HARDWARE DOCUMENT

GROUP 4

1st December 2016
Version 12

Abstract

This document details the entire process taken in designing and building the robot's hardware. It begins with assessments of ideas, weighing pros and cons, and feasibility, to come to conclusions on which components to build and test. The process then moves to construction, testing assessments, and finally to full assemblies. Once the first full robot is assembled, the iterative process begins. The robot undergoes many minor to significant improvements, all the while maintaining a functional prototype for use in software design, and testing.

Contents

1 BACKGROUND

1.1 Edit History

Jake Zhu: 2016-10-28, Initial set up

Kareem Halabi and Jake Zhu: 2016-10-29, Updated information for the brick

Quentin Norris: 2016-10-30 Updated problem statements, requirements, possible solutions, sketches, and feasibility for collectors, crane, and grabbers.

Benjamin Willms: 2016-10-31, Changed the section structure, edited terms, and edited problem statements and requirements for all pieces (lifters (formerly cranes), grabbers, collectors, etc.)

Quentin Norris: 2016-10-31, Updated pros and cons for grabbers and collectors. Drew sketches and finalized design plans for main two grabbers, the grabber claw and the motorized grabber.

Jake Zhu: 2016-10-31, Added pros, cons and optimum solution for the brick

Benjamin Willms: 2016-10-31, Edited all sub-sections of the identification of possible solutions, sketched the lifters, collectors, and hybrids, edited all sub-sections of the feasibility, edited pros/cons of lifters, hybrids, and locomotion, and edited all the sub-sections of optimum solution(s).

Jake Zhu: 2016-10-31: Added pictures of sketches

Benjamin Willms: 2016-11-04, Edited sections 2.4, 2.5, 2.6, and 2.7 to include the gravity fed hybrid, also outlined sections 3, 4, and 5, and completed section 3.

Jake Zhu: 2016-11-06: Added pictures of the gravity fed hybrid

Quentin Norris: 2016-11-06, Edited sections 4.1.3, 4.1.7, and 4.1.1 to include the dual brick chassis, the static collector and partial platform, and swinging collector/grabber hybrid. Added photos for all three and updated sections.

Benjamin Willms: 2016-11-06, Edited various sub sections of section 4 to include some descriptions, and edited some formatting.

Jake Zhu: 2016-11-07, Edited section 5.1 and added pictures of the sliding hybrid.

Benjamin Willms: 2016-11-10, Edited section 6, and outlined the structure for documenting hardware iterations.

Benjamin Willms: 2016-11-11, Completely documented hardware version 2 and 3, and added the structure for hardware version 4.

Benjamin Willms: 2016-11-12, Renamed the hardware versions for better representation (Version 2 is now 1.5, version 3 is now 2, and version 4 is now 2.5).

Benjamin Willms: 2016-11-13, Filled out sections of hardware version 2.5, and added and filled out sections of hardware version 2.55.

Benjamin Willms: 2016-11-15, Renamed hardware version 2.55 to hardware version 3, as it took on more changes than originally planned, also filled out the documentation for hardware version 3.

Jake Zhu: 2016-11-15, Rotated sideways pictures

Benjamin Willms: 2016-11-16, Added documentation for hardware version 3.01

Benjamin Willms: 2016-11-17, Added documentation for hardware version 3.02

Jake Zhu: 2016-11-21, Added clickable links

Benjamin Willms: 2016-11-22, Added documentation for hardware version 3.03

Benjamin Willms: 2016-11-23, Finished documentation for hardware version 3.03, and removed an unnecessary photo of the gravity fed hybrid

Benjamin Willms: 20126-11-30, Added the abstract

2 ASSESSMENTS

2.1 PROBLEM STATEMENTS

2.1.1 Collectors

The collector ensures that the block to be manipulated is in a position that allows the proper functioning of the grabber. It is imperative that the collector functions properly, and consistently, otherwise the grabber may fail.

The goal of this assessment is to determine the feasibility, and the pros and cons of the collector ideas currently brainstormed. In the end, this assessment will recommend one or two collector models to be built and tested.

2.1.2 Lifters

An extremely important function of the robot is the lifter. The lifter is what lifts the blocks so as to enable stacking. The lifter must be robust, light, and use a motor to provide the lifting. It is also closely related to the grabber (as they are attached together), and must provide enough space for the proper functioning of said grabber.

The goal of this assessment is to determine the feasibility, and the pros and cons of the crane ideas currently brainstormed. In the end, this assessment will recommend one or two lifter models to be built and tested.

2.1.3 Grabbers

The grabber is the device which latches on to the block to be lifted. It is imperative that the grabber functions properly, and consistently, otherwise blocks will be dropped, and an error may shift the robot, throwing off the odometer.

The goal of this assessment is to determine the feasibility, and the pros and cons of the grabber ideas currently brainstormed. In the end, this assessment will recommend one or two grabber models to be built and tested.

2.1.4 Collector/Grabber/Lifter Hybrids

In certain cases, the grabber, collector, and crane may be combined into one or two devices, simplifying the entire system. This is an important possibility, as it would allow for the use of fewer motors in the design. Such ideas are discussed here.

The goal of this assessment is to determine the feasibility, and the pros and cons of the hybrid ideas currently brainstormed. In the end, this assessment will recommend one or two hybrid models to be built and tested.

2.1.5 Bricks

The brick is one of the most important parts, if not the most important part, of the robot. The software team will upload code to the brick that will make it run based of the sensors and motors plugged into it. Our issue with the brick is that there may not be enough ports in order to supply all the sensors and motors that are necessary. This means that the possibility of using two bricks must be considered in the hardware design. Not only do the bricks have to communicate with each other, they must be positioned so that there will not be any problems while they are in use.

2.1.6 Locomotion

The issue with the locomotion is that there are discontinuities where boards meet. This may cause the robot to get stuck in the discontinuities and offset the odometer by a large margin. Due to this, alternative locomotion designs must be considered and assessed.

2.2 REQUIREMENTS

2.2.1 Collectors

- must orient the block to allow the grabber to latch on
- must set the block at the proper distance from the robot for the grabber to function properly
- must not cause issues in navigation or odometry (size/orientation issues causing collisions)
- should not exceed the use of 1 motor

2.2.2 Lifters

- must allow lifting high enough to create a stack of 3-5 blocks

- must not exceed the use of 1 motor
- must provide stability for the grabber
- must not flex to the point of throwing off the stacking process

2.2.3 Grabbers

- must grab the blocks with enough force so as to not let go accidentally
- must be able to grab blocks with the amount of error in their position and orientation that the collector leaves
- must be able to let go of the blocks at the proper heights for stacking
- must not exceed the use of 1 motor

2.2.4 Collector/Grabber/Lifter Hybrids

See sections 2.2.1, 2.2.2, and 2.2.3 for the requirements (as the hybrids combine the 3 sections)

- must not exceed the use of 3 motors

2.2.5 Bricks

- The slave brick must be able to receive a signal from the master brick.
- Both bricks must work with minimal delay
- The bricks have to be structured on the robot so that there is no interference with the processes

2.2.6 Locomotion

- must limit the chance of catching on the discontinuities
- must be able to turn without too much friction causing problems with the navigator and odometer
- must keep the robot balanced and stable

2.3 IDENTIFICATION OF POSSIBLE SOLUTIONS

2.3.1 Collectors

See System Document section 8.1

2.3.2 Lifters

See System Document section 8.1

2.3.3 Grabbers

See System Document section 8.1

2.3.4 Collector/Grabber/Lifter Hybrids

See System Document section 8.1

2.3.5 Bricks

We may have to use multiple bricks connected through USB, so the structure of the robot must take this into account.

For a single brick construction:

- the brick could be located in the center of the robot, parallel with the ground
- the brick could be located in the center of the robot, at an angle with the ground

For a dual brick construction:

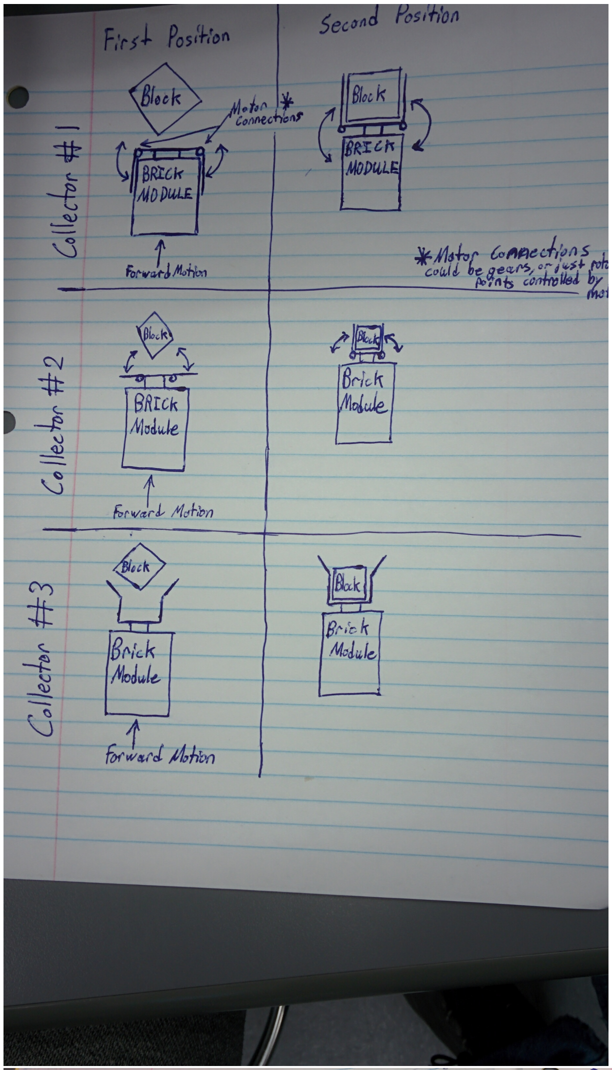
- the bricks could be located in the center of the robot, stacked on top of each other with enough room between them to allow viewing of the screens
- the bricks could be located on their sides, each above a motor for locomotion, with an empty space in between them

