Climbing Robot for Construction

Senior Design Research
Climbing Clankers

Date: 05/08/2026

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Problem Statement

What is the Problem?

- Structural assembly relies on manual, high-risk labor, heavy and large equipment, leading to inconsistencies and bottlenecks
- Bureau of Labor Statistics confirms ironworkers are among the **top 10** most **dangerous** jobs in the U.S
- Ex: **1075 of 5283** occupational fatalities in 2023 were in construction



Falling Equipment



Falling people



Lifting machinery

Can We Bring in Automation to Make it Safer?

Our Solution

- **Design a climbing robot** capable of ascending vertical steel columns and stabilizing itself for precise positioning

- Vertical attachment of steel beam (suspended by crane or other machinery) onto grounded beam using plates and bolts

- Replace manual high-risk bolting with a **fully automated process**, greatly reducing worker exposure to fall hazards, heavy equipment, and unstable structures



Design Overview

Target Specifications

Assumptions
Using Provided I beam



Multipurpose 6061 Aluminum I-Beams

- Yield Strength: 35,000 psi
- Hardness: Brinell 95 (Soft)
- Temper: T6
- Fabrication: Extruded
- Specifications Met: ASTM B221

Also known as American Standard I-Beams, these I-beams have tapered flanges with rounded corners. The most widely used aluminum, 6061 is fabricated into everything from pipe fittings and containers to automotive and aerospace parts. It is strong and corrosion resistant, plus it's easy to machine and weld.

Certificates with a traceable lot number are available for these products. Download certificates from **ORDER HISTORY** after your order ships.

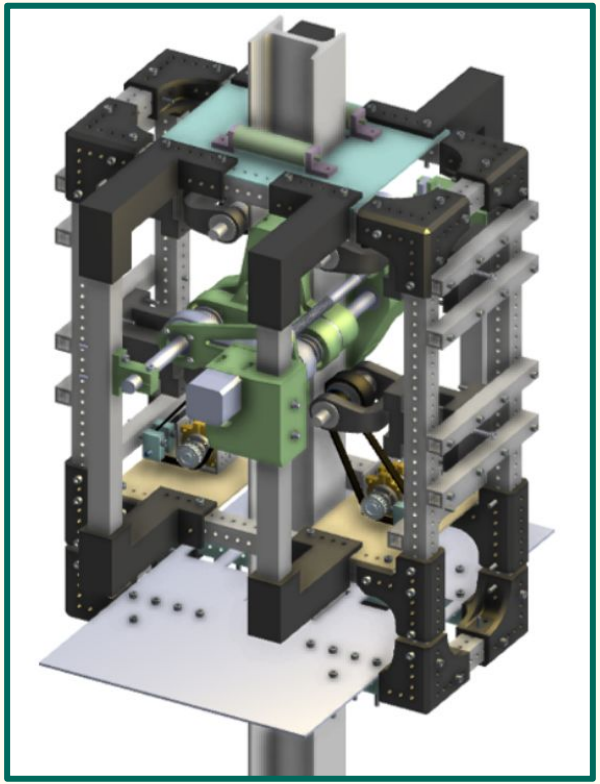
	Outside										
Ht.	Ht. Tolerance	Wd.	Wd. Tolerance	Wall Thick.	Wall Thick. Tolerance	Heat Treatment	Temperature Range, °F	Straightness Tolerance		3 ft. Lg.	6 ft. Lg.
3"	-0.048" to 0.048"	2.500"	-0.1" to 0.1"	0.348"	-0.008" to 0.008"	Hardened	-320° to 210°	0.0125" per ft.	8003K11	$80.91	$156.75

Fastener Preload Accuracy
'Specification for Structural Joints Using High-Strength Bolts,' Section 8.2.

*The RCSC specification requires bolt pretensions to be at least **70%** of the specified minimum tensile strength."*

Movement
- Travel 3ft up and down given I-beam
- Cycle time of < 1 minute (arbitrary)
- Wheel grip FOS = 2

