robot is at the bottom.

The image below shows only the left wheel. The right wheel is a mirror image.



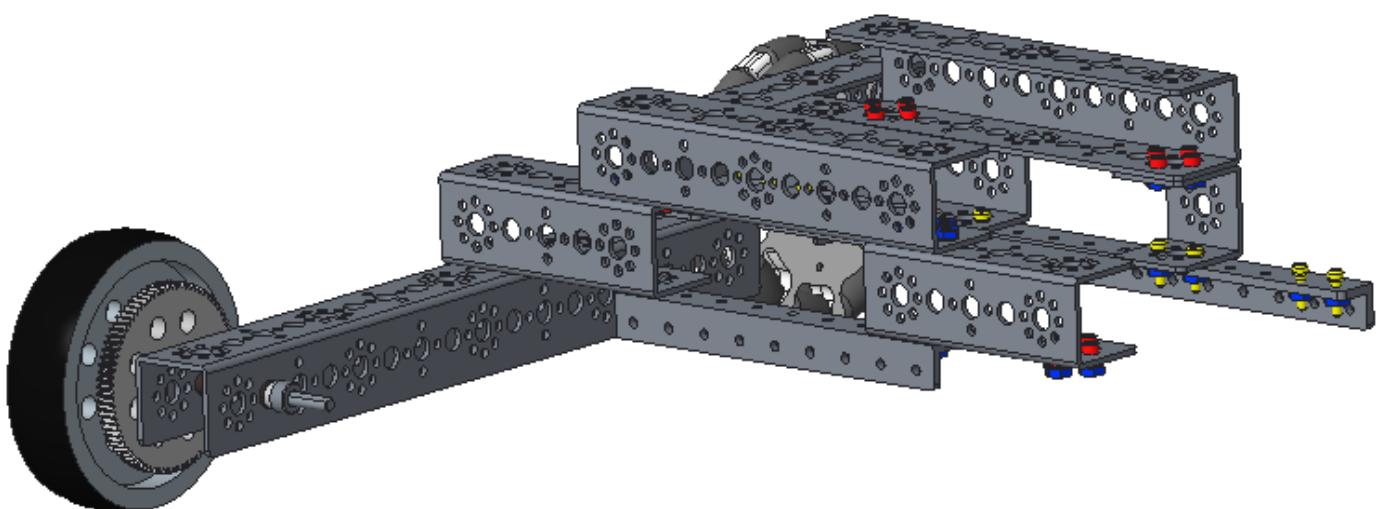
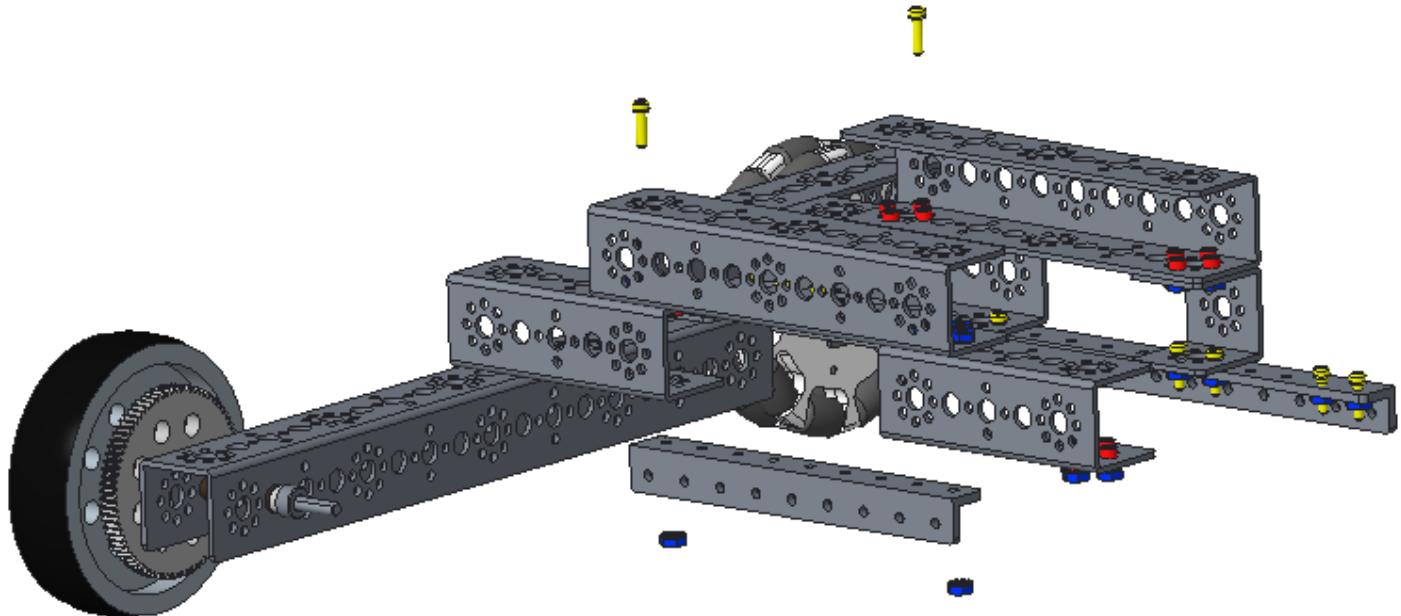
The omni wheels are mounted to the back of the robot.

## Adding the Arm Motor

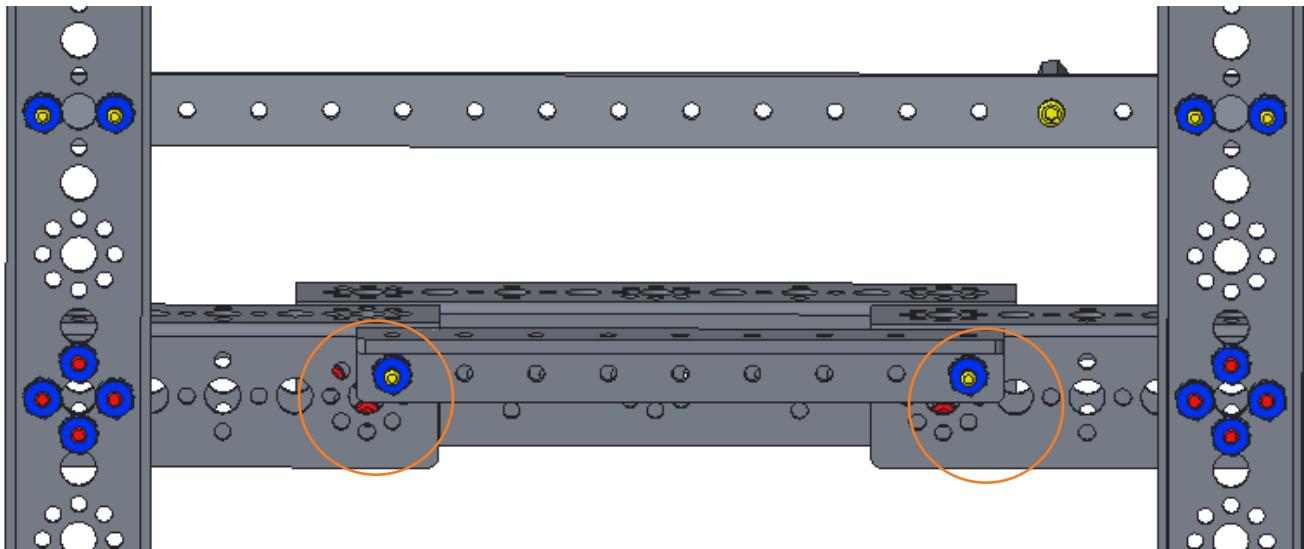
### Step 1: Motor Brace

chassis, 144 mm angle (1), 1/2" socket head cap screws (2), keps nuts (2)

Note that parts of the chassis (the left chassis rail and the front 288mm bar) have been hidden in these images.



Also note that the angle is not centered. It mounts closer to the left chassis rail than the right chassis rail. The **RIGHT** chassis rail is shown in this image; remember that the drive wheels are on the front of the robot.

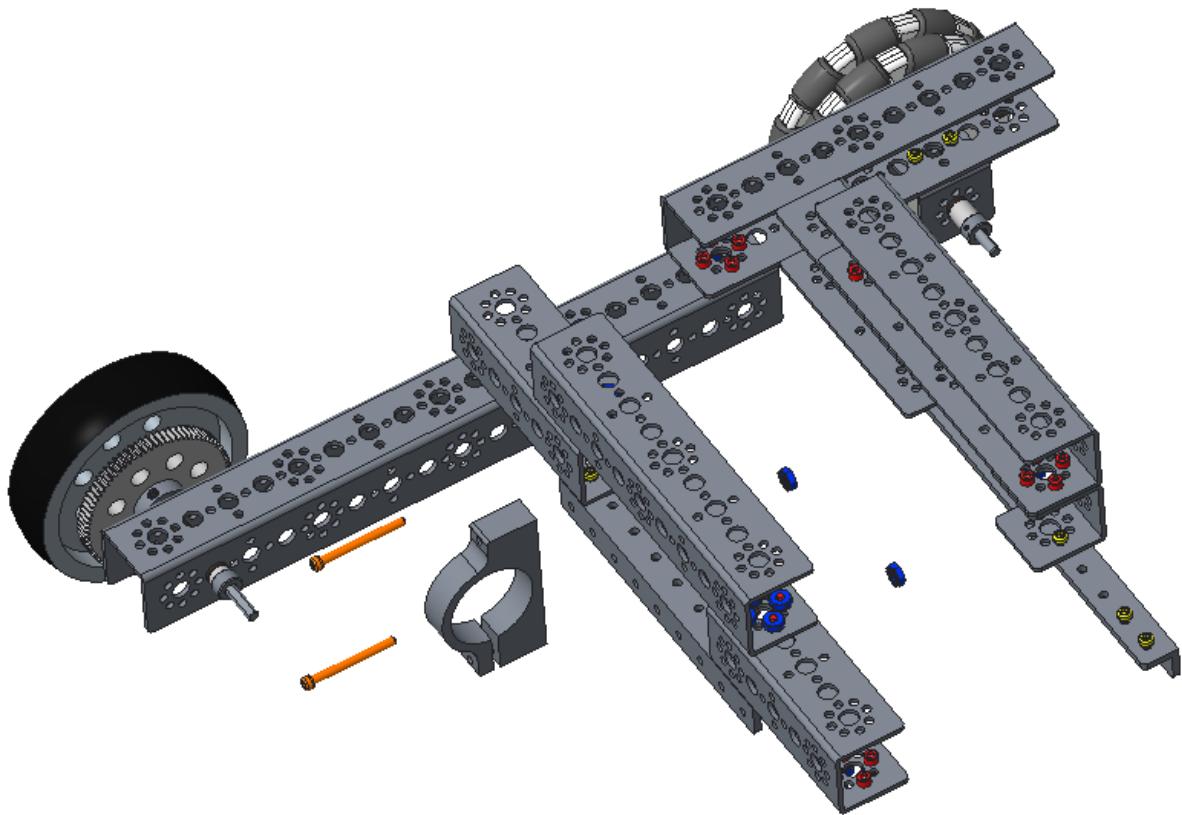


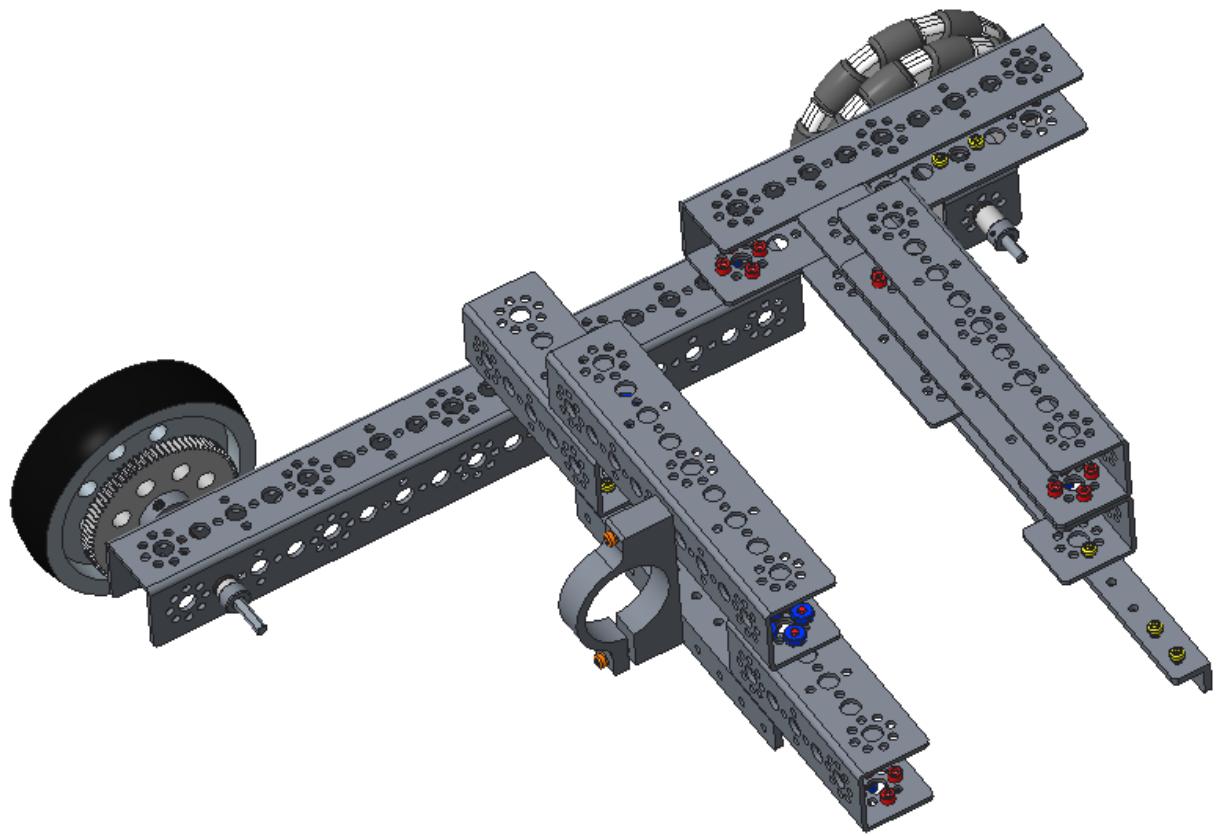
Note that the bolts are through the hole that is one down and to the right of the top hole. This allows the angle to be flush with the front face of the channel.

## Step 2: Motor Mount

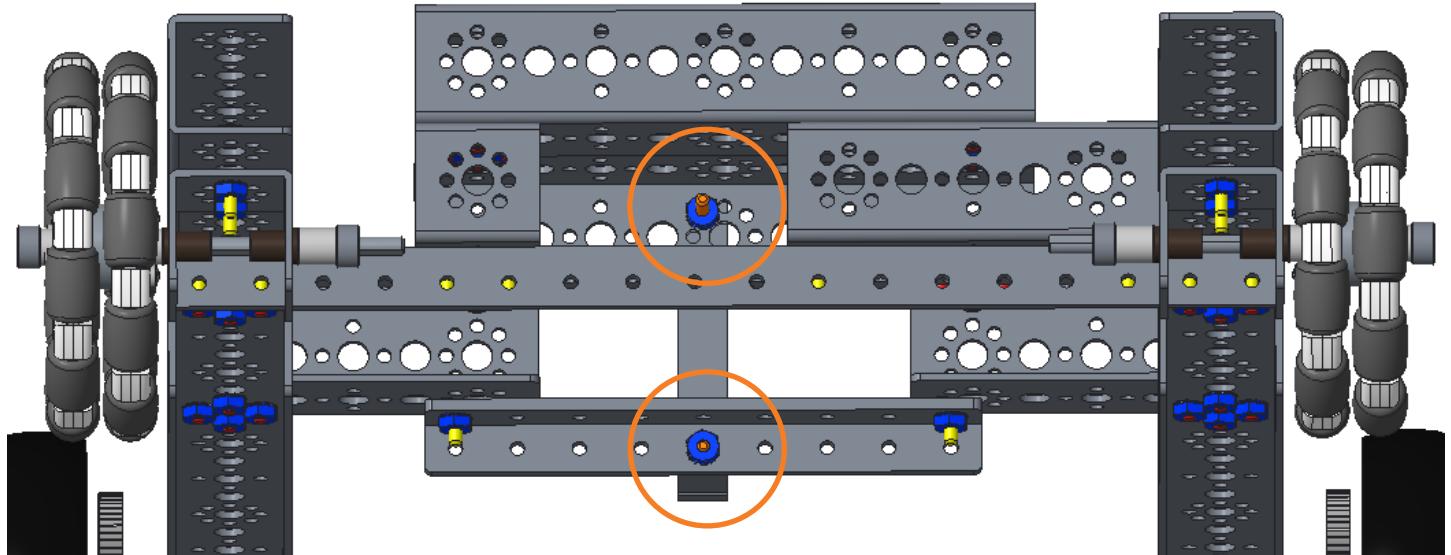
chassis, motor mount (1) and the bolts (2) and nuts (2) that come in the motor mount kit

Note: Do not tighten the lower motor mount bolt (the side with the gap) until the motor has been inserted. When this bolt is tightened, it clamps the motor in place.



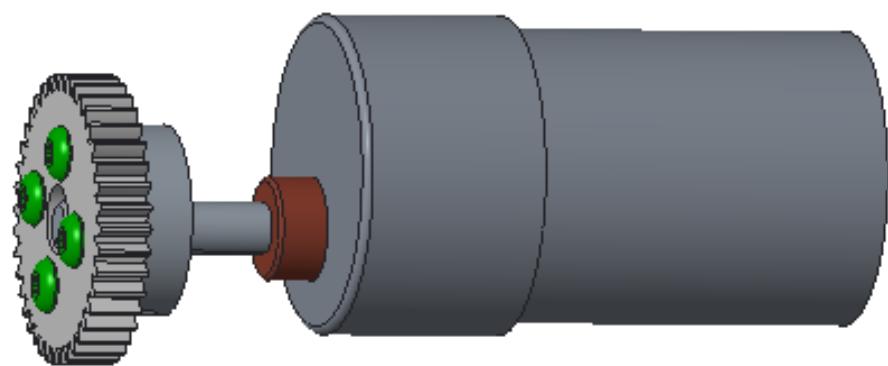
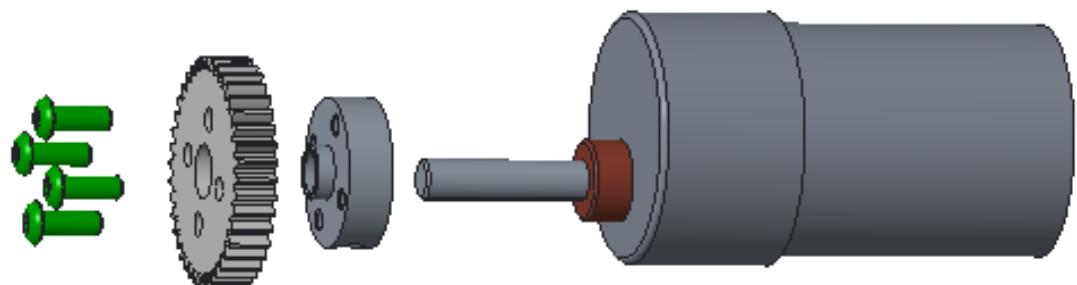


This is a view from the “inside of the robot” (underneath the back wheels looking towards the front of the robot). Note that the motor mount is not in the top hole. From the inside, it will be down and to the left. From the front of the robot, it will be down and to the right.

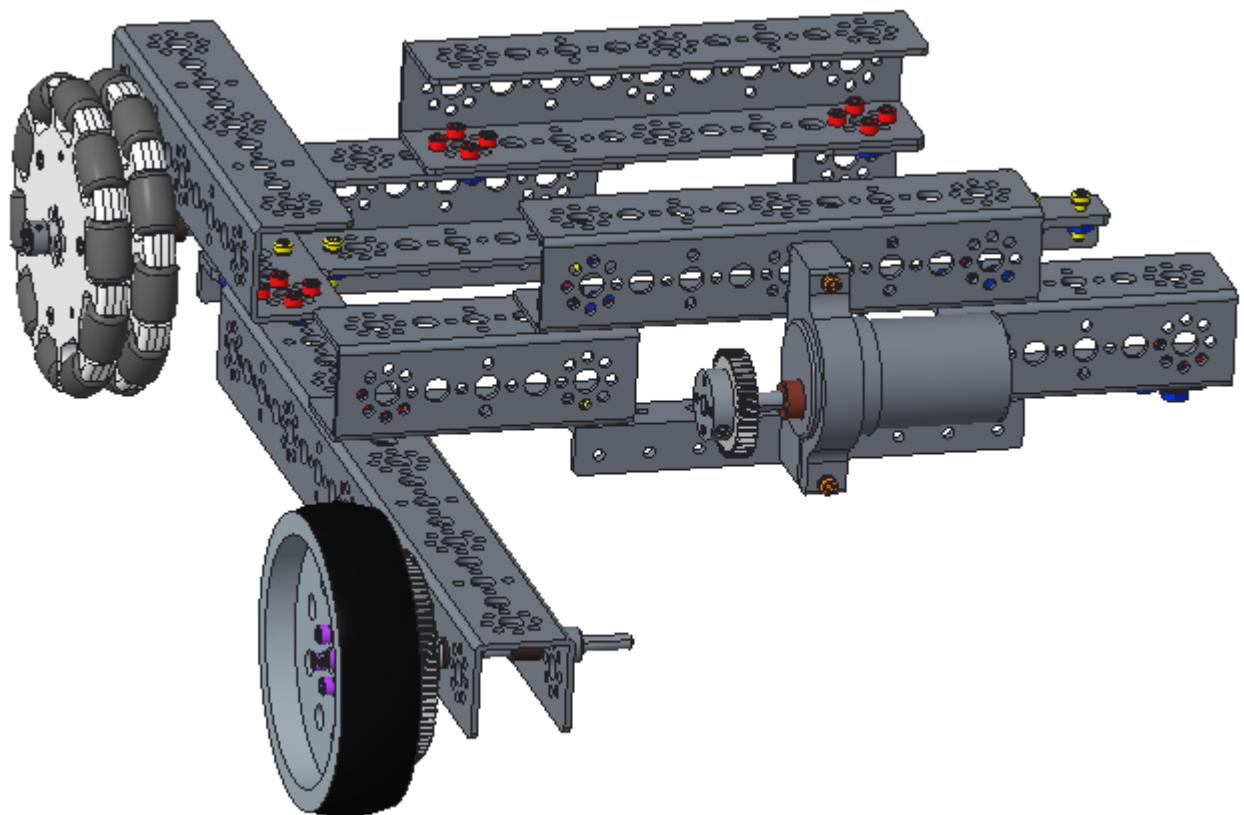
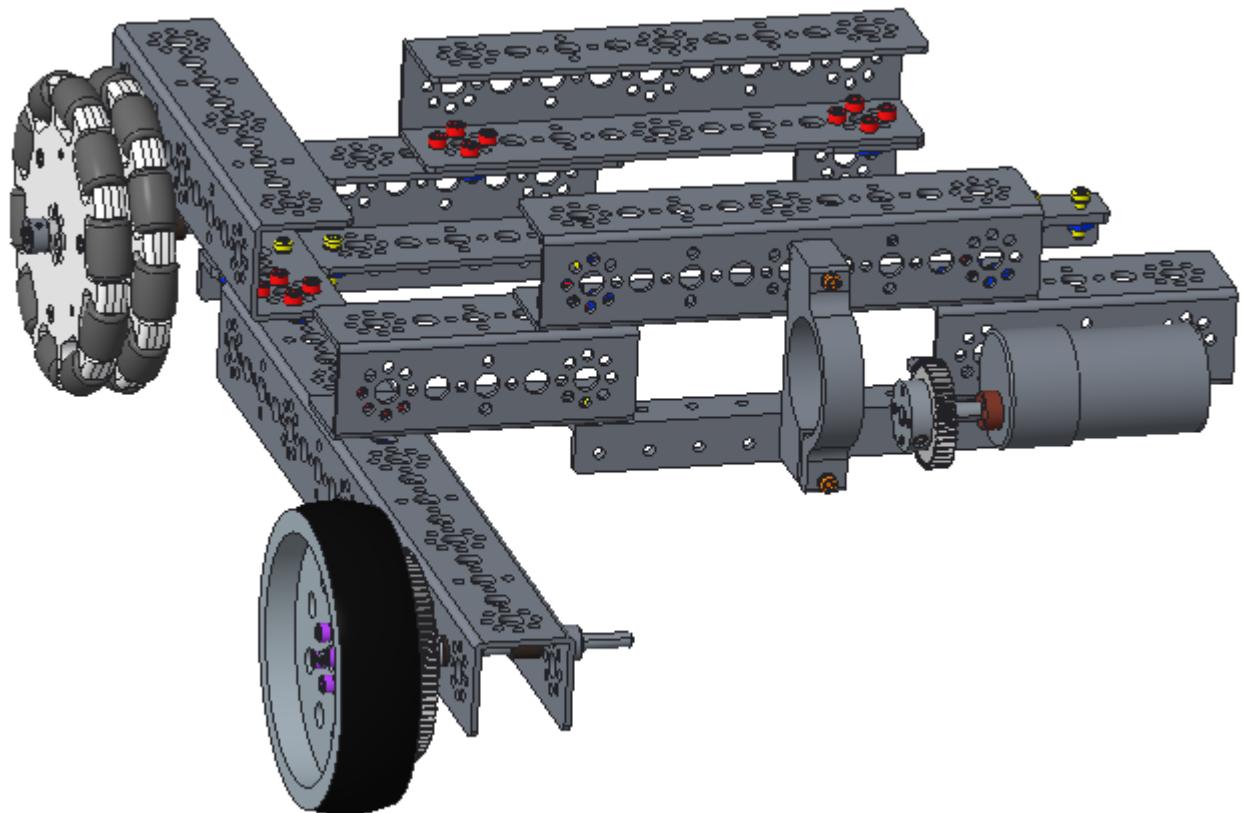


### Step 3: Motor and Gear Assembly

motor hub (1) with its included set screw (1), 40 tooth gear (1), DC motor (1), 3/8" button head cap screws (4)



