# Team 3476 **Code Orange**

## Technical Documentation

*Presenting our 2019 robot:*

# *CLOUDBREAK*

# Design Process

## Design Requirements

**Actions:**

- Pick up hatches from the driver station
- Pick up cargo from the driver station
- Pick up hatches from the floor
- Pick up cargo from the floor
- Place hatches on cargo ship or low rocket position
- Place cargo in low rocket position
- Place hatches in high rocket positions
- Place cargo in cargo ship or high rocket positions
- Climb to level 2
- Climb to level 3

**Temporary Wish, Prefer, Demand**

| | |
|---|---|
| Pick up hatches from the driver station | **Demand** |
| Pick up cargo from the driver station | **Demand** |
| Pick up hatches from the floor | **Prefer** |
| Pick up cargo from the floor | **Demand** |
| Place hatches on cargo ship or low rocket position | **Demand** |
| Place cargo in low rocket position | **Demand** |
| Place hatches in high rocket positions | **Demand** |
| Place cargo in cargo ship or high rocket positions | **Demand** |
| Place cargo and hatches to the sides of the robot | **Prefer** |
| Park on the platform | **Demand** |
| Climb to level 2 individually | **Wish** |
| Climb to level 3 individually | **Prefer** |
| Climb to level 3 with other robot(s) | **Wish** |

## Robot designs considered:

- Fixed elevator
    - Pros:
        - Simplest design
    - Cons:
        - Robot needs to turn around when moving between the driver station and rocket or cargo ship
- Side-mounted elevator
    - Pros:
        - Would make it unnecessary to turn the robot around when picking hatch/cargo up from the driver station
        - Easier to design than other options
    - Cons:
        - Center of gravity issues may affect climbing
        - Still need to turn the robot to place on the cargo ship or rocket
- Fixed passthrough elevator
    - Pros:
        - Would make it unnecessary to turn the robot around when picking hatch/cargo up from the driver station
    - Cons:
        - Game pieces are too large and difficult to pass through an elevator
- Turreted elevator
    - Pros:
        - Would allow hatch/cargo placement to all sides
        - Would allow more flexible positioning of ground intakes
        - Previous experience with turrets
    - Cons:
        - Complex
        - Difficult to integrate with climbers
- Fixed elevator with H-drive, holonomic drive, or swerve drive
    - Pros:
        - Would allow hatch/cargo placement to all sides
    - Cons:
        - No experience with this design
        - Difficult to integrate with climbers

# Drivebase

Design requirements:

- Largest possible wheelbase
- ~8ft/s low gear, ~18ft/s high gear
- Brushless drive with Rev NEO motors
- Enough ground clearance to drive up hab platform ramp
- Lightweight and low center of gravity
- Easy to build and repair
- Reliable and proven design
- Make use of COTS components to reduce amount of manufacturing
- Easy to access battery and main breaker
- Minimize length of wiring runs on bellypan

Designs considered:

- 4” wheels
    - Pros:
        - Increases height available for elevator
    - Cons:
        - Very little clearance between edge of drivebase and platform ramp
        - Possible to get stuck on angled edge of platform without wheels touching the ground
- 6” solid wheels
    - Pros:
        - Lots of clearance between edge of drivebase and platform ramp
        - Robot cannot get stuck on platform ramp
    - Cons:
        - Possible issues damaging wheels, shafts, or bearings when driving off level 2 or going up the ramp at high speed to launch onto level 2
- 6” pneumatic wheels
    - Pros:
        - Safer to drive off of level 2 and climb level 2 by hitting the ramp at high speed
        - Lots of clearance between edge of drivebase and platform ramp
        - Robot cannot get stuck on platform ramp
    - Cons:
        - Robot might be bouncy

# Turret

Design requirements:

- High rigidity - able to support and rotate the whole elevator
- Thin design to make integration easier
- Low or zero backlash
- Easy to build and repair
- More reliable design than previous turrets using low-quality lazy susan bearings

Designs considered:

- Chain or spur gear driven turret (like our 2016, 2017 designs)
    - Pros:
        - Proven design, few parts, reliable
    - Cons:
        - High backlash
- Roller pinion gear driven turret
    - Pros:
        - Zero backlash
    - Cons:
        - Untested
        - Lots of custom machining and many parts

# Elevator

Design requirements:

- Able to reach the height of the top rocket position
- Able to reach maximum height in less than 0.75 seconds
- High rigidity
- Lightweight and low center of gravity
- Easy to build and repair
- Minimize number of fasteners
- Use COTS gearbox for easier manufacturing
- Reliable and proven design

Designs considered:

- 2 stage cascading elevator (iteration of our 2018 design)

# Arm

Design requirements:

- Mounts on the elevator carriage
- Able to extend the manipulator fully outside the frame perimeter
- Pneumatically actuated
- High rigidity
- Lightweight
- Easy to build and repair
- Reliable and proven design

Designs considered:

- Telescoping arm
    - Pros:
        - Simple and relatively lightweight
        - Very rigid
    - Cons:
        - No experience with this design

# Manipulator

Design requirements:

- Mounts on the arm
- Able to pick up and eject balls and hatches
- Fits inside the frame perimeter when stowed
- Clamps game pieces tightly so that they do not fall out
- Self-aligning hatch ejection
- Lightweight
- Easy to build and repair
- Reliable and proven design

Designs considered:

- Claw with wheels for intaking on each side, pneumatically actuated
    - Pros:
        - Easy to design and build
        - Good compatibility with both cargo and hatches
        - Used successfully by many teams in the past

# Climber

Design requirements:

- Lift our own robot onto level 3
- Be able to reach level 2 if needed (can just launch off the platform ramp)
- Works quickly, minimum distinct actions required (single action preferred)
- Lightweight
- Minimal changes to robot structure to integrate climber
- Easy to build and repair
- Reliable