Master Assembly



Functions

01 Fastening

Bolt & Nut: Feeding/Driving
Plate Handling

02 Locomotion

Vertical Traversal
Traction & Stability

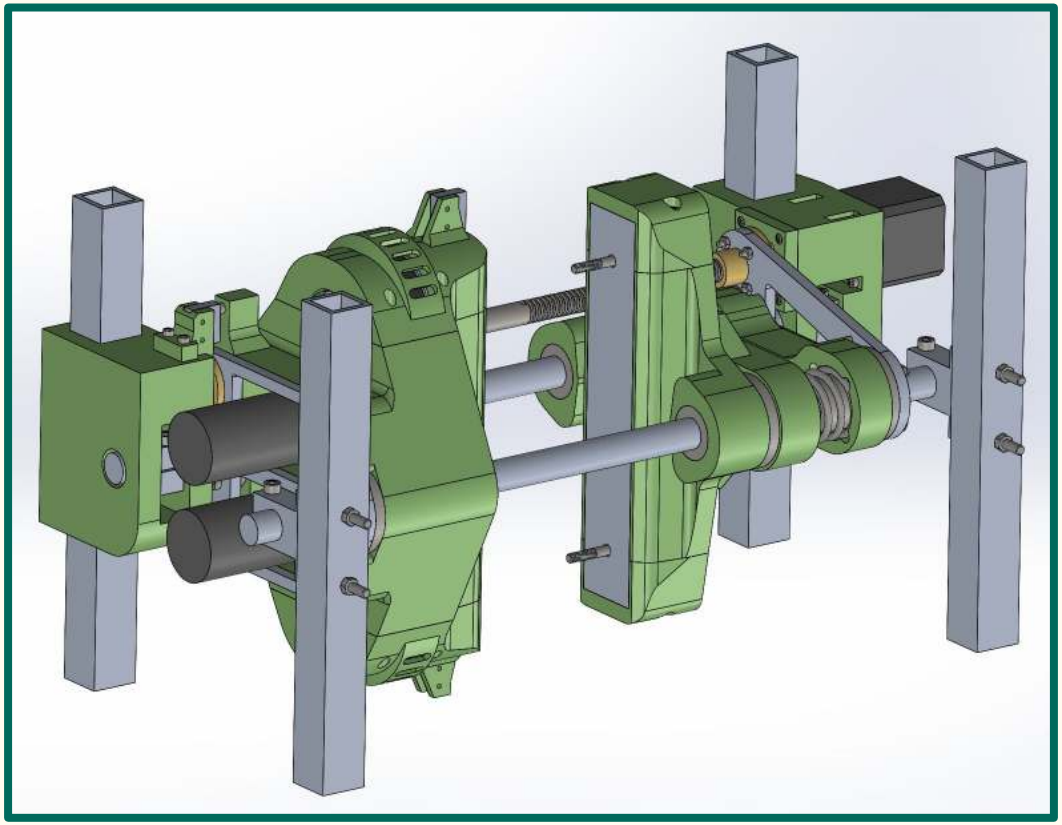
03 Structure/Frame

Mounting Interfaces
Material

04 Electronics/Control

Power Distribution
Motor Control

Fastening Assembly



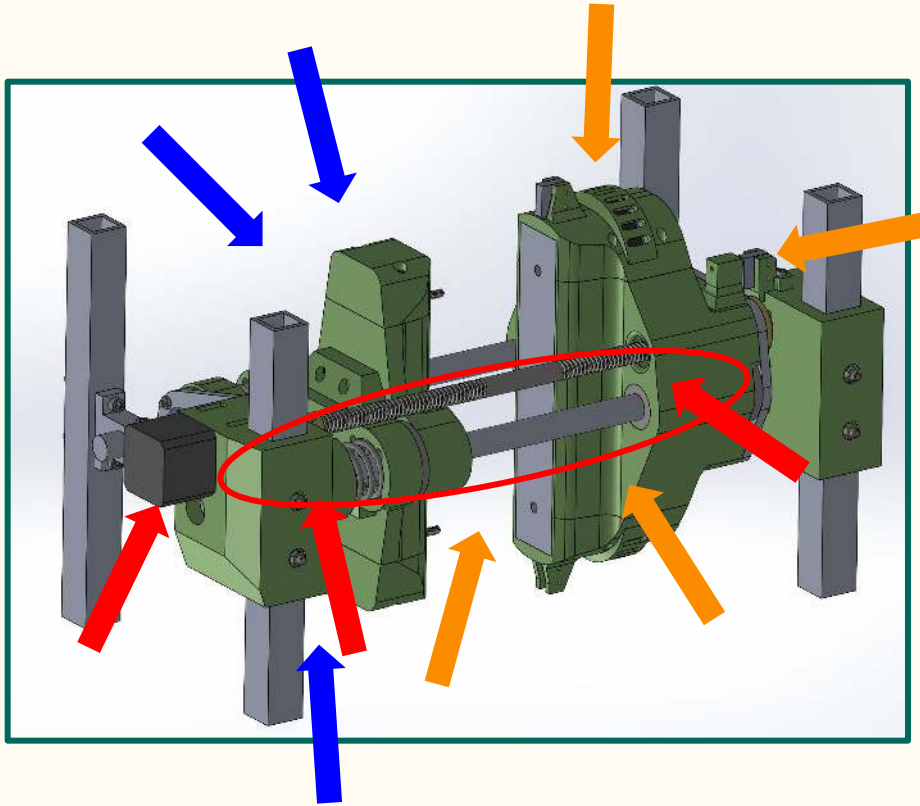
Sub-Assemblies Function

Bolt Carriage

- Suspension for misalignment
- Support Plate
- Hole Detection

Dual Lead Screw

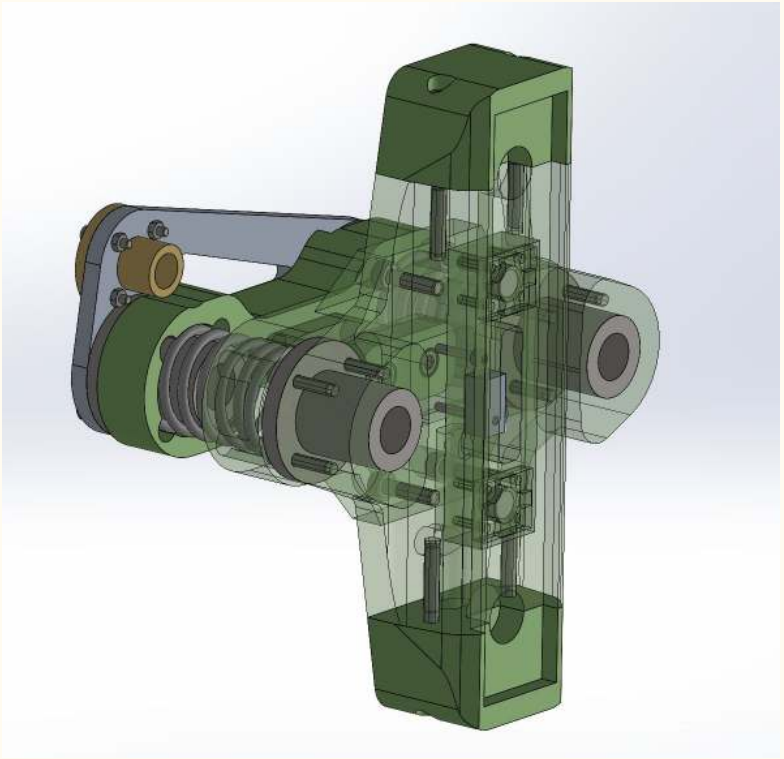
- Move carriages synchronously
- Linear shafts for movement and support