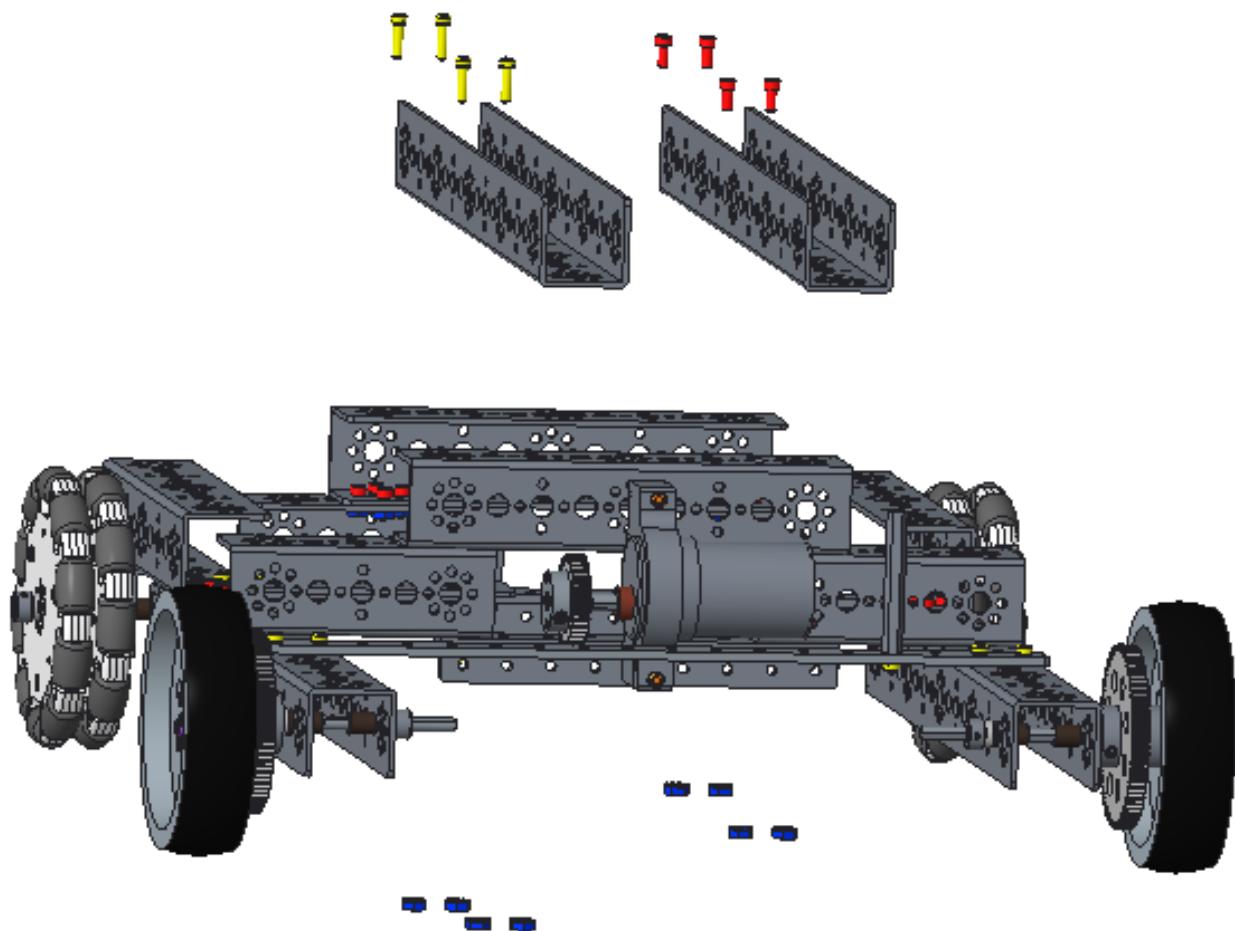
Step 4: Mounting the Motor  
chassis, assembly from the previous step



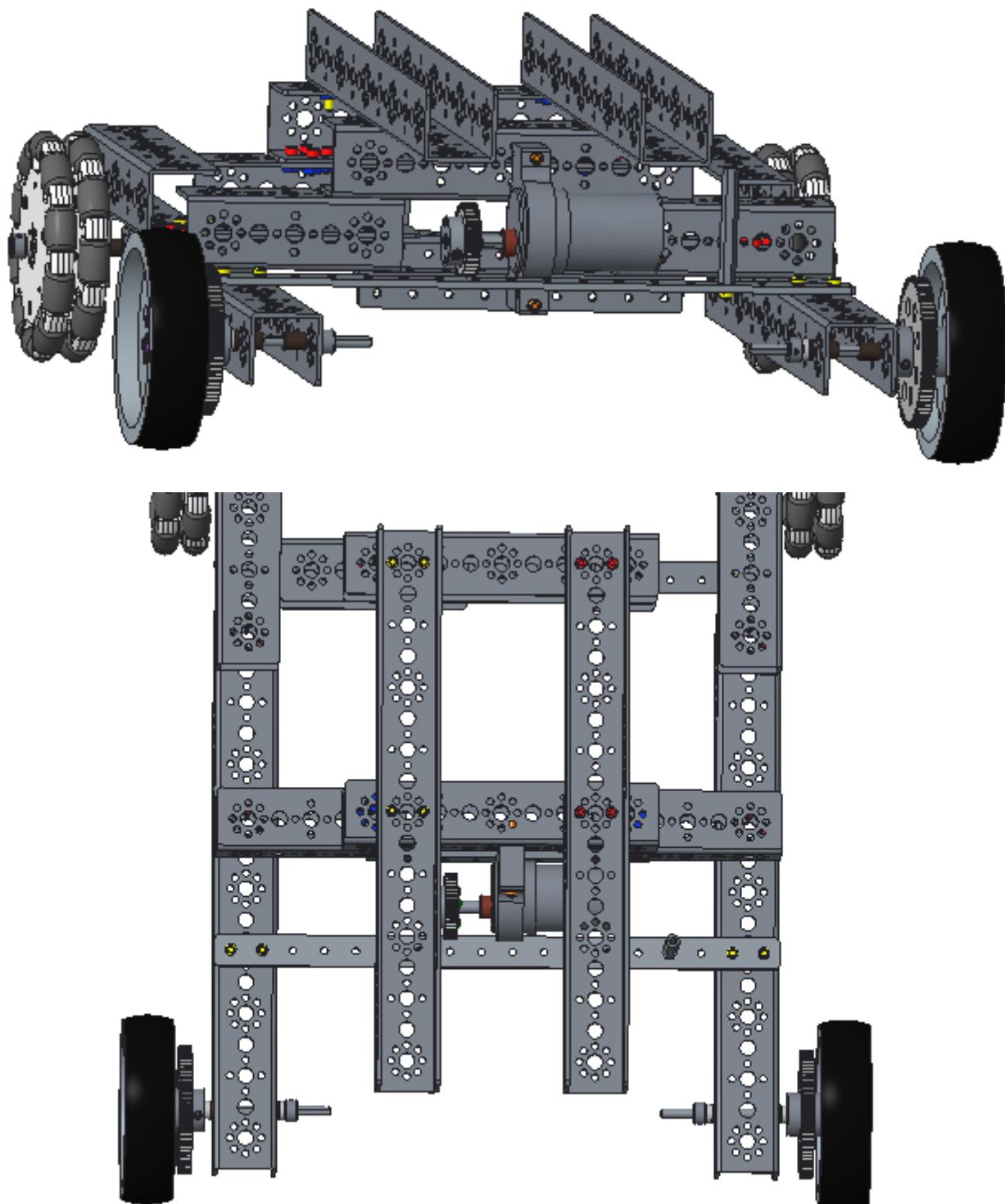
## Adding the Arm Rails

### Step 1: Arm Support Rails

chassis, 288 mm channels (2), 1/2" socket head cap screws (4), 5/16" socket head cap screws (4), keps nuts (8)



The front of the robot is at the bottom of the image.



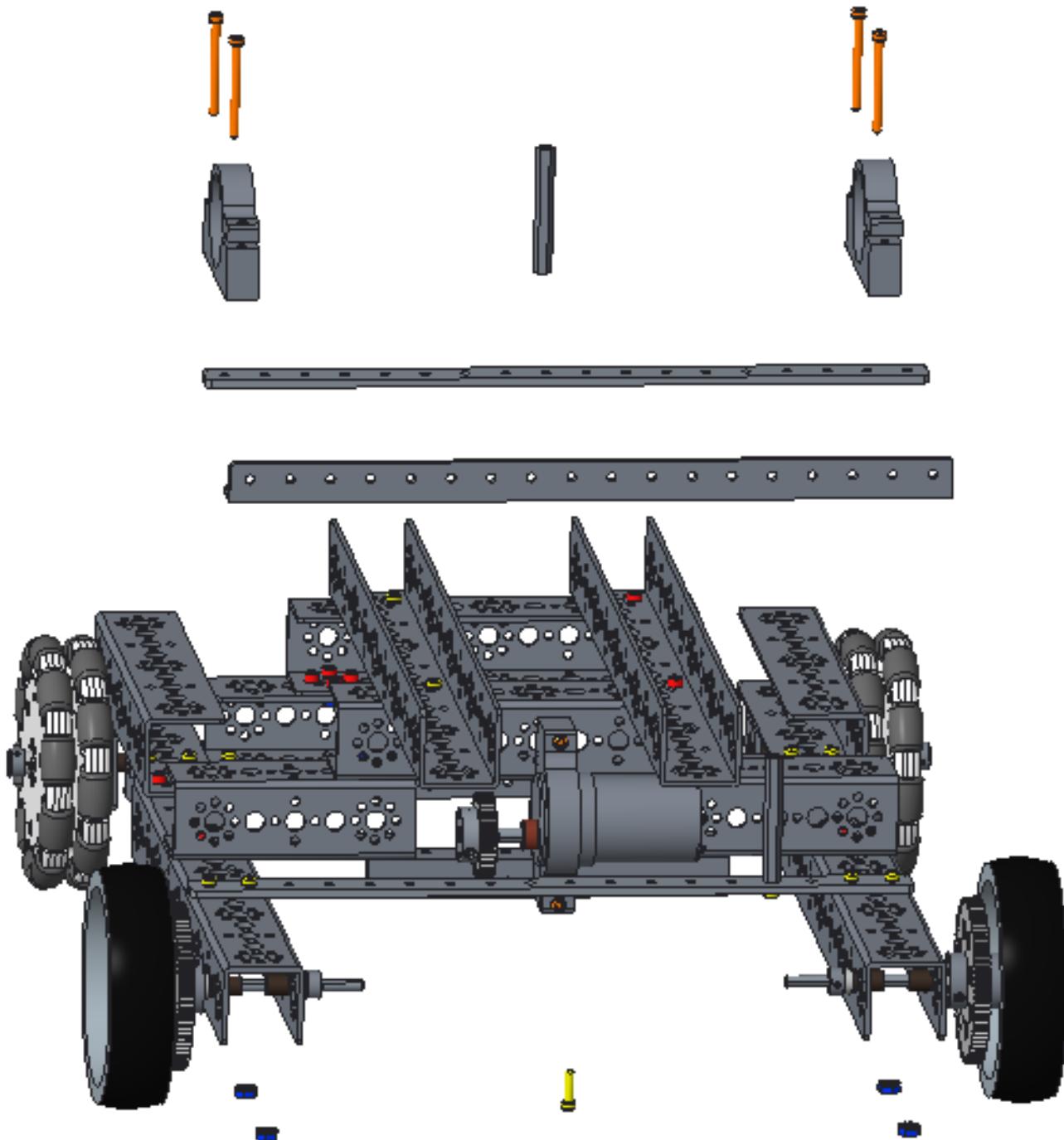
The above image shows the view from the top of the robot.

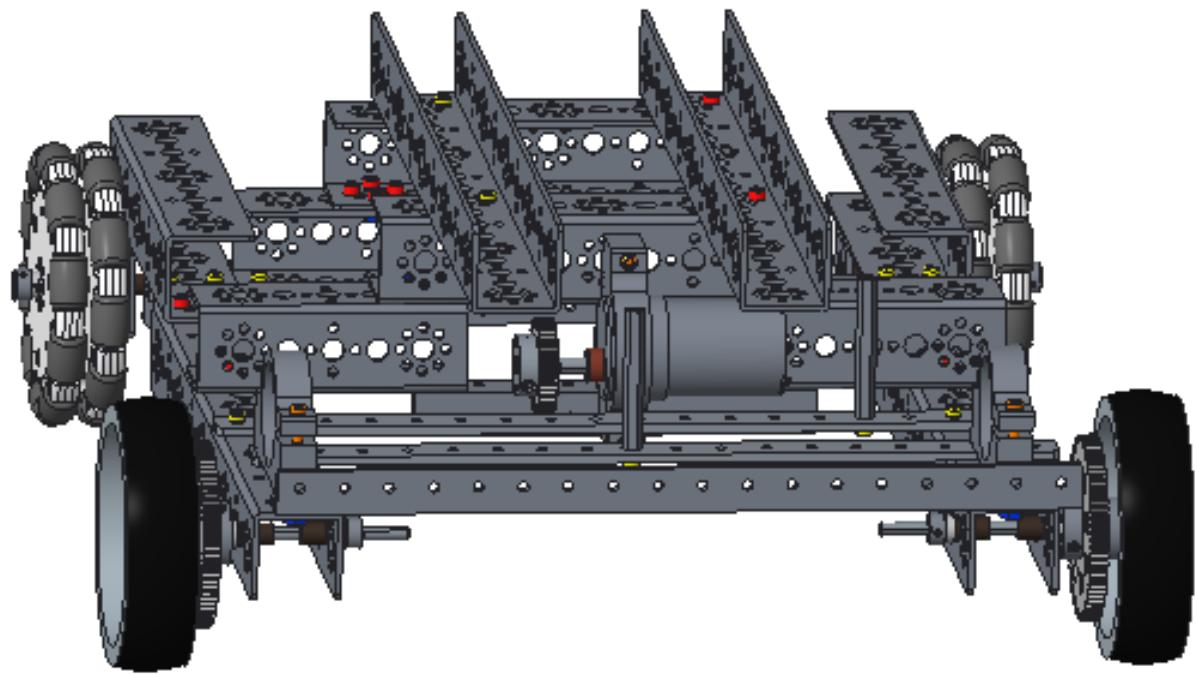
## Adding the Drive Motors

### Step 1: Drive Wheel Motor Mounts

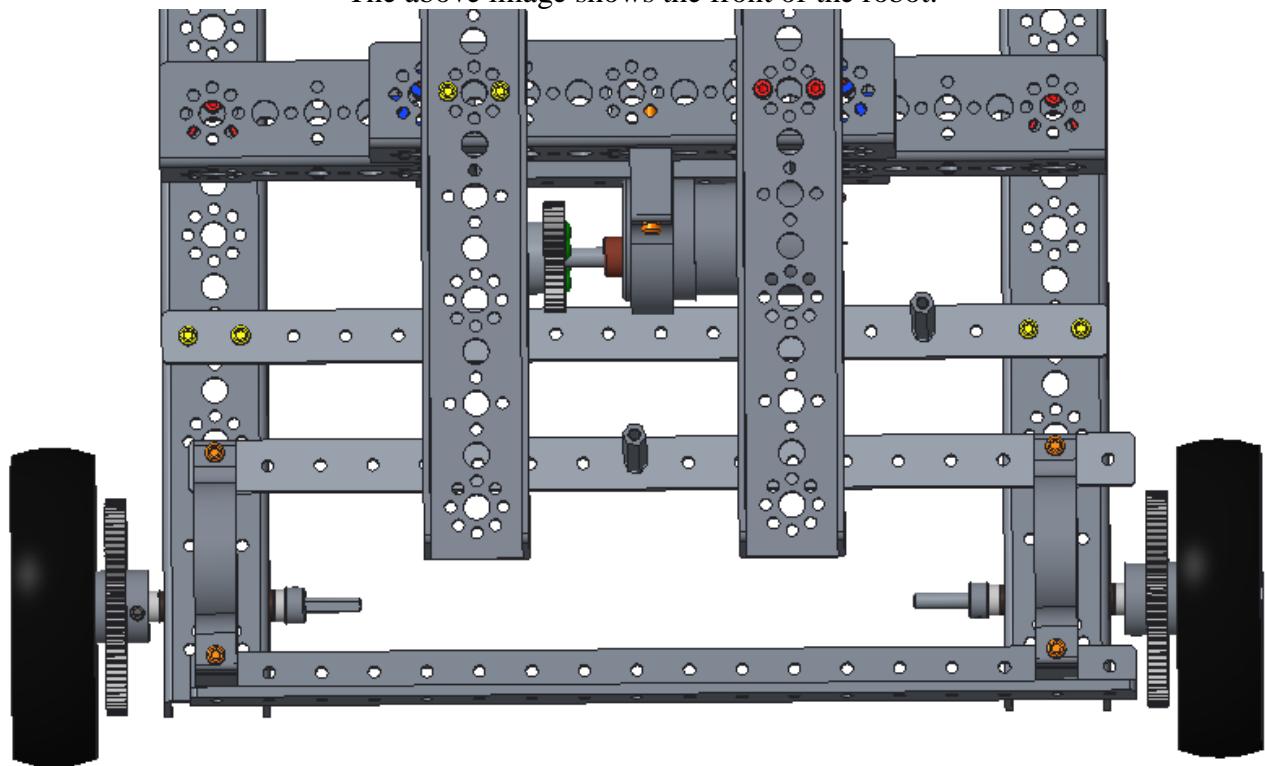
chassis, motor mounts (2) and the bolts (4) and nuts (4) that come in the motor mount kit, 288 mm flat bar (1), 288 mm angle (1), 2" stand-off (1)

Note: Do not tighten the motor mount bolts that control the clamp (i.e. the gap on one side of the mount) until the motors have been inserted, which happens at the end of this section. When this bolt is tightened, the motors can't be inserted into the mount.





The above image shows the front of the robot.



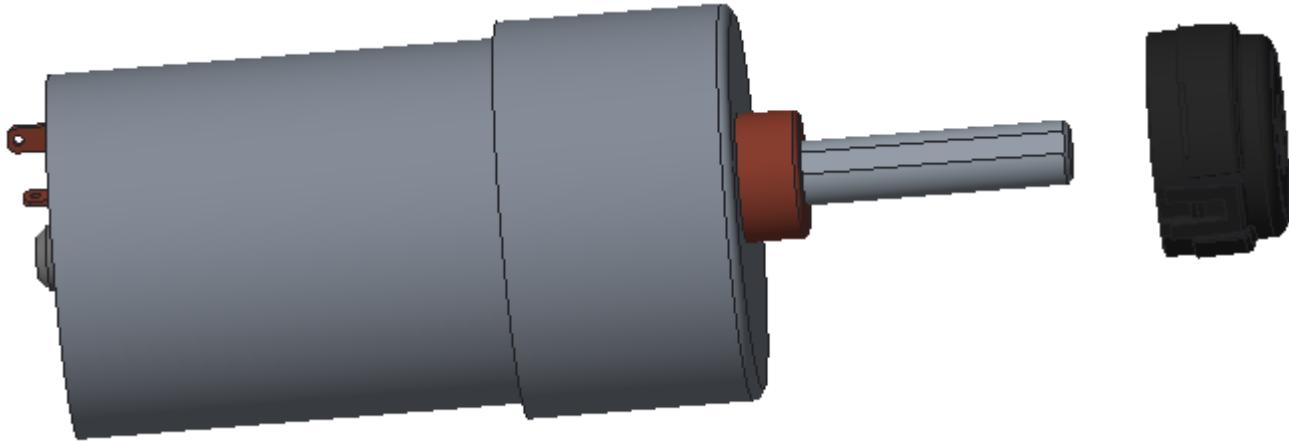
The above image shows the top of the robot.

## Step 2: Motor Encoder Assemblies

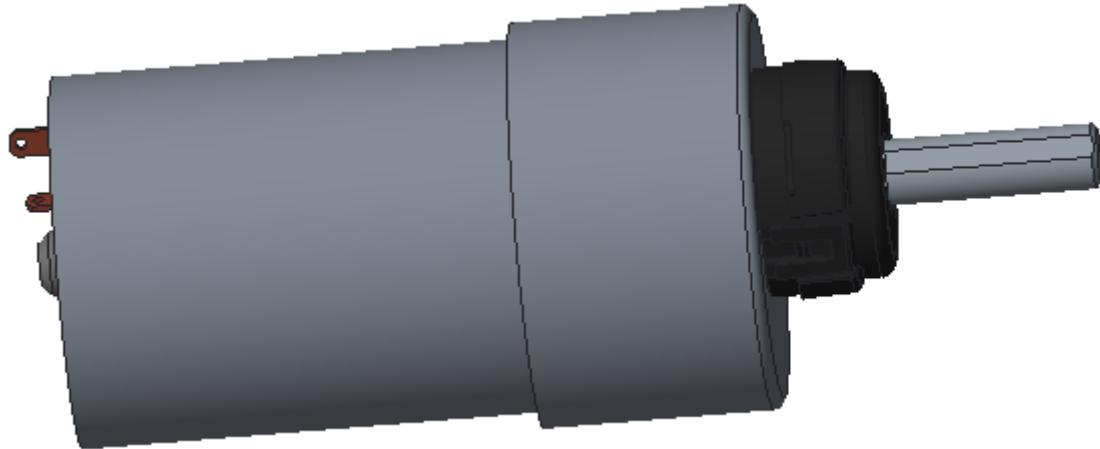
Make two.

DC motor (1), encoder (1)

Refer to the instructions from the encoder package to install the encoder onto the motor. Encoder styles vary, so the one in the kit of parts may not look like the one in this document.



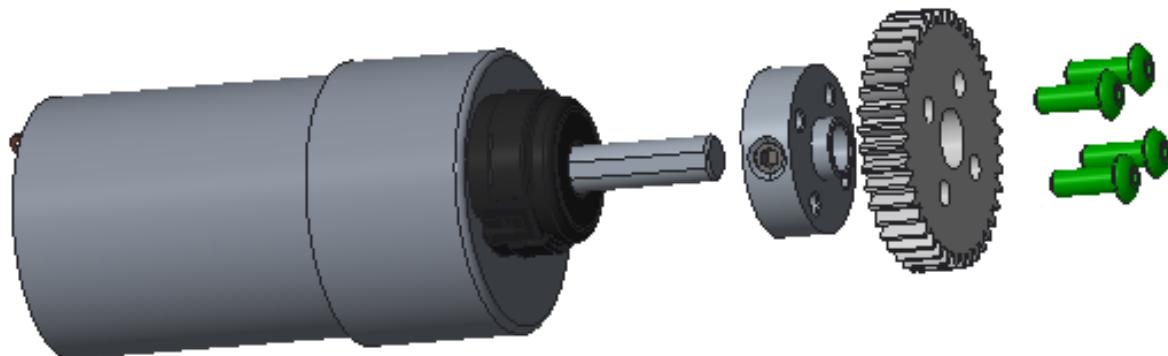
These images show only one motor. Make two.



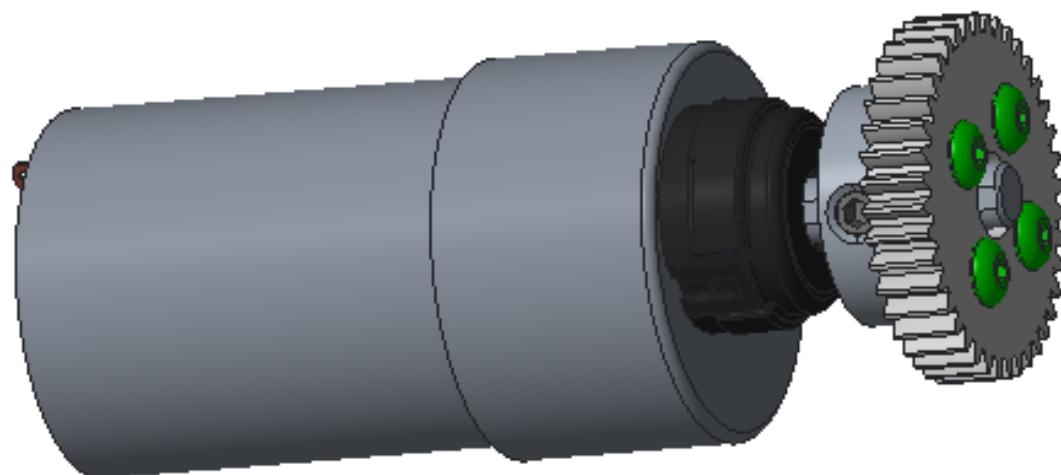
### Step 3: Motor and Gear Assemblies

Make two.

assemblies from the previous step (2), motor shaft hubs (2) with included set screws (2), 40-tooth gears (2), 3/8" button head cap screws (8)



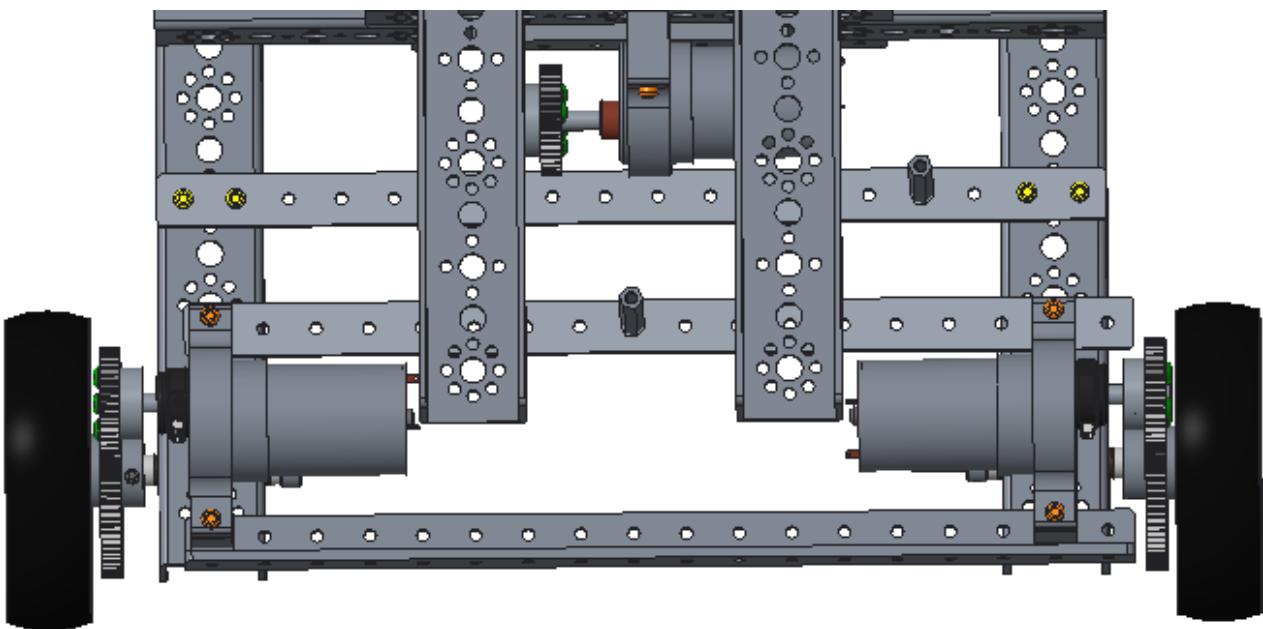
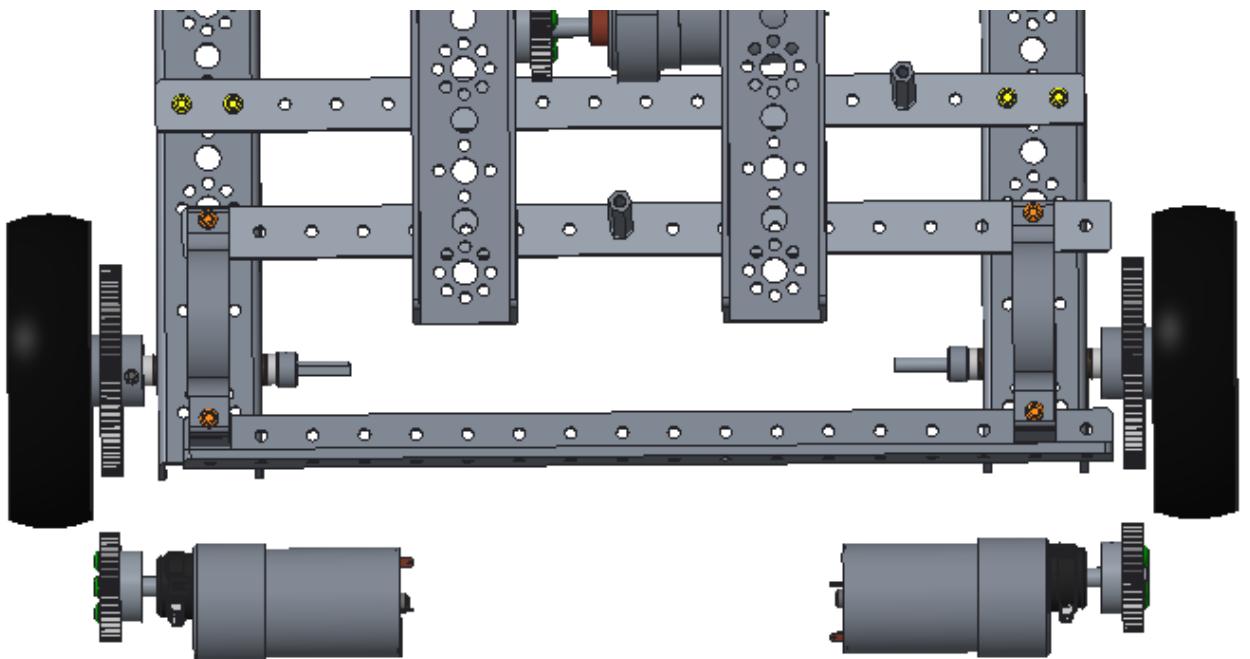
These images show only one motor. Make two.