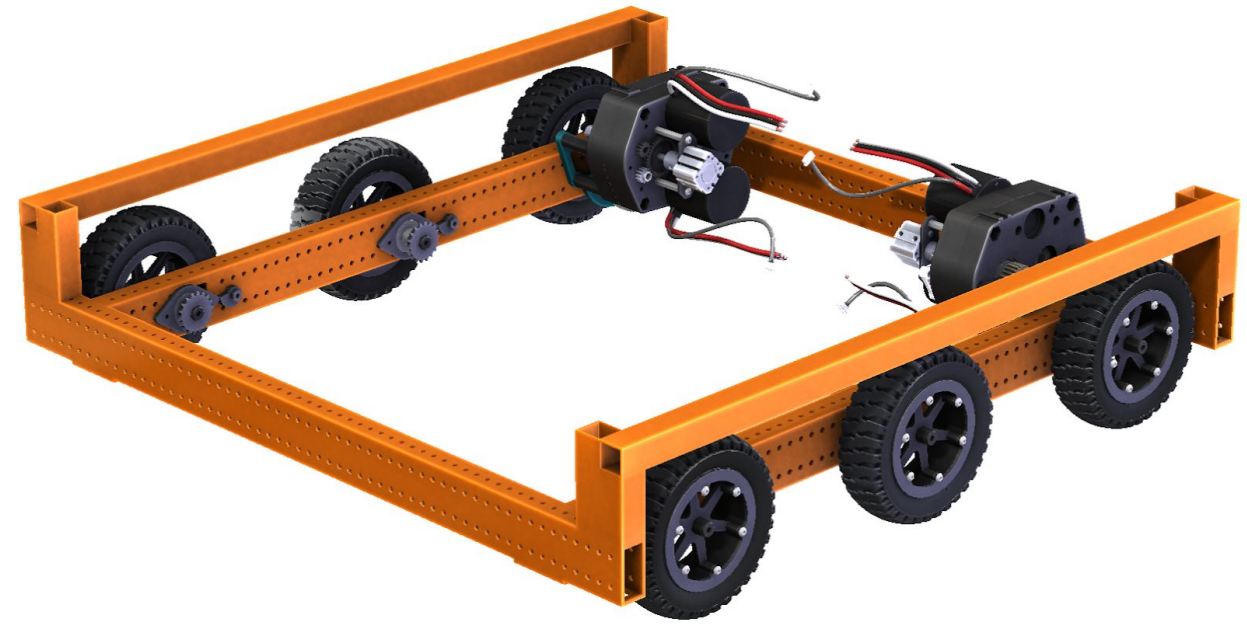
Designs considered:

- Clamping sides of platform
    - Pros:
        - Easy to design and build
        - Used successfully in RI3D
    - Cons:
        - Difficult to integrate into design
- Lifting robot vertically and driving onto platform
    - Pros:
        - Somewhat easy to design and build
    - Cons:
        - Most difficult to integrate into design
        - Multiple actions
- 4-bar under robot with single parallel lift action
    - Pros:
        - Easiest to integrate into robot design, can fit completely under drivebase
        - Single action, least potential for failure due to human error
    - Cons:
        - Untested
        - Requires high torque (~300 ft-lb) to lift, will require well-designed custom gearbox, possibly custom shafts or hubs