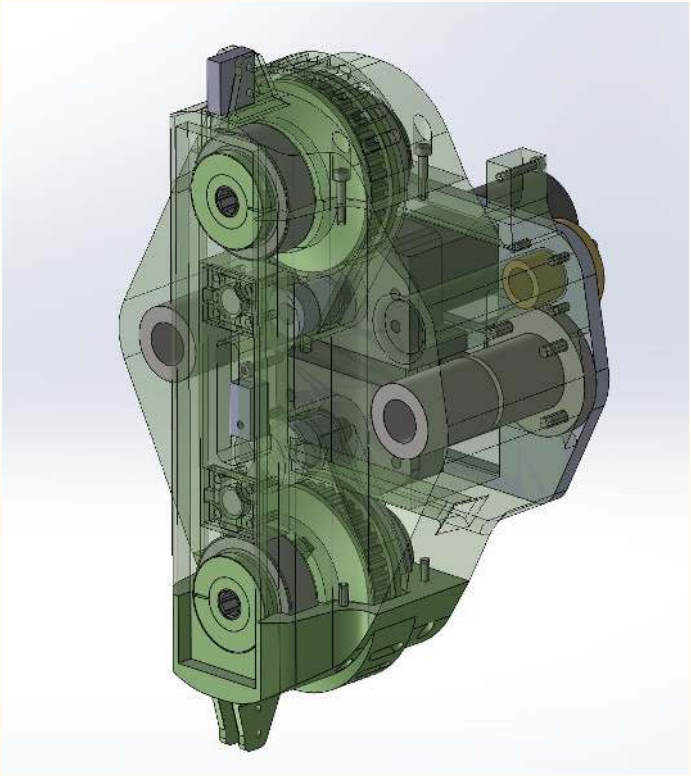


Nut Carriage

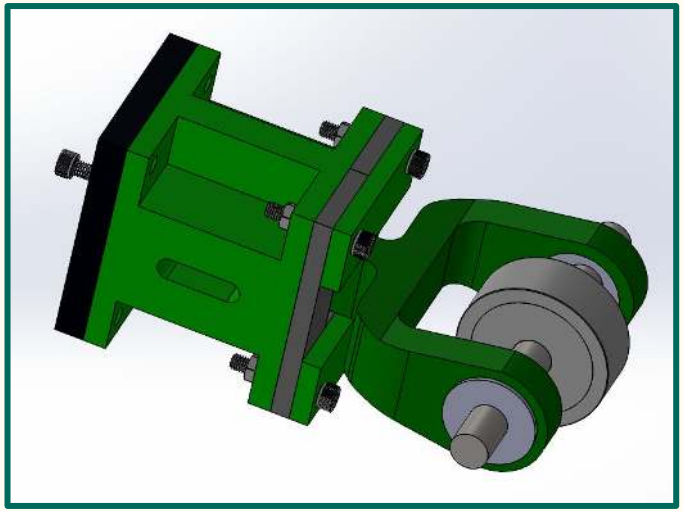
- Turn Nuts
- Support Plate
- Hole Detection
- Bolt Reload

