ME 72 Design Notebook

Anya Mischel

Team Pharaobots

Other team members: Daniel, Ana, Hannah, Miina, Lily, Sophia

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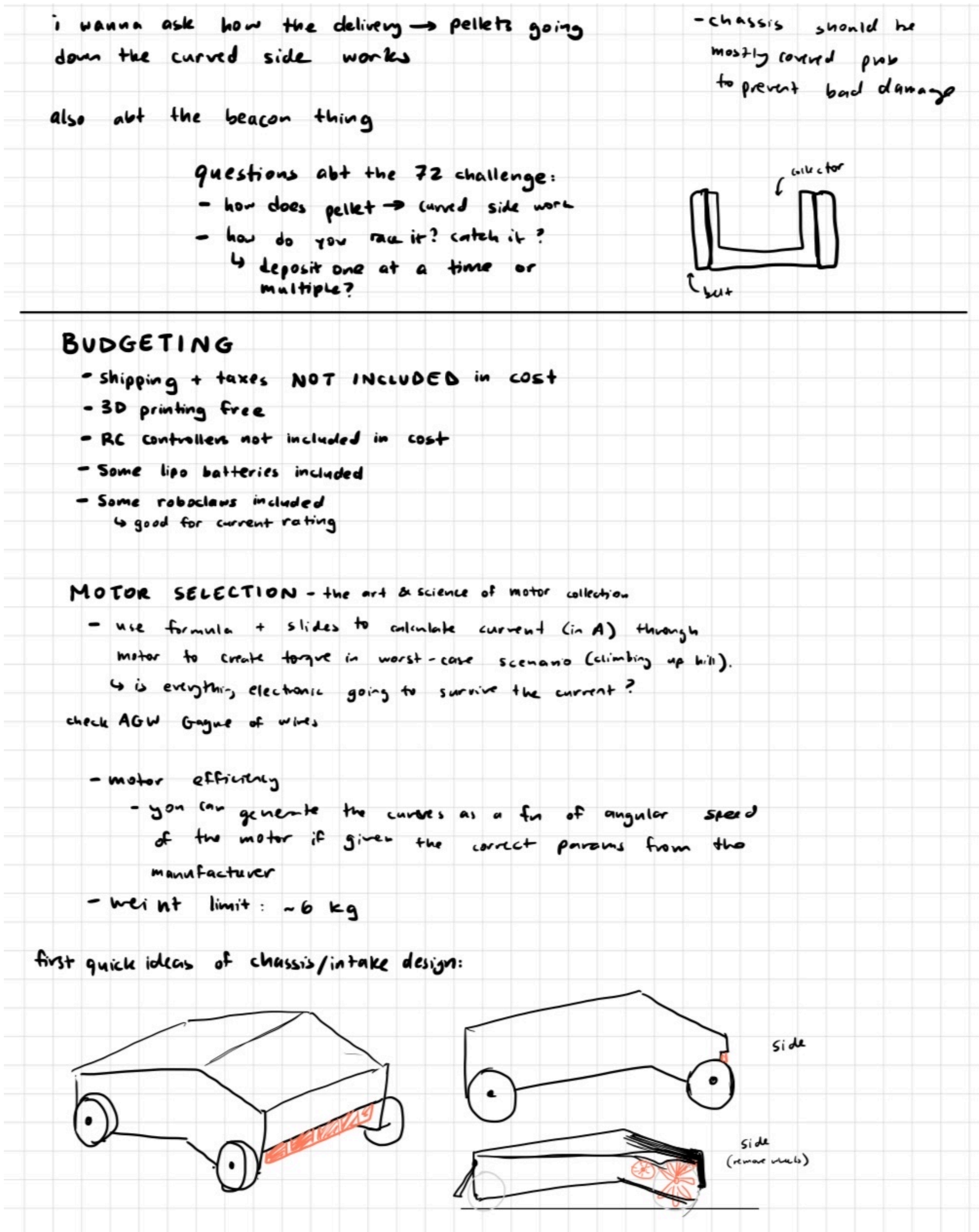
9/30 - First ME 72 class

On the first day of class, the competition details were released and I took notes on the competition. These notes are below.



i wanna ask how the delivery → pellets going down the curved side works

also abt the beacon thing

- chassis should be mostly covered prob to prevent bad damage

questions abt the 72 challenge:
- how does pellet → curved side work
- how do you race it? catch it?
  - ↳ deposit one at a time or multiple?