# Final Design

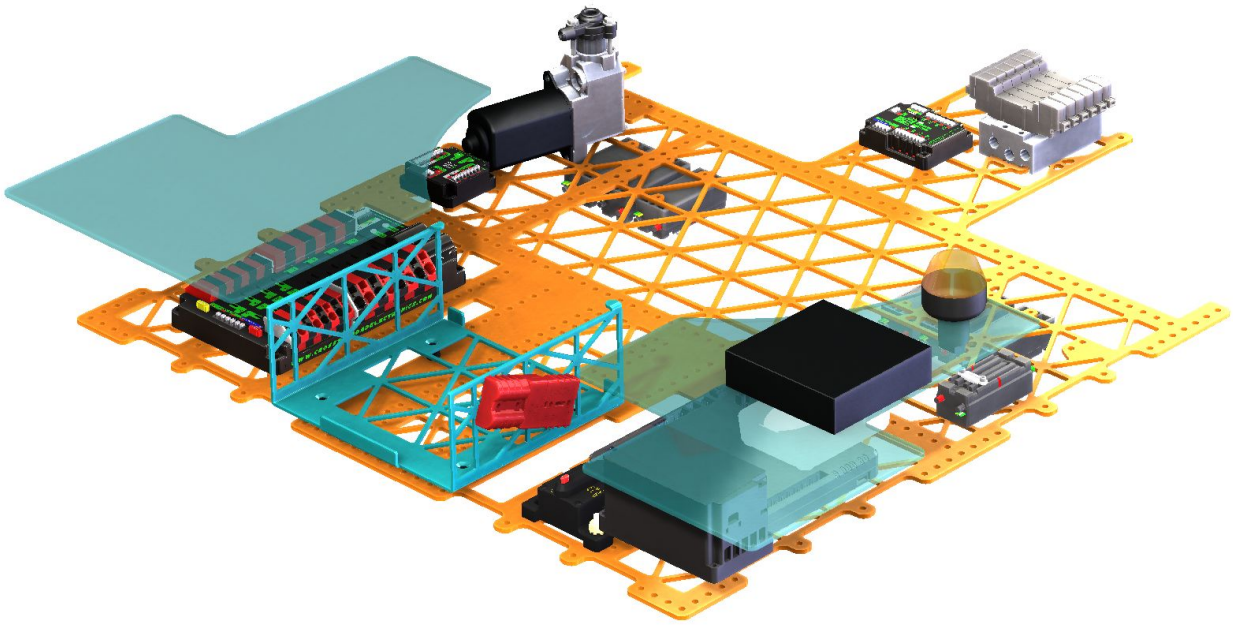
Dimensions: 29.5 x 29.5 x 48 in, 125 lb

# Drivebase

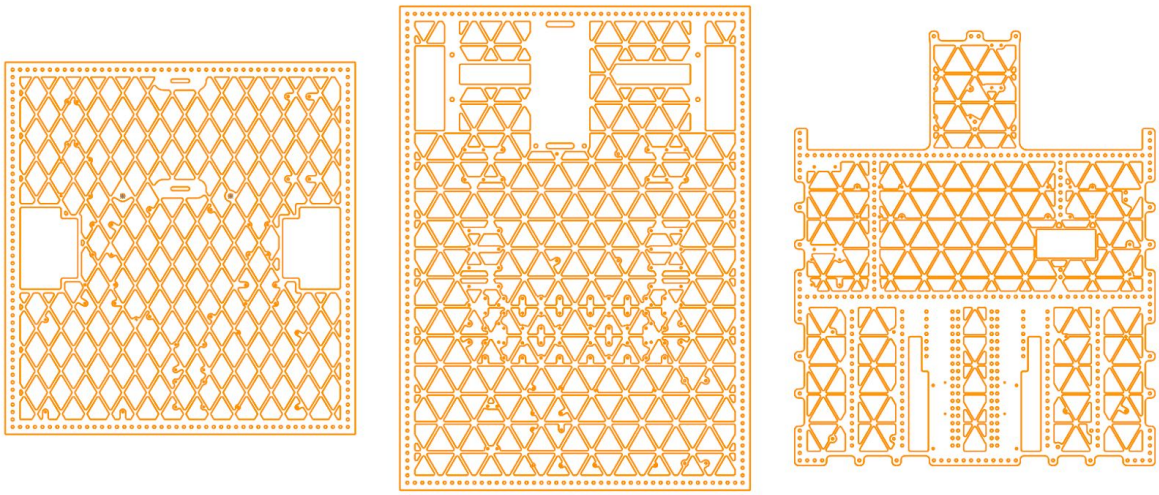


- West Coast Drive
  - 29.5x29.5”
  - 1x2” 0.125” wall thickness aluminum box tubing frame
  - 10.5” between wheels
  - 6” WCP pneumatic wheels - 1.875” ground clearance
  - High utilization of COTS parts for fast manufacturing
  - Overall weight: 25lb without motors, 28.8lb with 4 NEO motors
- Gearboxes
  - VexPro 3 CIM Ball Shifters, 4 NEOs with custom third stage
    - Low gear: 18.84:1, 8.12 ft/s
    - High gear: 8.74:1, 17.55 ft/s
  - #25 chain with 18t sprockets, tensioned using WCP cam tensioners
  - CTRE mag encoders
  - Rear mounted to maximize space for other subsystems
- Bumpers
  - 1x1” 0.0625” wall thickness aluminum box tubing bumper rails
  - Bumpers mount with slide latches on bumper rails