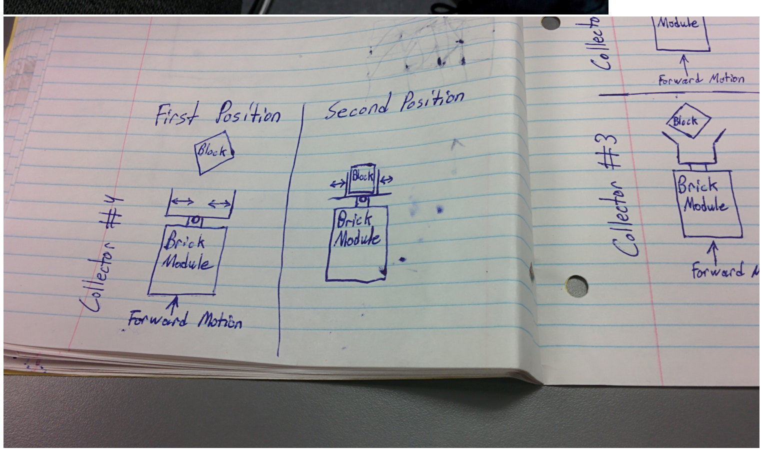
2.3.6 Locomotion

See System Document section 8.1

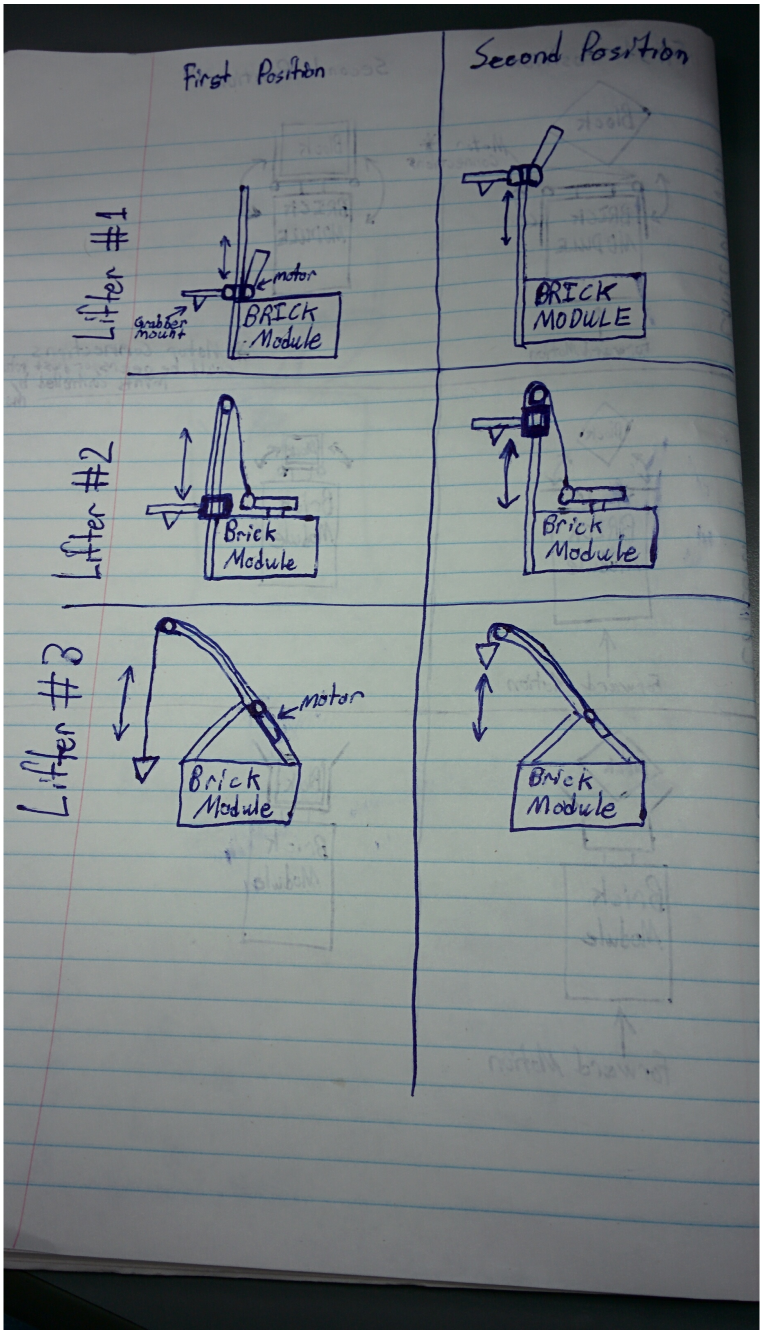
2.4 SKETCHES

2.4.1 Collectors

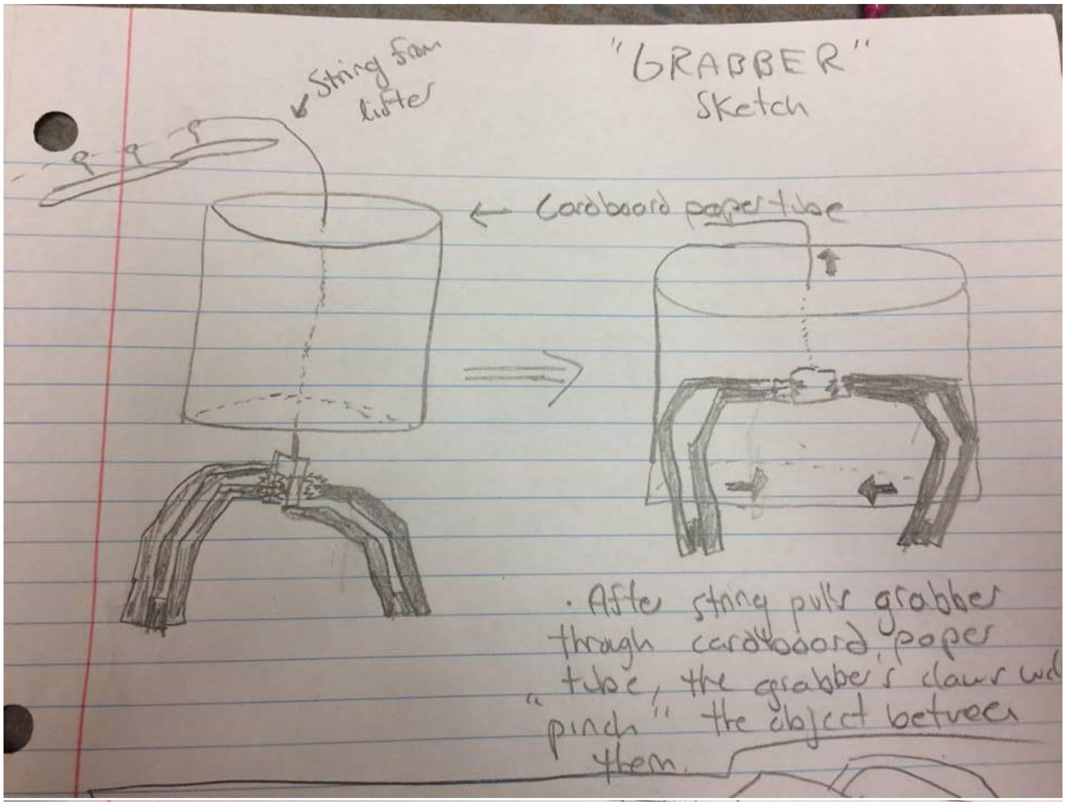


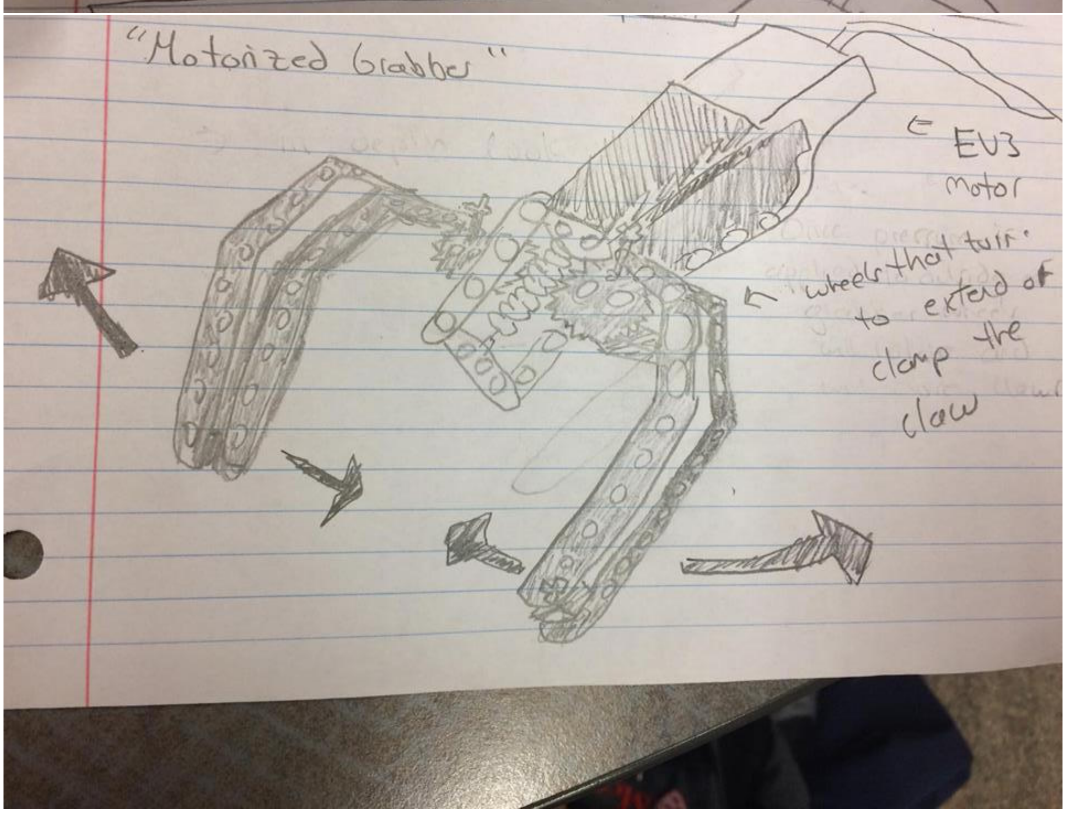


2.4.2 Lifters

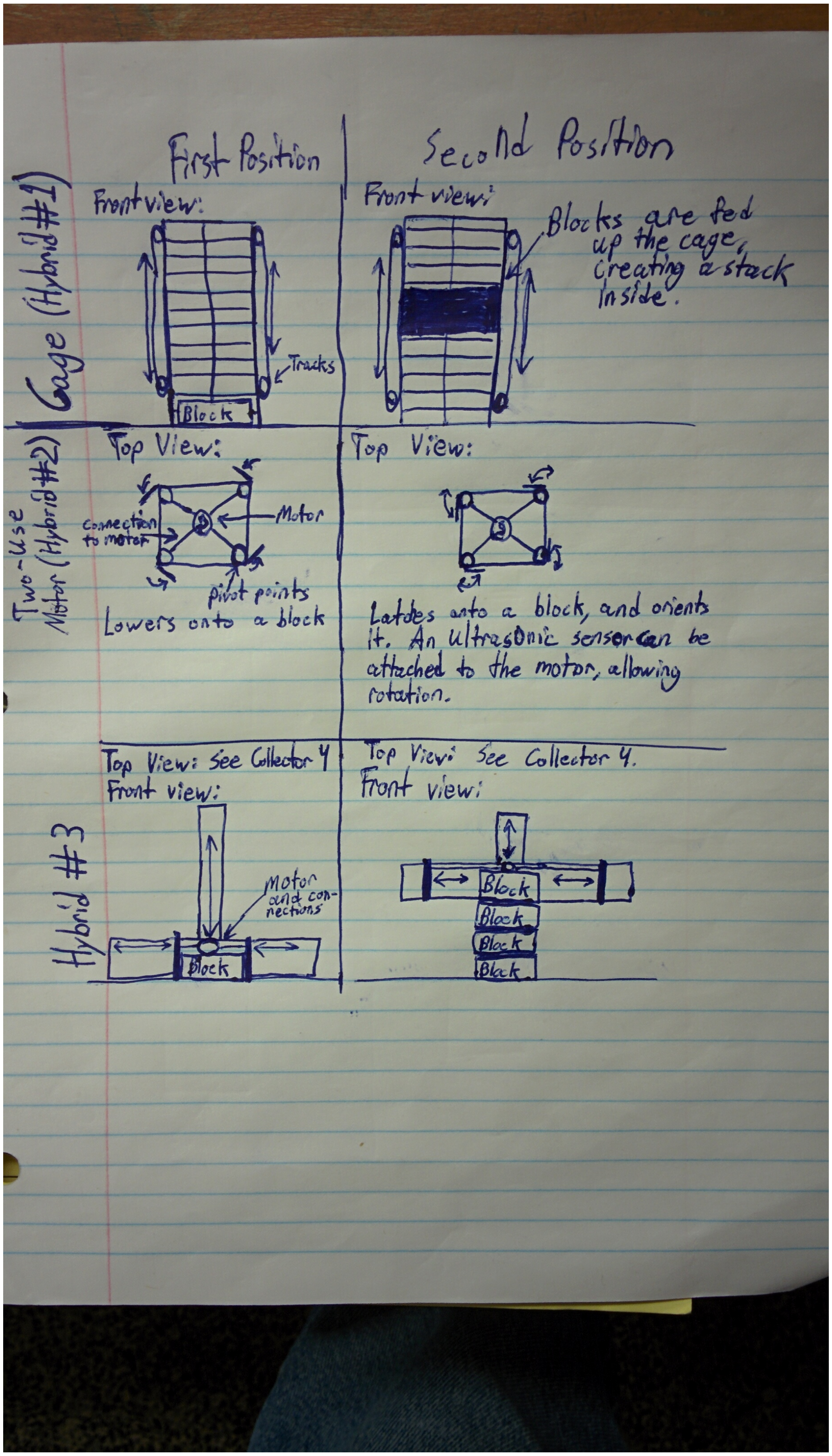

First Position
Second Position
Lifter #1
Lifter #2
Lifter #3
motor
Grabber mount
BRICK Module
BRICK MODULE
Brick Module
Brick Module
motor
Brick Module
Brick Module

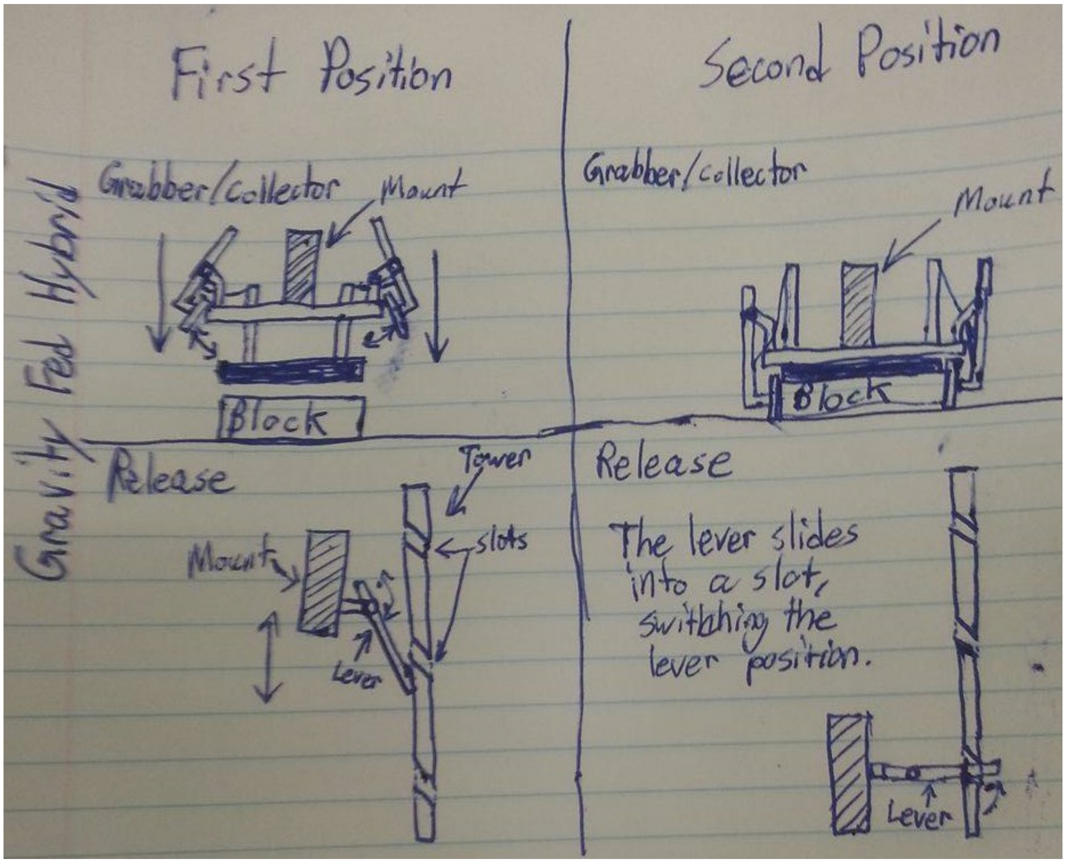
2.4.3 Grabbers





2.4.4 Collector/Grabber/Lifter Hybrids





2.4.5 Bricks

Look at MULTIPLE BRICKS TEST Document

2.4.6 Locomotion

LOOK at WHEELS TEST Document

2.5 FEASIBILITY

2.5.1 Collectors

All three collectors are feasible (similar designs were observed during lab 5). The sliding collector will be more difficult to implement as it requires the motor to translate its natural motion into two different motions.

2.5.2 Lifters

All three lifter designs will be simple to construct, and will work as intended. The sole feasibility issue for the lifters comes with the tower with a motor driving up and down it. The EV3 kits do not have any gear racks (long flat toothed pieces, allowing gears to roll along them). This means that the motor would need to be connected to a wheel which would clasp the tower to allow the up and down motion. This would likely have some issues with slipping, and causes such a design to be difficult to implement effectively.

2.5.3 Grabbers

The partial platform design, and the motorized design will both be relatively simple to construct. The pinching claw will have issues with getting it to release the blocks at the correct height, and a proper release mechanism may be difficult, or impossible to create with the lego form factor. The partial platform may not work in any case, as it relies on friction levels that are not completely controllable by the design itself, and the balance of the blocks in the contraption may be suspect.

2.5.4 Collector/Grabber/Lifter Hybrids

All four of the Hybrid options have some feasibility issues, namely:

- the cage design is extremely large, and will likely be difficult to get working with the lego blocks in the EV3 kits. It would require a vertical conveyor belt system that wouldn't shift the blocks into improper orientations, and must provide enough friction to lift the blocks, while simultaneously not being so tight that the blocks cannot enter the system. It is unlikely that the precision required to do all of this can be easily attained through lego construction.
- The two-use motor design would require precise use of gears to allow the four clamps to close in the desired manner, and at the proper places with respect to the blocks. This means that it would require significant time to construct, and get working in a consistent manner, and the budget may not allow it.
- The third hybrid design is simply re-purposing collector 4 so that it acts as a collector, and a grabber. It would use one of the tower lifters, and its feasibility is that same as both of them (both in 2.5.1, and 2.5.2).
- The gravity fed hybrid design may require the use of the non-wired tower lifter. It will also be difficult to create slots for the lever at the correct heights, and synchronize all of the necessary forces without causing unforeseen issues.

2.5.5 Bricks

The brick housing structures are all feasible, however the angled single-brick structure may be more difficult to implement than the other designs.

2.5.6 Locomotion

All three designs for the locomotion of the robot are equally feasible (all three were observed during different labs).