BUDGETING
- shipping + taxes NOT INCLUDED in cost
- 3D printing free
- RC controllers not included in cost
- Some lipo batteries included
- Some roboclaws included
  - ↳ good for current rating

MOTOR SELECTION - the art & science of motor collection
- use formula + slides to calculate current (in A) through motor to create torque in worst-case scenario (climbing up hill).
  - ↳ is everything electronic going to survive the current?

check AGW Gague of wires

- motor efficiency
  - you can generate the curves as a fn of angular speed of the motor if given the correct params from the manufacturer
- weight limit: ~6 kg

first quick ideas of chassis/intake design:

10/5 - First group meeting

In our first meeting of the term, we tried to better understand the competition rules and went through the rules document together. We took notes on the competition document and began researching.

Meeting 1 (10/5/2025)

- Things to figure out:
    - How to divide the tasks between robots and how to optimize points?
        - Have one robot ‘focused’ on climbing
        - Have one robot ‘focused’ on being fast and picking up/collecting
    - What is the basic design of the robot we want to use (4 wheels/materials for frame/etc.) and how do we plan to turn?
    - How do we want to command the robot (ie. how do we tell it when to turn, speed up, etc.) – what controllers are involved?
    - How do we pick up the pellets?
    - Later on: machining plan and budget (how much extra budget space do we want to have?)?
    - Subdivide up the robot designing and making initial diagrams?
        - Ie. two people per robot figure out the materials and specific dimensions required for all parts
- Carwash intake mechanism
- <u>Calculations</u>
    - Calculate whether we bottom out the robot when going up the incline
    - Calculate how tall the robot needs to be to successfully get on top of pyramid.
- Should we get a robot that goes to the top and stays at the top restricting everyone else?
- Strategy thoughts:
    - Have a robot that zooms out and pushes the button to get the energy tax reduction
    - Task of most importance: being able to collect the pellets
-
- <u>PDR Content</u>
    - Robot 1:
        - Climber + Pusher - high torque
    - Robot 2:
        - Picker upper - low torque (fast) + autonomous
    - Robot 3:
        - Climber - intermediate torque
- Motor choice

10/5

- - 4 higher torque motors for climbing 37 degrees
  - 4 intermediate torque motors for 37 degrees
  - 4 intermediate/less torque motors for 1 in: 3in → 18 degrees
  - Conveyer belt and intake motors (1 for conveyer belt, 3 for intake)
- Wheel choice
  - Climber with grippier & bigger wheels
  - Smaller for others?
- Robot design
  - Intake mechanism
    - Wheels vs spindles
    - Intake motor
    - Free hanging vs pinned down
  - Flat base or tilted base (inverse pyramid)
  - convey belt + reservoir + dumping mechanism

- Main material
  - Structure materials
  - Shielding materials (protection)
- Conveyer belt
  - Motor
  - Belt material
    - A material that is able to grip the pellets → rubber?
  - dimensions
- Overview budget
- Rough schedule

TO DO:

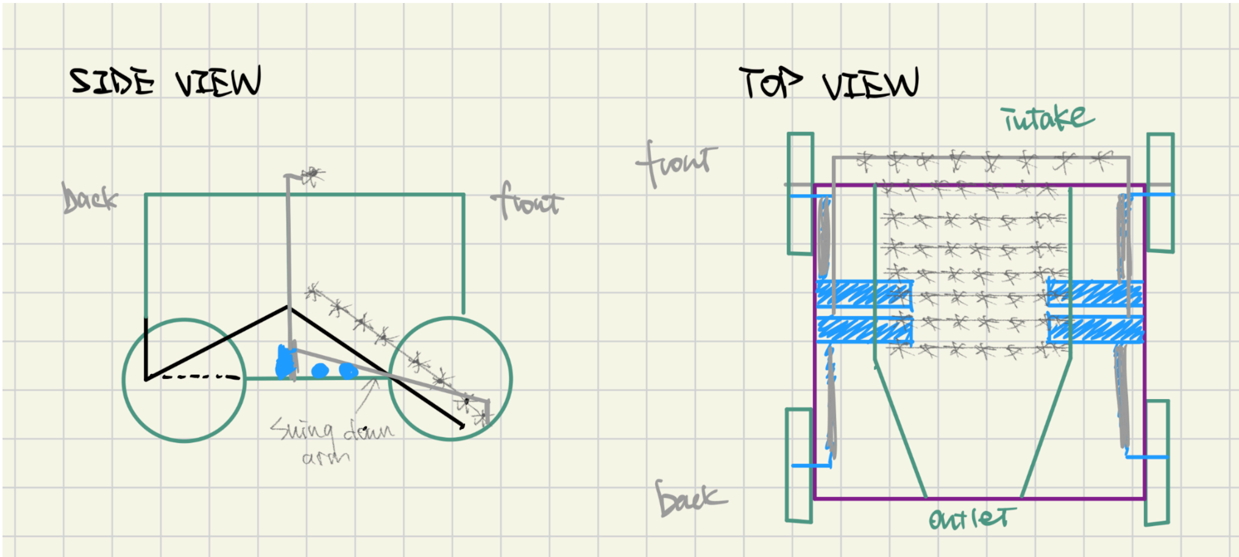
- [ ] Intake mechanism
  - [ ] Anya
  - [ ] hannah
- [ ] Motor Research
  - [ ] Miina
  - [ ] Daniel
- [ ] Wheels research
  - [ ] Lily
  - [ ] Ana