# Electronics

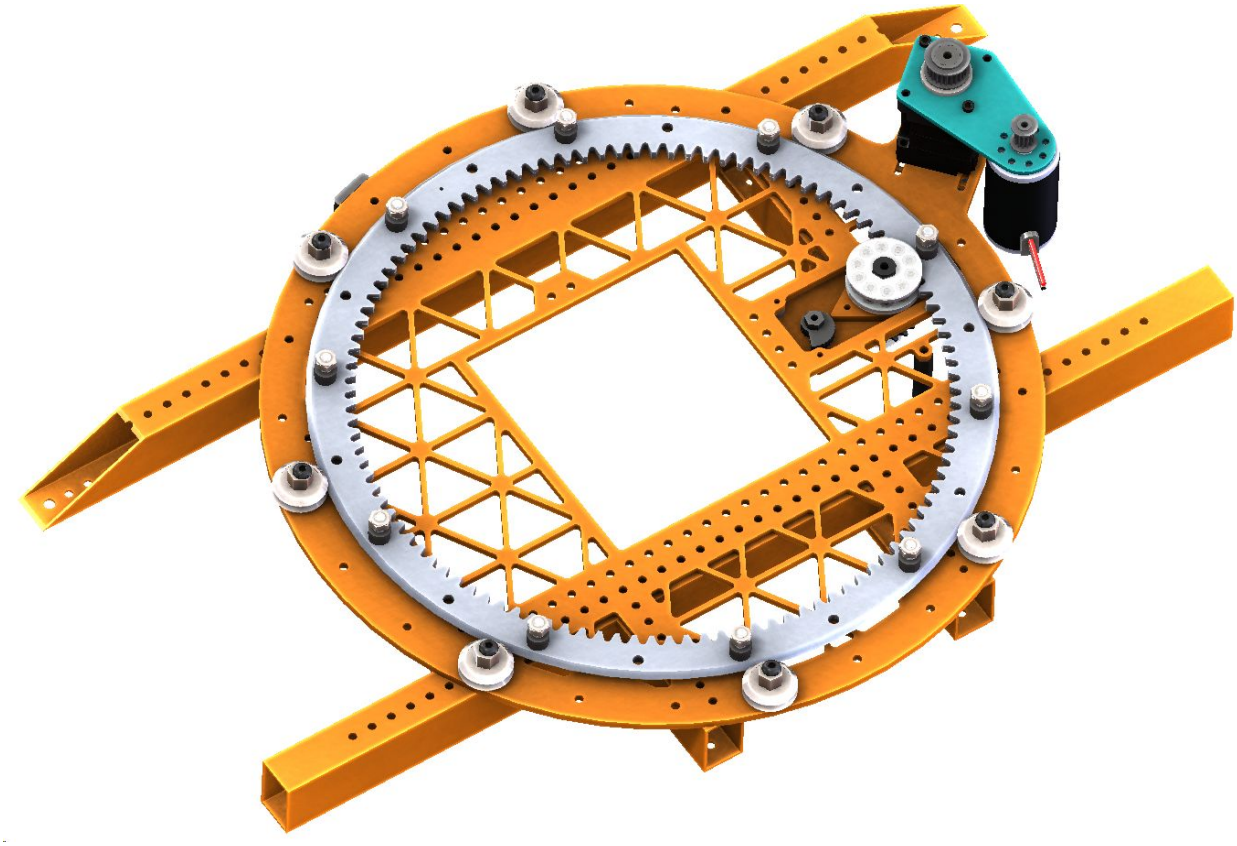


- 0.125” thick waterjetted aluminum mounting plate, iteration of our 2018 design
- 0.09” thick waterjetted and bent aluminum battery holder
- Tapped holes for mounting electronics, support strips for turret mounting
- 24.5x29.5” outer dimensions
- Mounted on top of drivebase to make room for climber underneath
- Mounting plate weight reduced to 3.02lb from 3.93lb on our 2018 robot
- Two polycarbonate plates attached to bumper rails to protect electronics and mount pneumatic components, signal light, radio, ethernet switch, and NVIDIA Jetson with custom 3D printed enclosure



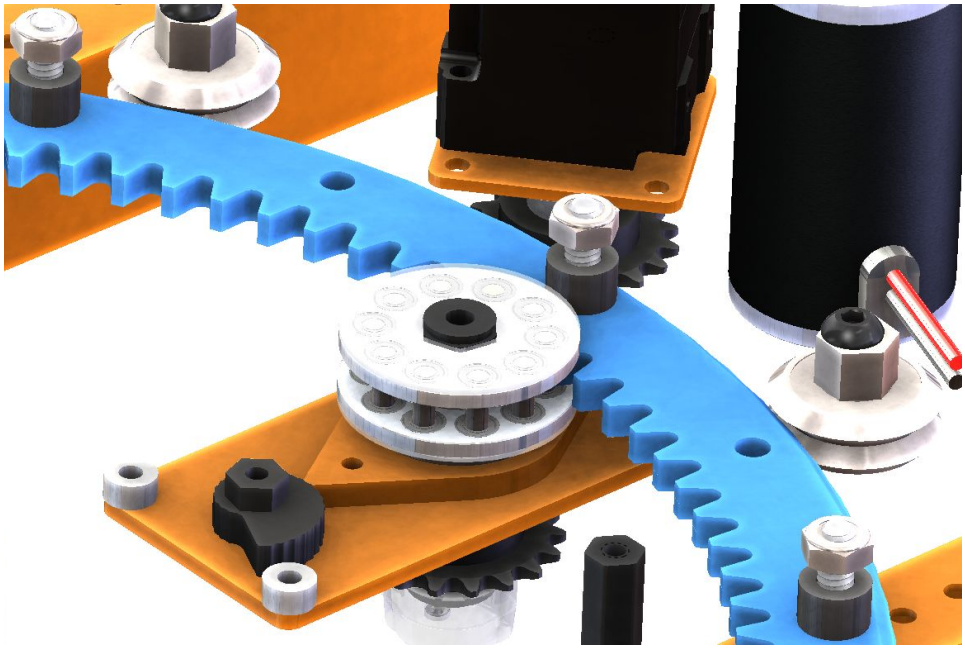
Comparison of our 2017, 2018, and 2019 electronics plates

# Turret

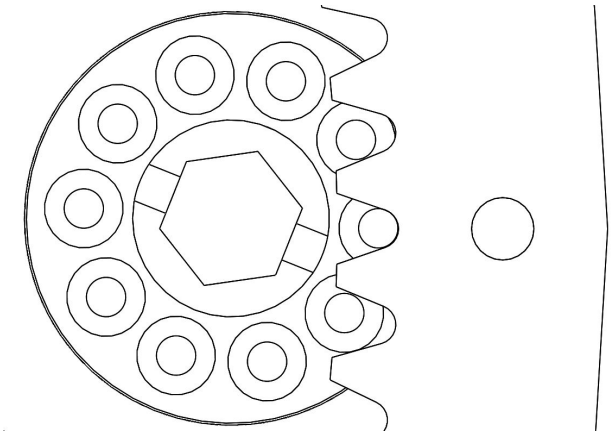


- Turret Structure
  - 1x1.5” 0.0625” wall thickness aluminum box tubing supports
  - 0.1875” thick waterjetted aluminum mounting plate
  - 15” diameter 0.25” thick aluminum internal ring gear (two 0.125” halves)
  - Overall weight: 7.45lb
- Gearing: Initial Reduction Stages
  - Connected to pinion shaft by #25 chain
  - CTRE mag encoder on pinion drive shaft for zero backlash
  - Hall effect sensor for homing
  - 1 VexPro BAG Motor, semi-custom 180 degree VersaPlanetary gearbox

