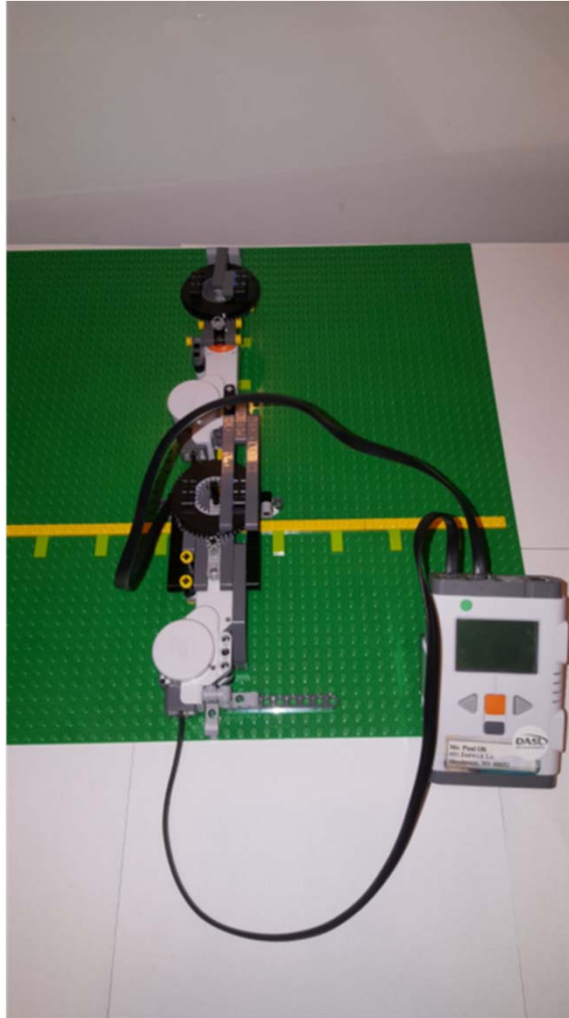


LEGO 2D Planar Manipulator

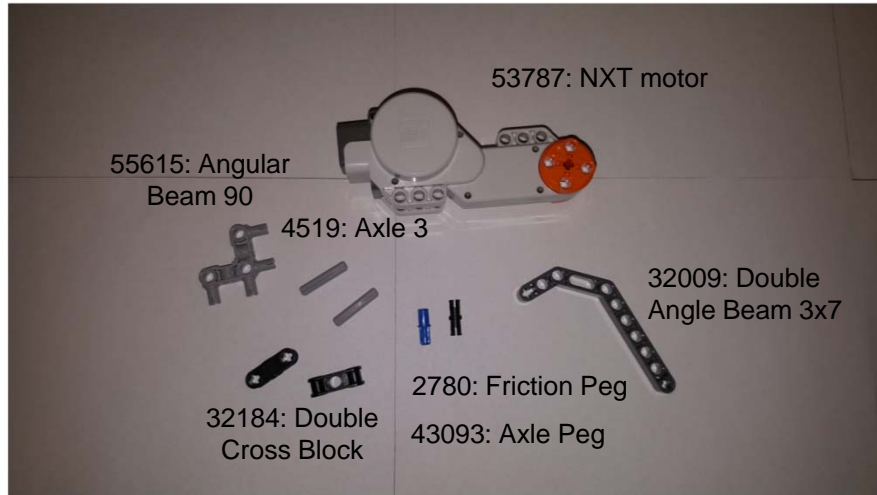
(with zero offset between Z1 and Z2 axes of rotation)



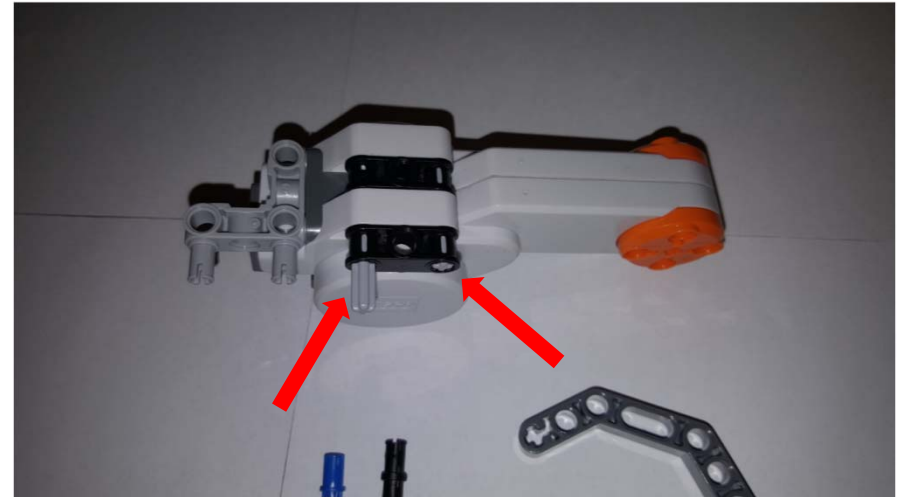
Uses some parts not found in NXT Mindstorms Kit 9797 e.g. 2nd Turntable, 1x12 plates, and **15100**: Pin-hole Friction Peg. Assembly plans last updated 01/15/18. Demo: <https://youtu.be/423IB09-Zb4> - and ikPlanarNoOffset2_0.nxc

Degree-of-Freedom (DOF) 1: Base

Step 1: DOF 1 (Base) Motor assembly



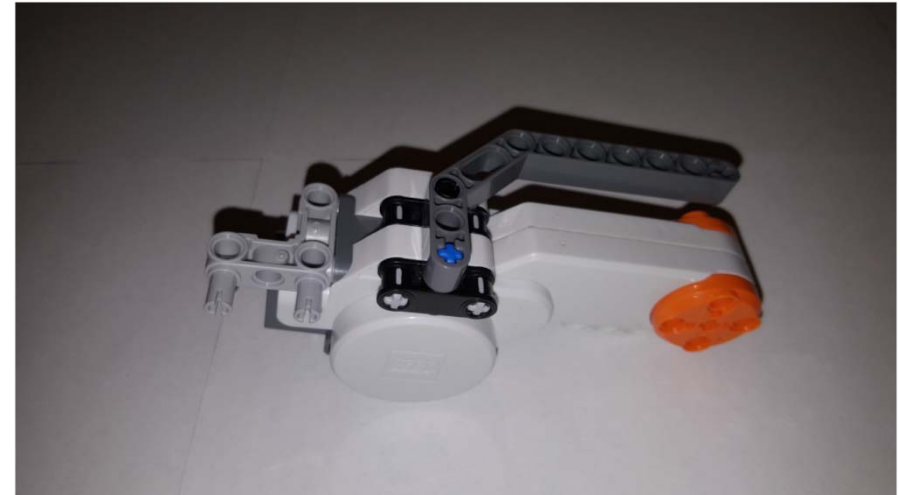
1A: Base and turntable fixture points – gather parts



1B: Mount Double Cross Blocks into NXT motor. Secure with two Beam 3 pieces. Mount Angular Beam 90 in motor



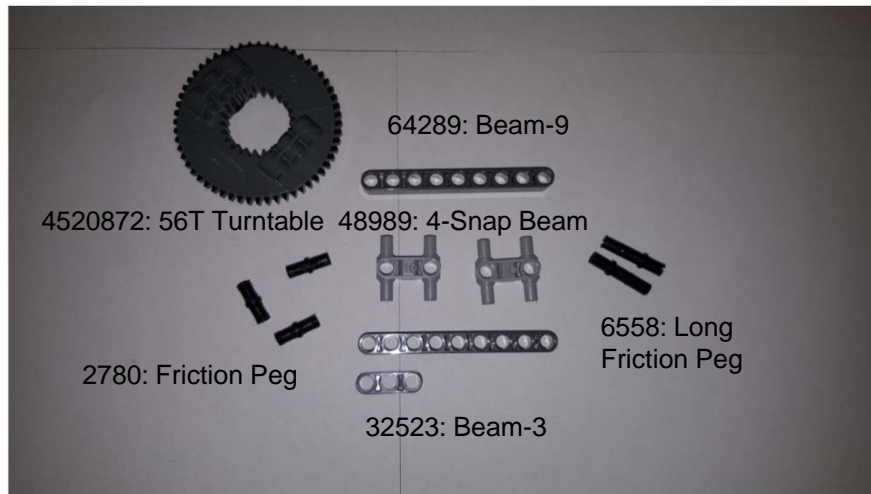
1C: Mount Friction and Axle Pegs into Double Cross Blocks.



1D: Attach Double Angle Beam 3x7. Beam will serve as hold Joint 1 turntable

Degree-of-Freedom (DOF) 1: Base

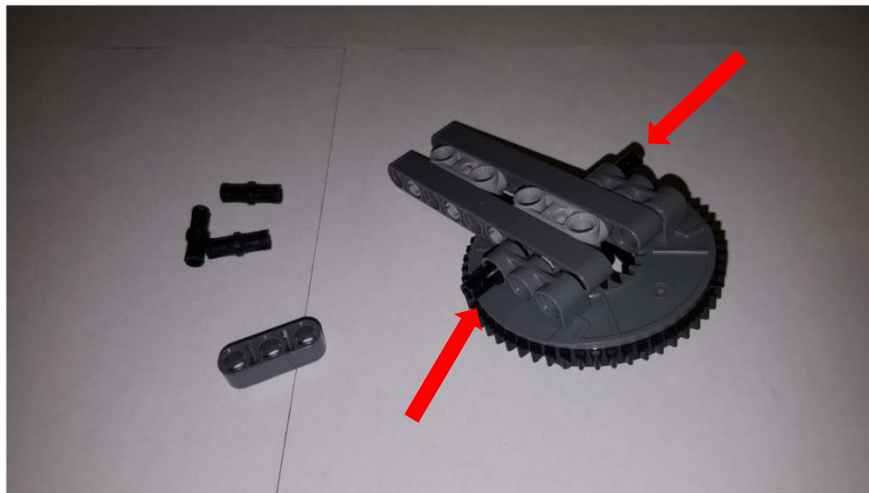
Step 2: Link 1 and Joint 1 Assembly



2A: Link 1 and Joint 1 – gather parts



2B: Create Link 1 - mount 4-Snap Beams into a Beam-9.