Link for intake video: https://www.youtube.com/watch?v=RCfMzZY3IC0

10/5

Another intake video: https://www.youtube.com/watch?v=QiQPEfmqbWU

Also kinda cool: https://www.youtube.com/shorts/dCKSPGX2xfg?feature=share



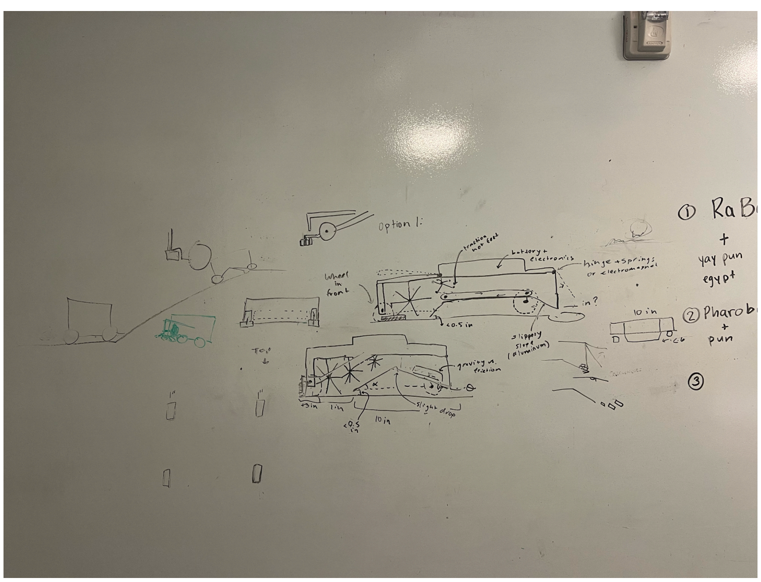
1 sq = 2 inches (to scale)

10/7 - First official design meeting

We had our first design meeting to discuss how we would approach the competition and start drawing out ideas on the whiteboard.

Meeting 2 (10/7/2025)

- Things to do:
  - Brief team goals and objectives discussion
  - Sign up for a PDR time
  - Sub-group briefs on research
  - Finalize intake mechanism design and major motor/wheel requirement estimations
  - Research about stabilizing the bottom of the robot to protect from clearance
  - Calculations for how fast we want to climb
    - 15.92s up the incline
  - Calculation for pushing force
  - Calculate the angle we need the ramp to be for gravity to do the work of putting pebbles down. Include weight of pebbles and friction force
- Notes on robot design
  - Wheel needs to be at front of the robot
  - Have spindles in the same plane as the robot front wheels?
  - Front plate goes in front of the
  - 15 - 20 lbs is a reasonable weight for the robot weight
  - Angled cuts for back of the robot to funnel into 6 in funnel size
  - Do we need



10/7
To Do

- ☐ Wheels:
  - ☐ Calculate the pushing force of wheels
  - ☐ Decide 3 in vs 3.5 in vs 4in
  - ☐ Wheel base design/chassi
    - ☐ **Anya and lily**
- ☐ Intake mechanism
  - ☐ Pro/cons for spindles or conveyer belt: decide
  - ☐ Space between spindles rotating and how many
  - ☐ Angled of intake ramp
    - ☐ **Anya and lily**
- ☐ Overall game strategy
  - ☐ **Daniel**
- ☐ Electronics
  - ☐ Control
  - ☐ Calculate battery (after motors)
    - ☐ **miina**
- ☐ Dumping Mechanism **(Hannah, Ana)**
  - ☐ Hinge motor/servo that can overpower the force of the magnets + weight of pellets
- ☐ General dimensions
  - ☐ Calculate the angle we need the ramp to be for gravity to do the work of putting pellets down. Include weight of pebbles and friction force **(hannah, ana)**
  - ☐ Calculate clearance from floor of front ramp (<0.5in)
  - ☐ Good to scale drawing of design - to make sure everything fits **(Hannah, ana)**
- ☐ Motors:
  - ☐ Wheel motor (decide which ones) (2 high torque one low torque)
  - ☐ Spindle motors (
  - ☐ Decide speed of other robot (Daniel - the fast one)
  - ☐ Will we use roboclaw (only brushed dc motors)? And how?
  - ☐ Costs

10/8 - Intake mechanism research

As our first task, Lily and I paired up to work on intake mechanism research. We compiled our notes into this google doc: https://docs.google.com/document/d/1jWoI_F_zL2oryKMQvdWf0PAvALD7GdXoBtbNfciabx0/edit?usp=sharing

Later, Hannah joined me and we continued the research. I also interviewed some of my friends that did the sumobots competition last year to ask about how their intake mechanism worked.