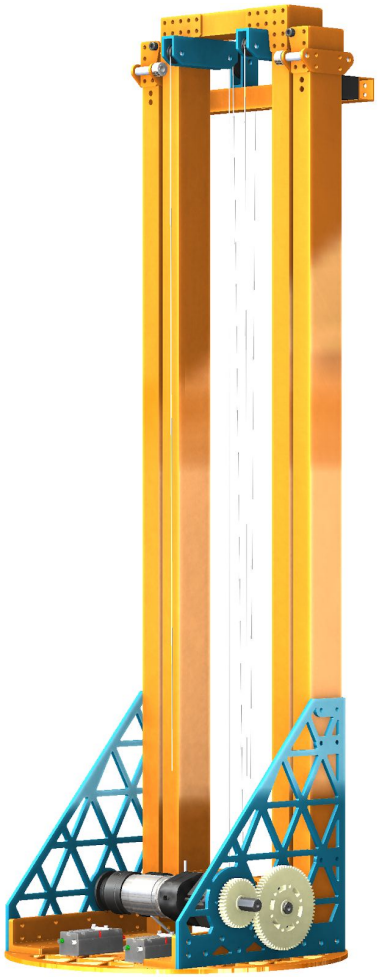
# Turret Bearings and Gearing

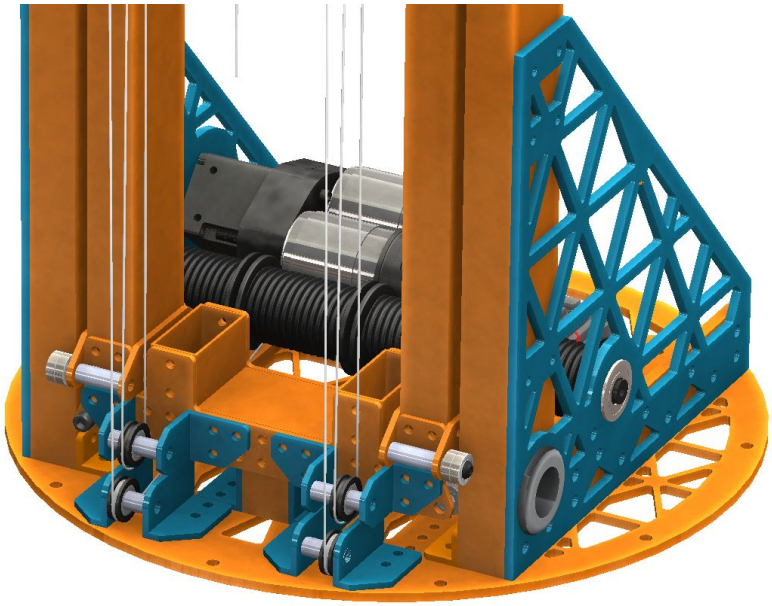


- Bearings
  - Chamfer cut into outside edge of ring gear to create v-groove profile
  - Supported by 8 RM2ZZ v-groove ball bearings
  - Bearings mounted on eccentric cam bushings for tensioning
- Gearing: Turret Drive
  - Custom designed zero backlash, low friction roller pinion gearing
  - Pinion: 30mm pitch diameter, 10 4mm hardened steel rollers, 13mm thick
  - Rollers supported by two 4mm ID x 8mm OD x 3mm thick ball bearings
  - Matching gear profile cut into bearing plate on CNC router
  - Preloaded using WCP cam tensioner with waterjetted bearing block
  - Reduction: 10.6:1



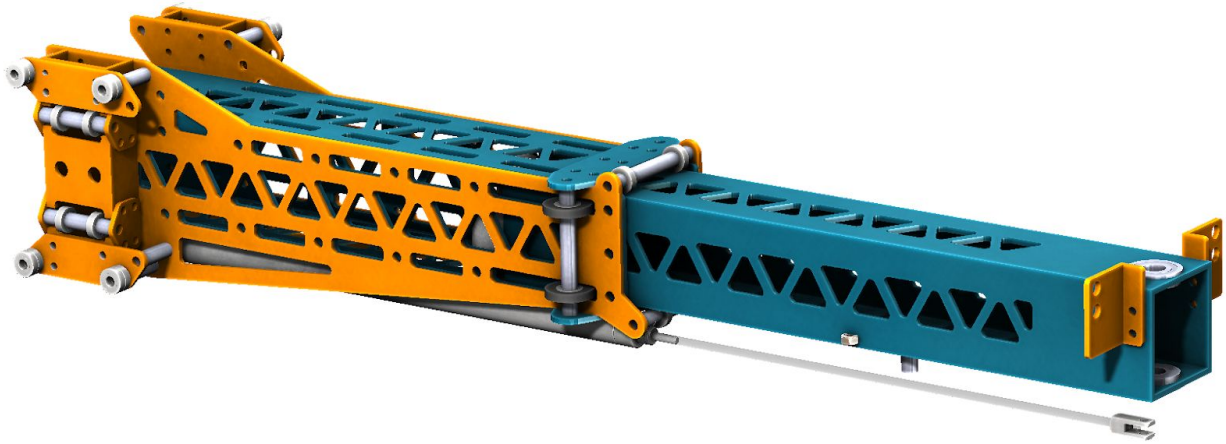
# Elevator



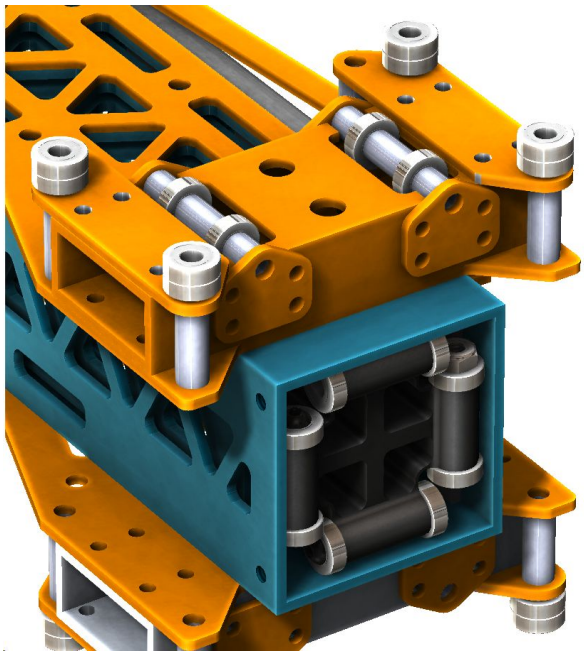


- Elevator
  - Two-stage continuous elevator, 60.8” travel distance
  - Lightweight, compact, and rigid design
  - Driven with 1.2mm Spectra (UHMWPE) rope
  - Custom-machined Delrin (POM) pulleys
  - 3D printed ABS spiral spool to assist rope coiling
  - 1x2” 0.0625” wall thickness box tubing frame
  - 0.1875” thick waterjetted aluminum base plate and side gusset plates
  - Bearings supported with screws through 0.125” thick aluminum bearing plates riveted to the frame
  - Weighs 17.18 lb without arm
- Gearbox
  - 56in/s top speed
  - 2 775pro motors, 15:1 VersaPlanetary, 70:40 final stage with 20dp gears
  - CTRE mag encoder on spool shaft

