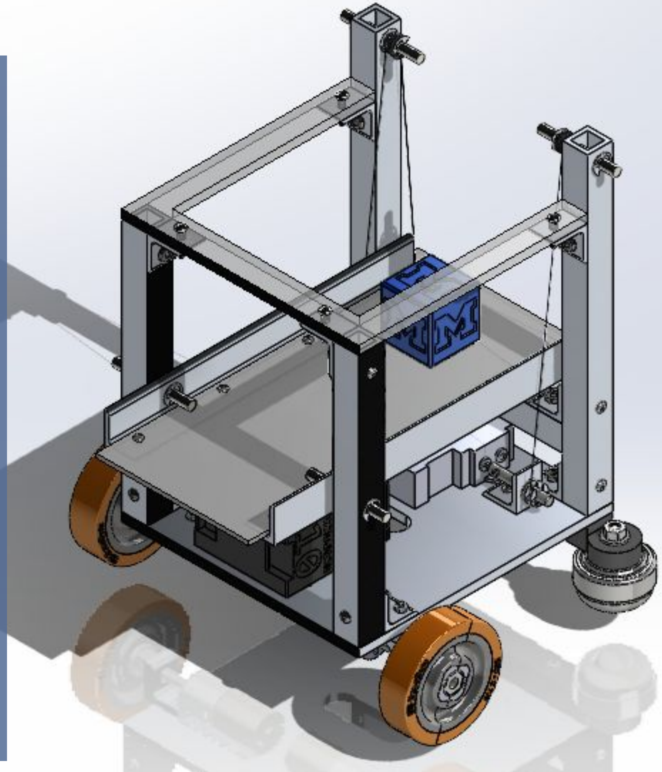
ME 250 Design Review: Team 33

Luis Barcenas, Ethan Feng, Ashley Ortenburg, Genna Urbain



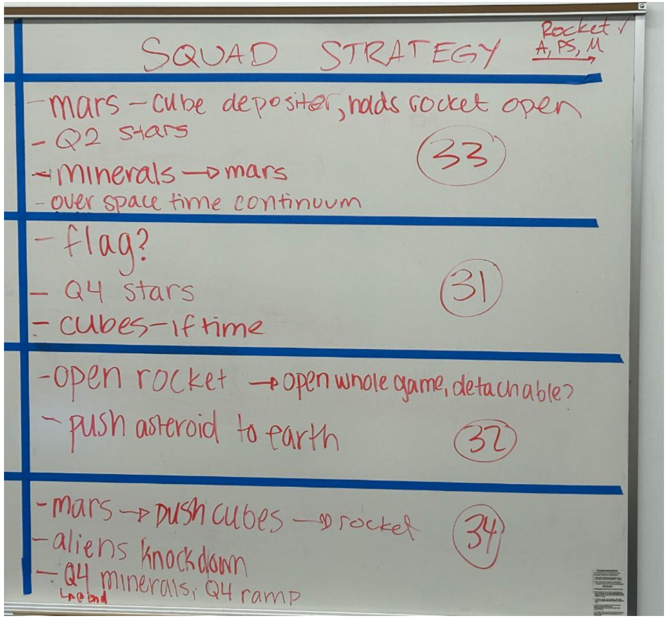
RMP Strategy Selection

Our Strategy:

1. Traverse the space-time continuum
2. Turn on all of the stars in Q2
3. Prop the rocket open
4. Transport cubes between Mars and the rocket

Why:

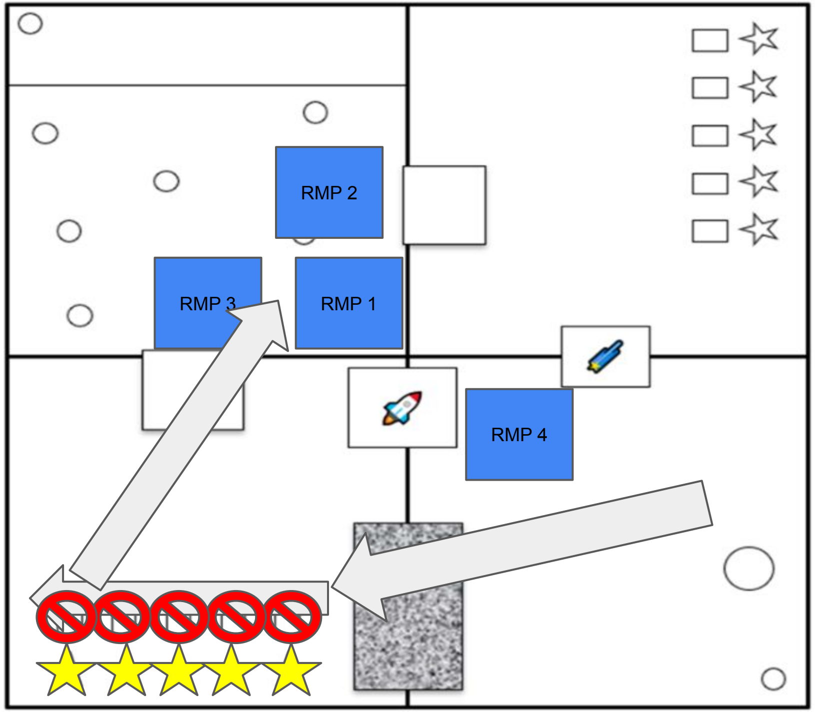
- Prop open rocket/deposit cubes was main task
- Space-time continuum is 1 of 2 ways to get to rocket opening
- We pass Q2 stars on the way to get to rocket opening



RMP Strategy Selection

Interactions:

- Traversing the space-time continuum
- Rely on RMP 4 to open rocket
- RMPs 2 & 3 rely on us to deposit cubes
- Collaborate with RMP 2 to turn on all 10 stars



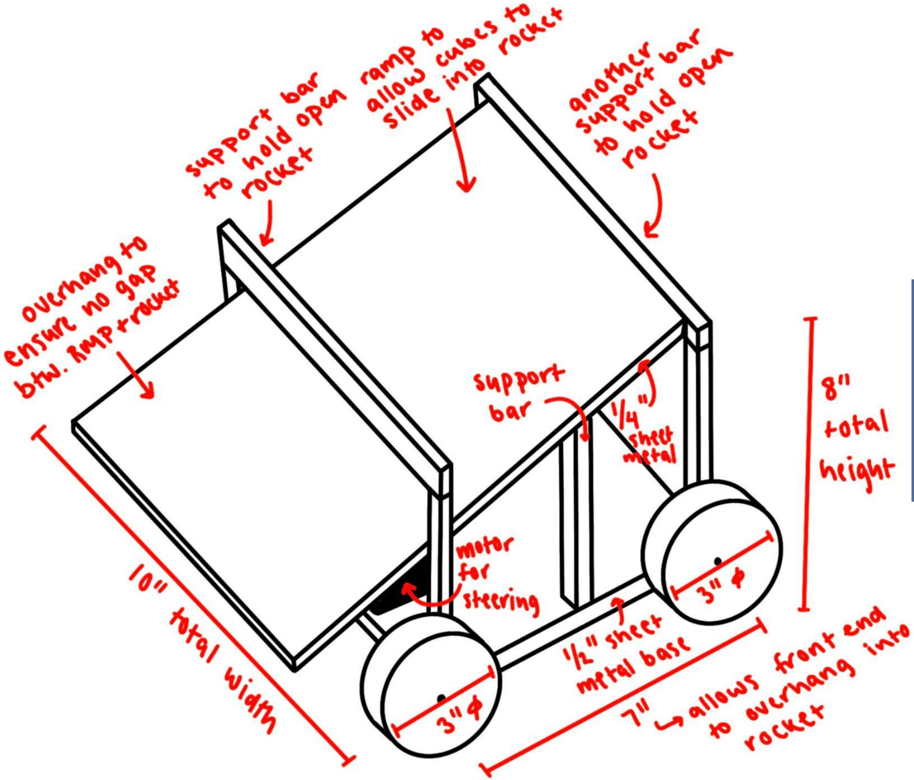
Top 3 Functional Requirements

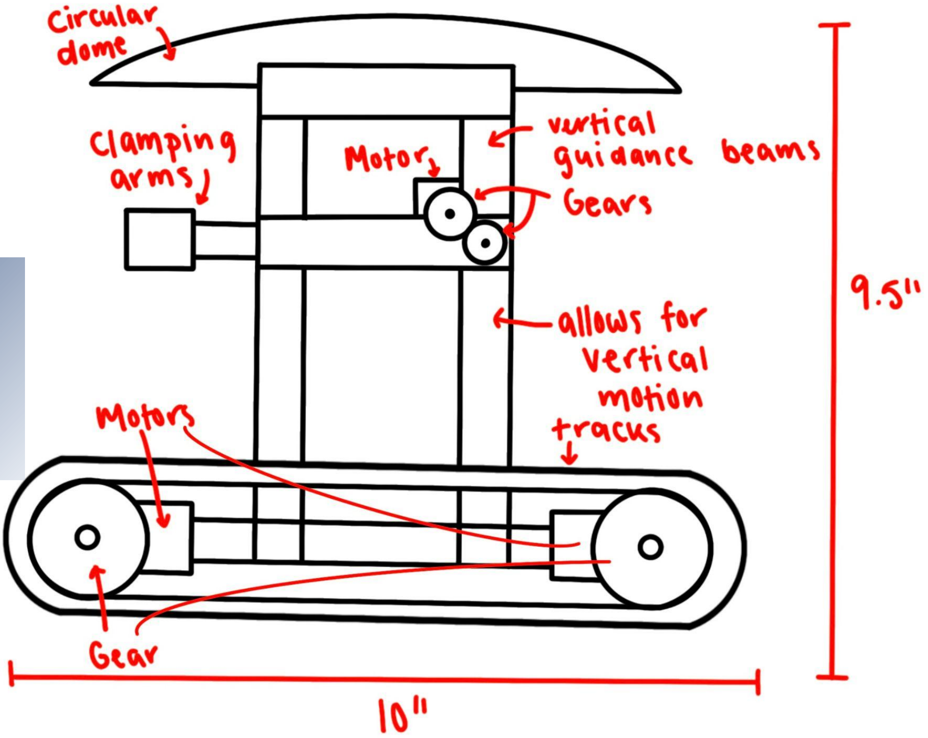
- RMP 1 must hold the rocket open at a height of 10 in (± 1 in)
- RMP 1 must be able to deposit 2 cubes (± 1 cube) at a time
- RMP 1 must be capable of driving up at least a 35° ramp

Why:

- If we cannot deposit cubes:
  - other RMPs must deposit them themselves (if they are even able to)
- If we cannot prop open the rocket:
  - other RMPs must move to Area 51 to deposit cubes (if they are even able to)
  - lose out on the point multiplier of the rocket
- If we cannot drive up ramp:
  - Same implications as above