10/11 - Initial electronics requirements research

Ana and I did research on electronics requirements for the robots, as shown below. I interviewed one of my friends who led his electronics team last year to ask about how they designed their schematic.

Brain:

- Raspberry Pi or Arduino Mega for autonomous robot
- From ME129: Raspberry Pi 4 Model B
- Arduino Mega: robust and might be in lab
- Motor controller board – Roboclaw is provided for other two robots
- Each board drives 2 motors
- Another roboclaw controller for smaller motors

Sensors:

- IR Sensors - to help with line following
- Motor controller: regulates power from battery

Battery:

- The one from ME14. 14.8V

Power:

- Motor behavior

Battery → motor controller → motors, arduino, receiver
Remote controller → receiver → arduino → motor controller → motor
All motors need a source of power

Servo:

- For servo, you might not need a motor controller, but might need to step down the power
- Mosfet power distribution boards
- Controlled by Arduino

Extra Notes:

- Electrical tape and hot glue before competition

10/14 - Initial battery research

Daniel found a few possible battery options, which are shown below.
https://www.google.com/aclk?sa=L&ai=DChsSEwi1idS3rKWQAxVfPUQIHafmPFoYACICCAEQDRoCZHo&ae=2&aspm=1&co=1&ase=2&gclid=Cj0KCQjw6bfHBhDNARIsAIGsqLgP4lj1UGdHiURQYqcKoacmXgozB9K8XVHeNB72TjDzorES6I_-KOwaAubjEALw_wcB&cid=CAASN-Roq1IxGtkf_T1pMMn3o9YWi3WO3Ju3tZGbR1Uk1XRHIy7JNTR7FOE76GS0i-MUnfuwfs5SA6U&cce=2&category=acrcp_v1_35&sig=AOD64_007DILHH9CaAc0-UruSq8vM62YIA&ctype=5&q=&nis=4&ved=2ahUKEwi5g8-3rKWQAxViJEQIHbJIFgEQ9aACKAB6BAgFEFk&adurl=

$65
https://rcbattery.com/liperior-5000mah-6s-65c-22-2v-lipo-battery-with-ec5-plug.html?gad_source=4&gad_campaignid=12748770885&gbraid=0AAAACRJLSaNmWLm5eFkNtRnkTI6ua4xP&gclid=Cj0KCQjw6bfHBhDNARIsAIGsqLhmUV96yO3NOrt7MHU6ankq1qEgj-OrY3TW2JHCKuFXDMR21VXrSTwaAnO1EALw_wcB

We also took some notes on calculating peak current needs in our electronics document:

Considerations:

1. **Voltage requirements**
    - Climber robot
        - Driving motors
            - 24V DC rated voltage required for the motors, so **24 V** voltage for the entire 2x60 A roboclaw
        - Intake Motors
            - 12V rated voltage per intake motor (2 intake motors), **24 V total** if powered separately, **12 V total** if powered in parallel
        - Back Door Motor
            - **6V** operating voltage (max case)
        - Arduino MEGA
            - 7-12 V to power, let's say **12 V** to stay on the higher side
        - Roboclaw
            - Additional **5 V ? need more research**
        - **TOTAL VOLTAGE: 24 V**
    - Speedy robot
        - Driving motors
            - 24V DC rated voltage required for the motors, so **24 V** voltage for the entire 2x60 A roboclaw
        - Intake Motors
            -

10/14

        - 12V rated voltage per intake motor (2 intake motors), **24 V total** if powered separately, **12 V total** if powered in parallel
    - Back Door Motor
        - **6V** operating voltage (max case)
    - Arduino MEGA
        - 7-12 V to power, let's say **12 V** to stay on the higher side
    - **TOTAL VOLTAGE: 24 V**

2. **Continuous Current**
    - Climber robot
        - Driving Motors
            - <2.6 Amps rated current per motor, **10.4 A total**
        - Intake Motors
            - Rated Current: 0.6Amp, **1.2 A total**
        - Back Door Motor
            - Online says ~1.2 A for stall current, let's be on the safe side and assume **~1 A** required to run (worst case)
        - Arduino MEGA
            - **~ 5A???? Idk im confused**
        - **TOTAL CONTINUOUS CURRENT: 17.6 A**
    - Speedy robot
        - Driving Motors
            - <2.6 Amps rated current per motor, **10.4 A total**
        - Intake Motors
            - Rated Current: 0.6Amp, **1.2 A total**
        - Back Door Motor
            - Online says ~1.2 A for stall current, let's be on the safe side and assume **~1 A** required to run (worst case)
        - Arduino MEGA
            - **~ 5A???? Idk im confused**
        - **TOTAL CONTINUOUS CURRENT: 17.6 A**

