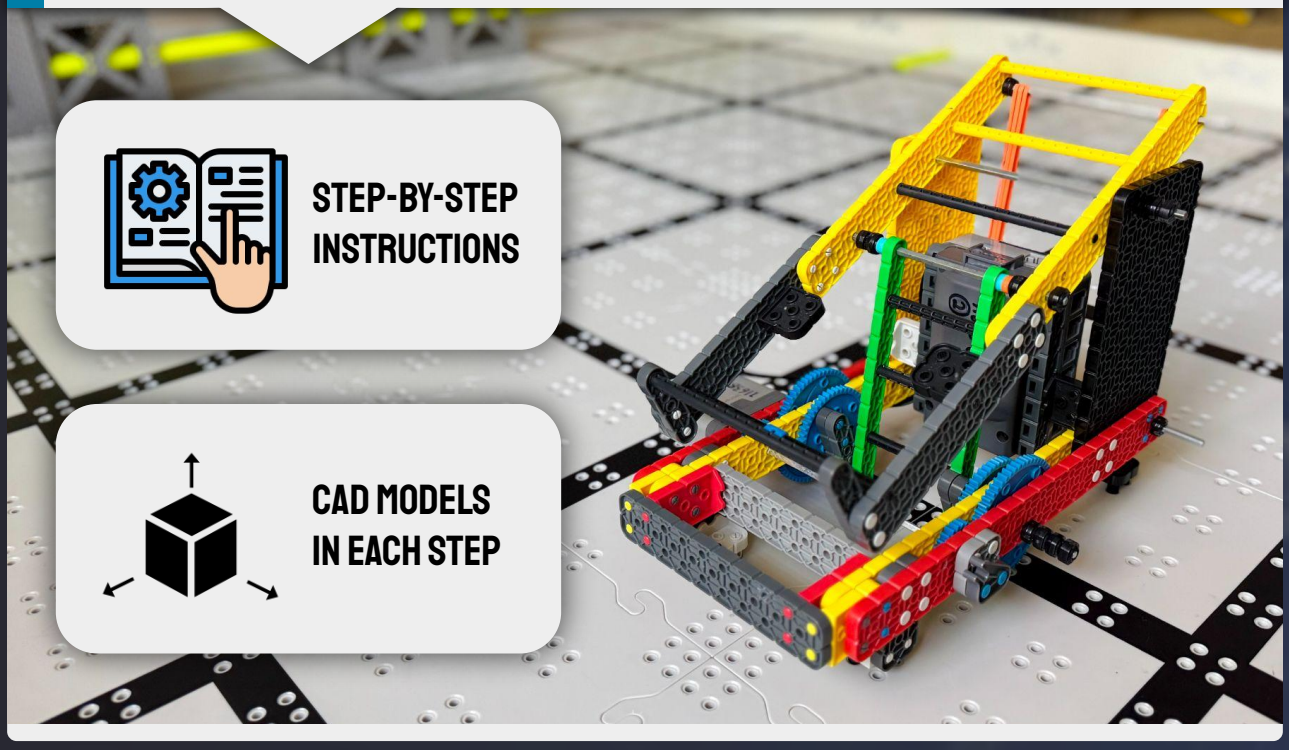
How to build a

1-MOTOR CHOO-CHOO CATAPULT



7163B • DAVIS, CA

Created By Team Chewbotca: Evan, Charlie P, Charlie W, Noah & Shane

ABOUT CATAPULTS

In recent VEX IQ games, such as *Pitching In* and *Rapid Relay,* catapults have been at the core of the top-performing robots. While their simplicity attracts many teams, creating a competitive catapult can be challenging, especially for teams unfamiliar with the key concepts that make catapults work.

What type of catapult is typically used in VEX IQ Robotics?

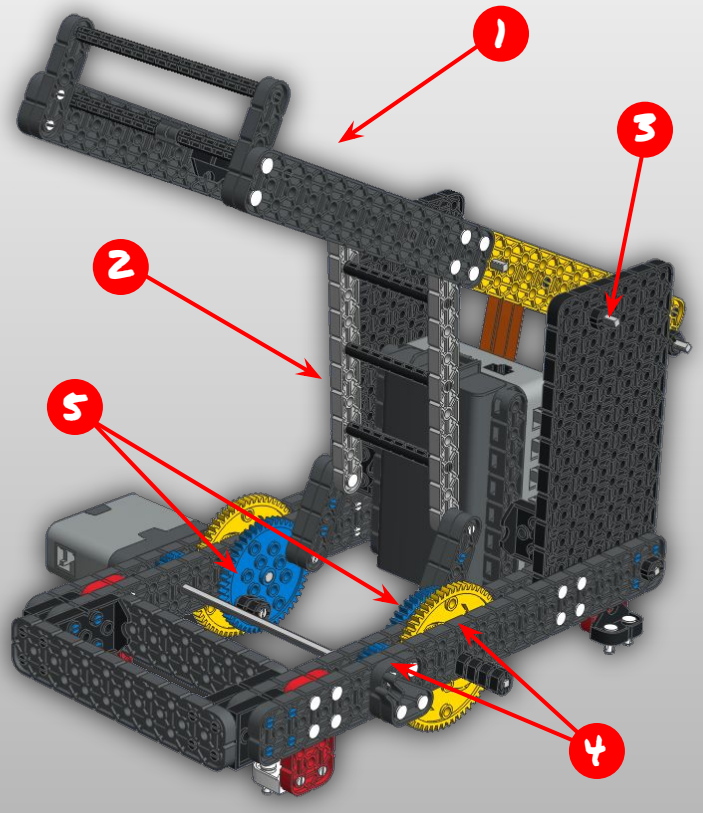
Ratchet and Choo-Choo Mechanisms are the two most commonly used catapult designs. We have chosen to build a Choo-Choo catapult because of its simple and versatile design.

The Features of Our Catapult Design:

*This catapult mechanism uses just **one motor,** allowing a team to easily integrate this design into their robot while reserving their remaining five motors for other mechanisms.*

LET'S IDENTIFY EACH PART OF THE CATAPULT:

1. **Catapult Tray:** Holds and shoots the game objects.
2. **Catapult Linkage:** Connects the *Choo-Choo Mechanism* to the *Tray.*
3. **Pivot Point:** The point at which the *Catapult Tray* rotates on a shaft.
4. **Gear Ratio:** The 60-t and 24-t gears form a 5:2 ratio, increasing the motor's torque.
5. **48-Tooth Choo-Choo Gears:** These two parallel gears are at the core of the Choo-Choo mechanism. Rotating them retracts and releases the Tray.



BUILD OVERVIEW

Below is a brief overview of each of the three sections in our instructions.

We've included tips along the way showing how each component of the catapult functions and how to avoid common mistakes.

1

BUILDING THE ONE-MOTOR CHOO-CHOO MECHANISM

The first step is building the One-Motor Choo-Choo Mechanism, which consists of two gear boxes that connect to a linkage of beams attached to the Catapult Tray. When the gears are rotated, the catapult retracts and shoots. This mechanism takes tweaking to perfect, as described in later pages.

2

BUILDING AND MOUNTING THE TRAY

After assembling the Choo-Choo, the next step is constructing and mounting the Catapult Tray. This part of the catapult holds the game elements. After being retracted, the Tray is released, shooting the game elements.

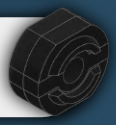
3

IMPROVING YOUR CATAPULT

With the basic One-Motor Choo-Choo Mechanism complete, you can easily modify it to tackle different challenges. The final section includes additional information about catapults, including common ways to vary shot power and tips for implementing a motor-free pneumatic system.

VISUAL PARTS LIST

Tip: *Gather the following parts before beginning the build.*

10x	–	228-3201-112	
4x	–	228-3201-114	
22x	–	228-3201-143	
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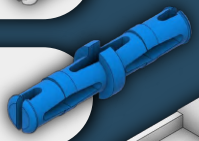
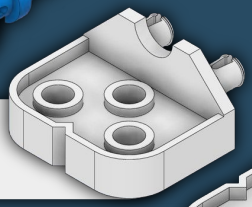
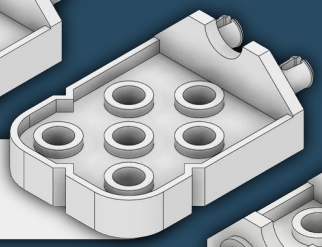
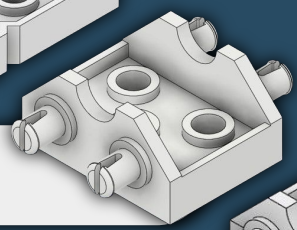
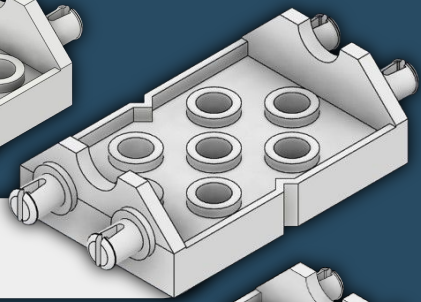
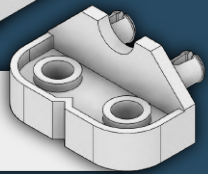
22x	0x2	228-2500-086	
24x	0x3	228-2500-087	
16x	2x2	228-3196-062	
2x	2x1.5	228-3201-135	
2x	2x2.5	228-2500-136	
2x	–	228-2500-274	
2x	–	228-2500-277	
2x	1x2	228-2500-128	
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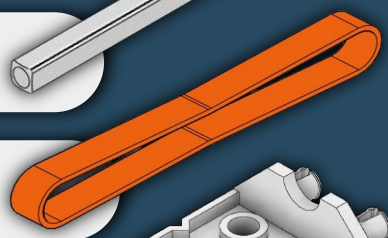
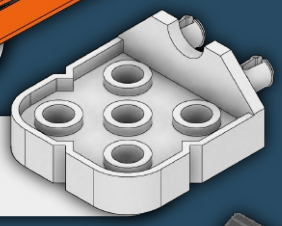
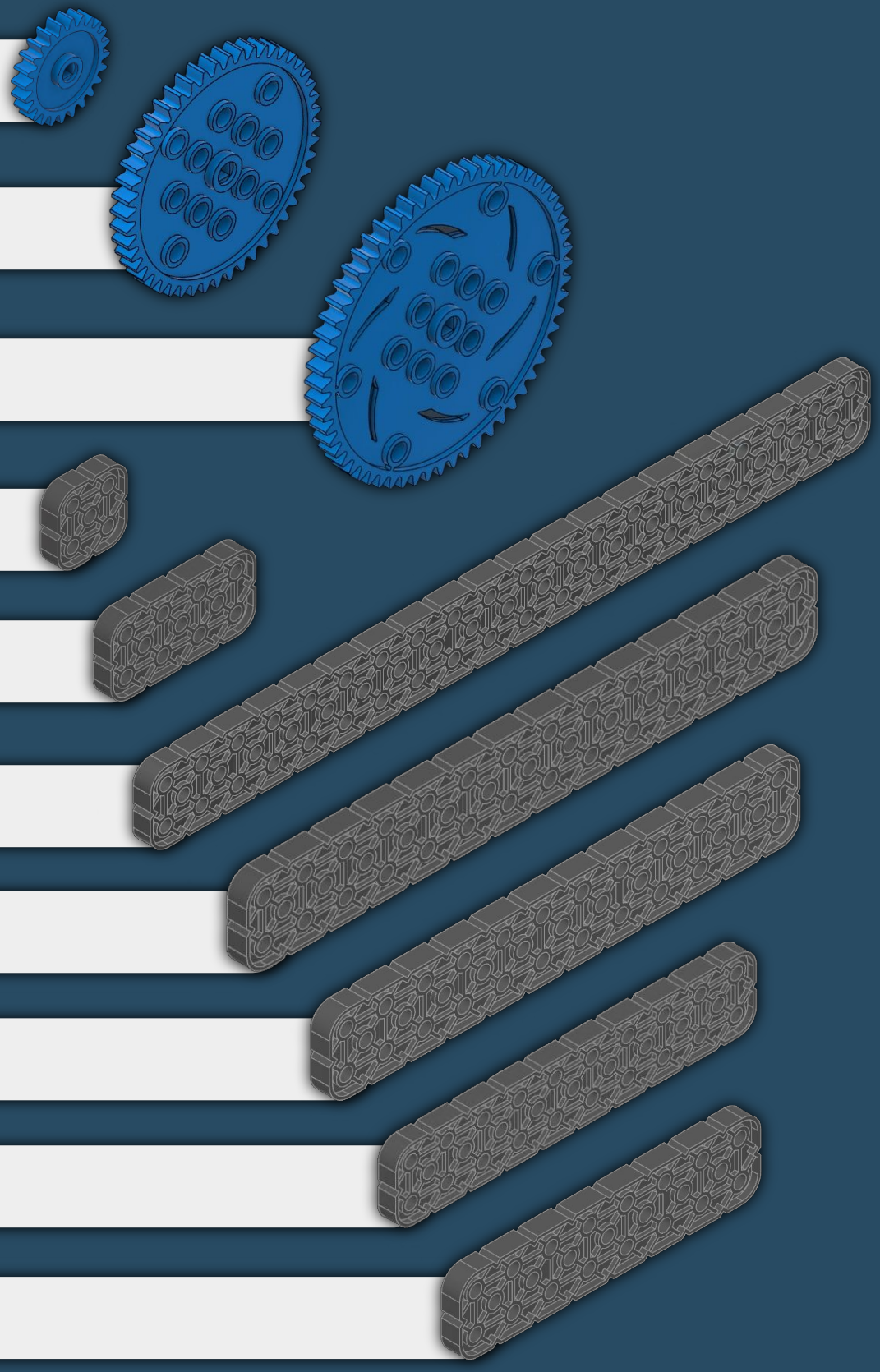
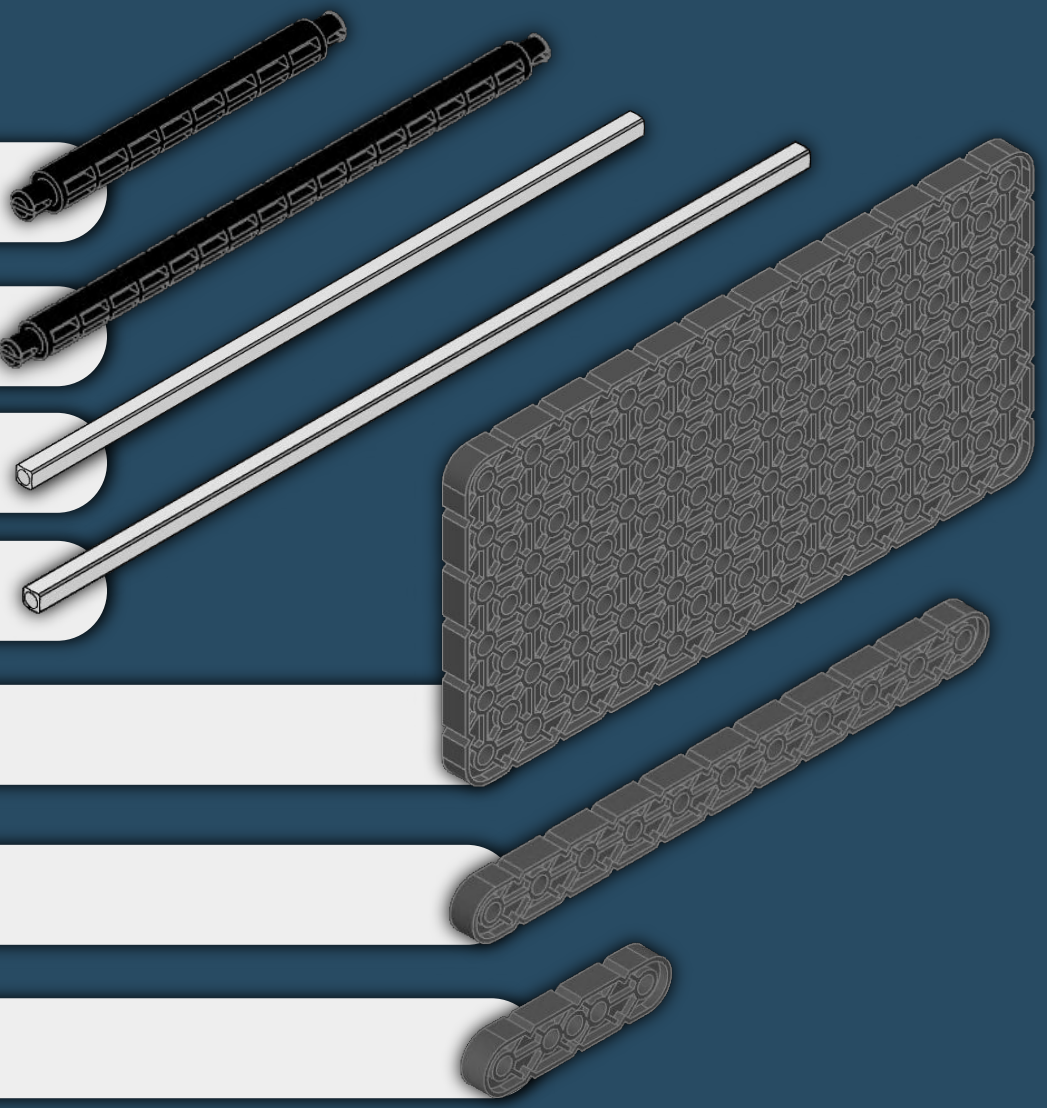
4x	#32	228-2500-468	
2x	2x2	228-2500-134	
1x	–	228-2500-157	
1x	–	228-2500-170	

VISUAL PARTS LIST

2x	24t	228-2500-227
2x	48t	228-2500-228
2x	60t	228-2500-215
1x	2x2	228-2500-019
4x	2x4	228-2500-019
4x	2x20	228-2500-030
2x	2x14	228-2500-027
2x	2x12	228-2500-026
1x	2x10	228-2500-025
1x	2x8	228-2500-023



VISUAL PARTS LIST



5x **4 Pitch** 228-2500-070

4x **8 Pitch** 228-2500-1061

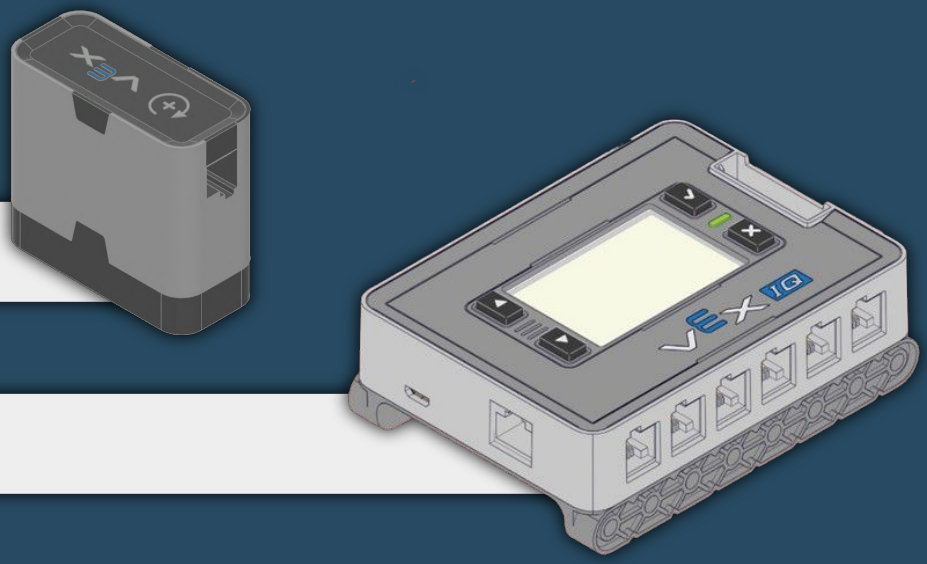
2x **5 Inch** 228-2500-261

3x **6 Inch** 228-2500-263

2x **6x12** 228-2500-051

2x **1x11** 228-2500-010

6x **1x4** 228-2500-003



1x **–** 228-2560

1x **–** 228-2540

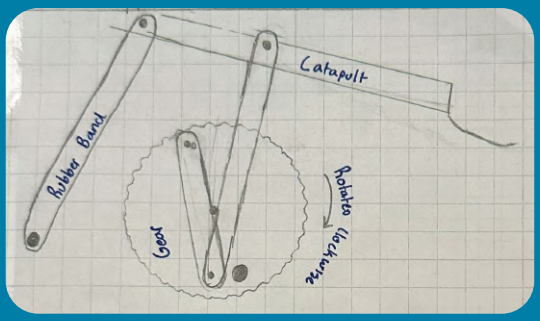
SECTION 1

BUILDING THE ONE-MOTOR CHOO-CHOO

We will begin by constructing the core of the catapult—the Choo-Choo mechanism. Choo-choo mechanisms are typically mounted to the drivetrain; however, for testing purposes, we will mount our Choo-Choo mechanism to the field.

What is a Choo-Choo Mechanism?

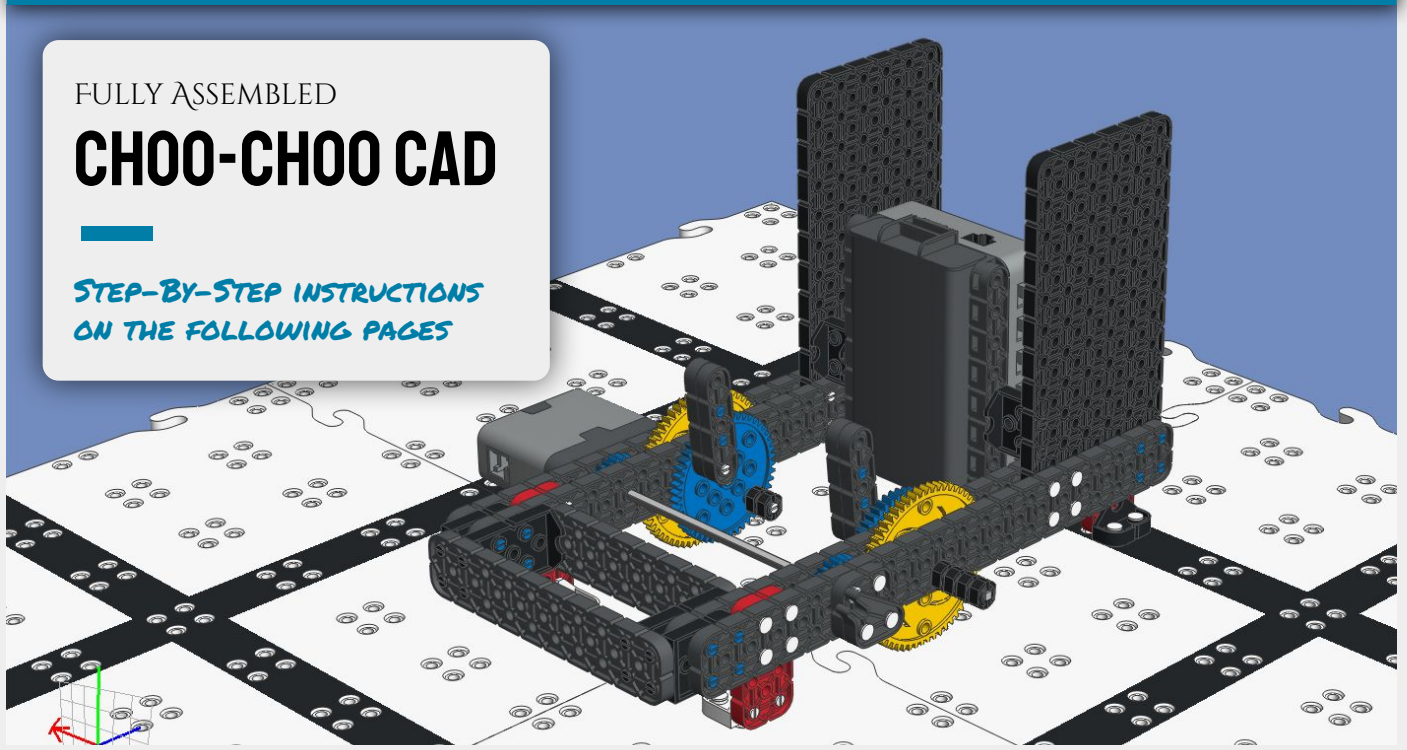
The Choo-Choo mechanism is central to the catapult system, positioned directly beneath the Catapult Tray. It includes a 48-tooth gear on each side, both connected to the catapult by a linkage of 1-by beams. When the motor spins the gears, the beams function as levers, pulling the catapult downwards and building up potential energy in the rubber bands. Once the Choo-Choo mechanism completes a full 360-degree rotation, the beams shoot upwards, releasing the tray, propelled by the rubber bands.