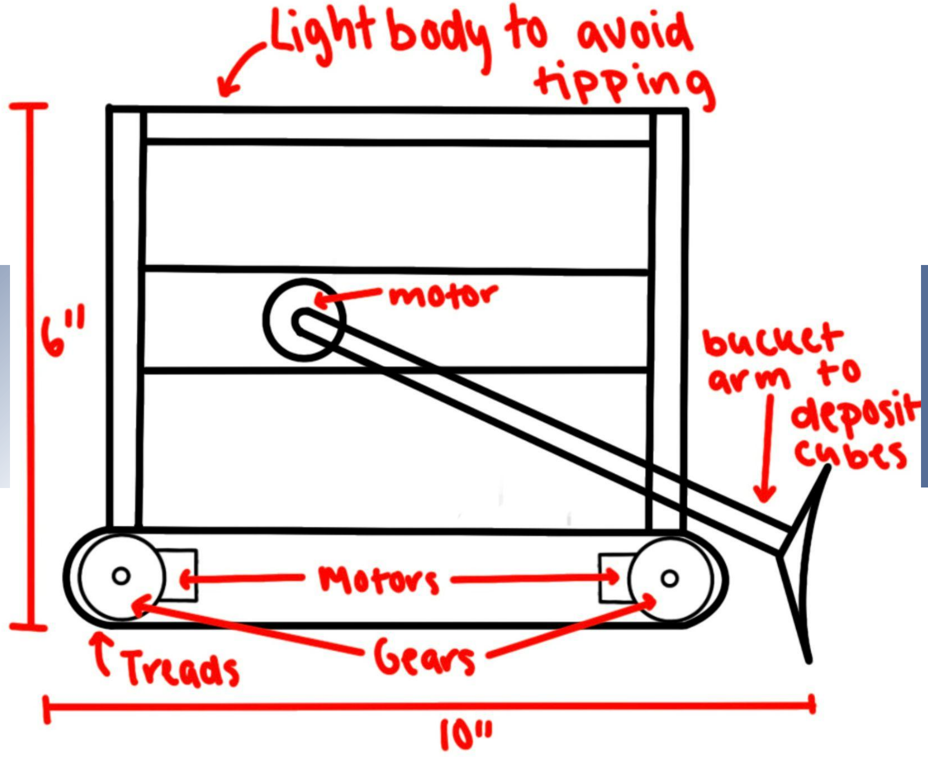
Design Concept #1



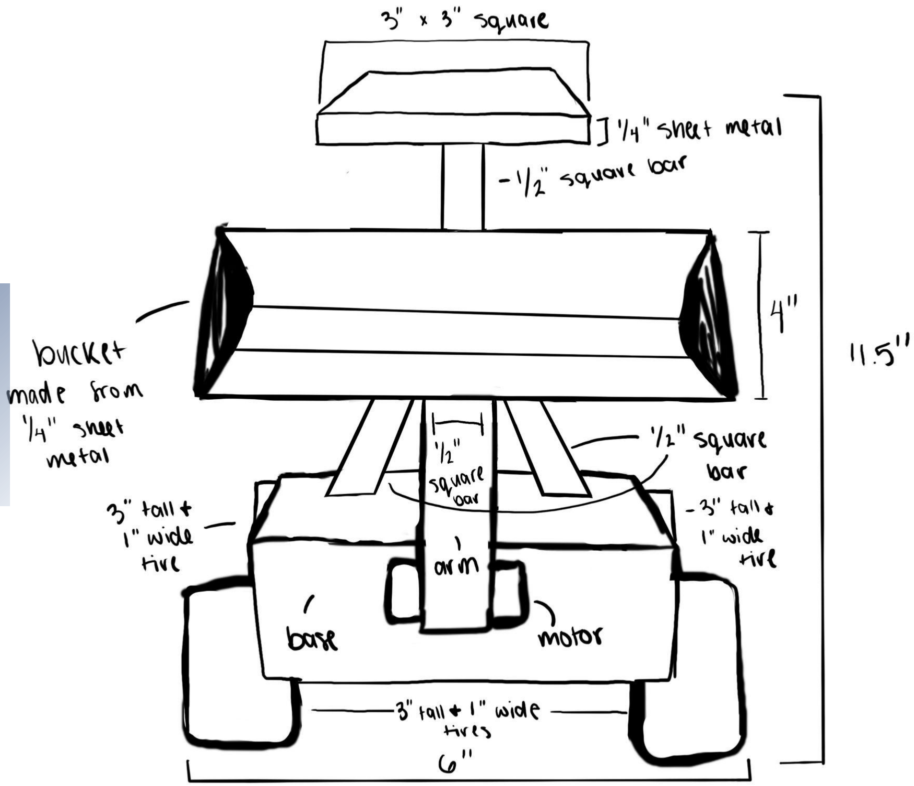


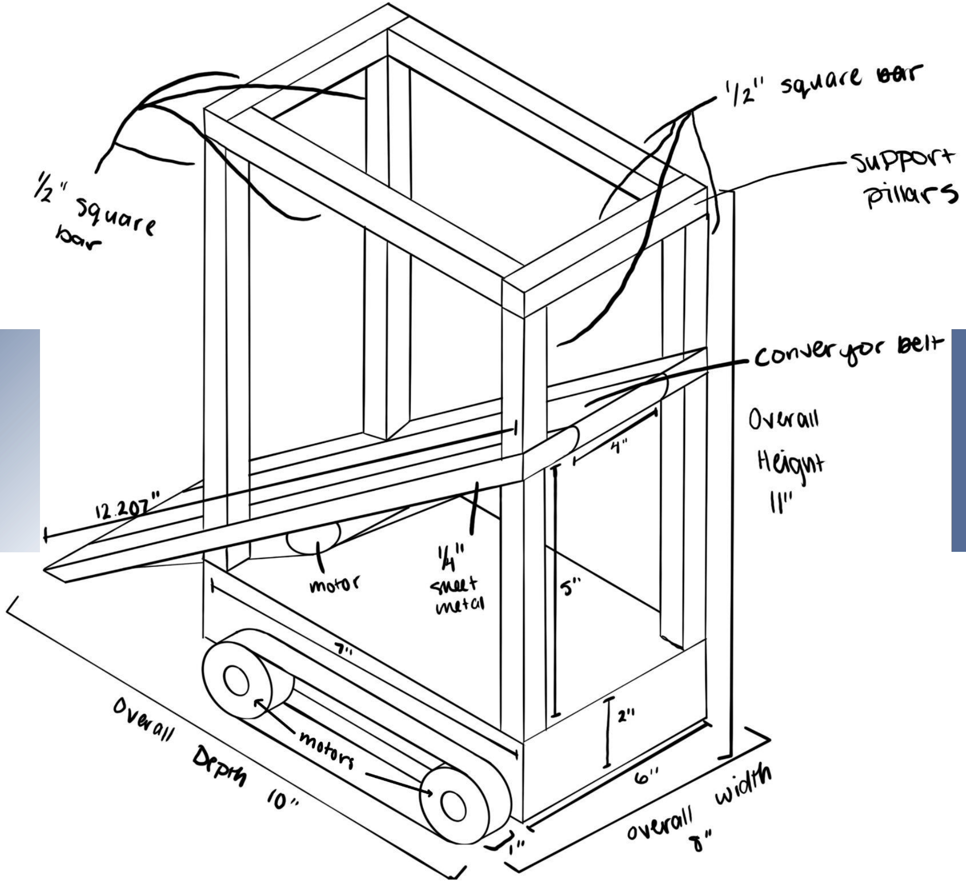
Design Concept #2

Design Concept #3



Design Concept #4





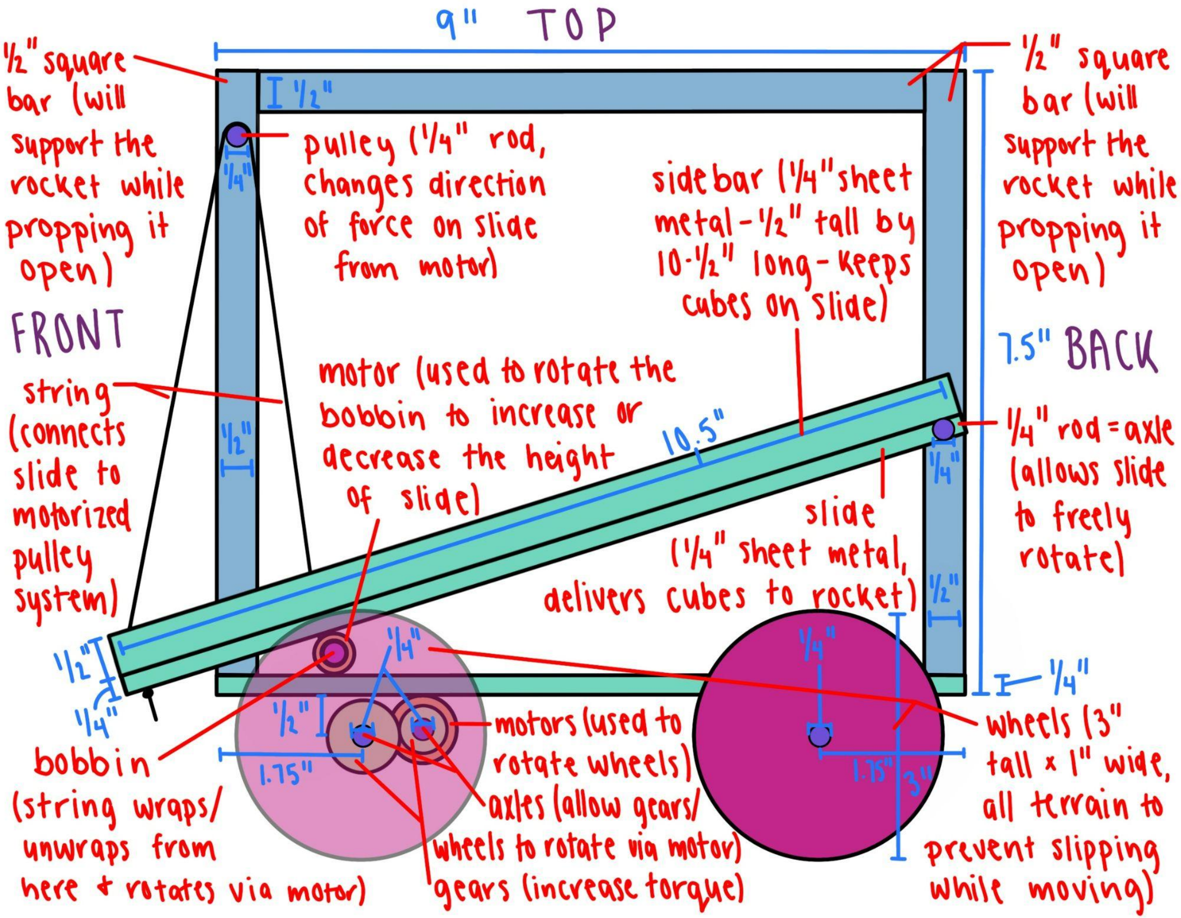
Design Concept #5

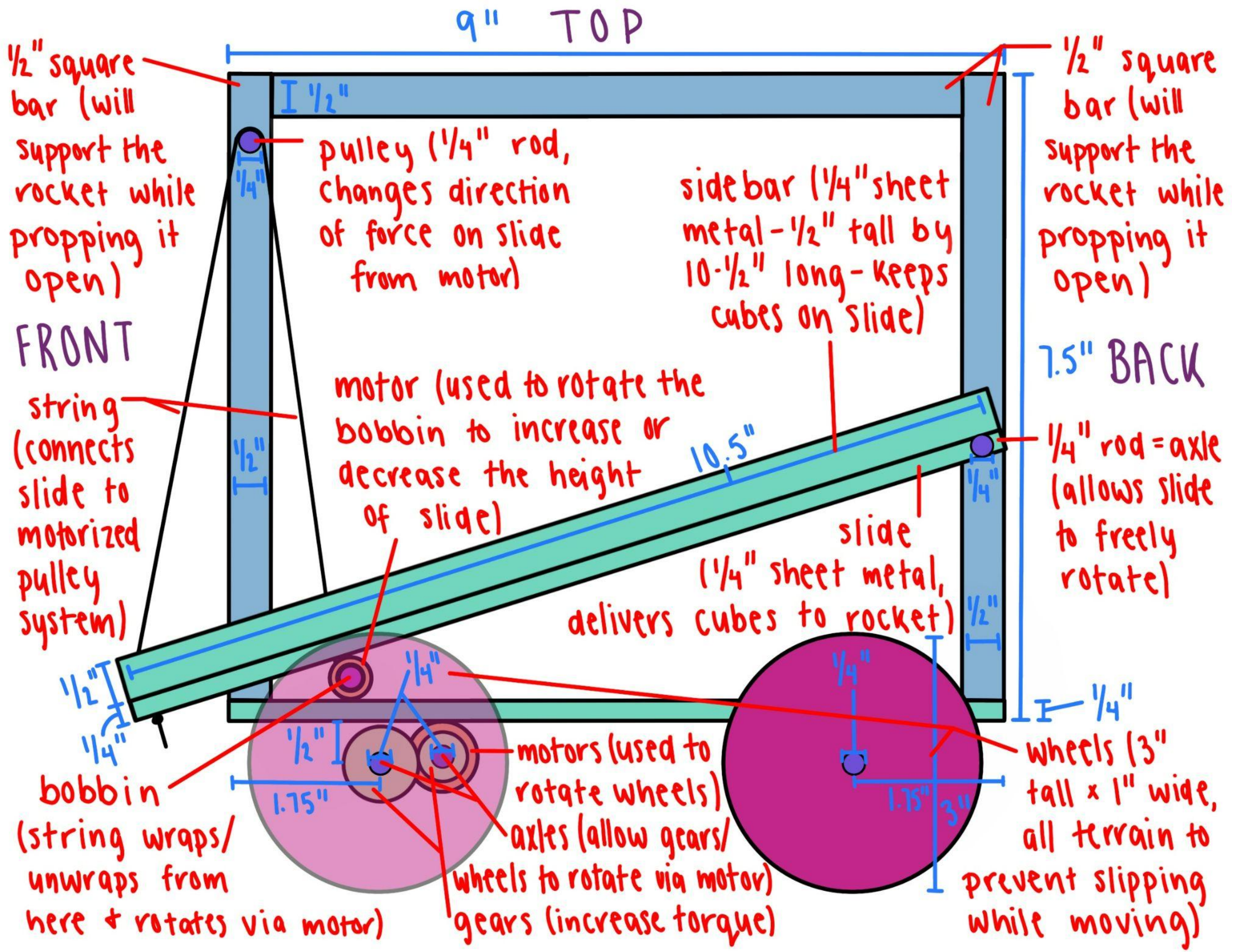
Pugh Chart Analysis

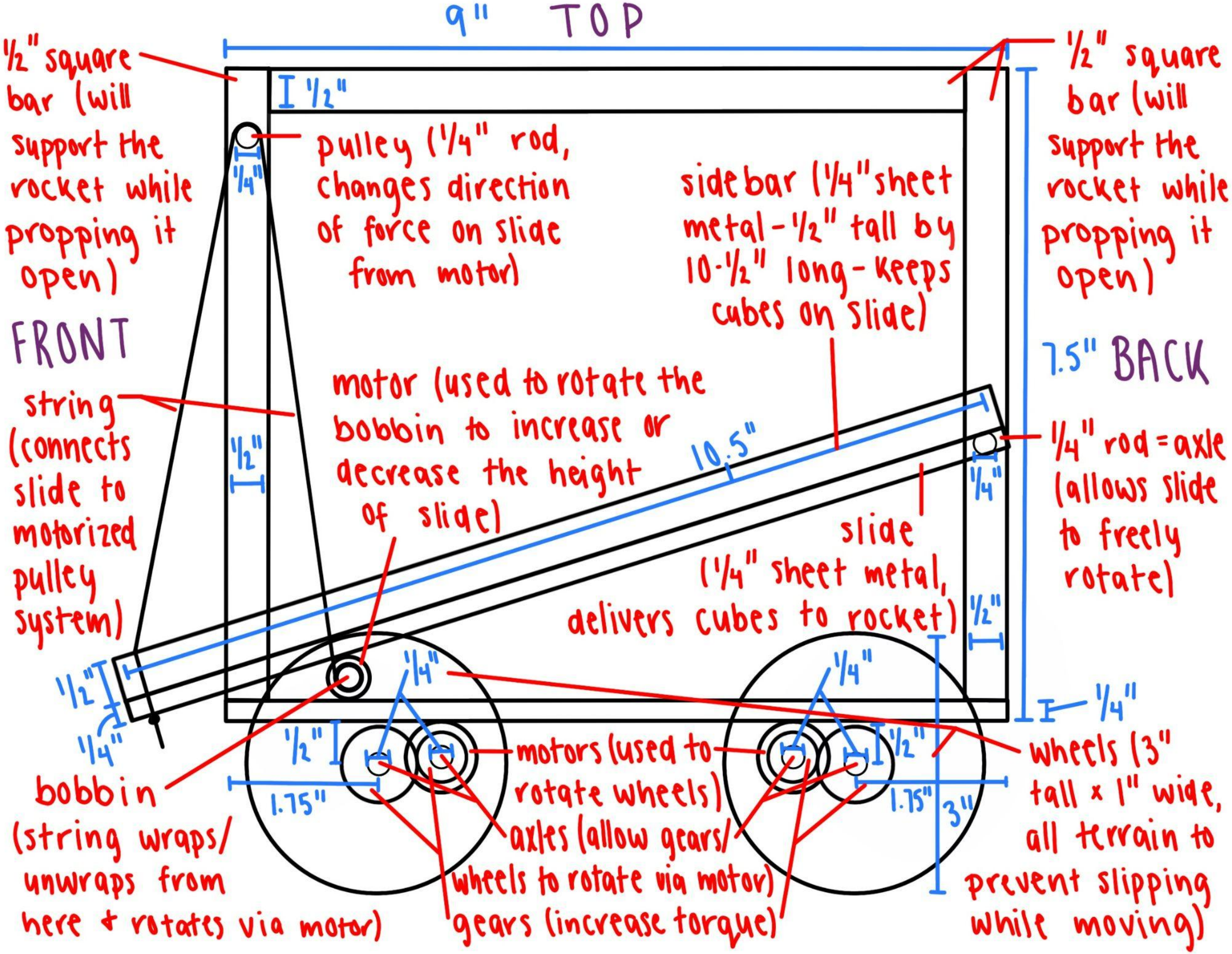
Requirement	Weight	Design Concept 1 (GU-1) **Baseline**	Design Concept 2 (EF-2)	Design Concept 3 (LB-1)	Design Concept 4 (AO-1)	Design Concept 5 (AO-2)
Can hold Rocket Open	3	0	+1	-1	0	+1
Can drive up the Ramp	3	0	0	+1	0	0
Can deposit Cubes	2	0	0	+1	-1	+1
Can traverse the Space-Time Continuum	2	0	-1	0	0	0
Can turn on stars	1	0	-1	-1	0	-1
Manufacturability	3	0	-1	0	0	0
Creativity	3	0	+1	0	+1	0
Total		0	0	+1	+1	+4

Concept Sketches

Right View



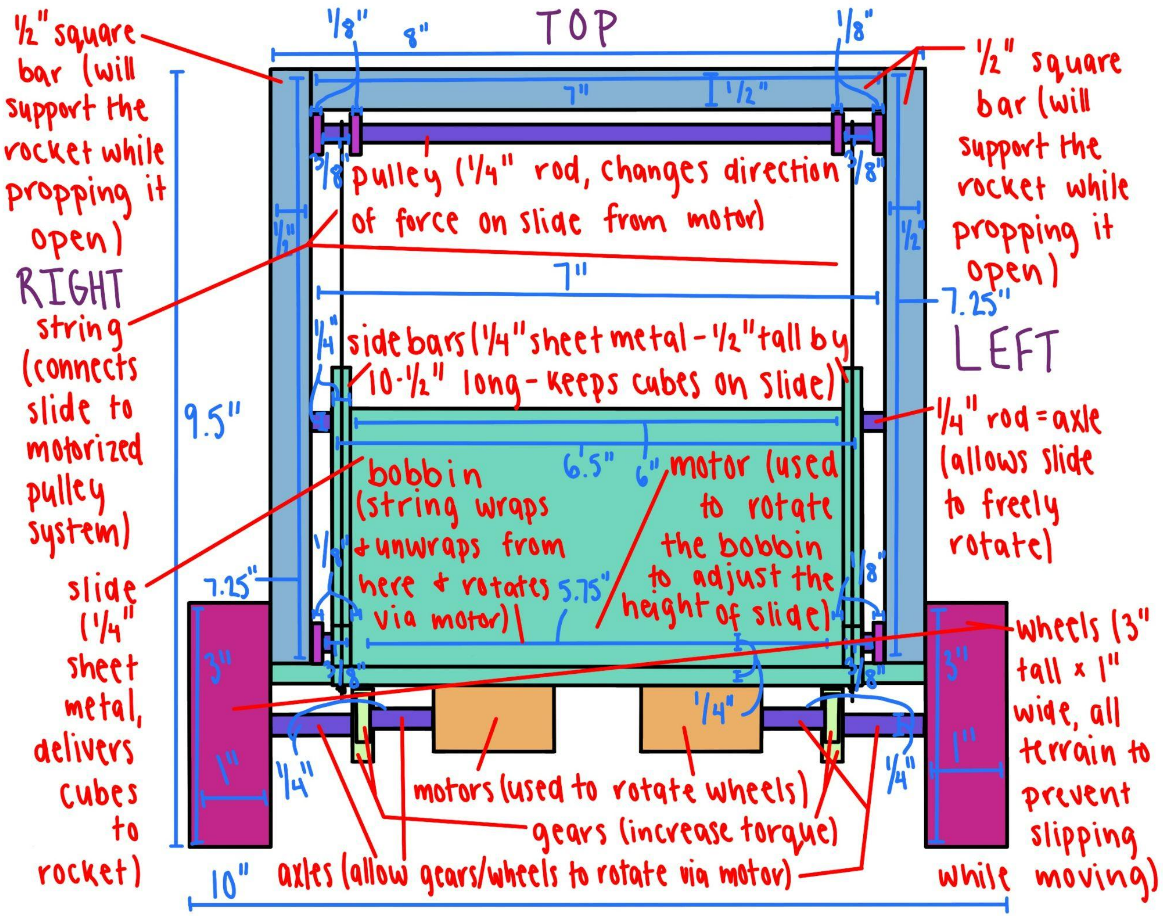

9" TOP
½" square bar (will support the rocket while propping it open)
½" square bar (will support the rocket while propping it open)
½"
pulley (¼" rod, changes direction of force on slide from motor)
¼"
sidebar (¼" sheet metal - ½" tall by 10-½" long - keeps cubes on slide)
FRONT
7.5" BACK
string (connects slide to motorized pulley system)
motor (used to rotate the bobbin to increase or decrease the height of slide)
10.5"
¼" rod = axle (allows slide to freely rotate)
½"
¼"
slide (¼" sheet metal, delivers cubes to rocket)
½"
½"
¼"
¼"
¼"
¼"
½"
¼"
motors (used to rotate wheels)
wheels (3" tall × 1" wide, all terrain to prevent slipping while moving)
bobbin (string wraps/unwraps from here & rotates via motor)
1.75"
axles (allow gears/wheels to rotate via motor)
gears (increase torque)
1.75"
3"

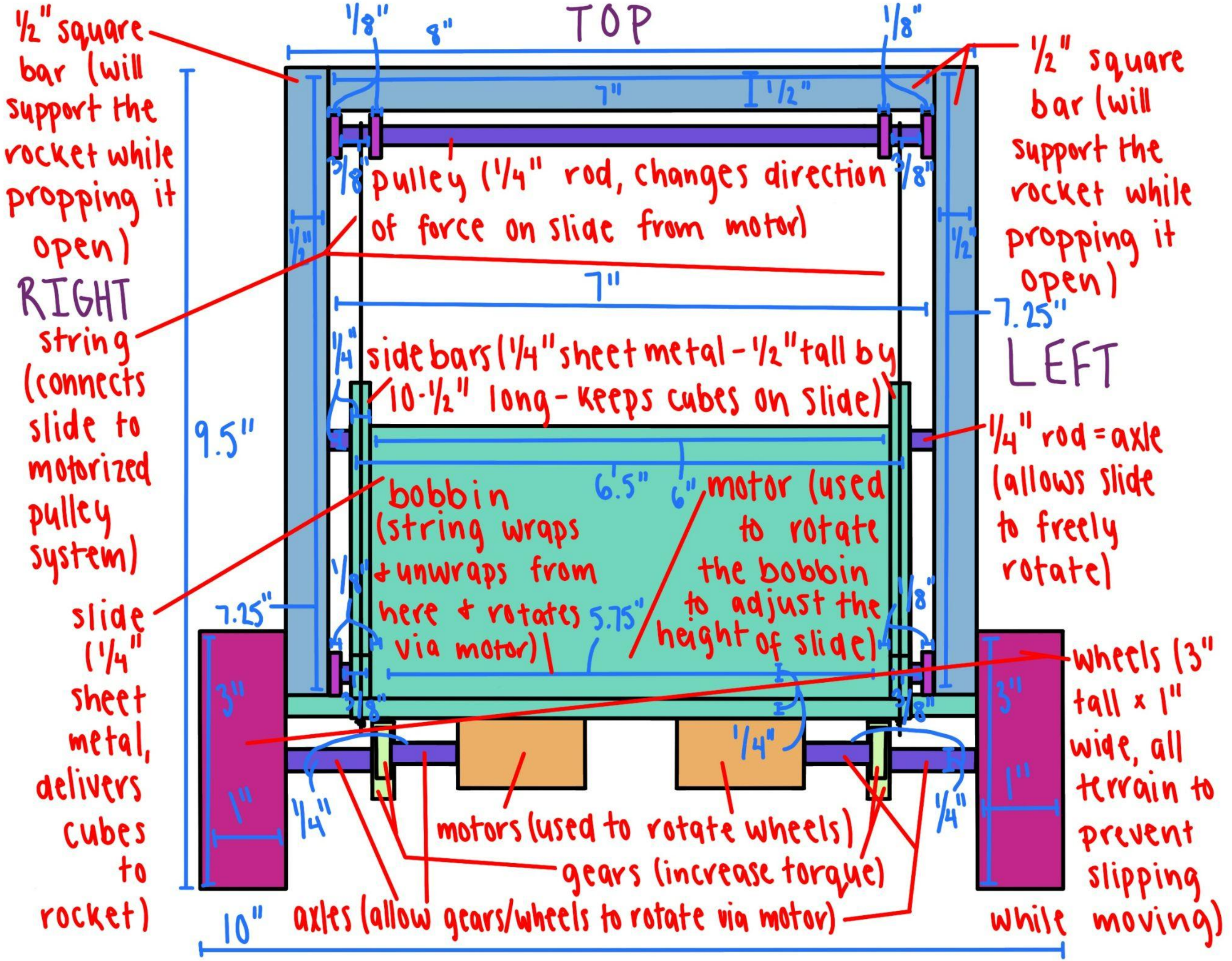


9"
TOP
1/2" square bar (will support the rocket while propping it open)
1/2"
pulley (1/4" rod, changes direction of force on slide from motor)
1/4"
side bar (1/4" sheet metal - 1/2" tall by 10-1/2" long - keeps cubes on slide)
1/2" square bar (will support the rocket while propping it open)
7.5"
BACK
FRONT
string (connects slide to motorized pulley system)
1/2"
motor (used to rotate the bobbin to increase or decrease the height of slide)
10.5"
1/4" rod = axle (allows slide to freely rotate)
1/4"
slide (1/4" sheet metal, delivers cubes to rocket)
1/2"
1/2"
1/4"
1/4"
1/4"
1/4"
1/4"
1/2"
1/2"
motors (used to rotate wheels)
wheels (3" tall x 1" wide, all terrain to prevent slipping while moving)
1.75"
1.75"
3"
bobbin (string wraps/unwraps from here & rotates via motor)
axles (allow gears/wheels to rotate via motor)
gears (increase torque)