#### Step 4: Mounting the Motors

chassis, assemblies from the previous step (2)

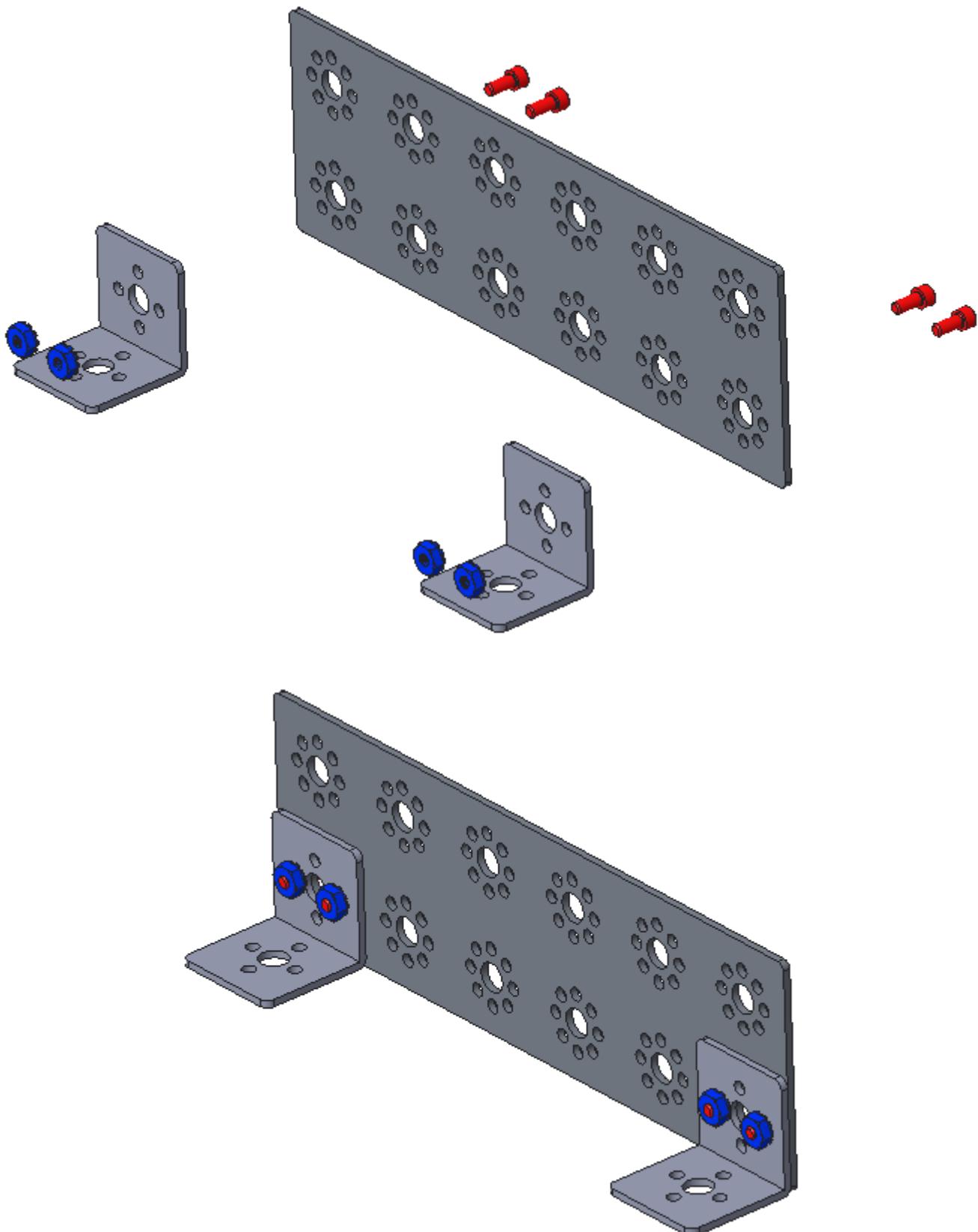
Insert the motors into the motor mounts, aligning the small gears on the motors with the medium gears on the wheels.



## Adding the Expansion Hub Assembly

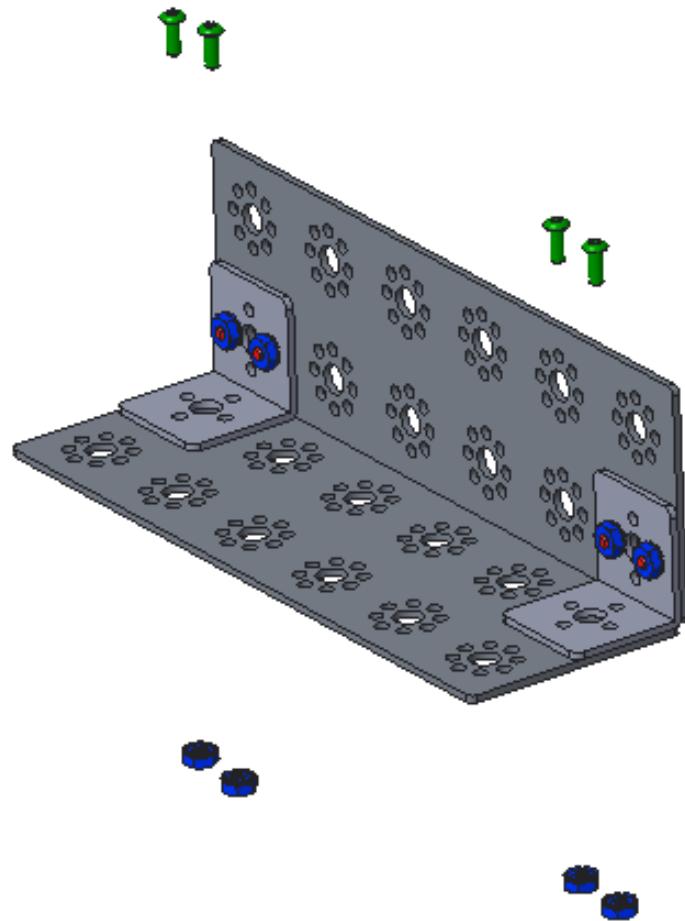
### Step 1: Vertical Support

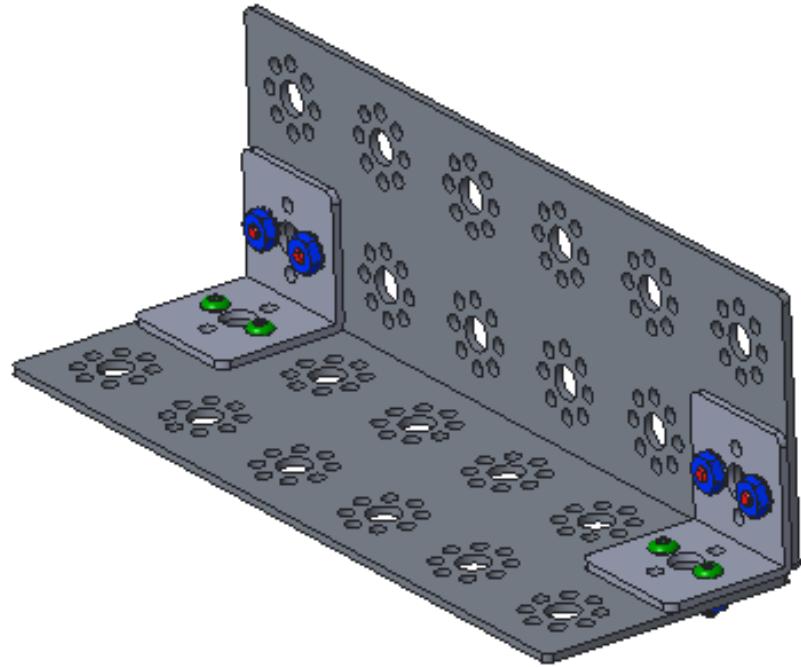
64 mm x 192 mm flat building plate (1), inside corner brackets (2), 5/16" socket head cap screws (4), keps nuts (4)



**Step 2: Horizontal Support**

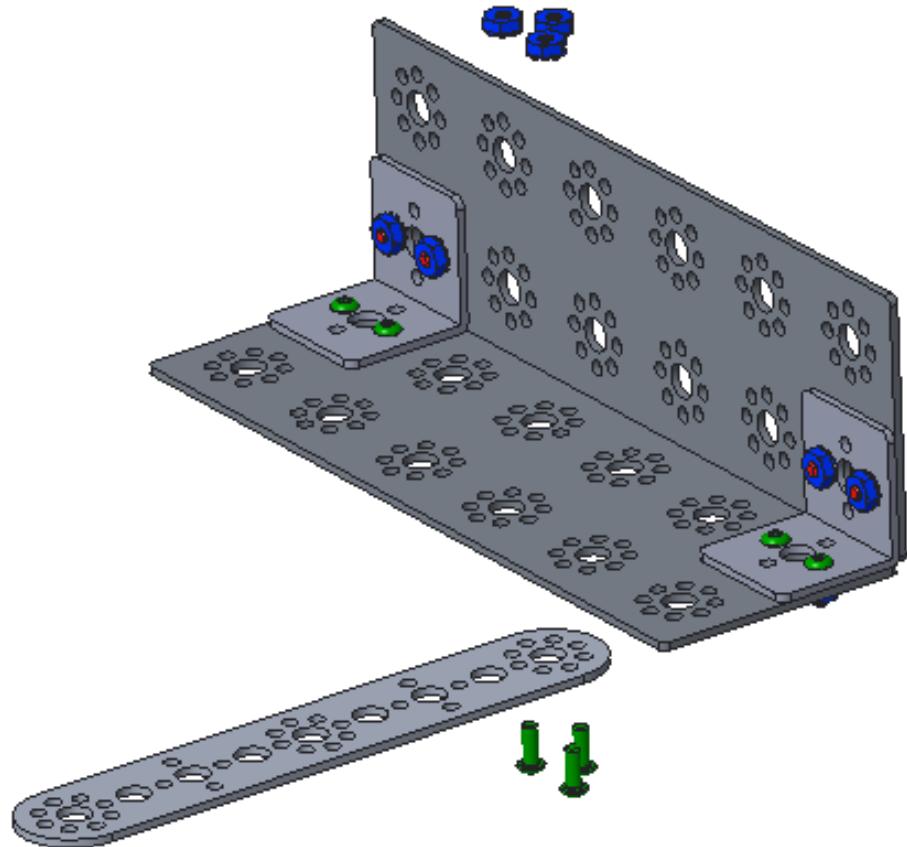
assemblies from the previous step, 64 mm x 192 mm flat building plate (1), 3/8" button head cap screws (4), keps nuts (4)

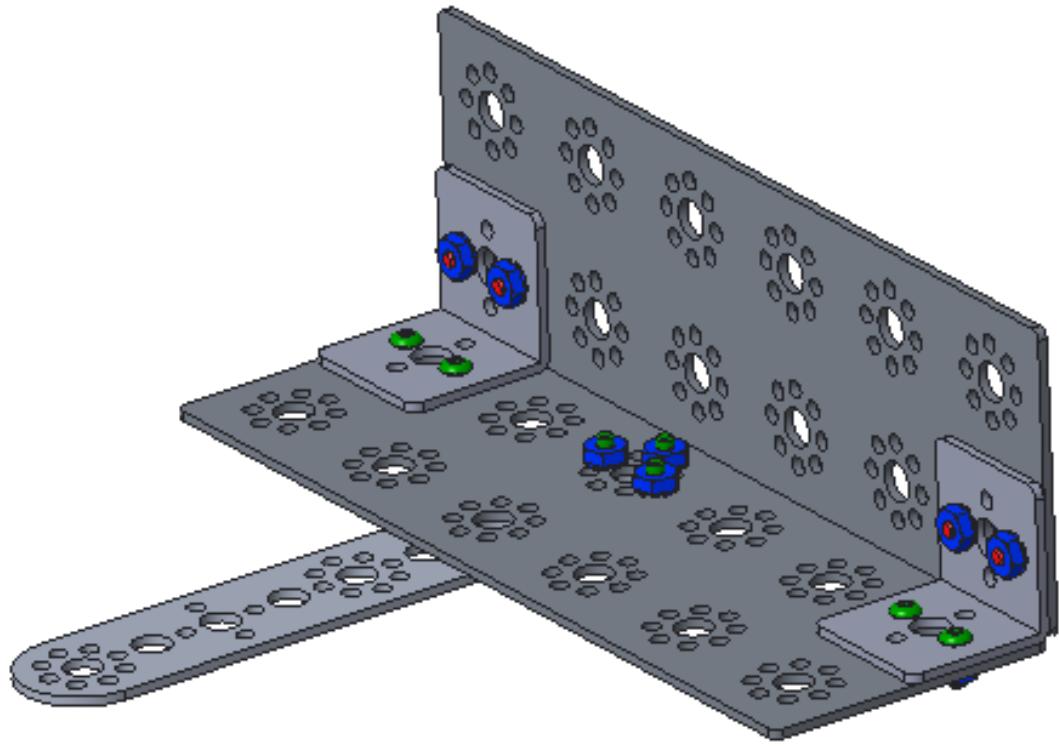




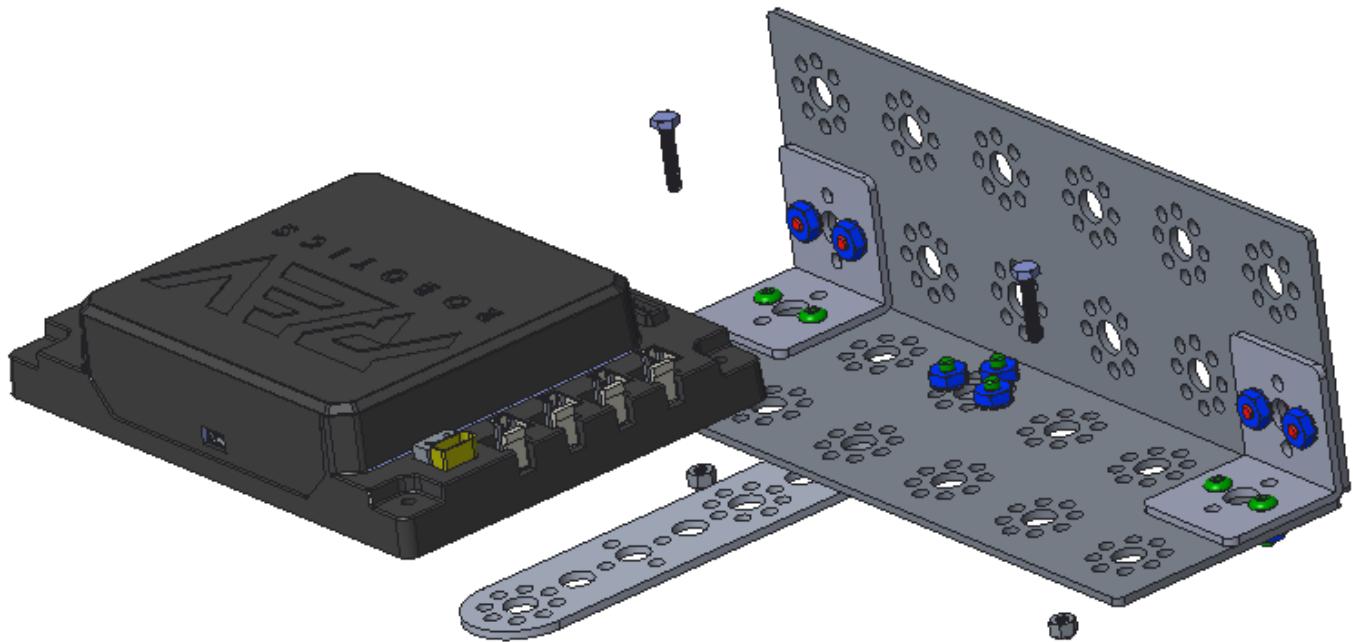
### Step 3: Expansion Hub Support

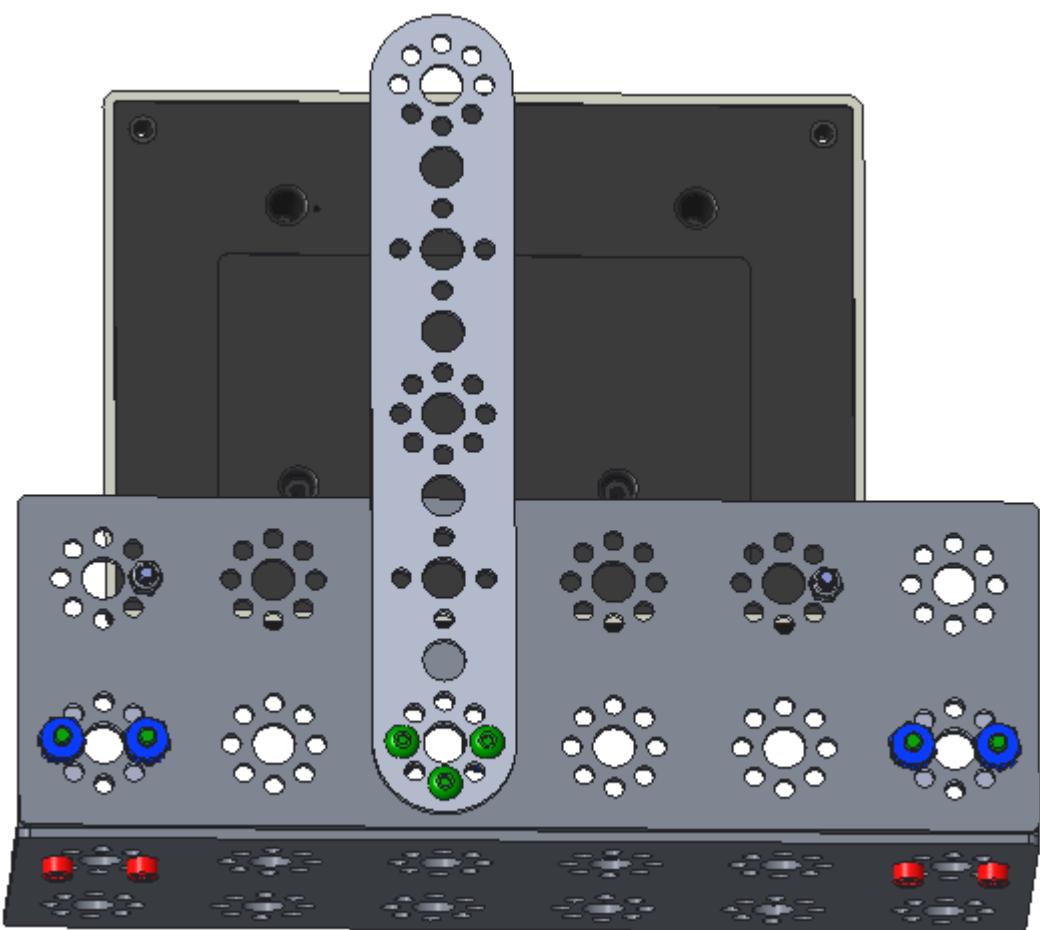
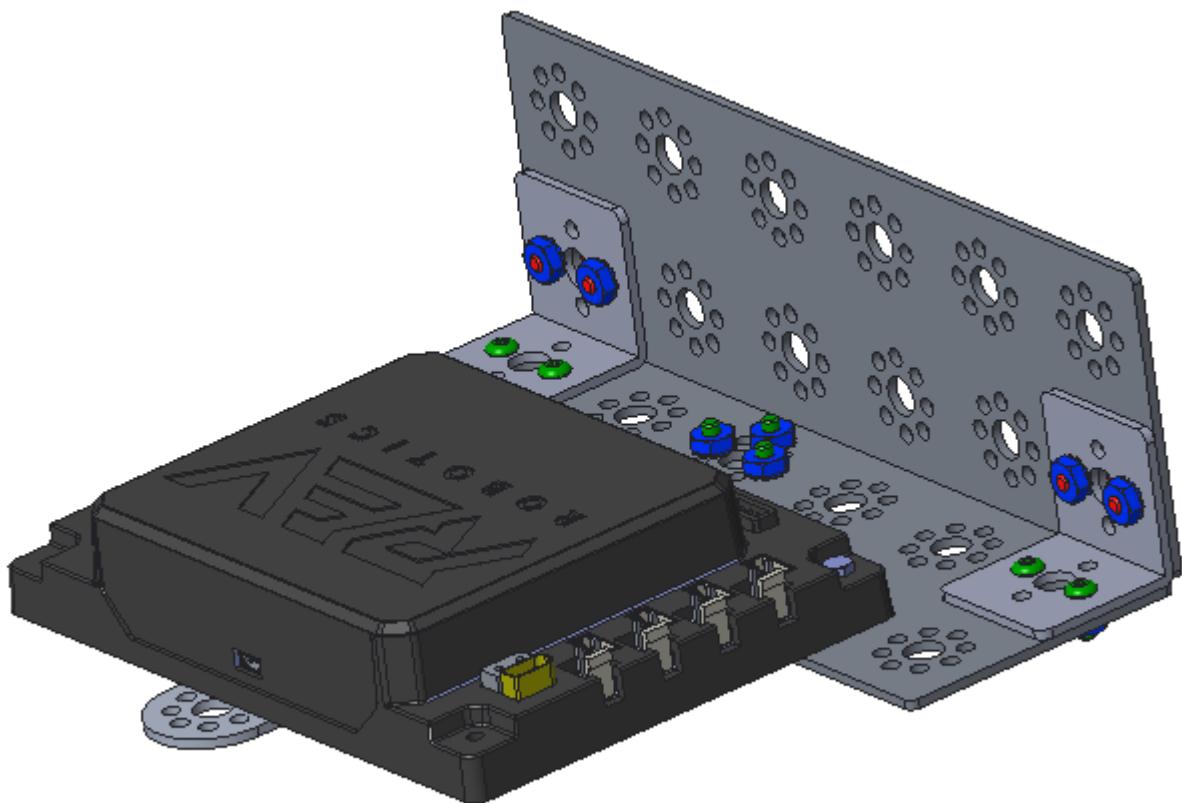
assembly from the previous step (1), 160 mm flat (1), 3/8" button head cap screws (3), keps nuts (3)





Step 4: Adding the Rev Robotics Expansion Hub  
assembly from the previous step (1), expansion hub (1) with included bolts (2) and nuts (2)