Sub System Parts

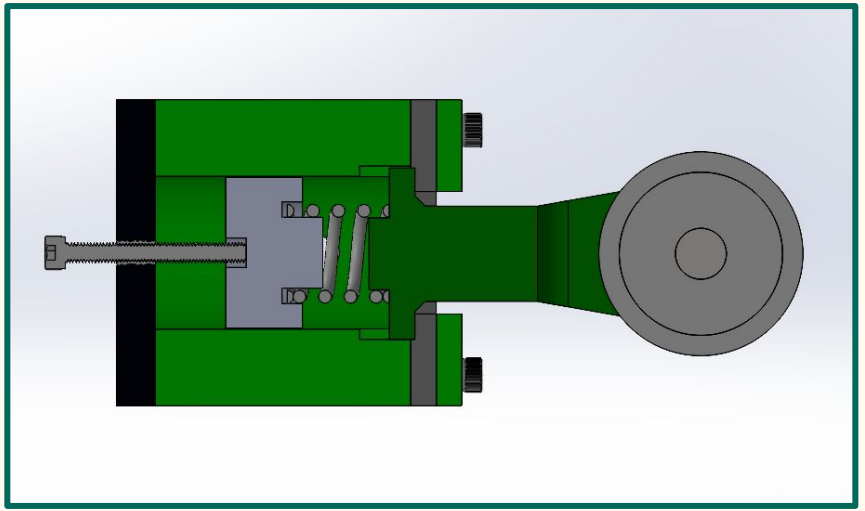




Locomotion: Wheel Module

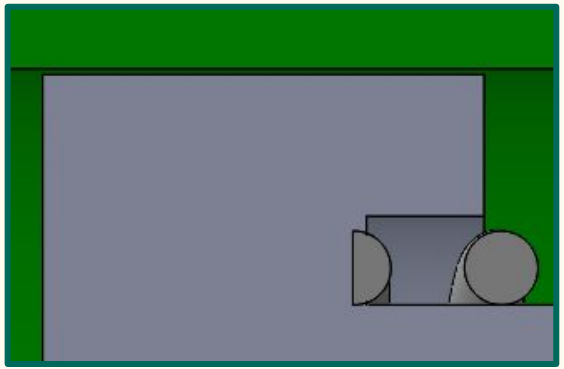


Most detailed view



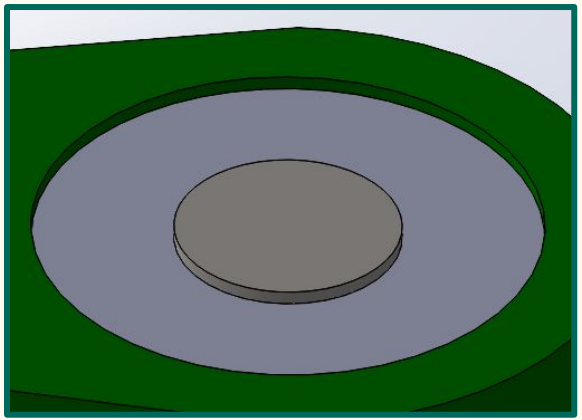
Cross sectional view

Wheel Module Tolerances



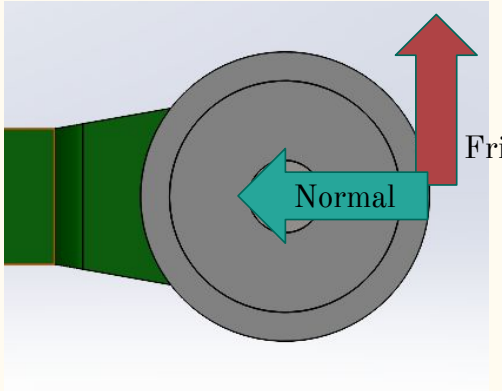
0.01 in. clearance between 3D-printed parts for housing

0.001 in. clearance between bearing and wheel attachment (press fit)



Spring Selection

Robot weight (lb)	50	lb
Coeff. of friction (static)	0.6	
Factor of safety	1.5	
Normal force	62.5	lb

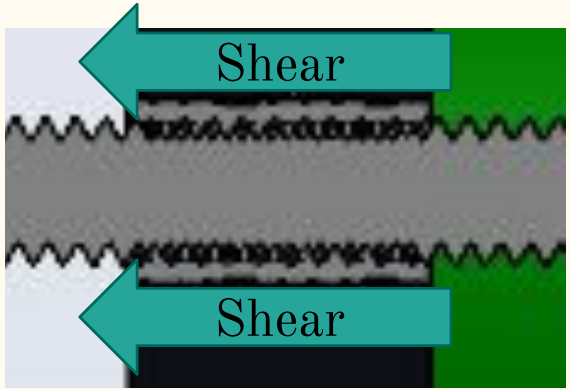


Normal force	62.5	lb
Spring constant (k)	210	lb/in
Length compression	0.30	in

$$F_N = \frac{FOS \cdot W}{2 \cdot \mu}$$

$$F_N = kx$$

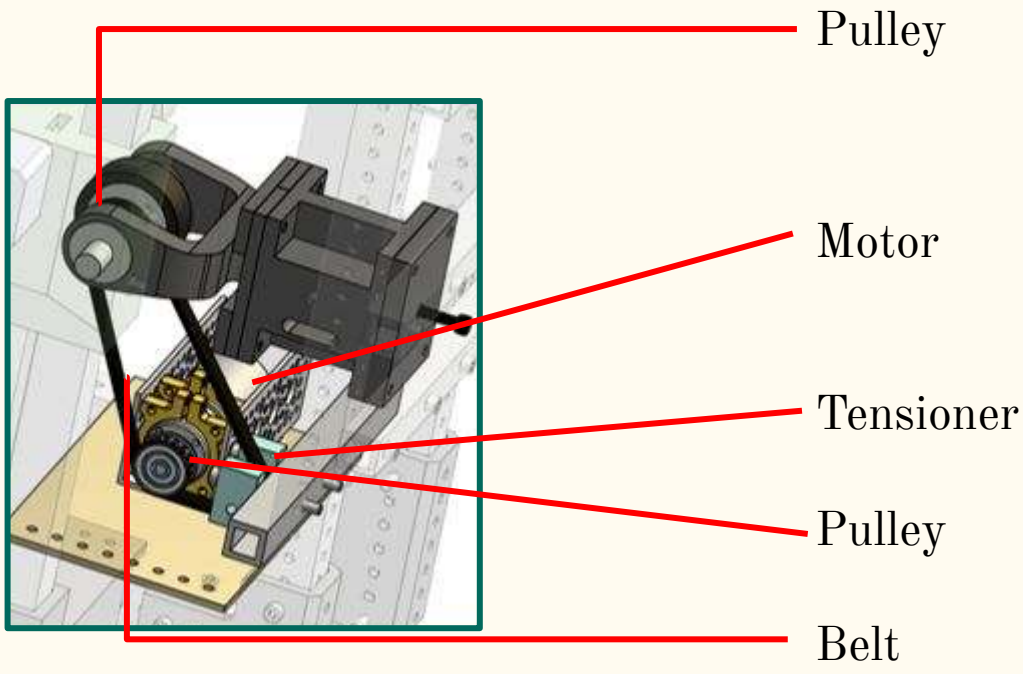
Stress Analysis on Heated Insert



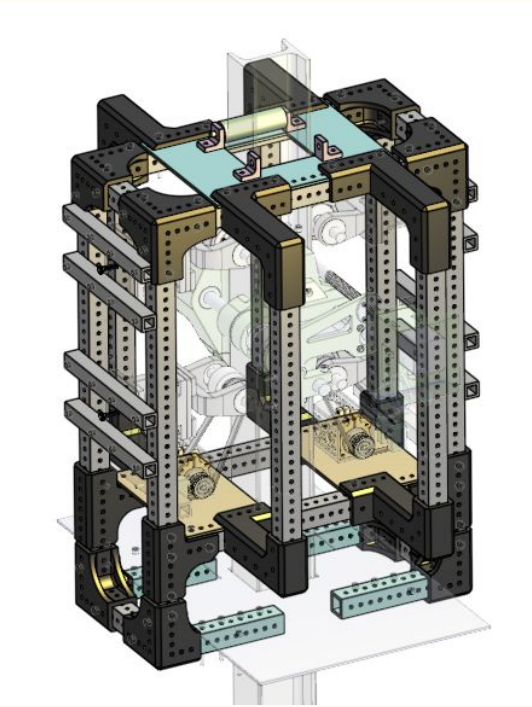
Insert size	Bore Ø D [mm]	Bore depth L [mm]	External Ø A [mm]	Min. wall B [mm]	Pull-out resistance [N]
M2 (short)	3.3	3.18	7.16	5.51	477
M2 (long)	3.3	3.99	7.26	5.61	572
M2.5	4.1	3.56	9.50	7.45	825
M3 (short)	4.1	3.56	9.24	7.19	813
M3 (long)	4.1	5.74	9.50	7.45	1 258
M4	5.7	4.70	12.76	9.91	1 372
M5	6.5	6.35	14.32	11.07	> 1 800
M6	8.1	7.92	17.52	13.47	> 1 800