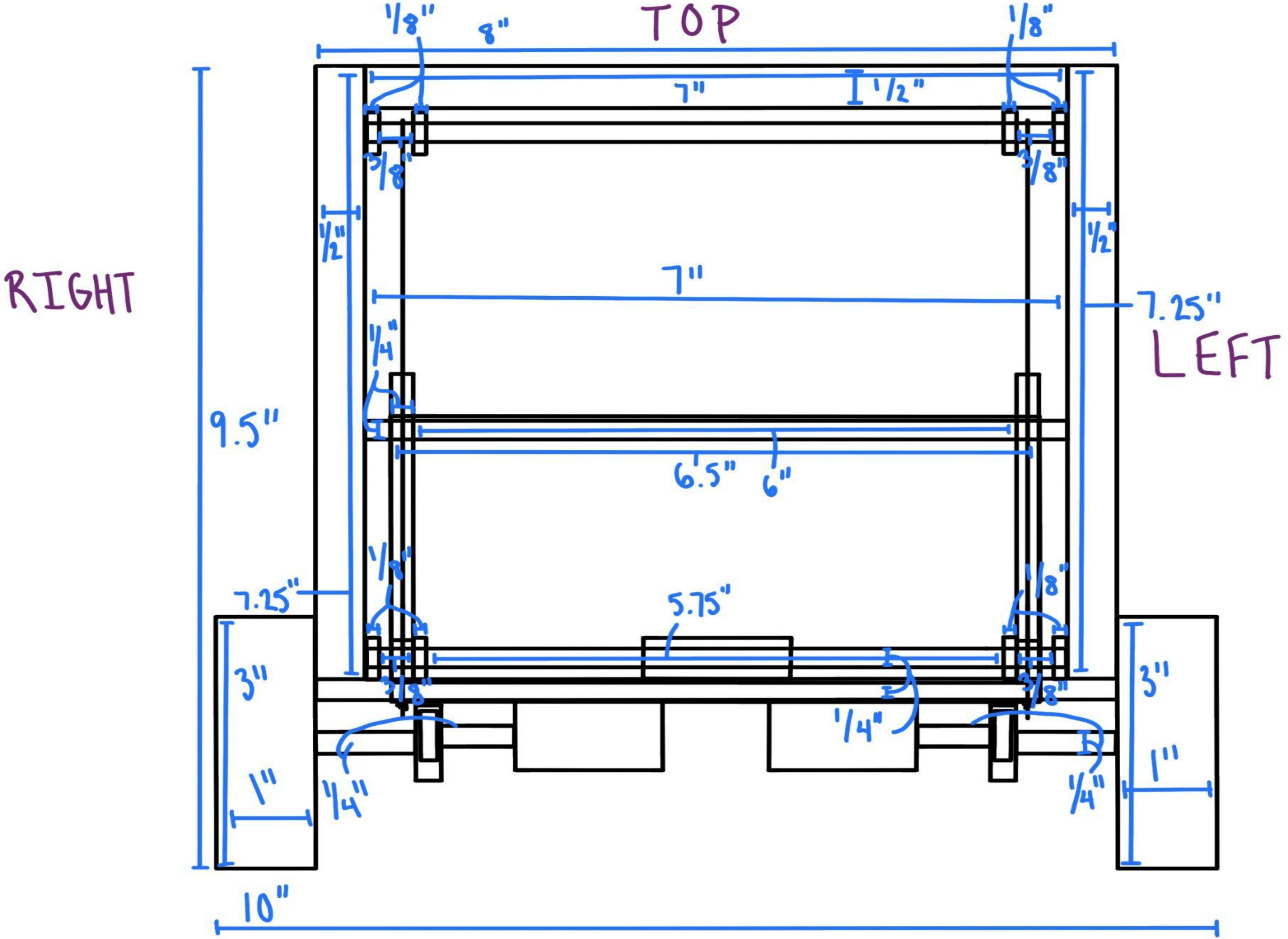
Concept Sketches

Front View





TOP
RIGHT
LEFT
1/2" square bar (will support the rocket while propping it open)
1/2" square bar (will support the rocket while propping it open)
1/8"
8"
1/8"
7"
1/2"
3/8"
3/8"
pulley (1/4" rod, changes direction of force on slide from motor)
1/2"
1/2"
7"
7.25"
string (connects slide to motorized pulley system)
9.5"
1/4"
side bars (1/4" sheet metal - 1/2" tall by 10-1/2" long - keeps cubes on slide)
1/4" rod = axle (allows slide to freely rotate)
6.5"
6"
bobbin (string wraps + unwraps from here + rotates via motor)
motor (used to rotate the bobbin to adjust the height of slide)
1/8"
1/8"
7.25"
5.75"
slide (1/4" sheet metal, delivers cubes to rocket)
3/8"
3/8"
1/4"
wheels (3" tall x 1" wide, all terrain to prevent slipping while moving)
3"
3"
1"
1"
1/4"
1/4"
motors (used to rotate wheels)
gears (increase torque)
axles (allow gears/wheels to rotate via motor)
10"



TOP
RIGHT
LEFT
8"
1/8"
1/8"
7"
1/2"
3/8"
3/8"
1/2"
1/2"
7"
7.25"
1/4"
9.5"
6.5"
6"
1/8"
1/8"
7.25"
5.75"
3/8"
3/8"
1/4"
3"
3"
1/4"
1/4"
1"
1"
10"

Decision Variables

Ramp Angle and Material

- Ramp angle must be large enough to slide cubes (FR), but low enough to meet height limitations
- Determined by empirical testing
  - Ease of test setup
  - Coefficient of friction is “unknown”
- Conclusion: Delrin has least coefficient of friction and 30 degrees of incline is more than sufficient

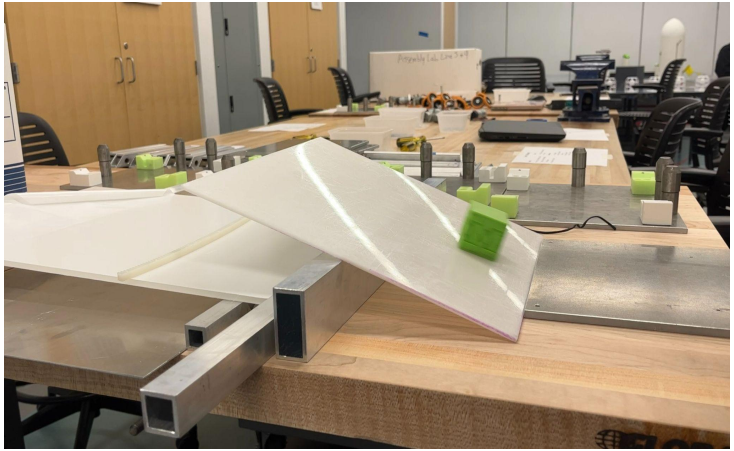
Motor Choices

- Motors must have sufficient torque for respective applications (FR)
- Determined by FPAs
  - Statically determinate– 3 equations, 3 unknowns
- Conclusion: Double gearbox motor for pulley, metal motors for wheels

Why Banebots Wheels and Caster Balls?

- Movement and maneuverability (most critical subsystem)
- Determined by engineering intuition
- Conclusion: Driven wheels in the front, caster balls in the rear

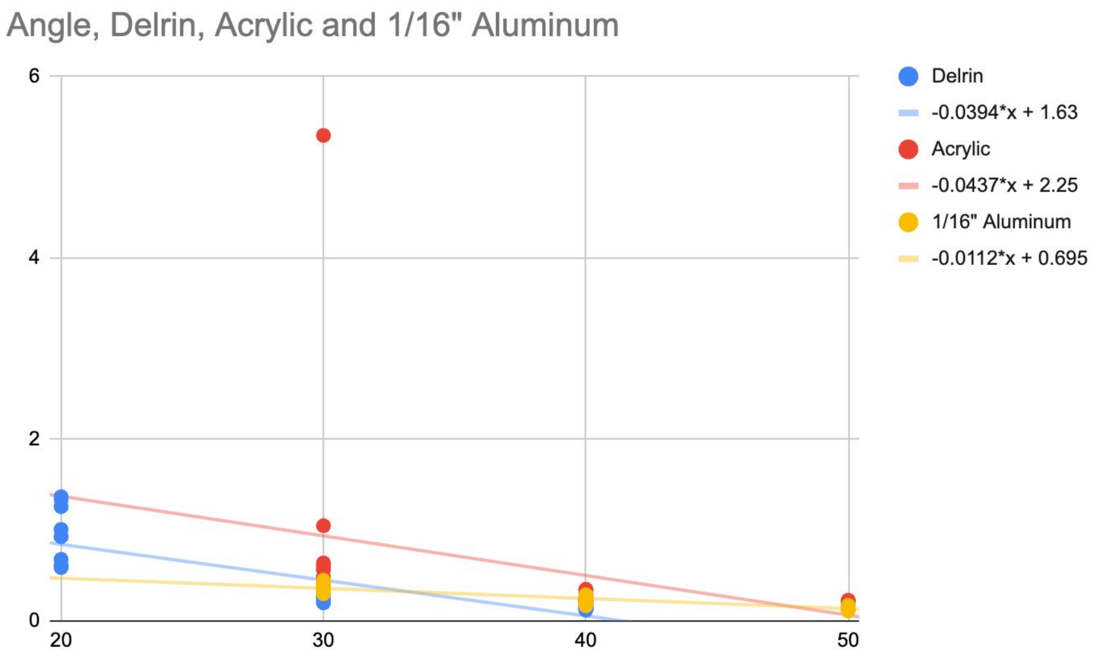
Empirical Testing: Optimal Ramp Angle and Material



Top Left: Acrylic
Bottom Left: Delrin
Right: Aluminum

Empirical Testing: Optimal Ramp Angle and Material

- Conclusion: Delrin around 25-30 degrees



* Some of the cubes did not slide at 20 degrees for Delrin

First Principles Analysis: Pulley Problem

$$\sum F_y = 0 = \cos(49.77) - W + C_y$$

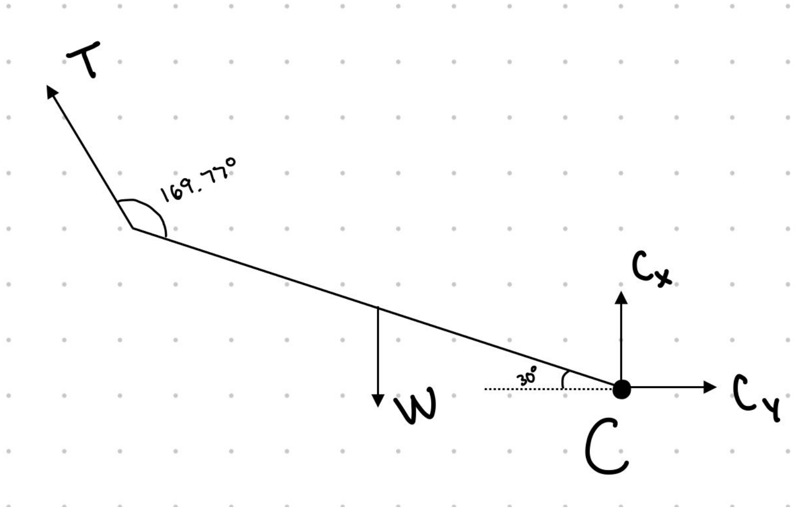
$$\sum F_x = 0 = -T\sin(49.77) + C_x$$

$$\sum M = 0 = -T\cos(49.77)(7.375\cos(30)) + T\sin(49.77)(7.375\sin(30)) + W(3.6875\cos(30))$$

$$\sum M = 0 = -1.3098T + 3.1935W$$

$T = 1.7067\,lb$

$T_{out} = 1.7067(0.25) = 0.4267\,\mathrm{lb}\cdot\mathrm{in}$=6.827 oz · in

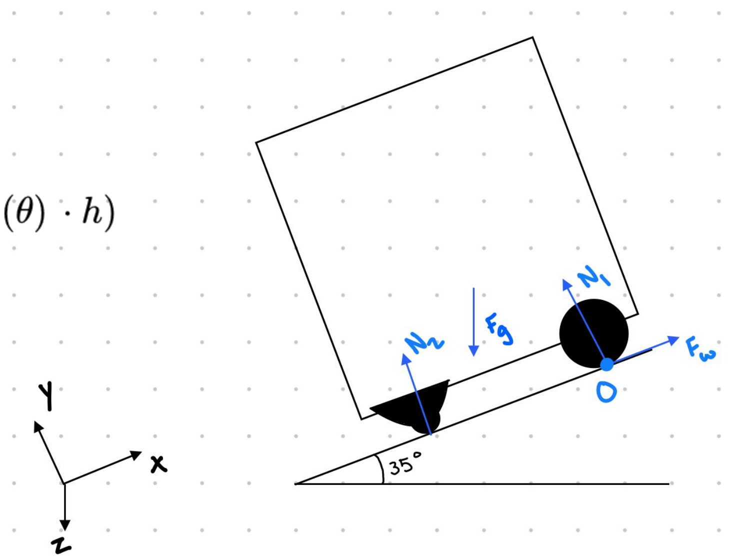


First Principles Analysis: Incline Torque Requirement

$$\sum F_x = 0 = F_W - F_g \sin(\theta)$$

$$\sum F_y = 0 = -F_g os(\theta) + N_1 + N_2$$

$$\sum M_O = 0 = (-N_2 \cdot d_{wheelbase}) + (F_g \cos(\theta) \cdot d_{COM}) + (F_g \sin(\theta) \cdot h)$$



$$\text{Approx. Weight} \cong 7\, lbs.$$

$$F_g = 7\, lbf$$

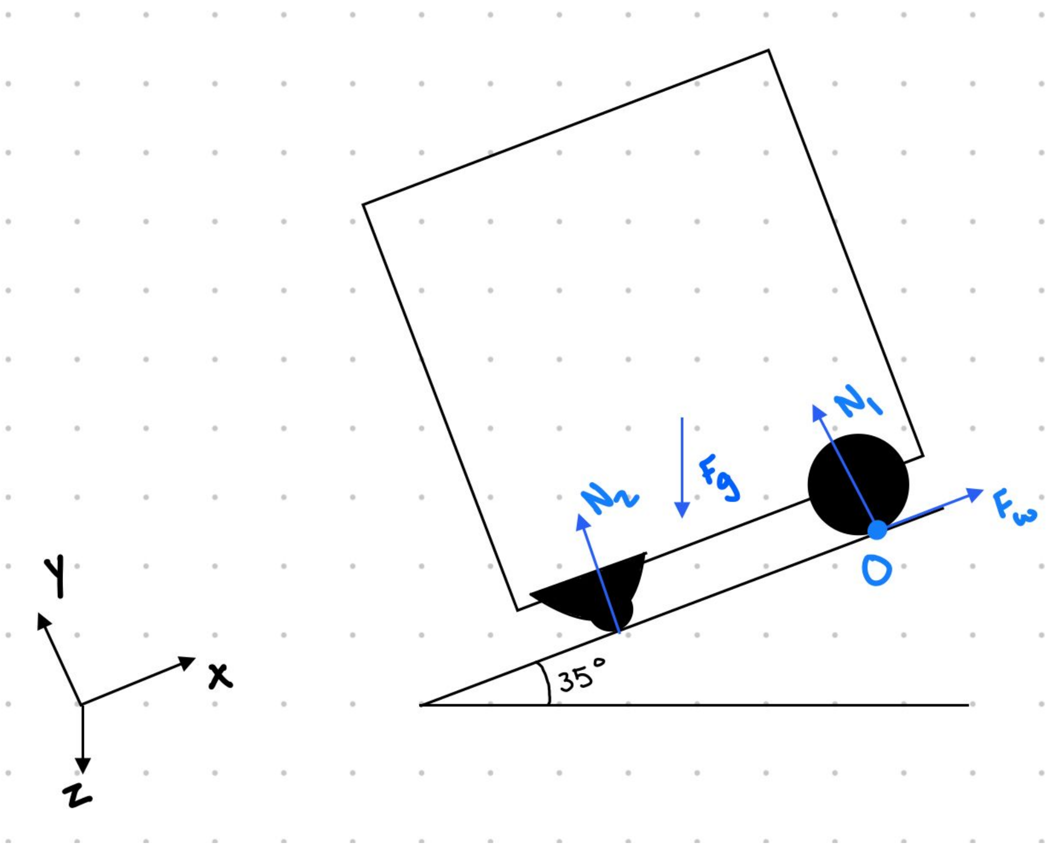
$$F_W = F_g \sin(\theta) = 7\, lbf \cdot \sin(45 \deg) = 4.1015\, lbf$$

$$T_{total,\, out} = F_W \times r_{wheel} = 4.1015\, lbf \times 1.4375\ in = 5.8816129\, lb \cdot in$$

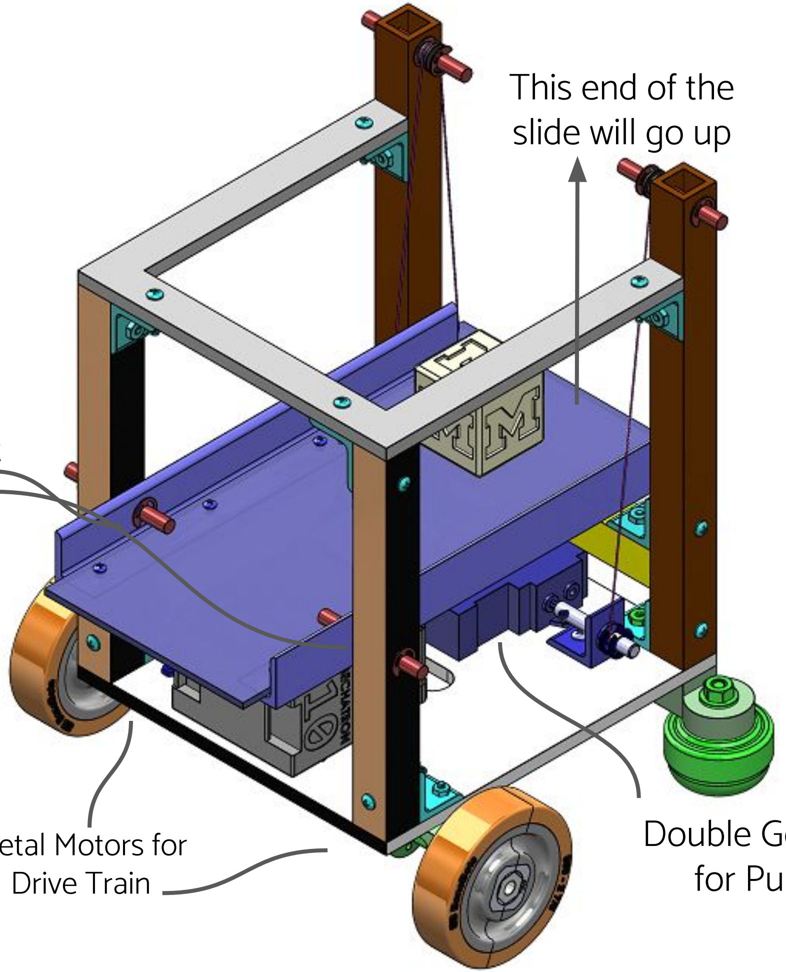
$$T_{wheel} = T_{total,\, out} \,/\, 2 = 2.8858\ lb \cdot in$$

$$T_{wheel,\, sf} = T_{wheel} \times S.F. = 5.8816129\ lb \cdot in\, (\text{with a safety factor} = 2)$$