FULLY ASSEMBLED

CHOO-CHOO CAD

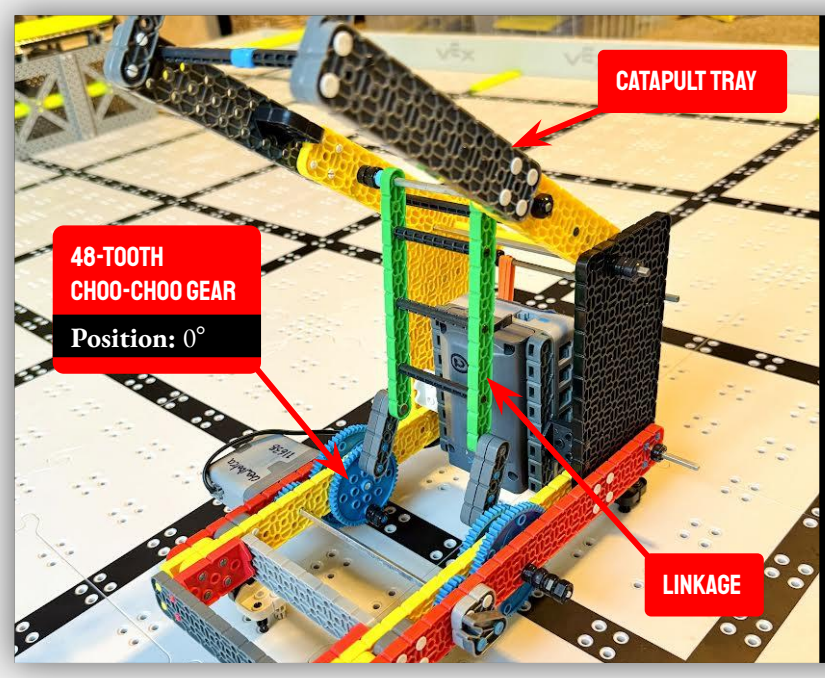
Step-By-Step instructions on the following pages



VISUAL EXPLANATION

How Do Choo-Choo Mechanisms Work?

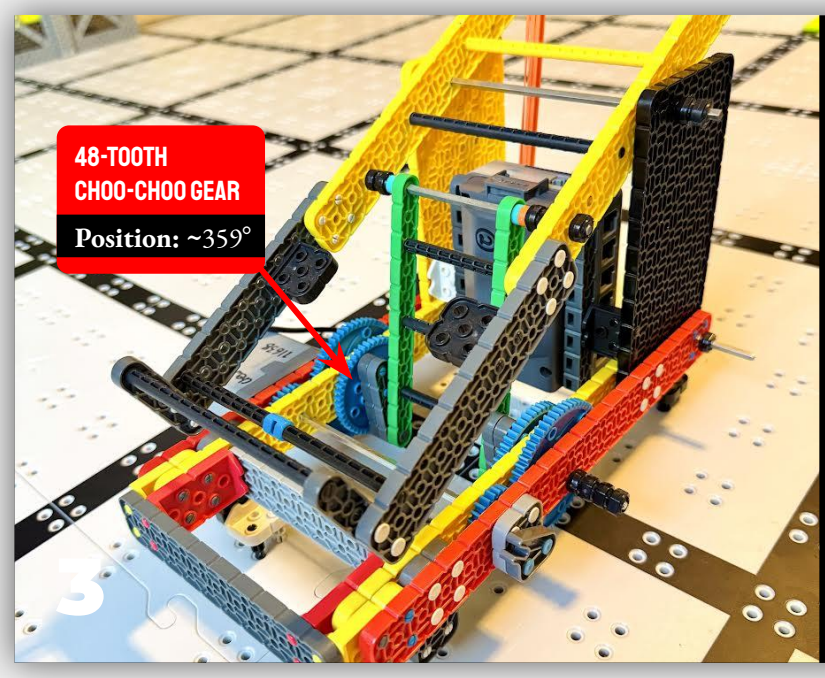
*Unlike some catapult mechanisms, Choo-Choo mechanisms retract and release while rotating in the **same direction.** The pictures below show how this works.*



EXTENDED POSITION

In its resting position, the 48-tooth Choo-Choo gears are at 0°, keeping the Catapult Linkage fully extended and the Tray in its upward position.

***Note:** The 48-tooth gears, labeled in the diagram, are connected to the linkage, meaning their position directly controls the Tray's position.*



RETRACTED POSITION

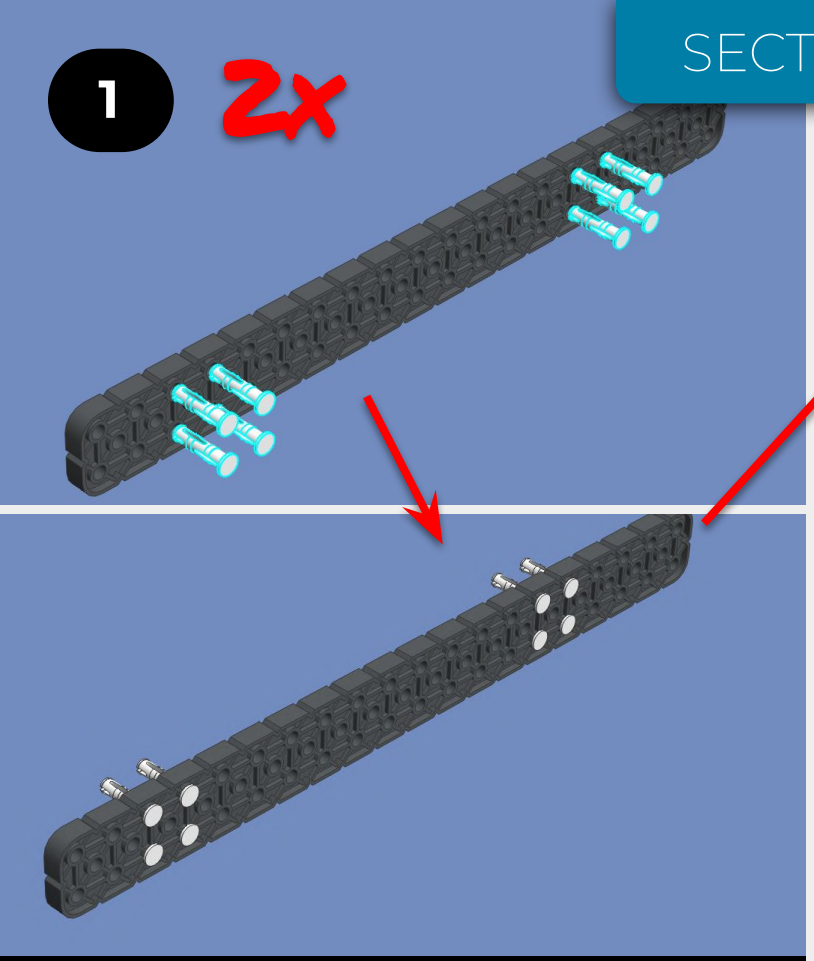
As the 48-tooth Choo-Choo gears rotate, they pull the linkage downward, retracting the Catapult Tray. Once the gears complete nearly a full rotation, the catapult is fully retracted. Rotating the gears past 359° instantly releases the Catapult Tray to its extended position, launching the game objects. *The cycle then repeats.*

LET'S START BUILDING THE CHOO-CHOO MECHANISM!

Tip: *Set your PDF zoom level to at least 100% to view the CAD models clearly.*

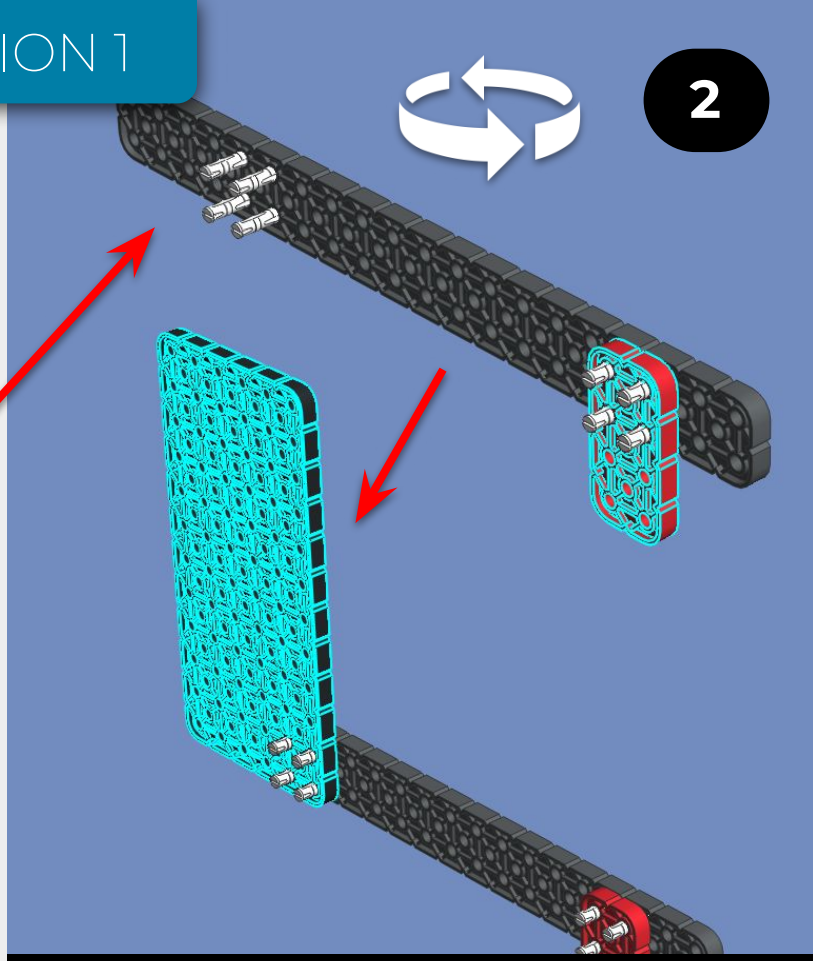
SECTION 1

1 2x



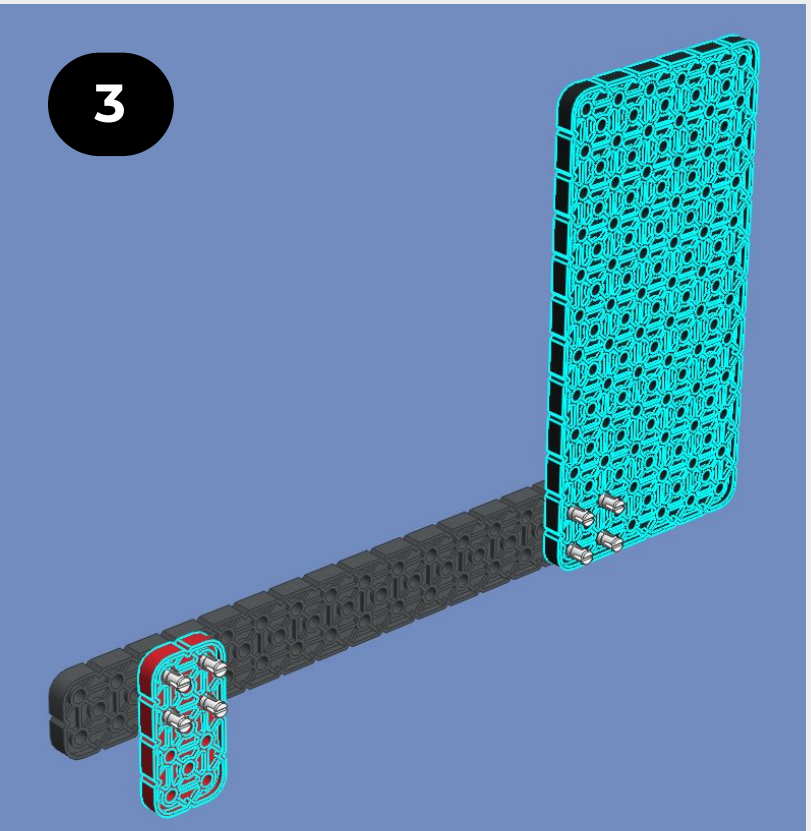
Begin by inserting eight 0x3 capped pins into a 2x20 beam in two groups of four as shown. **Repeat this step.**

2



Working with a 2x20 beam we assembled in Step 1, attach a 2x4 beam and a 6x12 beam to the ends of the 0x3 capped pins.

3

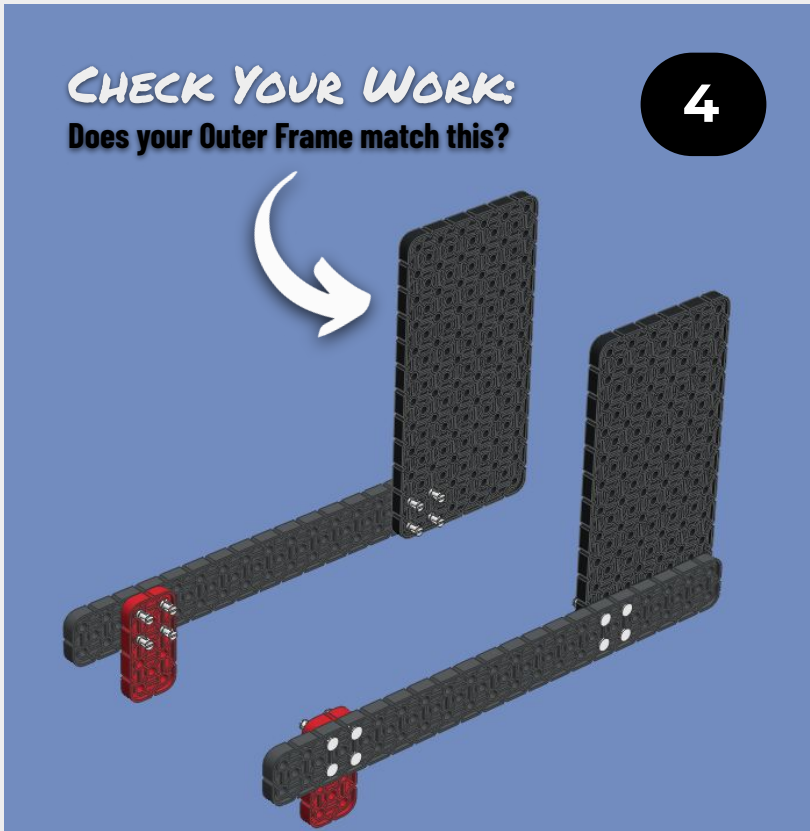


Using the remaining assembled beam from Step 1, repeat Step 2, forming a mirrored piece to the one assembled in Step 2.

4

Check Your Work:

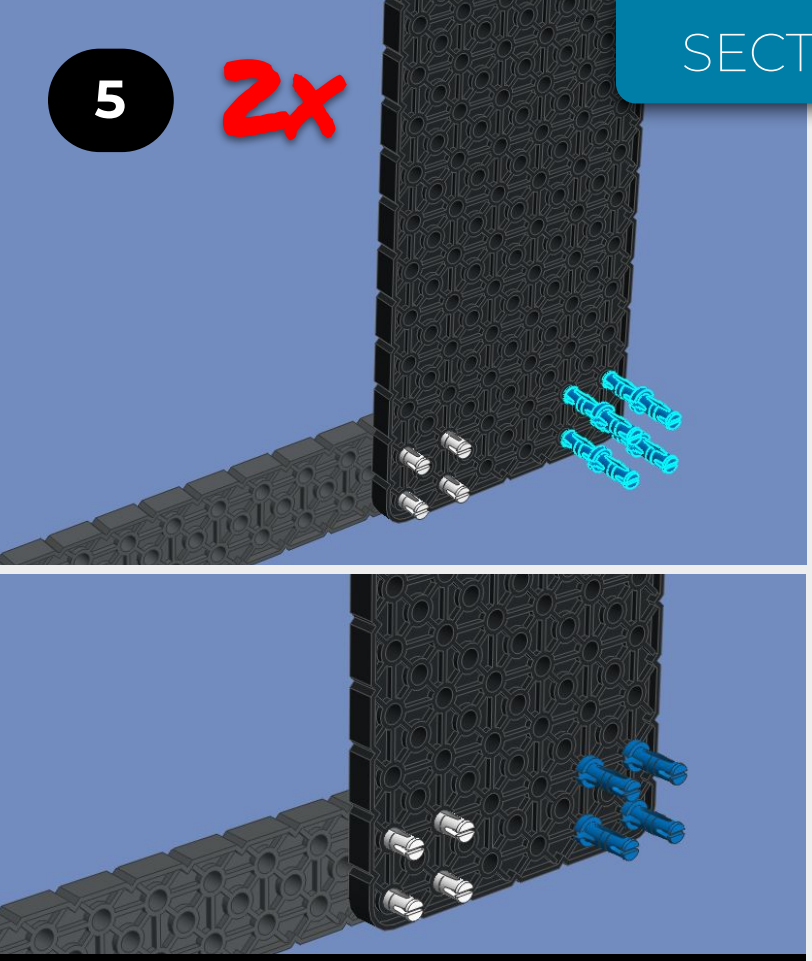
Does your Outer Frame match this?



Now, place the two assembled pieces of our Choo-Choo frame side by side. If done correctly, the sides should mirror each other.

5

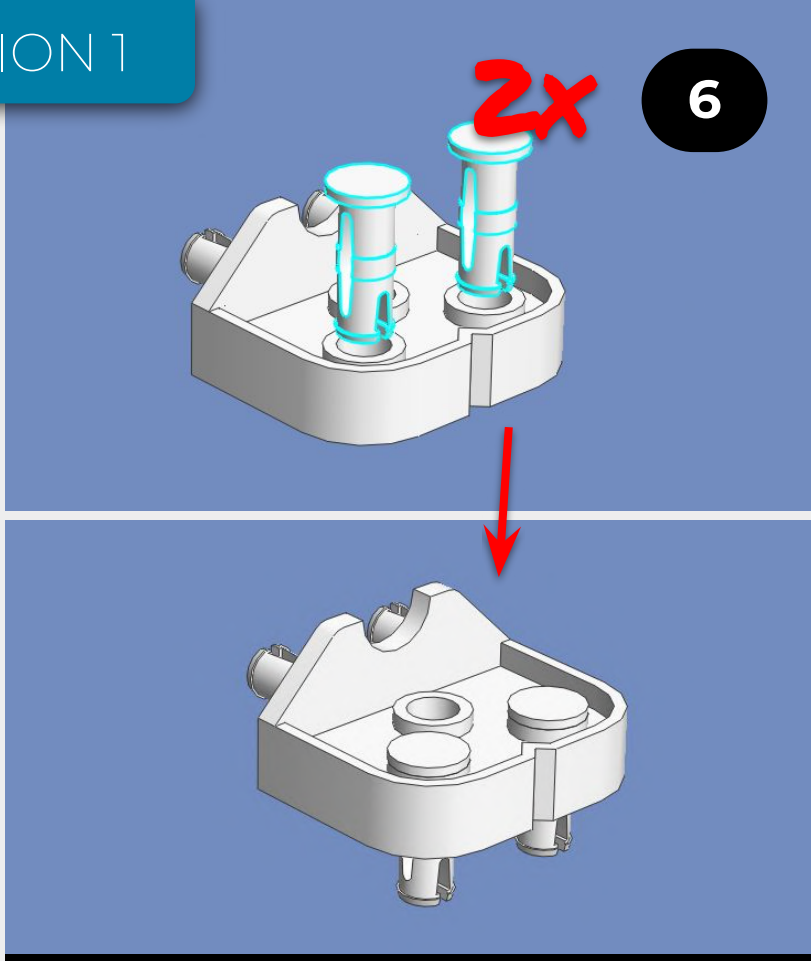
2x



For each side shown in Step 4, insert four 2x2 pins into the black 6x12 piece. **Make sure to do this step on both sides.**

6

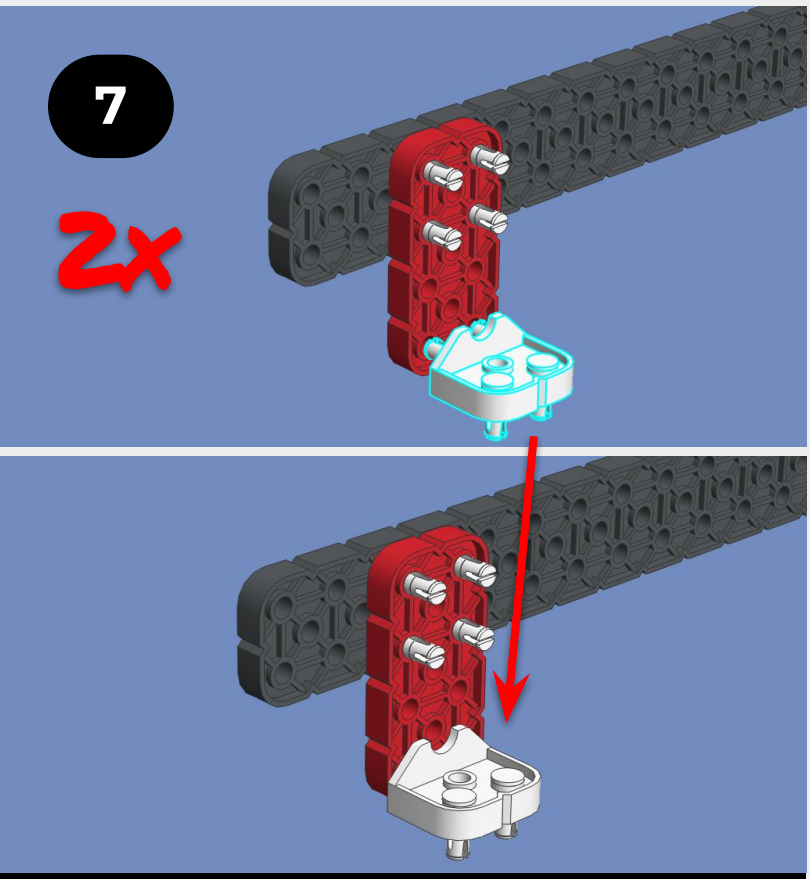
2x



Insert two 0x2 capped pins into the ends of a 2x1.5 connector. **Repeat this step.**

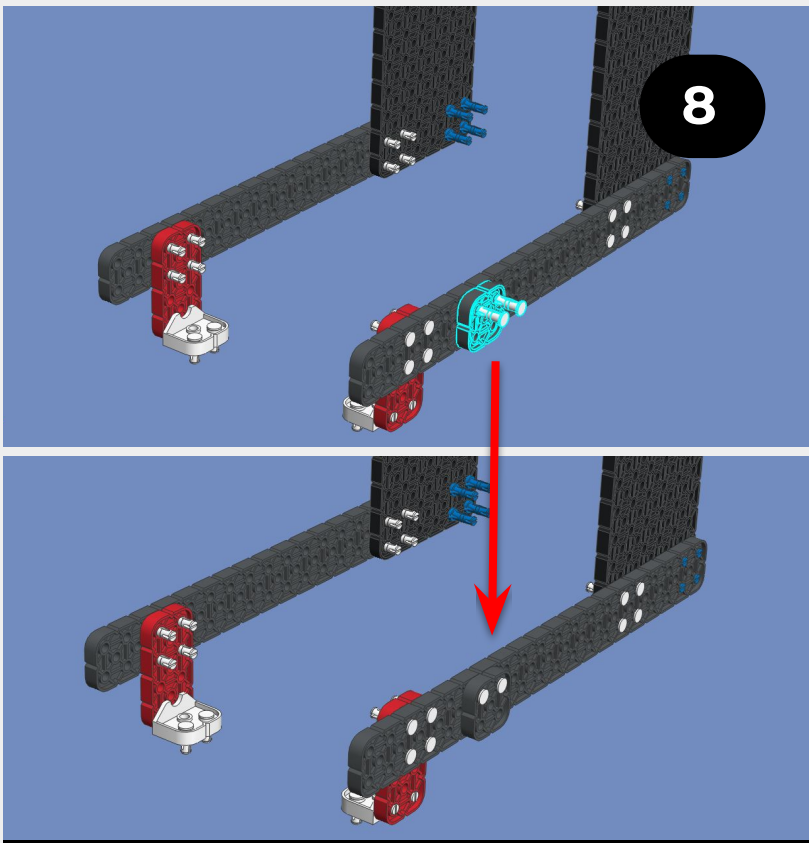
7

2x

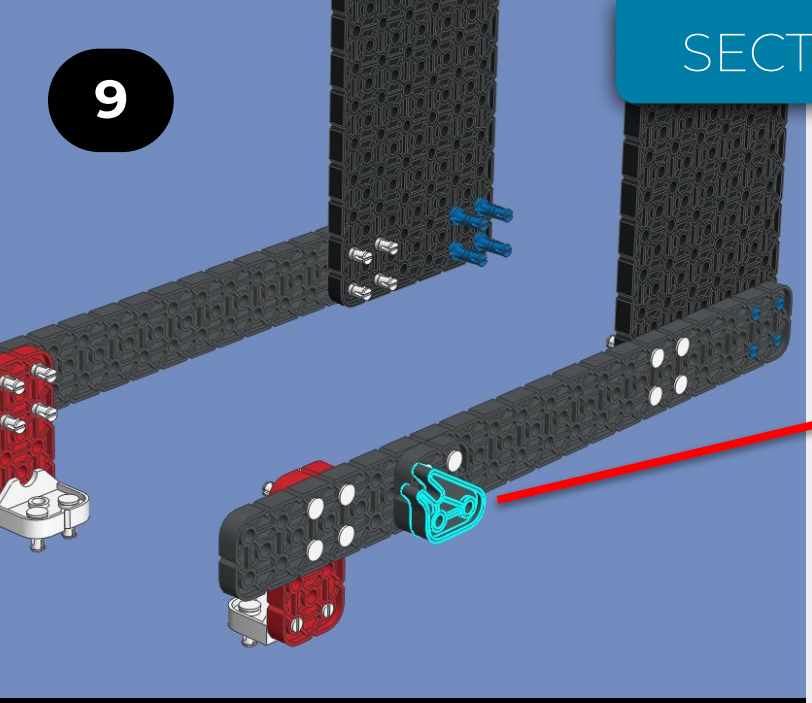


Mount the assembled connectors from Step 6 onto the bottom of each of the two 2x4s.