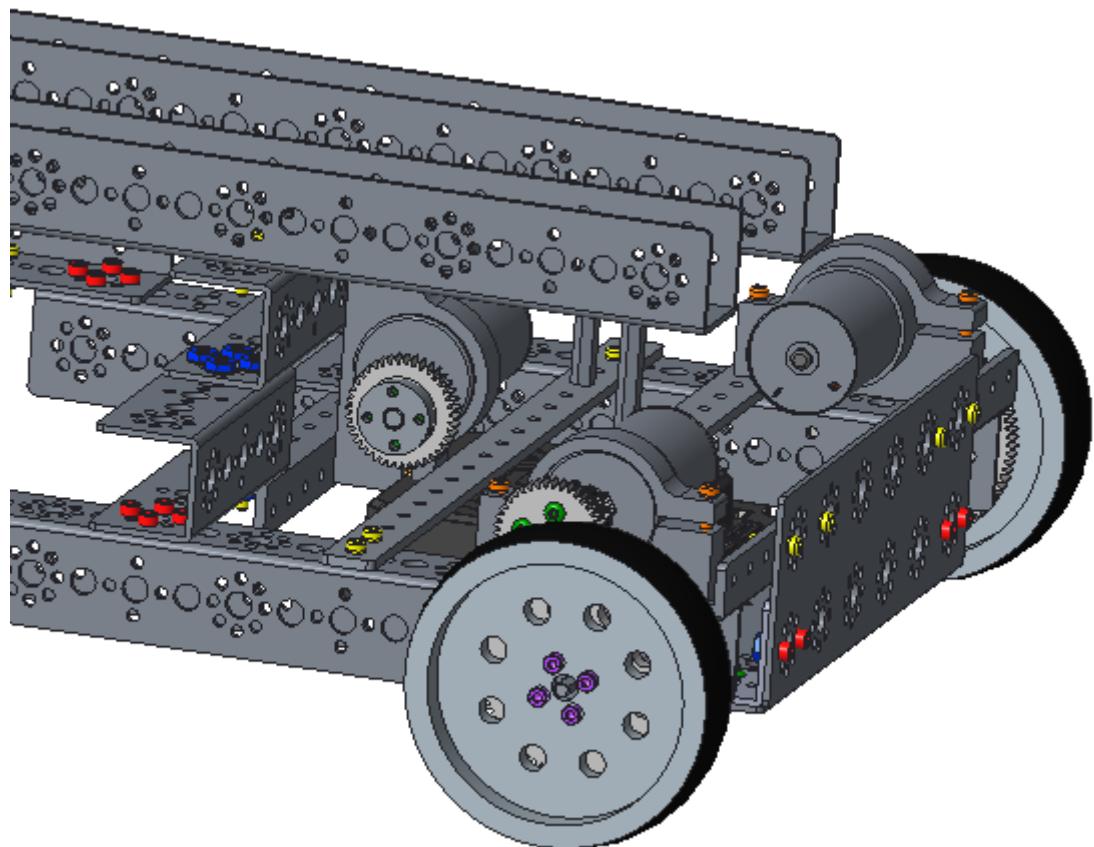
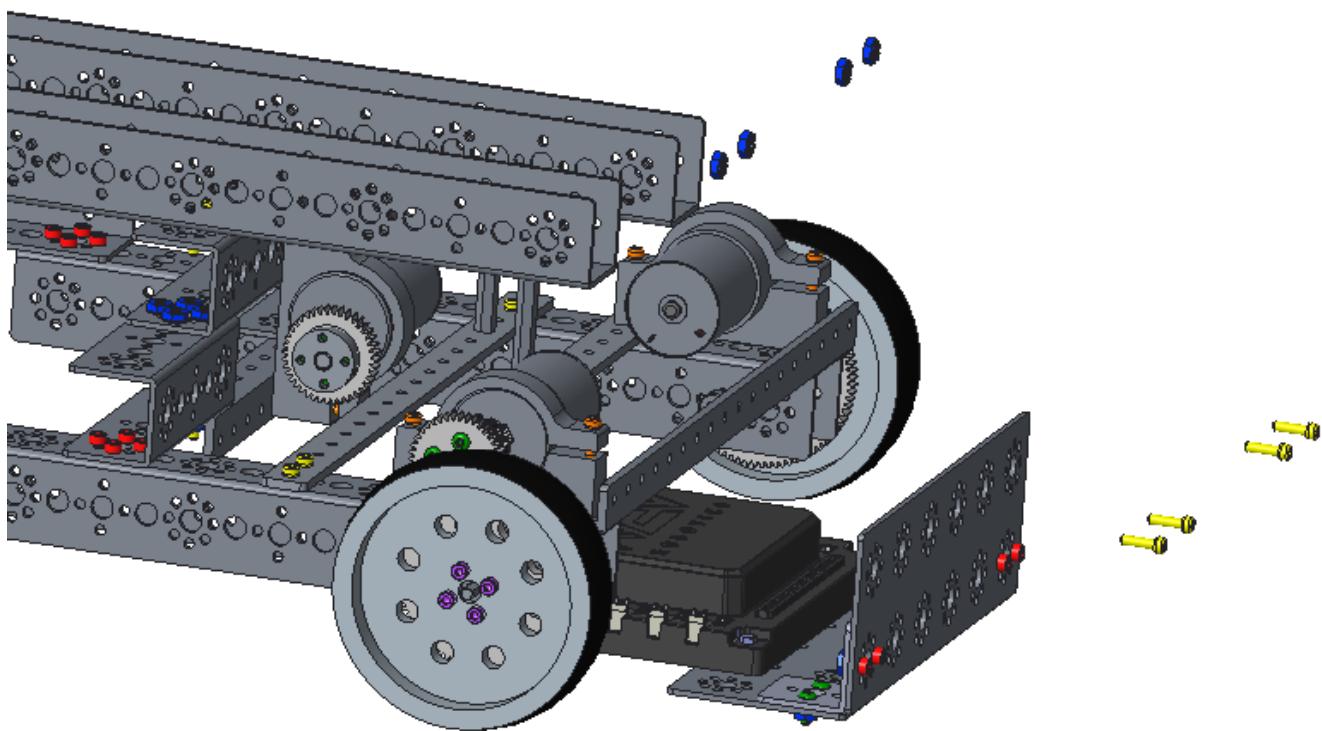




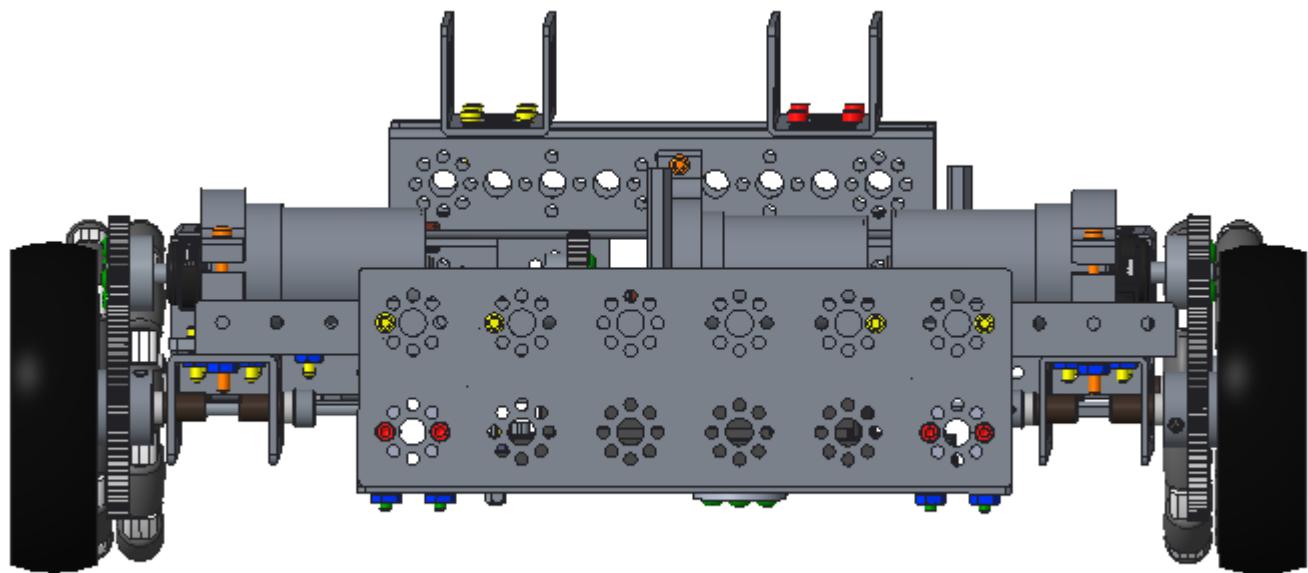
The above image shows the bottom of the assembly.

## Step 5: Attach Assembly to Chassis

chassis, assembly from the previous step (1), 1/2" socket head cap screws (4), keps nuts (4)



Notice on this rear view of the robot that the bolts are one up and to the left of the hole pattern. This brings the lower plate higher on the robot to allow for a higher drive clearance.

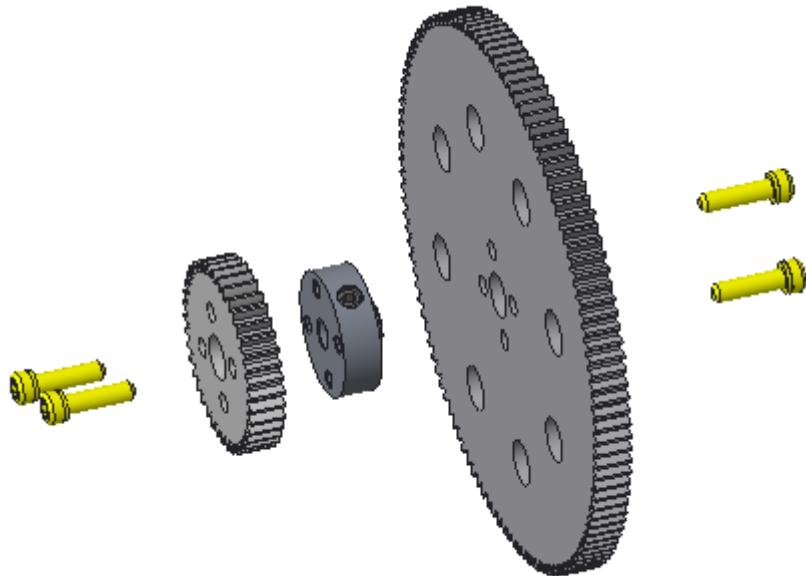


## Adding the Arm

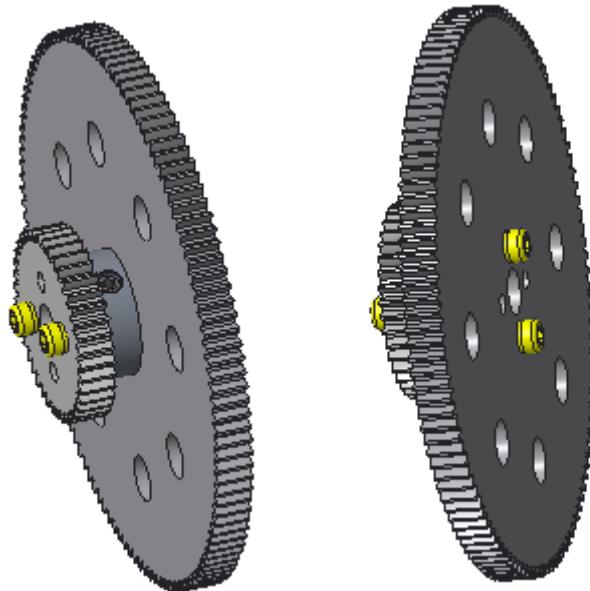
### Step 1: Arm Gear Box

120-tooth gear (1), 40-tooth gear (1), axle hub (1) with included set screw (1), 1/2" socket head cap screws (4)

Note that the bolts are inserted from opposite sides. The two bolts on each side are in opposite holes. The bolts on one side will be 90 degrees rotated from the bolts on the other side.



The image below shows the two sides of the same gear assembly.



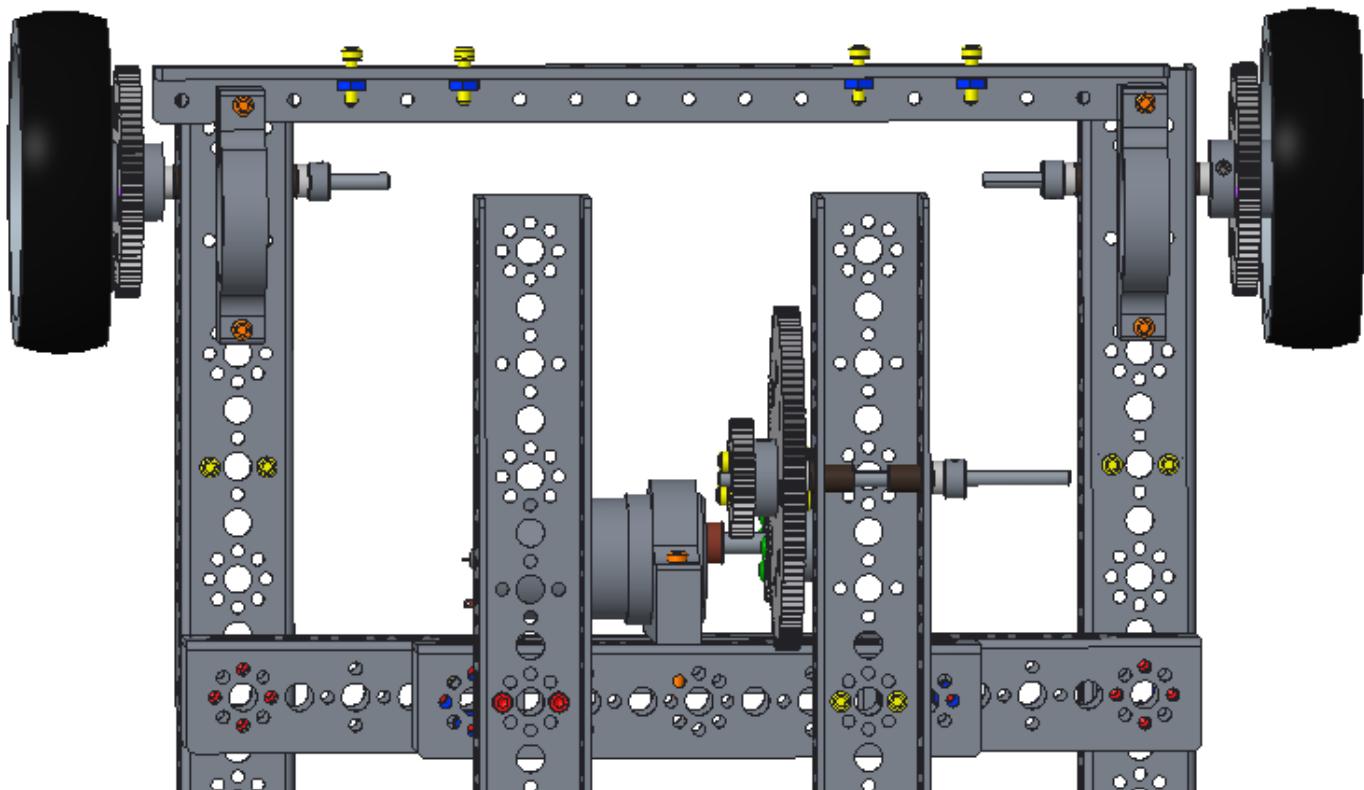
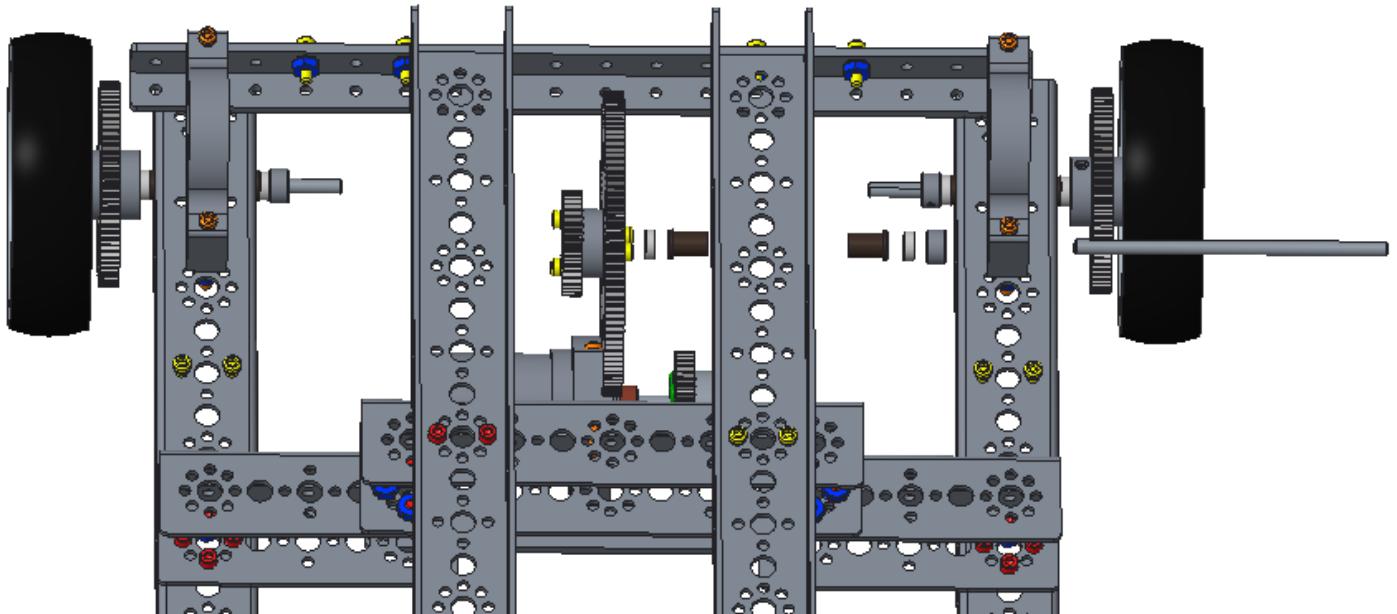
## Step 2: Adding the Arm Gear Box to the Chassis

chassis, assembly from the previous step, 1/8" axle spacers (2), 11 mm bronze bushings (2), axle set collar (1) with included set screw (1), 100 mm axle (1)

**Note that parts of the robot are hidden to make the picture more clear.**

Tighten the axle collar and axle clamp set screws, making sure the set screws face the flat side of the axle.

Note: Do not tighten the motor mount bolt that controls the clamp (i.e. the gap on one side of the mount) until the arm has been added, which happens at the end of this section) - the motor should remain disengaged from the gearing so that the arm gears will be free to spin as the arm is installed.

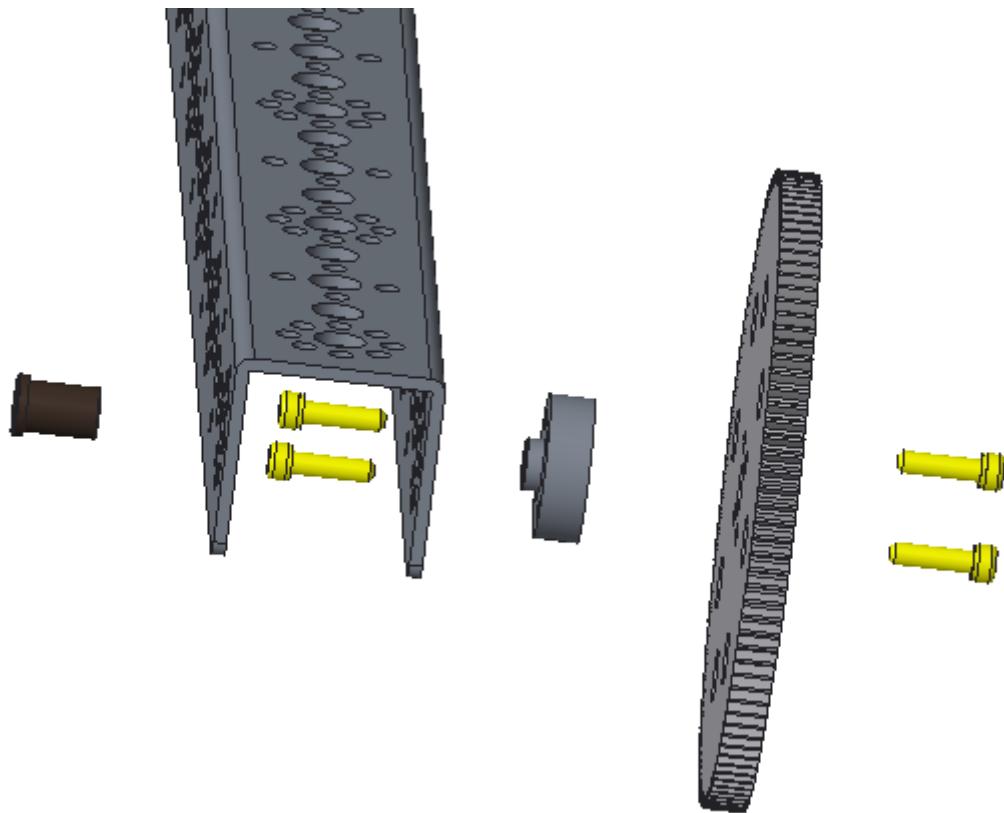


### Step 3: Arm Gear

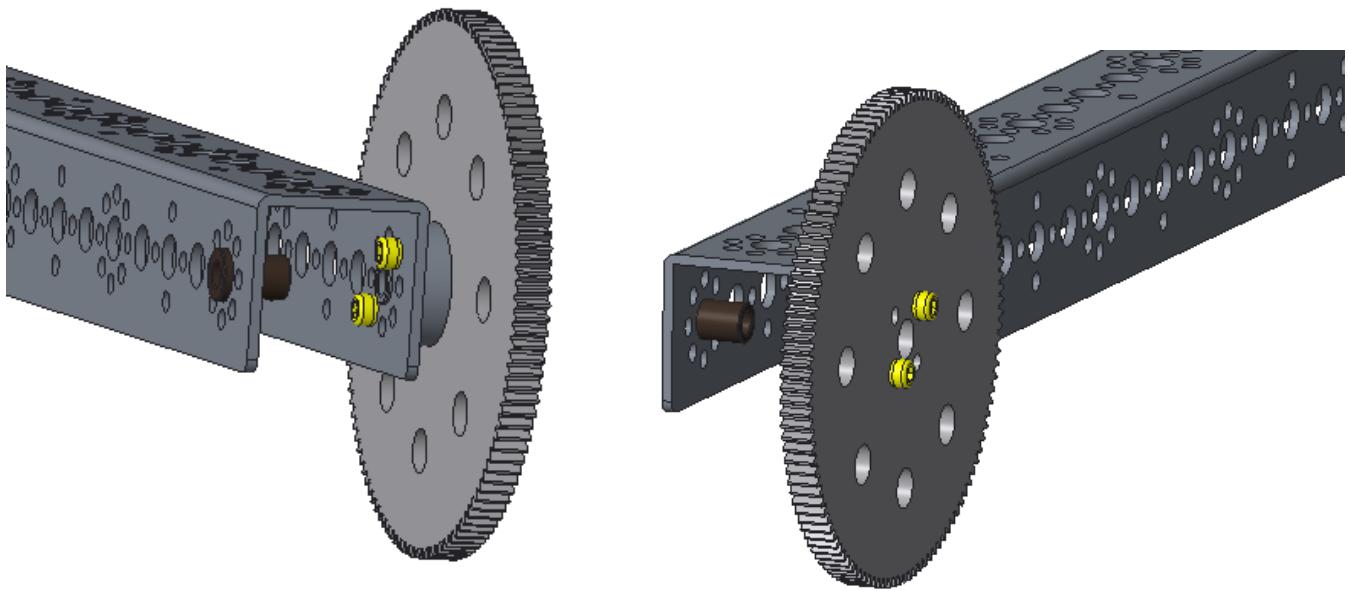
416 mm channel (1), 11 mm bronze bushing (1), 1/2" socket head cap screws (4), axle set collar (1) with included set screw (1)

Notice that the two bolts on one side are in opposite holes from the bolt on the other side.

Also take note of placing the axle clamp so its set screw faces the open end of the channel. This will make it easier to tighten/loosen with the arm in its final position.



The image below shows the two sides of the same gear assembly.

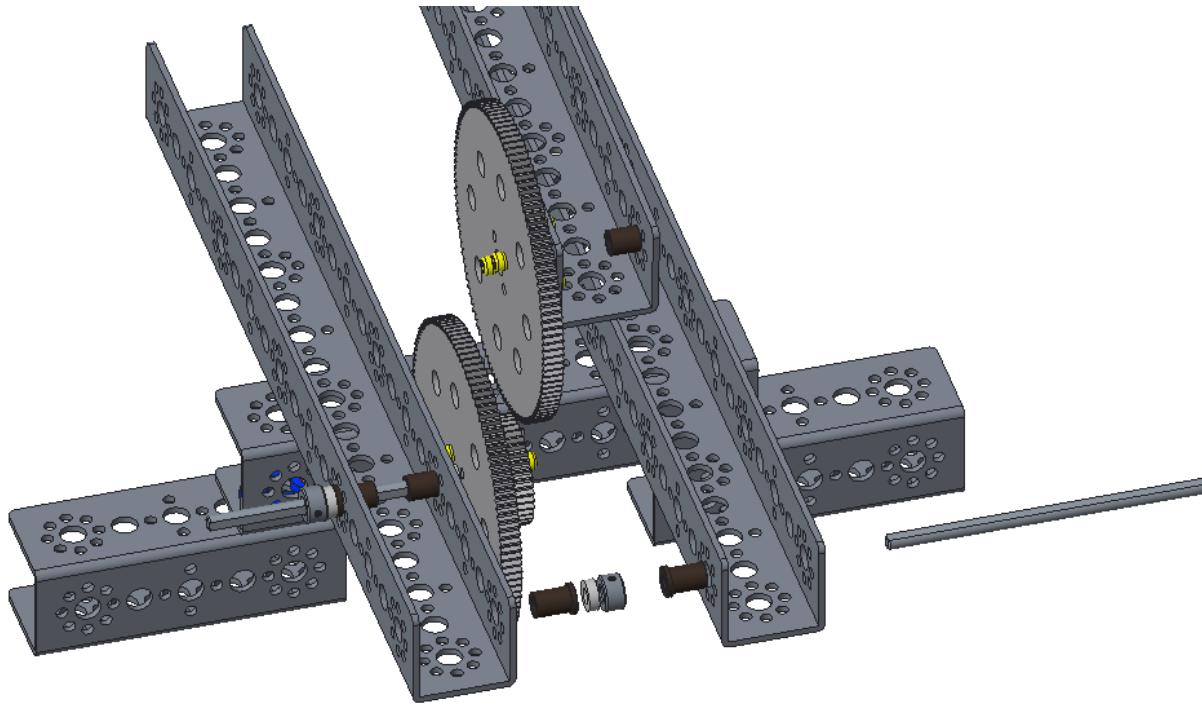


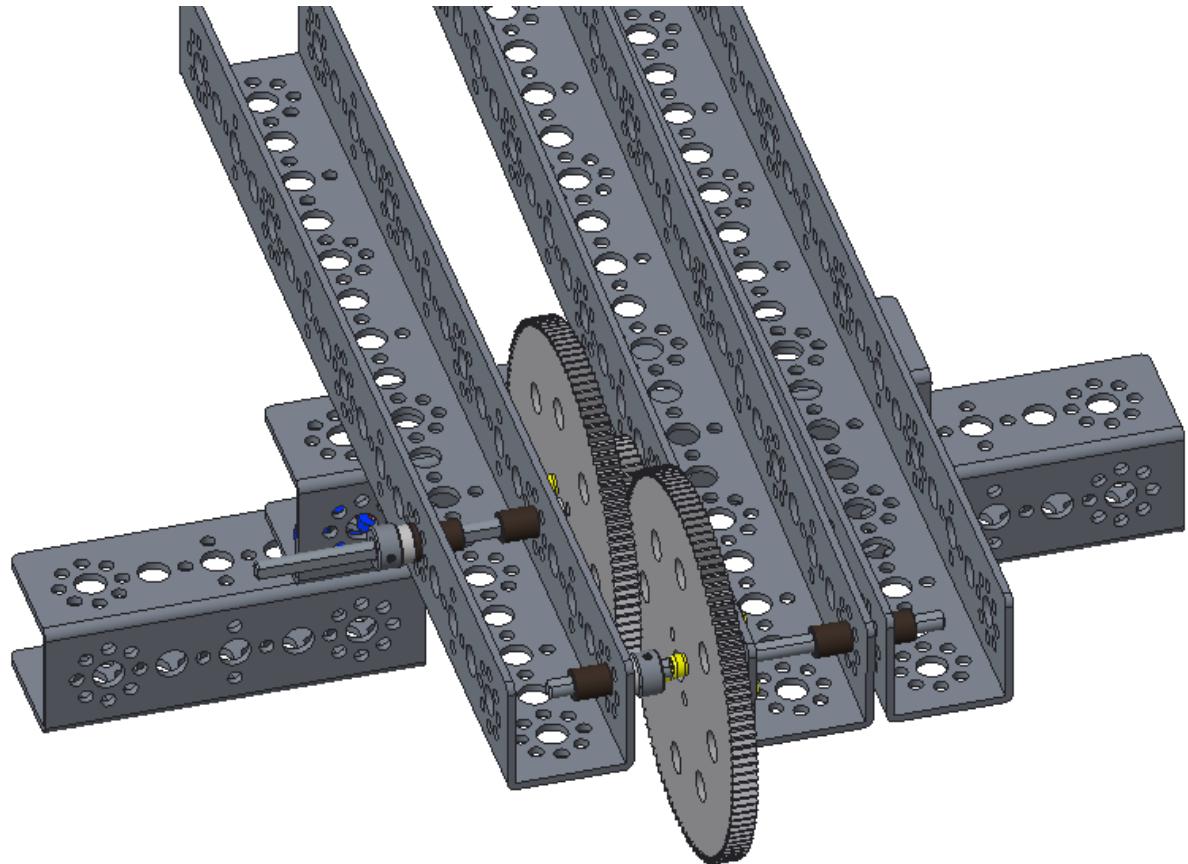
#### Step 4: Adding the Arm to the Chassis

chassis, arm assembly from the previous step, axle collar (1) with included set screw (1), 11 mm bronze bushings (2), 100 mm axle (1), 1/8" axle spacer (1).