1800 N = 405 lbs >> 62.5 lbs spring force

Climbing Mechanism



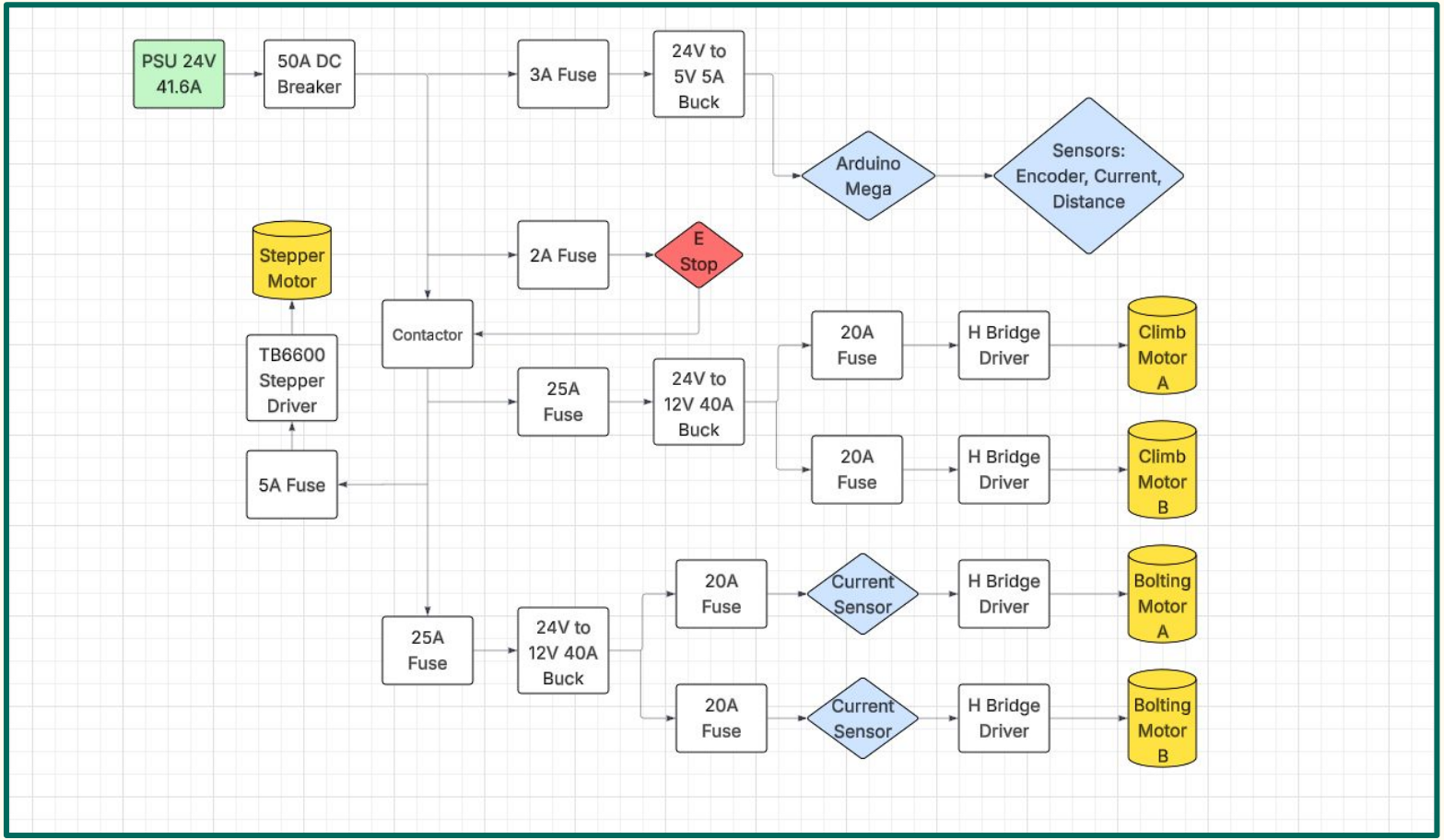
Structure

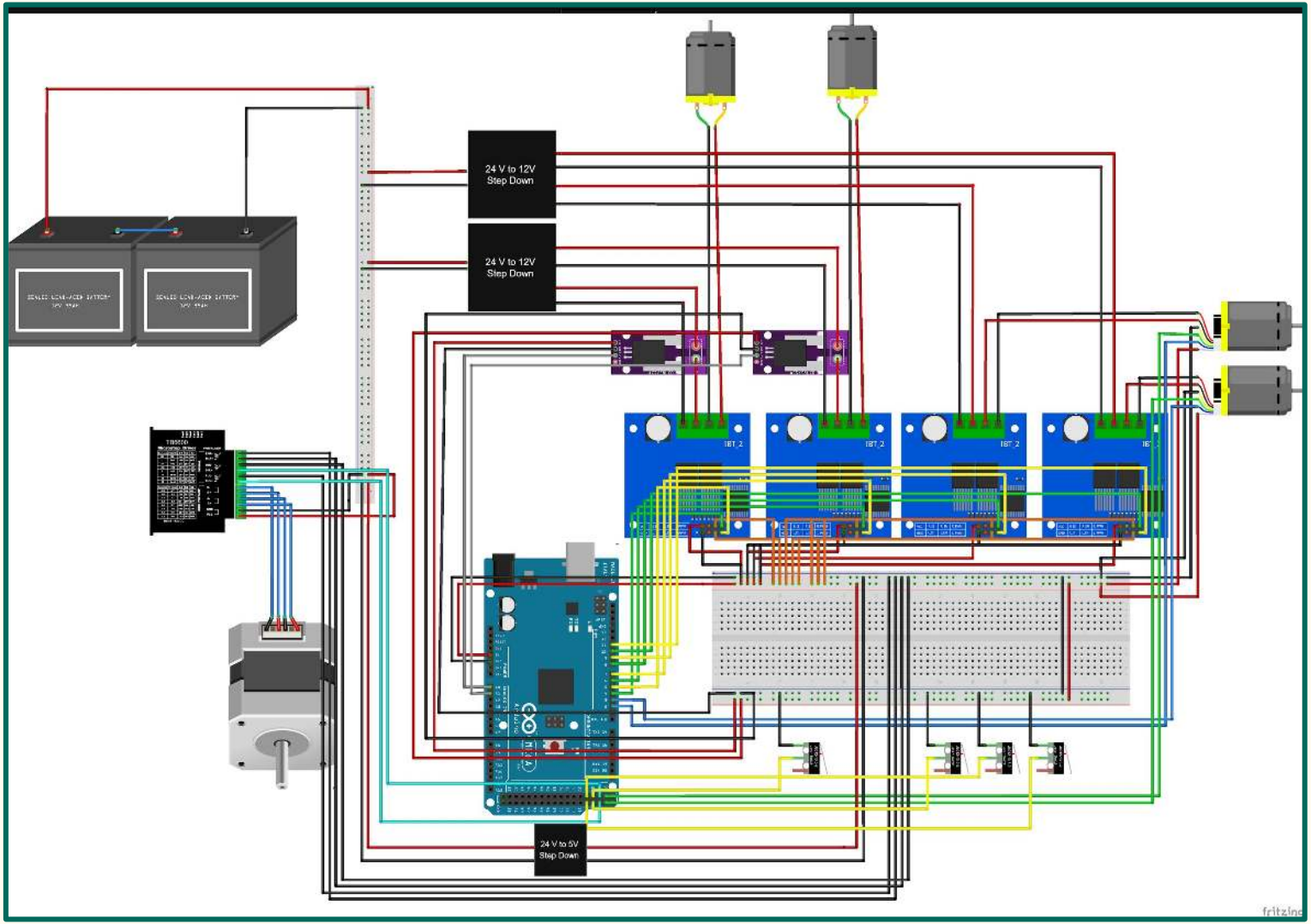


Frame Structure

- Frame
  - Utilizes pre-drilled aluminum tube extrusions for modular assembly
  - Supports active components (fastening, locomotion)