3. **Peak Current**
    - Climber robot
        - Driving Motors
            - < 21 A
            - 21 A stall current each, but since all four motors are technically in parallel (in parallel for each roboclaw output, and each roboclaw output is in parallel), the **total stall current is 84 A**

10/14

    - Intake Motors
        - Stall current unknown (estimate 5 A), 2 of them = **10 A** total
    - Back Door Motor
        - Online forums say ~**1.2 A** stall current
    - Arduino MEGA
        - **~0.5 A** to run
    - **MAX/PEAK TOTAL CURRENT: 95.7 A**
- Speedy robot
    - Driving Motors
        - < 21 A
        - 21 A stall current each, but since all four motors are technically in parallel (in parallel for each roboclaw output, and each roboclaw output is in parallel), the **total stall current is 84 A**
    - Intake Motors
        - Stall current unknown (estimate 5 A), 2 of them = **10 A** total
    - Back Door Motor
        - Online forums say ~**1.2 A** stall current
    - Arduino MEGA
        - **~0.5 A** to run
    - **MAX/PEAK TOTAL CURRENT: 95.7 A**

4. **mAh:**
    - Assuming the robots are operating for the entire 4 mins 30 seconds (worst case)
        - Climber robot: 17600 mAh * (0.075 hours) = **1320 mAh**
        - Speedy robot: 17600 mAh * (0.075 hours) = **1320 mAh**

Battery Criteria:
Capacity ~5000 - 6500 mAh
Voltage ~ 22.2 - 24 V
Current > 100 A
C - rating > 15C - 20C (depending on capacity and current)

10/15 - Electronics research

Morning:

Today, we did research on batteries that we can use for the robot.

Batteries we can put in series:

- https://www.walmart.com/ip/2x-14-8V-6500mAh-4S-LiPo-Battery-XT90-for-Rc-Helicopter-Airplane-Boat-Car-Truck/17703465586?wmlspartner=wlpa&selectedSellerId=102820850
    - 14.8V 6500 mAh 4S Lipo
    - Pack of 2
    - $76.25
    - At least 1 of these in the shop
- https://www.amazon.com/Socokin-Connector-Airplane-Quadcopter-Helicopter/dp/B0FK9ZGKRH
    - 11.1V 5200 mAh 3S Lipo
    - Pack of 2
    - $46.74
    - At least 1 of these in the shop

Other considerations:

- https://hobbyking.com/en_us/turnigy-5000mah-6s-25c-long-lipo-pack.html?srsltid=AfmBOooLdtmz5p1dDvEEhAQ15UzicVfQXQ3i__5IttLzpGQpWwLRJeS6&utm_source=chatgpt.com

Expensive but high mAh

https://rcbattery.com/liperior-7000mah-6s-35c-22-2v-lipo-battery-with-ec5-plug-for-rc-planes-rc-helicopters-drones.html?gad_source=1&gad_campaignid=12748770885&gbraid=0AAAAACRJLSa7Iw_b25m3iNp3DYJSN5uCk&gclid=Cj0KCQjwjL3HBhCgARIsAPUg7a4N_I1OBn98hGXPG5jyzDfeyUYdsblbls-ME5uFvI9VINMnFhbnEaIaAoJbEALw_wcB

Night:

At night, we finalized our slides and practiced the presentation for the CDR tomorrow. We are generally pretty prepared and are under time, which is good.

10/19 - CDR planning

Today, we met for a long meeting to discuss what we needed to get done for the CDR. Our notes are below.

Meeting 6 (10/19) - CDR planning

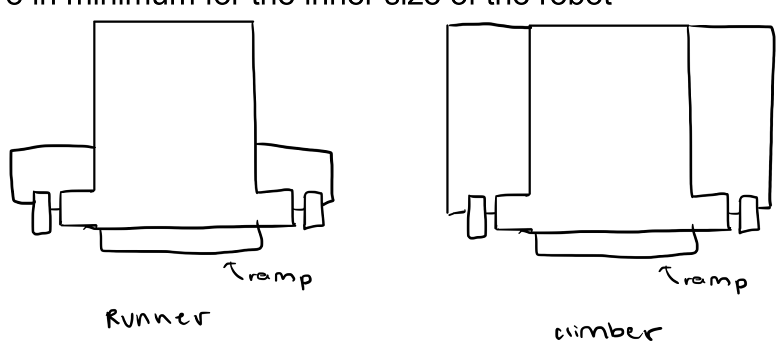
- CAD assembly
    - Assembly of drivetrain (the chain and motors and wheels)
        - Involves the inner walls and wall closest to the wheel
    - CAD the bottom plate with slots and how it will connect to ramp/inner walls
    - CAD the super outer protective walls → threaded rod structure
    - Assemble bottom plate to the inner walls
- GD & T
    - Inner wall
- Electronics wiring and more specific electronic calculations
    - Anya and daniel
- Deflection calculation for the chassis
    - Lily
- Magnets testing (jig design, holder)
    - Sophia
- The slip calculation (for incline running up and stopped on incline), necessity of magnets
    - lily
- Motor cooling (heat sinks, size, weight, etc)
    - Anya
- Plot angular speed vs. torque for motor
- Figure out how sorting of ECs vs pellets works in back storage of robot (not for cdr)