2.6 PROS/CONS

2.6.1 Collectors

Swinging Collector (Both Orientations):
Pros:

- Swinging motion of arms allow block to be trapped
- Can be done from on top of the robot or from side, or both
- Flexibility with swinging as well as the software team's ability to generate how strong of a swing gives us a lot of versatility with the positioning of the brick

Cons:

- Swinging motion may destabilize the bricks position
- Swinging motion would utilize one or two EV3 motors which would take up valuable resources for us to use for other designs

Sliding Collector:
Pros:

- Sliding motion of arms allow block to be trapped
- Lack of swinging motion will reduce the chance of destabilizing the block and moving it away from the robot by accident.

Cons:

- Sliding motion reduces versatility in actually capturing the block.
- Requires more precise orientation from robot in terms of navigating to block. Less versatility means the robot will have to be in a better position to "trap" the block.
- Sliding motion would utilize one or two EV3 motors which would take up valuable resources for us to use for other designs

Static Collector:
Pros:

- No EV3 motors required, allows us to use those ports for a more useful purpose.
- Static prongs and thus a lack of swinging motion will reduce the chance of destabilizing the block and moving it away from the robot by accident.

Cons:

- Will position block entirely upon robot's navigation code and positioning. Places more of the burden on the software team.
- Precision required to actually entrap and rotate the block would require constant use of ultrasonic sensor and light sensor. This draws a lot of energy and power.

2.6.2 Lifters

Tower Climbing Motor
Pros:

- Can provide downward force other than simply using gravity
- Solid design that won't allow for much shifting
- Can easily be updated to change the height

Cons:

- Difficult design to implement
- The wheels used for moving up and down may slip on the tower, throwing the entire system off
- Heavy design focused on one side of the robot (front or back)
- Would require a long cable for the motor, as its position is variable
- The wire and system may hinder the functionality of the robot
- The tower could get in the way of the grabber's necessary motion

Wired Tower
Pros:

- Solid design that won't allow for much shifting
- Can easily be updated to change the height
- Light construction

Cons:

- Slack wires could cause problems

- Wire choice may be imperative to the success of the design
- Room for the wires must be set aside
- Dropping a grabber onto a block may cause the wires to go slack
- The tower could get in the way of the grabber's necessary motion

Crane
Pros:

- The crane would be out of the way of the grabber
- Light Construction
- The motor would have many possible locations
- The wires pass through the structure

Cons:

- Slack wires could cause problems
- Wire Choice may be imperative to the success of the design
- Dropping a grabber onto a block may cause the wires to go slack
- The design would require balancing and extra support
- May allow the grabber to swing

2.6.3 Grabbers

Claw Grabber
Pros:

- Tube design ensures the secure transport of the block post pick up
- Easy on the budget, light construction
- Grabber claw is large enough to fit around most orientations for Styrofoam block

Cons:

- Requires a minimum height to be lifted successfully
- May be impaired by orientation at which EV3 robot lines up with
- If material for cardboard tube isn't strong enough it will not provide enough force to properly clamp the block

Motorized Grabber
Pros:

- Due to motor it will be easy to secure whatever it is holding onto by applying more force.
- Claw is versatile and can rotate itself outwards as far necessary due to motor.
- Design is efficient and will not require many legos to build, however may take some time to assemble

Cons:

- Requires the use of another EV3 motor, thus requiring another cable which may interrupt design.
- Will have to see the best way to implement this with a lifter as a string will not be able to hold it up
- Complexity of endeavor means it will take time to build and perfect

Partial Platform Grabber
Pros:

- Simplicity
- Lack of motors will allow us to use another motor in the design for something else

Cons:

- Lots of room for error as friction coefficients cannot be controlled by us in the lab
- Entirely successful based on block stability whilst being held - would have to design an entire system to stabilize block
- If the EV3 made a sharp turn or sudden change in speed block strong chance the block may fall off.

2.6.4 Collector/Grabber/Lifter Hybrids

Cage
Pros:

- Allows the stacking of blocks before reaching the desired location
- Would ensure the stack is structurally sound
- Would cut down on the time required to create the stack

Cons:

- Nearly impossible to construct
- Extremely heavy design focused on one end of the robot
- The release mechanism would most likely require another motor

- Difficult to initiate the feeding of the blocks into the cage

Two-Use Motor
Pros:

- Would allow for a centered rotating ultrasonic sensor
- Would cut down on the motors/sensors used
- Could cut out the need for a dedicated collector

Cons:

- Specialized gear design
- Low tolerance for error in the block's position
- Can only use the rotating sensor when a block hasn't been picked up
- Heavy design focused on one end of the robot

Hybrid 3
Pros:

- Would re-purpose a collector design
- Wouldn't require a distinct collector and grabber, as it would act as both
- Light design compared to the other motorized hybrids

Cons: See section 2.6.1

- Must use one of the two tower lifter designs

Gravity Fed Hybrid
Pros:

- No motors would be used for collecting and grabbing
- Light design due to no motors
- Simple coding for stacking

Cons:

- Reliance on lego structure for heights to release at, and grabbing angles
- Complicated mechanical design
- Possible need for more force than simply gravity (need for a specific lifter structure)

2.6.5 Brick

One Brick
Pros:

- Don't need to take care of a slave brick
- Easier to Debug

Cons:

- May not have enough ports for all the motors and sensors

Two Bricks Stacked:
Pros:

- Simplicity
- Can fit more ports
- Easy to plug in ports

Cons:

- Heavier because the two bricks are on top of each other

Two Bricks on Side:
Pros:

- Can fit more ports
- Bricks on their side will spread the weight

Cons:

- May be hard to take out the battery and ports if necessary

2.6.6 Locomotion

Metal Ball
Pros:

- Smooth motion
- Low friction
- Simple implementation

Cons:

- Difficulty with discontinuities
- Possible issues with balance
- Slipping in forward motion

Gear Wheel
Pros:

- Smooth motion

- Low friction

Cons:

- Possible issues with balance
- Difficulty with discontinuities
- Slipping in forward motion

Treads
Pros:

- Less slipping during forward motion
- No issues with discontinuities
- Good balance

Cons:

- The large contact surface with the ground could cause issues with turning
- High friction during turning could cause flex in the structure

2.7 OPTIMUM SOLUTION(S)

The assessments done in section 2 lead to the identification of solutions that will likely meet the requirements of the component with the most consistent performance, and the least downsides.

2.7.1 Collectors

As all three collectors are feasible, the optimum solution is either the sliding collector, or one of the swinging collectors. All three of these collectors are of similar design, and can easily be compared to each other, while their use of motors will allow them to successfully deal with blocks at more orientations and placements than the static collector.

2.7.2 Lifters

The optimal lifter is the non wired tower. However, because such a design would likely require a set of gear racks which are not included in the EV3 kits provided to us, the wired tower may have to suffice as the second optimum solution. The tower designs are the simplest structures, and can perform all the necessary functions of the lifter without causing too many problems with balance and weight.

2.7.3 Grabbers

The optimum grabber solution is the motorized grabber. It is the design with the least possible failure points, and can be easily constructed.

2.7.4 Collector/Grabber/Lifter Hybrids

The optimum hybrid design is Hybrid 3. Hybrid 3 is the only one that is likely to not cost an obscene amount of time to design and construct. It is also the solution that is most likely to succeed, and can re-use parts from the construction of collector 4 when it is complete.

2.7.5 Bricks

We would like to use one brick to ensure a simple design,however it may be necessary to use more ports. We would need to figure out which design for the used brick configuration will work better in terms of weight, balance, and port locations. The bricks/chassis design will be chosen after the necessary number of ports is determined. This means that it will not follow along with the same documentation as the other components from this point onward.

2.7.6 Locomotion

It is believed that the treads will be the optimum solution, as they will have no trouble with the discontinuities. The discontinuities are a problem that could cause a large amount of error in the odometer, which is to be avoided at nearly any cost. We don't believe that the treads will cause too much of a problem with the navigation, and turning, however this must be tested.

3 COMPONENTS TO BUILD

3.1 OBSERVATIONS ON COMPONENTS

3.1.1 Collectors and Grabbers

All three of the motorized collector designs can be altered slightly to become motorized grabbers. As grabbers, they will likely perform better than the motorized claw design discussed earlier as a formal grabber. This means that we have decided to forego the construction of independent grabbers and collectors, except in the case of the static collector and the partial platform grabber which would work well together (if they work at all).
Also, the swinging collector design with the front orientation will only work in the case where the robot's chassis is significantly wider than the block to be picked up. This means that it would likely only be useful in the case of using 2 bricks.

3.1.2 Lifters

The non-wired tower could be built using wheels at this point, to test it in a basic sense. This would allow for a proper decision on the lifter design to be made, and for the time required to request the use of gear racks, and order them online.

3.1.3 Collector/Grabber/Lifter Hybrids

The gravity fed hybrid design will likely require the non-wired tower to be its lifter, as gravity may not suffice for the forces necessary to properly operate its grabbing and release mechanism.

3.2 FINAL CONSTRUCTION DECISIONS

3.2.1 Collectors

The collectors which will be constructed are the swinging collector with the side orientation, the sliding collector, and the static collector. The swinging and sliding collectors will be built as collector/grabber hybrids.

3.2.2 Lifters

The lifter design which will be constructed is the wired tower design. This will be able to be updated into the non-wired version if desired.

3.2.3 Grabbers

The motorized grabber will likely not perform any better than a hybrid version of one of the motorized collectors. This means that the motorized grabber will not be constructed, and instead only the partial platform will be made.

3.2.4 Collector/Grabber/Lifter Hybrids

The gravity fed hybrid will be constructed, and the two motorized collectors will be modified into hybrid collector/grabbers as well.

3.2.5 Locomotion

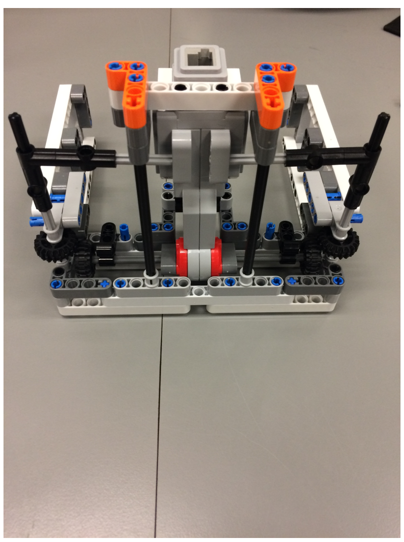
It is suggested that all three options are built and tested, as it is imperative that we make the correct choice of locomotion, and all three are easily constructed. Unforeseen circumstances may cause one of the options other than our optimal solution to truly be the best.

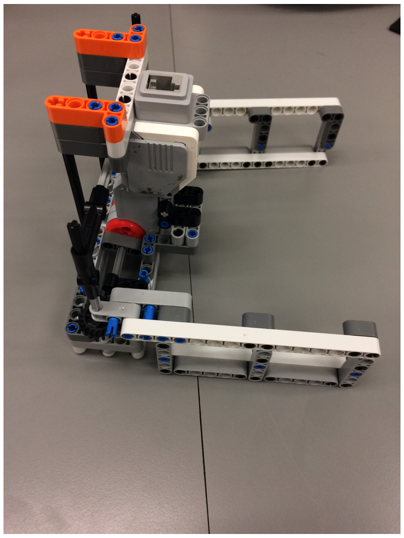
4 CONSTRUCTION

4.1 CONSTRUCTED MODELS AND COMMENTS ON CONSTRUCTION

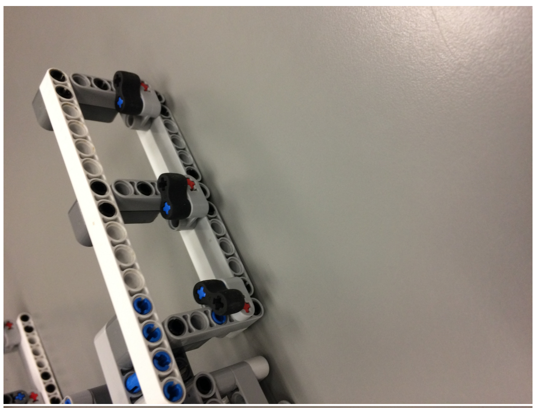
4.1.1 Swinging Collector/Grabber Hybrid

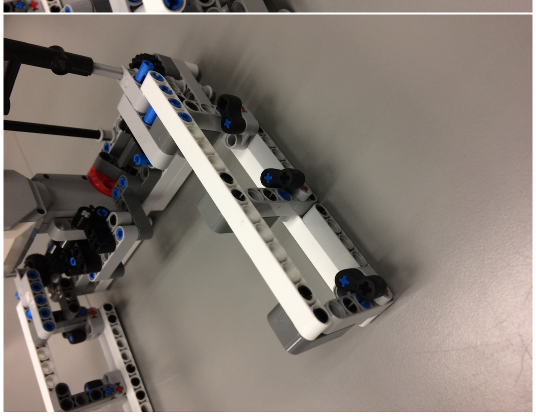
Collector version:





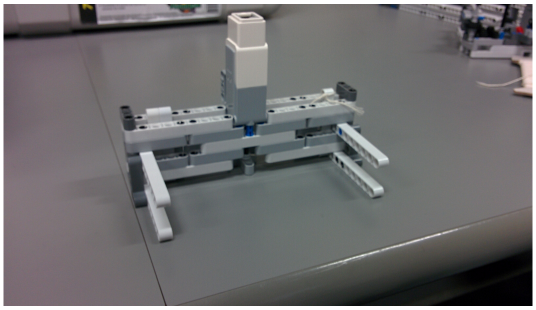
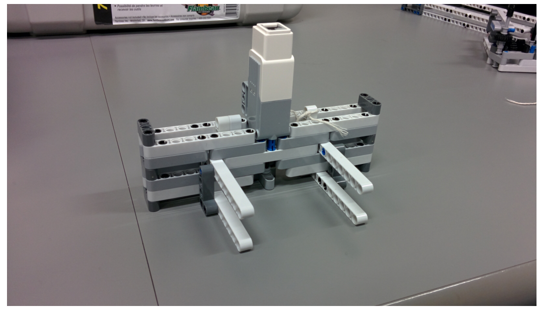
Modifications for grabbing:





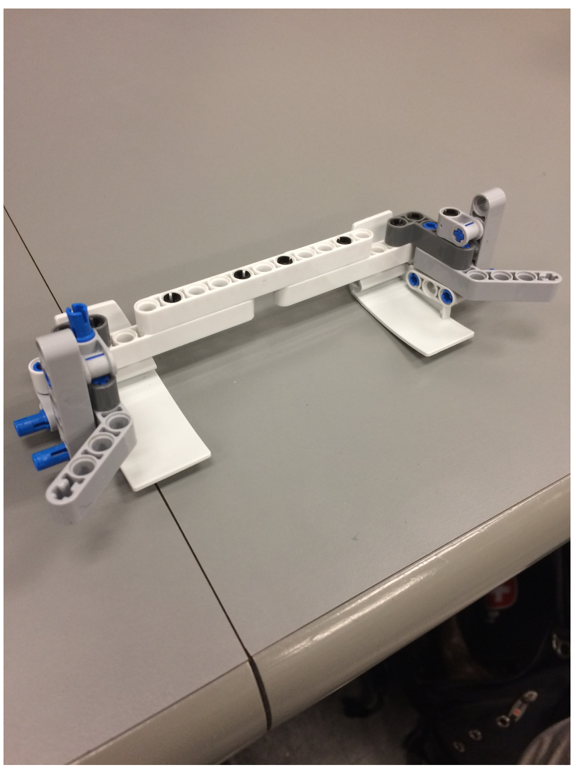
This design has the issue of having a large wingspan during closure. It also has issues when it contacts a heavy object while closing, as this causes the gears to skip rungs, which sets the two arms at different orientations.