8

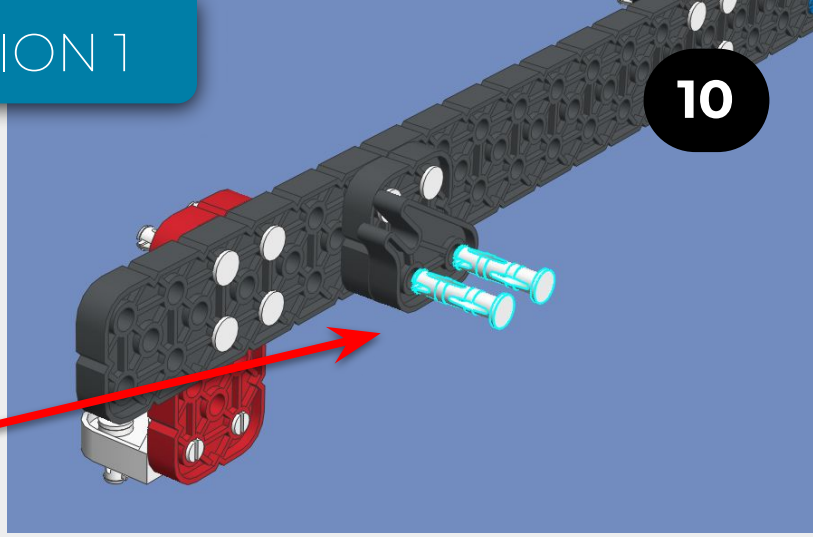


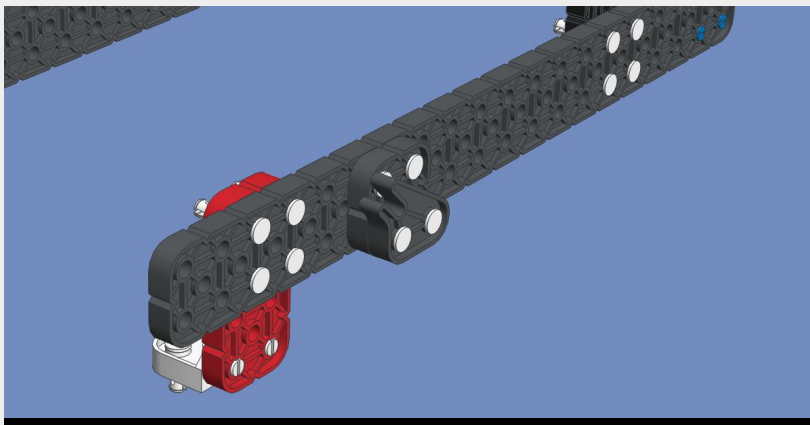
Following the picture above, place a 2x2 beam in the 6th and 7th holes of the right 2x20, counting from the left. Then, add two 0x2 capped pins into the upper holes of the 2x2 beam.



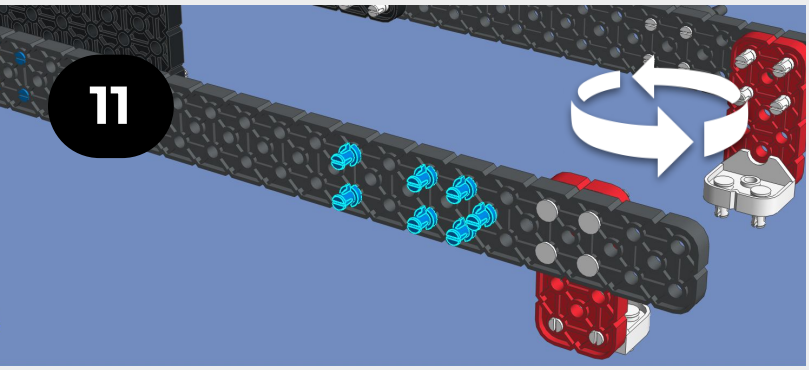
Place a 1x2 hooked plate over the lower holes of the 2x2.

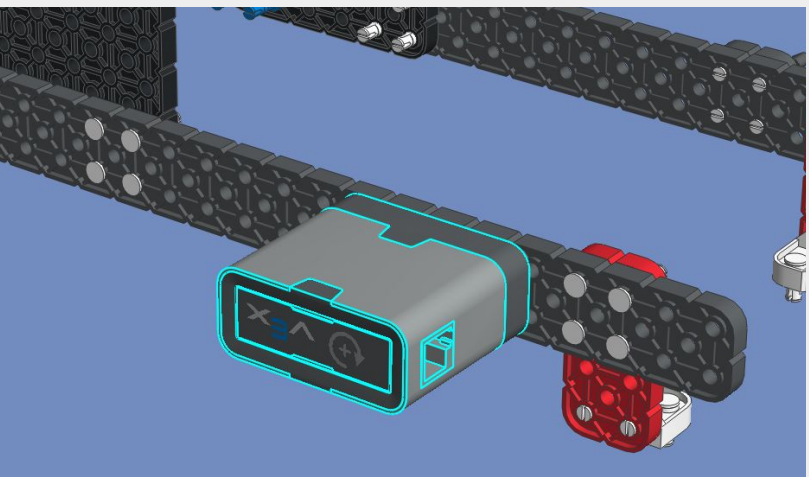
Quick Explanation: Before going further, let's go over what we're doing. To begin, we built most of the outer Choo-Choo frame. The frame supports the Choo-Choo gears, motor, and shafts. Now, we are adding some small parts to the right side of the frame that will prevent the shaft (added later) from slipping.



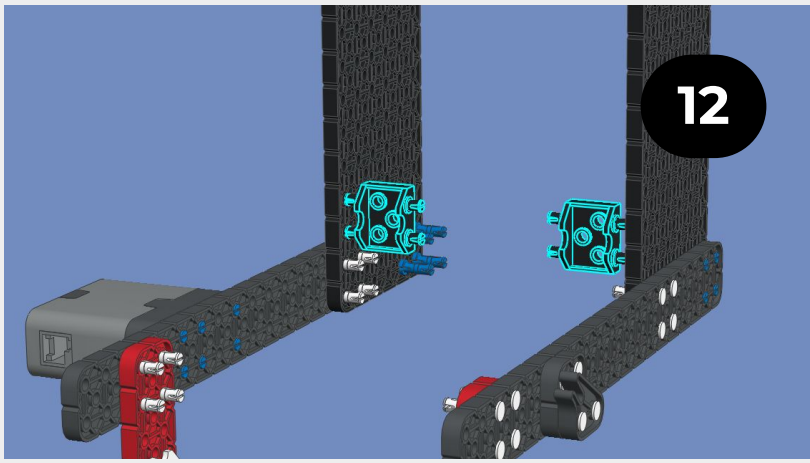


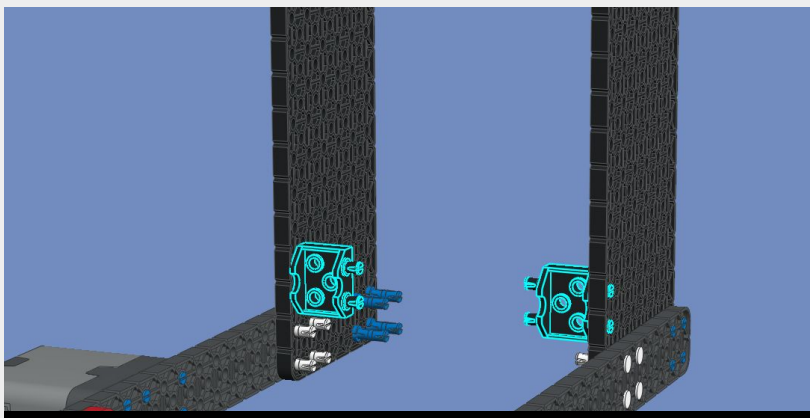
Insert two 0x3 capped pins through the 1x2 hooked plate, 2x2 beam, and 2x20 as shown above.





Working with the left side of the outer frame, insert seven 1x1 pins into the left 2x20 in the formation shown above, then slide a motor over the pins.





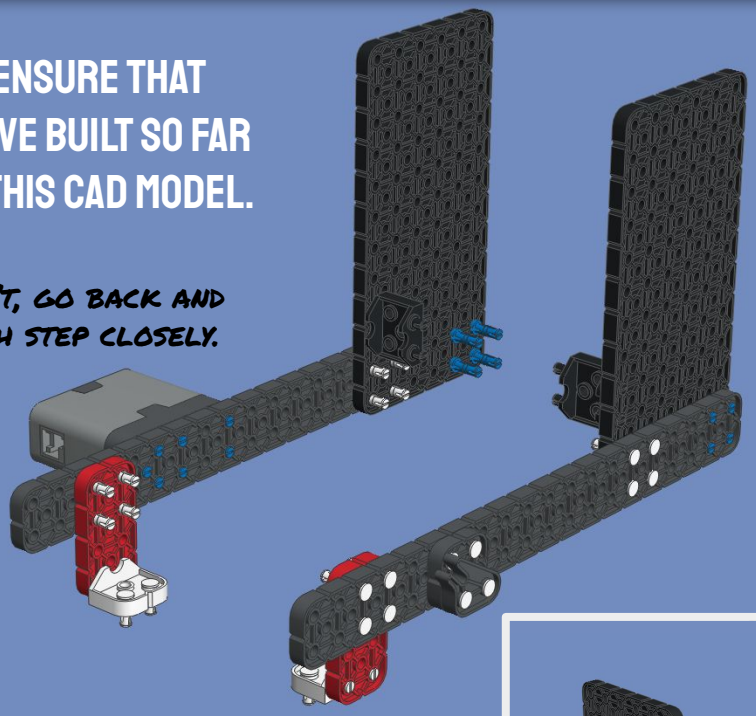
Following the picture, insert a 2x1.5 double-sided connecter into each of the two 6x12s, 2 holes from the bottom.

PAUSE—LET'S CHECK OUR PROGRESS.

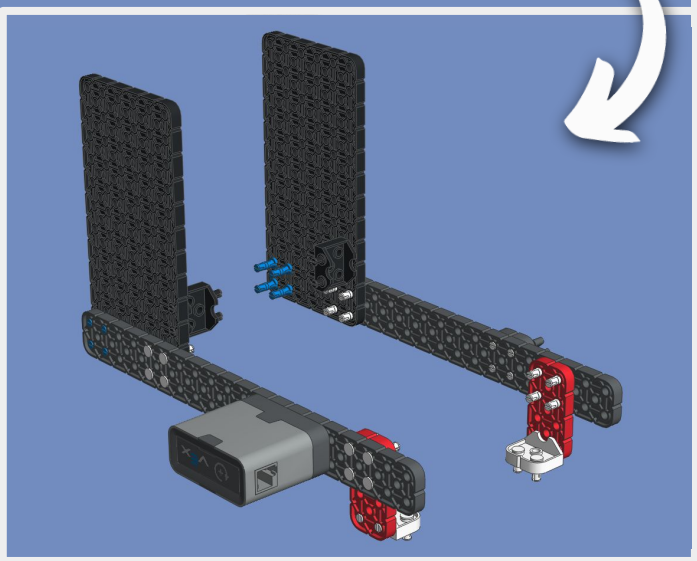
What have we done so far?
At this point, we have nearly completed the outer frame of the Choo-Choo mechanism. In the following steps, we will work on the gearing and inner frame. *In the final steps of this section, we will attach the outer frame to the gearing and inner frame. For now, set aside the outer frame.*

CHECK TO ENSURE THAT WHAT YOU'VE BUILT SO FAR MATCHES THIS CAD MODEL.

If it doesn't, go back and review each step closely.



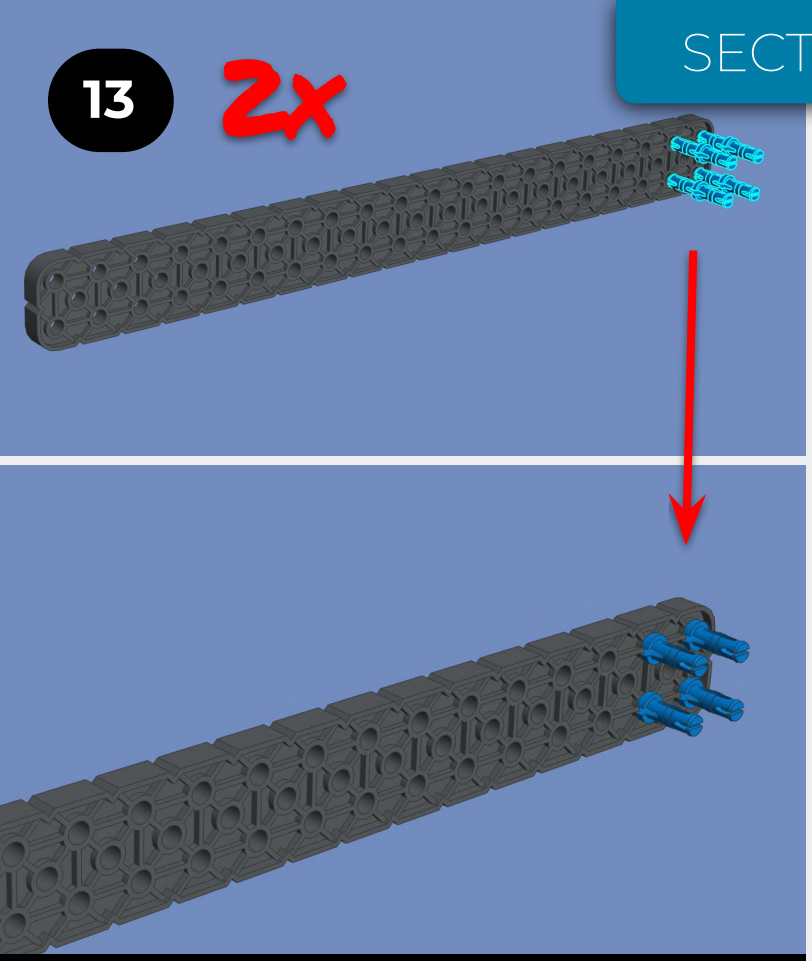
Here's a view of the same model from a different angle.



Tip: *Create a stable frame for your Choo-Choo*

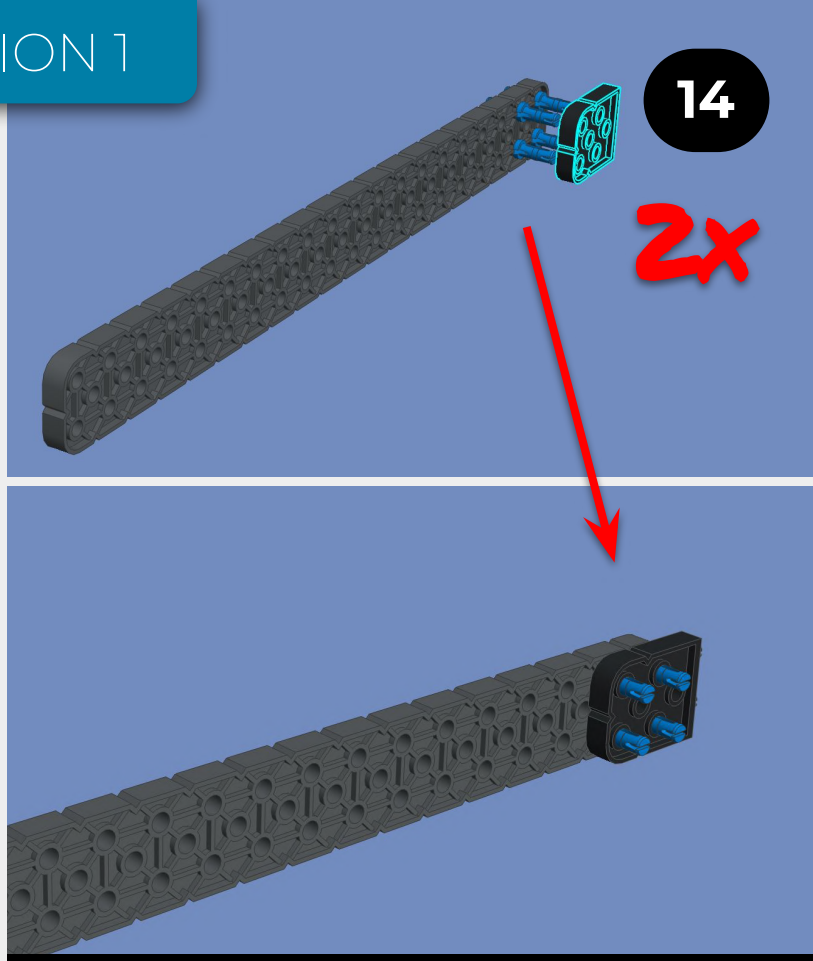
Creating a stable frame is essential both to reduce friction and to ensure the catapult is adequately supported so that it stays intact during use. As we continue, pay close attention to how we support our Choo-Choo Mechanism with a frame.

13 2x



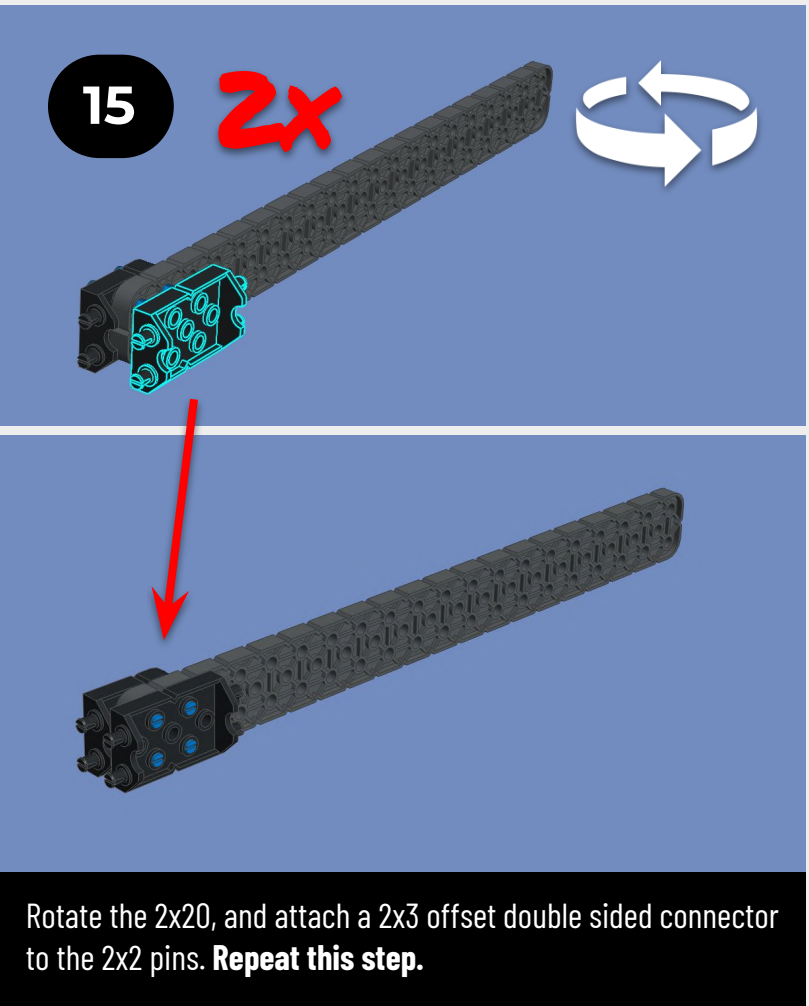
Insert four 2x2 pins into the far end of a 2x20 as shown. **Repeat this step.**

14 2x



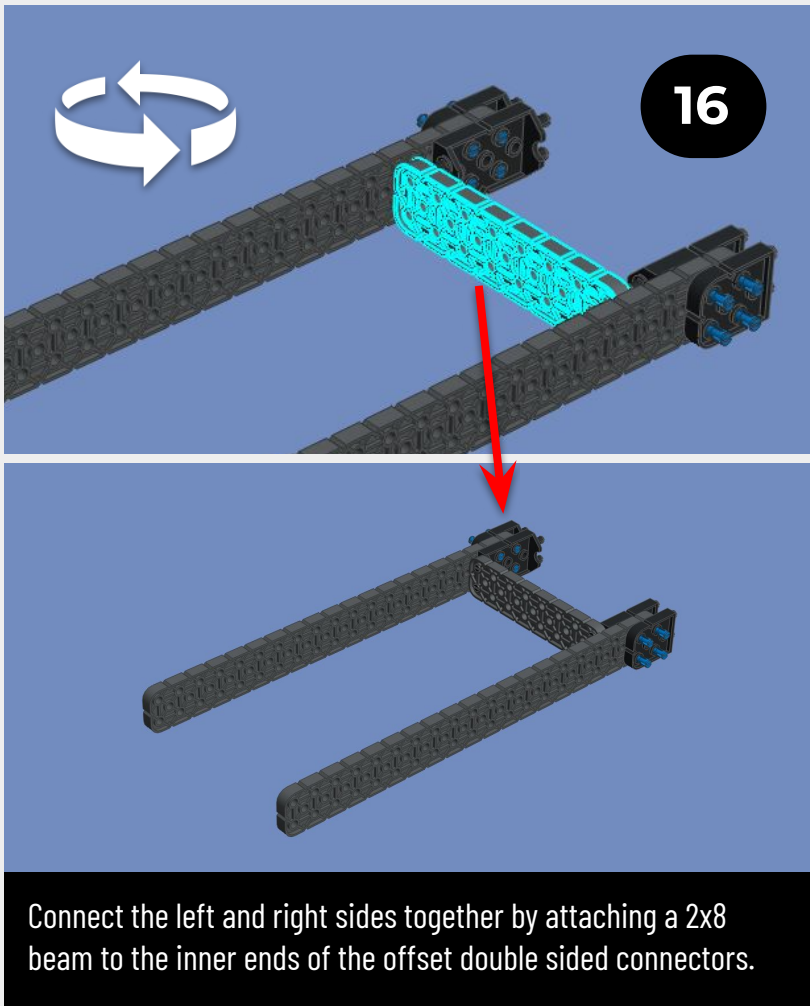
Attach a 2x2.5 connecter onto the 2x2 pins added in Step 13. Make sure to add the connector on the correct side, as shown.

15 2x



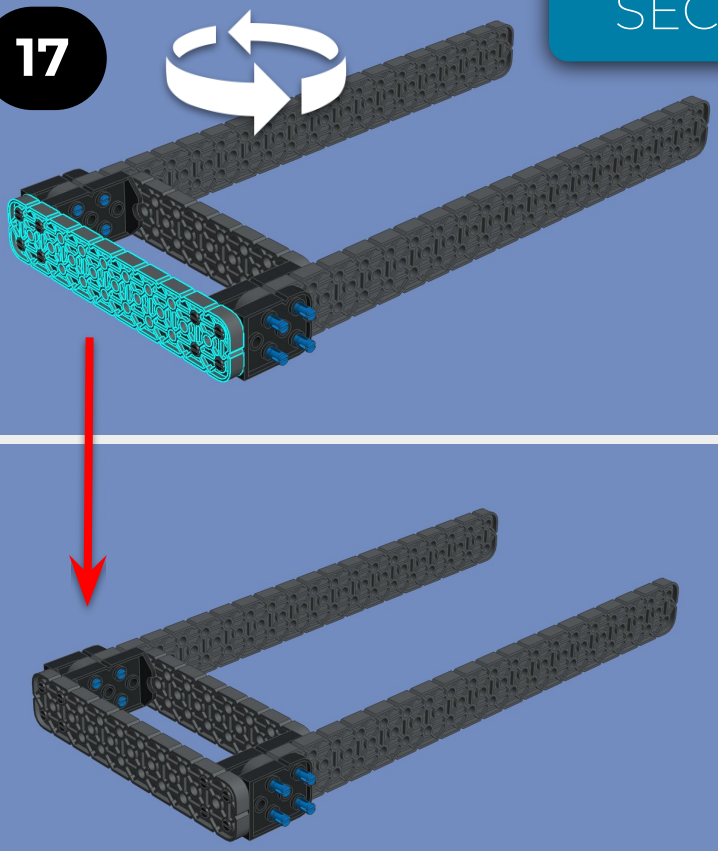
Rotate the 2x20, and attach a 2x3 offset double sided connector to the 2x2 pins. **Repeat this step.**

16



Connect the left and right sides together by attaching a 2x8 beam to the inner ends of the offset double sided connectors.