  - Houses electrical systems
  - Aligns robot with beam
  - Resists gravitational forces from robot weight and reaction forces from active components

Electronic (Power Distribution)



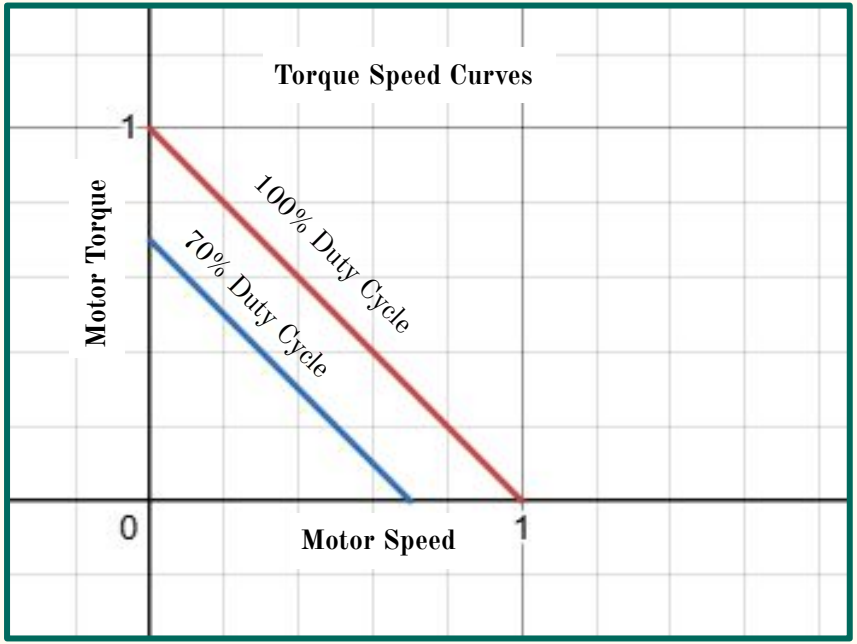

24 V to 12V
Step Down
24 V to 12V
Step Down
24 V to 5V
Step Down
fritzing

Electronics (Motor Control)