4.1.2 Sliding Collector/Grabber Hybrid

This design has some issues that were not resolved in time for the third meeting (namely issues with the arms shifting while sliding, and difficulty stringing the wires properly), meaning it was not thrown out as a possibility, but was postponed and kept as a possible improvement to be added to a later hardware version.

4.1.3 Static Collector + Partial Platform Grabber

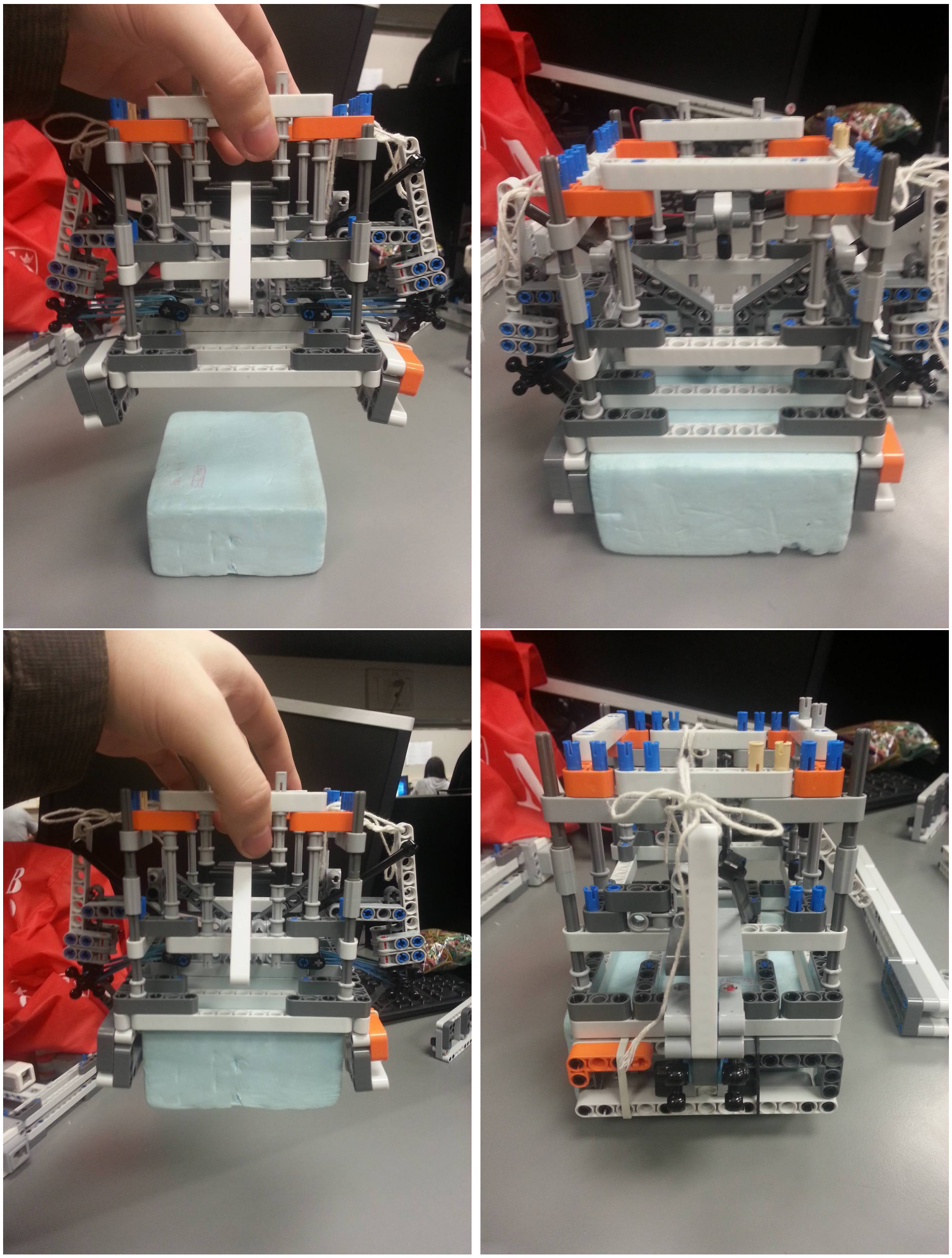


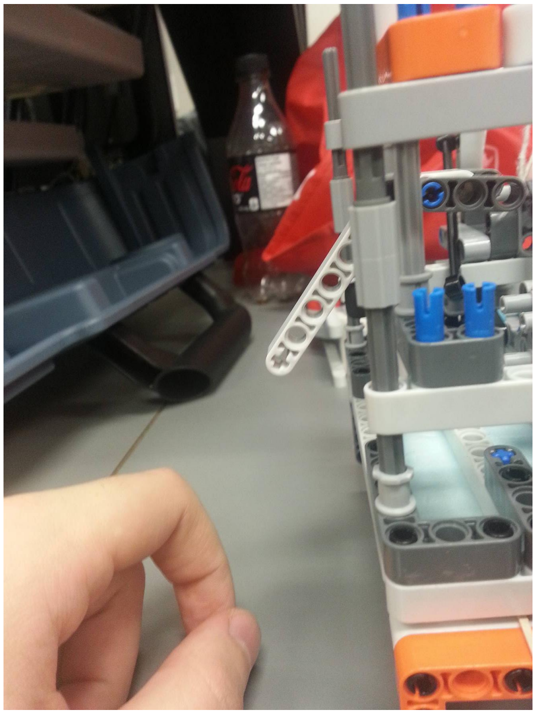
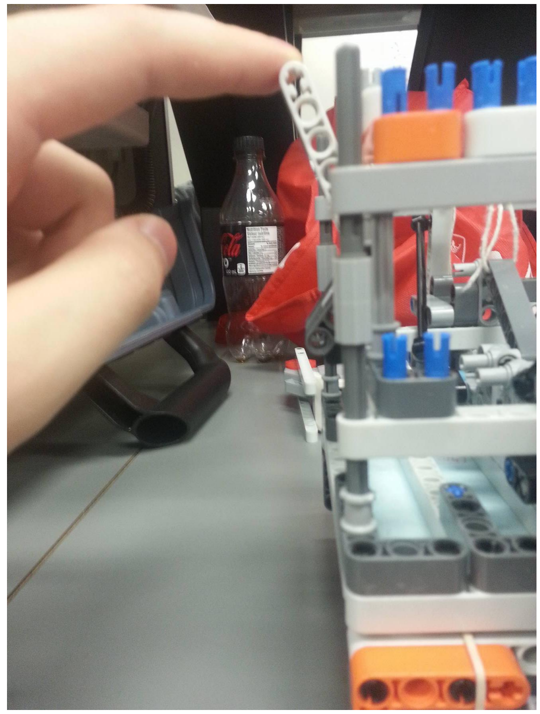
This design was more of a proof-of-concept for the partial platform than a design that was actually supposed to work. The partial platform was not big enough to balance the brick, and so it could not lift it. The idea was to test if the platform could slide under the brick successfully.

4.1.4 Wired Tower Lifter

This was the only lifter design built at this stage, as the necessary pieces for the non-wired version were not in our possession at the time of this initial construction stage.

4.1.5 Gravity Fed Hybrid

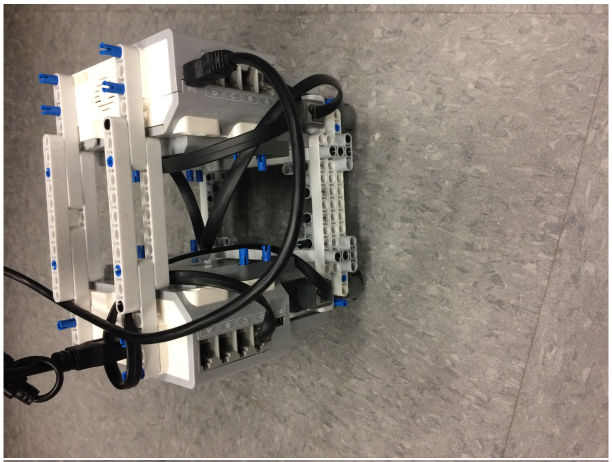


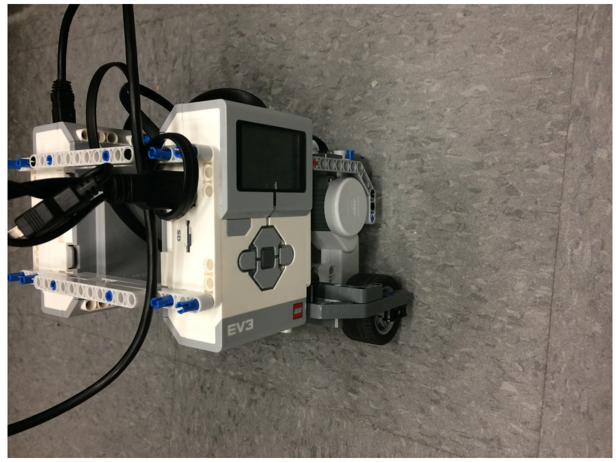



The three positions of the lever for the release mechanism illustrate a crippling issue; the lever must swing up further than the height of 1 block, which means that releasing the blocks at the correct heights for stacking would be impossible. For this reason construction on the gravity fed hybrid was halted at this point, and other designs were looked to for hardware version 1. This design may be revisited at a later point.

4.1.6 Chassis

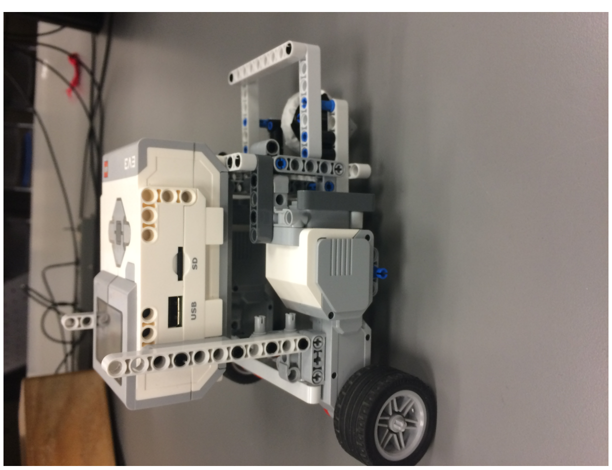
Dual Brick Chassis:

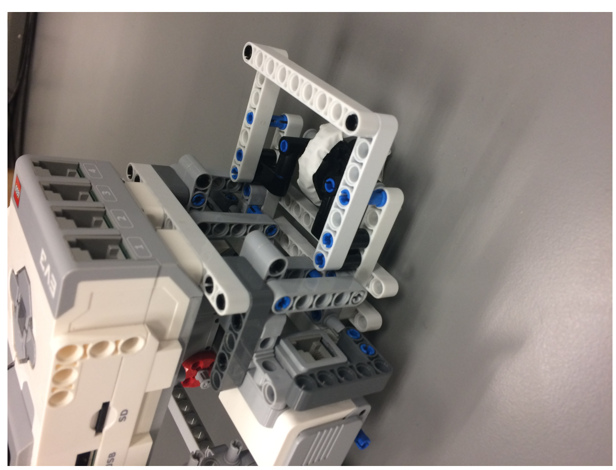


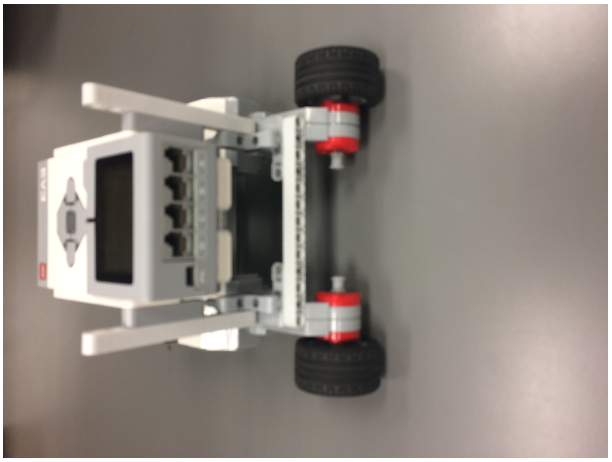


This was built as a first prototype for the dual brick chassis for use if it was decided to use two bricks.

Single Brick Chassis:







This was built as a first prototype for the single brick chassis for use if it was decided to use one brick.

4.2 REQUESTS FOR TESTING

4.2.1 Static Collector + Partial Platform Grabber

It is requested that a test be devised and performed to determine if blocks can be successfully collected and if the partial platform can slide under the blocks.

4.2.2 Swinging Collector/Grabber Hybrid

It is requested that a test be devised and performed to determine if blocks can be successfully collected and grabbed by the swinging collector/grabber hybrid.

5 COMPONENT TESTING ASSESSMENTS

5.1 TESTING CONCLUSIONS

5.1.1 Static Collector + Partial Platform Grabber

See the PARTIAL PLATFORM GRABBER TEST Document and STATIC COLLECTOR TEST Document.

5.1.2 Swinging Collector/Grabber Hybrid

See the HYBRID TEST Document.