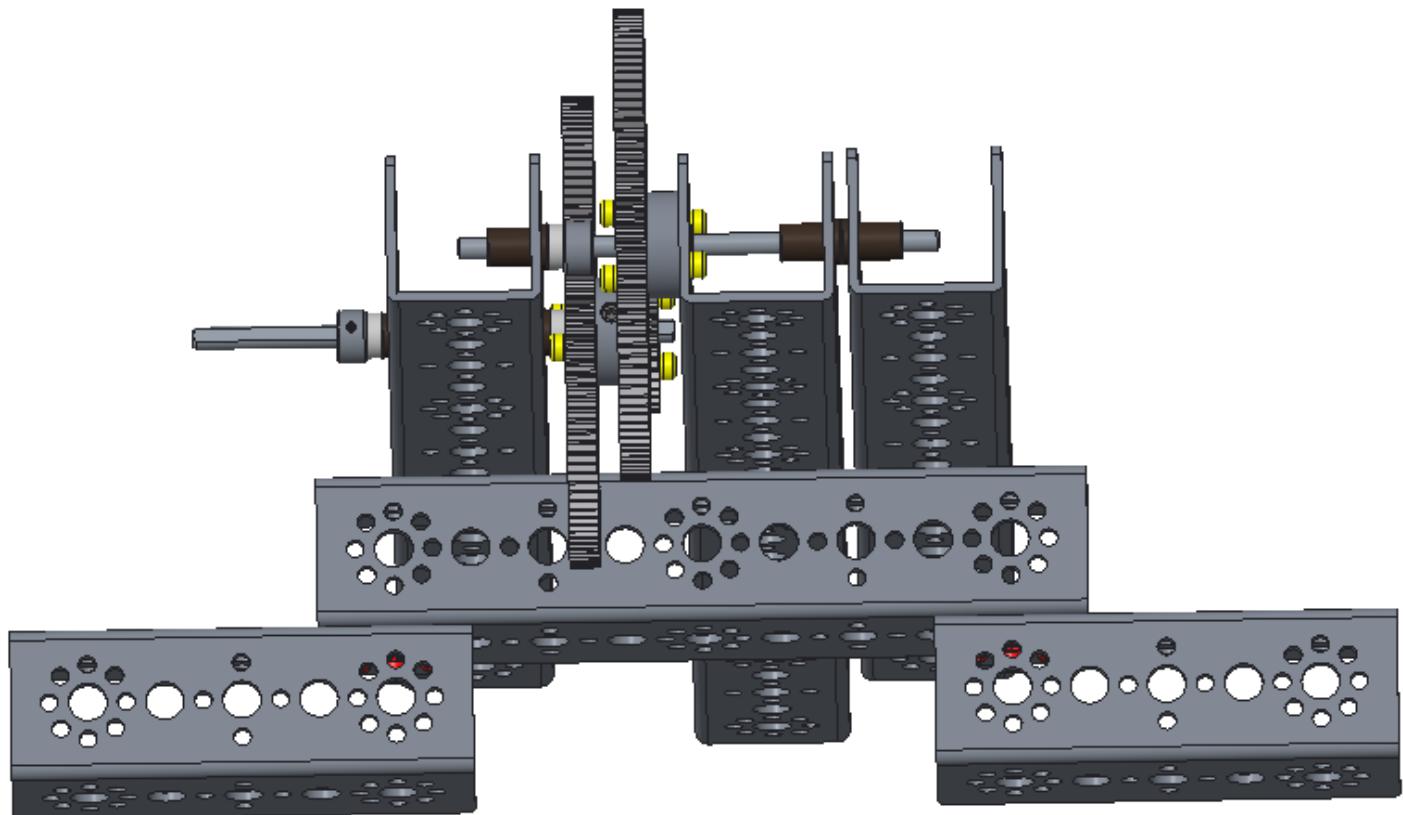
Make sure the set screws of the collar and clamp are facing the flat side of the axle.

The order from left to right in the image below is bushing, channel, spacer, collar, [space], arm, bushing, bushing, channel. Align the large arm gear with the small gear on the chassis.





The image below is of the front of the robot and from slightly below.



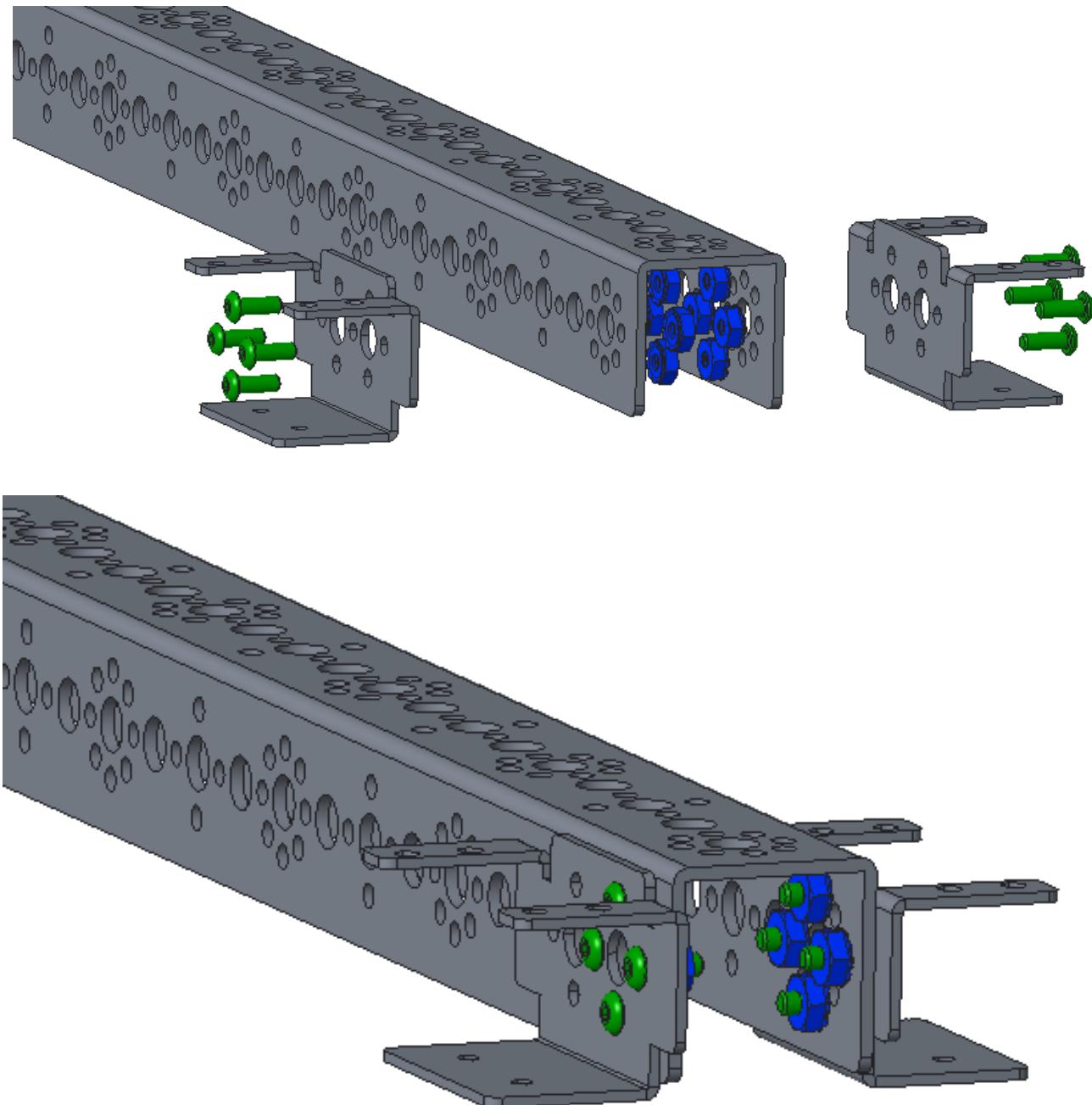


## Adding the Hands

### Step 1: Hand Servo Brackets

chassis, single standard-scale servo motor mounting brackets (2), 3/8" button head cap screws (8), keps nuts (8)

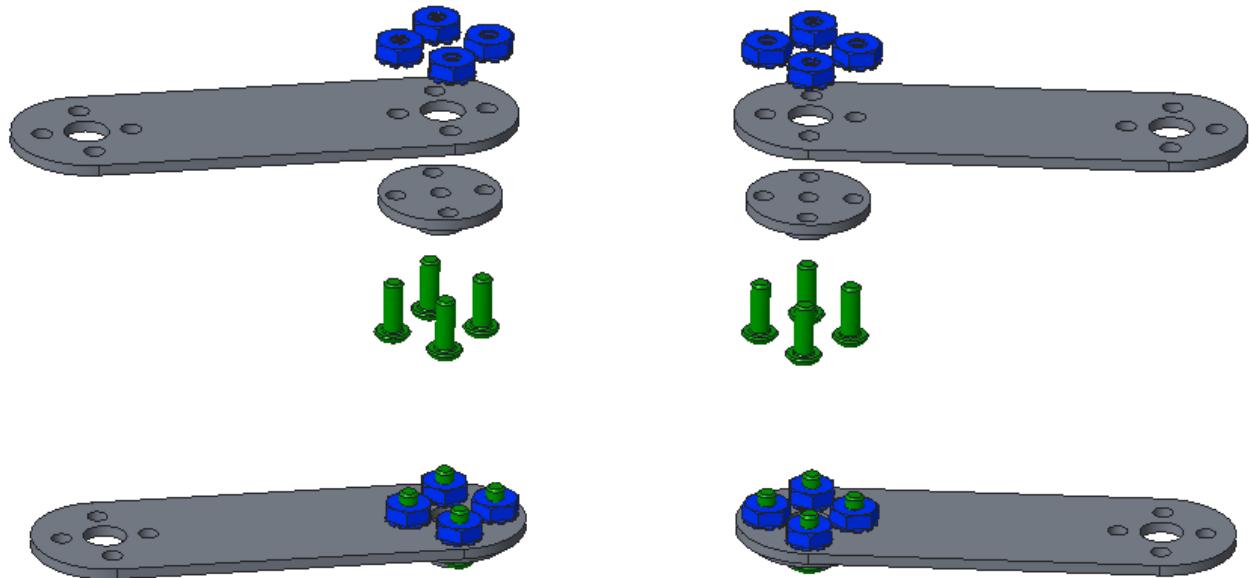
The arm motor is not yet engaged with the gear system, so rotate the arm so it is in the orientation shown below.



## Step 2: Hand Part 1

flat brackets (2), quarter-scale servo horns (2), 3/8" button head cap screws (4), keps nuts (8)

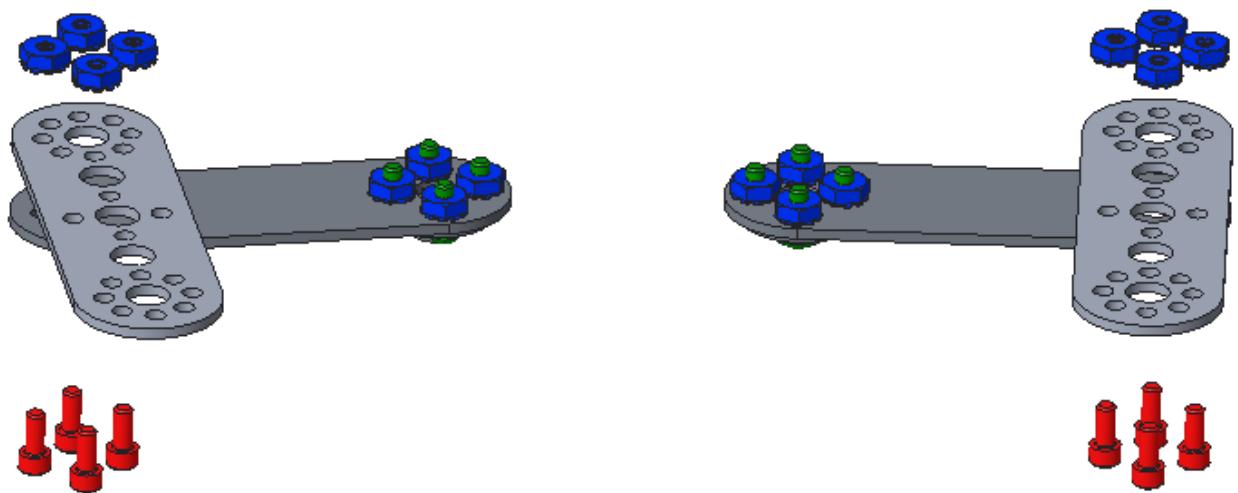
This step shows the making of both hands. Do not duplicate this step.

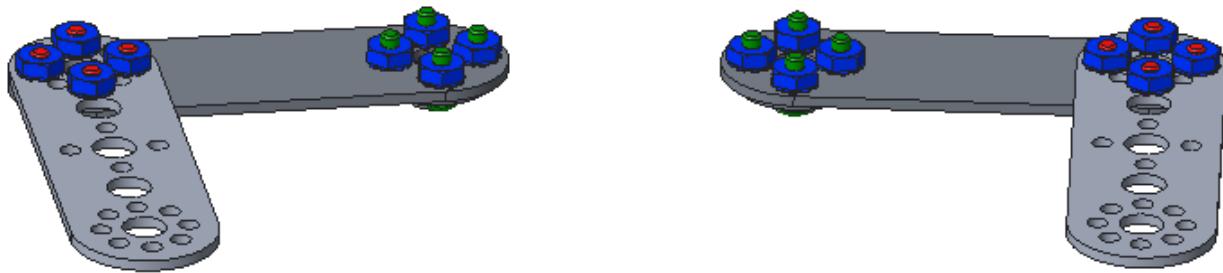


## Step 3: Hand Part 2

assembly from the previous step (2), 96 mm flat (2), 5/16" socket head cap screw (8), keps nuts (8)

This step shows the making of both hands. Do not duplicate this step.

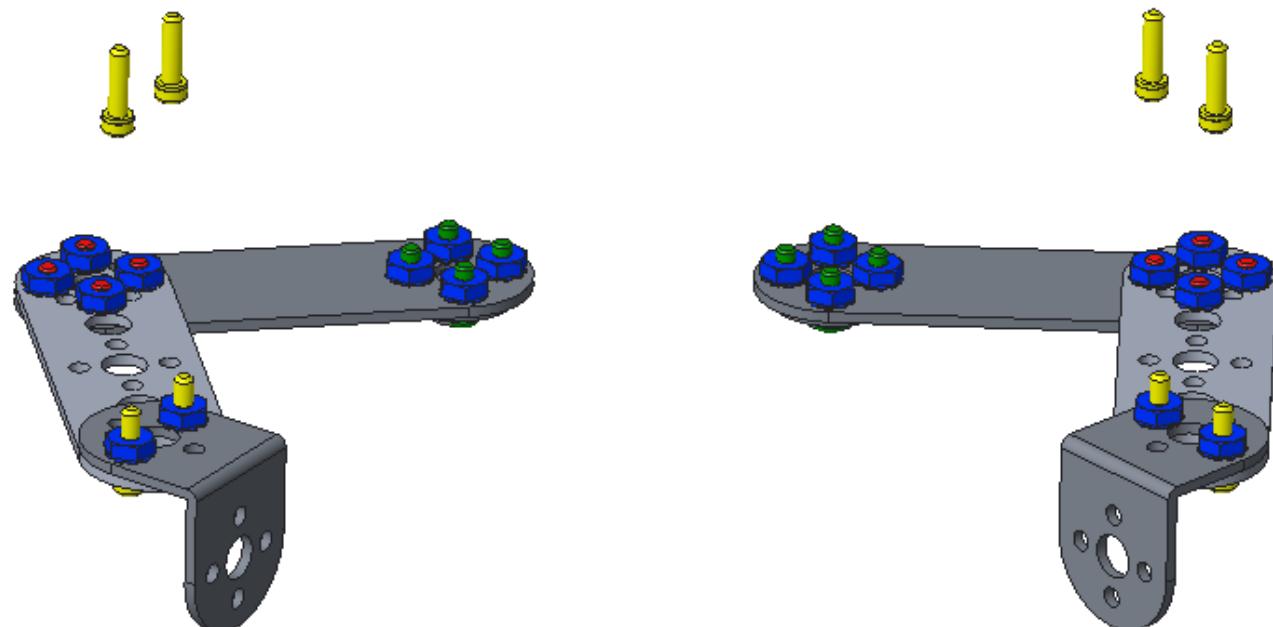
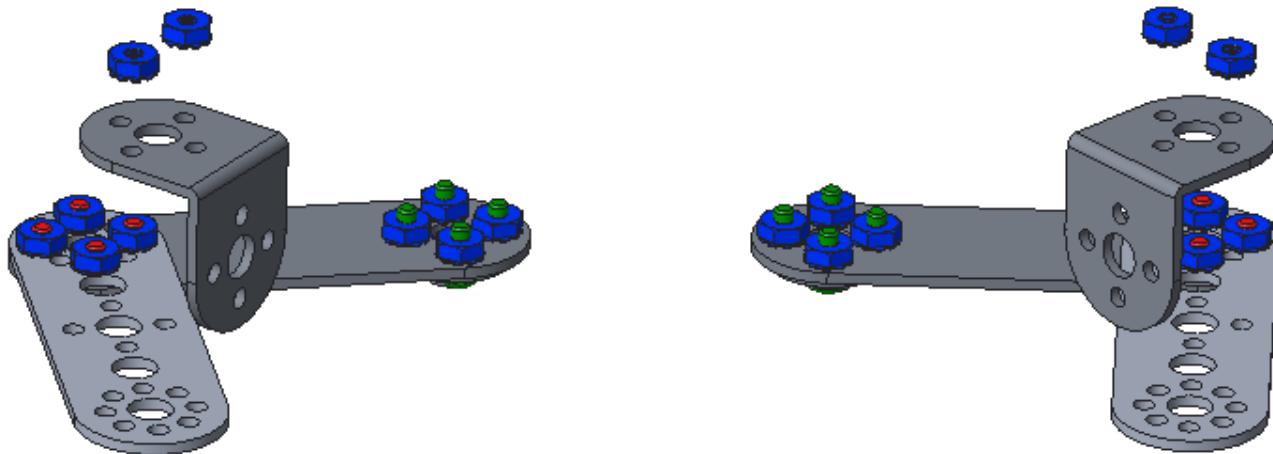




#### Step 4: Hand Part 3

assemblies from the previous step (2), L-brackets (2), 1/2" socket head cap screws (4), keps nuts (4)

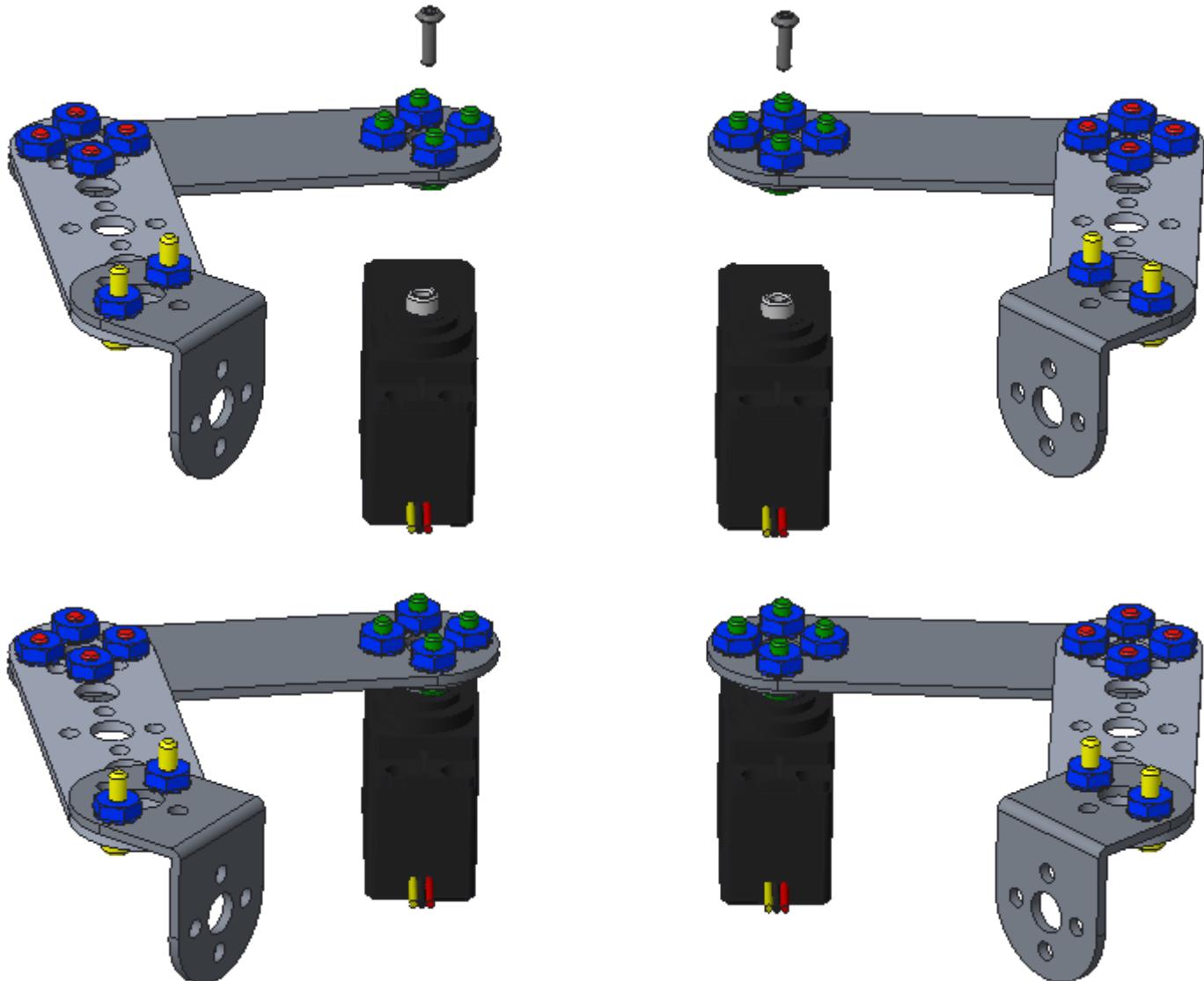
This step shows the making of both hands. Do not duplicate this step.



## Step 5: Attaching Hands to Servos

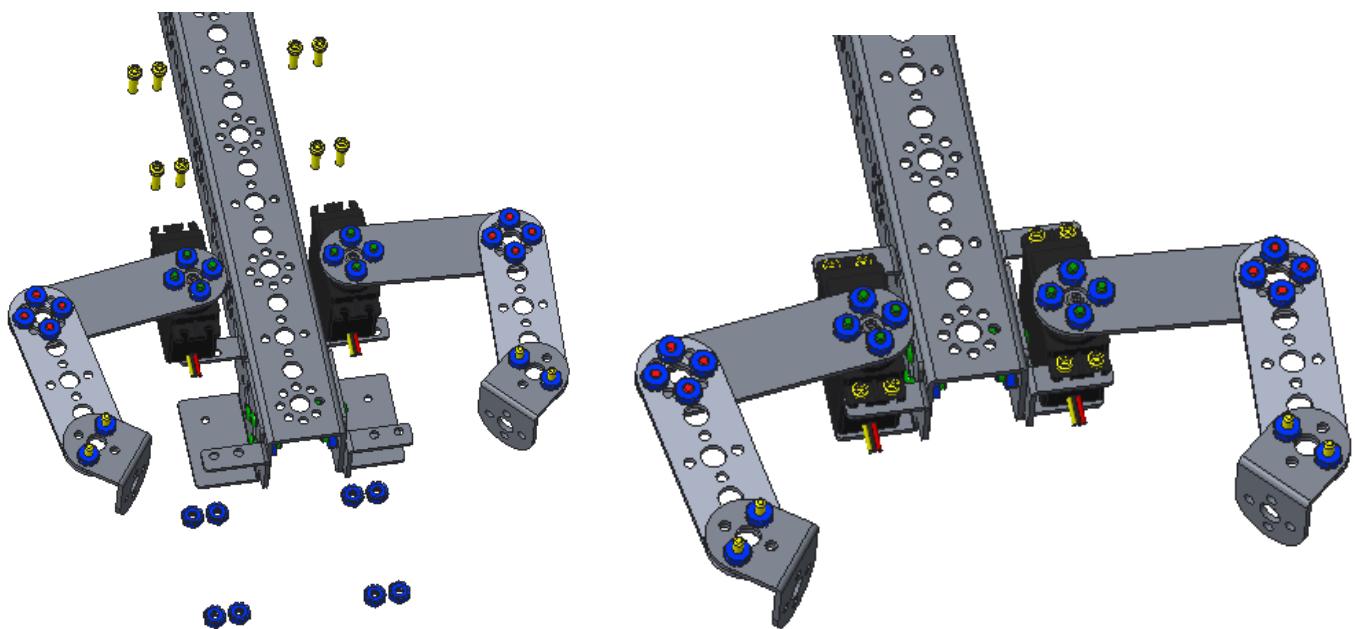
assemblies from the previous step (2), standard-scale servo motors (2) with included screws (2)

This step shows the making of both hands. Do not duplicate this step.