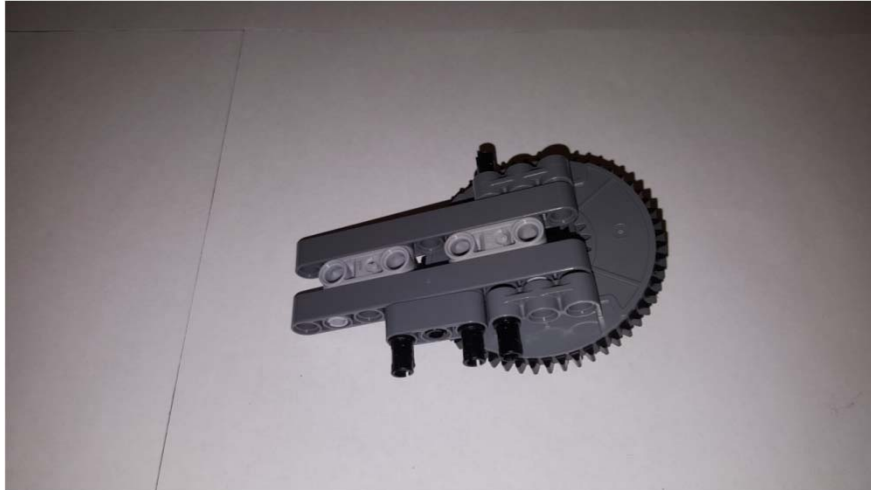
2C: Complete Link 1 – attach second Beam-9 and insert into 56T Turntable. Secure with Long Friction Pegs



2D: Insert Friction peg in Link 1. Insert two Friction pegs into Beam-3

Degree-of-Freedom (DOF) 1: Base

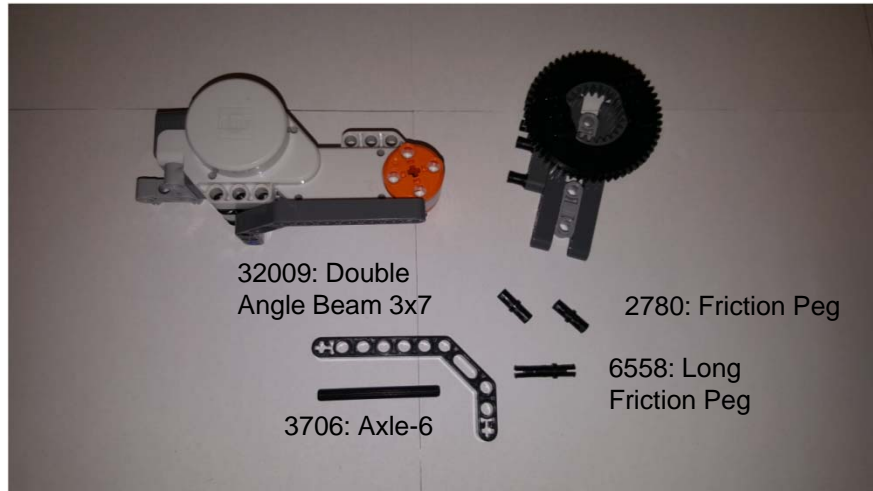
Step 2 continued:



2E: Attach Beam-3 onto Link 1

Degree-of-Freedom (DOF) 1: Base

Step 3: Joint 1

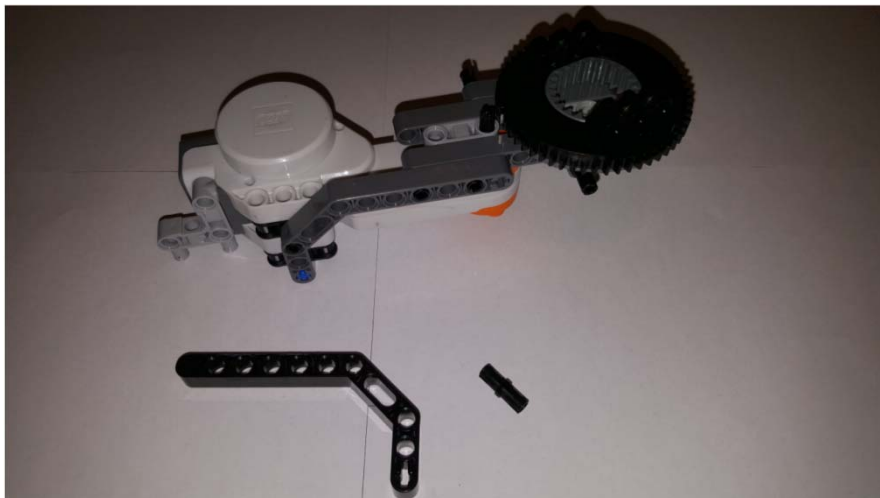


3A: Gather previous Base Motor assembly and Link 1



Degree-of-Freedom (DOF) 1: Base

Step 3: Joint 1 Continued



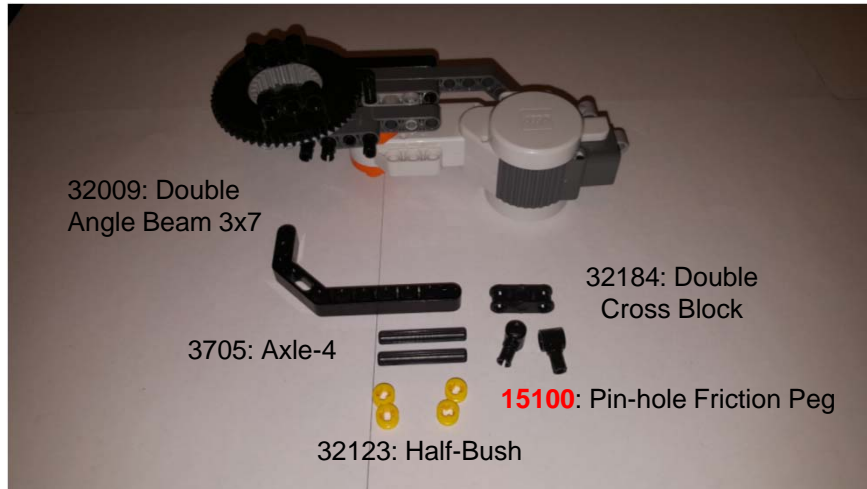
3E: Prepare Double Angle Beam



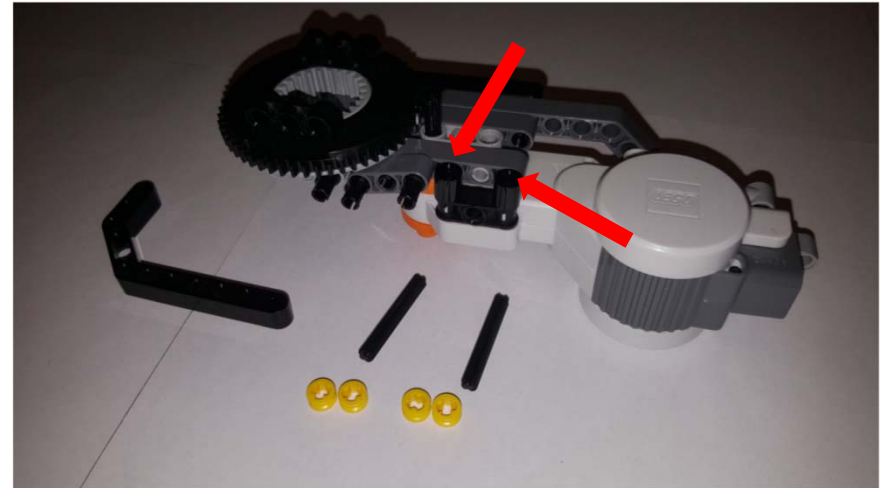
3F: Secure Double Angle Beam to Link 1 with Friction Peg

Degree-of-Freedom (DOF) 1: Base

Step 4: Joint 1 Base Assembly Mount



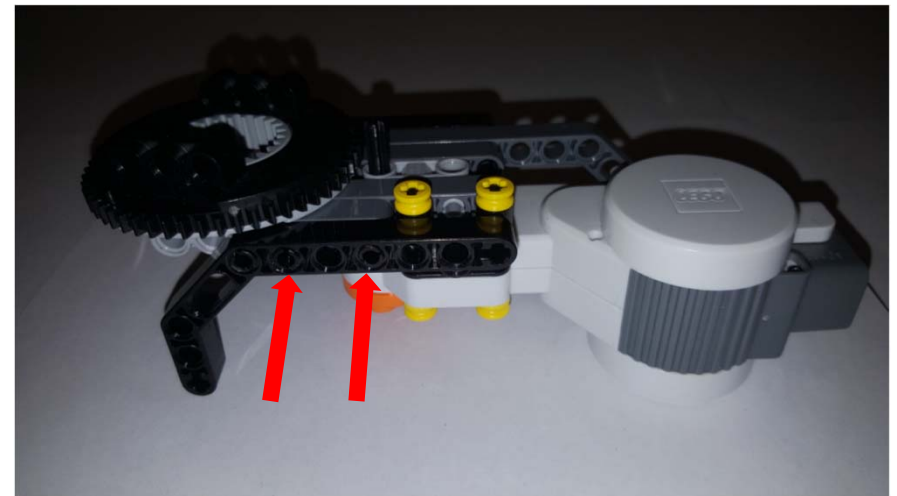
4A: Gather previous Base Motor assembly and Link 1 and listed parts. NB: Non NXT part 15100