6 HARDWARE VERSION 1

Builders: Ben, Kareem, Quentin, Jake **Completion Date:** 2016-11-07

INCEPTION

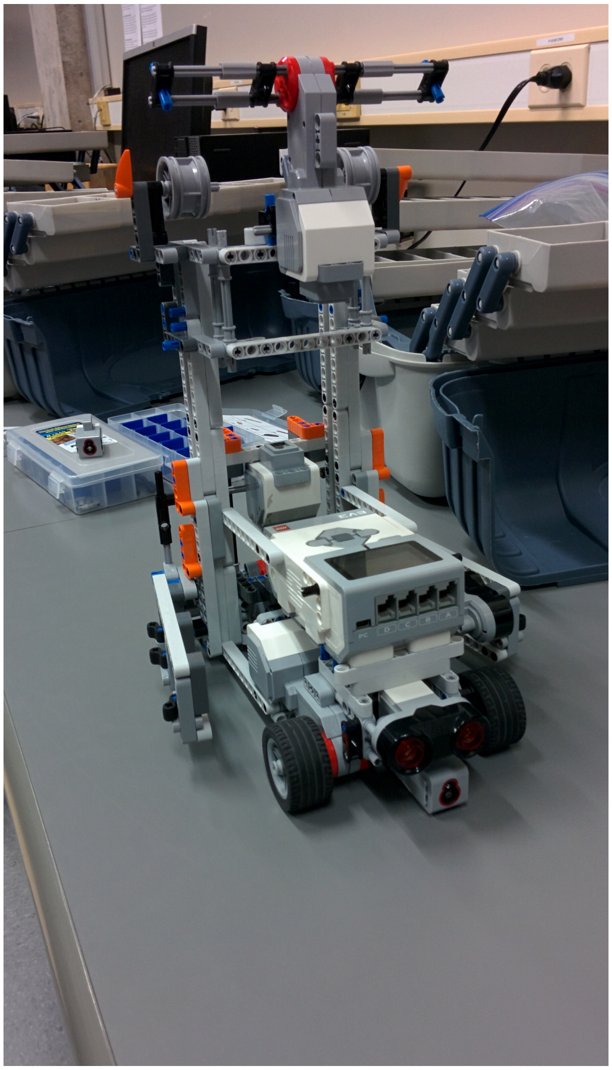
6.1 NOTABLE PIECES

- 4 EV3 large regulated motors
- 2 ultrasonic sensors
- 1 colour sensor
- 4 wheels (2 with tires)
- 2 ball bearing casters
- 4 medium gears
- 1 EV3 brick

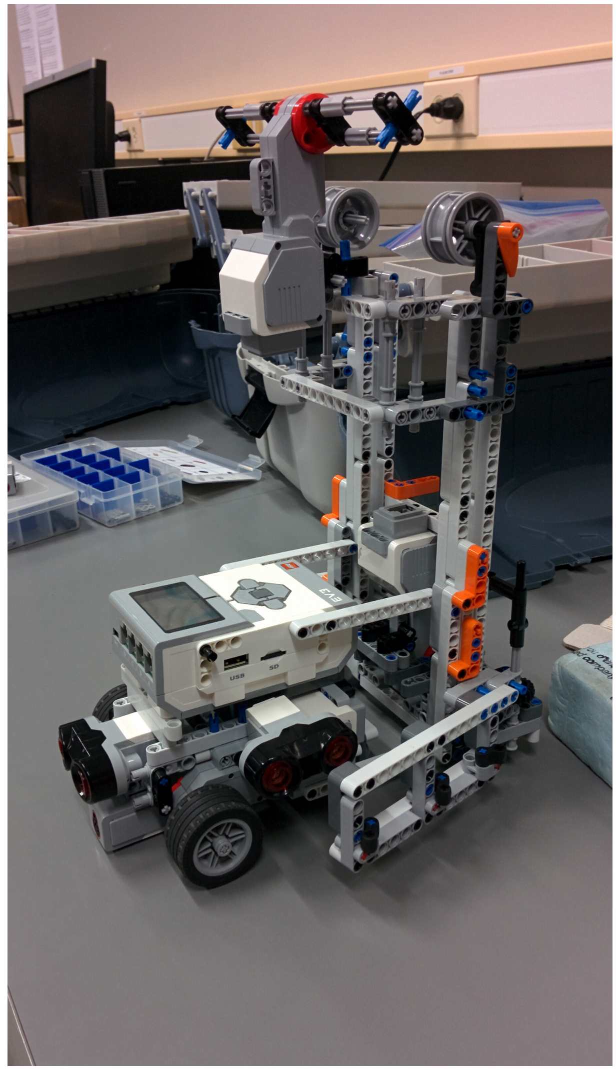
6.2 FUNCTIONALITY

This initial model did not include strings for the lifting mechanism, or wires for the sensors or motors. It was a structural design meant to show our vision for the robot, and act as a base for the first truly functional version (version 2).

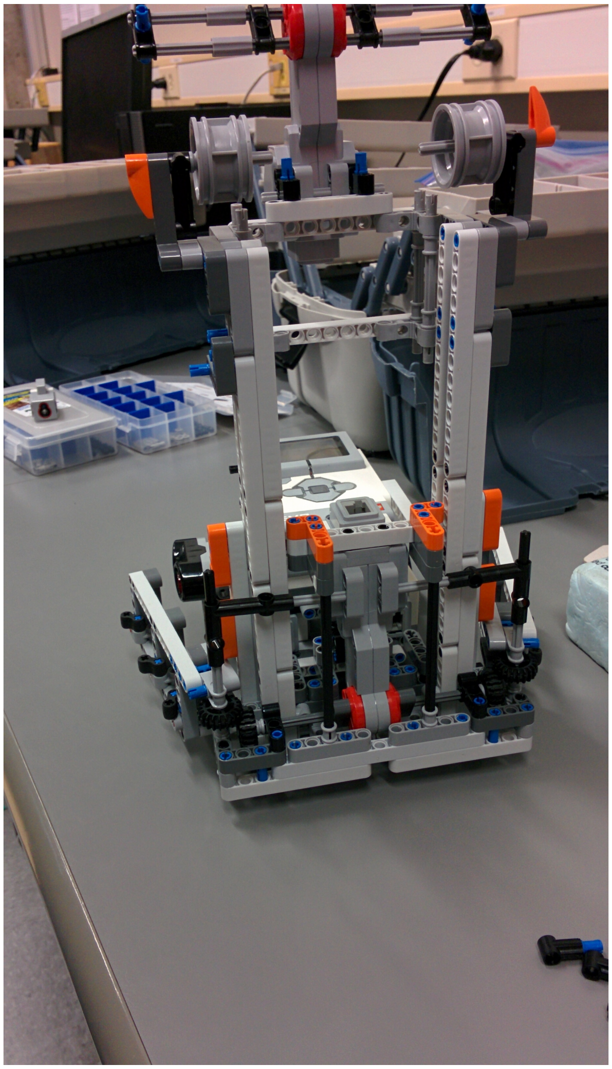
6.3 MODEL



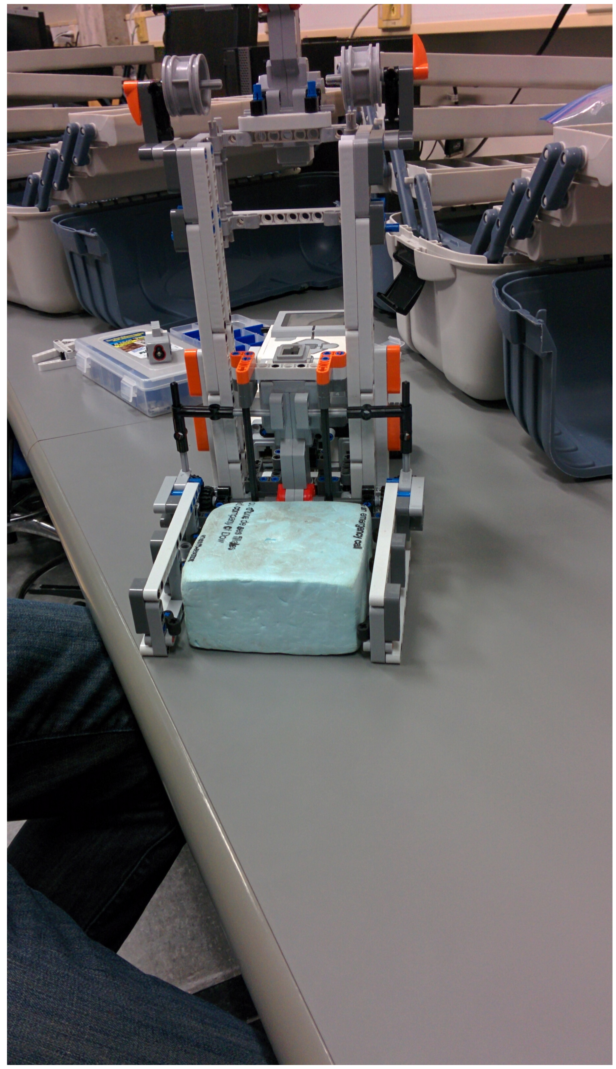
Front right view



Front left view



Rear view (grabber open)



Rear view (grabber closed)

6.4 POSSIBLE IMPROVEMENTS

- The gears in the grabbing mechanism tend to skip teeth when under pressure, so an improved gear structure could be developed.
- The upper level of the grabbing mechanism is not attached to the tower, leading to the whole mechanism leaning outwards, so a stabilizer could be developed.
- The wheels on top of the tower can easily bend inwards, so a stabilizer could be developed.
- The entire robot leans towards the back, lowering the traction for the wheels, so the balance could be improved.
- The mount for the motor on top of the tower is flexible and unstable, so a way to stabilize and strengthen the mount could be found.

- There is no downward facing colour sensor, so it could be added.
- The leftward facing ultrasonic gets blocked by the swinging arm of the grabber, so it could be relocated.
- The front ultrasonic and colour sensor are not completely centered, so that issue could be remedied.
- All the wires could be added.
- The lifter's string could be added.
- The front colour sensor is extremely close to the ground, and may get caught on discontinuities, so it could be raised.
- This version uses ball bearing casters, which have been shown to have issues with discontinuities, so new casters based on tests done should be adopted.

7 HARDWARE VERSION 1.5

Builders: Ben **Completion Date:** 2016-11-8

AWAKENING

7.1 NOTABLE PIECES

- 4 EV3 large regulated motors
- 2 ultrasonic sensors
- 2 colour sensors
- 4 wheels (2 with tires)
- 2 ball bearing casters
- 4 medium gears
- 1 EV3 brick

7.2 CHANGES MADE

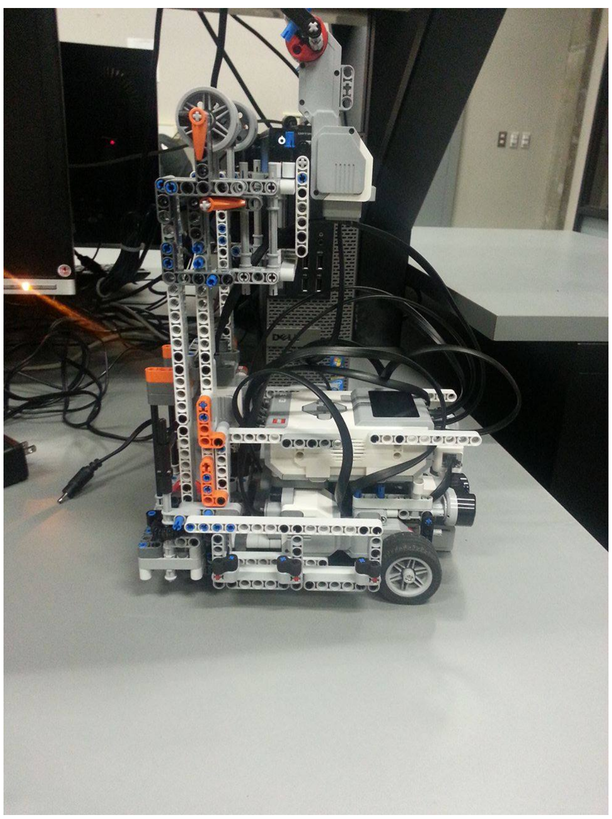
- Stabilizers were added to the top of the grabbing mechanism, to the wheels at the top of the tower, and to the mount for the lifter motor.
- A downward facing colour sensor was added.

- The leftward facing US was moved to the front of the robot, to keep it from being blocked by the swinging arms.
- All sensors and motors were wired.
- The tower was moved closer to the main chassis, and the ball bearing casters were attached in between the back of the chassis and the tower. This improved the balance of the robot.

7.3 FUNCTIONALITY

This version of the robot can drive, use its sensors, and grab blocks. The tower does not have strings attached, so it can't lift. Also, if the strings were attached, the wiring for the sensors get in the way of the grabbing mechanism when sliding up the tower, so it wouldn't be able to lift much, even if the strings were attached.

7.4 MODEL



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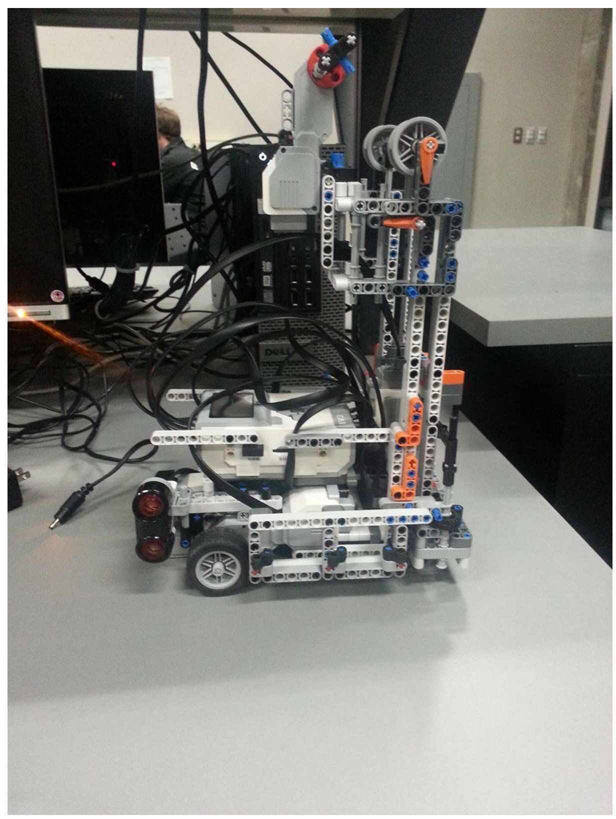