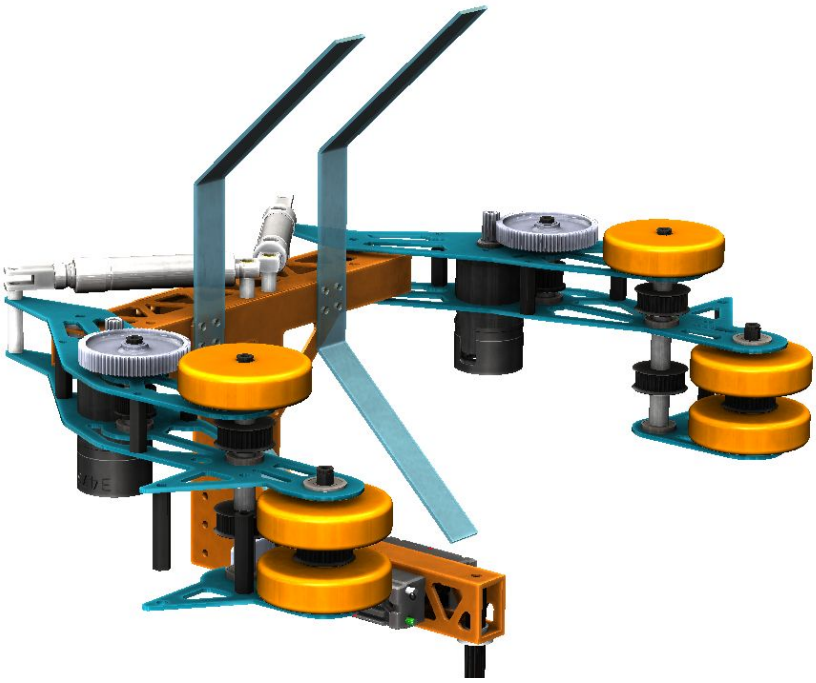
# Elevator Arm



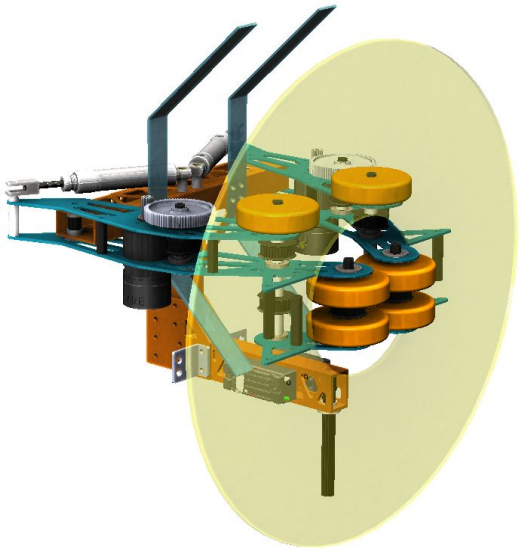
- 3” square telescoping arm
- 18” retracted length and 30” extended length (12” travel distance)
- Actuated by pneumatic cylinder with quick exhaust valves
- 3x3” 0.125” wall thickness box tubing outer section and 2.5x2.5” inner
- 0.125” thick waterjetted aluminum reinforcement plates on each side
- Pocketed box tubing and plates for weight reduction
- Outer bearings supported with screws through 0.125” thick aluminum bearing plates riveted to the frame
- Inner bearings supported by 3D printed ABS bearing block
- Weighs 5.94 lb