4B: Secure Cross-Block to Link 1 assembly with Pin-hole Friction Peg



4C: Reinforce Cross-Block with Axle-4 and half-bushes



4D: Complete reinforcement with remaining Axle-4 and half-bushes. Attach Double Angle Beam 3x7 to Link 1's Beam-3

Degree-of-Freedom (DOF) 1: Base

Step 5: Joint 1 Base Assembly Feet



5A: Feet serve to secure Motor Base Assembly to a plate.
NB: Need non-NXT part 15100



5B: Secure 90-deg Cross-Blocks to Motor Base Assembly with an Axle-3. Insert Friction Pegs into Pin-hole Friction Peg



5C: Attach Pin-hole Friction Pegs to Motor Base Assembly's Double Angle Beam. Repeat Step 5B for remaining leg



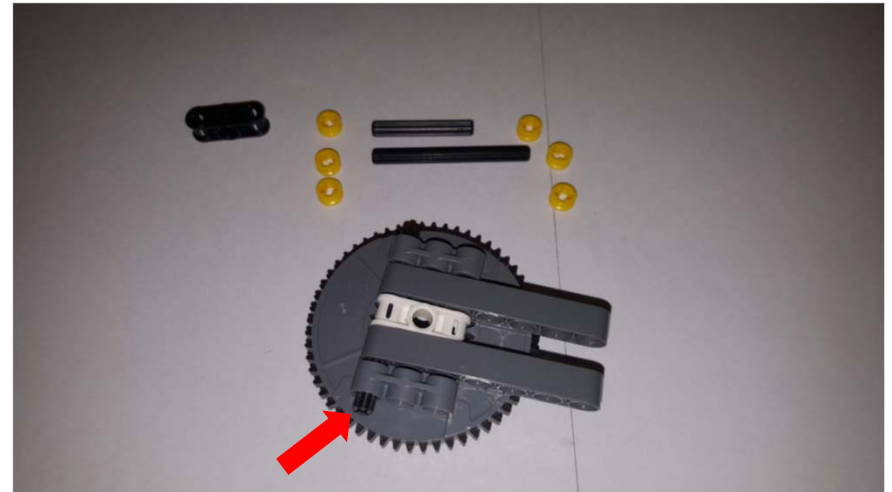
5D: Completed Assembly Feet for Joint 1 and Link 1

Degree-of-Freedom 2

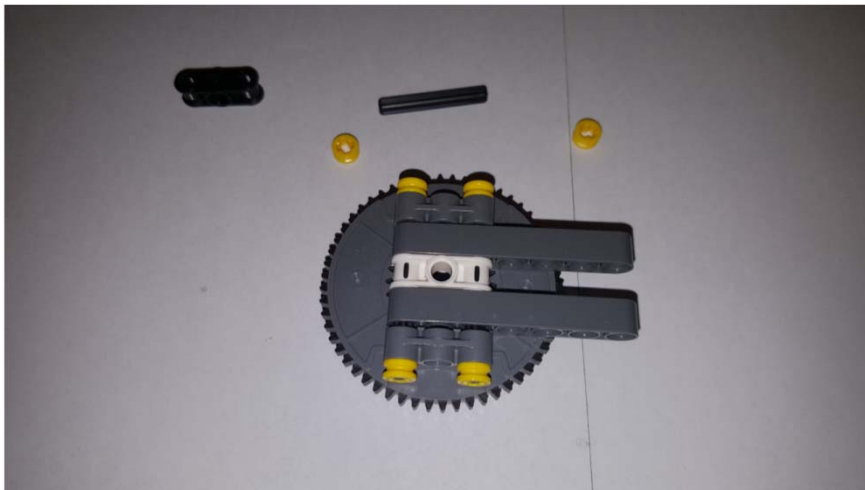
Step 6: Joint 2 assembly



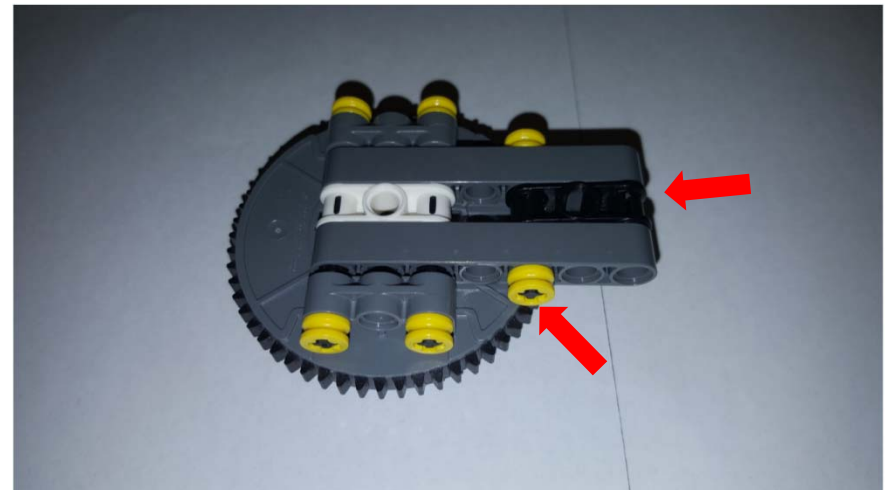
6A: Joint 2 assembly will attach to a second NXT motor in later steps. NB: NXT kit has only 1 Turntable



6B: Insert Cross-block and two Beam-7 parts in 56T Turntable and secure with Axle-6.



6C: Insert remaining Axle-6 and secure with half-bushes



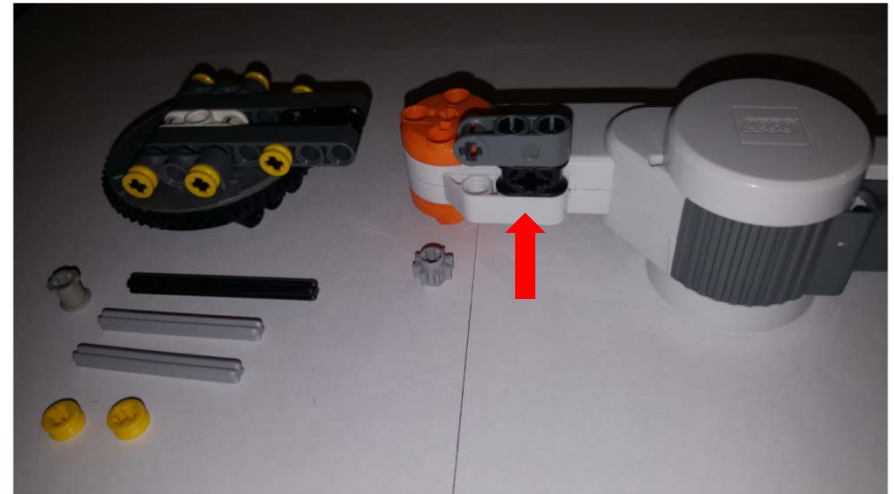
6D: Insert remaining cross-block and secure with Axle-4

Degree-of-Freedom 2

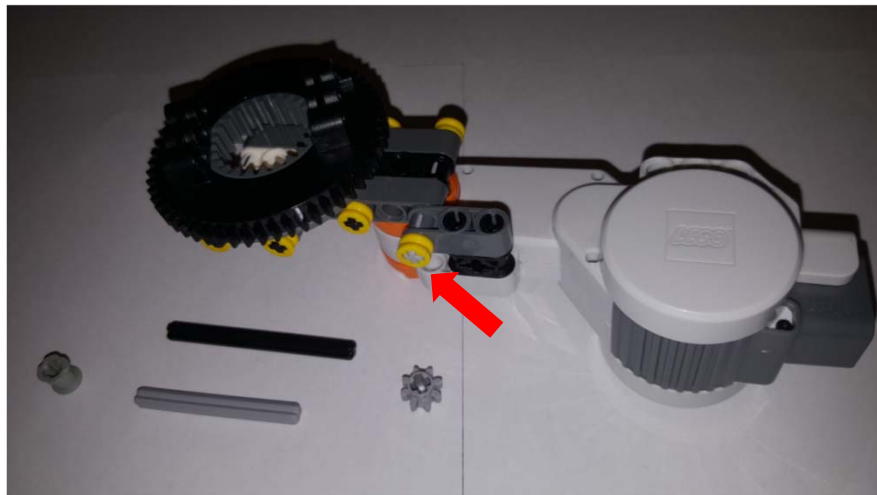
Step 7: Motor 2 Assembly



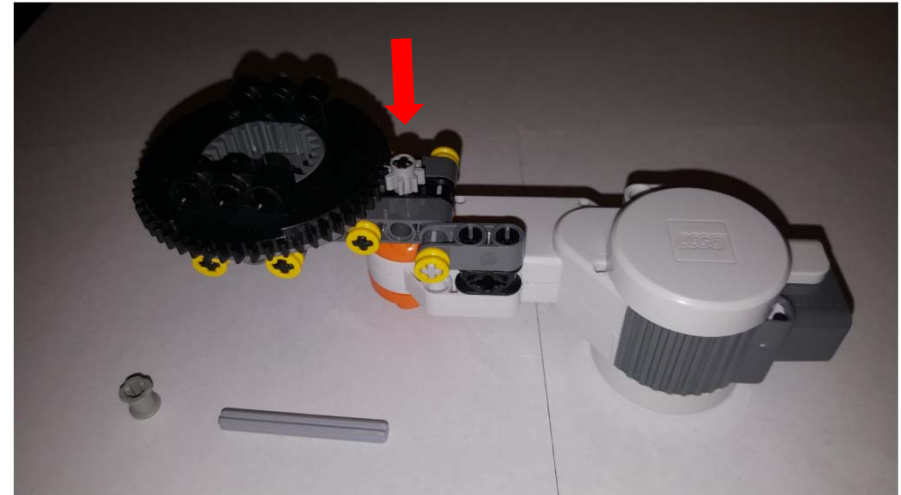
7A: Gather listed parts and Motor 2 with Joint 2 assembly from previous step