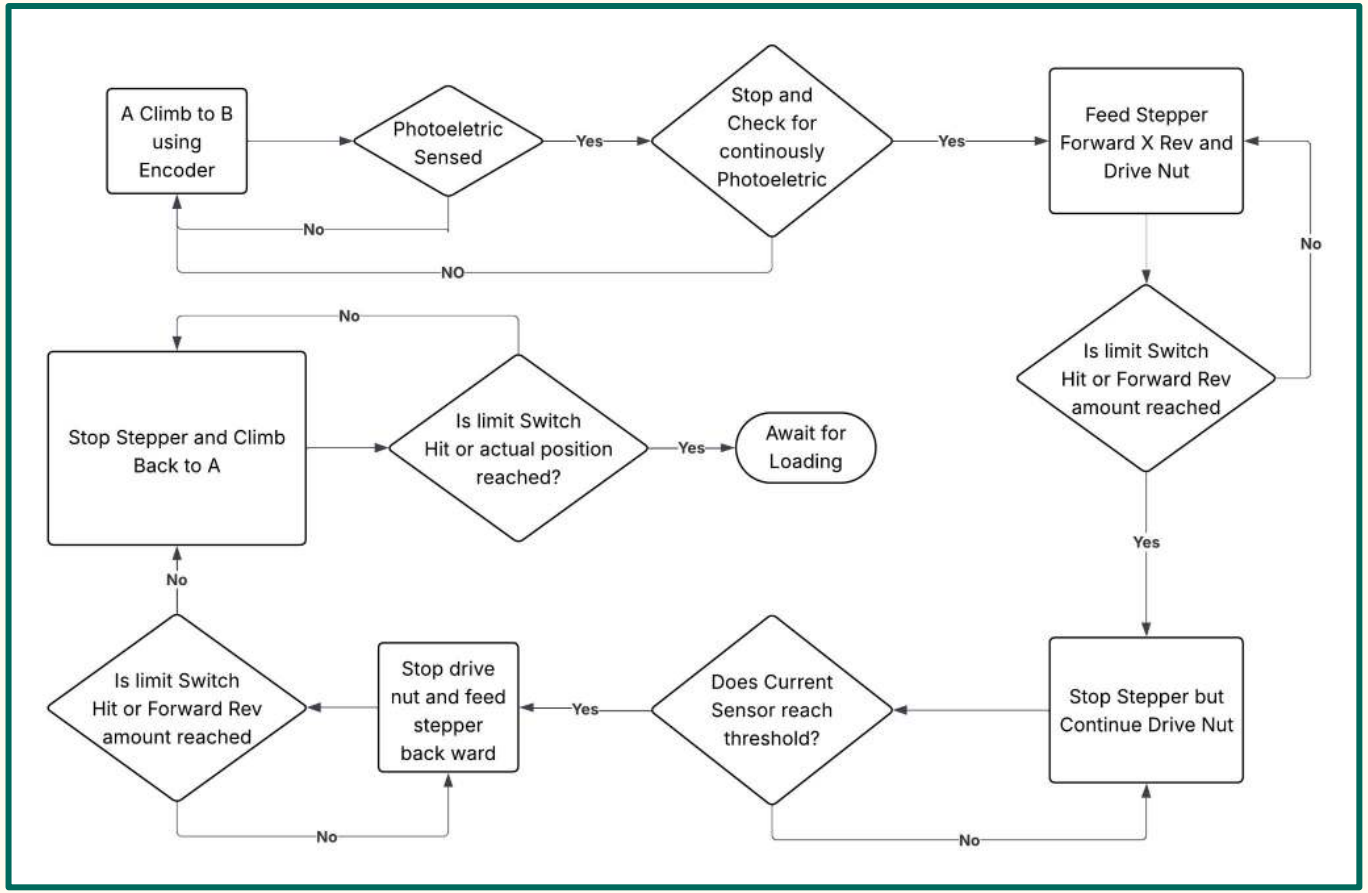
Climbing Motor: Closed Loop Speed (Encoder) & Stop Checkpoint (Photoelectric Sensor)

Bolting Motor: Open Loop Control Checkpoint Based (Current Sensor)

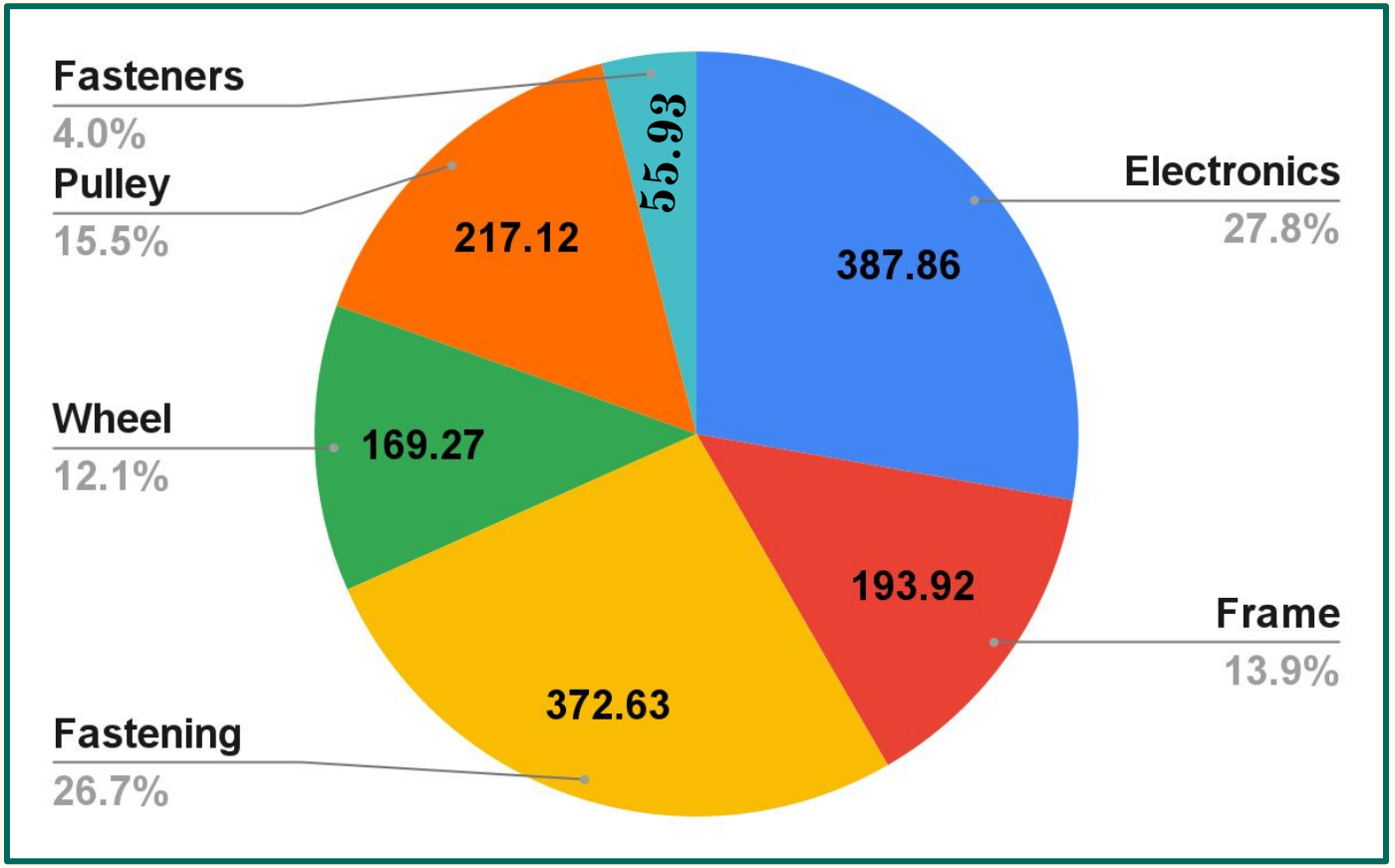
Clamping Stepper Motor: Open Loop & Checkpoint Based (Limit Switch and Current Sensor)