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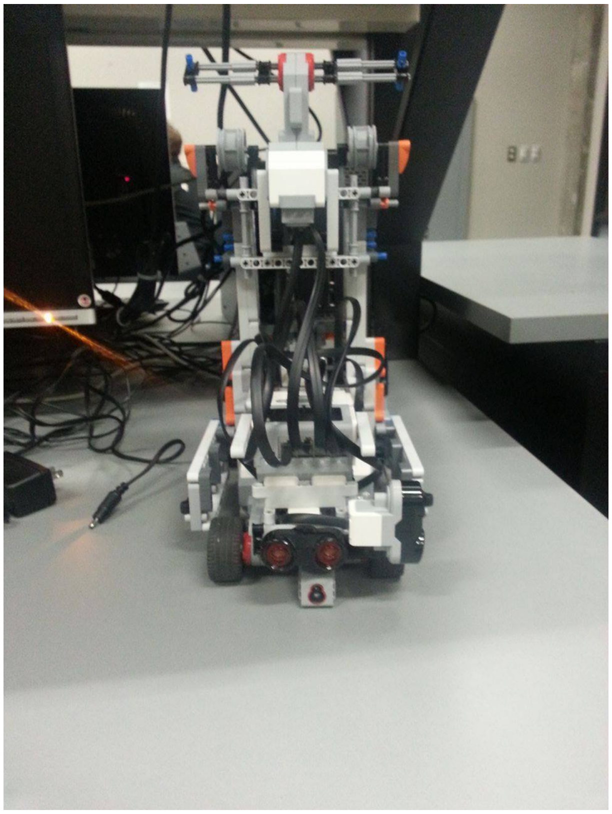
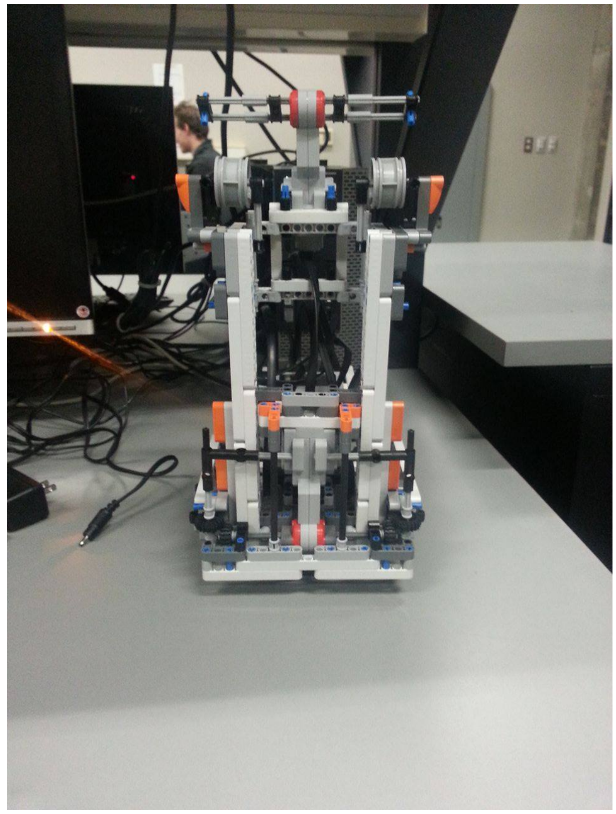
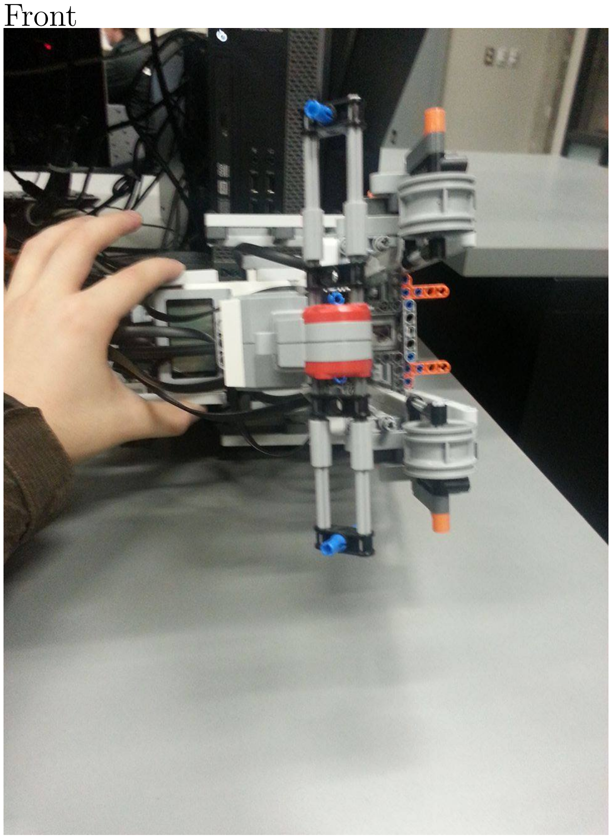


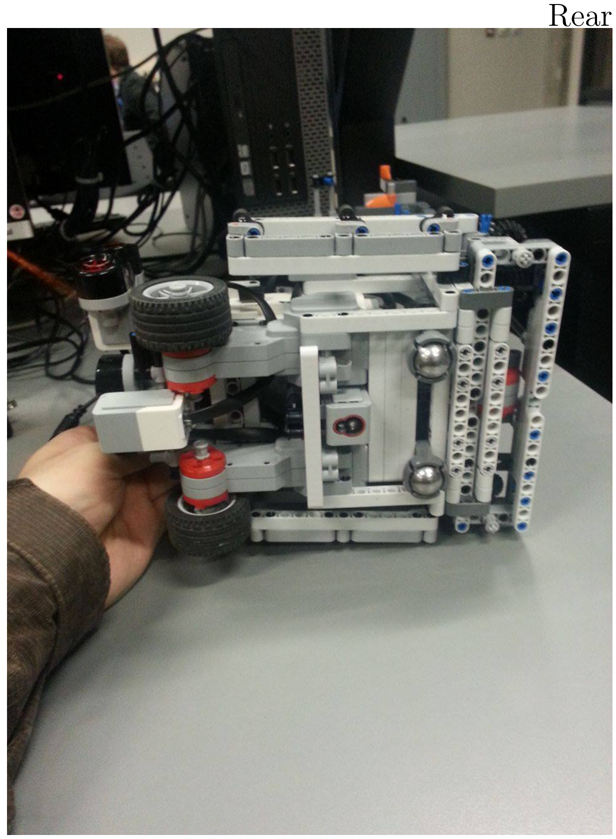
Front



Rear



Top



Bottom

7.5 POSSIBLE IMPROVEMENTS

- The gears in the grabbing mechanism tend to skip teeth when under pressure, so an improved gear structure could be developed.
- The entire robot still leans towards the back, lowering the traction for the wheels, so the balance could be improved.
- The front ultrasonic and colour sensor are not completely centered, so that issue could be remedied.
- The wiring could be redone to avoid blocking the upwards motion of the grabbing mechanism.
- The lifter's string could be added.
- The front colour sensor is extremely close to the ground, and may get caught on discontinuities, so it could be raised.
- This version uses ball bearing casters, which have been shown to have issues with discontinuities, so new casters based on tests done should be adopted.

7.6 TESTING

See the "Localization Timing Test for Hardware Version 1.5" document for details on the balance issues of hardware version 1.5.

8 HARDWARE VERSION 2

Builders: Ben **Completion Date:** 2016-11-11

Heightened Reality

8.1 NOTABLE PIECES

- 4 EV3 large regulated motors
- 2 ultrasonic sensors
- 2 colour sensors
- 4 wheels (2 with tires)
- 2 ball bearing casters
- 4 medium gears

- 1 EV3 brick

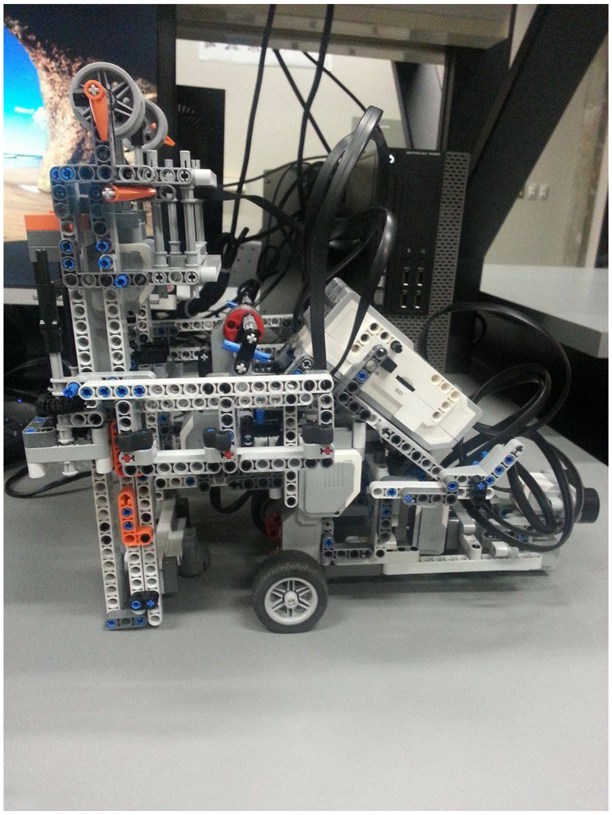
8.2 CHANGES MADE

- The entire chassis was rebuilt in an attempt to improve the balance, and focus the weight on the wheels.
- Switched to rear wheel drive.
- The tower motor was moved to the back of the chassis.
- The ball bearing casters were moved to the front and back of the robot.
- The front US and CS were centered.
- The front CS was raised slightly.
- The wires were reworked, and no longer block the upward motion of the grabbing mechanism.

8.3 FUNCTIONALITY

The robot features the same functionality of version 2, except for the possibility to lift the grabbing mechanism. Although the strings are not attached, the wires no longer block the lifting motion, and so a quick modification will be able to enable lifting.

8.4 MODEL



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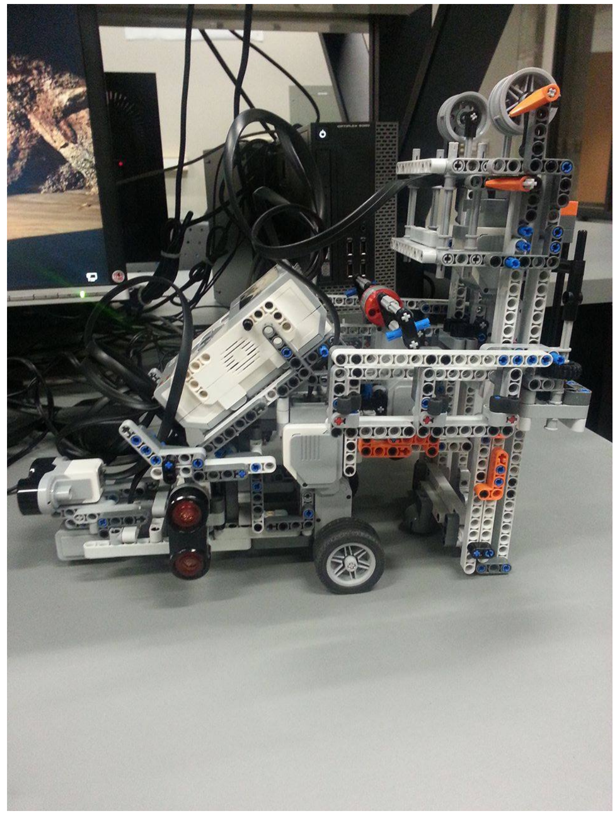

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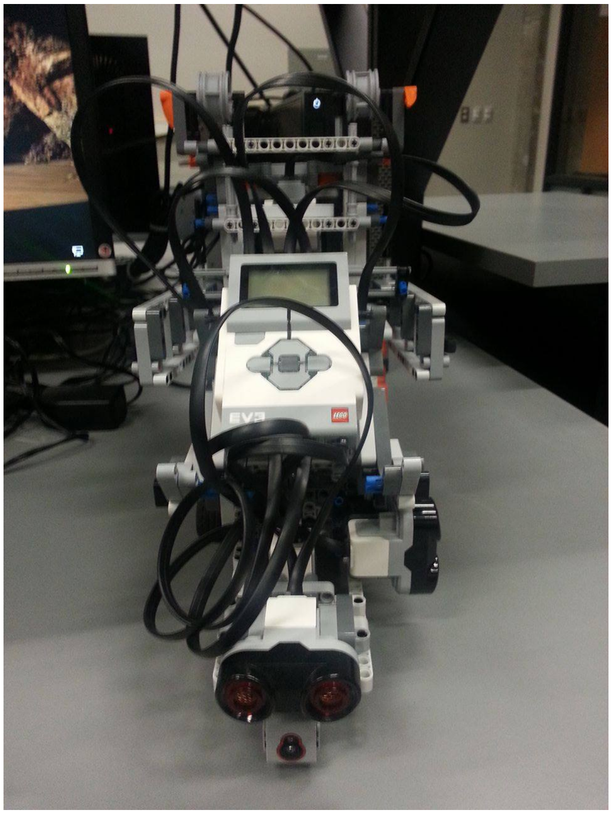
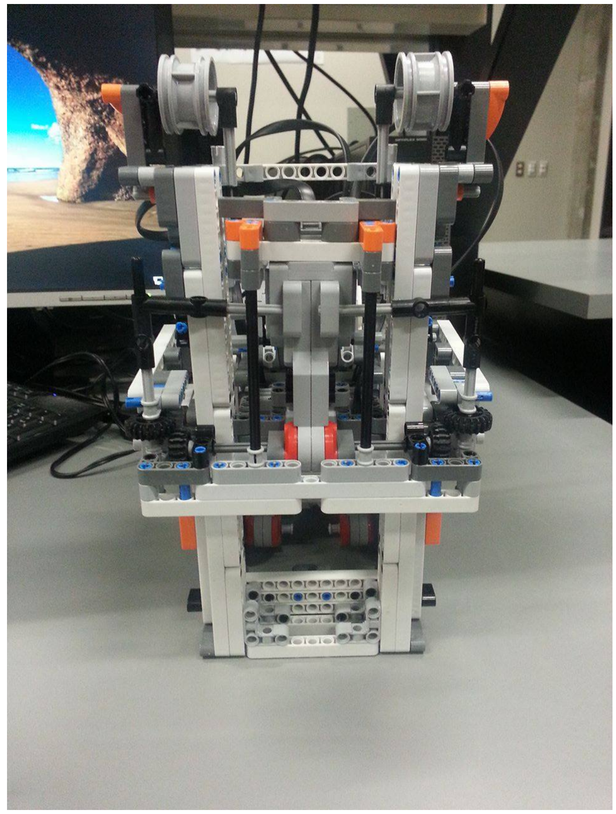
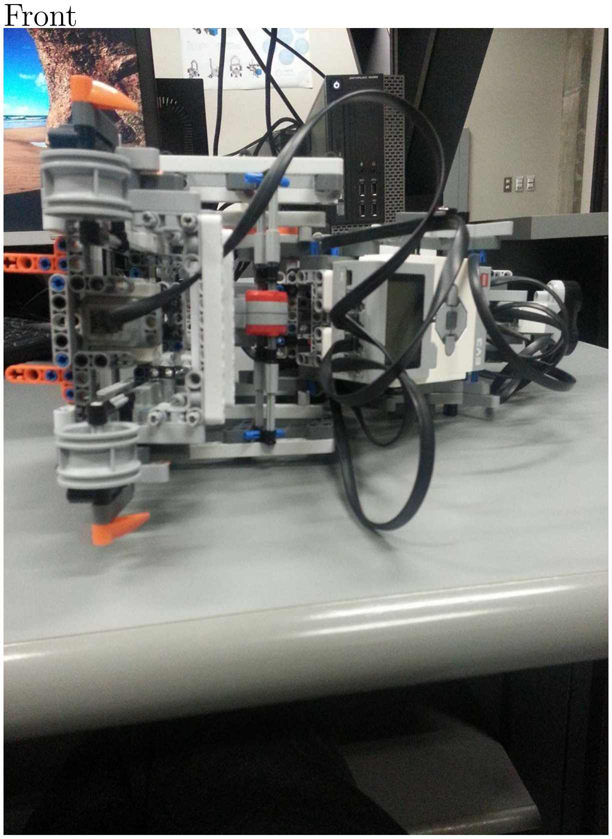
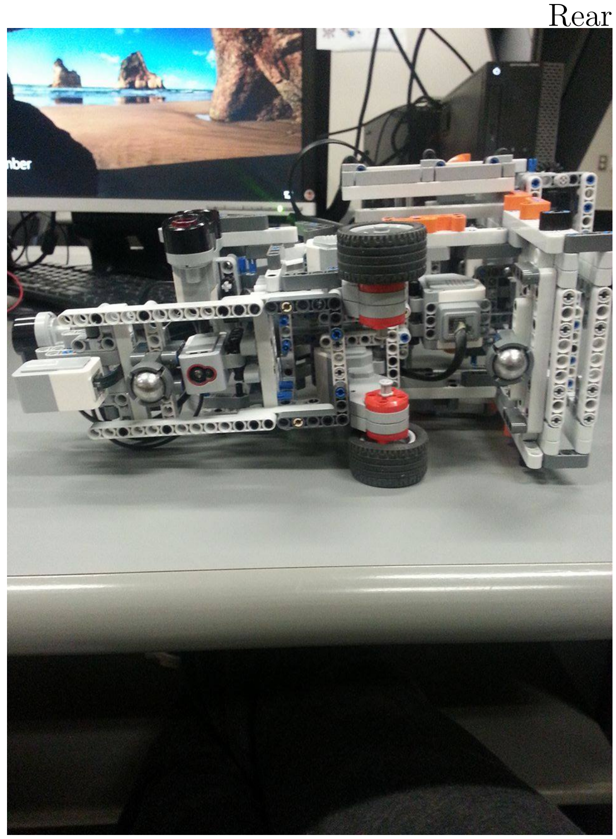




Front

Rear





Top

Bottom

8.5 POSSIBLE IMPROVEMENTS

- The center of mass could be lowered.
- The length of the robot could be shortened.
- The tower is not well attached to the chassis, so its mount could be improved.
- The gears in the grabbing mechanism tend to skip teeth when under pressure, so an improved gear structure could be developed.
- The lifter's string could be added.
- This version uses ball bearing casters, which have been shown to have issues with discontinuities, so new casters based on tests done should be adopted.