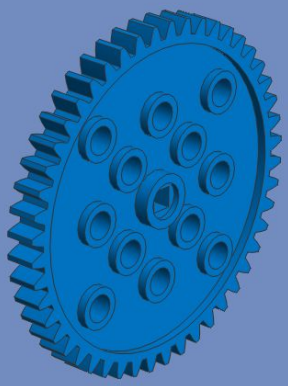
17



Attach a 2x10 beam to the four available connectors. When done correctly, the 2x10 should be parallel to the 2x8 from Step 16.

18

2x

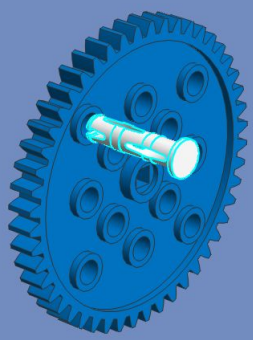


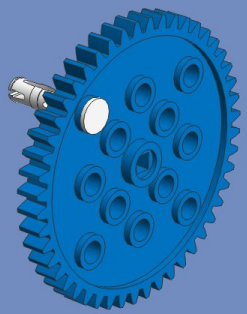
PAUSE:

Before going further with our inner frame, we must first assemble the Choo-Choo gears. For now, set aside the inner frame—we'll come back to it soon.

19

2x

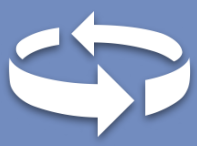


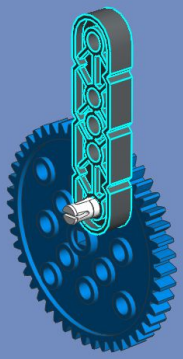


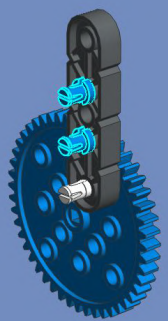
Fully insert a 0x3 capped pin into one of the outer holes of a 48-tooth gear. **Repeat this step.**

20

2x

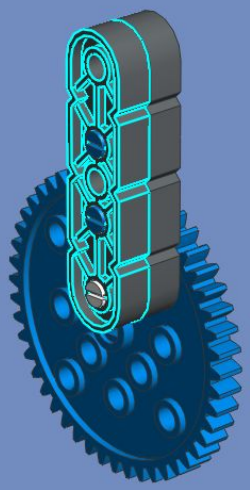






Begin by attaching the end of a 1x4 beam to the 0x3 capped pin. Then insert two 1x1 pins into the center holes of the 1x4.

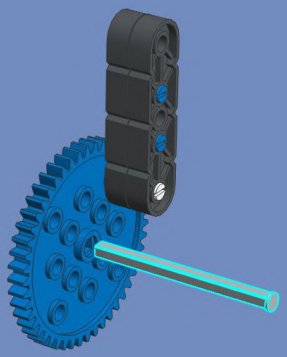
21 2x

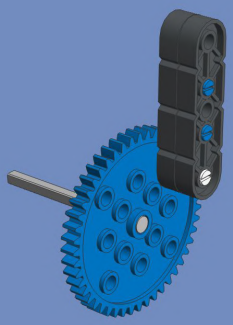


Attach another 1x4 beam over the other 1x4 so that the pins are *sandwiched* between. **Repeat this step for both gears.**

22

2x

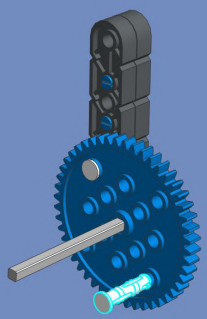


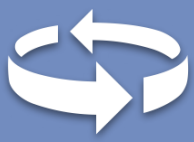


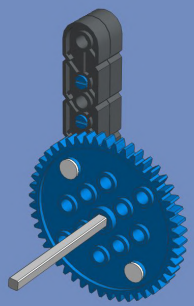
Insert a 2-inch metal capped shaft into the center hole of each 48 tooth gear. ***TIP:*** *Make sure the shaft faces away from the 1x4s.*

23

2x



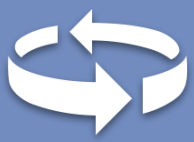


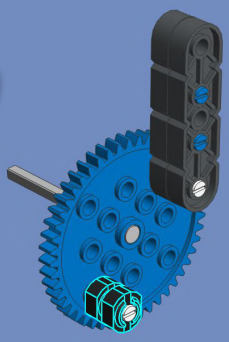


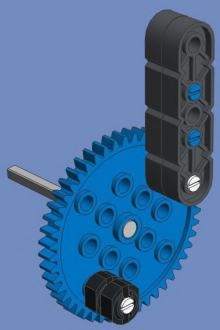
Rotate the 48-tooth gear, and insert a 0x3 capped pin directly across from the other 0x3 capped pin into the gear.

24

2x

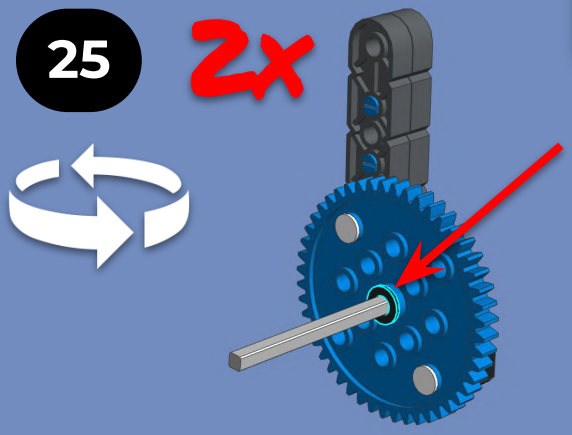


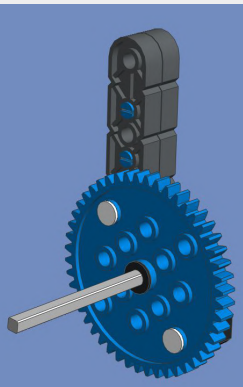




Insert two rubber shaft collars onto the end of the 0x3 capped pin. This may require some force.

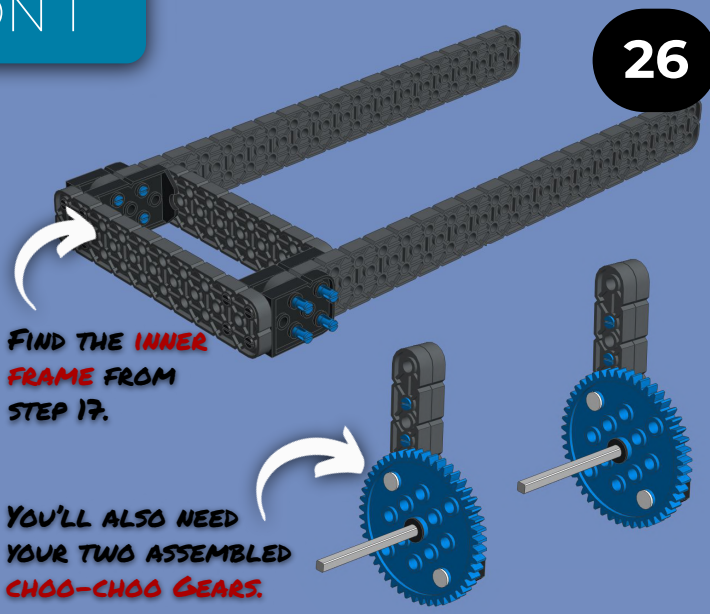
25





Rotate the gear, and insert a thin plastic spacer onto the capped shaft as shown in the CAD model. **Repeat step for both gears.**

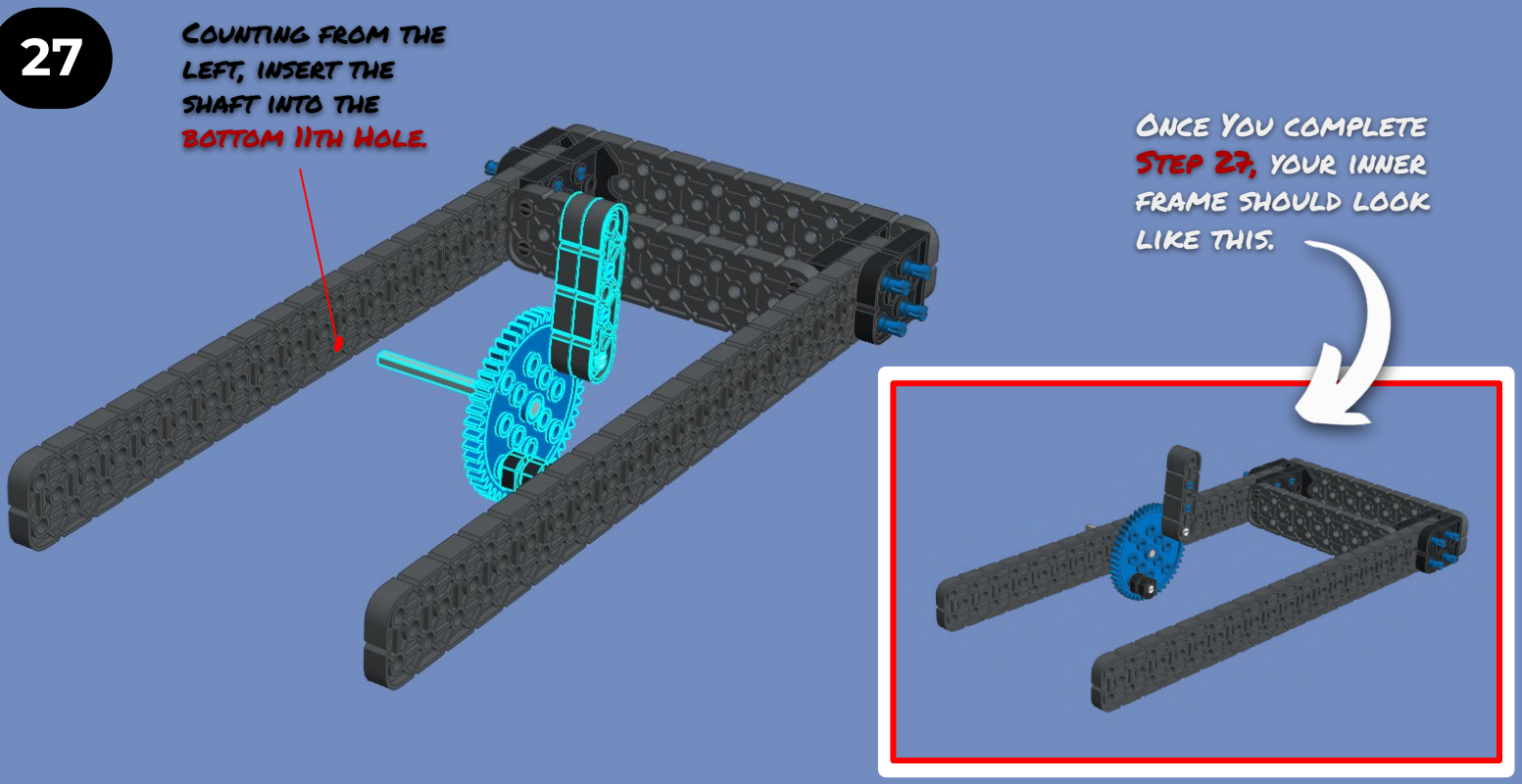
26



PAUSE:

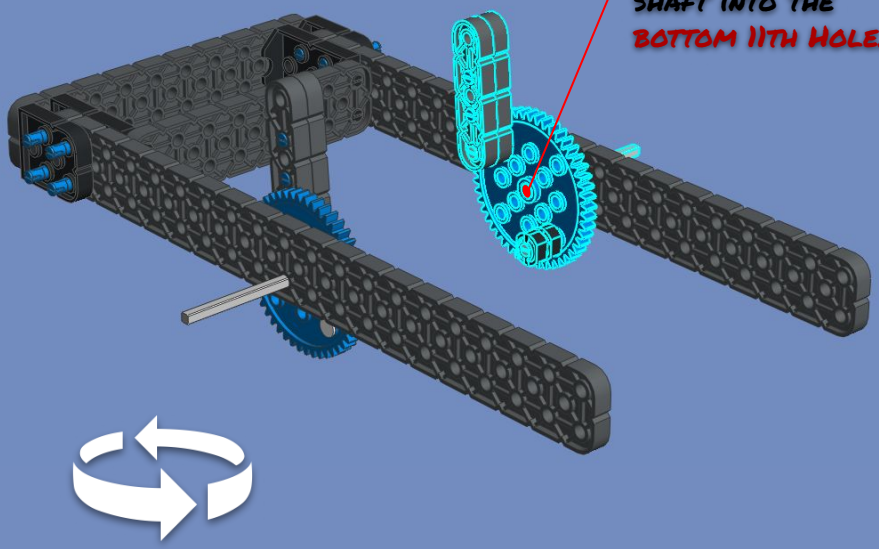
In Step 25, we completed the 48-tooth Choo-Choo gear assembly. Find the inner frame that we set aside in Step 17. We'll now attach the Choo-Choo gears, completing the inner frame.

27

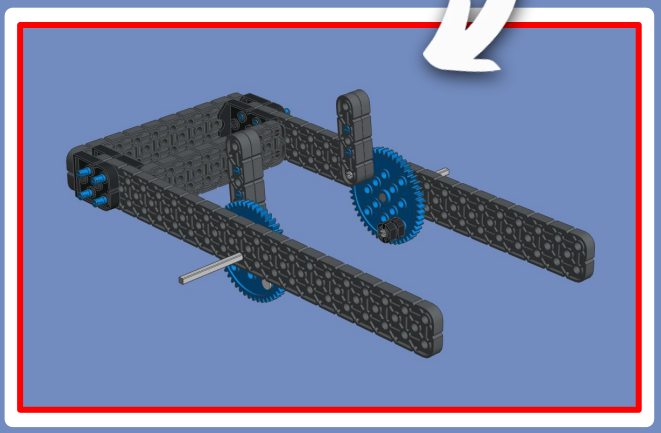


We'll take the next few steps slowly because it's a little tricky to get the gears positioned correctly. Working with one assembled Choo-Choo gear, follow the labeled CAD Model above and insert the capped shaft into the bottom 11th hole (counting from the left).

28



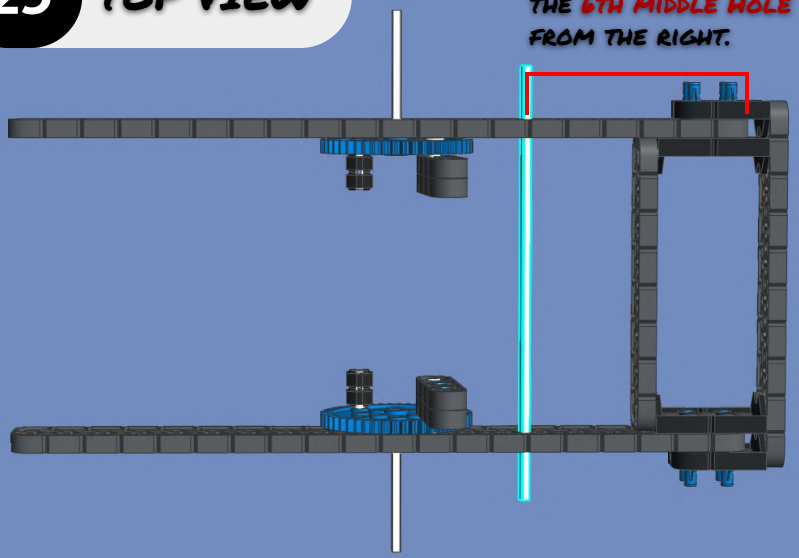
Once you complete Step 28, your inner frame should look like this.



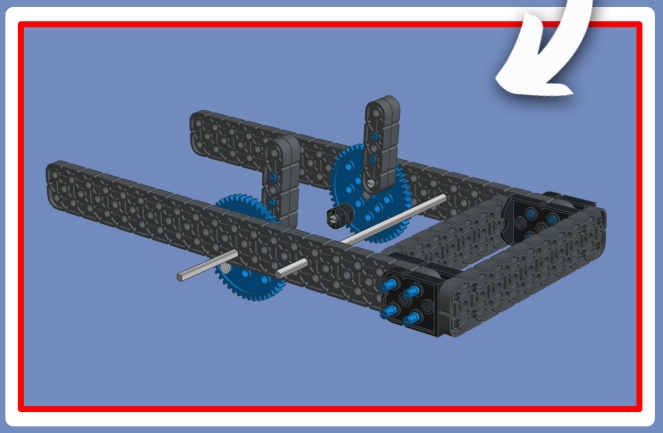
With one of our 48-tooth Choo-Choo gears mounted, it's time to mount our other 48-tooth gear. This gear should be inserted into the eleventh hole counting from the right, mirroring the first 48-tooth gear.

Quick Explanation: At this point, we've mounted both 48-tooth gears, and in the following steps we'll add some more gears, but what do all these gears do? The 48-tooth gears connect to a 1-by-beam linkage, which will ultimately retract the Catapult Tray. The next four gears we add will create a 5:2 gear ratio that will increase the torque, allowing our catapult mechanism to be powered by just one motor.

29 TOP VIEW

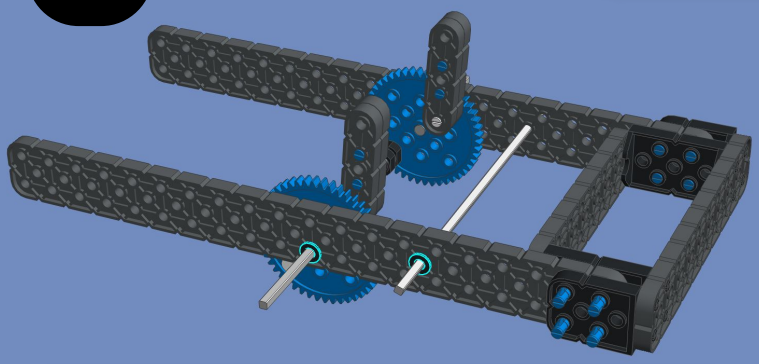


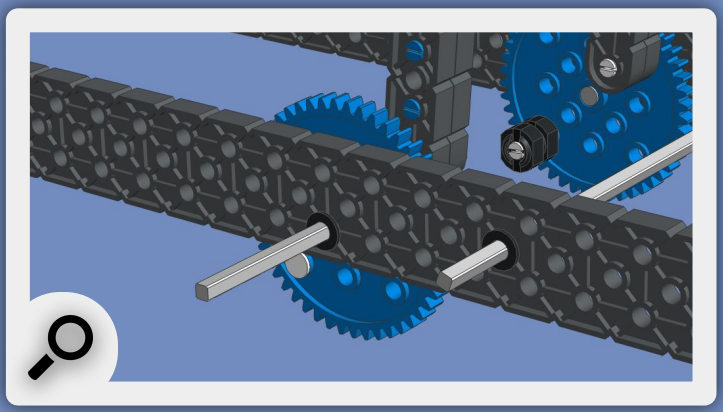
Once you complete Step 29, your inner frame should look like this.



Counting from the right side of the parallel 2x20s and following the CAD model above, insert a 6" metal shaft through the 6th center hole of the parallel 2x20 beams. ***Tip:*** *Longer shafts can bend over time, so before inserting your shaft, check to make sure it's straight.*

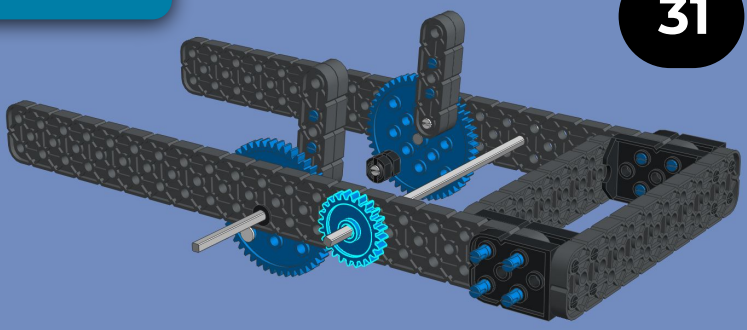
30

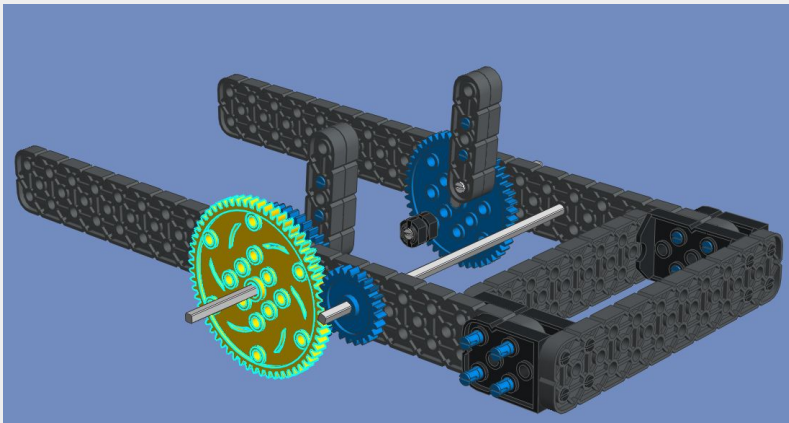




Slide a thin plastic spacer onto the end of the right 48-tooth gear shaft and the right end of the 6″ shaft.

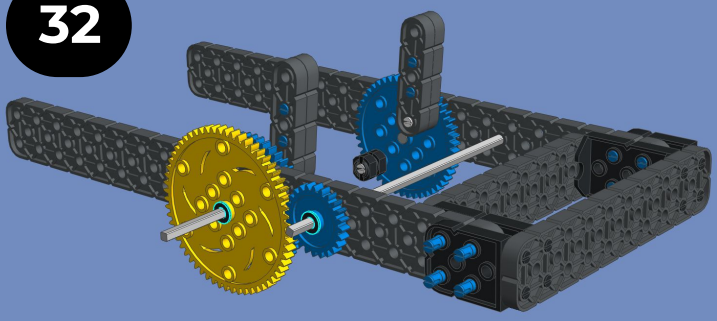
31

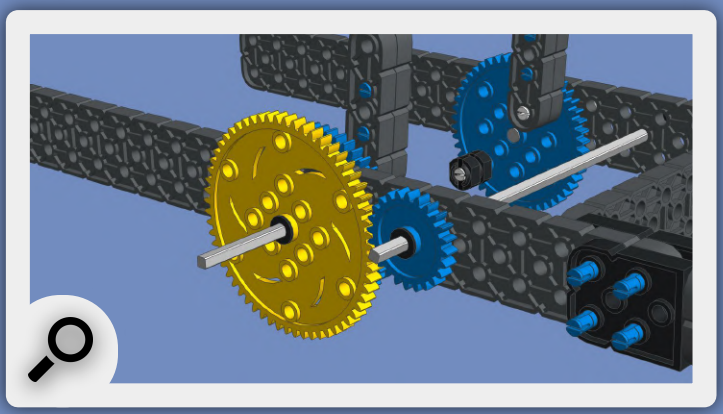




Slide a 24-t gear onto the right end of the 6″ metal shaft. Then slide a 60-t gear onto the end of the right 48-t gear shaft.

32



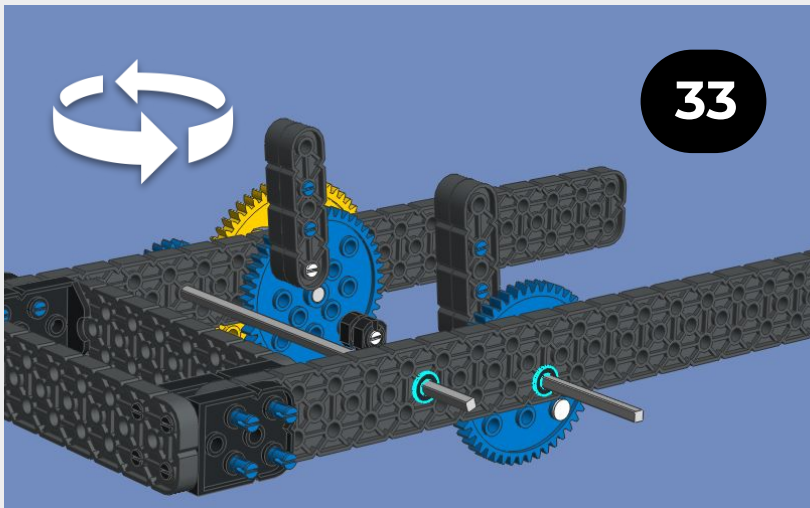


Slide a thin plastic spacer over the 24-tooth gear we added in Step 31, and another onto the 60-tooth gear.