7B: Secure Cross-Block 3M to Motor 2 with Module Bush



7C: Secure Joint 2 assembly to Motor 2 with Axle-5 and half-bushes



7D: Insert Axle-6 through Joint 2 and Motor 2's axes. Secure with Gear-8

Degree-of-Freedom 2

Step 7: Continued



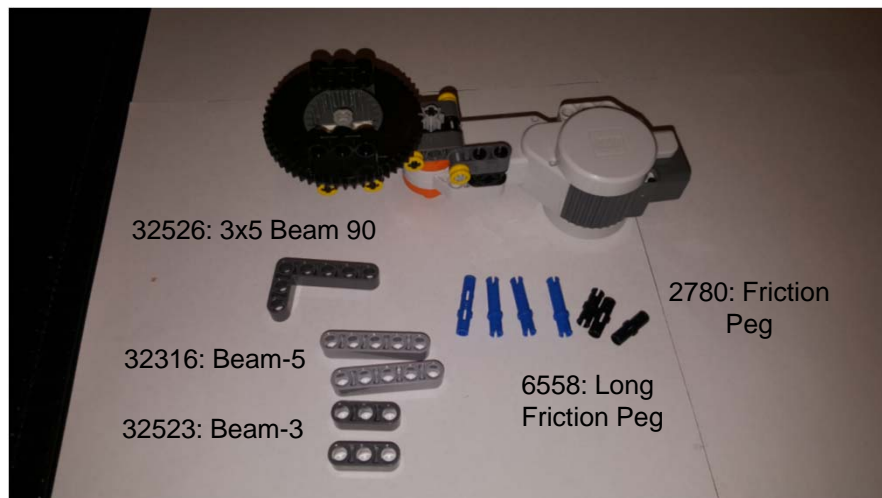
7E: Insert Axle-5 through Turntable and secure with bush



Bottom view shows Axle-5 and Axle-6 thru Turntable and Motor 2's axes respectively

Degree-of-Freedom 2

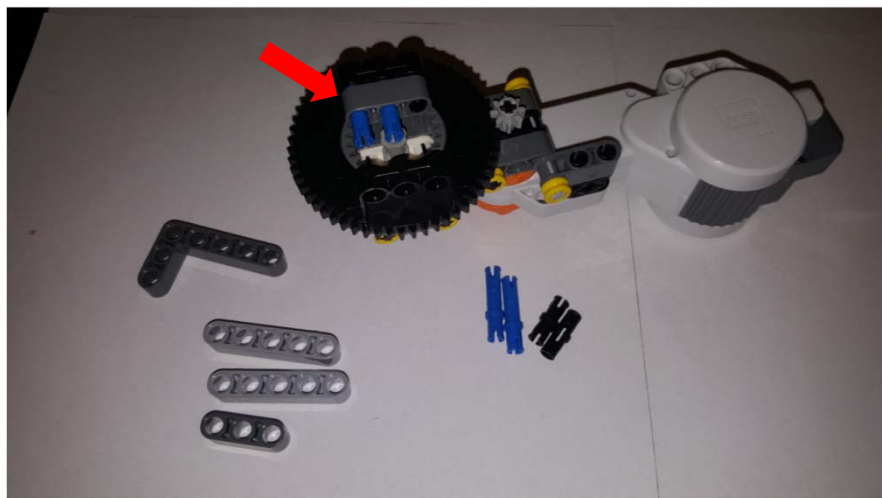
Step 8: Link 2 Assembly



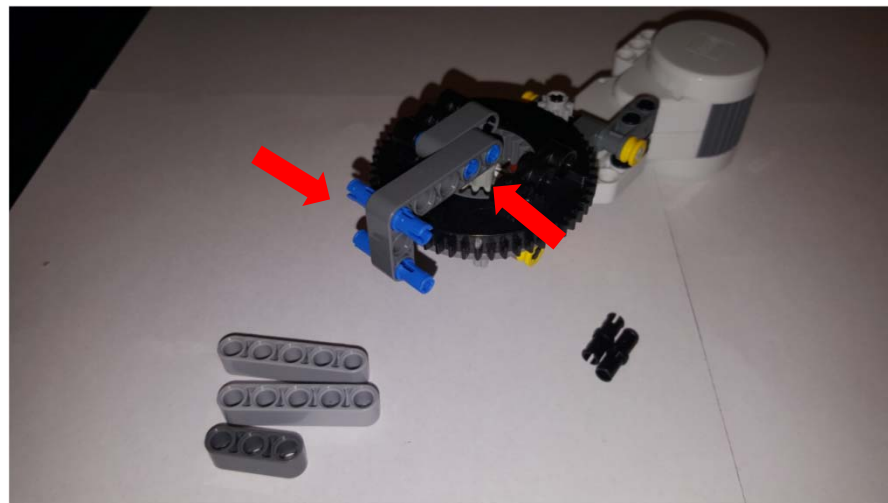
8A: Gather listed parts and Motor 2 Assembly from previous step



8B: Insert Long Friction Pegs and Friction peg in Turntable



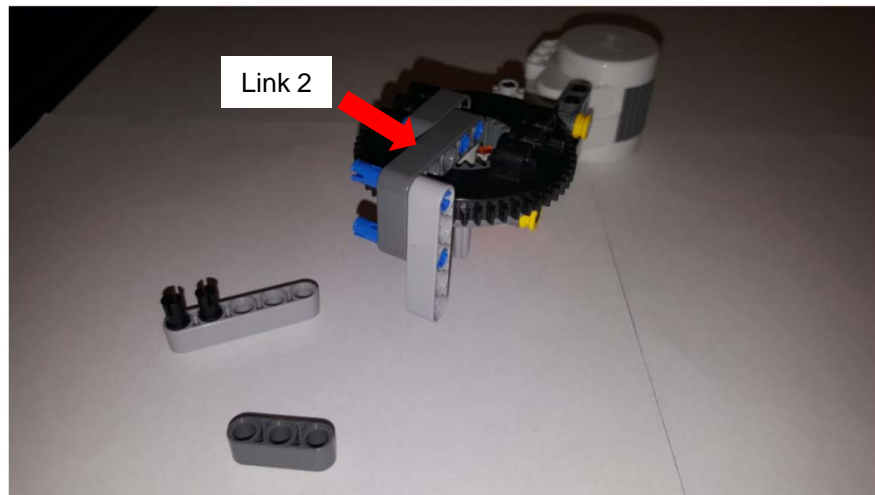
8C: Attach Beam-3 to Turntable



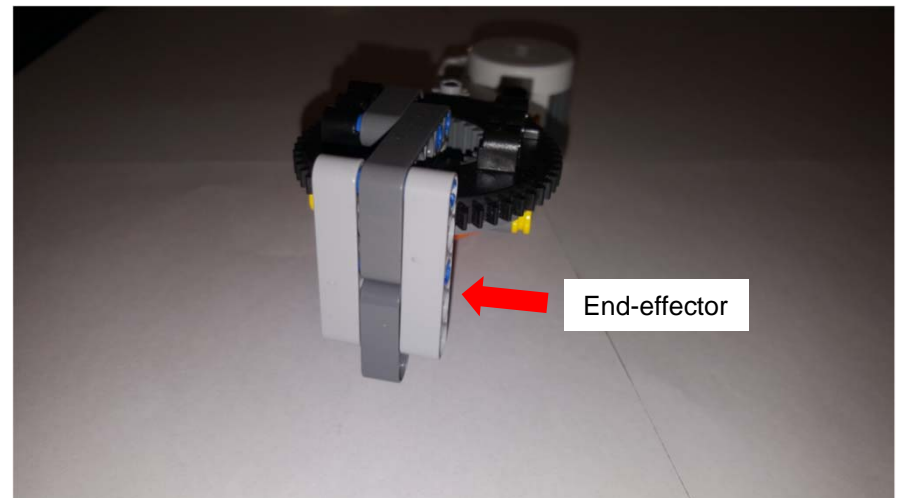
8D: Attach 3x5 Beam 90 to Beam-3. Insert two Long Friction pins to 3x5 Beam 90

Degree-of-Freedom 2

Step 8: Continued



8E: Create end-effector; attach Beam-5 to 3x5 Beam 90. Insert Friction pegs in remaining Beam-5



8F: Attach Beam-3 to Beam-5 and secure to 3x5 Beam 90



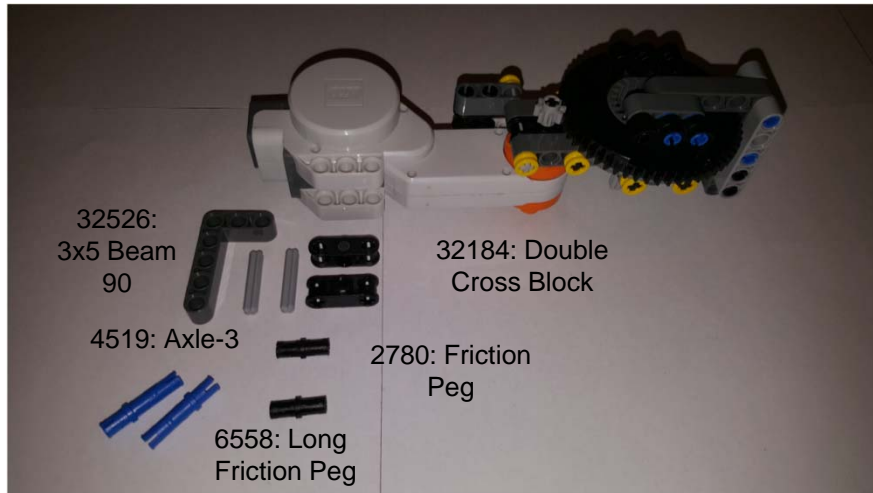
Alternative view of Link 2 assembly with end-effector