9 HARDWARE VERSION 2.5

Builders: Ben, Quentin **Completion Date:** 2016-11-12

Strung Up

9.1 NOTABLE PIECES

- 4 EV3 large regulated motors
- 2 ultrasonic sensors
- 2 colour sensors
- 4 wheels (2 with tires)
- 1 ball bearing caster
- 4 four pronged gears
- 1 EV3 brick

9.2 CHANGES MADE

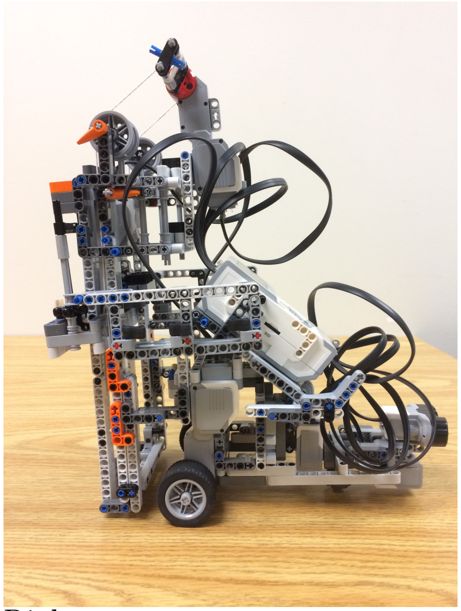
- The tower motor was returned to its position on top of the tower.
- The moving of the tower motor opened up space, allowing the mount for the tower to be shortened, bringing the tower closer to the main chassis. The mount was also redesigned to be stronger.

- The gears in the grabbing mechanism were replaced with the 4 pronged gears, to avoid the skipping of rungs. Various bars were replaced in the mechanism to accommodate this change.
- The strings for lifting were tied to the grabbing mechanism, and the arms of the tower motor.

9.3 FUNCTIONALITY

This version of the robot has the ability to fulfill all necessary functions. It has full use of the lifting ability, block grabbing, the US sensors for object detection and avoidance, the colour sensor for object identification, the colour sensor for odometry correction, and the motors for navigation. The improved balance of the robot, and the centering of the weight on the wheels should allow the robot to navigate and turn without slipping. This will be tested.

9.4 MODEL



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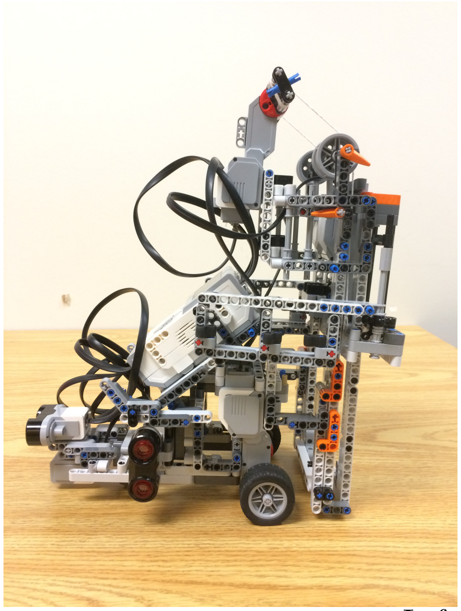

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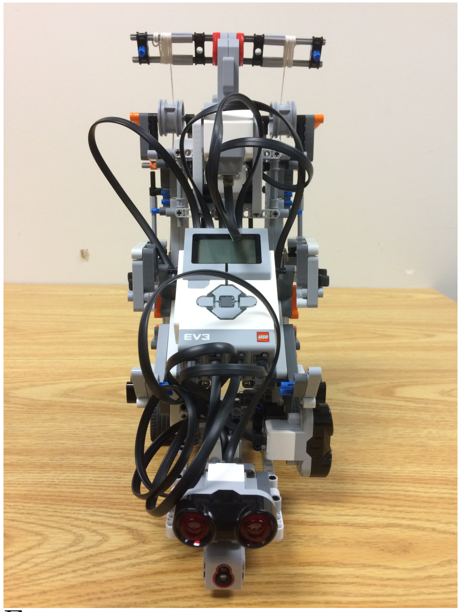
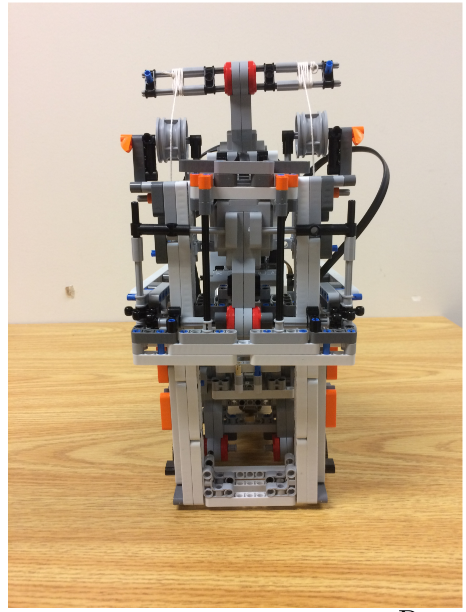
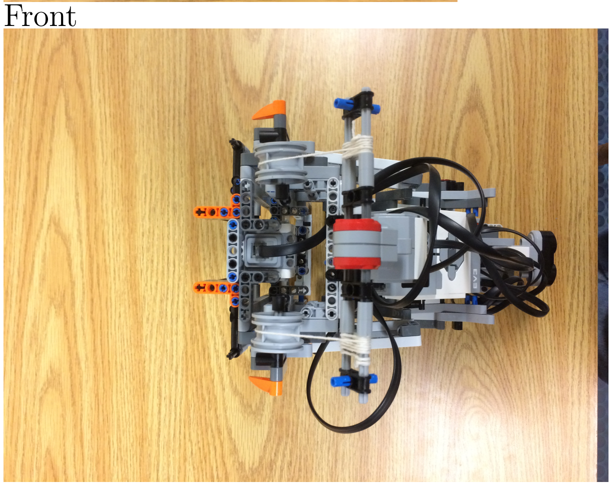
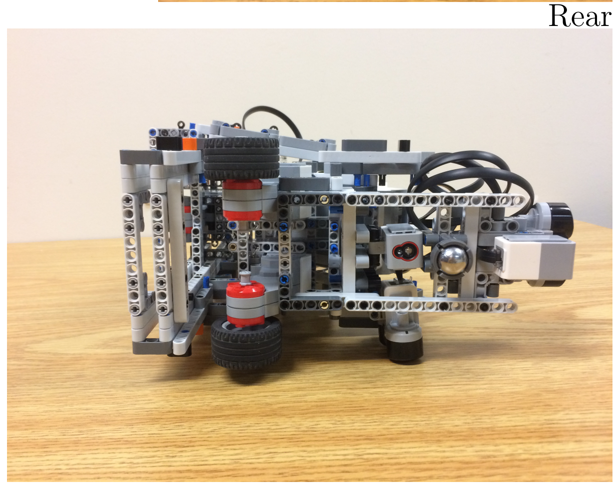




Front Rear





Top Bottom

9.5 POSSIBLE IMPROVEMENTS

- The center of mass could be lowered.
- The length of the robot could be further shortened.
- The front mount for the caster, and the sensors flexes regularly, so it could be strengthened.
- The caster on the front extends too far down, causing the robot to lean backwards. This causes the grabbing mechanism to scrape the ground when closing. So the caster and sensors could be raised one level.
- This version uses ball bearing casters, which have been shown to have issues with

discontinuities, so new casters based on tests done should be adopted.

- The arms on the tower motor could be more completely secured to the motor, so as to prevent them from popping off when under strain.

9.6 TESTING

See the "HARDWARE VERSION 2.5 AND 3 DISCONTINUITIES TEST" document for testing results of crossing discontinuities.

Also see the "HARDWARE VERSION 2.5 AND 3 NAVIGATION/ODOMETER TEST" document for testing results of driving in a square with odometry.

10 HARDWARE VERSION 3

Builders: Ben, Quentin **Completion Date:** 2016-11-15

Spoon Fed

10.1 NOTABLE PIECES

- 4 EV3 large regulated motors
- 2 ultrasonic sensors
- 2 colour sensors
- 4 wheels (2 with tires)
- 1 spoon caster
- 4 four pronged gears
- 1 EV3 brick

10.2 CHANGES MADE

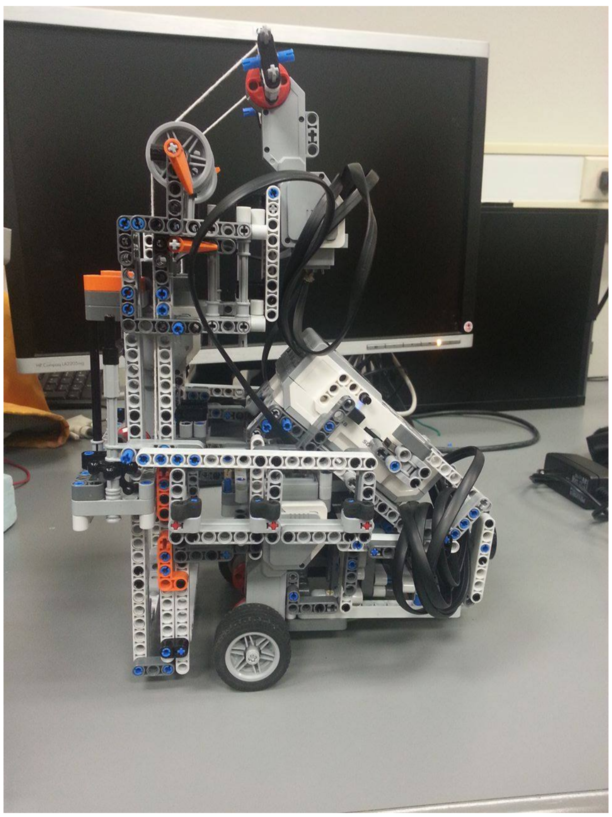
- The ball bearing caster was replaced with a spoon in an attempt to improve performance when crossing discontinuities in the floor.
- The downward facing CS was moved between the wheels.
- The length of the robot was reduced.

- The caster and front sensors were raised 1 block.
- A support was added to ensure that the mount for the front sensors does not sage towards the ground.
- The tower's arms were reinforced.

10.3 FUNCTIONALITY

The same as version 2.5.

10.4 MODEL



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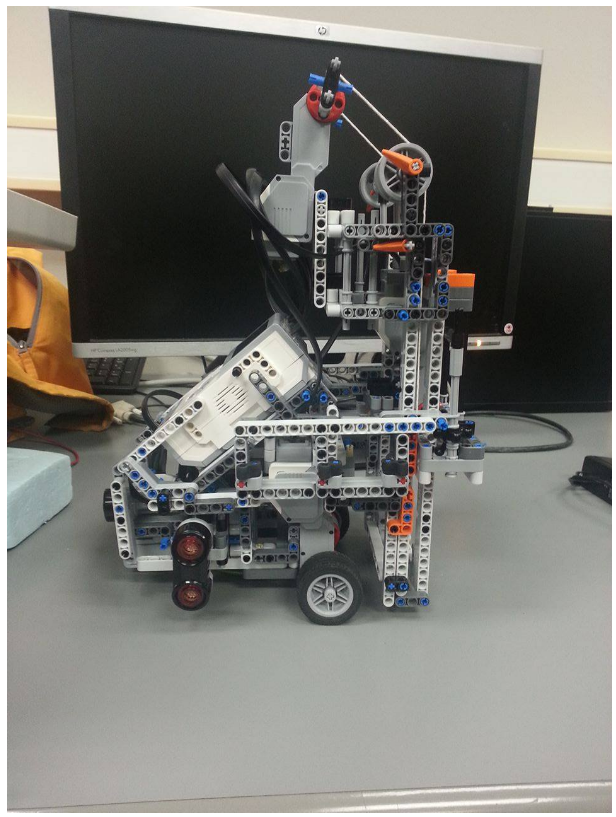