PAUSE:

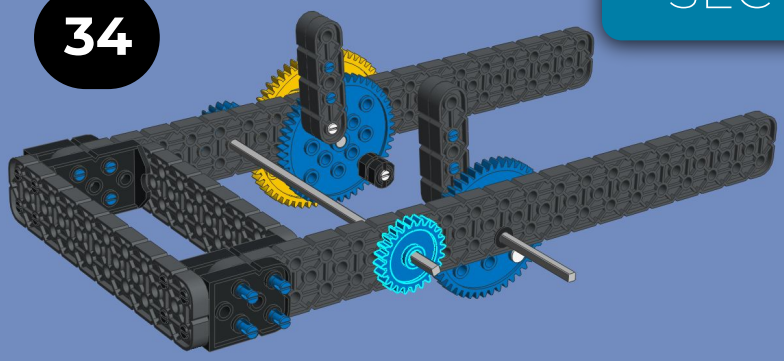
In Step 32, we completed the gearing on the right side of the inner frame! Now we will mirror the gearing for the left side.

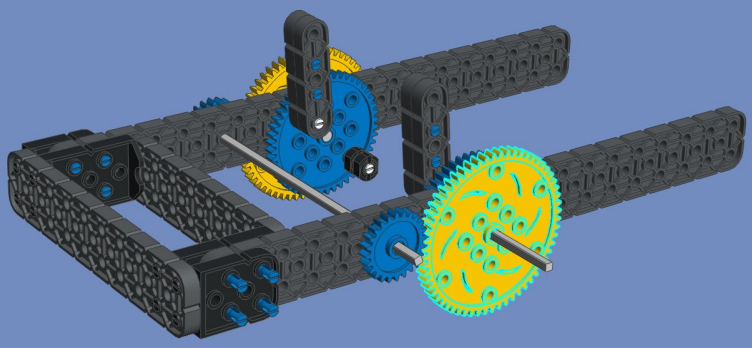
33



Slide a thin plastic spacer onto the the end of the left 48-tooth gear shaft and another onto the left end of the 6″ shaft.

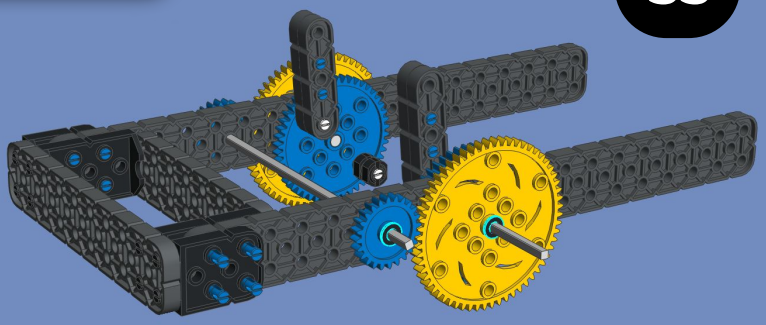
34

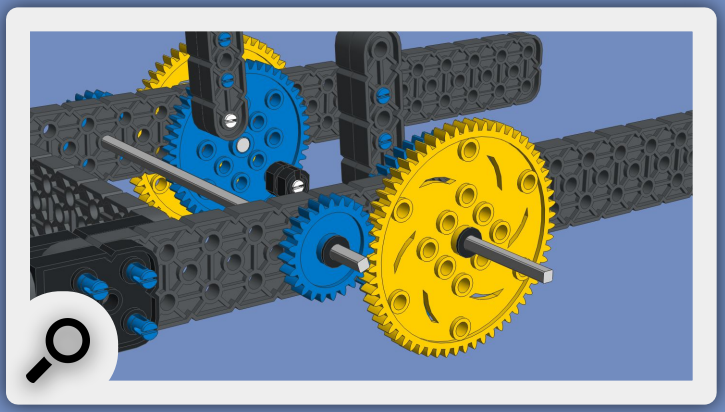




Slide a 24-t gear onto the left end of 6" metal shaft. Then slide a 60-t gear onto the end of the left 48-t gear shaft.

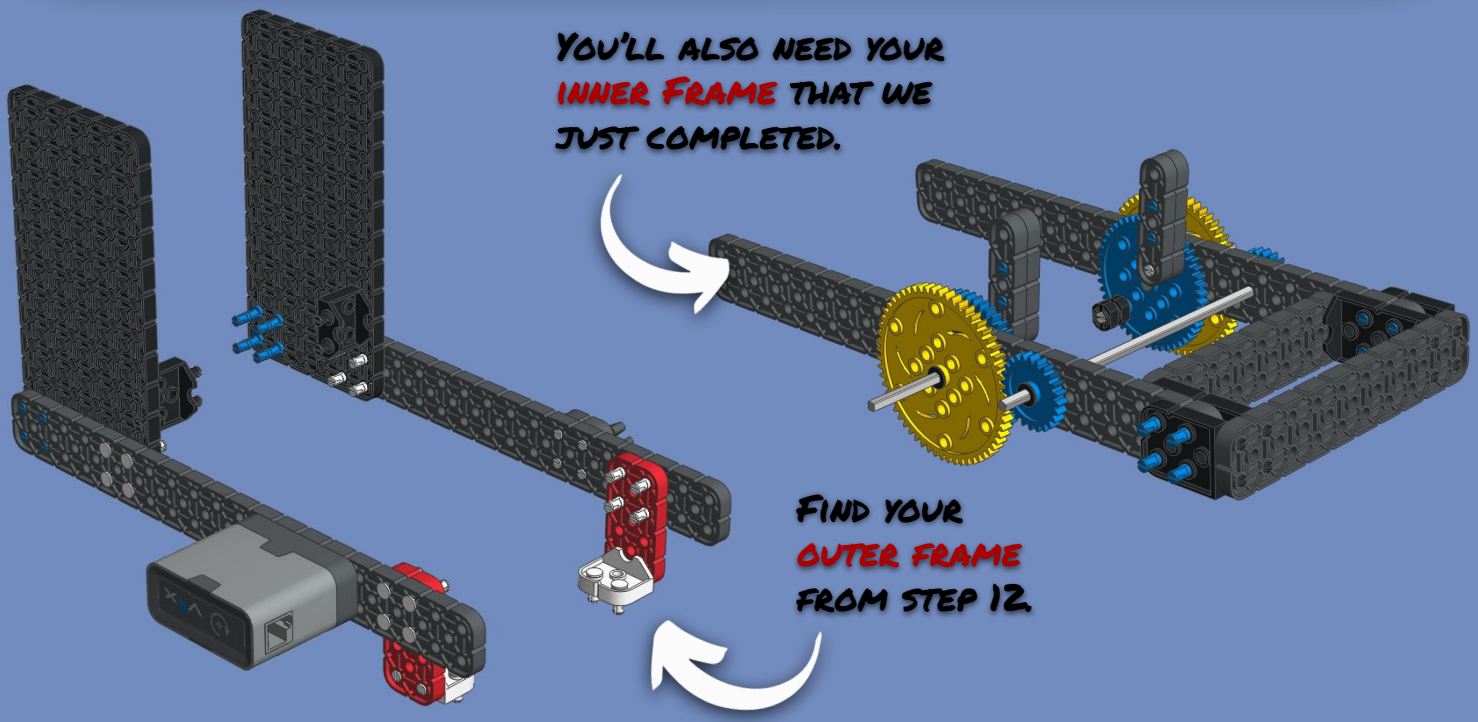
35



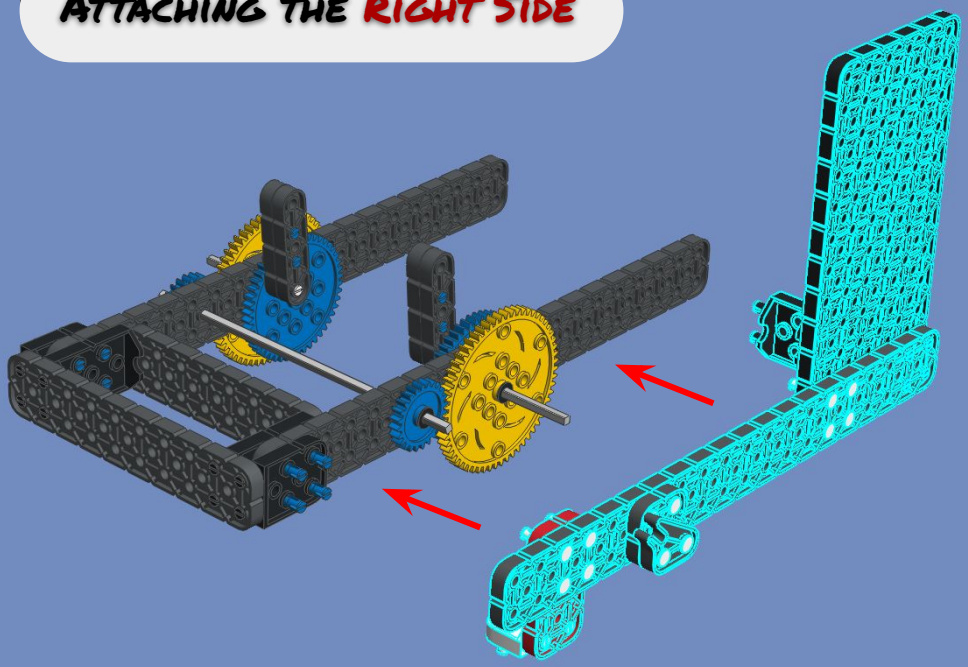


Slide a thin plastic spacer over the 24-tooth gear we added in Step 34, and another onto the 60-tooth gear.

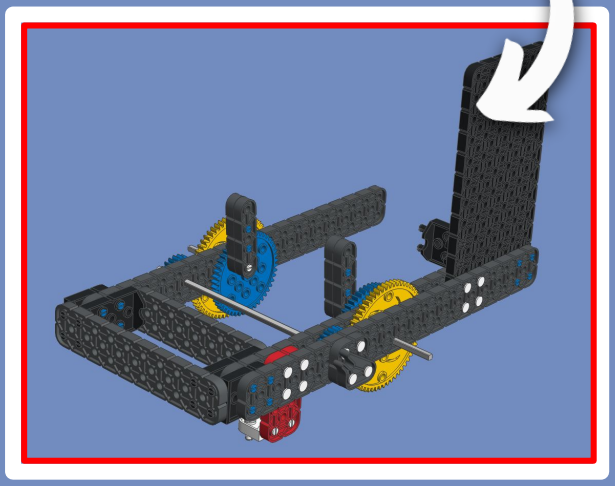
Quick Explanation: At this point, we've fully built the Inner Frame! With both the Inner and Outer Frames complete, it's time to put them together. With loose shafts and spacers on the Inner Frame, it's important to follow the CAD models closely and manipulate each piece with care because tilting or shaking the frame can break this delicate mechanism at this stage in the build.



36 Attaching the Right Side

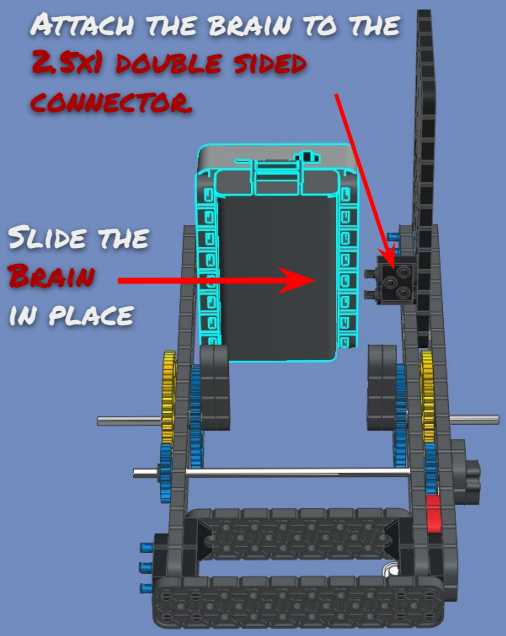


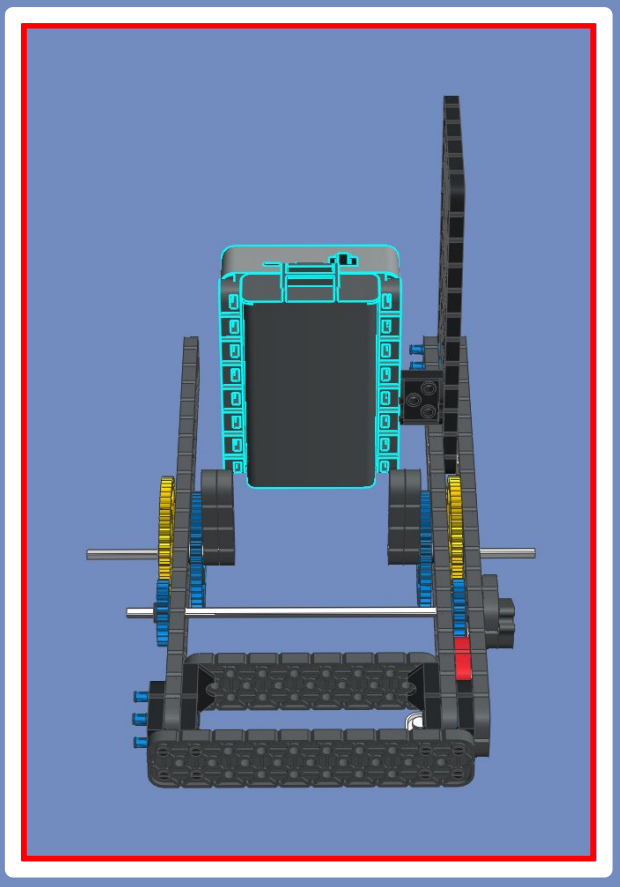
Once You complete **Step 36,** your Choo-Choo should look like this.



Working with the **Right Side** of the **Outer Frame,** carefully position the pins and shafts from the Inner and Outer Frames so that the 2x20s running down the Inner and Outer Frames align.

37 Attaching the Brain

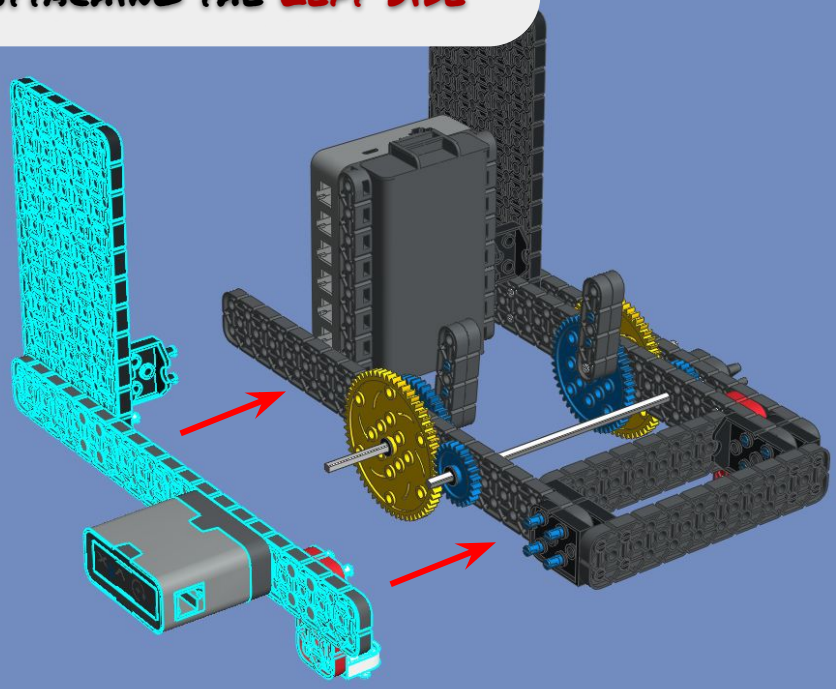




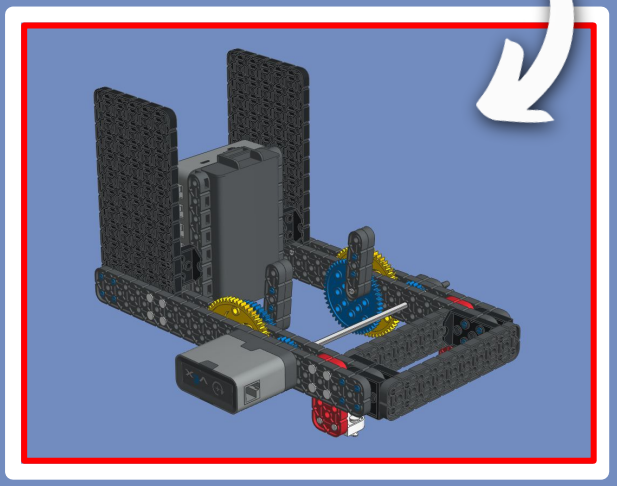
Once You complete **Step 37,** your Choo-Choo should look like this.

Before attaching the **Left Side** of the **Outer Frame,** let's quickly mount the **Brain** because mounting it later would be more difficult. Align the 2x1.5 double-sided connector in holes 3 and 4 of the brain, counting from the bottom, and slide the brain into place.

38 Attaching the Left Side



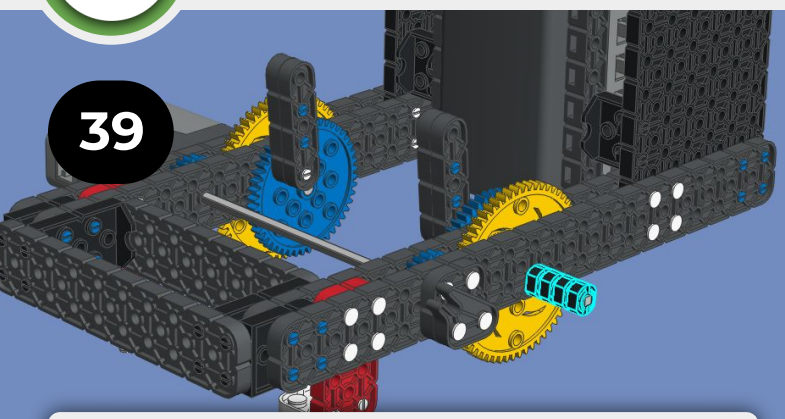
Once You complete **Step 38,** your Choo-Choo should look like this.

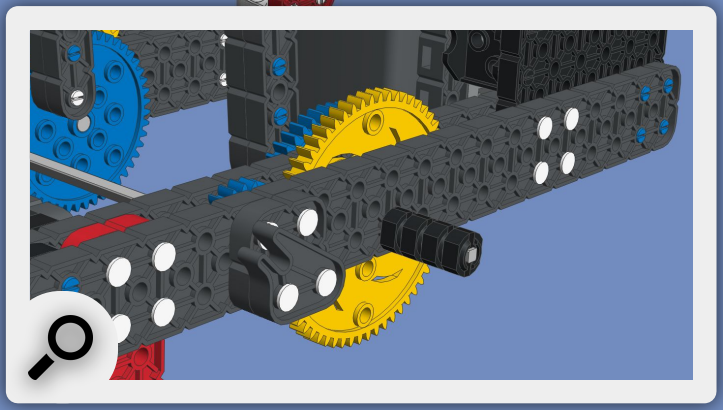


Working with the **Left Side** of your **Outer Frame,** carefully position the pins and shafts from the Inner and Outer Frames so that the 2x20s running down the Inner and Outer Frames align. ***Tip:*** *Rotate the gears slightly to easily slide the motor onto the shaft.*

With the Inner and Outer Choo-Choo Frames attached to each other, we have just a few final steps left in Section 1!

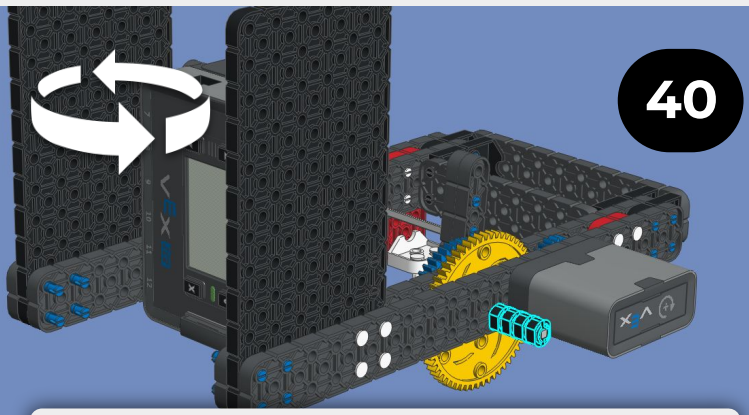
39

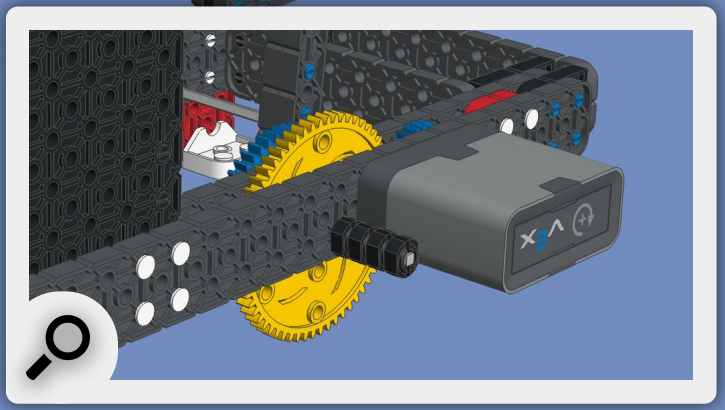




Slide four rubber shaft collars onto the end of the capped shaft that runs through the right 48-t Choo-Choo gear and 60-t gear.

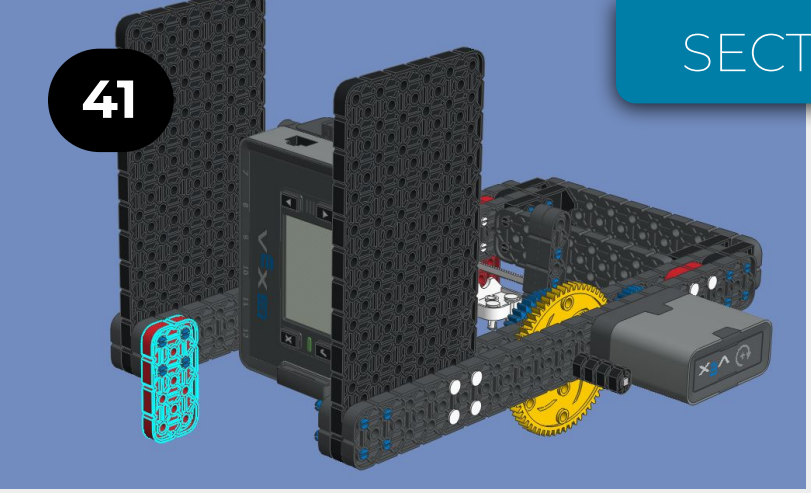
40





Mirroring Step 39, slide four rubber shaft collars onto the end of the capped shaft next to the motor.

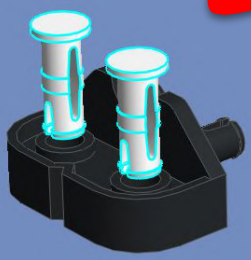
41

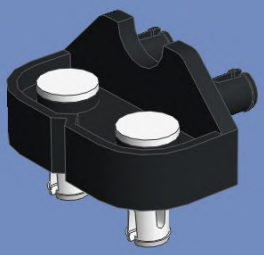


Attach a 2x4 beam over the four blue pins on one side of the inner frame, and then add another 2x4 on the other side.

2x

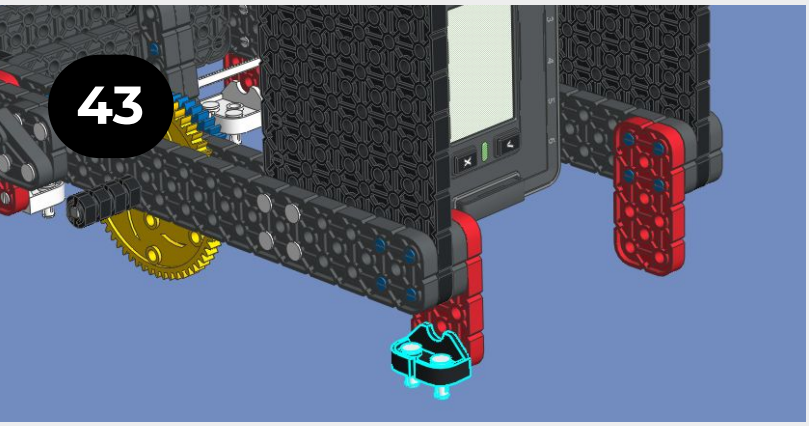
42

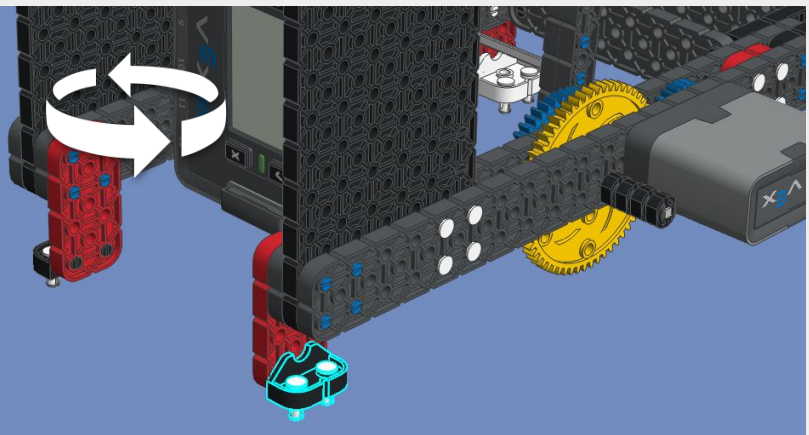




Insert two 0x2 capped pins through the top of a 1x2 connector. **Repeat this step.**

43





Insert the two connectors assembled in Step 42 into the outside bottom holes of the 2x4s from Step 41 as shown.