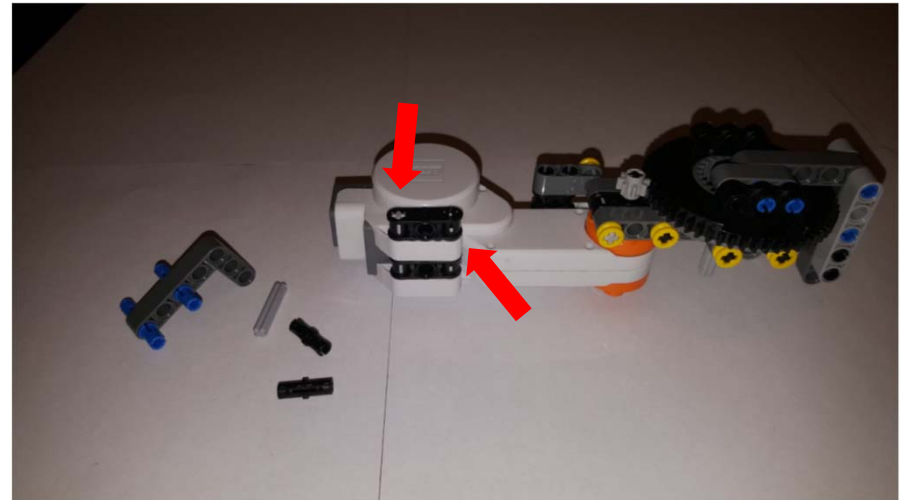
Alternative (top) view of Link 2 assembly with end-effector

Degree-of-Freedom 2

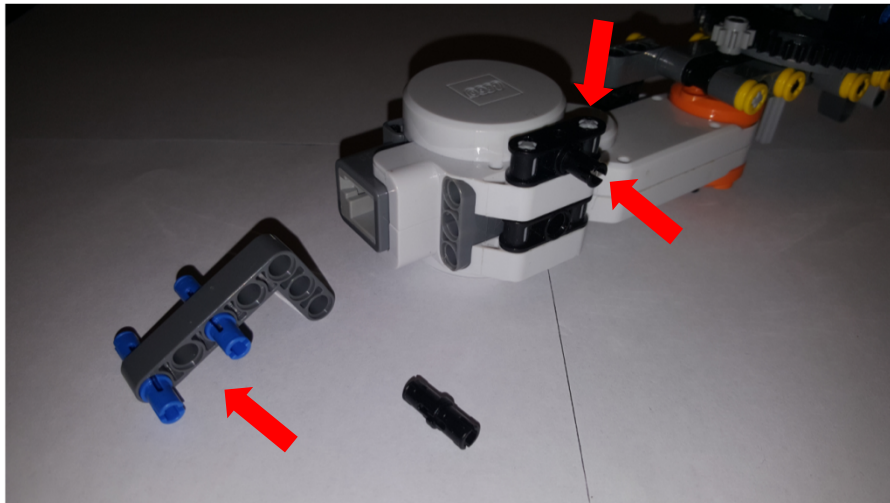
Step 9: Motor 2 Assembly Mount



9A: Gather listed parts and Motor 2 Assembly from previous step



9B: Insert both Double Cross-blocks into Motor 2 Assembly. Secure with an Axle-3



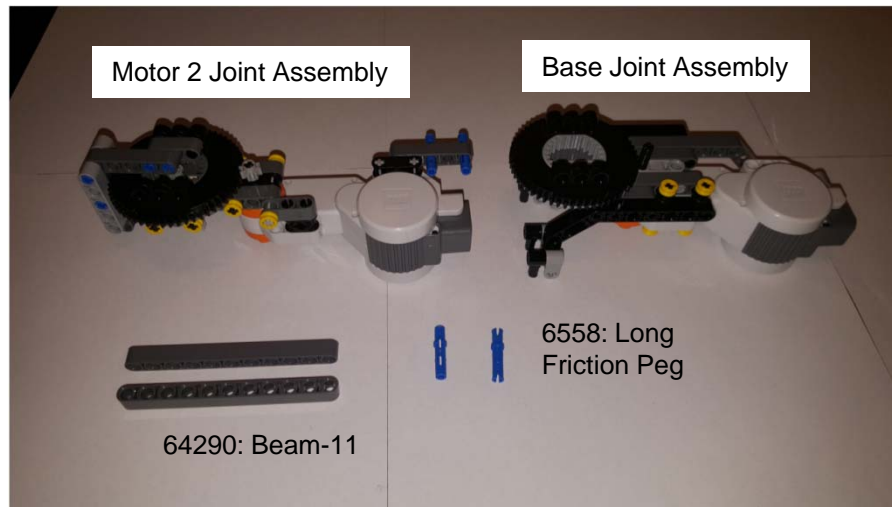
9C: Insert second Axle-3 into both Double Cross-blocks. Insert Long Friction pegs in 3x5 Beam 90. Insert Friction peg to Double Cross-block



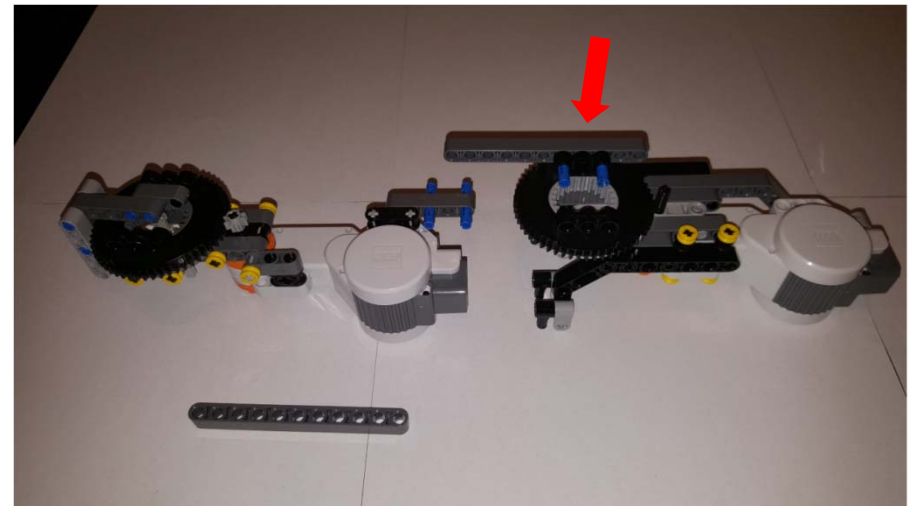
9D: Insert remaining friction peg to Double Cross-block and attach 3x5 Beam 90.

DOF 1 to DOF 2 Linkage

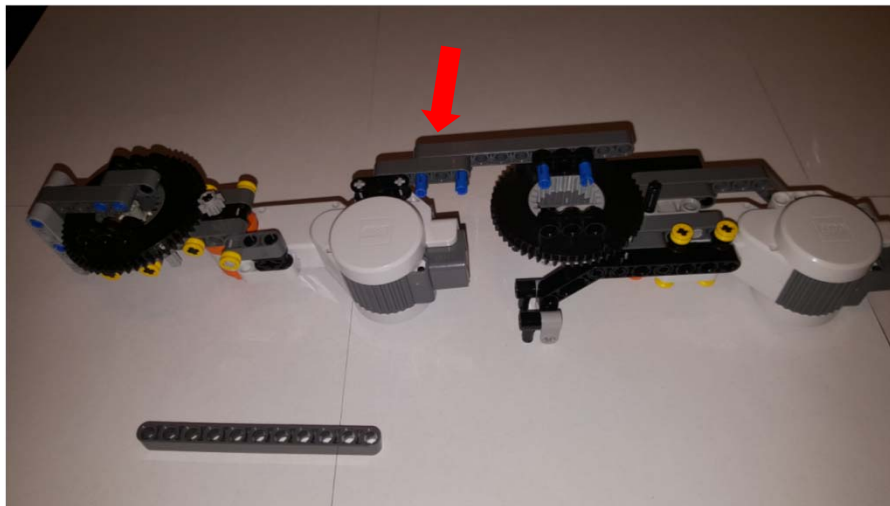
Step 10: Linking DOF 1 and DOF 2



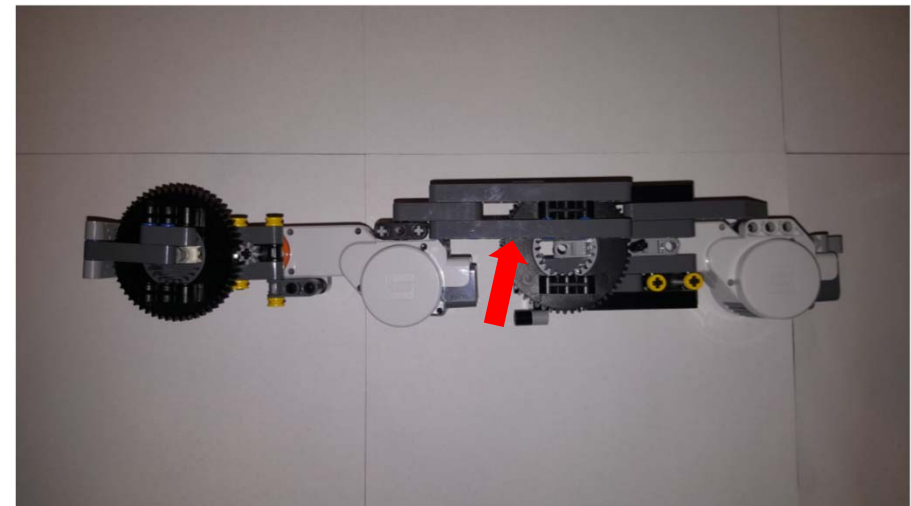
10A: Gather listed parts and the two joint assemblies