Meeting 6 (10/19) - CDR planning

- What Mello wants based on PDR notes:
    - The slip calculation for the robot when moving up the ramp and when stuck in one place on the ramp (in lecture notes)
        - https://caltech.instructure.com/courses/8785/files/1990768?module_item_id=341438
    - More information about the magnets we plan to use under the robot
        - How do we have clearance while also having magnets close to the surface?
        - We should consider redoing the magnet section of PDR – maybe having magnets on the wheels (the thin side of the magnet would need to have north/south)

10/19

  - compute and plot power versus angular speed (and torque) to estimate maximum power and efficiency
    - Remember that the maximum torque occurs at stall, which is not a sustainable operating point
    - Ensure your motors can provide adequate steady-state power for climbing.
  - Continue designing for fast assembly and disassembly to facilitate quick repairs.
  - Detailed Gantt chart??
  - More details on electrical wiring diagram
- From TA notes to clarify
  - Also confirm that planetary-geared motors and sprockets won't yield under torque?
  - Clarify in your CDR how you'll handle a motor that lacks an encoder and whether you plan to add one later.
  - Verify that Roboclaws can handle the current demand of your chosen motors.
    - I think we have this already…?
- What we need to still decide design-wise:
  - What material are we using for the side walls (acrylic, etc.)?
    - Aluminum
    - Have different front design for climbers or the speedy robot
    - Should start CAD from the inner walls of the robot to see how ramp is attaching and all other parts would attach
    - 8 in minimum for the inner size of the robot



  - Does the intake extend to the chassis bottom layer with motors or not (ie. are they one connected plate that goes upward)?
    - Have a long inner wall that reaches up to the top of the inclined
    - Find bearings for the spindle ½ inner diameter
    - Thick bottom plate to support all the parts being connected to it
    - Thick side plates to protect wheels connected through rods

10/19

- Do we want to adapt to longer spindles to take in the energy credits also? And this would mean an overall increase in size between the two inclined plates inside the robot to fit ecs also?
  - Yes spindle size is now 1.7 in radius
- Does our ramp need to reach even lower to pick up pellets 0.5 in vs 0.6 in?
- What belt mechanism are we using for the spindle connection (will this be located inside the gear train section of the robot)?
- Should we change out the gears to be less costly?

- What we need to CAD:
  Base visualization:

https://www.instructables.com/Designing-Our-FTC-Bot-2023-2024-1/

- The mounts for all the motors
- The chassis bottom layer
- The intake mechanism - motors, spindles, and their connection
- The smaller robot → how are we achieving the desired decrease in weight? (what do we plan to cut out)
- The dumping mechanism CAD
- What units are we doing CAD in?
- How do we split or not?

10/19

To do:

- Send next questions email
  - Anya
- Email petitioning for the battery (and to move cdr pleeease)
  - Daniel and Anya
  - Miina for section on motors
- Look for alternative motors that can be powered by 4S batteries
  - Sophia
- Slip calculations
- Magnet stuff, and calculation with strongest magnet
- Complete electronics schematic
  - Daniel and Anya
- Meet with Trent again for electronics
  - Daniel and Anya
- CAD inner chassis wall
- CAD back wall
- CAD motors and wheels
  - Miina
- Find bearings for spindle rod (1/2'')
  - Lily
- Cardboard model testing of clearances

10/21 - Writing battery and motor selection petitions

Daniel, Miina, and I worked on writing a battery proposal to use the 22.2 V battery over the 14.8 V battery from the shop in order to support more powerful motors following the battery requirement changes to the rules after the PDR. We drafted this proposal in the link below and emailed it to Professor Mello:
https://docs.google.com/document/d/1IQ8EBDHlxkhZlzci__ctgxOqehNm2OsuHXRj3hKdwwY/edit?tab=t.0

Professor Mello also asked for a table with our motor option specifications, so Daniel and I worked on this so that Prof. Mello could check our motor calculations. This table is below:

Climber Bot Integrated Gear Motor
https://www.robotshop.com/products/e-s-motor-36mm-diameter-high-torque-planetary-gear-motor-24v-440rpm?pr_prod_strat=e5_desc&pr_rec_id=2ae7d25cc&pr_rec_pid=7487499698337&pr_ref_pid=7487504318625&pr_seq=uniform

Spec	Value
Rated Voltage	24 V
No-Load Speed	440 RPM
No-Load Current	< 500 mA
Rated Speed	330 RPM
Rated Current	< 2.6 A
Rated Torque	21 kg-cm
Stall Torque	60 kg-cm
Stall Current	< 21 A
Gear Ratio	1:27

Speedy Bot Integrated Gear Motor
https://www.robotshop.com/products/e-s-motor-36mm-diameter-high-torque-planetary-gear-motor-24v-90rpm?qd=6c7f8dec114b652a6858faa5e4322687

Spec	Value
Rated Voltage	24 V
No-load Speed	630 RPM
No-Load Current	< 500 mA

Rated Speed	490 RPM
Rated Current	< 2.6 A
Rated Torque	14 kg-cm
Stall Torque	50 kg-cm
Stall Current	< 21 A
Gear Ratio	1/19

10/22 - Battery calculations for CDR

The night before the CDR, I continued working on finalizing the calculations of the battery for the presentation and justified our choice of the battery and electronics. I created tables which made it easier to visualize the total current needed for all of our electronics, as shown below.

All Electronics Parts

Runner Robot

Part	Link	Quantity	Voltage needed	Current needed	Peak current	Total voltage	Total cont. current	Total pk. current
Driving Motor	https://www.robotshop.com/products/e-s-motor-42mm-dc-planetary-gear-motor-12v-315-rpm	4	12 V	~6 A	12 A	12 V	24 A	48 A
Backdoor Motor	https://www.jsumo.com/mg995-metal-gear-rc-servo-motor-towerpro	1	4.8-6 V	~0.4 A	~1.2 A	~5 V	0.4 A	1.2
Intake Motor	https://www.amazon.com/Greartisan-Electric-Reduction-Centric-Diameter/dp/B072R5G5GR?th=1	2	12 V	0.5 A	Not listed	12 V	1 A	??
Receiver	https://www.amazon.com/GoolRC-FS-iA6B-Receiver-Compatible-Transmitter/dp/B07XJWDMFX?th=1	1	4.0-6.5 V	~0.5 A (not listed)	Not listed	~5 V	~0.5 A	--
Arduino MEGA	https://docs.arduino.cc/hardware/mega-2560/#tech-specs	1	5 V	0.05 - 0.07 A (depends on what is run, probably want to recalculate more thoroughly later)	Not listed (depends on what is run, probably want to recalculate more thoroughly later)	5 V	0.07 A	--
Infrared sensor	https://www.digikey.com/en/products/detail/sunfounder/ST0050/22116814	3	3.3-5V	~0.01 A (not actually listed)	Not listed	3.3 - 5 V	~0.03 A	--
2x60 A Roboclaw	https://www.gobilda.com/roboclaw-2x60a-motor-controller/?setCurrencyId=1&sku=IMC414&gad_source=1&gad_campaignid=12299979486&gbraid=0AAAAAC78-tPIdWUYAyoAaF1Qh8Q4YA0qs&gclid=CjwKCAjwpOfHBhAxEiwAm1SwEu-3FXTkgZxeVK-AFWX-RZ6MmTzAYi64YOKH8KaoCeiv3rPAwWByLRoC0WgQAvD_BwE	1	-	-	-	Supplies additional 5 V voltage (source: Spec sheet from https://www.gobilda.com/roboclaw-2x60a-motor-controller/?setCurrencyId=1&sku=IMC414&gad_source=1&gad_campaignid=12299979486&gbraid=0AAAAAC78-tPIdWUYAyoAaF1Qh8Q4YA0qs&gclid=CjwKCAjwpOfHBhAxEiwAm1SwEu-3FXTkgZxeVK-AFWX-RZ6MmTzAYi64YOKH8KaoCeiv3rPAwWByLRoC0WgQAvD_BwE)	Supplies additional 3A current (source: Spec sheet from https://www.gobilda.com/roboclaw-2x60a-motor-controller/?setCurrencyId=1&sku=IMC414&gad_source=1&gad_campaignid=12299979486&gbraid=0AAAAAC78-tPIdWUYAyoAaF1Qh8Q4YA0qs&gclid=CjwKCAjwpOfHBhAxEiwAm1SwEu-3FXTkgZxeVK-AFWX-RZ6MmTzAYi64YOKH8KaoCeiv3rPAwWByLRoC0WgQAvD_BwE)	--