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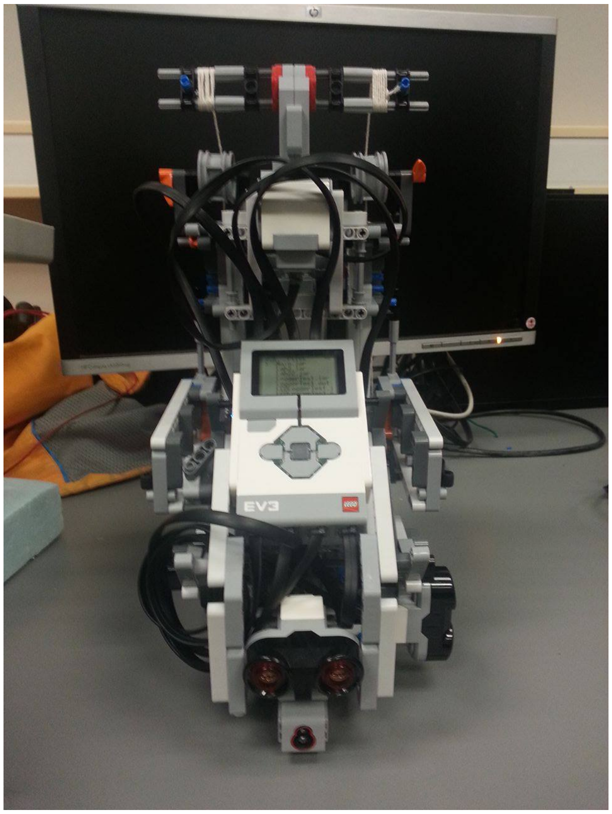
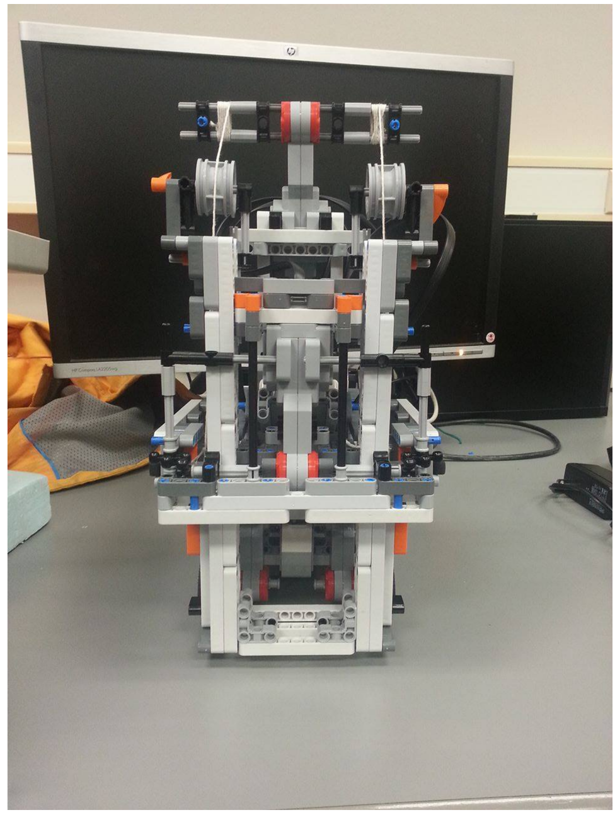
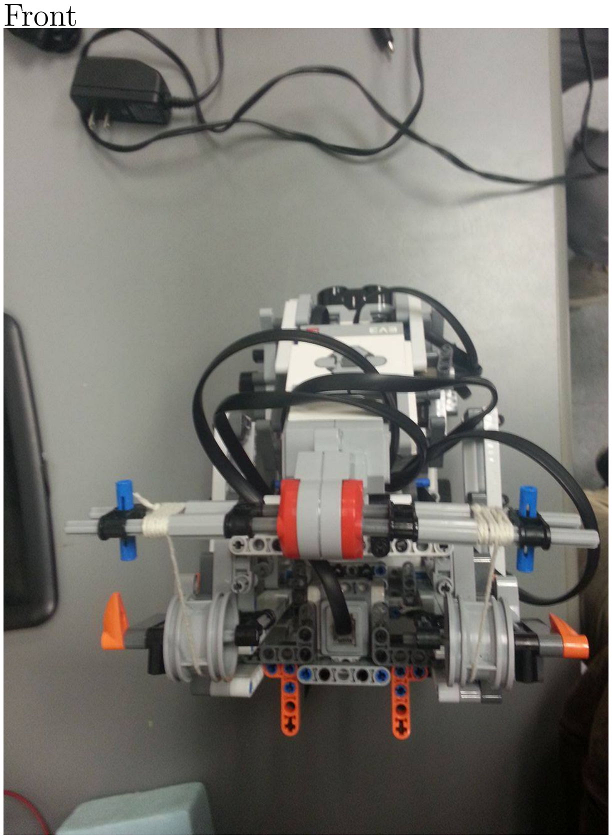
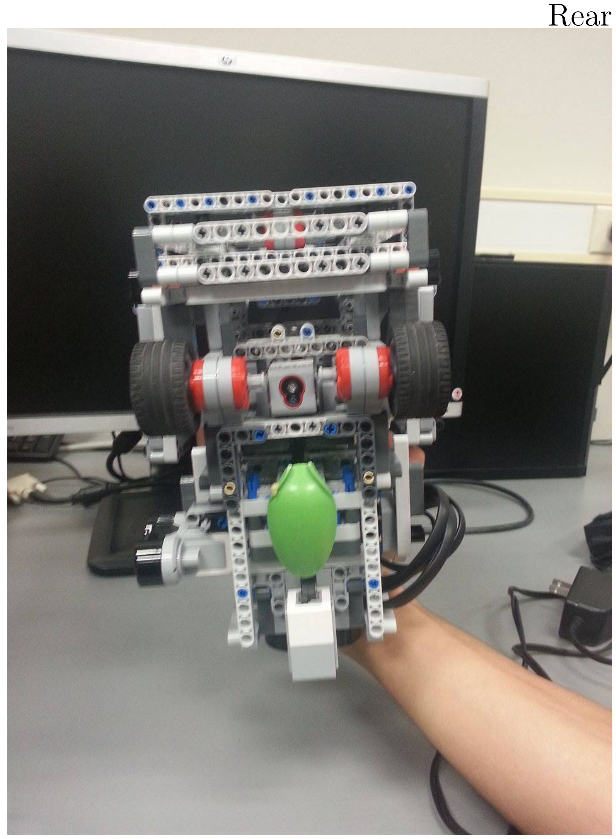




Front

Rear





Top

Bottom

10.5 POSSIBLE IMPROVEMENTS

- The center of mass could be lowered.
- The charging port could be made easier to access.
- Wire management could be improved.
- The tires could be made more solid to avoid squishing, which changes the wheel radius.
- A blocker could be added to the top of the tower to avoid the grabbing device falling out of the tower when it is raised to the top.

10.6 TESTING

See the "HARDWARE VERSION 2.5 AND 3 DISCONTINUITIES TEST" document for testing results of crossing discontinuities.

See the "HARDWARE VERSION 2.5 AND 3 NAVIGATION/ODOMETER TEST" document for testing results of driving in a square with odometry.

See the "" document for lifting results that identify an issue with the tower arms.

11 HARDWARE VERSION 3.01

Builders: Quentin **Completion Date:** 2016-11-16

Screwed Up

11.1 NOTABLE PIECES

The same as version 3.

11.2 CHANGES MADE

- The tower arms were replaced with a single bar through the center of the motor. This ensures that the arms will not pull off of the motor during lifting.

11.3 FUNCTIONALITY

The same as version 2.5.

11.4 MODEL

The same as version 3, except the tower arms:

11.5 POSSIBLE IMPROVEMENTS

The same as version 3.

11.6 TESTING

See the "OBJECT PICKUP TEST" document for results on the improved tower arm structure.

12 HARDWARE VERSION 3.02

Builders: Tristan, Alexis **Completion Date:** 2016-11-17

Cross-Eyed

12.1 NOTABLE PIECES

The same as version 3.

12.2 CHANGES MADE

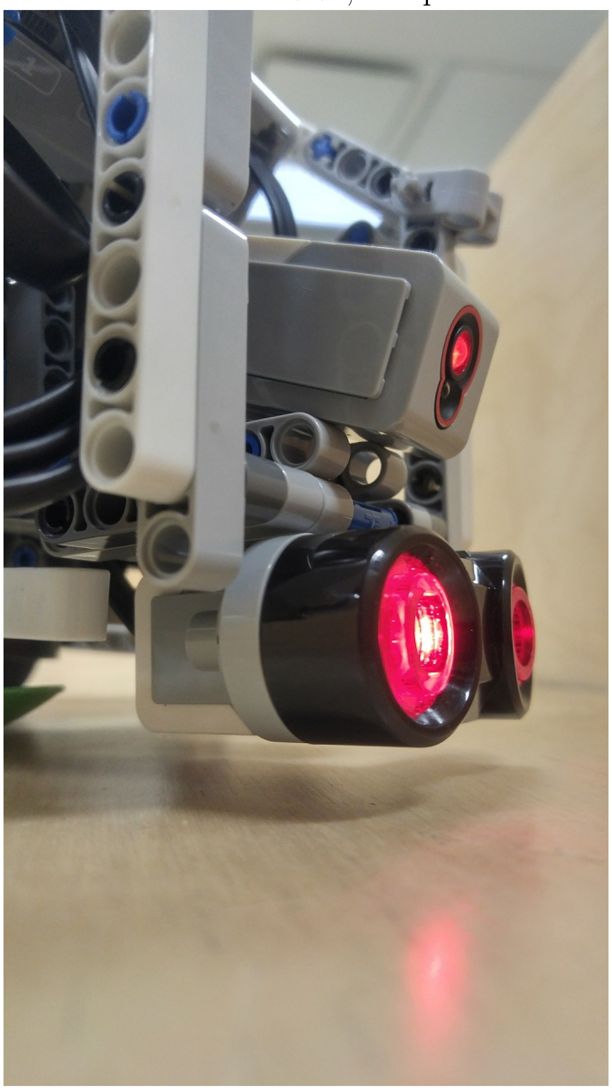
- The front sensors were flipped, so that the US is on the bottom, and the CS is on the top. The CS was also angled down, so that it can detect the block colours. This was done to allow the US to detect the styrofoam blocks correctly.

12.3 FUNCTIONALITY

The same as version 2.5.

12.4 MODEL

The same as version 3.01, except the front sensor mount/placement:



12.5 POSSIBLE IMPROVEMENTS

The same as version 3.

13 HARDWARE VERSION 3.02

Builders: Ben **Completion Date:** 2016-11-22

Lanky

13.1 NOTABLE PIECES

The same as version 3.

13.2 CHANGES MADE

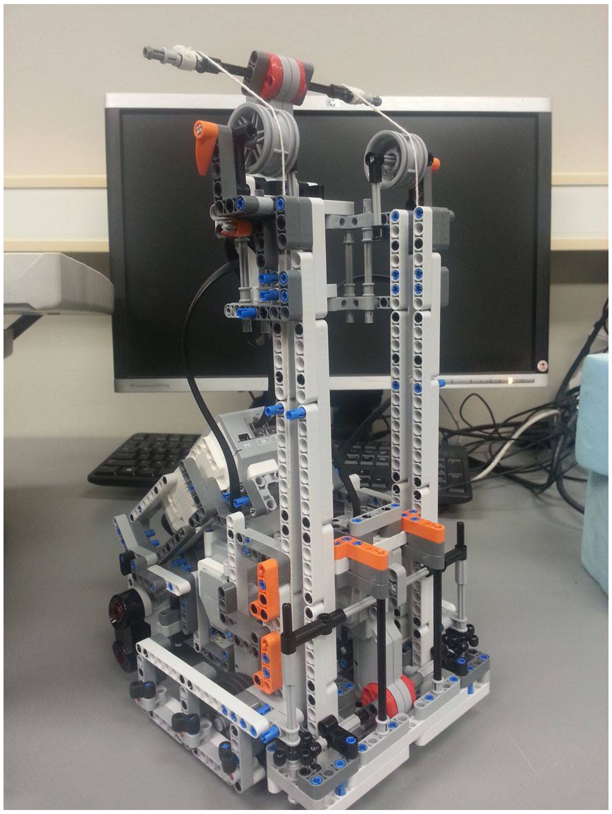
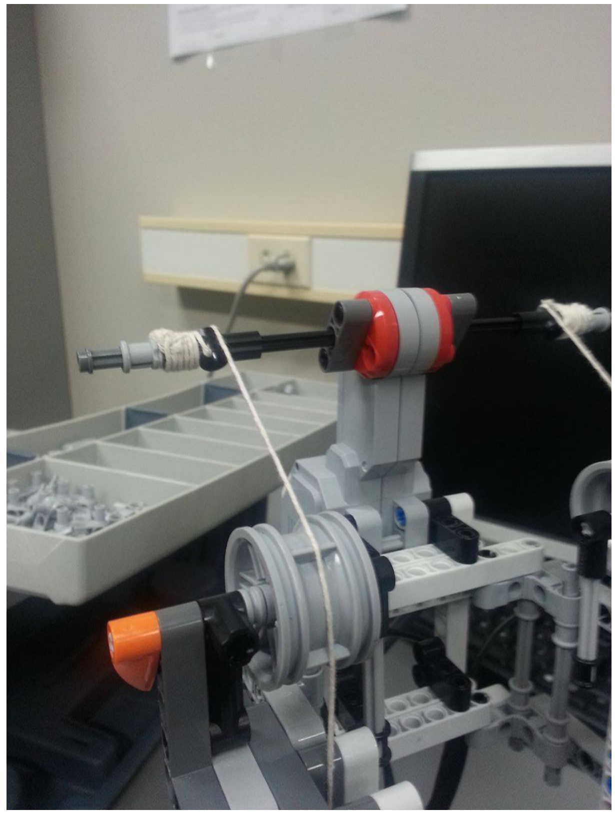
- The tower was extended to allow for the stacking of 4 blocks, and the ability to open the arms above the obstacles.
- The tower arms were lengthened, and made to be a single bar instead of two, which ensures that the raising is constant for every degree of rotation.
- The downward facing CS was moved to the front right of the robot, to allow for a certain method of odometry correction.
- The sensors' wires were shortened, and fed through the frame of the robot to keep clutter to a minimum.

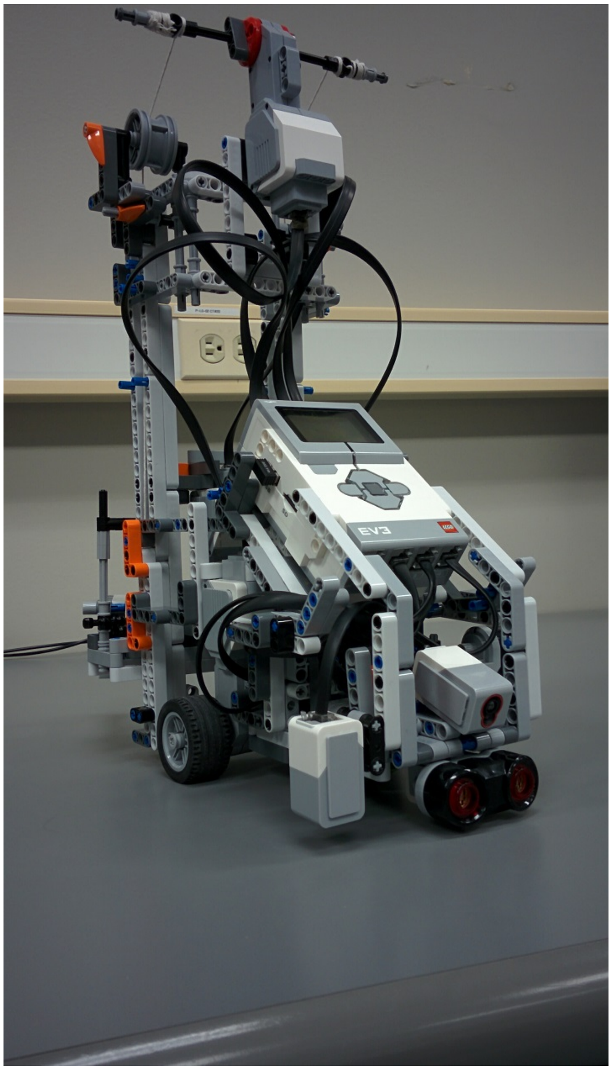
13.3 FUNCTIONALITY

The same as version 2.5.

13.4 MODEL

The same as version 3.02, except the tower height, tower arms, wire management, and the downward facing CS's position:



13.5 POSSIBLE IMPROVEMENTS

The same as version 3.