SECTION 2

BUILDING THE CATAPULT TRAY

With the One-Motor Choo-Choo Mechanism complete, it's time to build the Catapult Tray. We've designed our Catapult Tray to carry the 6" plush balls used in VEX IQ Rapid Relay, but this basic design can be easily adapted to shoot various game elements. Catapult Trays can take many different shapes—some are wider to hold two balls side by side, and others are longer to hold multiple balls vertically. However, this basic Tray design has served as a foundation for catapults in many games.

HOW DOES THE CATAPULT TRAY WORK?

The Catapult Tray is positioned directly above the Choo-Choo mechanism. When trying to achieve a desired shot trajectory, the Catapult Tray design is crucial. The pivot point (the point where the Tray rotates on a shaft) is primarily what determines the number of rubber bands needed, while adjusting the 1x beam linkage placement affects how fast the catapult retracts. We'll further detail these mechanical principles in Section 3.

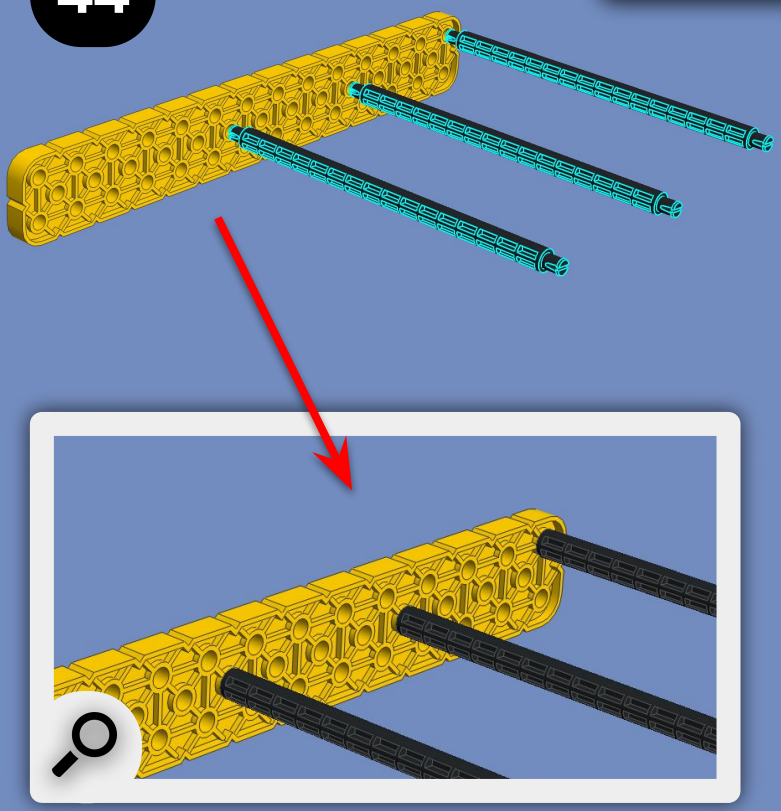
FULLY ASSEMBLED

CATAPULT CAD

STEP-BY-STEP INSTRUCTIONS ON THE FOLLOWING PAGES

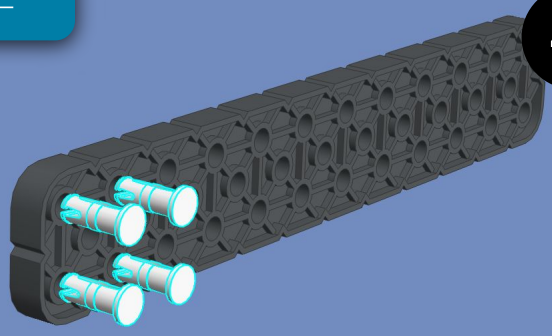
The Catapult Tray we're building in this section will be attached to the Choo-Choo Mechanism from Section 1.

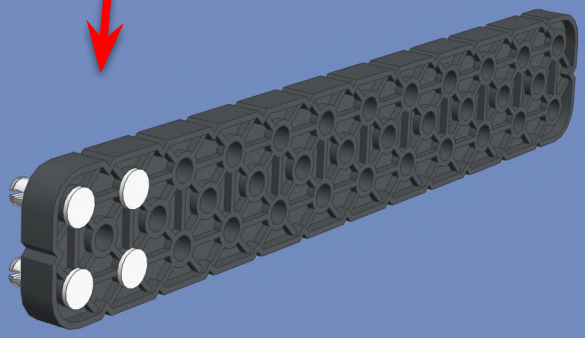
44



Insert three 8-pitch (4-inch) standoffs into a 2x14 beam—counting from the right, 1st upper hole, 4th and 8th middle holes.

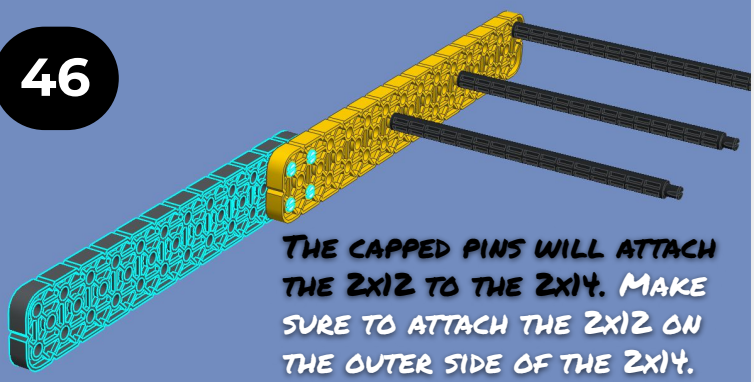
45



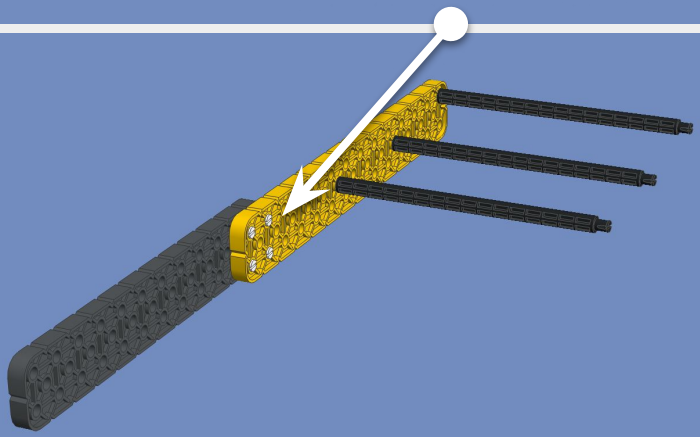


Set aside the 2x14 beam. Insert four 0x2 capped pins into the first two upper and lower holes of a 2x12 beam as shown above.

46

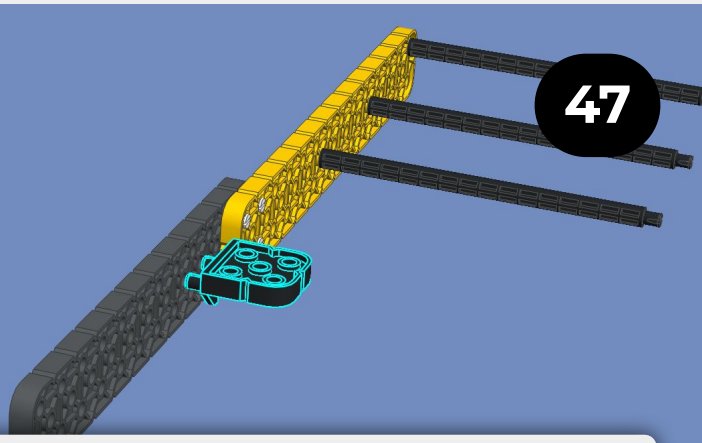


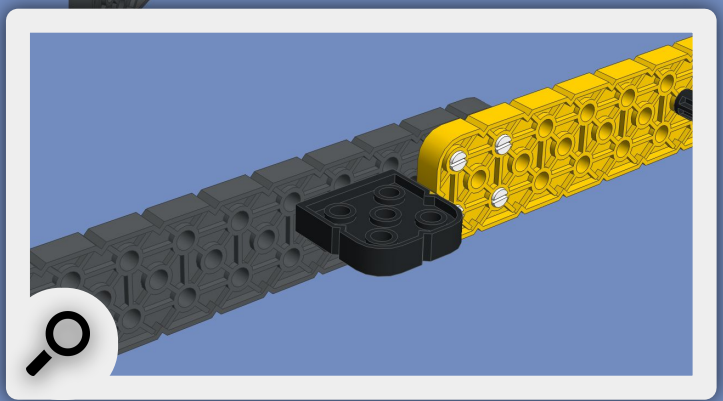
The capped pins will attach the 2x12 to the 2x14. Make sure to attach the 2x12 on the outer side of the 2x14.



Attach the 2x12 beam from Step 45 onto the **outside** of the left end of the 2x14 we assembled in Step 44.

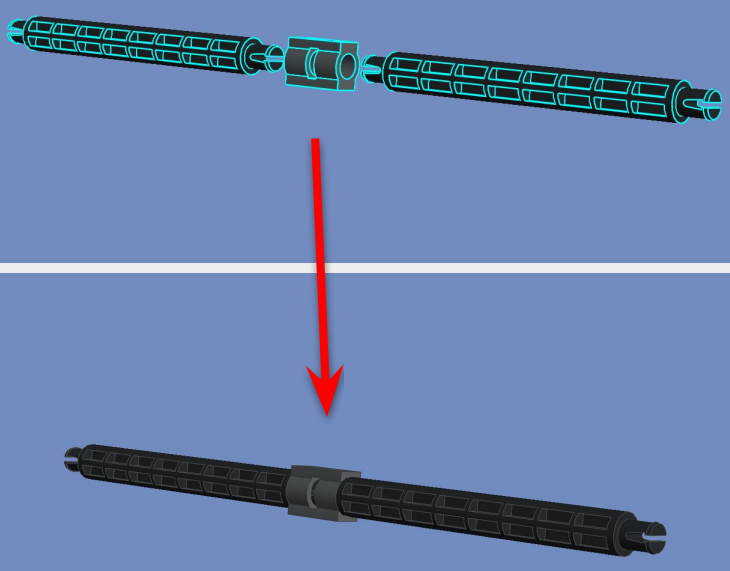
47





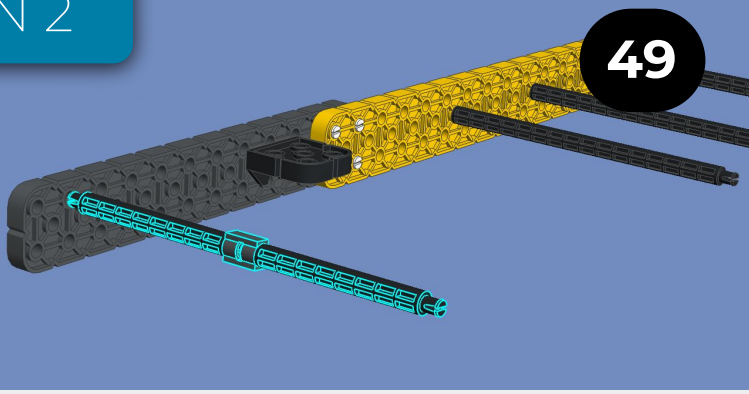
Insert a 2x2 connector into the 8th and 9th center holes of the 2x12, counting from the left.

48



Briefly set aside your Catapult Tray. Connect two 4-pitch (2-inch) standoffs together with a standoff connector.

49



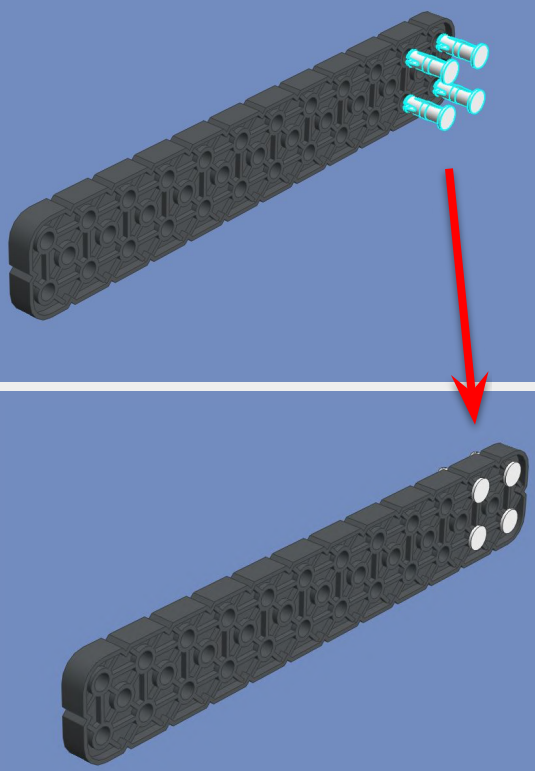
Now, take the standoffs we just connected together, and insert one end into the 2nd upper hole from the left of the 2x12.

50

PAUSE:

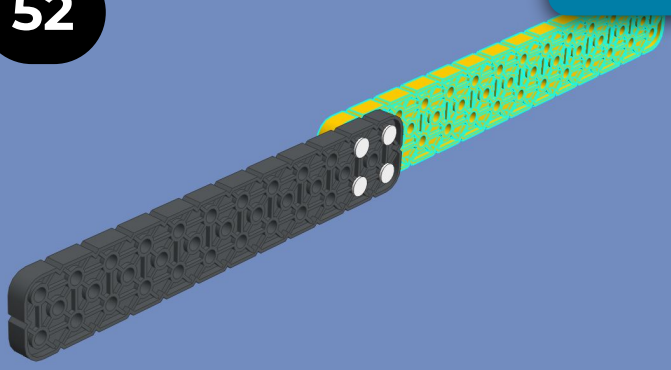
In Step 49, we completed the left side of the Catapult Tray. Now, we'll build the right side. For now, set aside your left side of the Catapult Tray—we'll come back to it later.

51



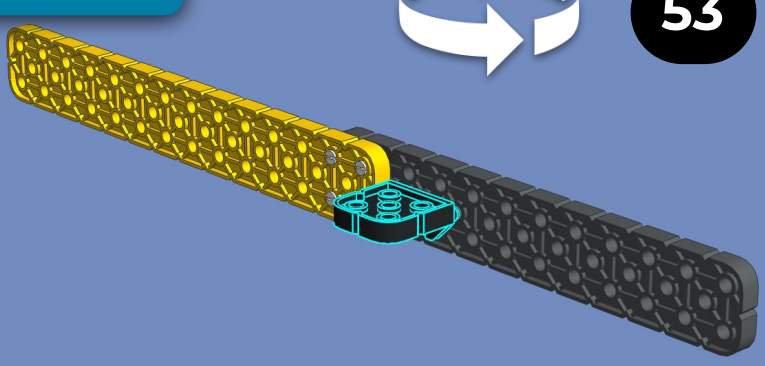
Insert four 0x2 capped pins into the first two upper holes and first two lower holes on the right end of a 2x12 beam.

52



Attach a 2x14 beam to the four open 0x2 pins sticking through the end of the 2x12.

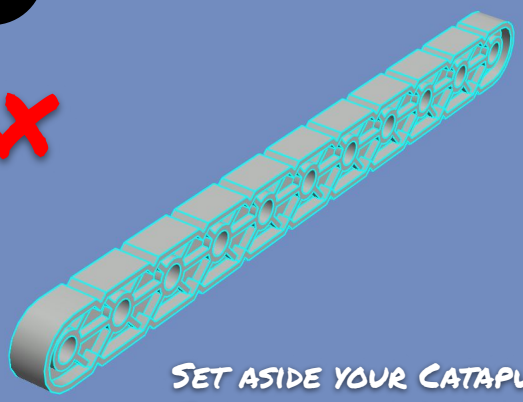
53



Insert a 2x2 connector into the 8th and 9th center holes of the 2x12, counting from the right.

54

2x



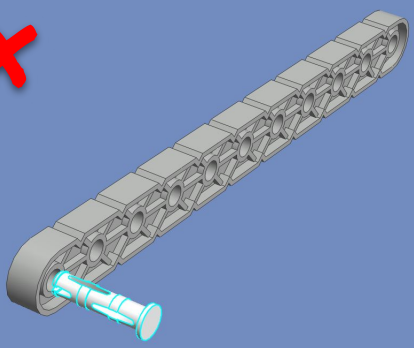
Set aside your Catapult Tray. Find two 1x11s for the catapult linkage.

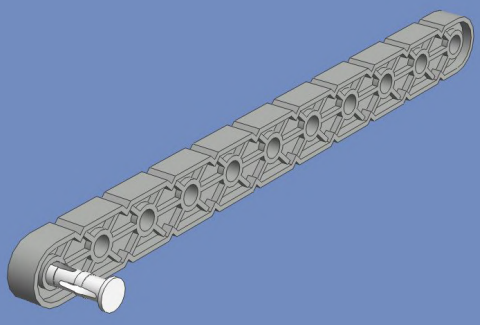
PAUSE:

In Step 53, we completed the right side of the Catapult Tray. Before connecting both sides of the frame together, let's build the catapult linkage.

2x

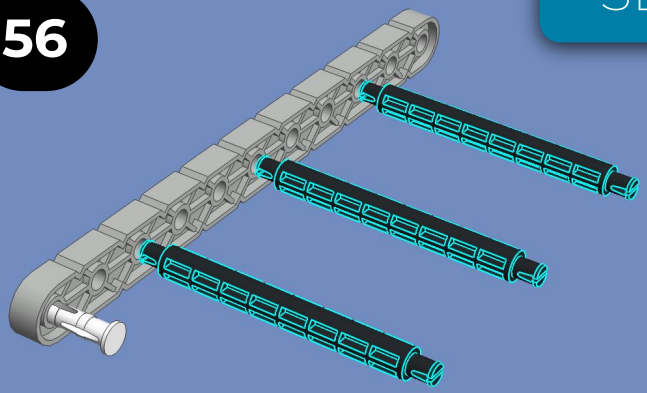
55



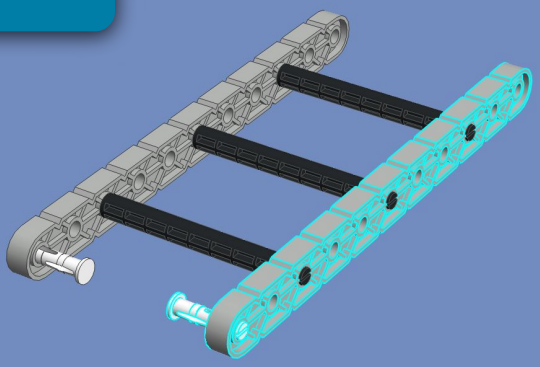


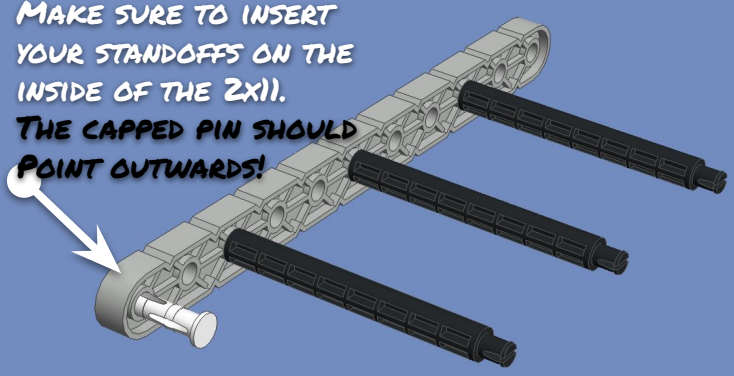
Insert a 0x3 capped pin into the left end of a 1x11. **Repeat this step.**

56

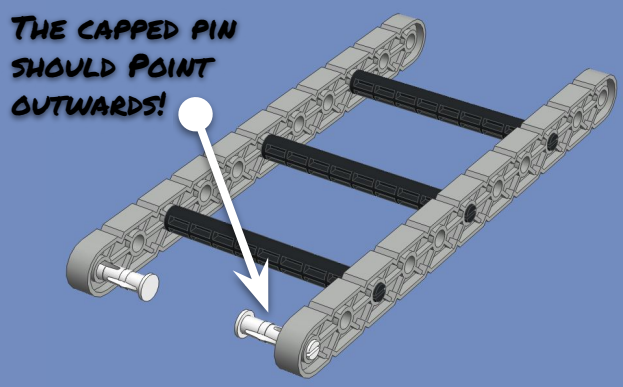


57



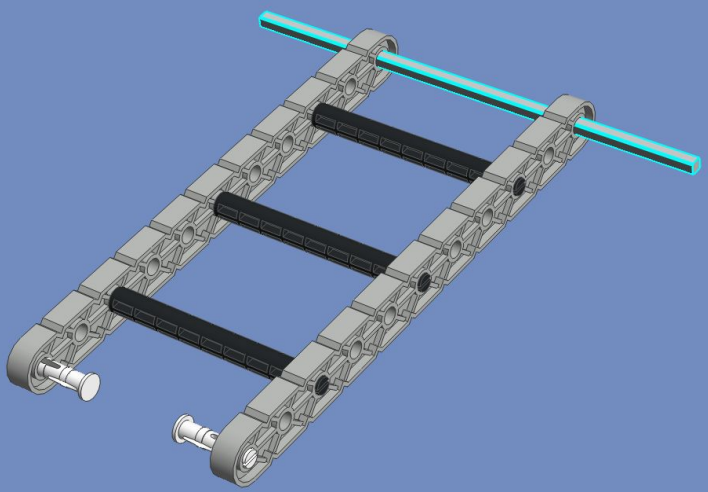


Counting from the left, insert a 4-pitch (2-inch) standoff into the the 3rd, 6th, and 9th holes of one of the 2x11s.



Now, take the other assembled 1x11 from Step 55 and attach it to the standoffs from Step 56, mirroring the other 1x11.

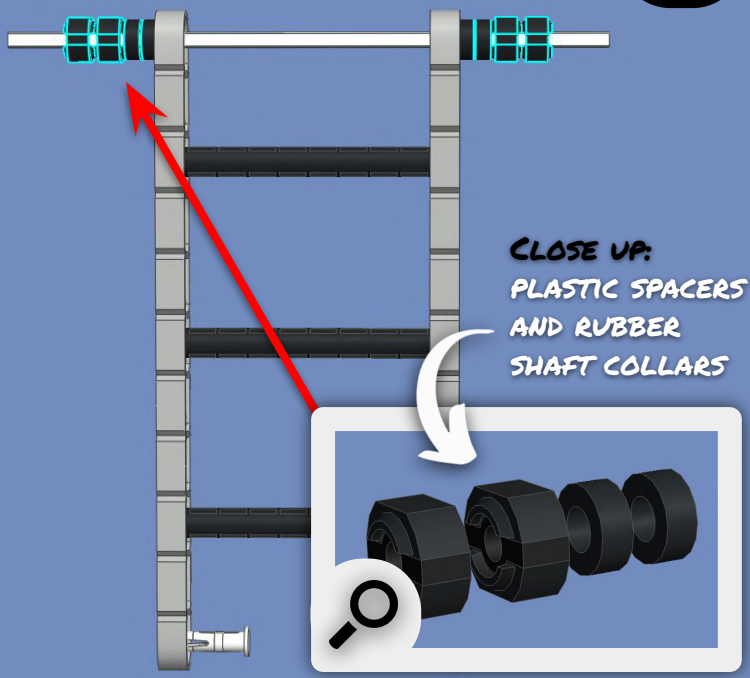
58



Insert a 5-inch metal shaft through the first hole of the 1x11s. This shaft will connect the Catapult Linkage to the Catapult Tray.