## Step 6: Attaching Hands to the Arm

chassis, assemblies from the previous step (2), 1/2" socket head cap screws (8), keps nuts (8)



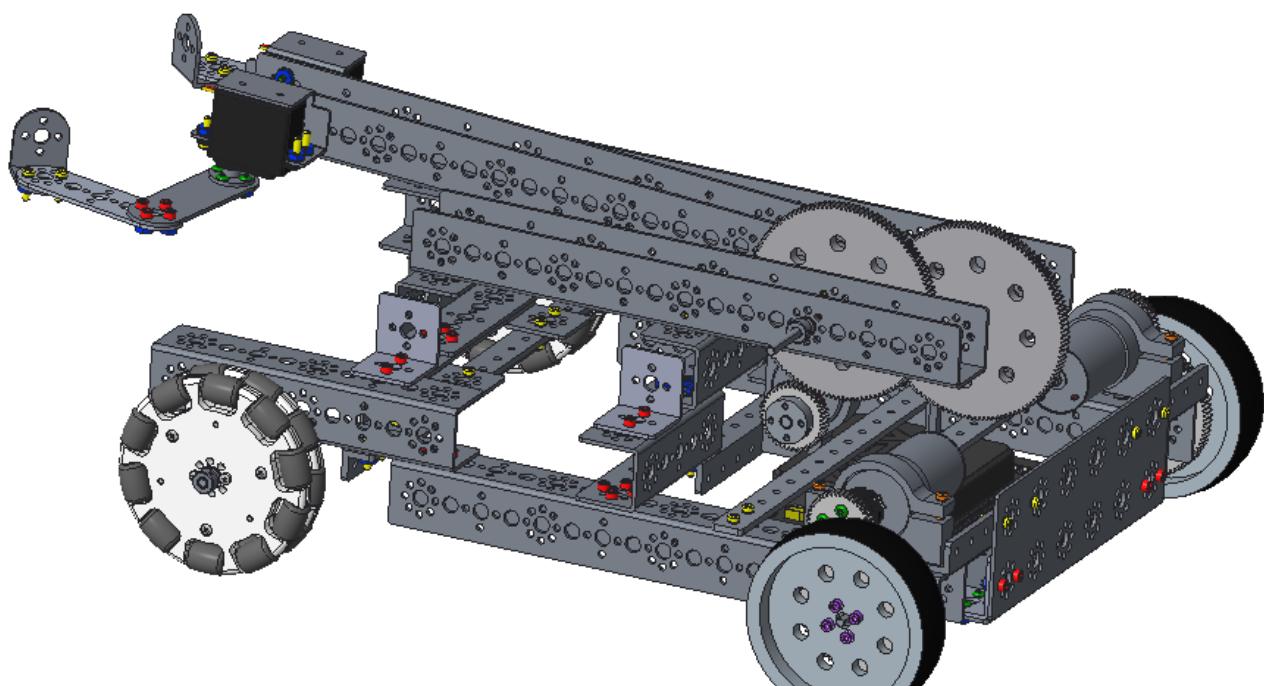
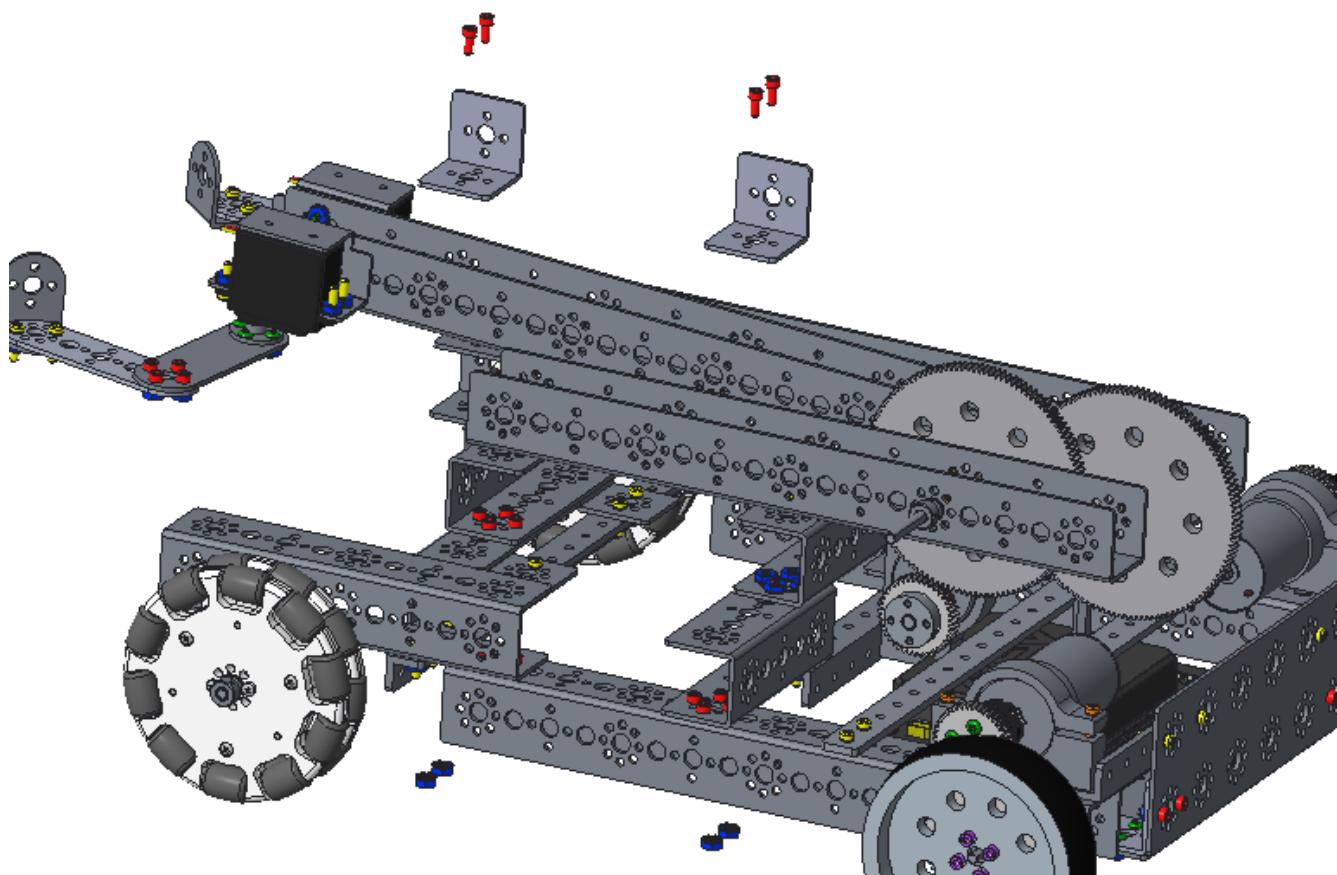
## Step 7: Tighten Arm Motor

Rotate the arm to a convenient position, align the arm motor gear with the large gear, and then tighten the arm motor screw, so the motor will no longer rotate.

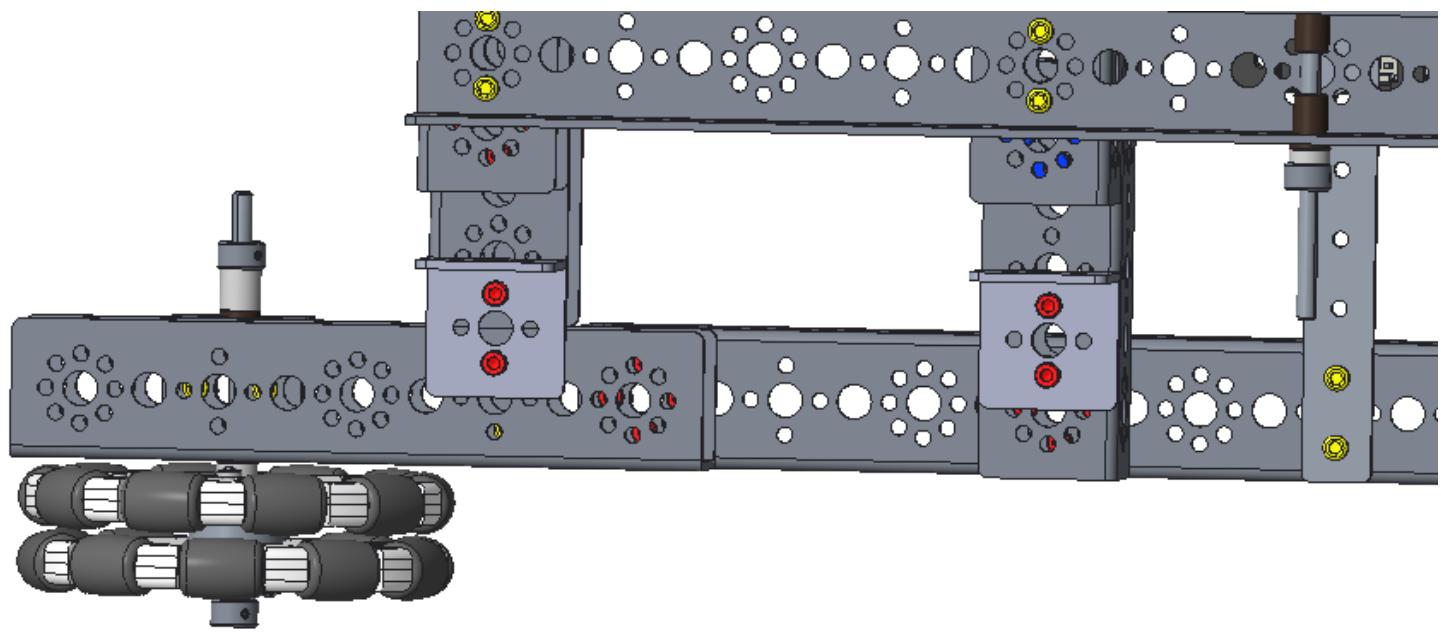
## Adding the Phone and Flag Holders

### Step 1: Phone Front Support

chassis, inside corner brackets (2), 5/16" socket head cap screws (4), keps nuts (4)

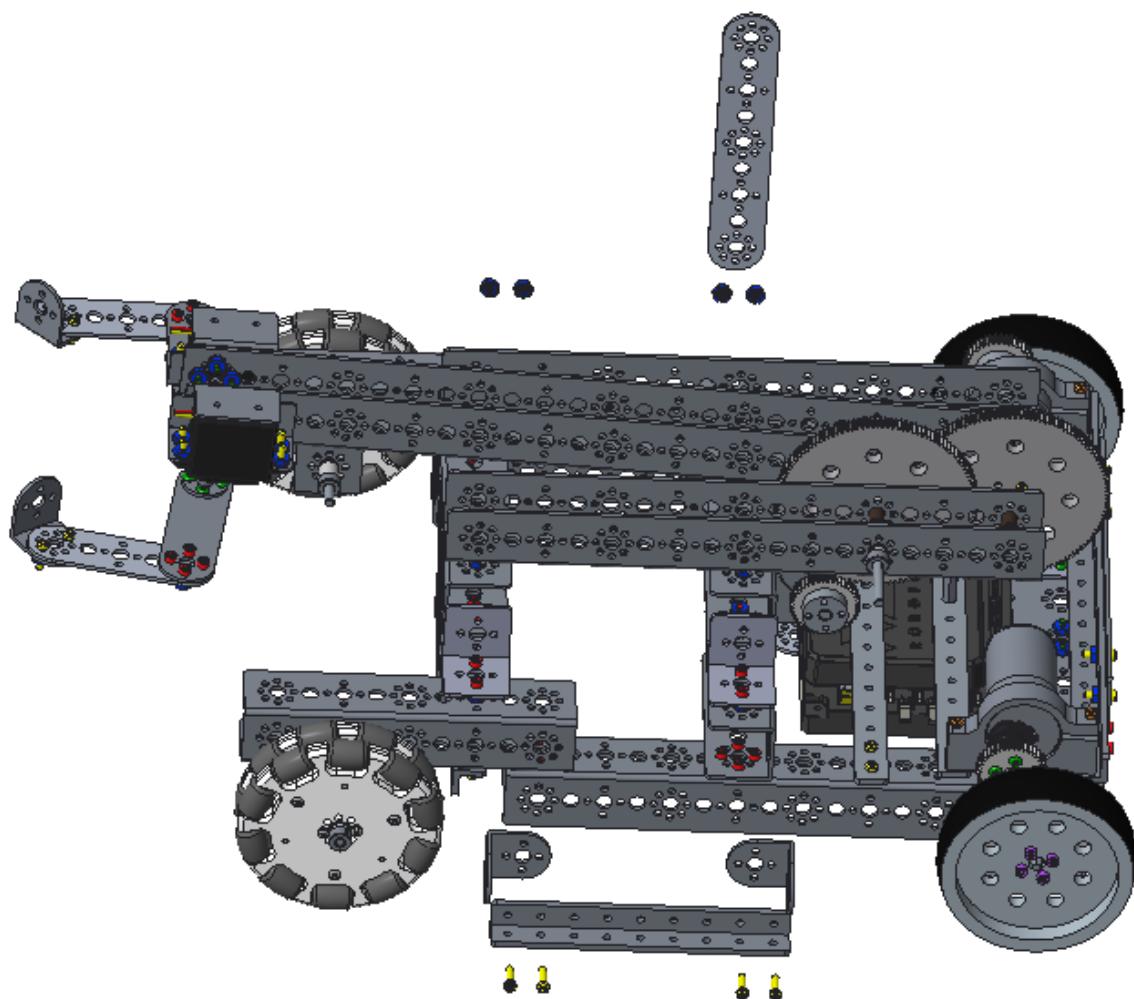


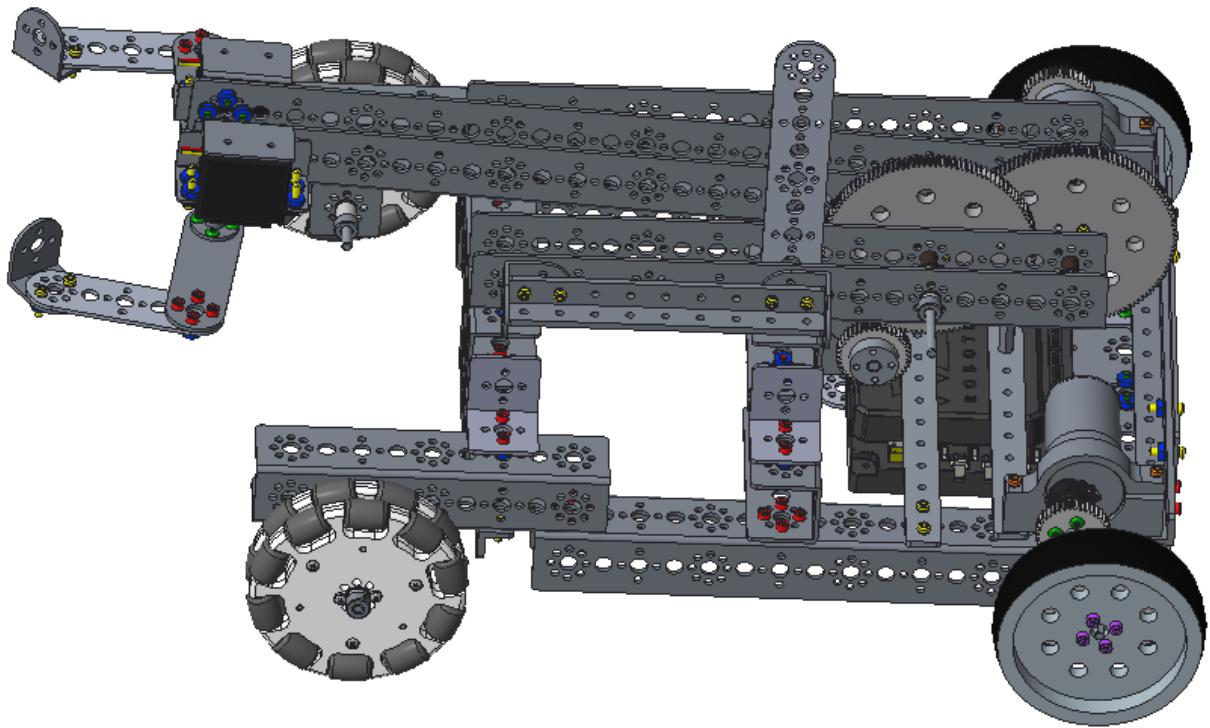
The image below is a top view of the robot.



## Step 2: Vertical Support

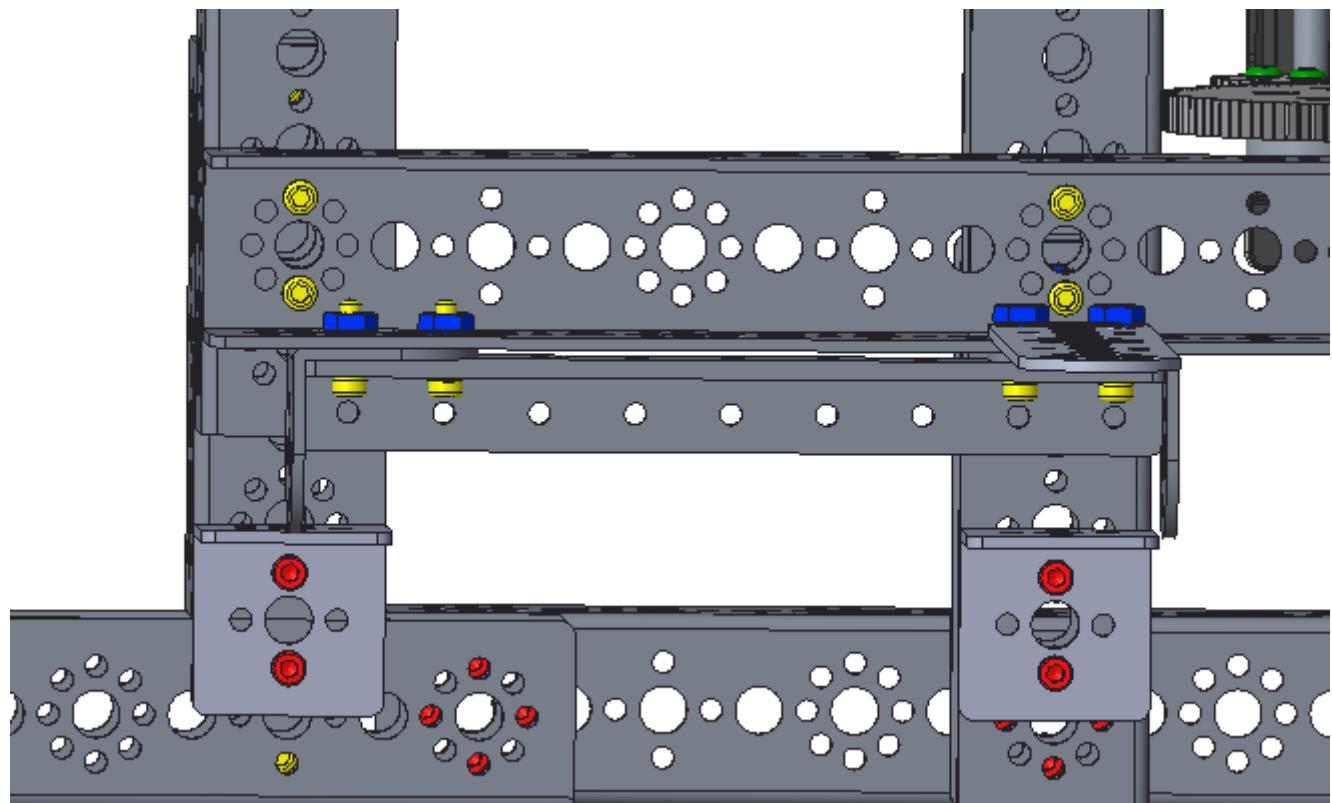
chassis, 144 mm angle (1), 1-brackets (2), 160 mm flat (1), 1/2" socket head cap screws (4), keps nuts (4)





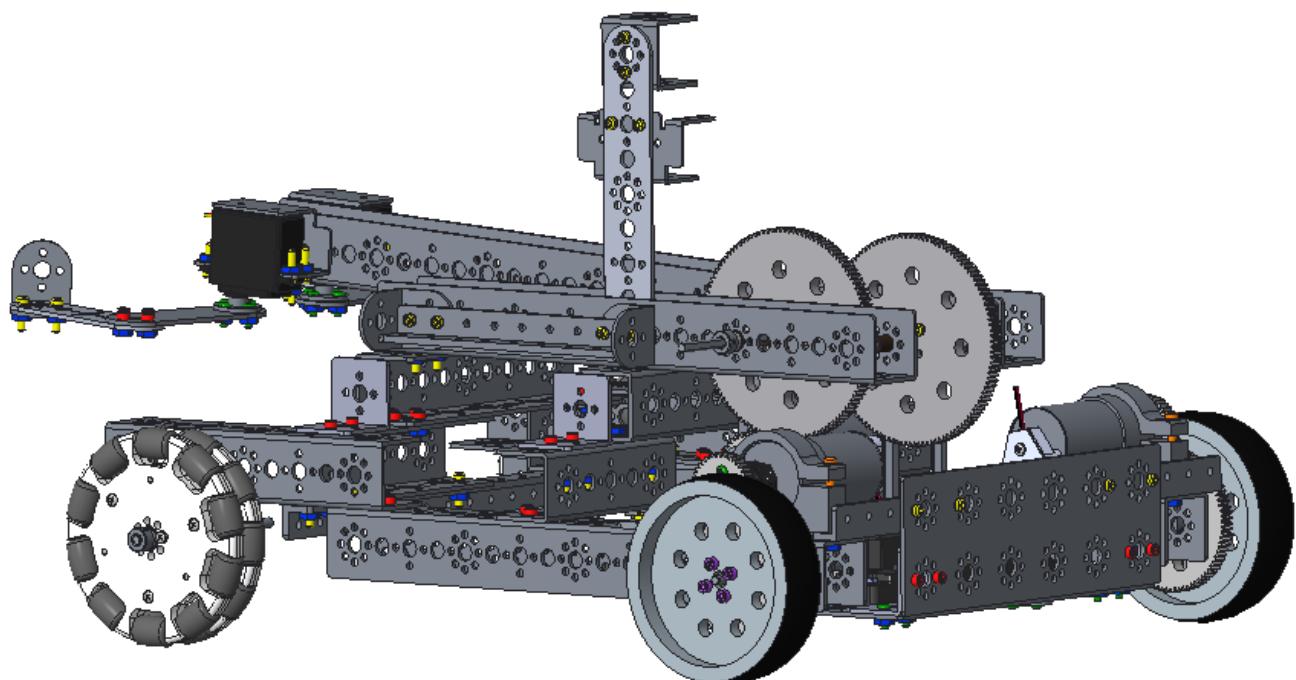
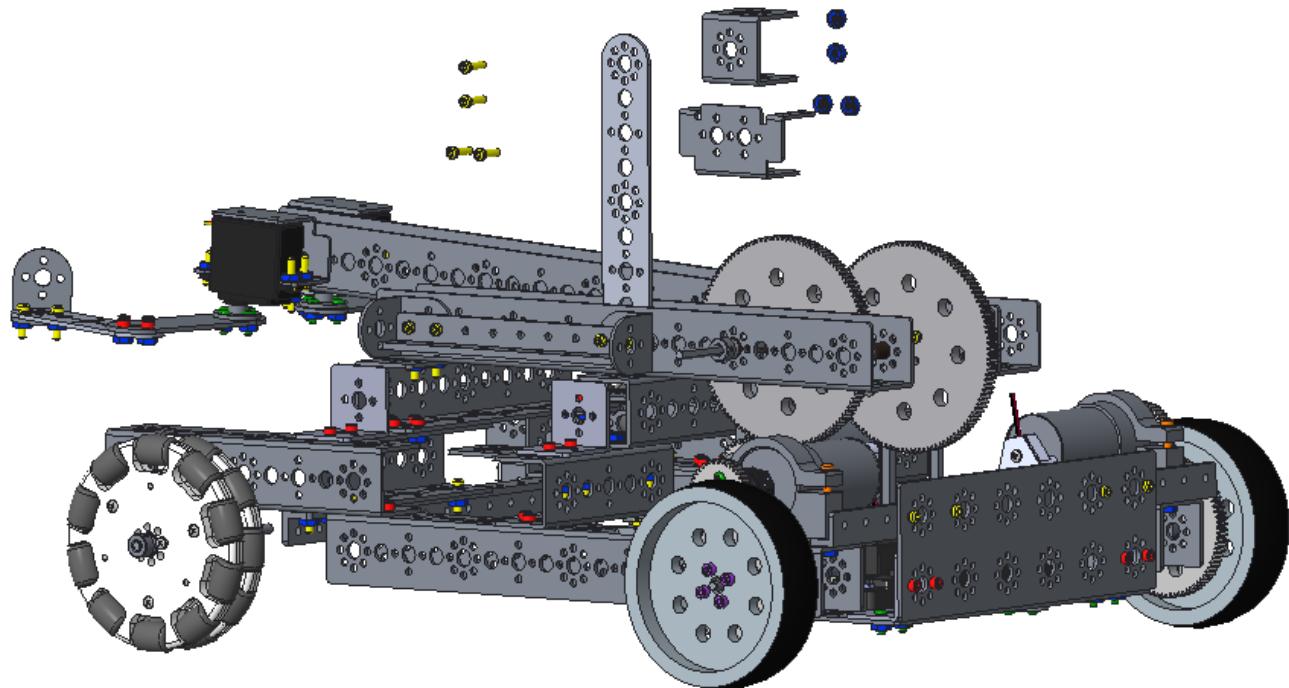
Note that the bolts on the right side hold the angle and l-bracket onto the outside of the channel and the flat bar on the inside of the channel.

The image below is a top view of the robot.