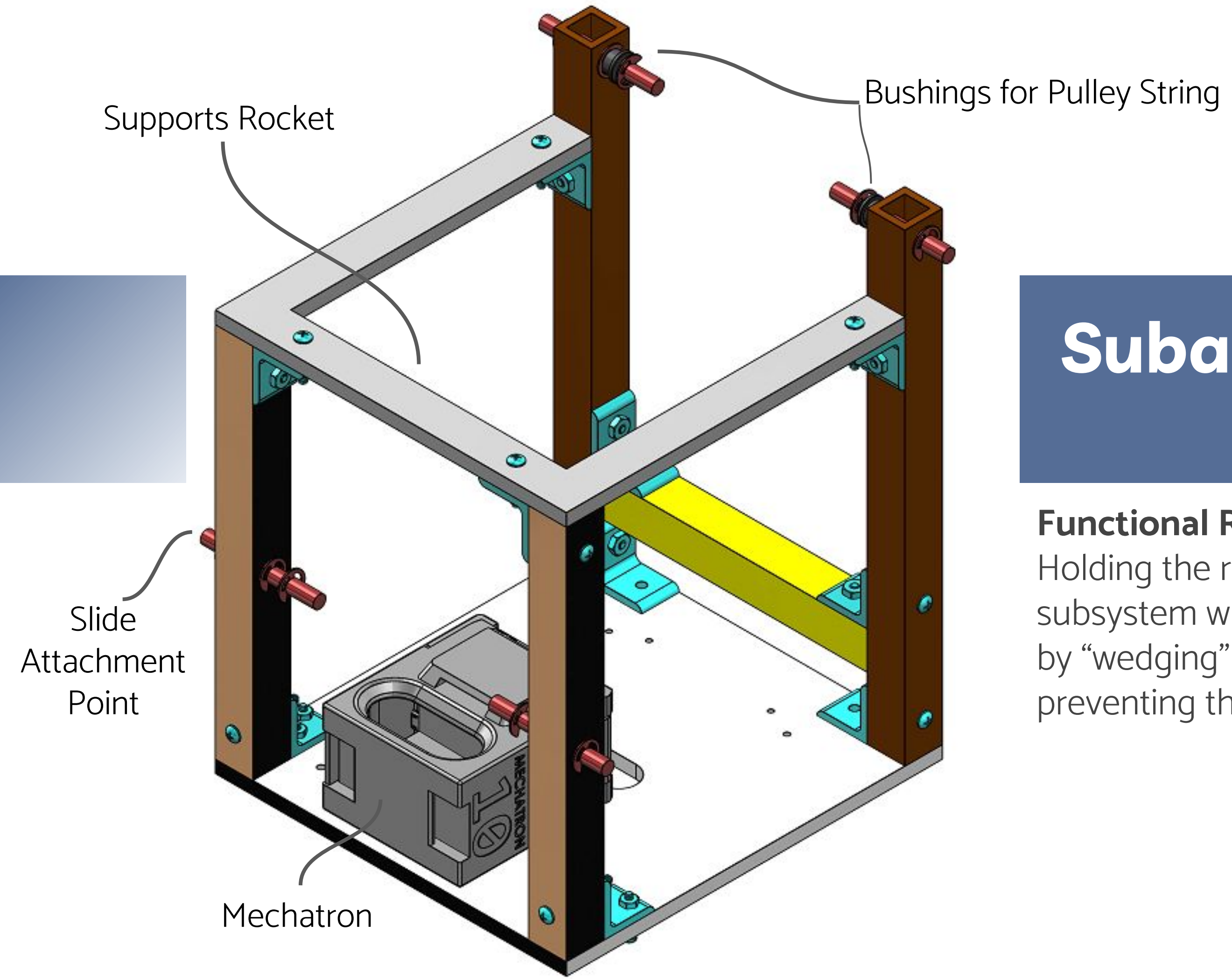
First Principles Analysis: Incline Torque Requirement



Final RMP: Full Assembly

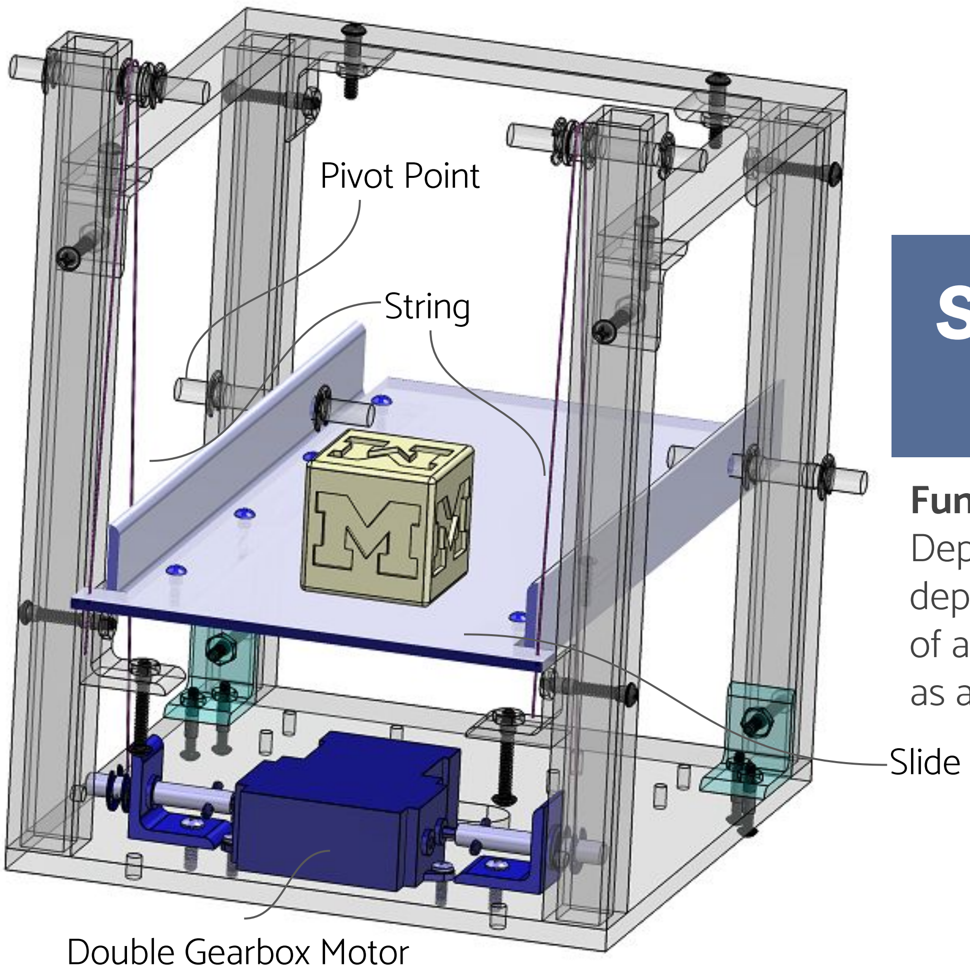


- We chose the final design concept because it was the design with the highest score from the Pugh chart
- The redesigns that we made were done with the purpose of increasing the manufacturability and creativity of the design
- Additionally, the highest ranking design contained many elements from our other designs and thus will effectively achieve the functional requirements.



Subassembly 1: Chassis

Functional Requirement:
Holding the rocket open. This subsystem will fulfill this requirement by “wedging” open the rocket doors, preventing them from closing.

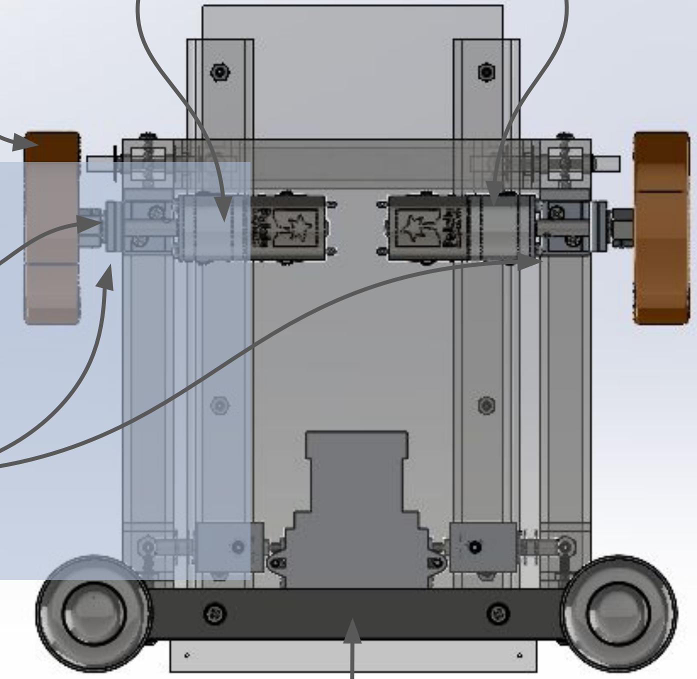


Subassembly 2: Slide

Functional Requirement:
Depositing Cubes into Rocket. The depositing cube mechanism consists of a pivoting ramp that effectively acts as a slide for cubes into the rocket.

Subassembly 3: Most Critical

- Movement and maneuverability
- Most complex
- Many failure modes

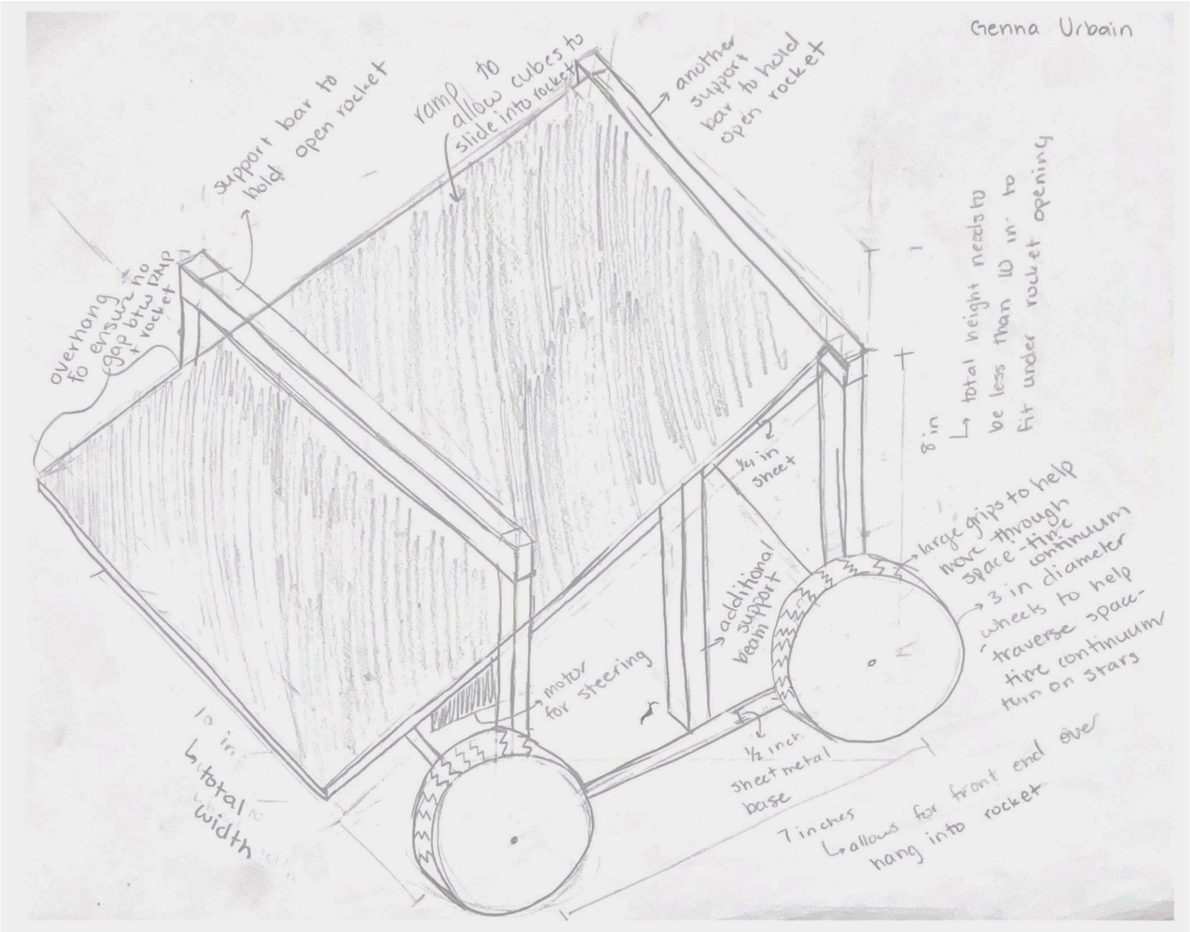


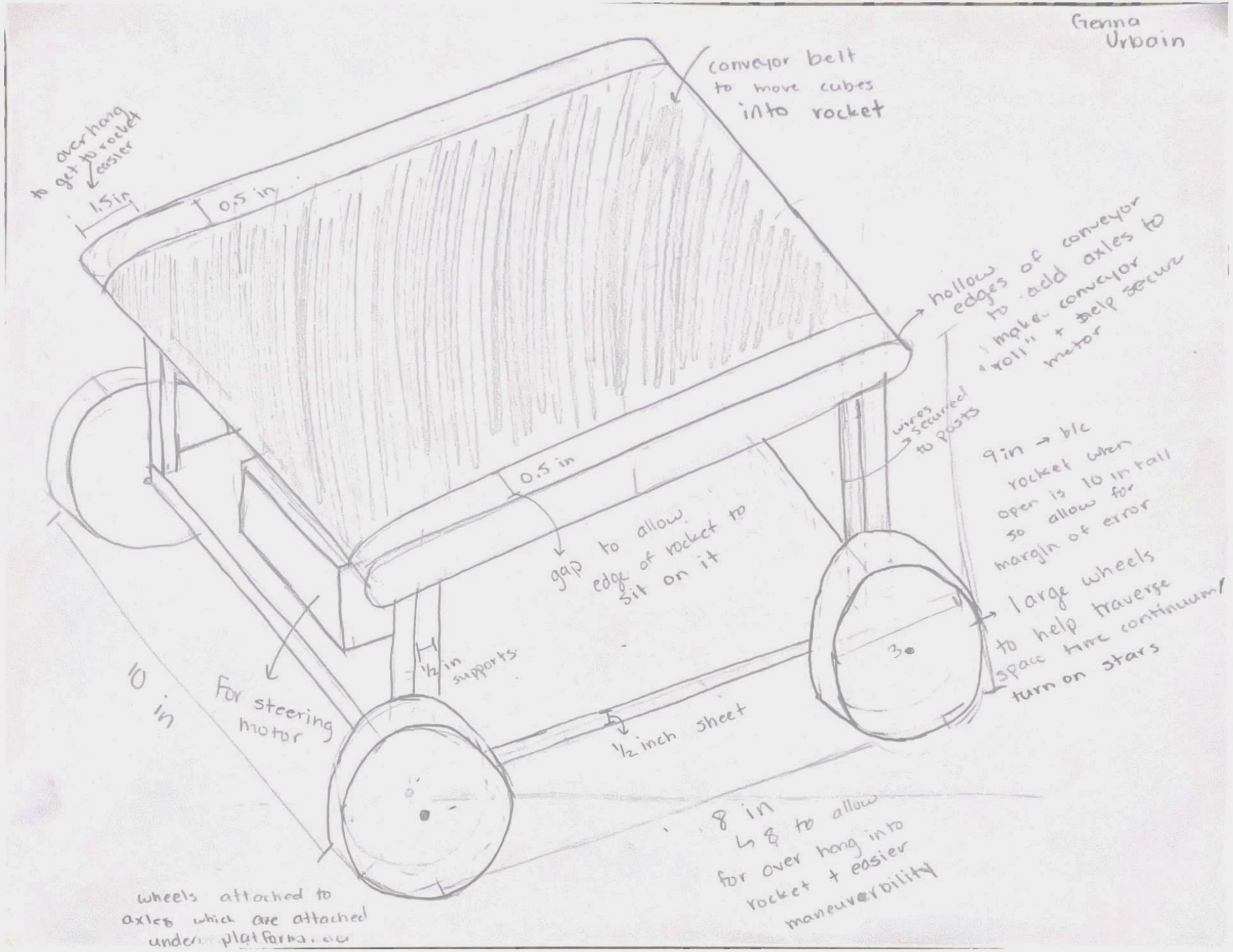
Concluding Issues

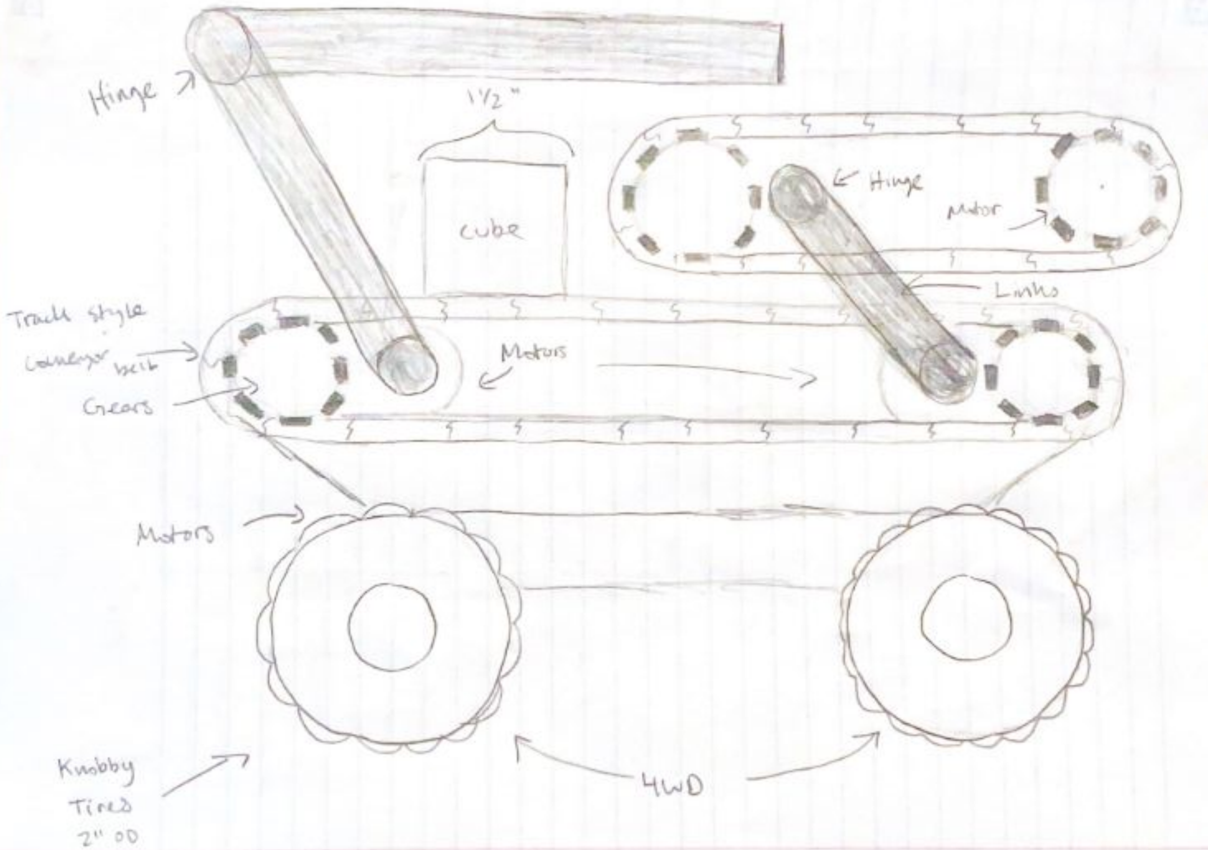
- Special Materials/Components:
    - May have to use 6-32 1.25” screws
- Expected Design and Manufacturing Challenges
    - Long wait times for waterjet (for base plate and top support)
    - Imprecise milling on parts leading to assembly failure
- Risks of Strategy/Design
    - If for some reason, the double gearbox cannot pull up the slide properly, then the RMP will not be able to deposit cubes
    - Not being able to trade enough materials in order to get the materials needed
    - Caster ball spacer may have too much stress