10B: Attach Beam-11 to Base Joint Assembly with Long Friction pegs



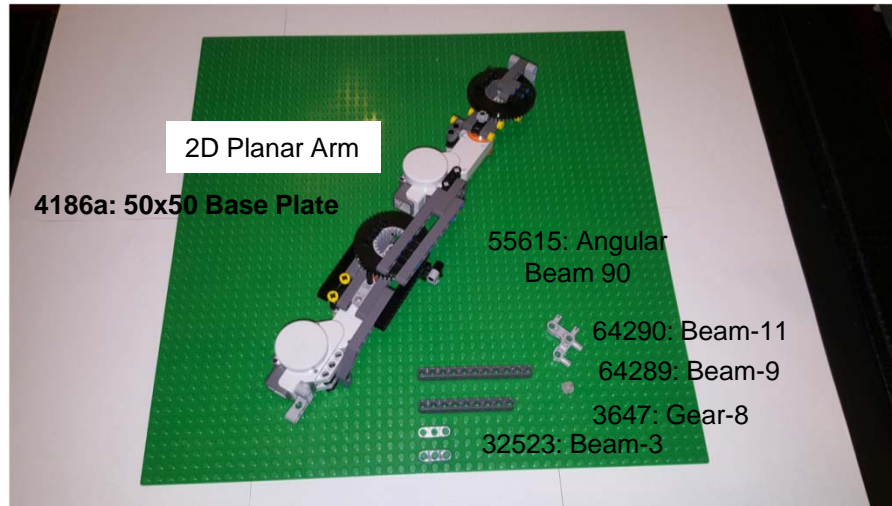
10C: Attach Motor 2 Joint Assembly to Beam-11



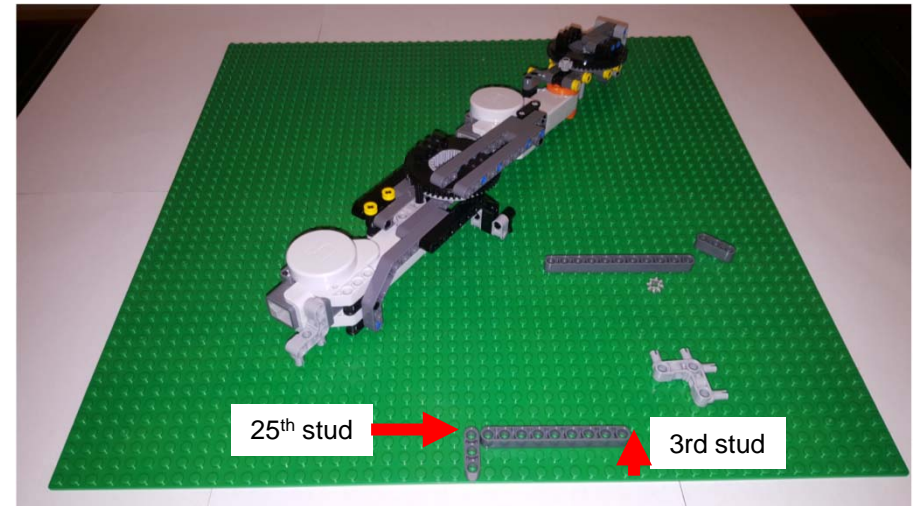
10D: Attach remaining Beam-11 to secure the two joint assemblies

XY Plane Assembly

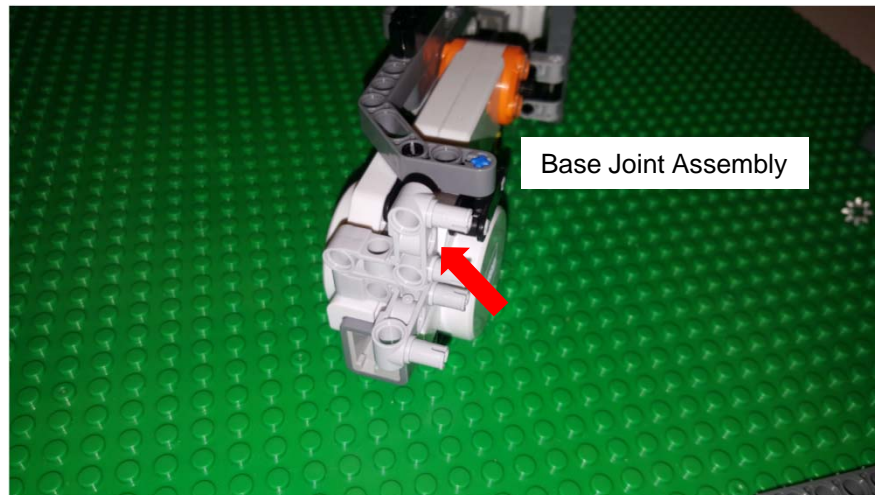
Step 11: 2D Arm to Base Plate fixture



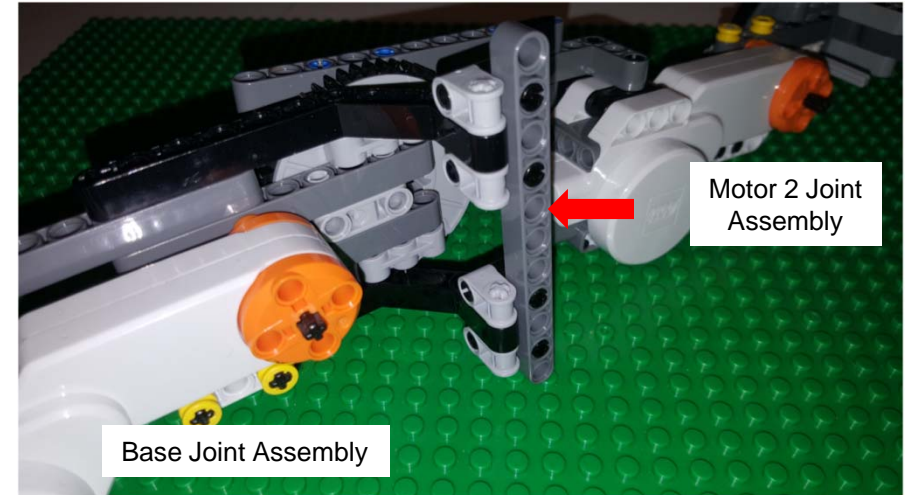
11A: Gather listed parts and 2D Planar Arm. NB: 50x50 Base Plate is non-NXT part



11B: Attach Beam-3 and Beam-9 to plate at defined positions



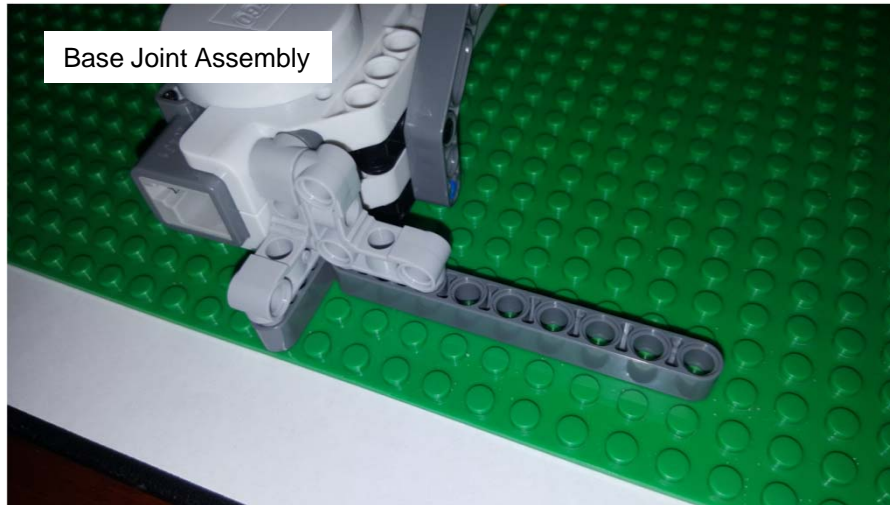
11C: Insert Angular Beam 90 into NXT Motor 1 (Base Assembly)



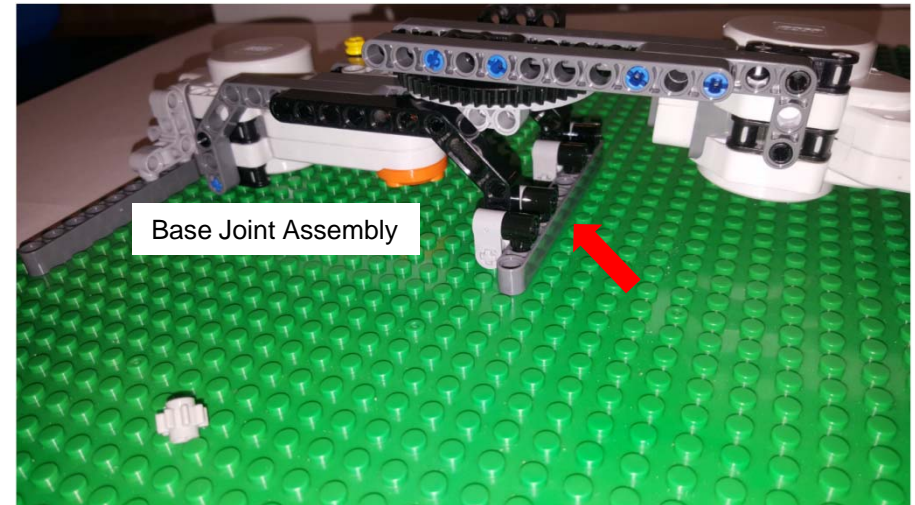
11D: Attach Beam-11 to feet of Base Assembly