Electronics (Motor Control)



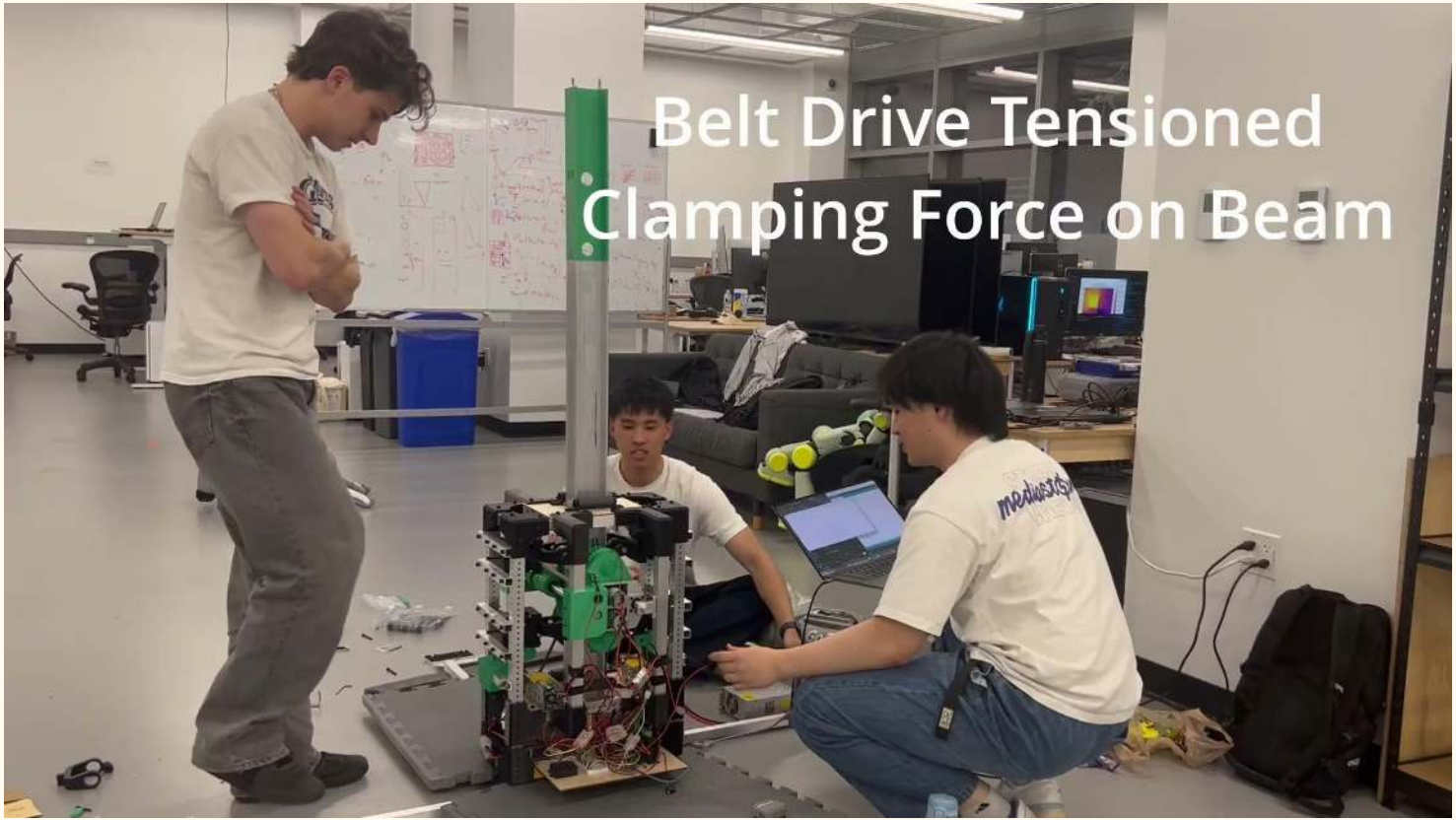
Budget Breakdown



Total Cost: $1396.73

Final Results

Testing Results



Testing Results

Results

- Wheel grip FOS = 1.5
- Cycle time approx. 2.5 minutes
- Climb Speed 4.2 cm/s
- Fastening time 1.4 minutes

Target Specifications

- Wheel grip FOS = 2
- Cycle time < 1 minute
- Climb Speed 10 cm/s
- Fastening Time 30 seconds



Next Steps

Next Steps

- **Continue testing** to improve specifications (shorten cycle time, increase FOS, etc.)
    - Improve timing belt pulley
- **Compile data** for conclusive results
- **Expand design** to support horizontal traversal, practical set-up



Q&A

Any questions?
Ask away!

Climbing Construction Robots