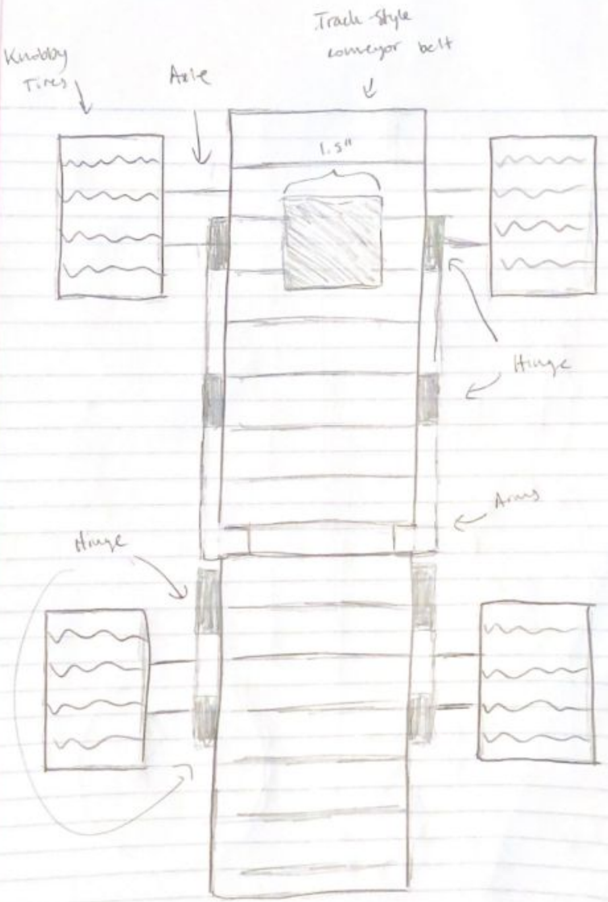
Appendix

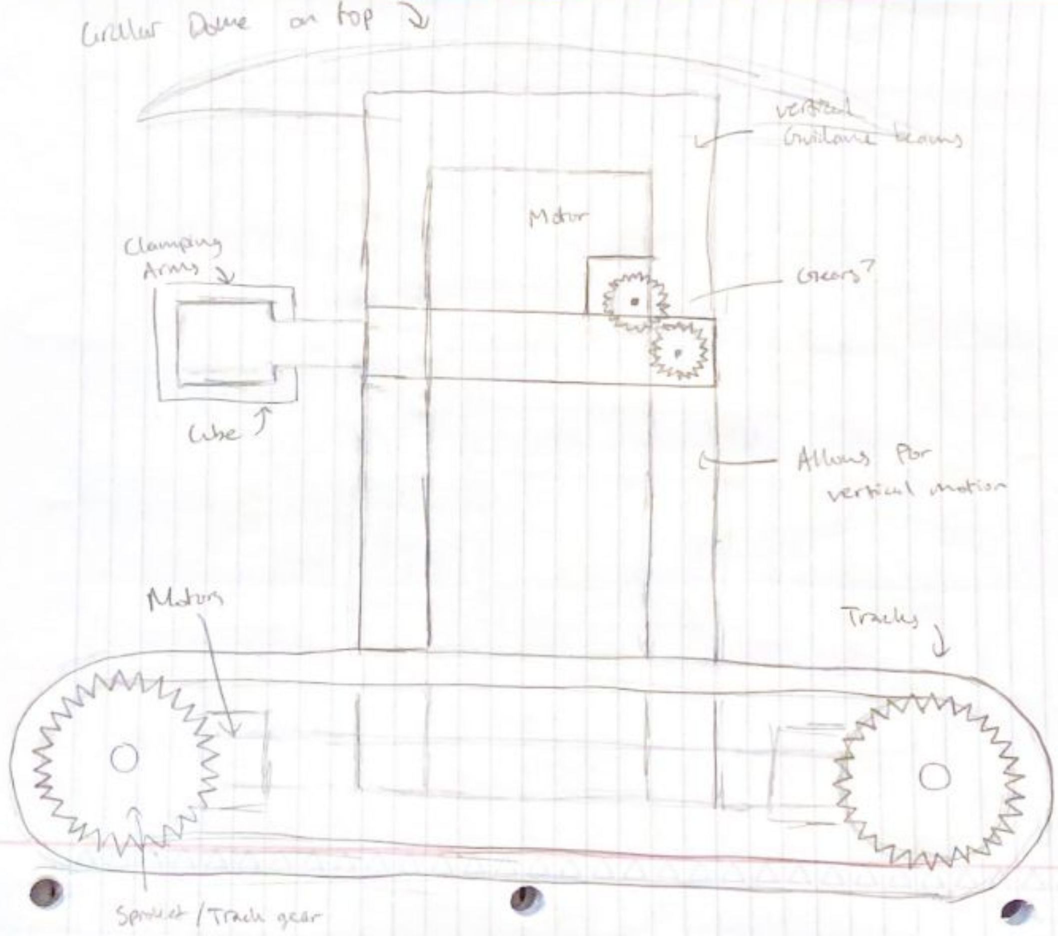
Preliminary Design Concept Sketches:

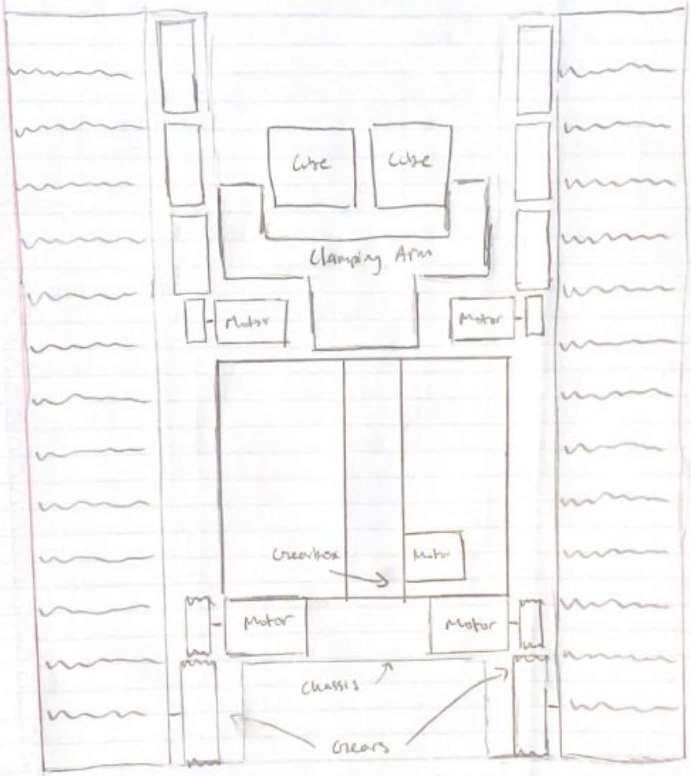



Genna Urbain
conveyor belt to move cubes into rocket
overhang to get to rocket easier
1.5 in
0.5 in
hollow edges of conveyor to add axles to make conveyor "roll" + help secure motor
wires secured to posts
9 in → b/c rocket when open is 10 in tall so allow for margin of error
0.5 in
gap to allow edge of rocket to sit on it
large wheels to help traverse space time continuum/ turn on stars
3
½ in supports
For steering motor
10 in
½ inch sheet
8 in ↳ 8 to allow for over hang into rocket + easier maneuverbility
wheels attached to axles which are attached under platform

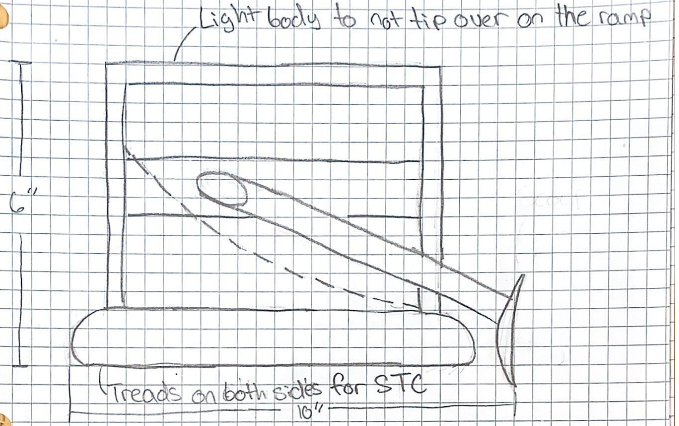

Hinge
1 1/2"
cube
Hinge
Motor
Links
Track style
conveyor belt
Motors
Gears
Motors
Knobby
Tires
2" OD
4WD


Knobby Tires
Axle
Track-Style conveyor belt
1.5"
Hinge
Arms
Hinge

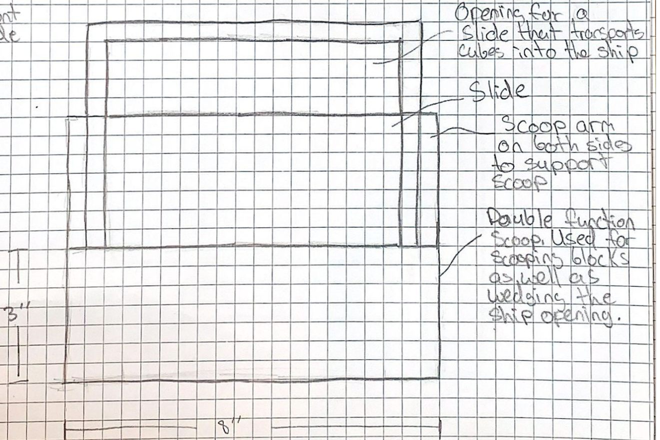

Grillar Dome on top
vertical Guidance beams
Motor
Clamping Arms
Gears?
Cube
Allows for vertical motion
Motors
Tracks
Sprocket / Track gear

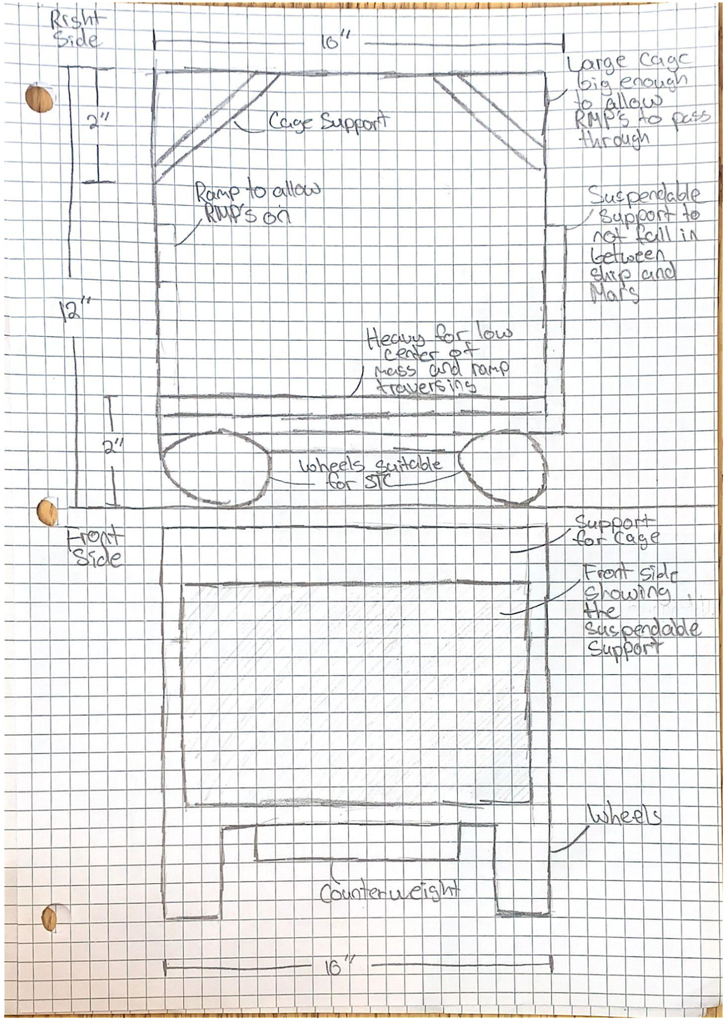

Cube
Cube
Clamping Arm
Motor
Motor
Gearbox
Motor
Motor
Motor
Chassis
Gears

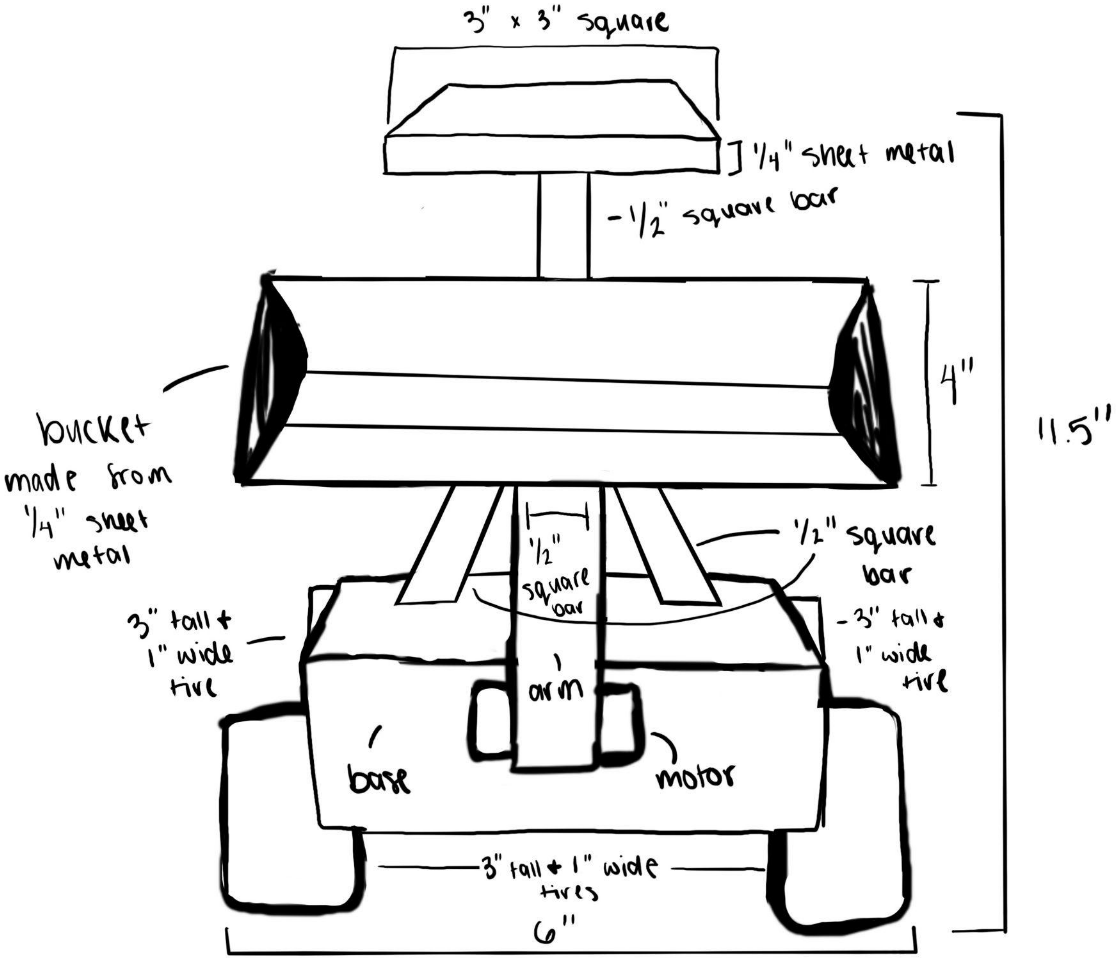
Right Side

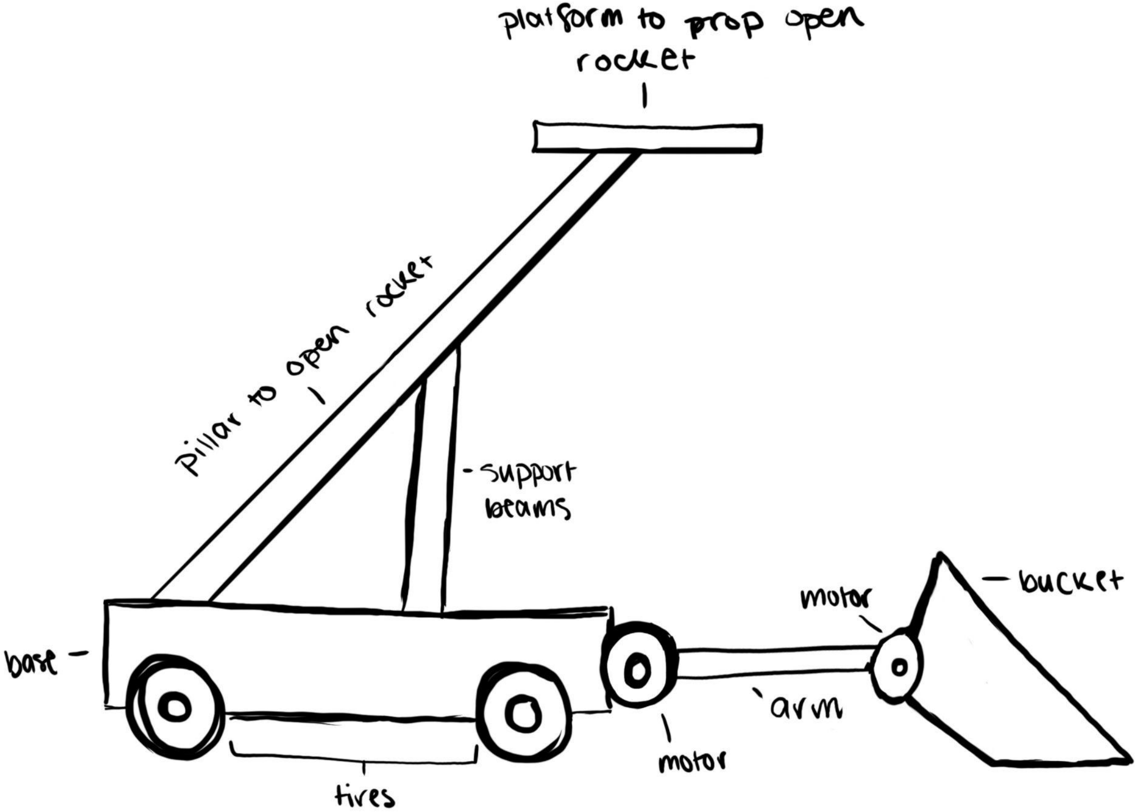


Front Side

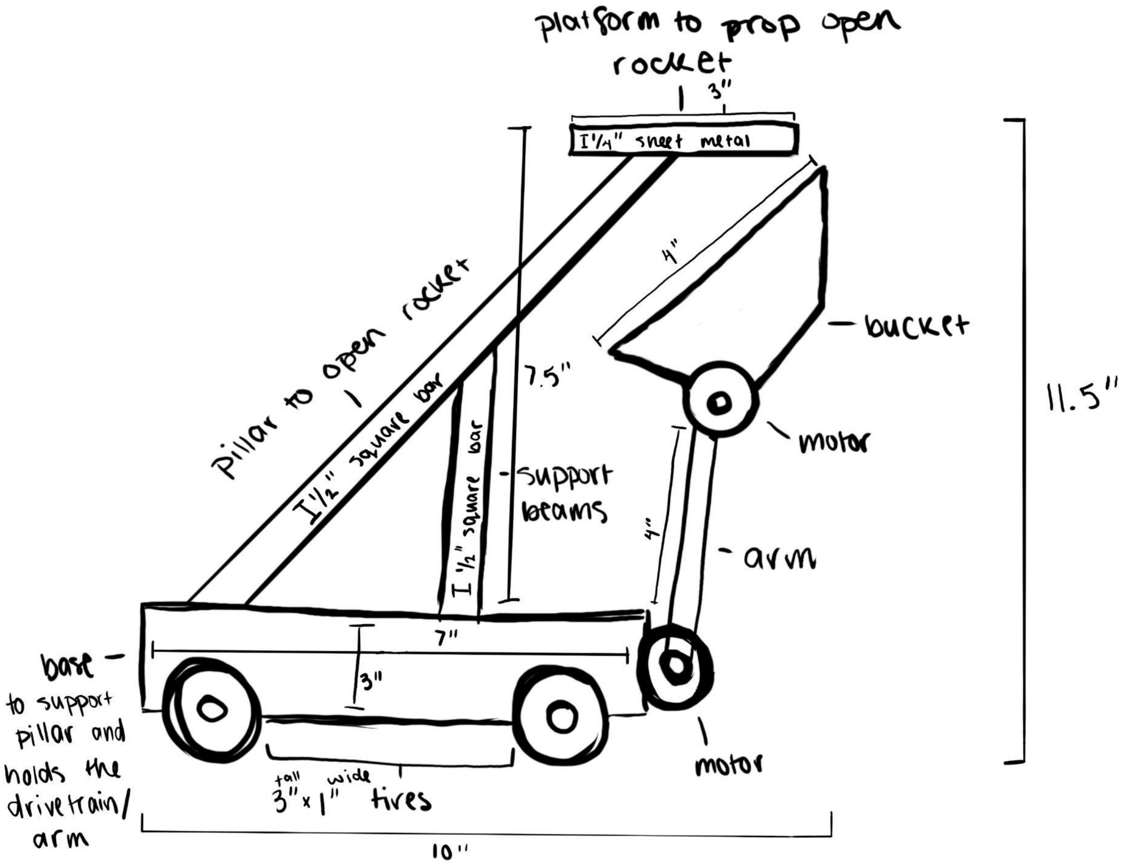



Right Side
16"
Large cage big enough to allow RMP's to pass through
2"
Cage Support
Ramp to allow RMP's on
Suspendable support to not fall in between ship and Mars
12"
Heavy for low center of mass and ramp traversing
2"
Wheels suitable for STC
Front Side
Support for Cage
Front side showing the suspendable support
Wheels
Counterweight
16"