### Step 3: Flag Holder Assembly

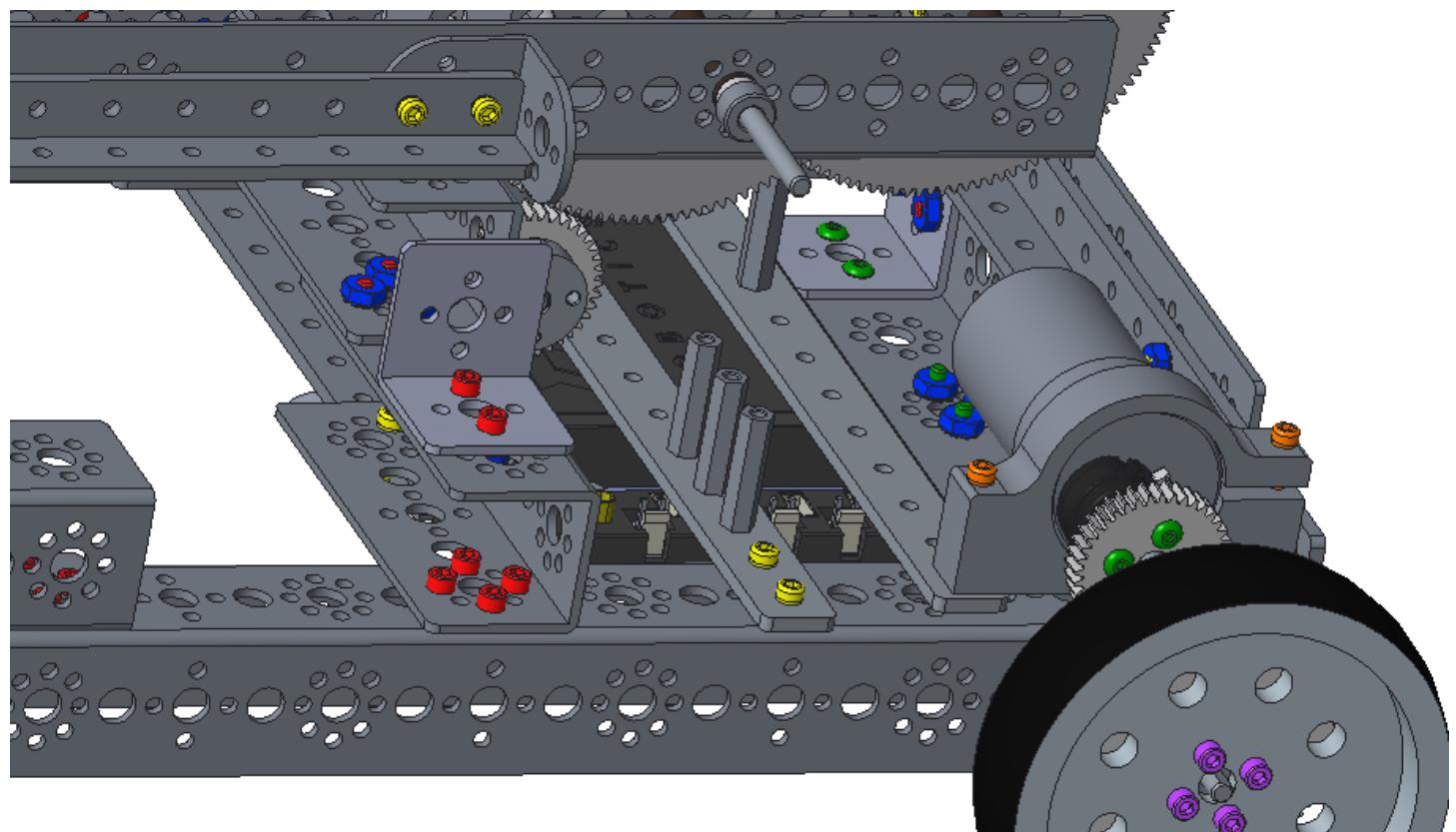
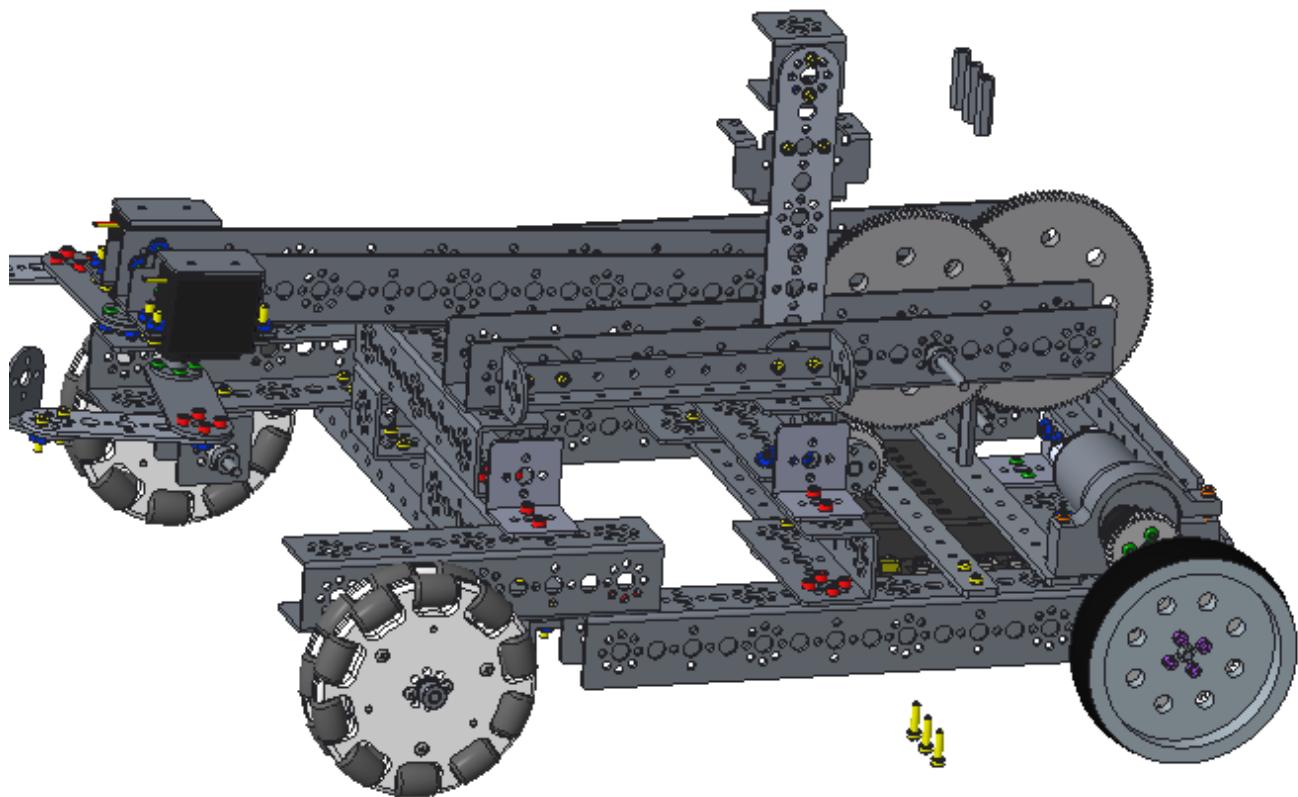
chassis, single standard-scale servo motor mounting bracket (1), 32 mm channel (1), 1/2" socket head cap screws (4), keps nuts (4)



## Adding the Power Switch Plate

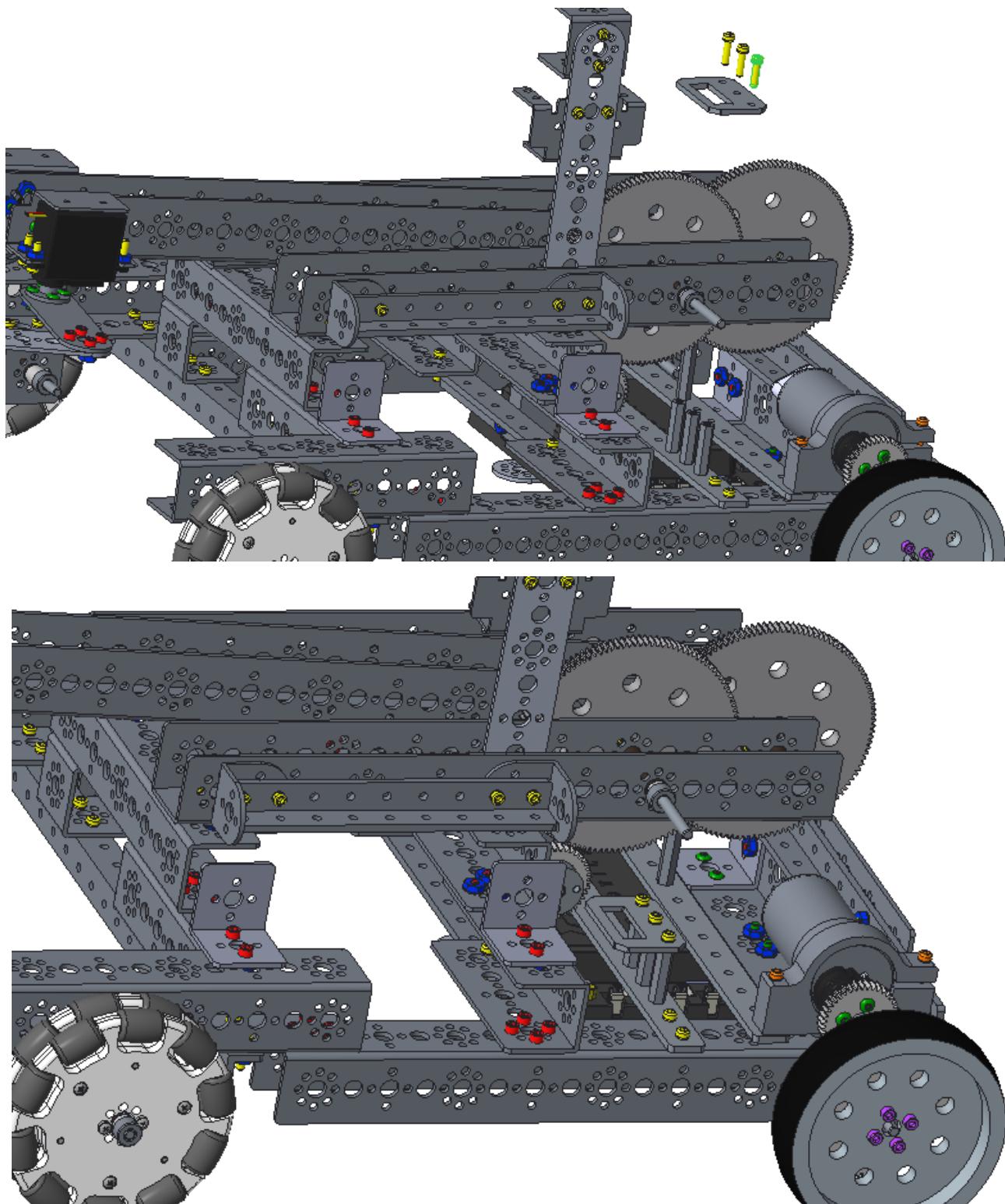
### Step 1: Support

assembly from the previous step, 1" stand-off posts (3), 1/2" socket head cap screws (3)



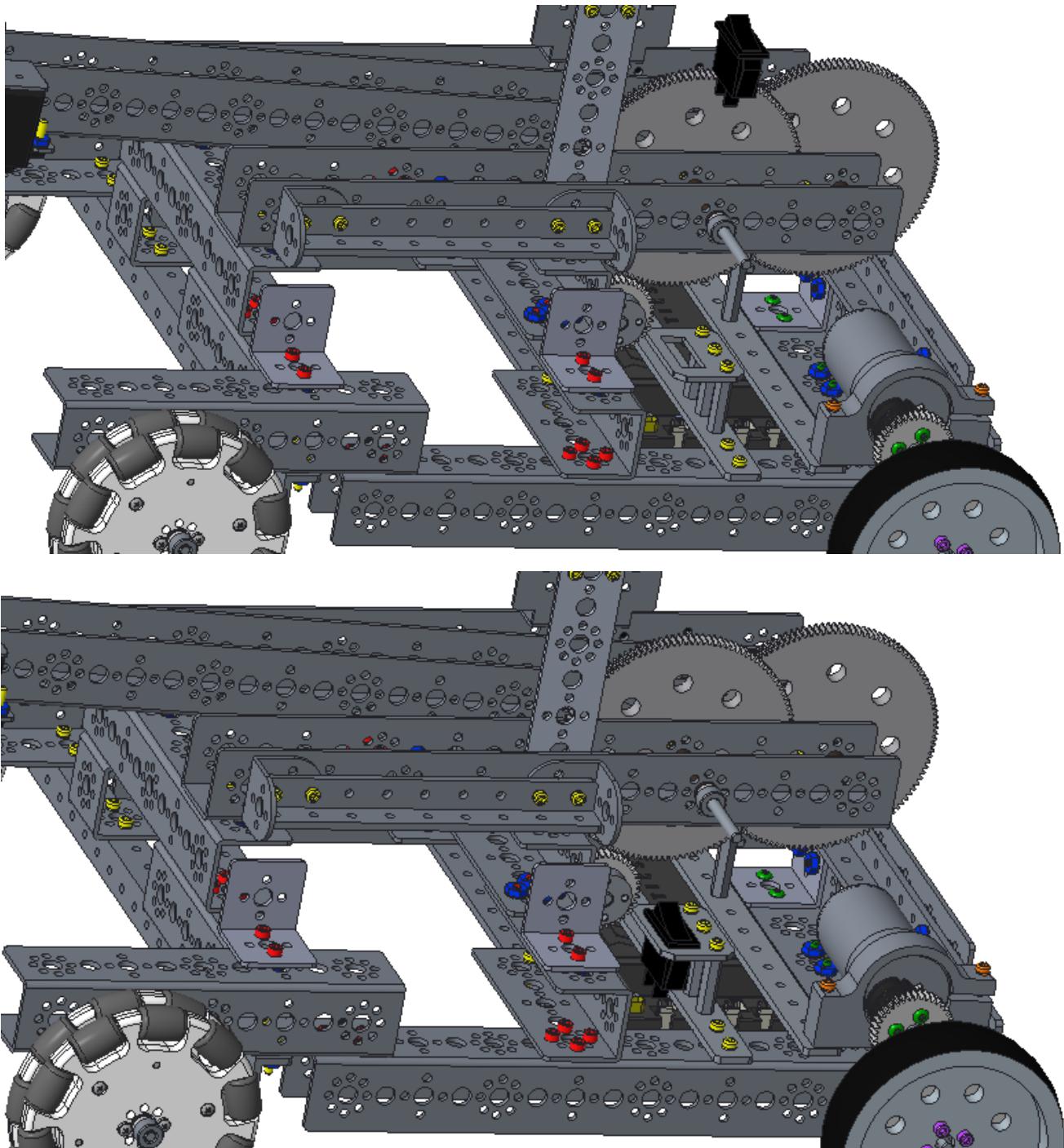
## Step 2: Adding the Switch Plate

assembly from the previous step, power switch plate (1), 1/2" socket head cap screws (3)



## Step 3: Adding the Switch

assembly from the previous step, power switch (1)



## Electronics

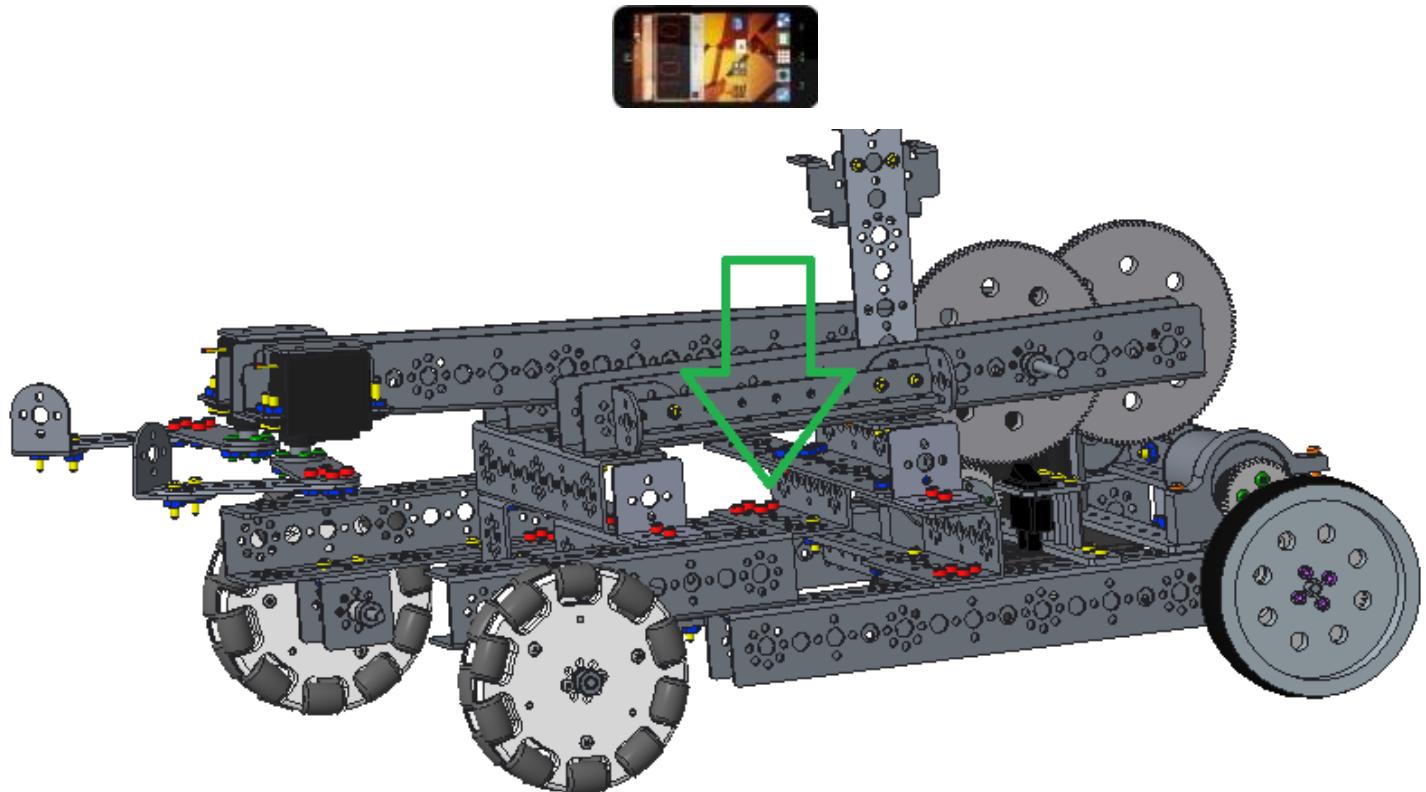
This section will outline the installation of the electronics onto the chassis.

### Robot Controller

Step 1: Add the Robot Controller Cell Phone to the Chassis  
chassis, robot controller cell phone (1)

Place the robot controller cell phone (check the game rules to determine which phones are approved for this year's game - the ZTE Speed is shown) into the holder (green arrow).

Note that the robot phone needs to rotate 90 degrees counterclockwise (as shown below) to fit into the holder. The phone's left side is supported by the cross braces. Its front is supported by the inside corner brackets. Its back is supported by the 144 mm angle. Its top and bottom are supported by the L-brackets.



## Step 2: Connect the Phone to the USB Cable

chassis, USB Type A male to type mini-B male cable (1)

Connect the mini-b end of the cable with the port on the phone.

Note: The phone is inside the phone holder, but the robot is not shown in the image below.



## Step 3: Connect the USB Cable to the Micro USB OTG Adapter Cable

chassis, micro USB OTG adapter cable (1)

Connect the USB end of the USB Type A male to type mini-B male cable with the USB end of the OTG adapter cable.

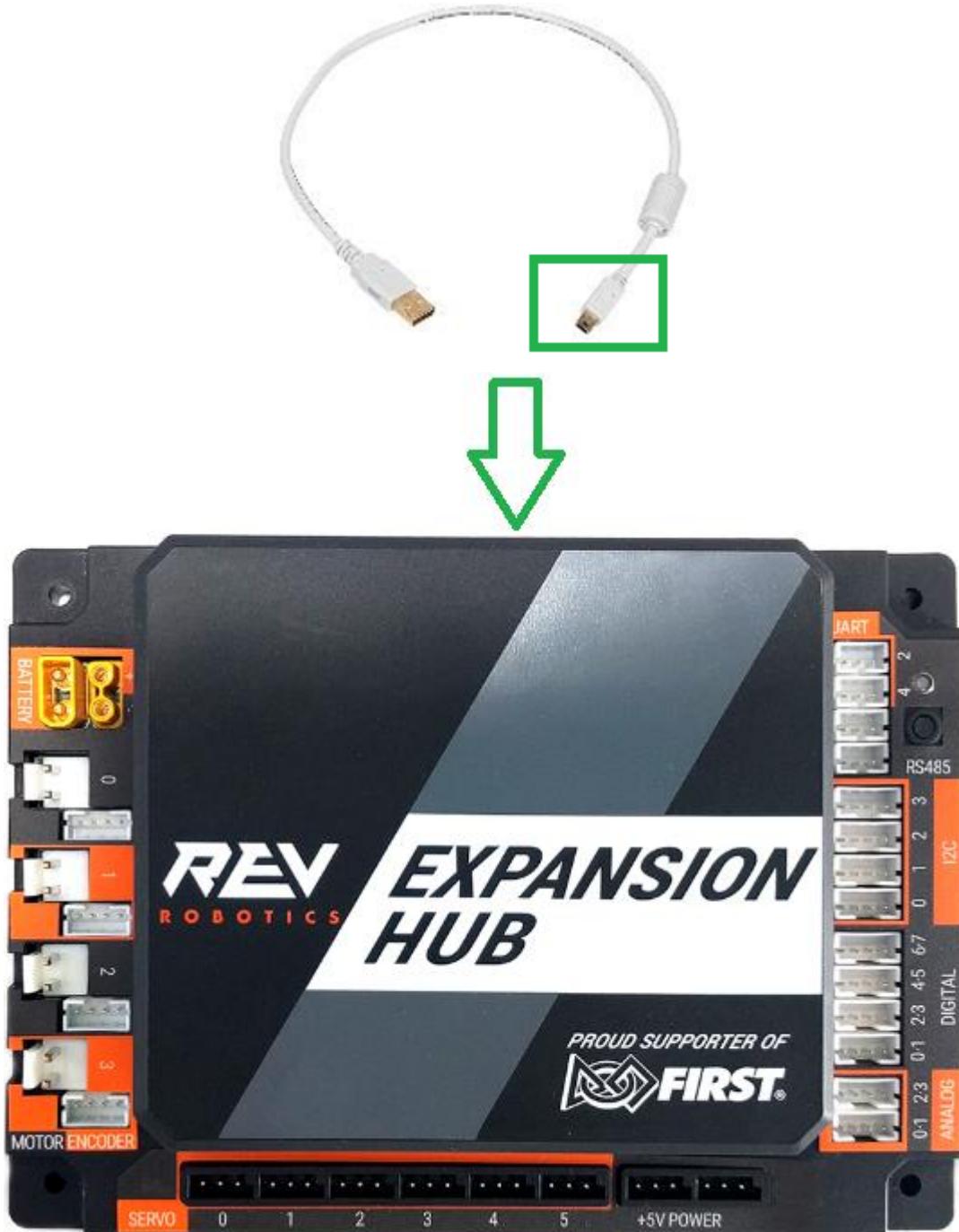
Note: The USB cable is attached to the phone, which is on the robot. This is not shown in the images below.



Step 4: Connect the Micro USB OTG Adapter Cable to the Expansion Hub chassis

Connect the micro USB end of the OTG adapter cable with the port on the expansion hub.

Note: The cable and expansion hub are on the robot. This is not shown in the images below.



## Servos

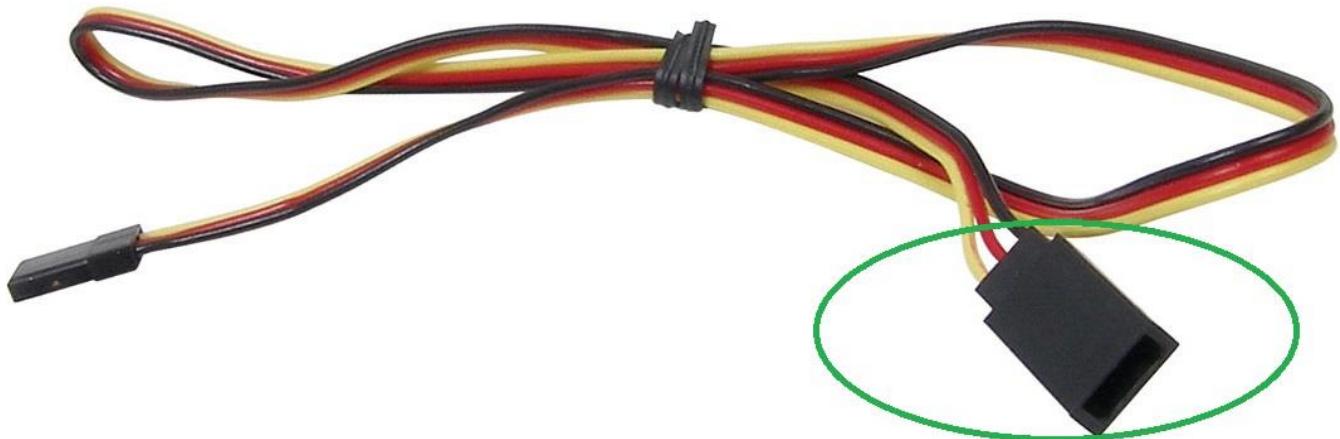
### Step 1: Servo Extension Wires to Servos

Perform twice.

servo extension wires (2)

Connect the wire coming from the servo with the servo extension wire (the connector circled in green).

Note: Match the colors.