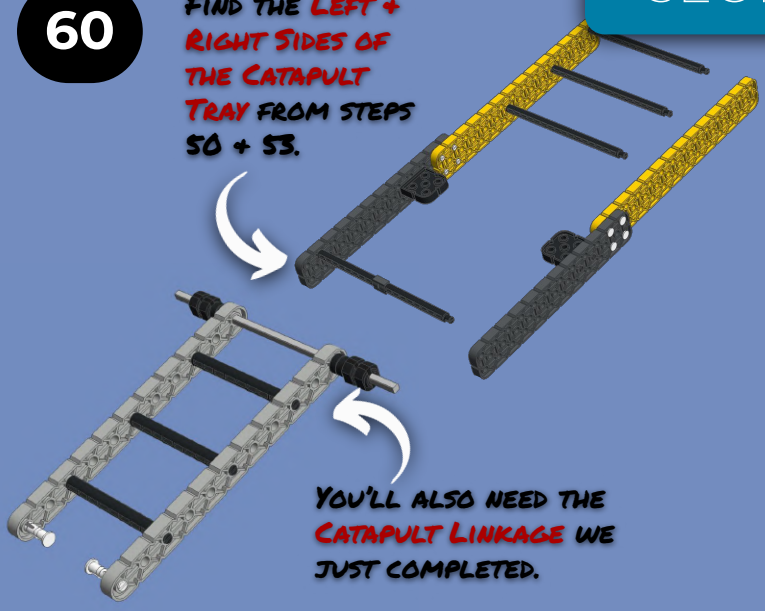
Top View:

59



Slide two plastic spacers onto each end of the 5" shaft. Then, slide two rubber shaft collars onto each end, locking everything in place.

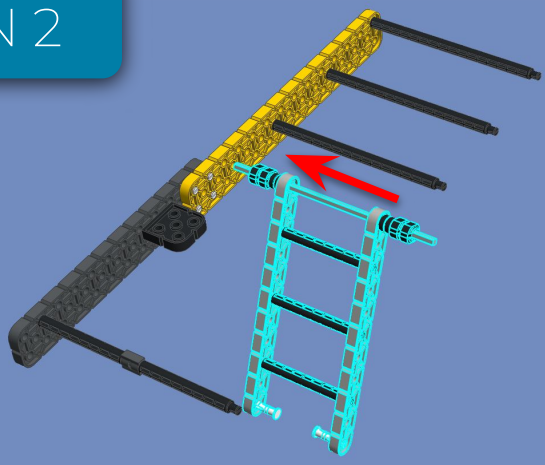
60

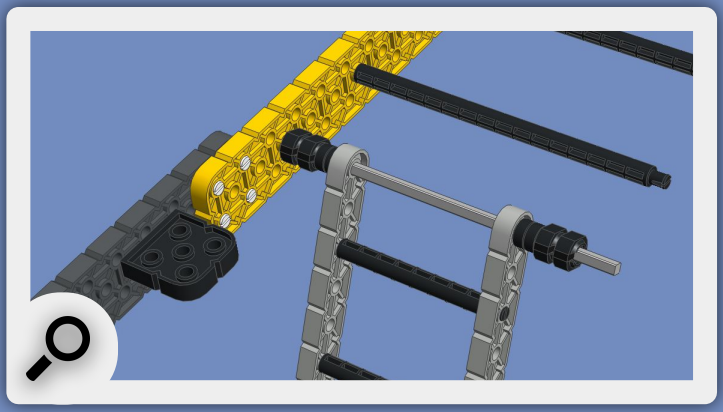


PAUSE:

In Step 59, we completed the Catapult Linkage. Find the left and right sides of the Catapult Tray we set aside in Steps 50 and 53. We'll now attach the linkage between the two sides of the Tray, and then add a few more parts to complete the Tray!

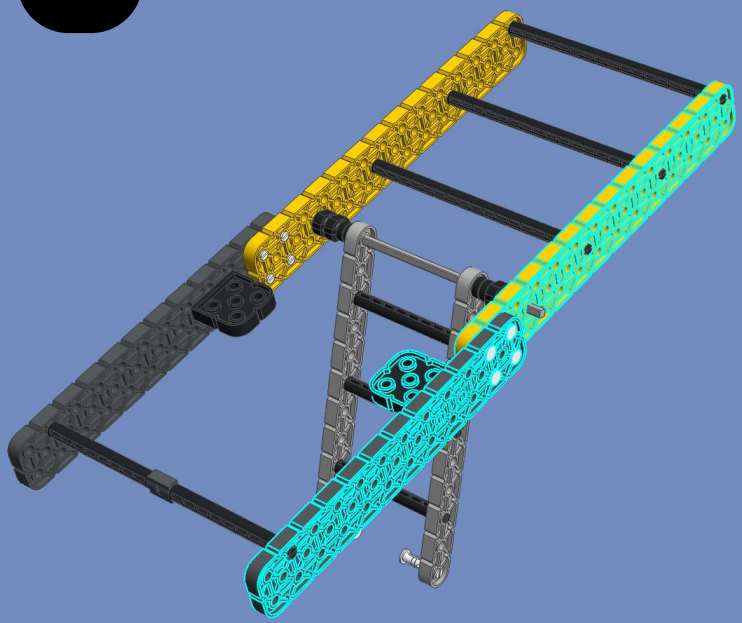
61





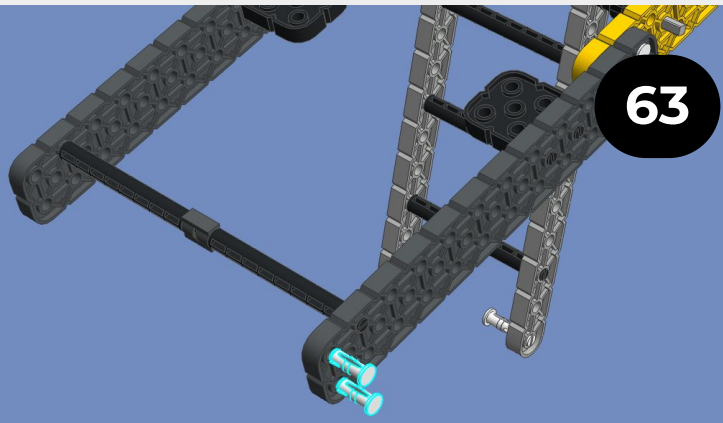
Slide one end of the shaft that runs through the linkage into the 3rd center hole of the 2x14 on the left side of the Tray.

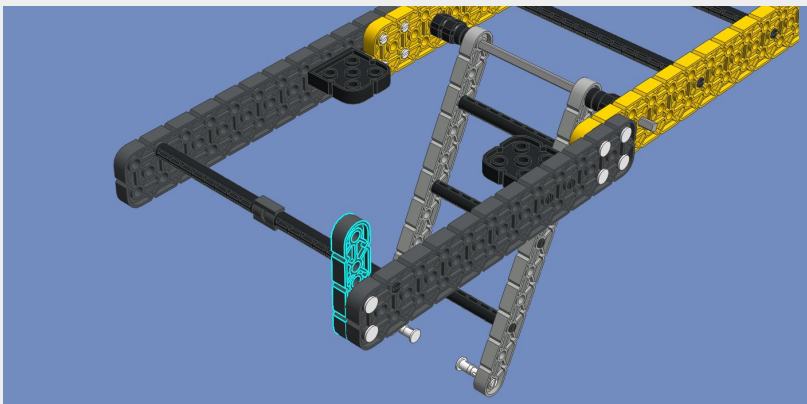
62



Slide the right side of the Tray into place, mirroring the left. Follow the CAD model closely to ensure everything is aligned.

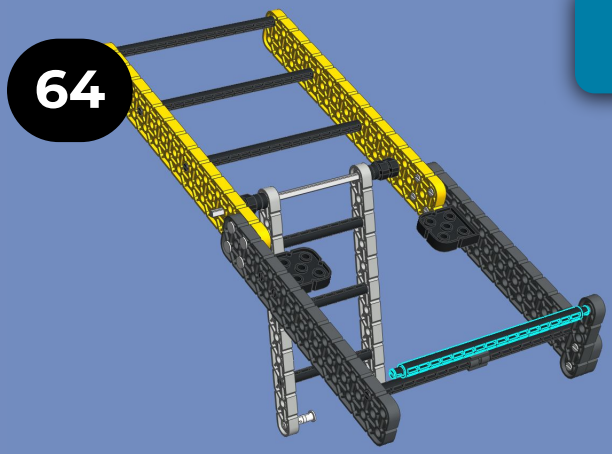
63

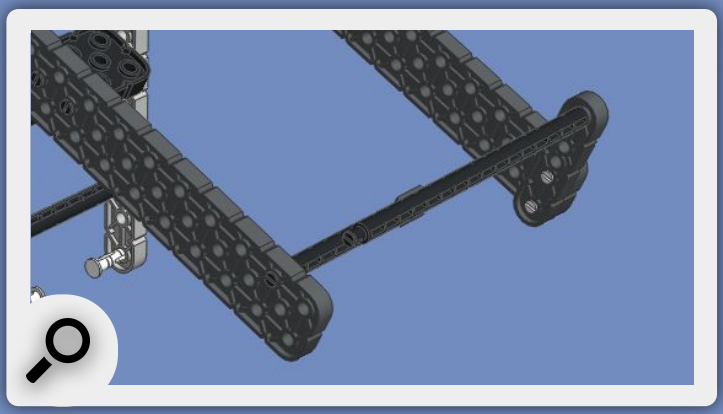




Slide two 0x2 capped pins into the first upper and lower holes of the right 2x12. Then attach a 1x4 with two holes overhanging above.

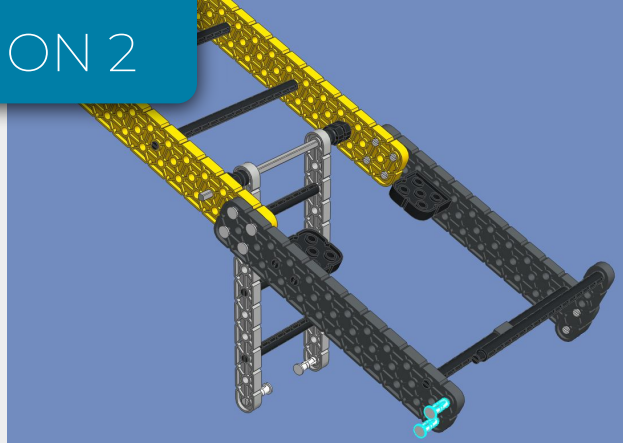
64

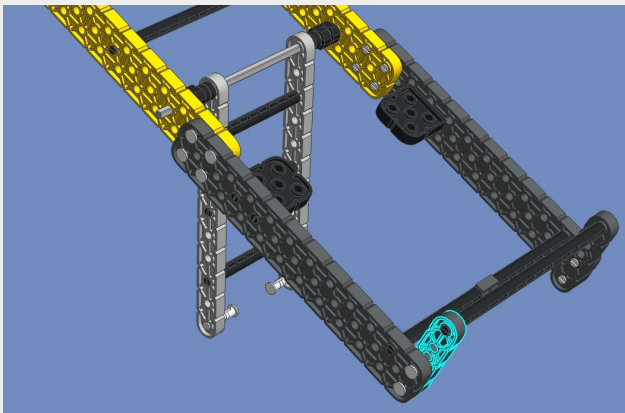




Following the CAD above, insert an 8-pitch (4 inch) standoff into the top hole of the 1x4.

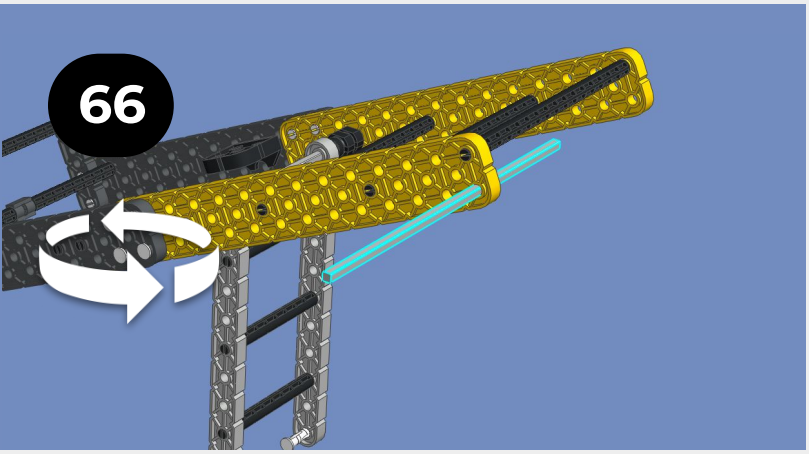
65

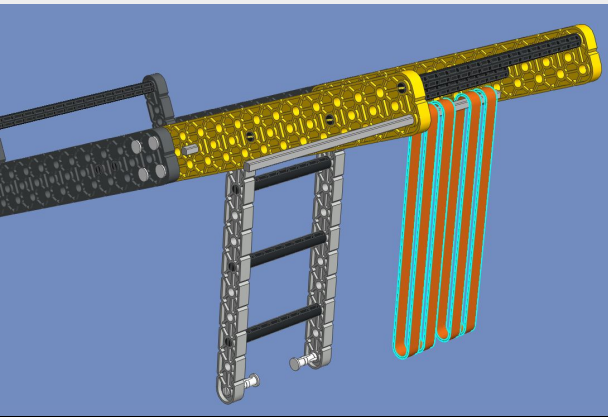




Slide two 0x2 capped pins into the upper and lower front holes of the left 2x12. Then attach a 1x4 mirroring the 1x4 on the right.

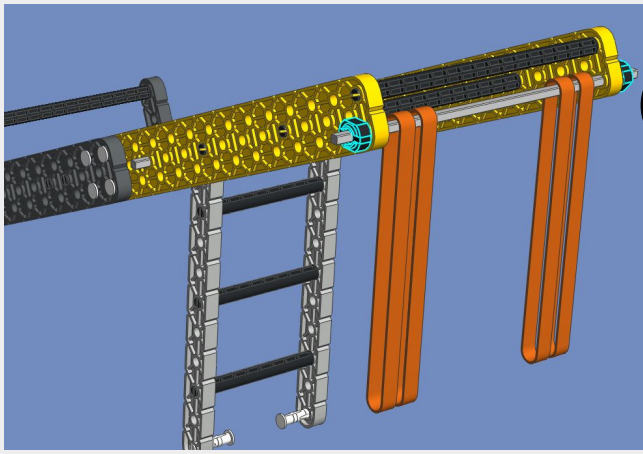
66

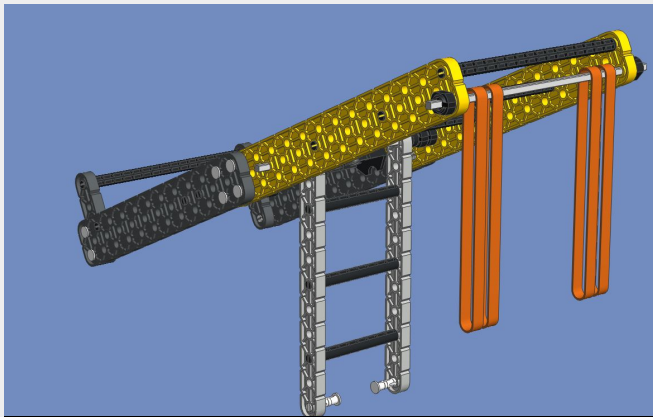




Insert a 5-inch metal shaft through the last lower hole of the right 2x14 beam. Then slide four #32 non-latex rubber bands on.

67





Push the shaft all the way through the left 2x14 beam, and then slide a rubber shaft collar onto each end of the shaft.

PAUSE—LET'S CHECK OUR PROGRESS.

What have we done so far?
At this point, we have fully completed the Catapult Tray. Now, all that's left to do is mount the Tray to the Choo-Choo. We'll cover these final steps in the following pages of this section, but first, let's take a closer look at the Tray.

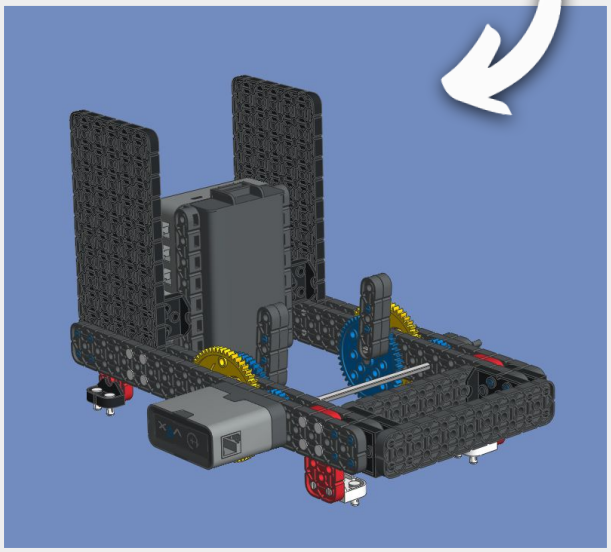
CHECK TO ENSURE THAT YOUR CATAPULT TRAY MATCHES THIS CAD MODEL.

If it doesn't, go back and review each step closely.

Quick Prep:
Find your Choo-Choo mechanism from section 1. We'll use it in the following steps.

Tip: *Create a durable Catapult Linkage*

In our final shot at the State Championship match in VEX IQ Pitching In, our Choo-Choo linkage exploded upwards, disconnecting from the Choo-Choo. After that experience, we learned that there are two keys to a durable linkage. First, using capped pins (specifically size 0x3) holds the beam in place. Second, using a shaft as a *hard stop* (we use the shaft holding the rubber bands) absorbs the pressure of the shot, effectively transferring that force away from the linkage. With these tricks, our catapult linkage hasn't broken since!

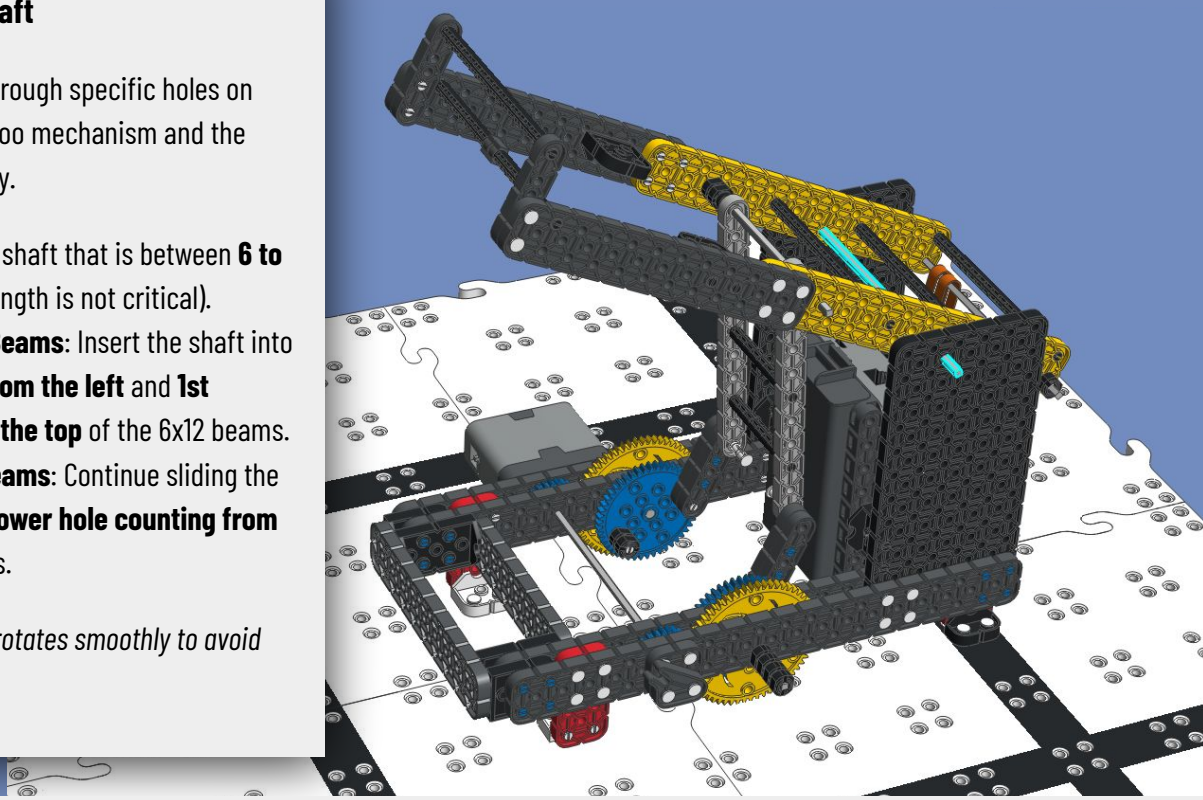


Inserting the Pivot-Point Shaft

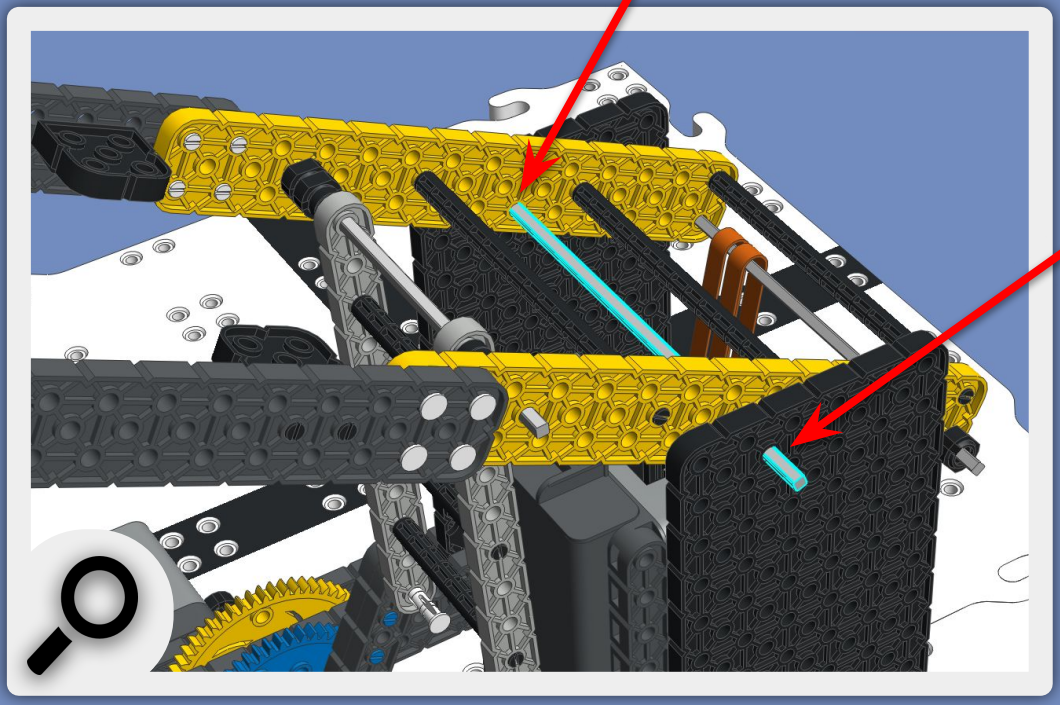
In this step, we'll slide a shaft through specific holes on the **6x12 beams** of the Choo-Choo mechanism and the **2x14 beams** of the Catapult Tray.

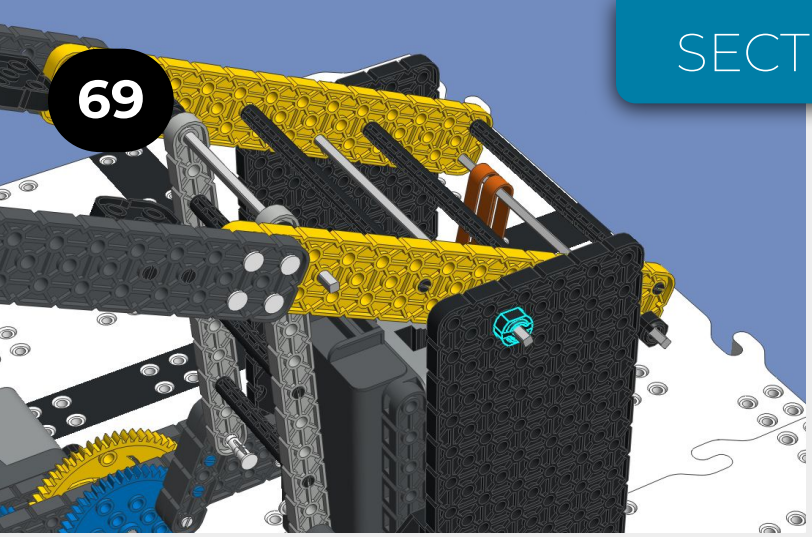
1. **Choose a Shaft**: Use a shaft that is between **6 to 8 inches long** (exact length is not critical).
2. **Position on the 6x12 Beams**: Insert the shaft into the **2nd middle hole from the left** and **1st middle hole row from the top** of the 6x12 beams.
3. **Align with the 2x14 Beams**: Continue sliding the shaft through the **6th lower hole counting from right** of the 2x14 beams.