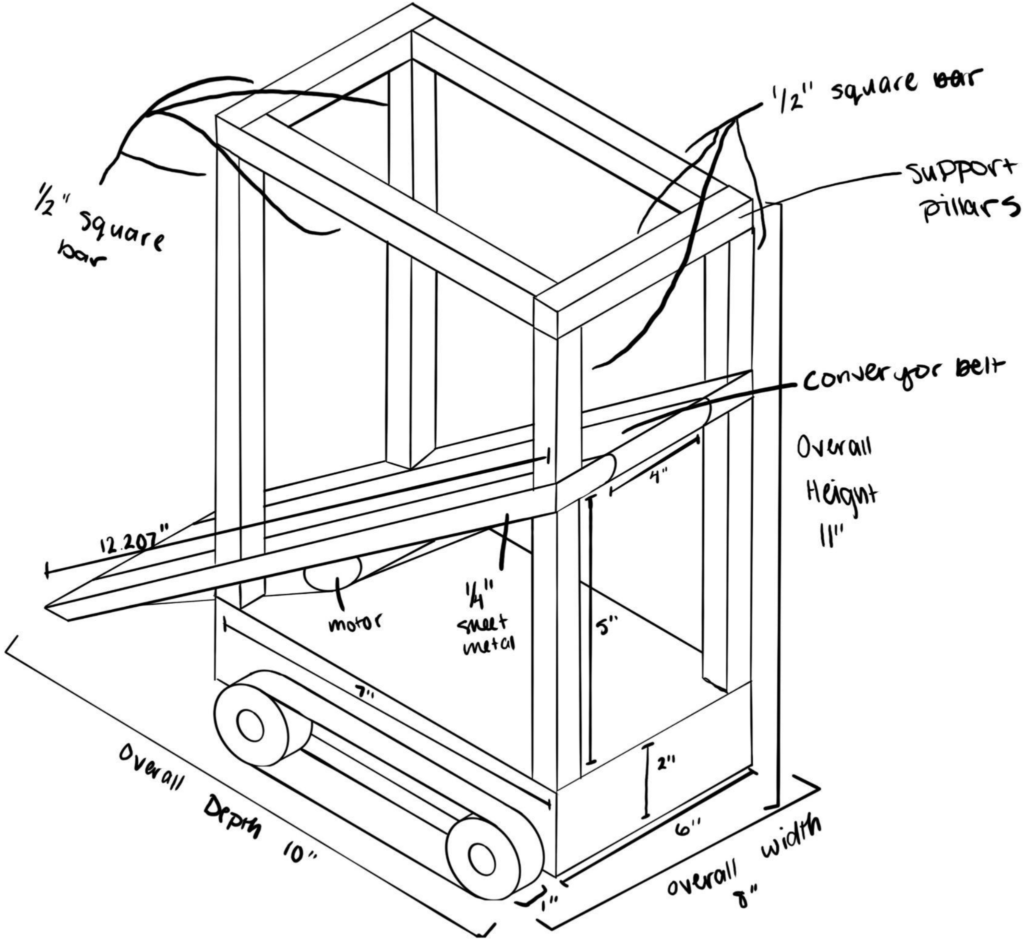

3" x 3" square
1/4" sheet metal
1/2" square bar
4"
11.5"
bucket made from 1/4" sheet metal
1/2" square bar
1/2" square bar
3" tall + 1" wide tire
3" tall + 1" wide tire
arm
base
motor
3" tall + 1" wide tires
6"



working position

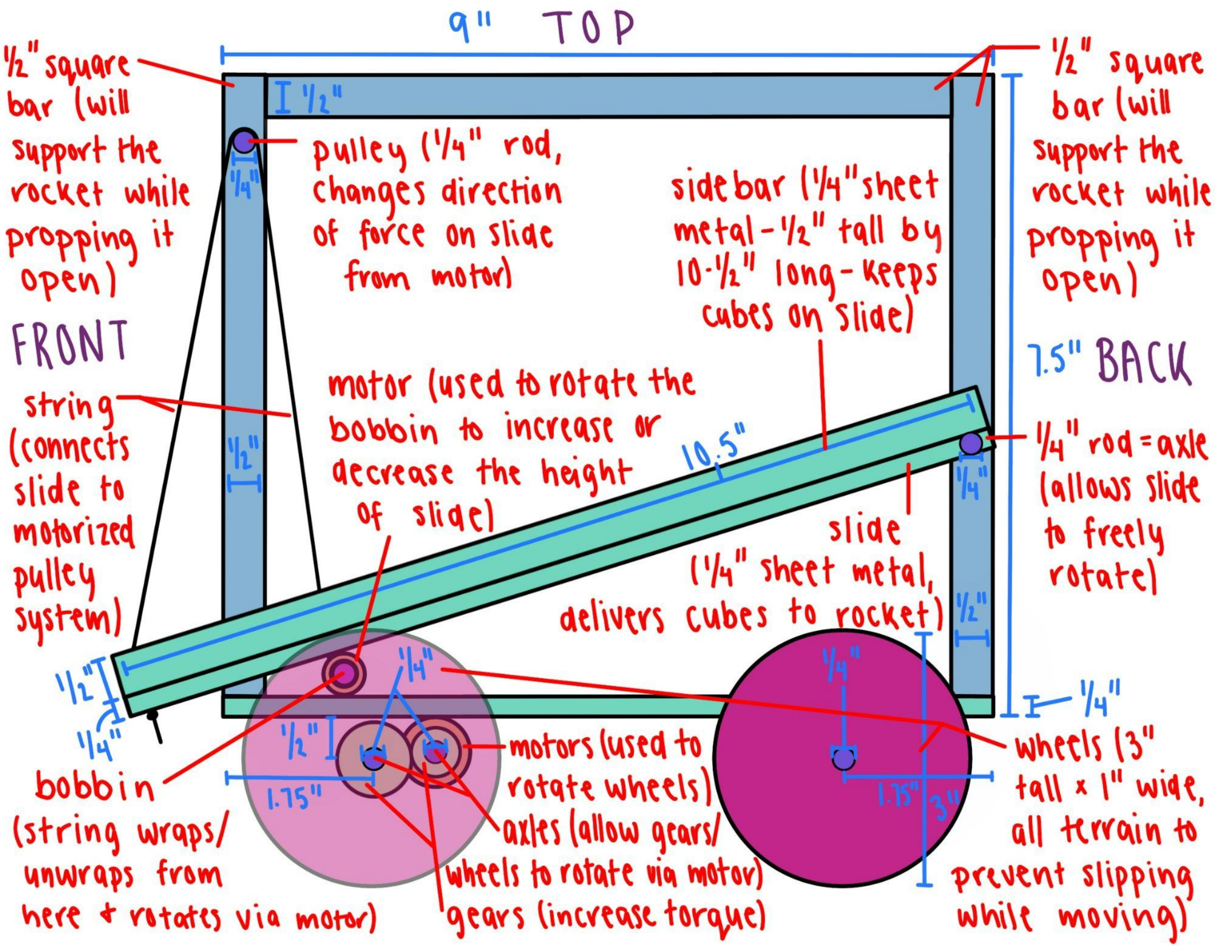


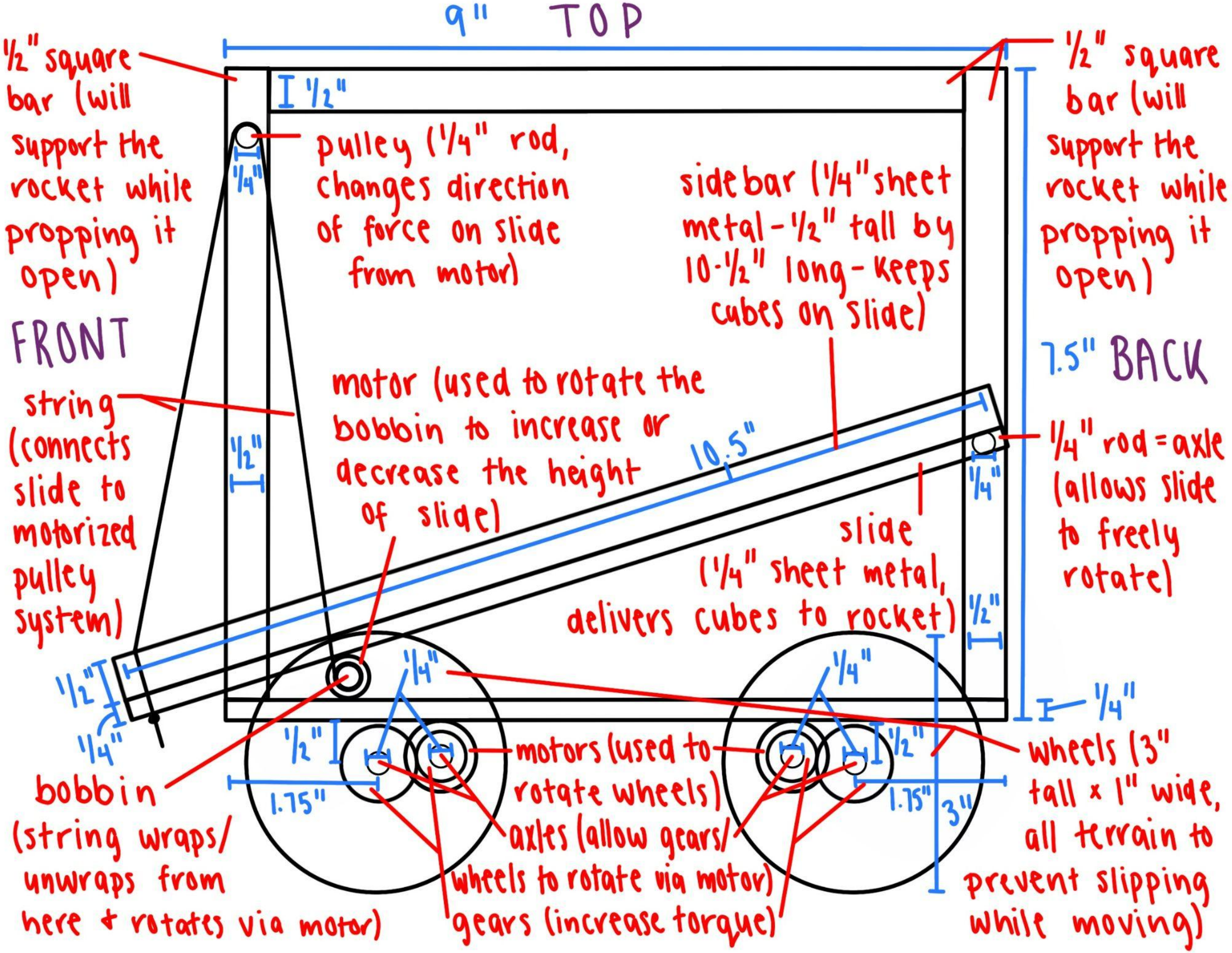
starting position

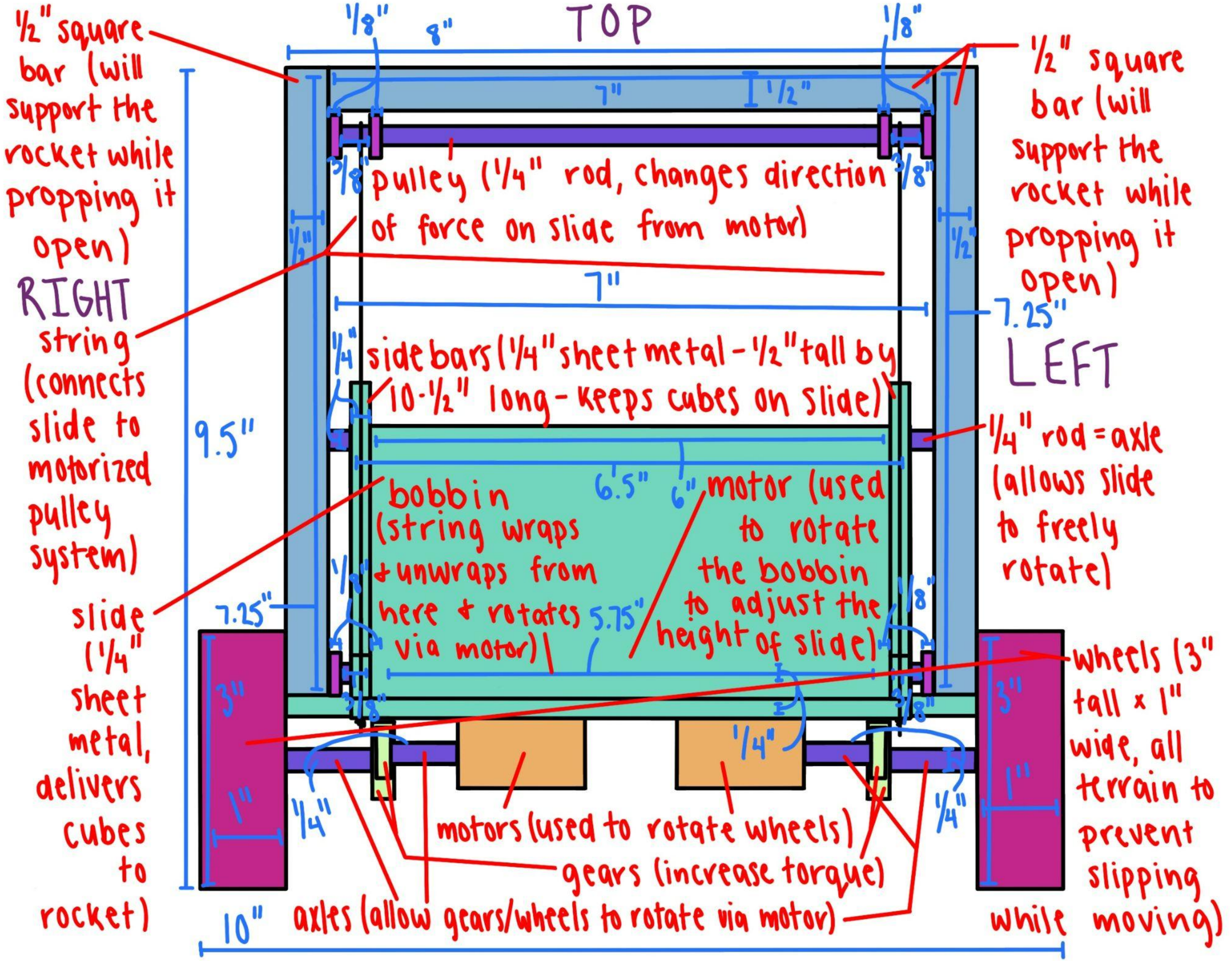


1/2" square bar
1/2" square bar
support pillars
conveyor belt
Overall Height 11"
12.207"
4"
1/4" sheet metal
motor
5"
7"
2"
6"
1"
Overall Depth 10"
overall width 8"

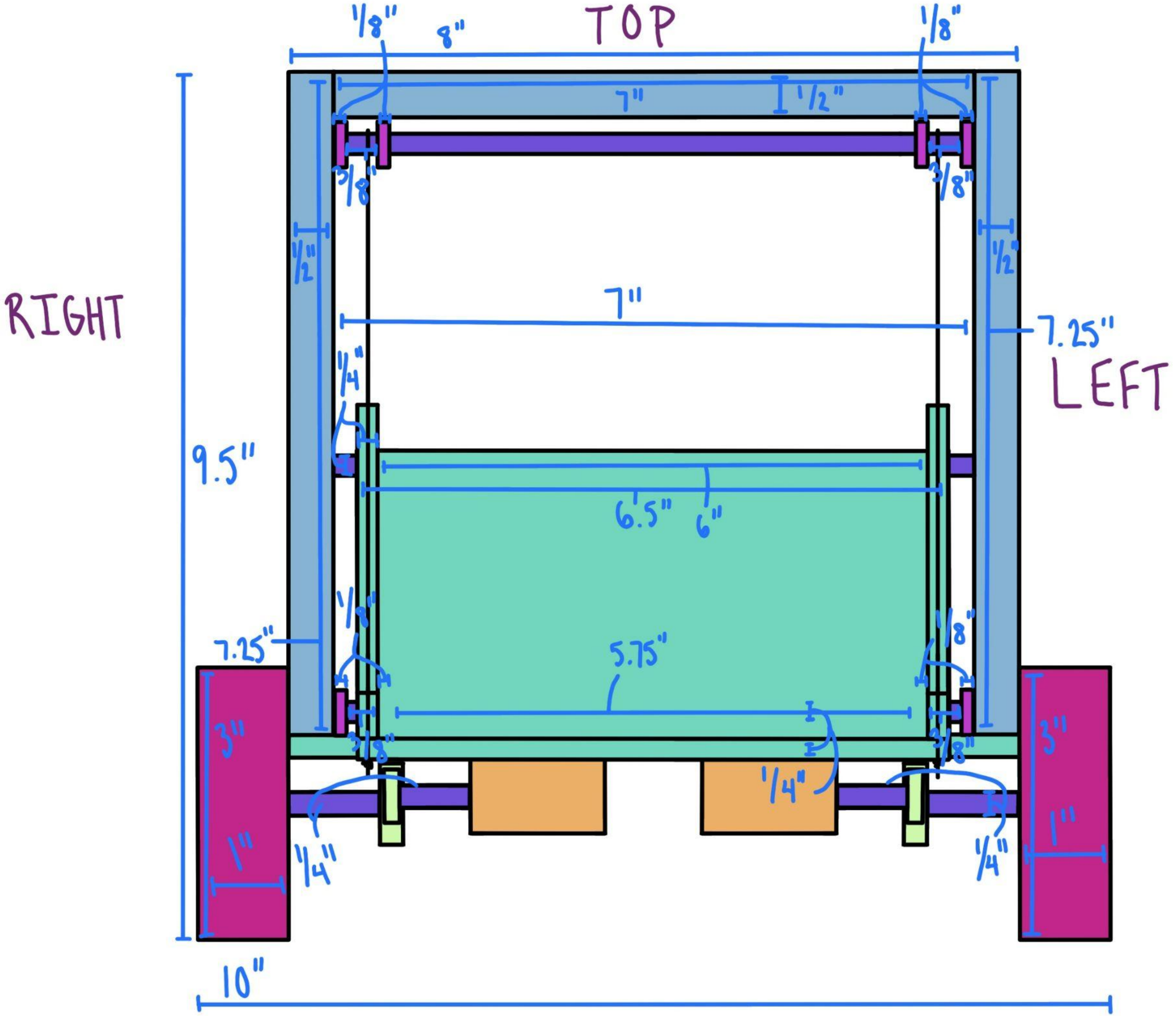
More RMP Final Concept Sketches:

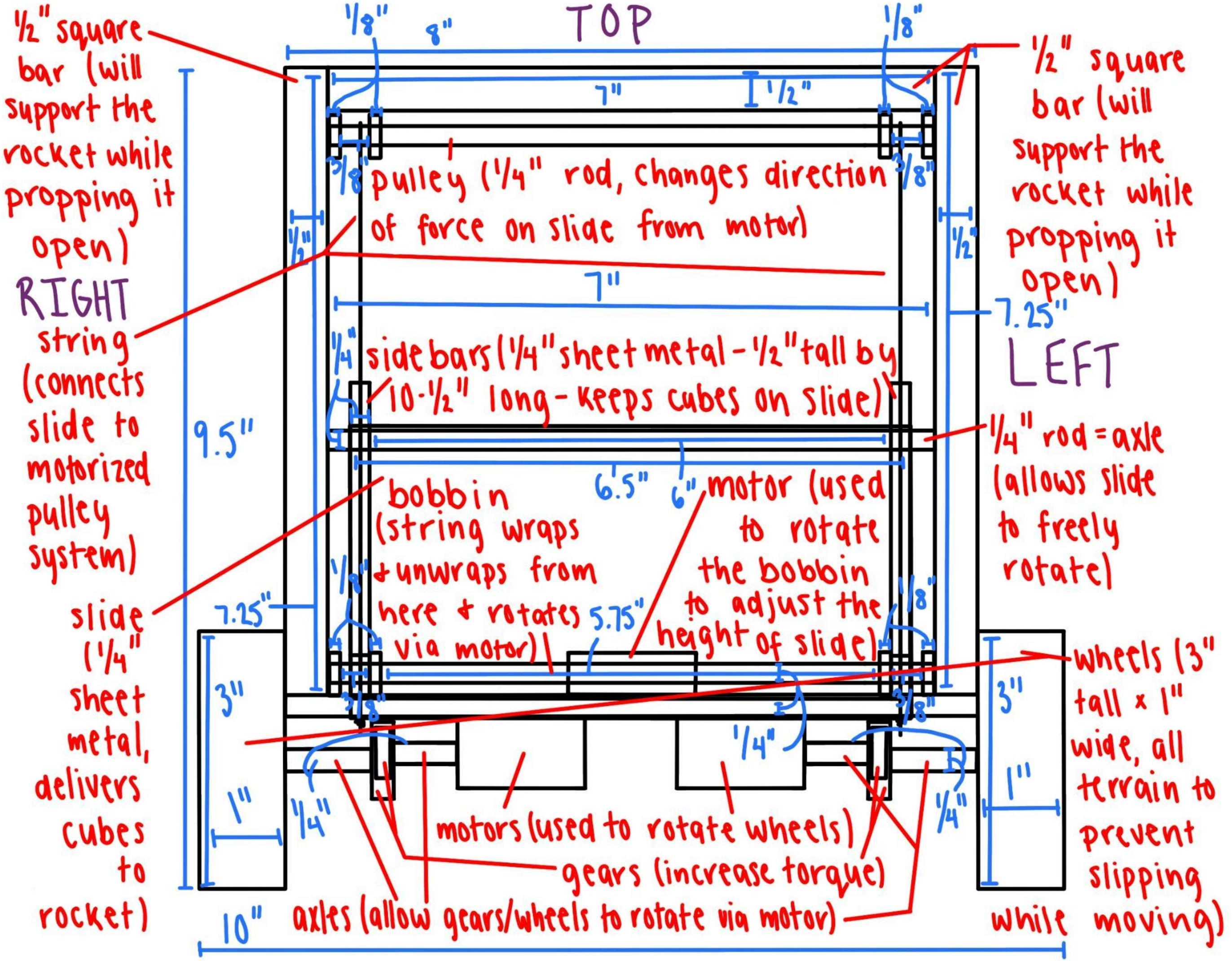



9"
TOP
½" square bar (will support the rocket while propping it open)
½"
pulley (¼" rod, changes direction of force on slide from motor)
¼"
½" square bar (will support the rocket while propping it open)
sidebar (¼" sheet metal - ½" tall by 10-½" long - keeps cubes on slide)
7.5"
BACK
FRONT
string (connects slide to motorized pulley system)
½"
motor (used to rotate the bobbin to increase or decrease the height of slide)
10.5"
¼" rod = axle (allows slide to freely rotate)
¼"
slide (¼" sheet metal, delivers cubes to rocket)
½"
½"
¼"
¼"
¼"
¼"
½"
½"
1.75"
1.75"
3"
bobbin (string wraps/unwraps from here & rotates via motor)
motors (used to rotate wheels)
axles (allow gears/wheels to rotate via motor)
gears (increase torque)
wheels (3" tall x 1" wide, all terrain to prevent slipping while moving)

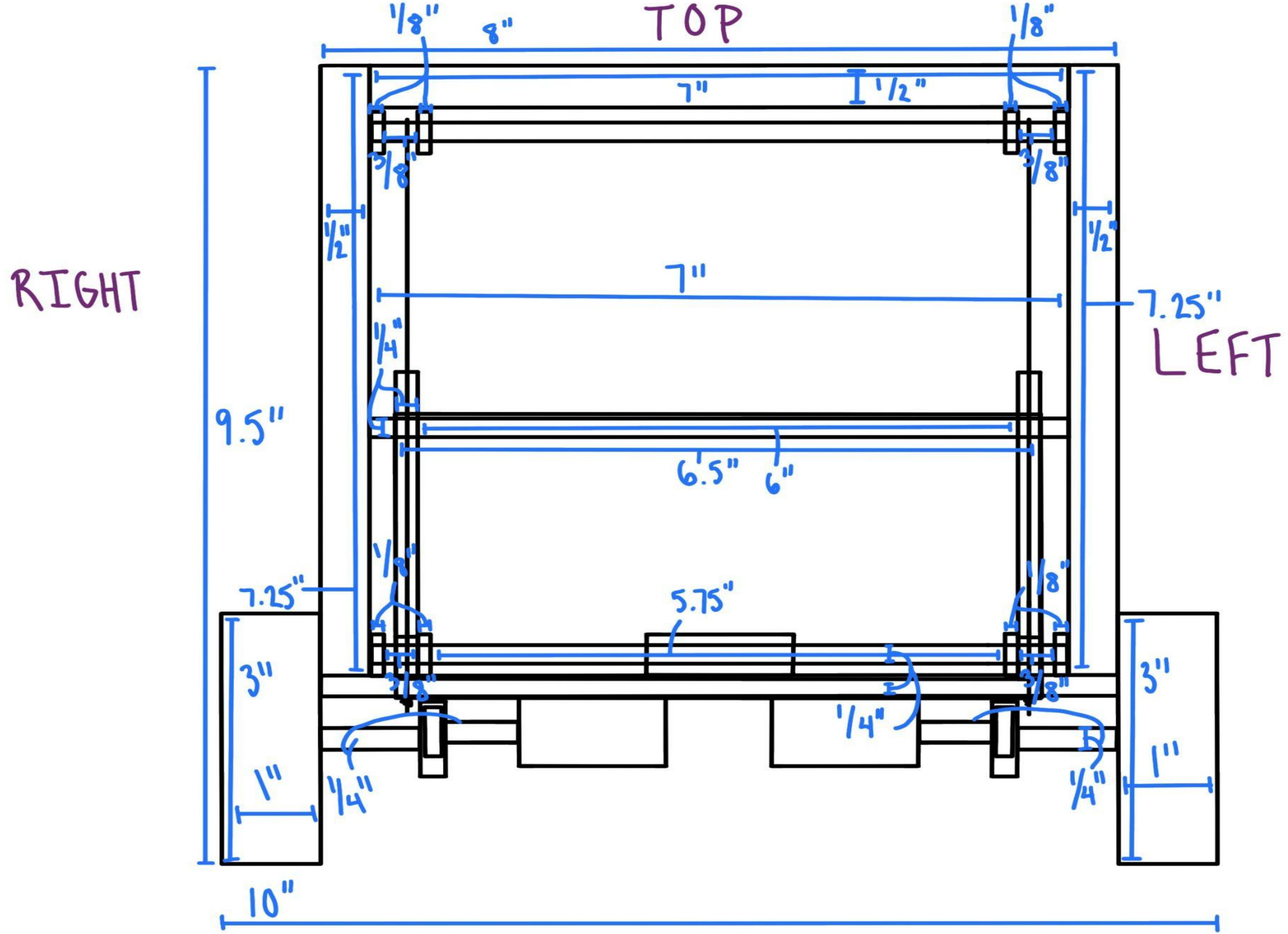


TOP
RIGHT
LEFT
1/2" square bar (will support the rocket while propping it open)
1/2" square bar (will support the rocket while propping it open)
1/8"
8"
1/8"
7"
1/2"
3/8"
3/8"
pulley (1/4" rod, changes direction of force on slide from motor)
1/2"
1/2"
7"
7.25"
string (connects slide to motorized pulley system)
1/4"
side bars (1/4" sheet metal - 1/2" tall by 10-1/2" long - keeps cubes on slide)
1/4" rod = axle (allows slide to freely rotate)
9.5"
6.5"
6"
bobbin (string wraps + unwraps from here + rotates via motor)
motor (used to rotate the bobbin to adjust the height of slide)
1/8"
1/8"
7.25"
5.75"
slide (1/4" sheet metal, delivers cubes to rocket)
wheels (3" tall x 1" wide, all terrain to prevent slipping while moving)
3"
3"
3/8"
3/8"
1/4"
1"
1"
1/4"
1/4"
motors (used to rotate wheels)
gears (increase torque)
axles (allow gears/wheels to rotate via motor)
10"

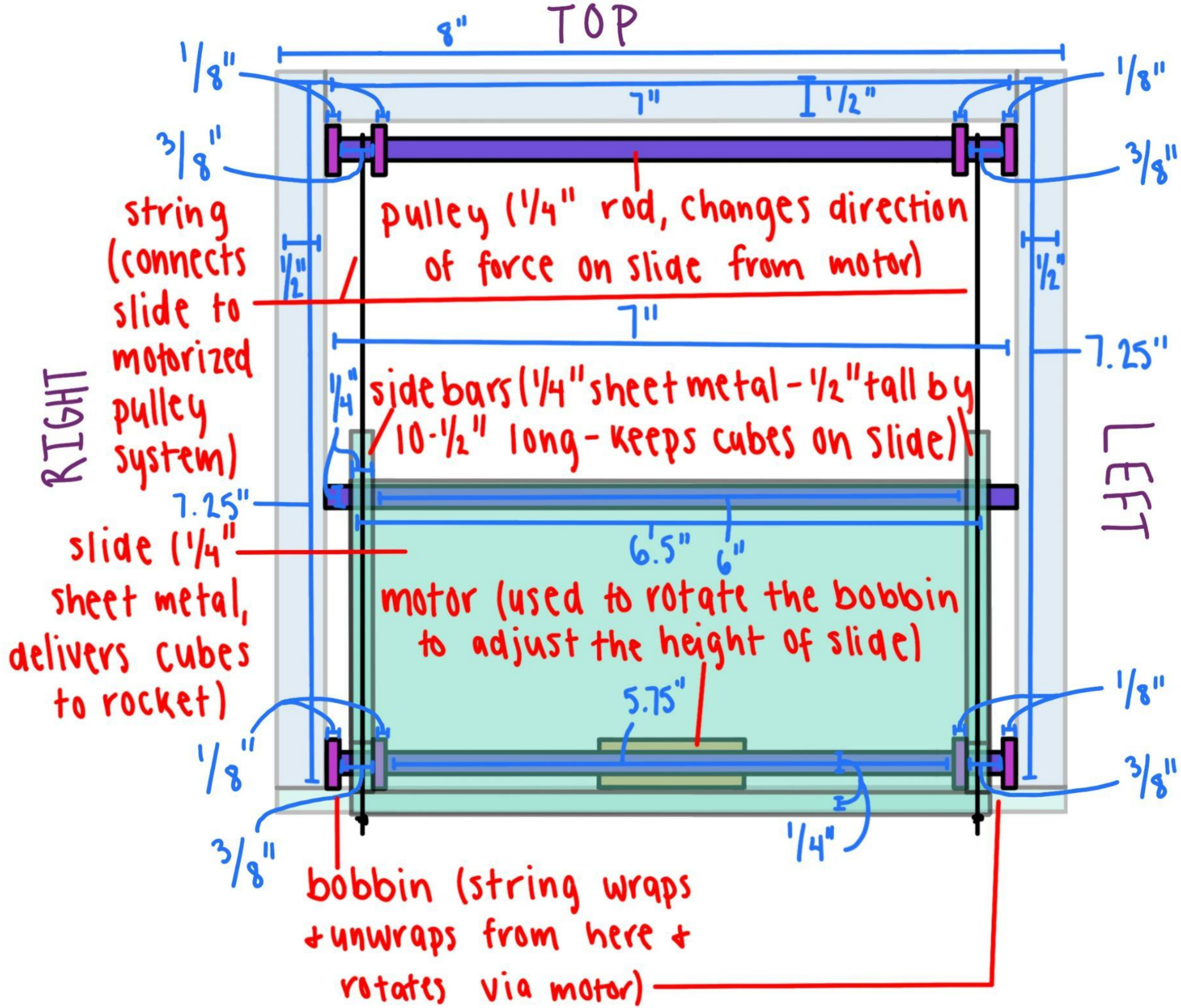

TOP
RIGHT
LEFT
1/8"
8"
1/8"
7"
1/2"
3/8"
3/8"
1/2"
1/2"
7"
7.25"
1/4"
9.5"
6.5"
6"
1/8"
1/8"
7.25"
5.75"
3/8"
3/8"
3"
3"
1/4"
1/4"
1/4"
1"
1"
10"

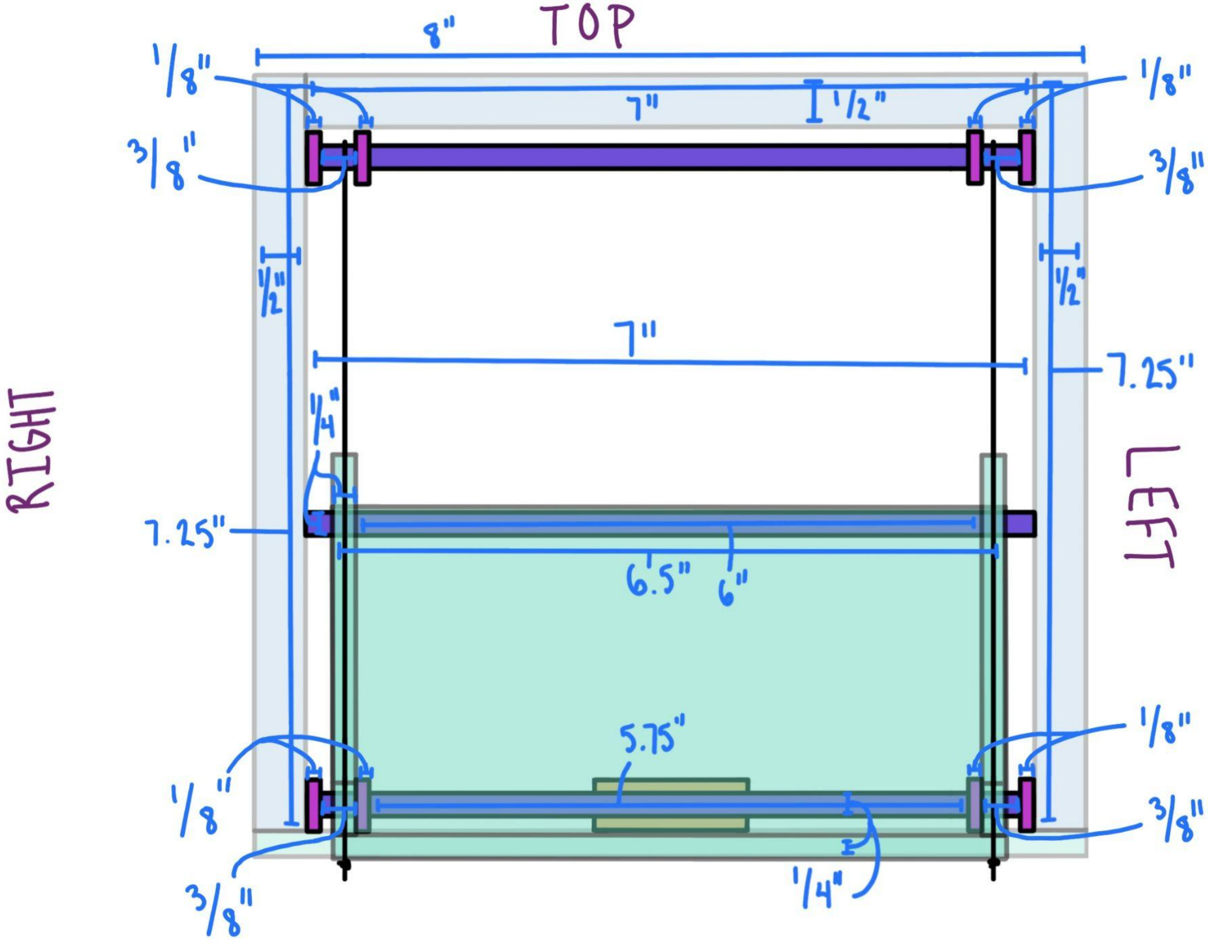


TOP
1/8"
8"
1/8"
1/2" square bar (will support the rocket while propping it open)
1/2" square bar (will support the rocket while propping it open)
7"
1/2"
3/8"
3/8"
pulley (1/4" rod, changes direction of force on slide from motor)
1/2"
1/2"
RIGHT
7"
7.25"
LEFT
string (connects slide to motorized pulley system)
1/4"
side bars (1/4" sheet metal - 1/2" tall by 10-1/2" long - keeps cubes on slide)
1/4" rod = axle (allows slide to freely rotate)
9.5"
6.5"
6"
bobbin (string wraps & unwraps from here & rotates via motor)
motor (used to rotate the bobbin to adjust the height of slide)
1/8"
1/8"
7.25"
5.75"
slide (1/4" sheet metal, delivers cubes to rocket)
wheels (3" tall x 1" wide, all terrain to prevent slipping while moving)
3"
3"
3/8"
3/8"
1/4"
1"
1"
1/4"
1/4"
motors (used to rotate wheels)
gears (increase torque)
axles (allow gears/wheels to rotate via motor)
10"