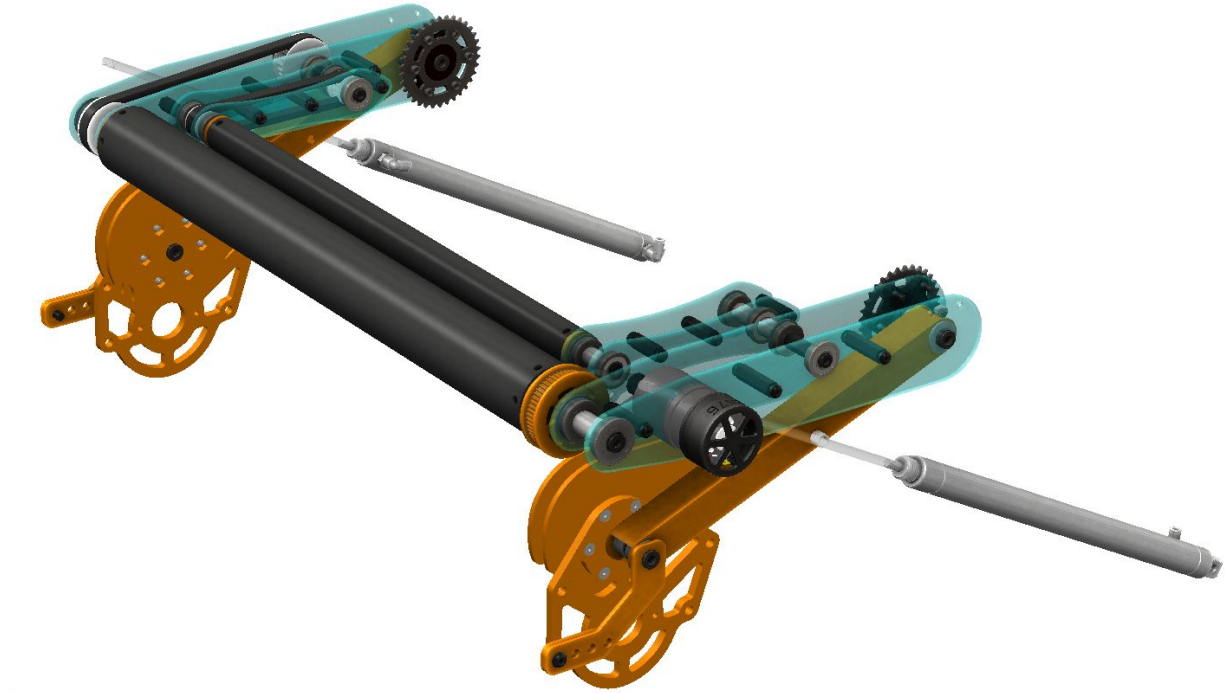
# Cargo and Hatch Manipulator

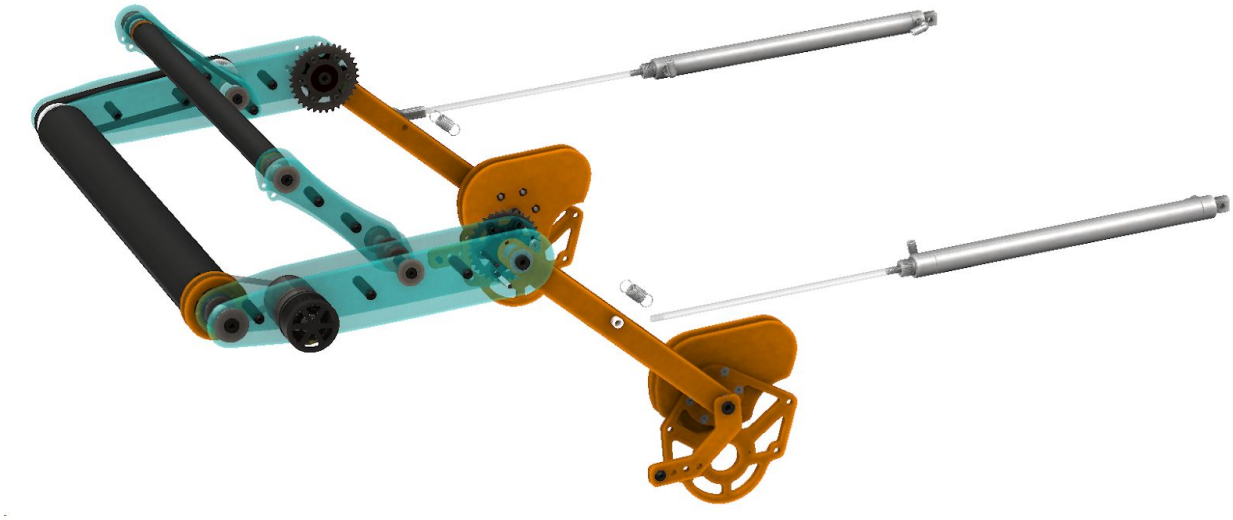


- Claw with two pneumatically actuated arms
- Entire mechanism on a spring loaded pivot to automatically align hatch panels
- Actuated by 2 pneumatic cylinders
- 2 775pro motors, n:1 gear ratio, driven with 3D printed ABS pulleys
- 3 3” BaneBots compliant wheels on each side
- 0.09” thick waterjetted aluminum arms, aluminum box tubing frame
- Weighs 6.27 lb