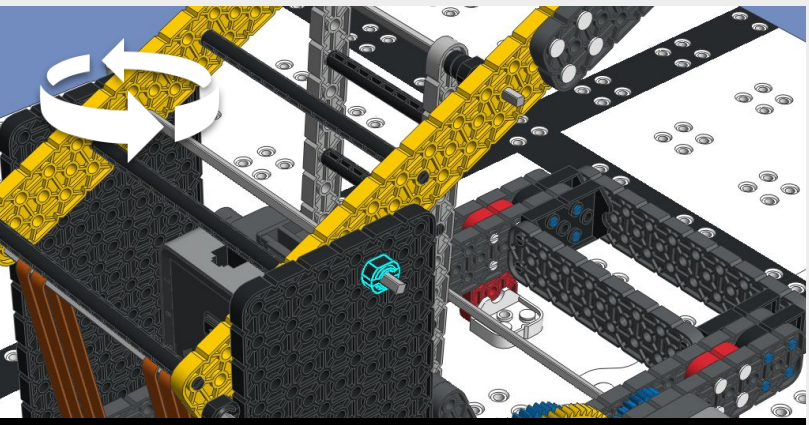
Ensure the shaft is straight and rotates smoothly to avoid binding or misalignment.



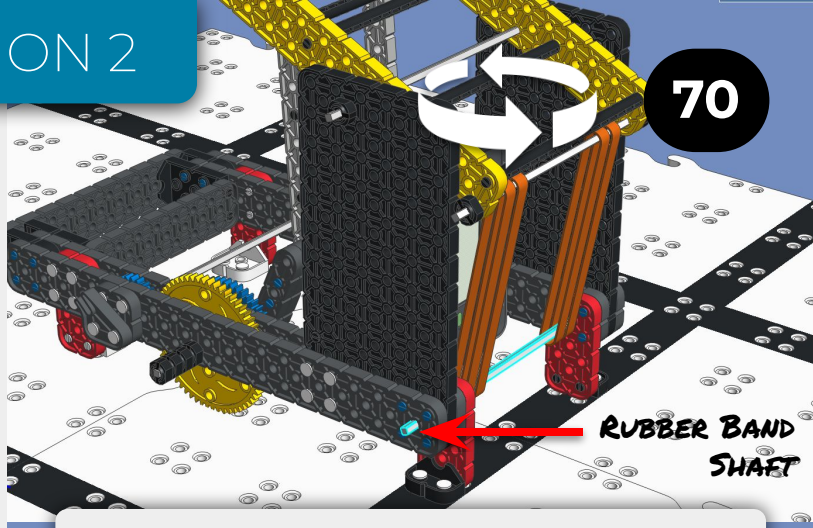
Close Up: Pivot Point

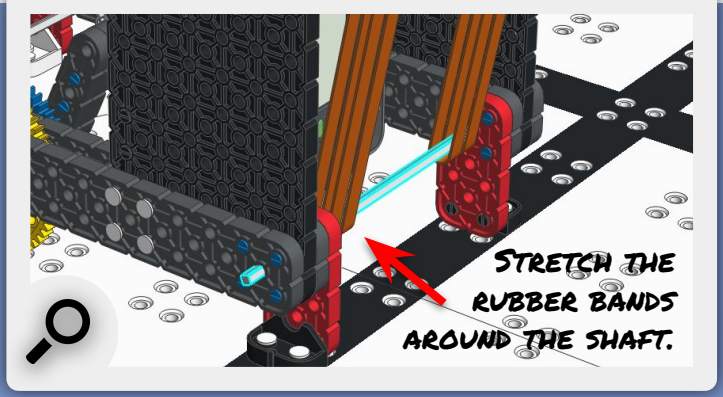




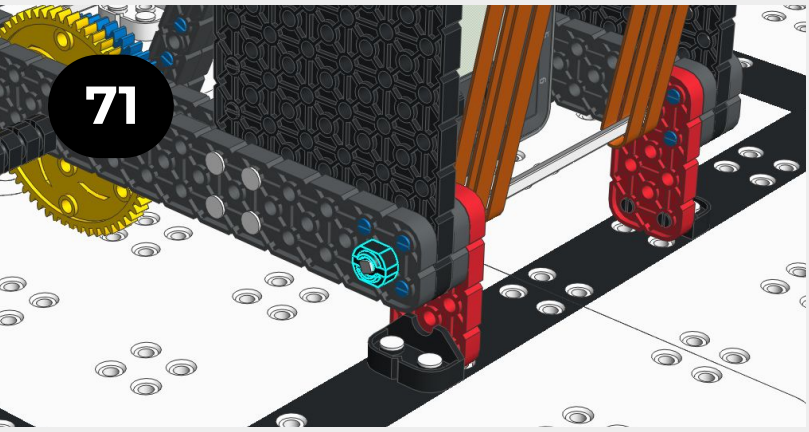


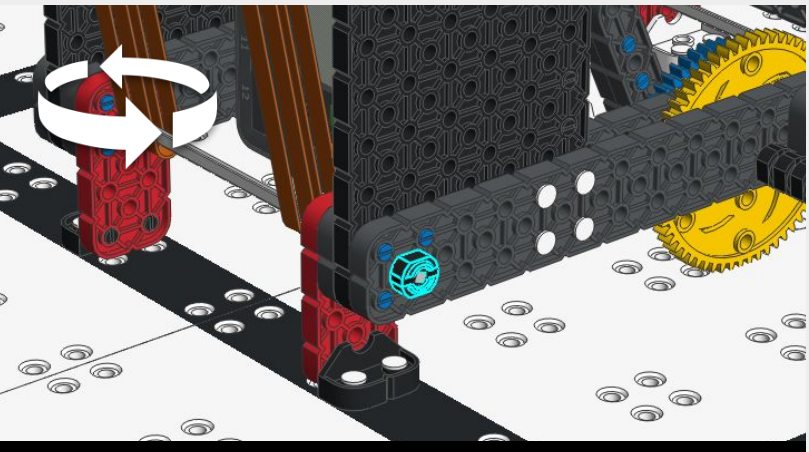
Slide a rubber shaft collar onto the left end and another onto the right end of the Pivot-Point shaft from Step 68.



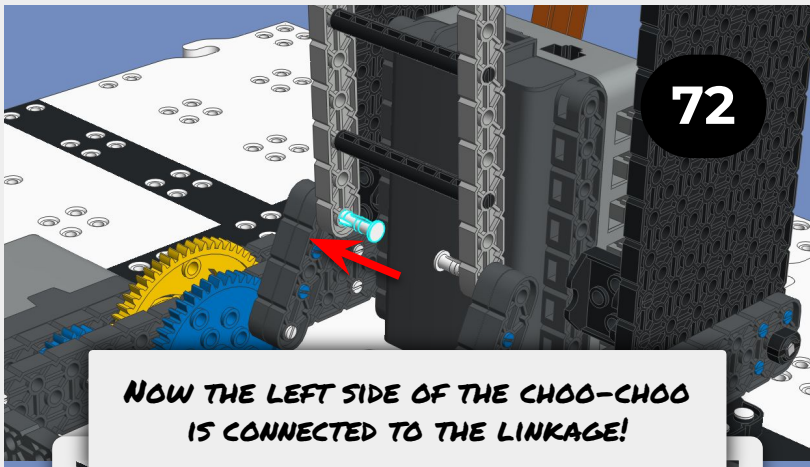


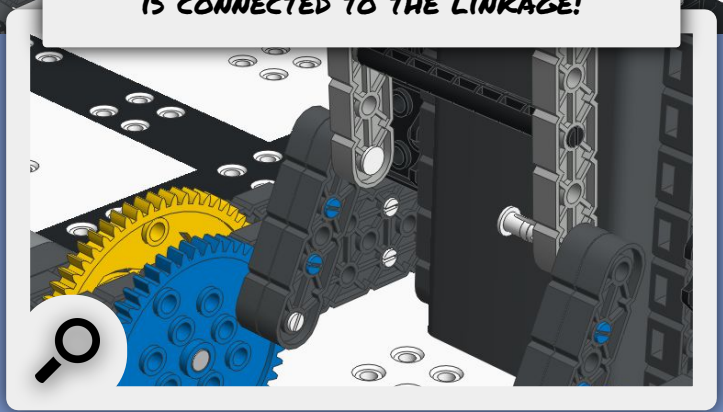
Slide a 6-inch metal shaft through the first middle hole in the 2x20 frame beams, stretching the rubber bands around the shaft.



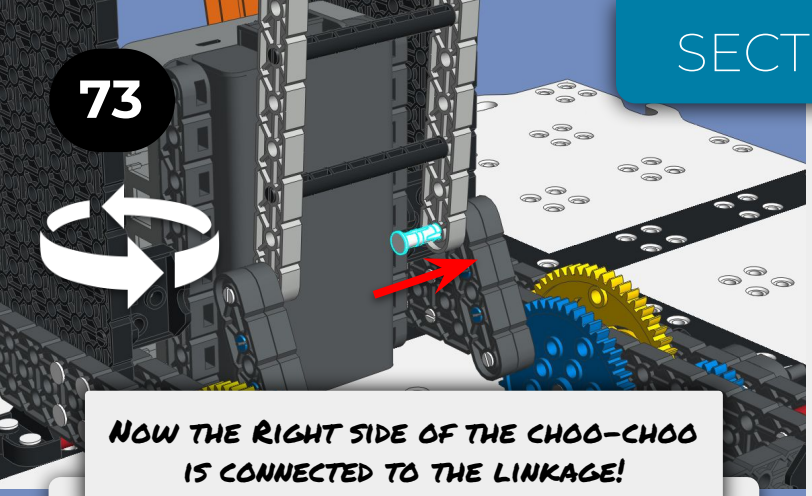


Slide a rubber washer onto each end of the rubber band shaft from Step 70.

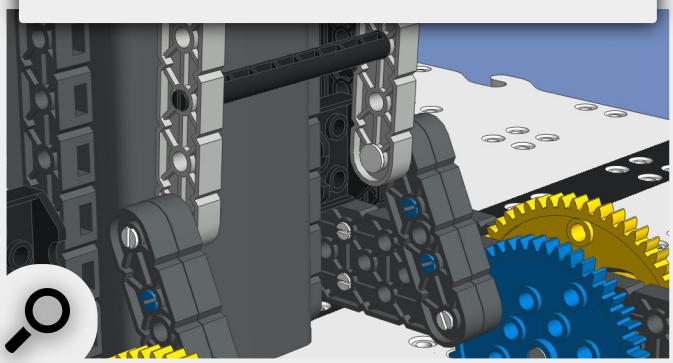




Push the 0x3 capped pin all the way into the top hole of the 1x4 beams on the left side of the Choo-Choo.



NOW THE RIGHT SIDE OF THE CHOO-CHOO IS CONNECTED TO THE LINKAGE!



Mirroring the left side, push the 0x3 capped pin all the way into the top hole of the 1x4 beams on the right side of the Choo-Choo.

YOU DID IT!

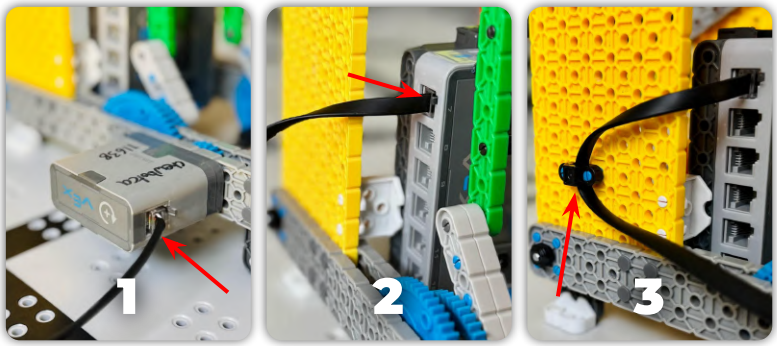
Congrats, you completed the Catapult!

GO A STEP FURTHER

WIRING YOUR CATAPULT + BASIC CODING

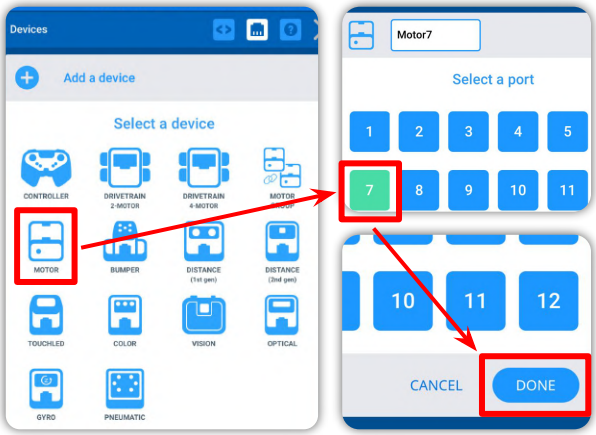
Wiring

1. Insert one end of a **300mm wire** into the motor port.
2. Insert the other end of the wire into **Port 7** of the brain.
3. ***Optional Cable Routing:*** *Attaching a cable holder onto the left 6x12 beam, holding the cable in place.*



Basic Coding

In the *devices* menu of VEX IQ Code Blocks, add a **motor,** select **Port 7,** and click **DONE.**



Tip: *Consider experimenting with this basic programming setup and a* ***2nd Gen Distance Sensor*** *to retract your catapult to an exact position with just the click of a button!*

SECTION 3

IMPROVING YOUR CATAPULT

Now that your catapult is built, it's time to fine-tune its performance. ***In this final section, we'll guide you through troubleshooting, adjusting, and optimizing your catapult.***

Fine tuning the catapult:

Even a well-built catapult may not perform perfectly right away because of minor errors in the construction. This section will help you identify and fix common problems, while introducing key concepts to streamline the tuning process. Finally, we'll explore some common catapult modifications to help you unlock the full potential of your mechanism.

TROUBLESHOOTING **ADJUSTING** **OPTIMIZING**

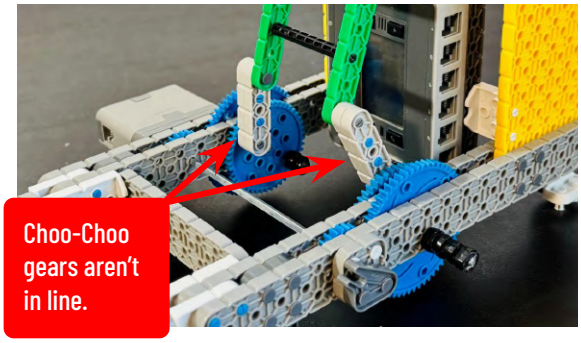
TROUBLESHOOTING

Misaligned Choo-Choo Gears

Misaligned Choo-Choo Gears *are one of the most common challenges teams face when building a Choo-Choo mechanism for the first time. To help avoid this issue, we'll explain how to identify misaligned gears and provide simple steps to fix them.*

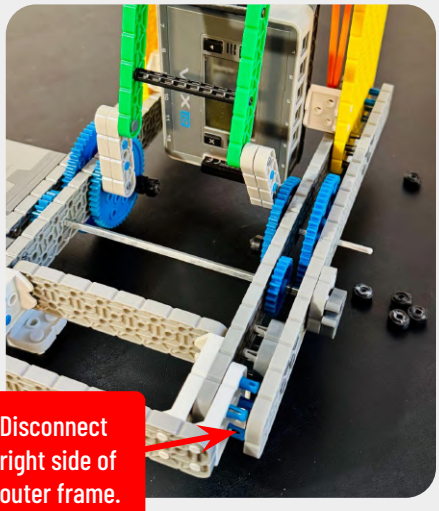
What are Misaligned Choo-Choo Gears?

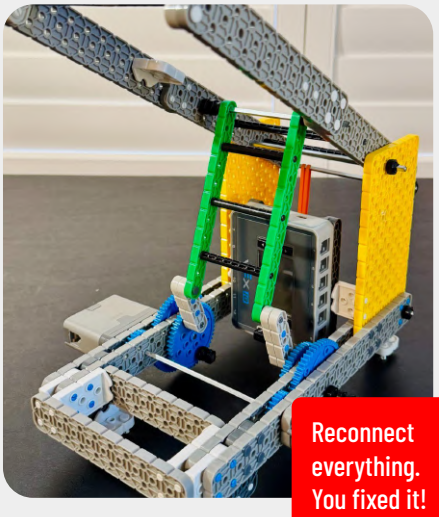
Often when installing the 48-tooth Choo-Choo gears in Steps 27-35, one 48-tooth gear will be rotated to a different position than the 48-tooth gear on the opposite side. If these gears don't rotate together, the linkage won't receive even pressure from the left and right 48-tooth gears, causing the Catapult Tray to retract and shoot unevenly.



Fixing Misaligned Choo-Choo Gears:

1. Remove the 5 rubber shaft collars from the right side of the outer frame.
2. Disconnect the right side of the outer frame from the inner frame.
3. Slide the right 60-tooth gear outwards so that it no longer touches the 24-tooth gear.
4. Rotate the right 48-tooth gear until it aligns perfectly with the left 48-tooth gear.
5. Slide the 60-tooth gear back into place, reconnect the outer frame and slide the 5 rubber shaft collars back into place.





ADJUSTING

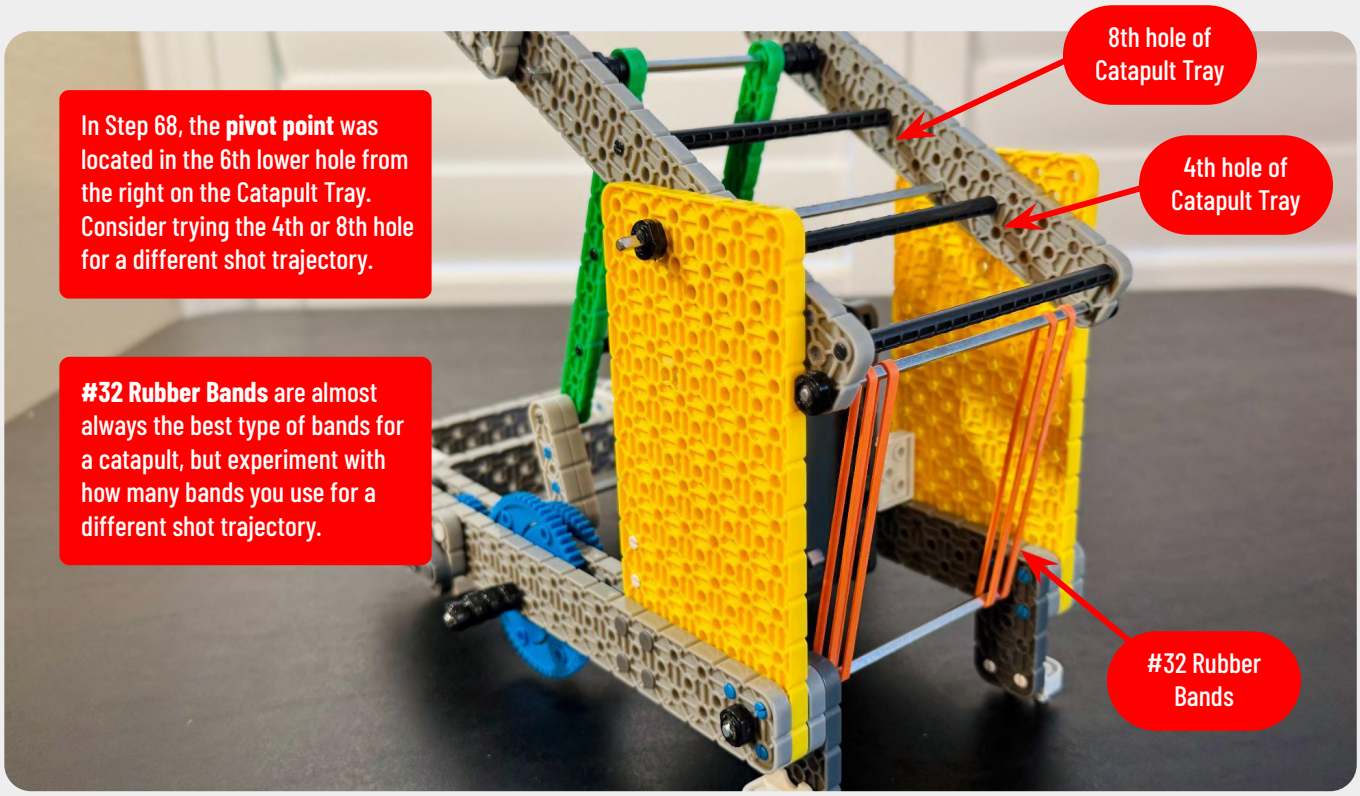
Shot Trajectory

When the catapult is first built, it likely won't hit the desired trajectory. However, you can experiment with several adjustments to improve its accuracy.

The 2 factors that affect shot trajectory most

Pivot Point: The pivot point is where the Catapult Tray rotates on a shaft. Moving this shaft closer to the front of the tray increases shot power but lowers the trajectory, creating a cannon-like shot. Shifting the pivot point toward the back of the tray reduces power but raises the trajectory for a higher arc.

Rubber Bands: Rubber bands create tension in the catapult. Through rigorous testing, we've found that #32 non-latex rubber bands create the most reliable and consistent shot. Adding more rubber bands increases the shot power, but the number of rubber bands you'll need is closely connected to the position of the pivot point.



OPTIMIZING

Shot Control Systems

*If you're looking to take your One-Motor Choo-Choo Catapult to the next level, consider experimenting with a **shot control system** to change your shot trajectory mid-match.*

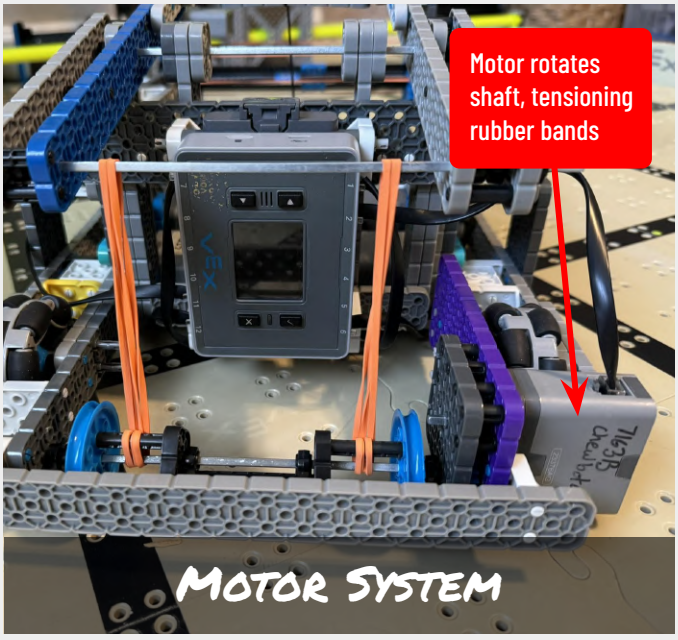
2 common ways of varying shot trajectory mid-match

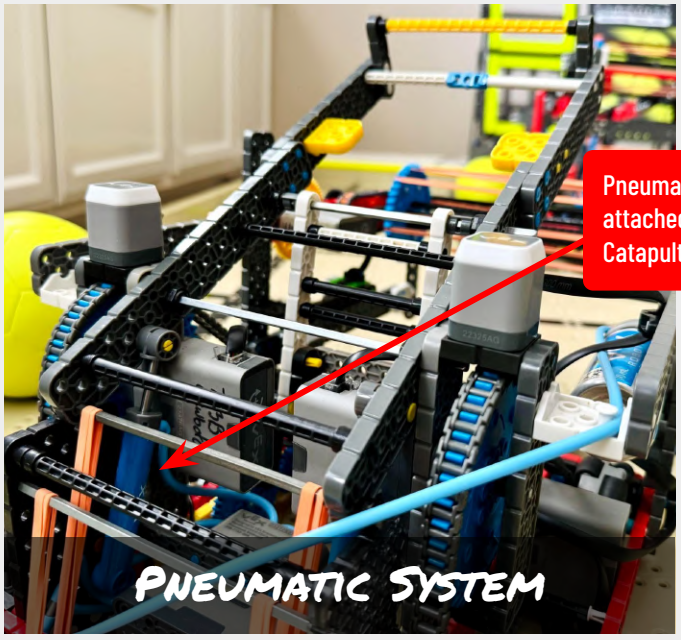
Motor-Based System: An easy way to change the power of your catapult shot mid-match is to implement a motor-based tensioning system. These systems work by rotating the shaft that holds the rubber bands. As the rubber bands wind around the shaft, the tension increases, resulting in a more powerful shot.

Pneumatic-Based System: A more advanced way to vary shot power mid-match is by using a pneumatic system mounted directly to the Catapult Tray. The advantage of this system is that it doesn't require an additional motor. However, tuning a pneumatic system can be challenging. We recommend starting with a motor-based tensioning system before experimenting with pneumatics.

Here are 2 different shot control systems:

Take them as inspiration for your own catapult!





VIDEO TUTORIAL

Check out our youtube video to see the catapult in Action!

THESE INSTRUCTIONS WERE PRODUCED ENTIRELY BY THE STUDENTS OF CHEWBOTCA.