XY Plane Assembly

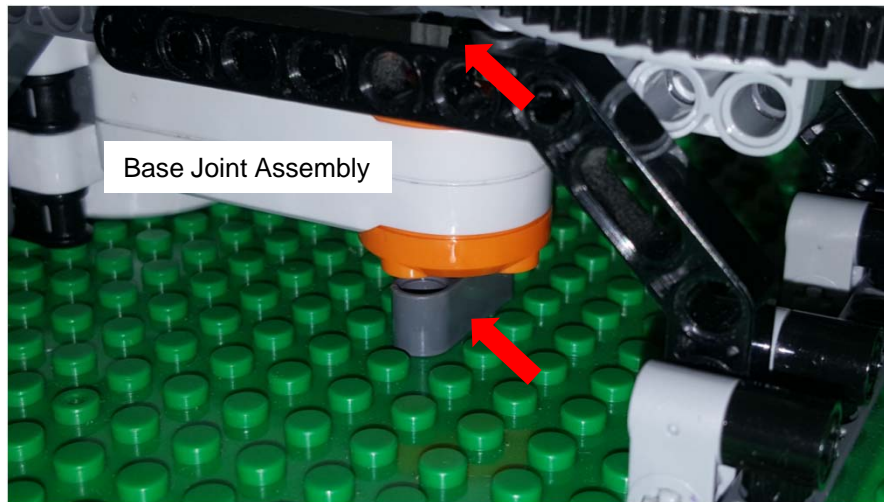
Step 11: Continued



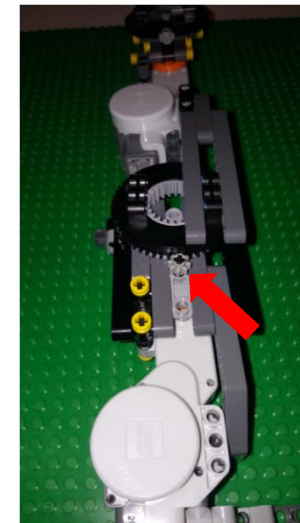
11E: Insert Base Motor Assembly to Beam-3 and Beam-9



11F: Secure Base Assembly's feet to plate via Beam-11



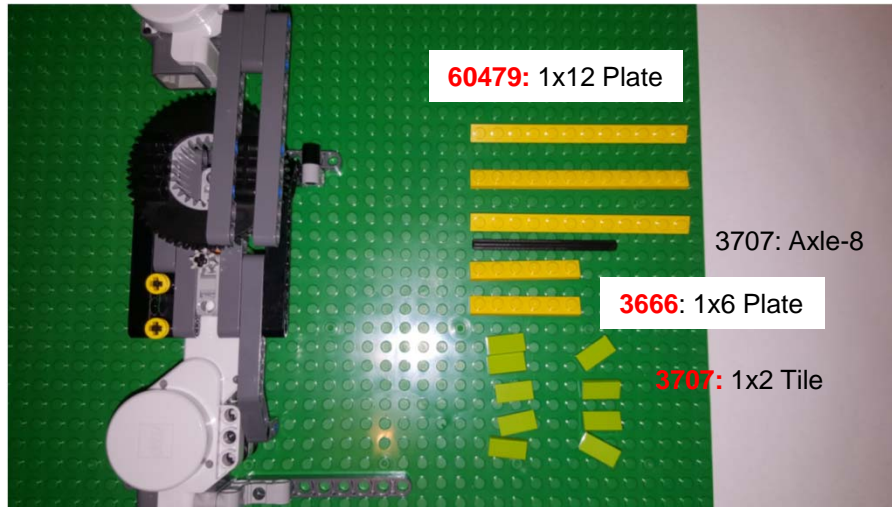
11G: Attach remaining Beam-3 to base plate; center Beam-3 to be under Motor 1's axis. Secure with Gear-8



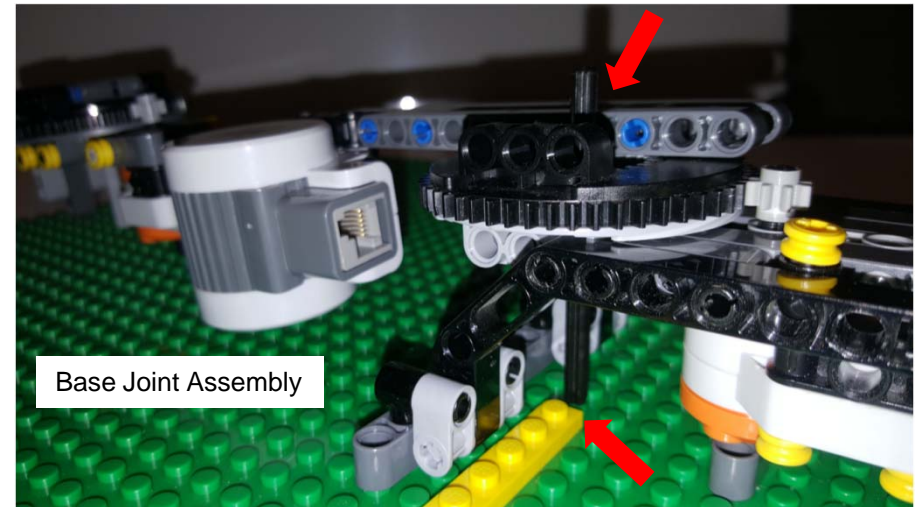
Alternative (top) view: shows position of Gear-8 and completed 2D Planar Arm attached to XY Plane

XY Plane Assembly

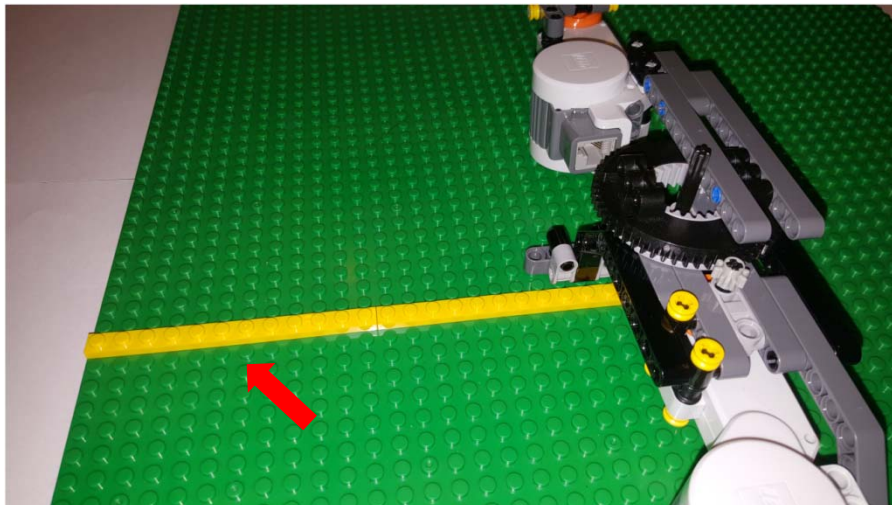
Step 12: Cartesian Axes



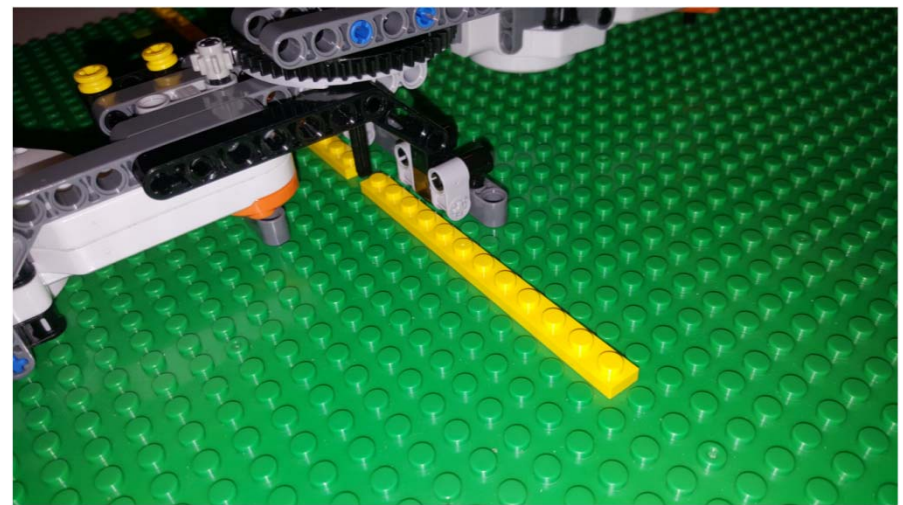
12A: Create Y-axes. NB: plates are non-NXT parts. Also NXT kit only has 2 Tiles



12B: Insert Axle-8 thru Turntable axes. Attach 1x12 plate next to axle. Plate serves as +Y-axis