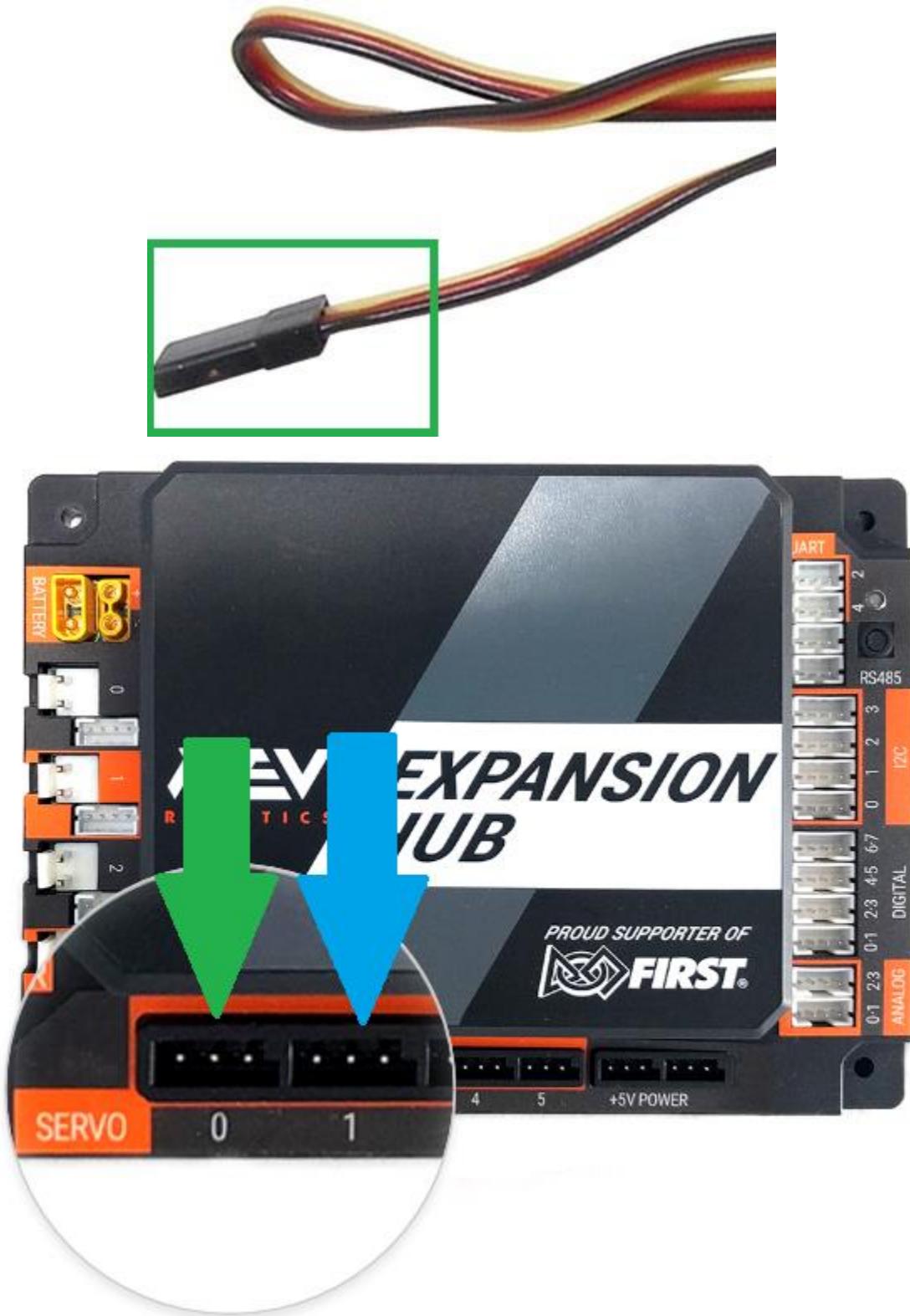


The image only shows one; make two.

Step 2: Servo Extension Wires to Expansion Hub  
chassis (with the now attached servo extension wires)

Run the extension wires down the center of the arm channel and over the axle to prevent damage to the wires.

Plug the left servo's extension wire into the expansion hub's servo port 0. Plug the right servo's extension into the hub's servo port 1.



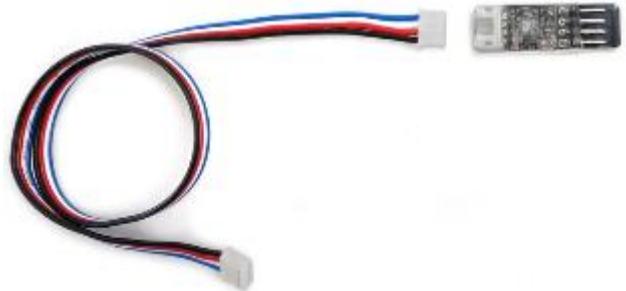
## Encoders

Make two.

### Step 1: Level Shifter Wires to Level Shifters

level shifter wires (2), level shifters (2)

Connect the wires with the shifters.



The image only shows one; make two.

### Step 2: Level Shifters to Encoder Wires

level shifter (2), encoder wire (2)



The image only shows one; make two.

Step 3: Level Shifter Wires to Expansion Hub  
chassis, level shifter wire assemblies (2)

Connect the end of one level shifter wire (circled in green) with **port 0** of the expansion hub (indicated by a green arrow in the bottom image). Connect the other end (the encoder wire of the level shifter assembly) with the encoder on the left drive motor (not shown).

Connect the end of the other wire with **port 1** of the expansion hub (indicated by a blue arrow in the bottom image). Connect the other end with the encoder on the right drive motor (not shown).



The above image only shows one assembly; use two.



## DC Motors

### Step 1: Motor Power Cables to Extension Hub Cables

Make three.

motor power cable (3), Anderson to JST VH cable (3)

Plug the end of one motor power cable (circled in green) into the Anderson power pole end (circled in green) of the Anderson to JST VH cable.



The images show only one of each cable; make three.

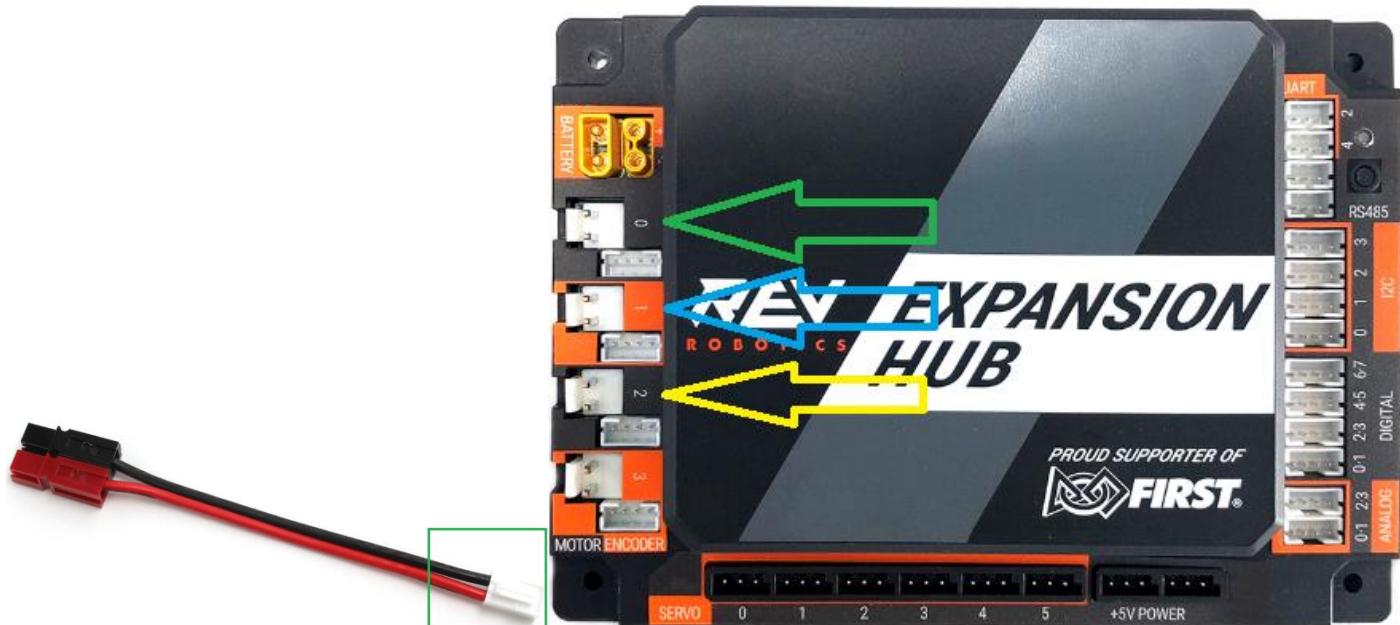
### Step 2: Motor Power Cables to Extension Hub

chassis, assemblies from the previous step

Connect the JST VH end (circled in green) of the Anderson to JST VH cable with **port 0** of the expansion hub (indicated by a **green** arrow in the bottom image). Connect the other end (the DC motor wire of the cable assembly) into the DC motor on the **left** side of the robot (not shown).

Connect the JST VH end of a second wire assembly with **port 1** of the expansion hub (indicated by a **blue** arrow in the bottom image). Connect the other end with the DC motor on the **right** side of the robot (not shown).

Connect the JST VH end of a third wire assembly with **port 2** of the expansion hub (indicated by a **yellow** arrow in the bottom image). Connect the other end with the DC motor on the **arm** of the robot (not shown).

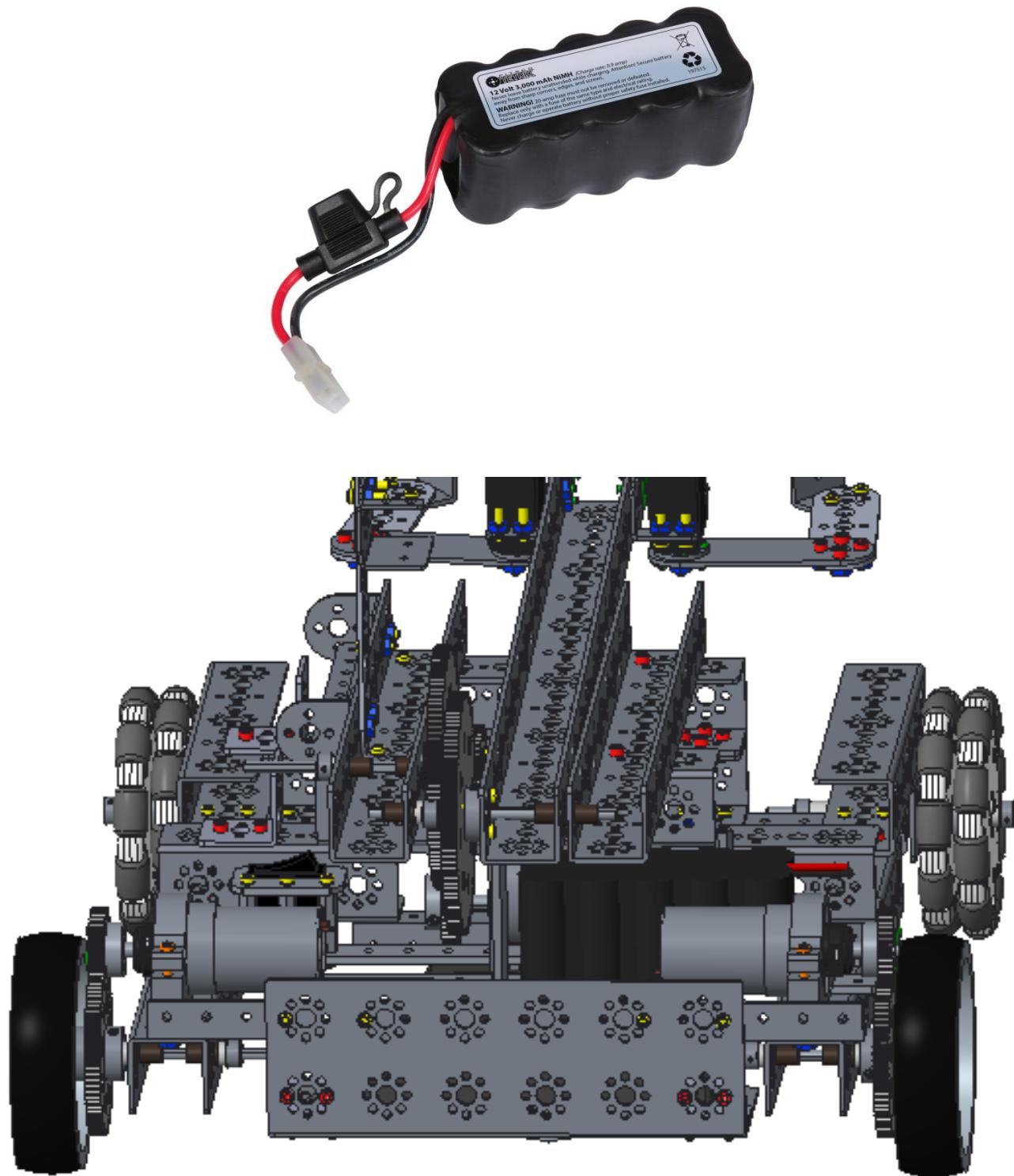


## Battery and Switch

### Step 1: Install Battery

chassis, battery, zip tie (not shown)

Place the battery on the 288 mm flat bars. The two 2" standoffs will help keep the battery in place. Use a zip tie (not shown) around the center of the battery and the two flat bars to secure the battery to the bars.



**Step 2: Install Switch  
chassis, switch (1)**

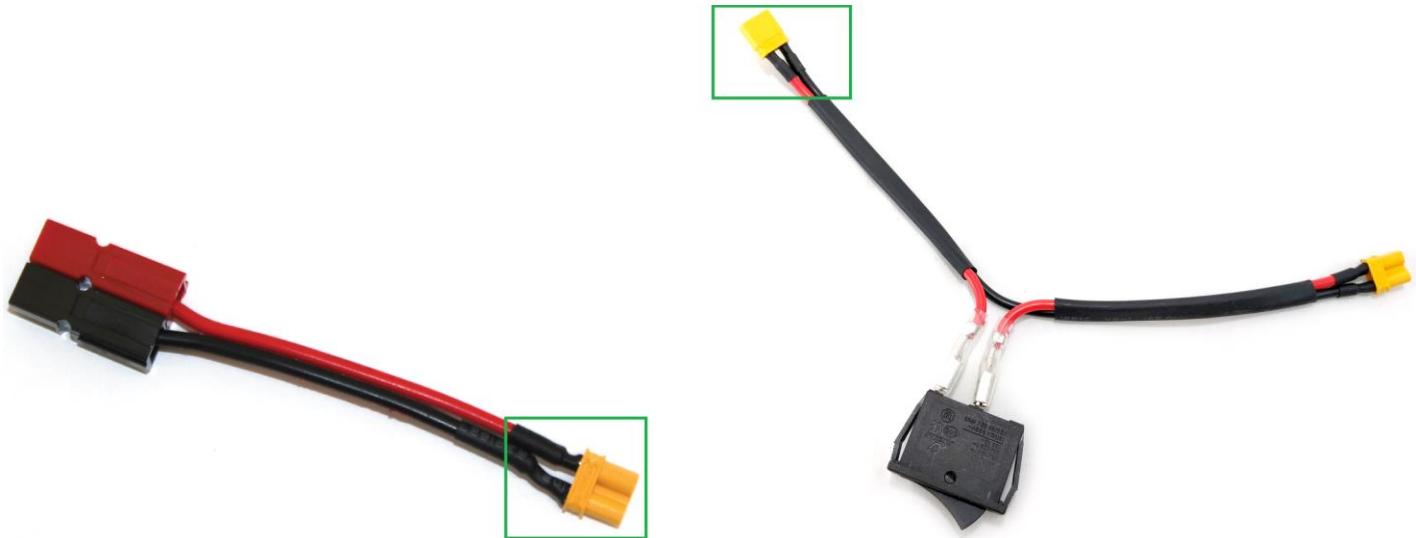
Run the wires through the switch bracket, which is mounted on the left side of the robot. Plug the expansion hub end of the switch (green square) into the expansion hub (green square).





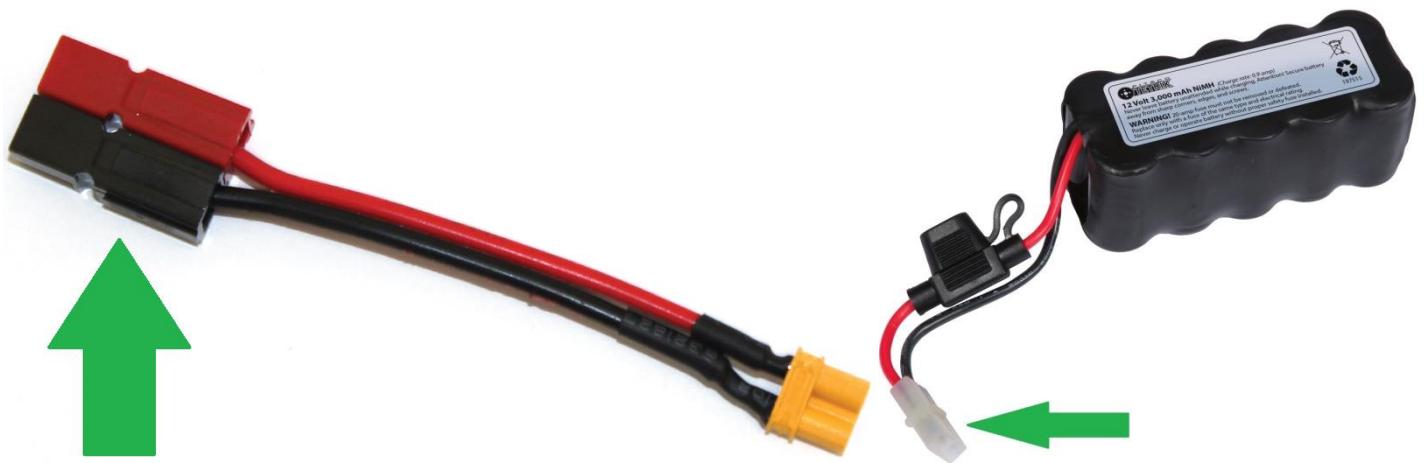
Step 3: Connect the Switch to the Switch Adapter Cable chassis, Anderson Power Pole to XT30 Adapter (1)

Plug the XT30 end of the adapter into the switch wire - green squares.



Step 4: Connect the Battery to the Switch Adapter Cable chassis

Plug the Anderson Power Pole end of the adapter (green arrow) into the battery connector (green arrow).



## Final Steps

The robot has been built, but that is only the beginning. Gear Trains need fine adjustments. Wires need to be secured. Programming will be needed to make the robot functional. Testing should be done to determine whether anything needs to be changed or optimized for the season's game rules. It will also show whether more cables need to be secured or re-routed. Numbers and other stickers will be needed to make the robot competition ready. Check the game rules for all of the applicable stickers - usually the game rules include a self-inspection check list. **USE THIS CHECK LIST BEFORE COMPETITION!**

**Visit the FIRST website for programming instructions and game rules.**

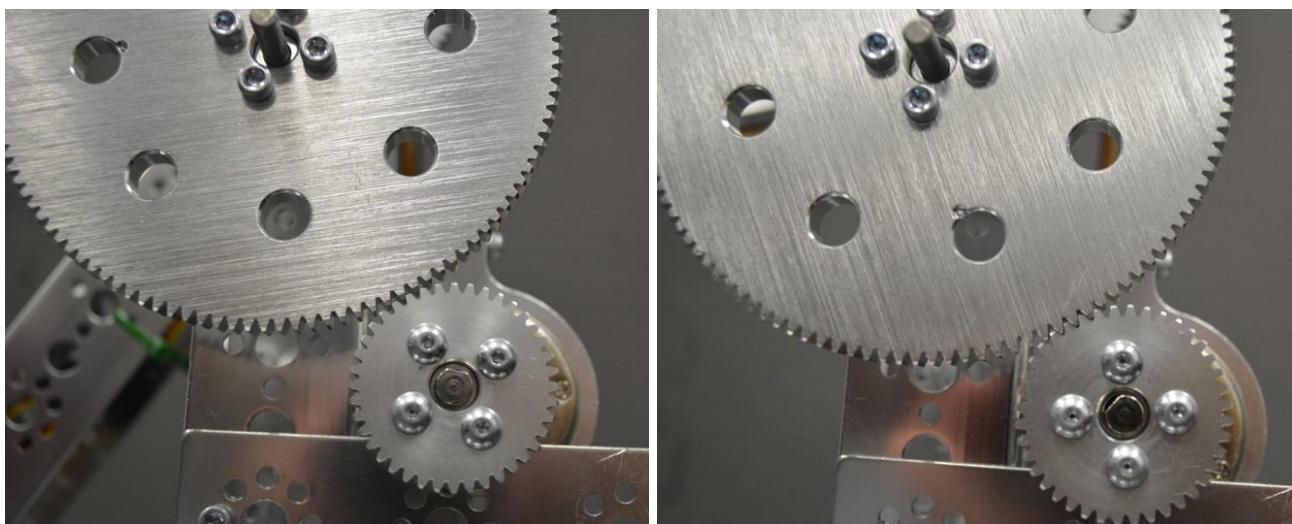
### Wiring Safety

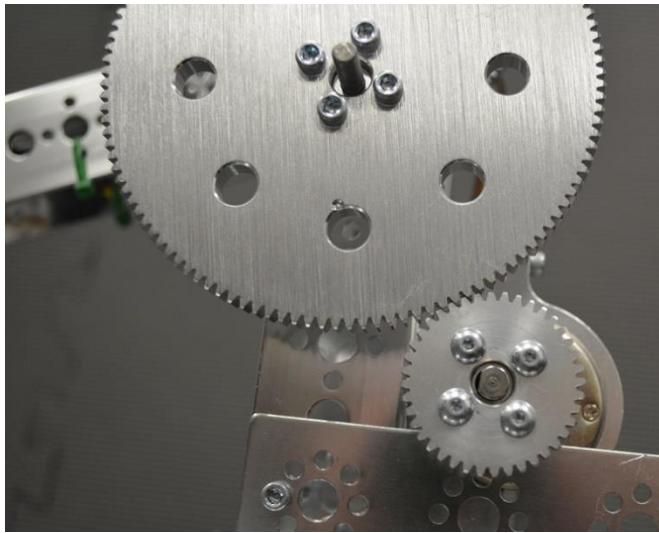
Additional zip ties should be purchased for securing wires to the chassis. The standard four-inch size works well for this. Also, electrical tape can be used to secure motor wires to the motor. Longer zip ties or Velcro straps can be used to keep the battery from falling out of the robot in case it tips over. Make sure that axle hub, motor hub, and axle collar set screws are installed, so that the screw is on the flat side of the axle, which will prevent assemblies from spinning on the axle.

### Mesh Gears Properly

The following pictures show examples of meshing the gears. The first is too loose; the second is too tight; the third (center below) is a good mesh. To test, rotate the mechanism by hand. If the gear teeth slip, then it is too loose. If the mechanism binds, then it is too tight.

Remember to tighten the motor mount bolt, so the motor will not rotate.





### Square the Frame

Make sure that the frame is square. Once the frame is square, make sure that all of the frames bolts are tight. It is hard to drive a crooked robot straight!

### Optimizing the Phone Holder

It is recommended that an approved material such as non-skid be layered in the back of the phone holder to prevent damage to the phone.

It is recommended that the phone be secured in the holder using a zip tie or some other mechanism to prevent it from being separated from the robot during competition.

### Optimizing the Battery Holder

It is recommended that the battery be secured in the holder using a zip tie or some other mechanism to prevent it from being separated from the robot during competition.

### Optimizing the Hand/Grippers

Place non-skid around the gripper to provide extra grip...so hockey pucks, wiffle balls, pipes, racquetballs, crates, rings, blocks or practice golf balls, or red herrings can be collected with ease!

### Add Team Numbers

Usually team numbers need to be on both sides of the robot. Make them BIG (the team numbers below are not to scale - refer to the game manual for height, width and stroke width, etc.). Make them easy to distinguish from other robots. Show off team numbers. They will be examined by many scouts while the robot is on the field.

A large, stylized number "2843" is displayed in a gradient color scheme. The digits are thick and rounded. The colors transition from red/orange for the '2', through yellow and green for the '8' and '4', to blue for the '3'. The background is plain white.

## Appendix A: Bill of Material List

This list does not include the cell phones, the Rev Robotics Expansion Hub, nor the cables that connect the electronics.

Quantity	CAD Name	Common Name
4	<a href="#">TETRIX_739068_2012</a>	288 mm Channel
4	<a href="#">TETRIX_739067_2012</a>	160 mm Channel
52	<a href="#">TETRIX_739098_2012</a>	6-32 x 5/16" Socket Head Cap Screws
127	<a href="#">TETRIX_739094_2013</a>	Kep Nuts
4	<a href="#">TETRIX_739065_2012</a>	32 mm Channel
62	<a href="#">TETRIX_739097_2013</a>	6-32 x 1/2" Socket Head Cap Screws
8	<a href="#">TETRIX_736466_HUB_2012</a>	4" Omni Wheel
17	<a href="#">TETRIX_739091_2013</a>	Bronze Bushing

11	<a href="#">TETRIX_739100_2012</a>	1/8" Nylon Axle Spacer
8	<a href="#">TETRIX_739092_COLLAR_2012</a>	Axle Set Collar
6	<a href="#">TETRIX_739088_2013</a>	100 mm Axle
2	<a href="#">TETRIX_739101_2012</a>	3/8" Nylon Axle Spacer
2	<a href="#">TETRIX_739055_2012</a>	4" Tire/Wheel
2	<a href="#">TETRIX_739090_2012</a>	Hub Gear Spacer
2	<a href="#">TETRIX_739086_2012</a>	80-Tooth Gear
4	<a href="#">TETRIX_739172_COLLAR_2012</a>	Axle Hub
2	<a href="#">TETRIX_739071_2012</a>	288 mm Angle
3	<a href="#">TETRIX_739066_2012</a>	96 mm Channel
2	<a href="#">TETRIX_739070_2012</a>	288 mm Flat Bar
2	<a href="#">TETRIX_739103_2012</a>	2" Stand-off Post
2	<a href="#">TETRIX_731901_120_2013</a>	120-Tooth Gear
4	<a href="#">TETRIX_739028_2012</a>	40-Tooth Gear
1	<a href="#">TETRIX_739069_2012</a>	416 mm Channel
3	<a href="#">TETRIX_739060_2012</a>	Standard-Scale Servo Motor Brackets
2	<a href="#">TETRIX_739197_SERVO_2012</a>	Standard-Scale HS-485HB Servo Motor
35	<a href="#">TETRIX_739111_2012</a>	6-32 x 3/8" Button Head Cap Screws
2	<a href="#">TETRIX_739061_2012</a>	Flat Bracket
2	<a href="#">TETRIX_739273_2013</a>	96 mm Flat
4	<a href="#">TETRIX_739062_2012</a>	L-Bracket
2	<a href="#">TETRIX_739072_2012</a>	144 mm Angle
3	<a href="#">TETRIX_739089_2012</a>	DC Motor Mount
3	<a href="#">TETRIX_739079_COLLAR_2012</a>	Motor Shaft Hub
3	<a href="#">TETRIX_739083_MOTOR_2012</a>	DC Motor
2	<a href="#">TETRIX_738000_2012</a>	DC Motor Encoder
2	<a href="#">TETRIX_739073_2012</a>	64 mm x 192 mm Flat Building Plate
4	<a href="#">TETRIX_739281_CORNER_BRA_2013</a>	Inside Corner Bracket
2	<a href="#">TETRIX_739272_2013</a>	160 mm Flat

1	<a href="#"><u>TETRIX_739057_2012</u></a>	Battery
3	<a href="#"><u>TETRIX_739102_2012</u></a>	1" Stand-off Post
1	<a href="#"><u>ACRYLIC_SWITCH_BRACKET</u></a>	Power Switch Bracket
1	<a href="#"><u>SWITCH</u></a>	Power Switch

## Special Thanks and Best Wishes

We'd like to thank Mary and Laura Spangler for helping us finish this project. Mary stepped in at the last minute and helped with CREO while David was otherwise occupied. Laura made yummy peach ice cream and used that to help encourage us to finish.

We hope you have enjoyed the time you spent building your Push 'Bot. If you have any questions or comments, please feel free to contact us at [ssi@lydean-david.net](mailto:ssi@lydean-david.net).

David and Lydean

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