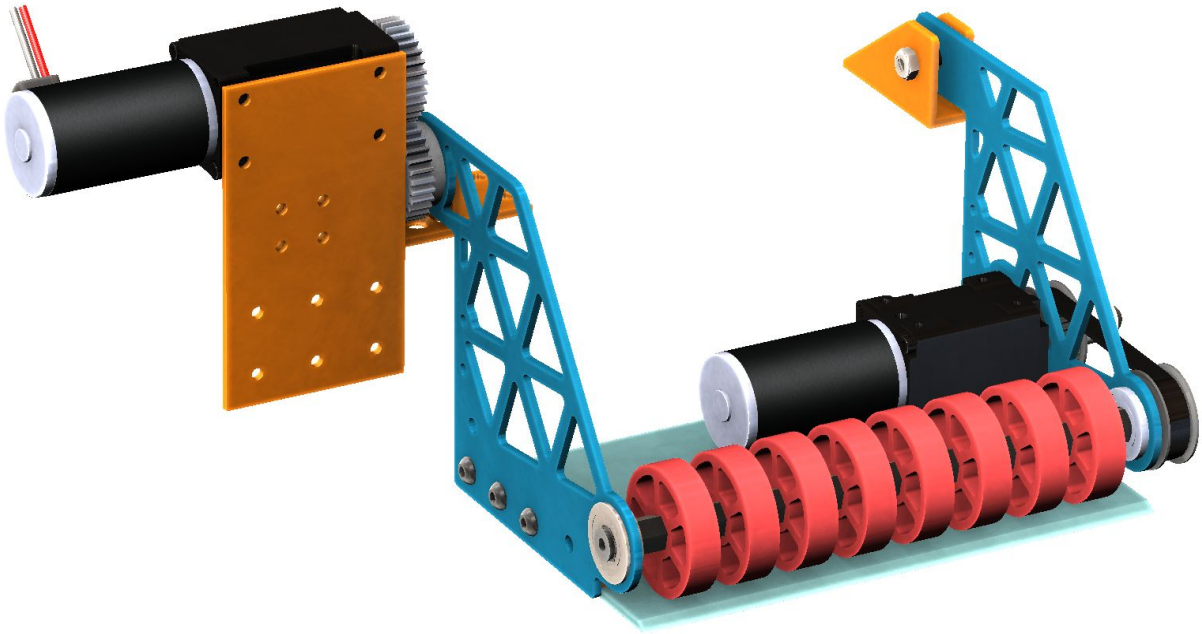
# Ground Cargo Intake





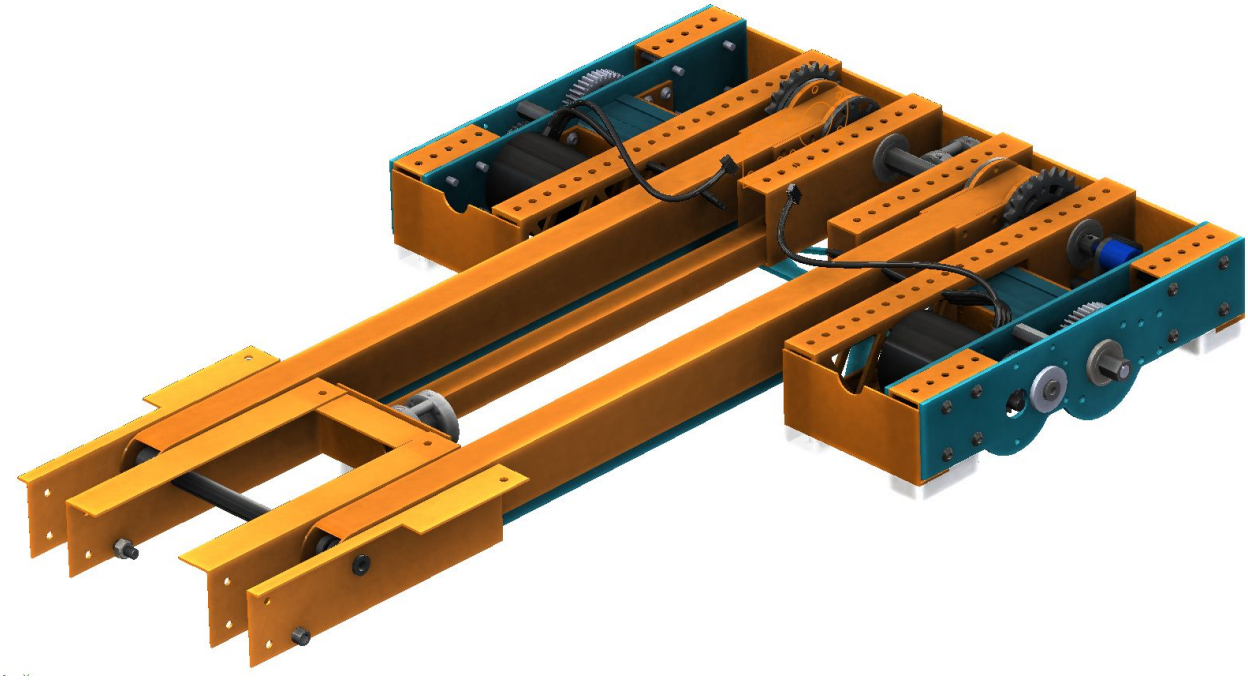
- Pneumatically actuated chain linked virtual 4-bar over-bumper-deployment mechanism with rope driven deployment for second roller
- 2” and 1” diameter silicone-covered ABS plastic tube rollers
- Both rollers spring loaded
- Driven with belts and 3D printed ABS pulleys with 1 775pro motor
- Aluminum box tubing and 0.125” thick polycarbonate construction
- Weighs 6.53 lb

# Ground Hatch Intake



- Wheeled hatch pickup using custom-made waterjetted 2” silicone wheels
- HDPE floor scraper with sharpened edge to slide under hatches
- Deploys through bumper cutout and stows over battery
- Pivots up to hand hatch off to manipulator and further back to stow
- Wheels driven by BAG motor with 5:1 VersaPlanetary
- Deployed and stowed by BAG motor with 144:1 VersaPlanetary
- 0.125” thick waterjetted aluminum frame
- Weighs 5.27 lb

# Climber



- 4-bar robot lifter mounted inside drivebase frame rails
- 21.125” lever length
- ~1.6 seconds to climb
- Locks in place with small pneumatic cylinders when stowed
- Powered by 2 NEO motors with 460.8:1 overall gear ratio
- 64:1 AM 57 Sport Heavy Duty gearbox
- 3:1 gear ratio final stage with #35 chain
- Potentiometer for position feedback
- Weighs 16.75 lb

# Software Requirements

Autonomous

- Place hatch or cargo where designated within the 15 second auto period.
- Provide ability to choose which auto will be used
- Use editable scripts with measured position coordinates on the field
- Vision track targets on the field to automatically place game pieces

Drive

- Provide operator controls for driving and shifting
- Compensate for mechanical inefficiencies for consistency in driving and turning
- Limit acceleration to prevent tipping

Intake

- Provide operator assisted modes for hatch pickup (includes moving elevator for handoff, deploying and retracting hatch intake, running hatch intake rollers)
- Provide operator assisted modes for cargo pickup (includes moving elevator for handoff, running cargo intake rollers, opening manipulator)
- Provide operator controls for ejecting game pieces
- Maintain constant current drive mode to keep game pieces in intakes
- Sense when game pieces are fully held by the intake

Turret

- Home turret on robot startup
- Provide ability to automatically turn turret to handoff position
- Provide operator controls to manually rotate turret
- Stabilize turret position based on gyro feedback for field relative positioning
- Set rate limits on turret to prevent accelerating/decelerating too fast

Elevator and Arm

- Home elevator on robot startup
- Provide operator controls to set the elevator height to correct setpoints
- Provide operator controls to extend and retract arm when placing game pieces
- Set rate limits on elevator to prevent accelerating/decelerating too fast
- Provide current limiting to prevent damage to elevator
- Automatically lift the elevator to avoid collision when ground intake in use

Climber

- Provide operator controls to activate the climber
- Provide current limiting to prevent damage to climber