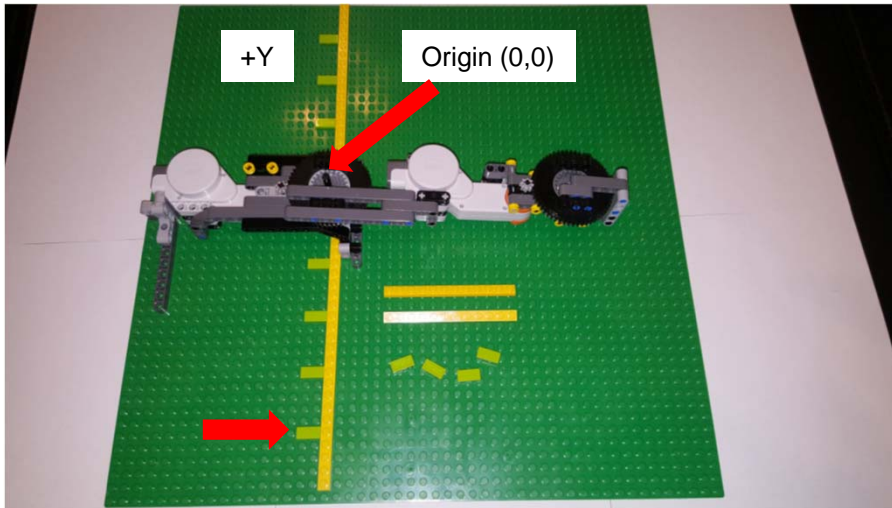
12C: Attach second 1x12 plate to 50x50 base plate. This completes +Y-axes



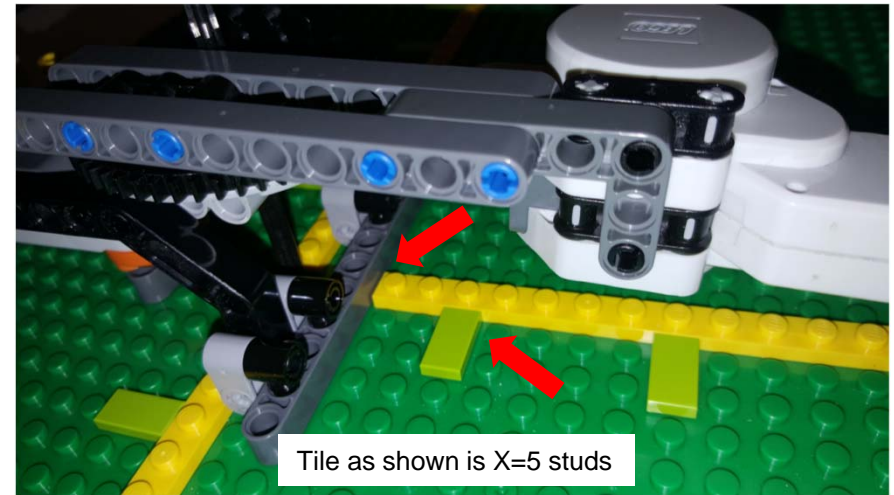
12D: Attach last 1x12 plate to other side (this defines -Y-axis)

XY Plane Assembly

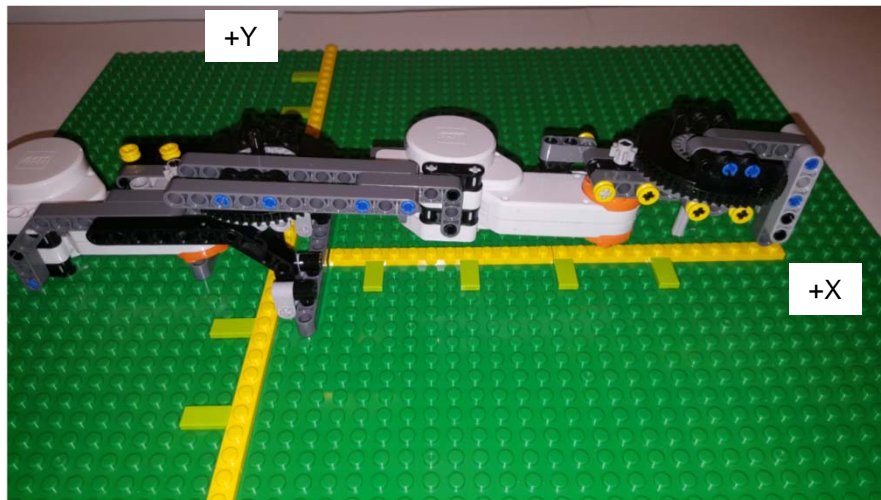
Step 12: Continued



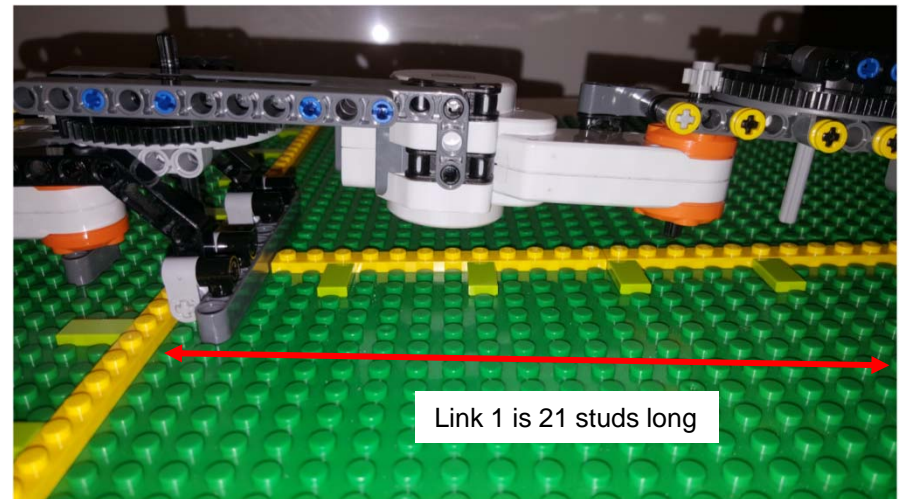
12E: Attach 1x2 Tiles at every 5 peg. This defines the Y-axis' grid lines



12F: Construct +X-axis. Attach 1x12 plate. Note position of first 1x2 Tile



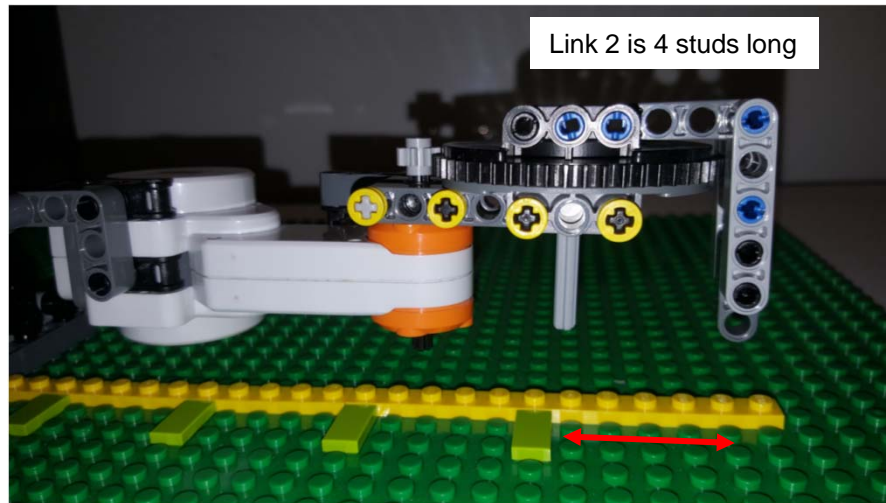
12G: Complete +X-axis with 1x12 plates and 1x2 Tiles



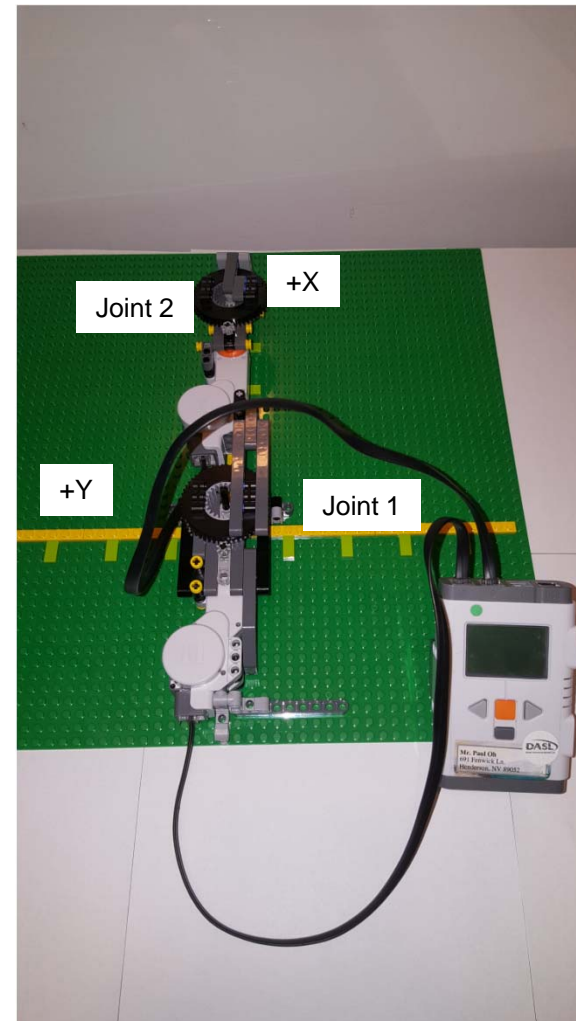
Dimensions: Counting studs from origin to Joint 1 axis

XY Plane Assembly

Step 12: Continued



Dimensions: Counting studs from origin to Joint 2 axis



Completed 2D Planar Arm with zero offset. Motor 1 and 2 connect to NXT Brick's Ports A and B respectively