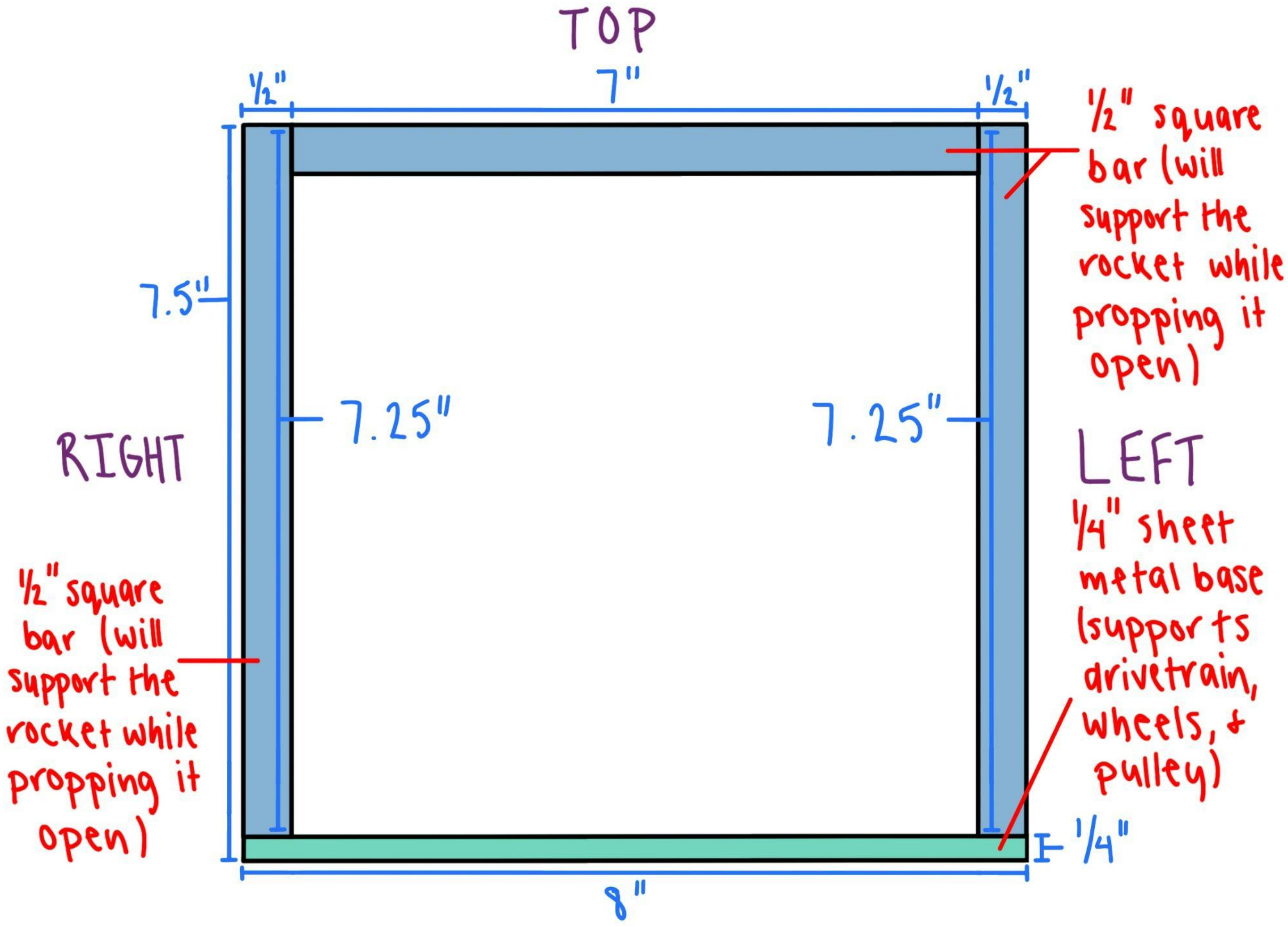


TOP
RIGHT
LEFT
1/8"
8"
1/8"
7"
1/2"
3/8"
3/8"
1/2"
1/2"
7"
7.25"
1/4"
9.5"
6.5"
6"
1/8"
1/8"
7.25"
5.75"
3"
3/8"
3/8"
3"
1/4"
1/4"
1"
1"
1/4"
1/4"
10"

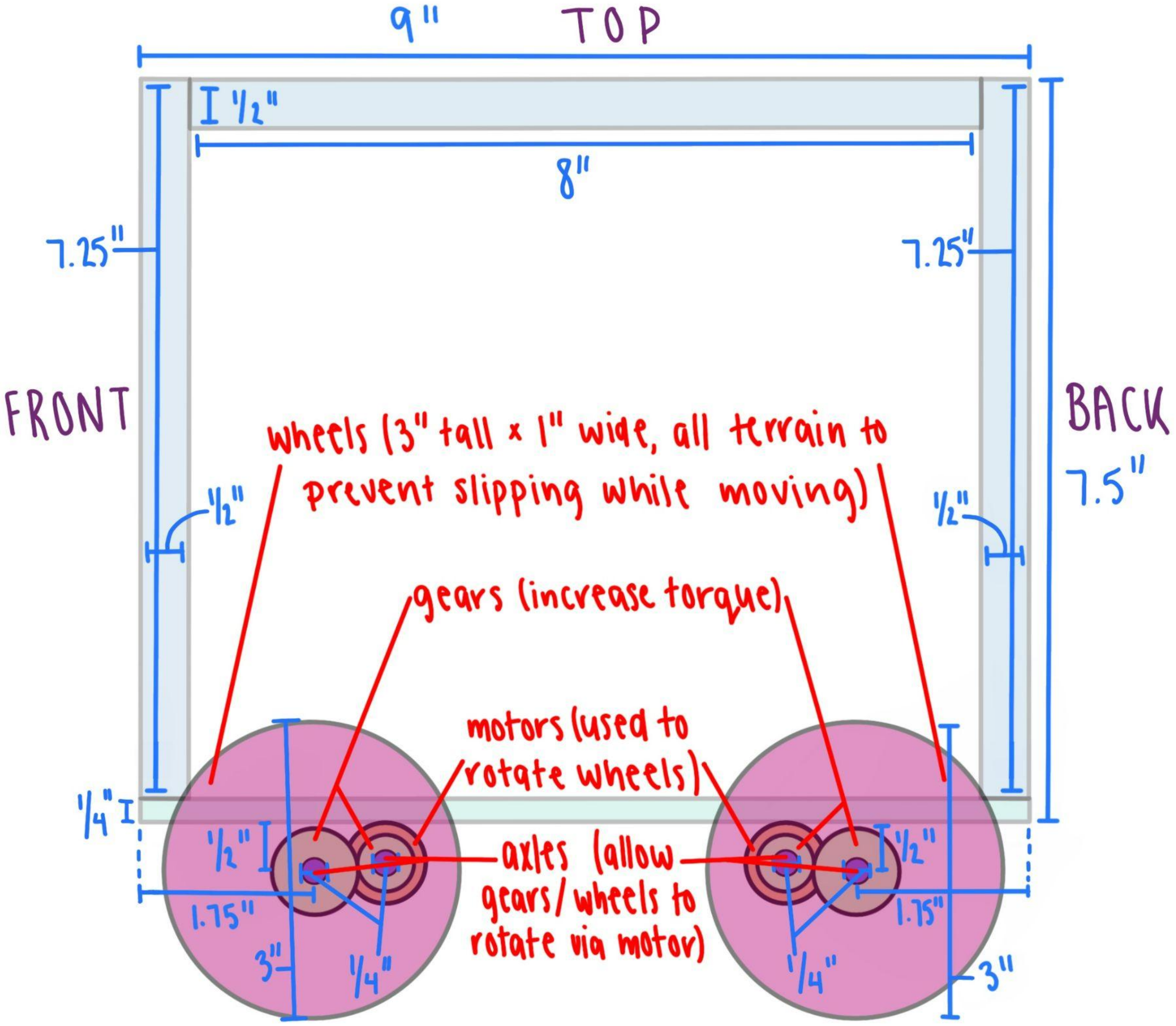

TOP
8"
1/8"
1/8"
7"
1/2"
3/8"
3/8"
pulley (1/4" rod, changes direction of force on slide from motor)
string (connects slide to motorized pulley system)
1/2"
1/2"
7"
7.25"
RIGHT
LEFT
1/4"
side bars (1/4" sheet metal - 1/2" tall by 10-1/2" long - keeps cubes on slide)
7.25"
6.5"
6"
slide (1/4" sheet metal, delivers cubes to rocket)
motor (used to rotate the bobbin to adjust the height of slide)
5.75"
1/8"
1/8"
3/8"
3/8"
1/4"
bobbin (string wraps + unwraps from here + rotates via motor)



TOP
8"
1/8"
1/8"
7"
1/2"
3/8"
3/8"
1/2"
1/2"
7"
7.25"
RIGHT
LEFT
1/4"
7.25"
6.5"
6"
5.75"
1/8"
1/8"
3/8"
3/8"
1/4"



TOP
½"
7"
½"
½" square bar (will support the rocket while propping it open)
7.5"
7.25"
7.25"
RIGHT
LEFT
¼" sheet metal base (supports drivetrain, wheels, & pulley)
½" square bar (will support the rocket while propping it open)
¼"
8"



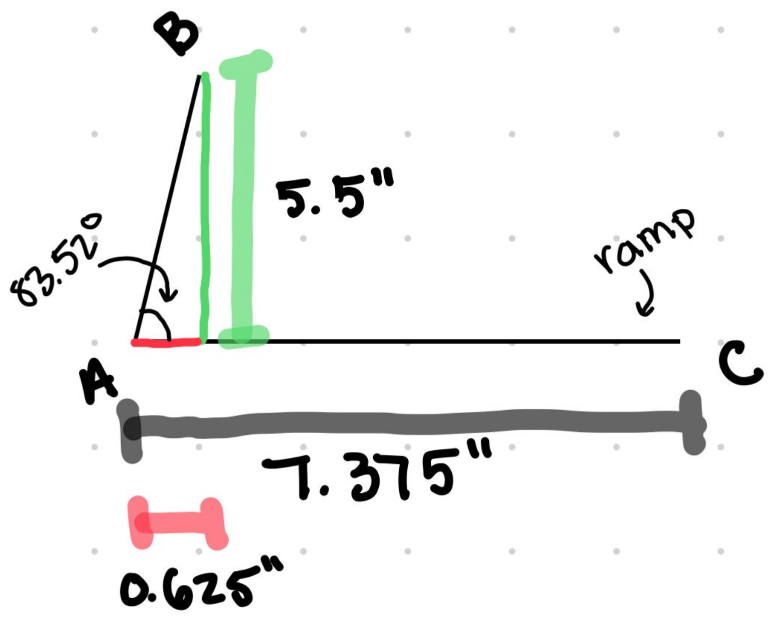
TOP
9"
1/2"
8"
7.25"
7.25"
FRONT
BACK
7.5"
wheels (3" tall x 1" wide, all terrain to prevent slipping while moving)
1/2"
1/2"
gears (increase torque)
motors (used to rotate wheels)
1/4"
1/2"
1/2"
axles (allow gears/wheels to rotate via motor)
1.75"
1.75"
3"
1/4"
1/4"
3"

Empirical Testing Data

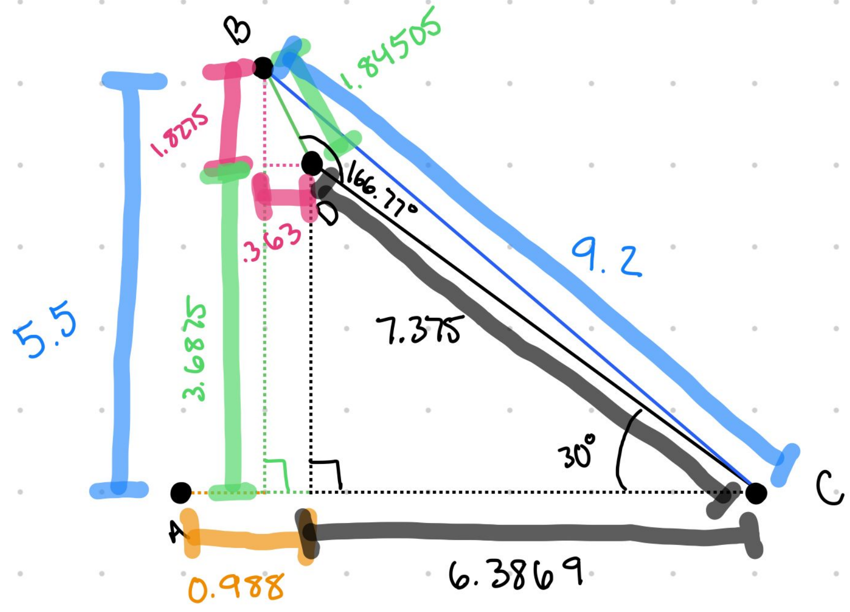
Material	Delrin			Acrylic			1/16 in Sheet Metal		
Angle	**20 degrees**	**30 degrees**	**40 degrees**	**30 degrees**	**40 degrees**	**50 degrees**	**30 degrees**	**40 degrees**	**50 degrees**
Trial 1	0.93	0.33	0.15	5.35	0.35	0.18	0.43	0.25	0.16
Trial 2	1.37	0.2	0.12	0.57	0.24	0.17	0.31	0.29	0.17
Trial 3	0.68	0.26	0.15	0.64	0.19	0.16	0.45	0.25	0.17
Trial 4	1.34	0.21	0.13	0.57	0.23	0.2	0.3	0.17	0.17
Trial 5	0.61	0.3	0.16	0.38	0.2	0.19	0.33	0.19	0.15
Trial 6	1.01	0.28	0.17	0.48	0.31	0.21	0.43	0.17	0.11
Trial 7	0.61	0.29	0.13	0.61	0.34	0.23	0.34	0.25	0.13
Trial 8	1.26	0.3	0.14	0.48	0.22	0.21	0.4	0.27	0.15
Trial 9	0.59	0.25	0.16	0.46	0.28	0.15	0.37	0.2	0.16
Trial 10	0.93	0.32	0.14	1.05	0.25	0.16	0.37	0.19	0.13

First Principles Analysis: Incline Torque Requirement

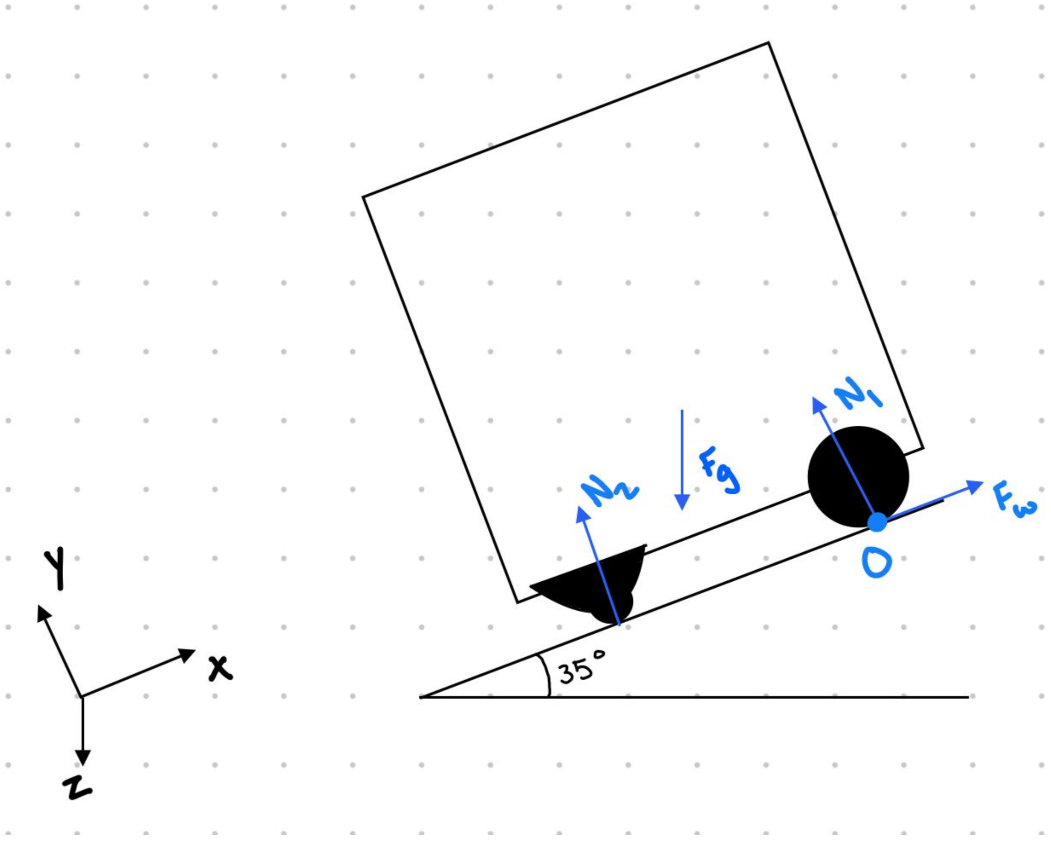
State 1:



State 2:



First Principles Analysis: Incline Torque Requirement



Metal Motor Analysis

Gear Ratio(@98.78)	Theoretical Torque Output(oz*in)	Angular Speed(RPM)	Angular Speed(Rad/s)	Linear Speed(IN/S)
1	210	99	10.362	0.8154894
0.2	42	495	51.81	4.077447
0.25	52.5	396	41.448	3.2619576
0.33	69.3	300	31.4	2.47118
0.5	105	198	20.724	1.6309788
2	420	49.5	5.181	0.4077447
3	630	33	3.454	0.2718298
4	840	24.75	2.5905	0.20387235
5	1050	19.8	2.0724	0.16309788

$$T = 1.7067\, lb$$

$$T_{out} = 1.7067(0.25) = 0.4267\,\mathrm{lb}\cdot\mathrm{in}{=}6.827\ \mathrm{oz}\cdot\mathrm{in}$$

Double Gearbox Motor Analysis

Gear Ratio	Torque Output(oz*in)	Angular Speed(RPM)	Angular Speed(Rad/s)	Linear Speed(IN/S)
12.7	1.27	968.503937	101.3700787	5.990971654
38	3.8	323.6842105	33.87894737	2.002245789
115	11.5	106.9565217	11.19478261	0.6616116522
344	34.4	35.75581395	3.74244186	0.221178314

$T = 1.7067\,lb$

$T_{out} = 1.7067(0.25) = 0.4267\,\mathrm{lb} \cdot \mathrm{in} = 6.827\ \mathrm{oz} \cdot \mathrm{in}$

Planetary Motor Analysis

Gear Ratio	Torque Output(oz*in)	Angular Speed(RPM)	Angular Speed(Rad/s)	Linear Speed(IN/S)
4	0.96	1700	177.9333333	14.00335333
5	1.2	1360	142.3466667	11.20268267
16	3.84	425	44.48333333	3.500838333
20	4.8	340	35.58666667	2.800670667
25	6	272	28.46933333	2.240536533
80	19.2	85	8.896666667	0.7001676667
100	24	68	7.117333333	0.5601341333
400	96	17	1.779333333	0.1400335333

Motor and Wheel Assembly Closeup