10/22

Climber Robot

Part	Link	Quantity	Voltage needed	Current needed	Peak current	Total voltage	Total cont. current	Total pk. current
Driving Motor	https://www.robotshop.com/products/e-s-motor-42mm-dc-planetary-gear-motor-12v-315-rpm	4	12 V	~6 A	12 A	12 V	24 A	48 A
Backdoor Motor	https://www.jsumo.com/mg995-metal-gear-rc-servo-motor-towerpro	1	4.8-6 V	~0.4 A	~1.2 A	~5 V	0.4 A	1.2 A
Intake Motor	https://www.amazon.com/Greartisan-Electric-Reduction-Centric-Diameter/dp/B072R5G5GR?th=1	2	12 V	0.5 A	Not listed	12 V	1 A	??
Receiver	https://www.amazon.com/GoolRC-FS-iA6B-Receiver-Compatible-Transmitter/dp/B07XJWDMFX?th=1	1	4.0-6.5 V	~0.5 A (not listed)	Not listed	~5 V	~0.5 A	--
Arduino MEGA	https://docs.arduino.cc/hardware/mega-2560/#tech-specs	1	5 V	0.05 - 0.07 A (depends on what is run, probably want to recalculate more thoroughly later)	Not listed (depends on what is run, probably want to recalculate more thoroughly later)	5 V	0.07 A	--
2x60 A Roboclaw	https://www.gobilda.com/roboclaw-2x60a-motor-controller/?setCurrencyId=1&sku=IMC414&gad_source=1&gad_campaignid=12299979486&gbraid=0AAAAAC78-tPIdWUYAyoAaF1Qh8Q4YA0qs&gclid=CjwKCAjwpOfHBhAxEiwAm1SwEu-3FXTkgZxeVK-AFWX-RZ6MmTzAYi64YOKH8KaoCeiv3rPAwWByLRoC0WgQAvD_BwE	1	-	-	-	Supplies additional 5 V voltage (source: Spec sheet from https://www.gobilda.com/roboclaw-2x60a-motor-controller/?setCurrencyId=1&sku=IMC414&gad_source=1&gad_campaignid=12299979486&gbraid=0AAAAAC78-tPIdWUYAyoAaF1Qh8Q4YA0qs&gclid=CjwKCAjwpOfHBhAxEiwAm1SwEu-3FXTkgZxeVK-AFWX-RZ6MmTzAYi64YOKH8KaoCeiv3rPAwWByLRoC0WgQAvD_BwE)	Supplies additional 3A current (source: Spec sheet from https://www.gobilda.com/roboclaw-2x60a-motor-controller/?setCurrencyId=1&sku=IMC414&gad_source=1&gad_campaignid=12299979486&gbraid=0AAAAAC78-tPIdWUYAyoAaF1Qh8Q4YA0qs&gclid=CjwKCAjwpOfHBhAxEiwAm1SwEu-3FXTkgZxeVK-AFWX-RZ6MmTzAYi64YOKH8KaoCeiv3rPAwWByLRoC0WgQAvD_BwE)	--

Final Battery Choice Comparison

Green = petitioned, most likely end up with Turnigy nano-tech

Battery	**Liperior 5000mAh**	**Liperior 5000mAh 6S**	**Turnigy nano-tech**
Voltage	7S	6S	4S
Capacity	5000mah	5000mah	2200mah
C-rating	65-130C	65-130C	25~50C
Dimensions	161 x 50 x 50mm	154 x 48 x 43mm	100x35x30mm
Weight	839g	695g	241g

The remainder of the details of the calculations for the battery are listed in the CDR powerpoint.

10/23 - CDR

Leading up to the CDR, I worked on finalizing the electronics schematic and formatting of the slide deck for the electronics section, as well as practicing my parts of the presentation. The presentation ended up going very well and some of the questions were helpful. Prof. Mello did not have time to respond to our battery petition before the CDR, but he provided feedback that we had done more than enough research into electronics to ensure that if we wanted to use the larger battery, he would let us. Following the CDR, I would like to improve the organization of our team by switching from a text group chat to a discord server so that we can organize our files and information through channels.

10/27 - Motor selection post-CDR

Following the CDR, we read through our feedback and discussed a bit about what design changes we needed to make. We agreed that there should be a front plate on the robot, as well as a bottom plate which provides increased structural stability. We also decided on the 12V 315RPM motors for the first robot due to the high torque and high velocity we expect it to provide. Although this puts an initial strain on our budget and will require us to change our drivetrain (among other reasons), we have cheaper motors that can specialize for high torque that can be bought for the second robot. We decided against the 24V motors for multiple reasons. If we wanted to run the motors at 24V, we would need to purchase new batteries which are not as frequently used in the shop. If we wanted to run 24V motors at 12V instead, the motors would lose significant performance making them the exact same as the cheaper alternative motors we plan to use in case of budgeting issues.

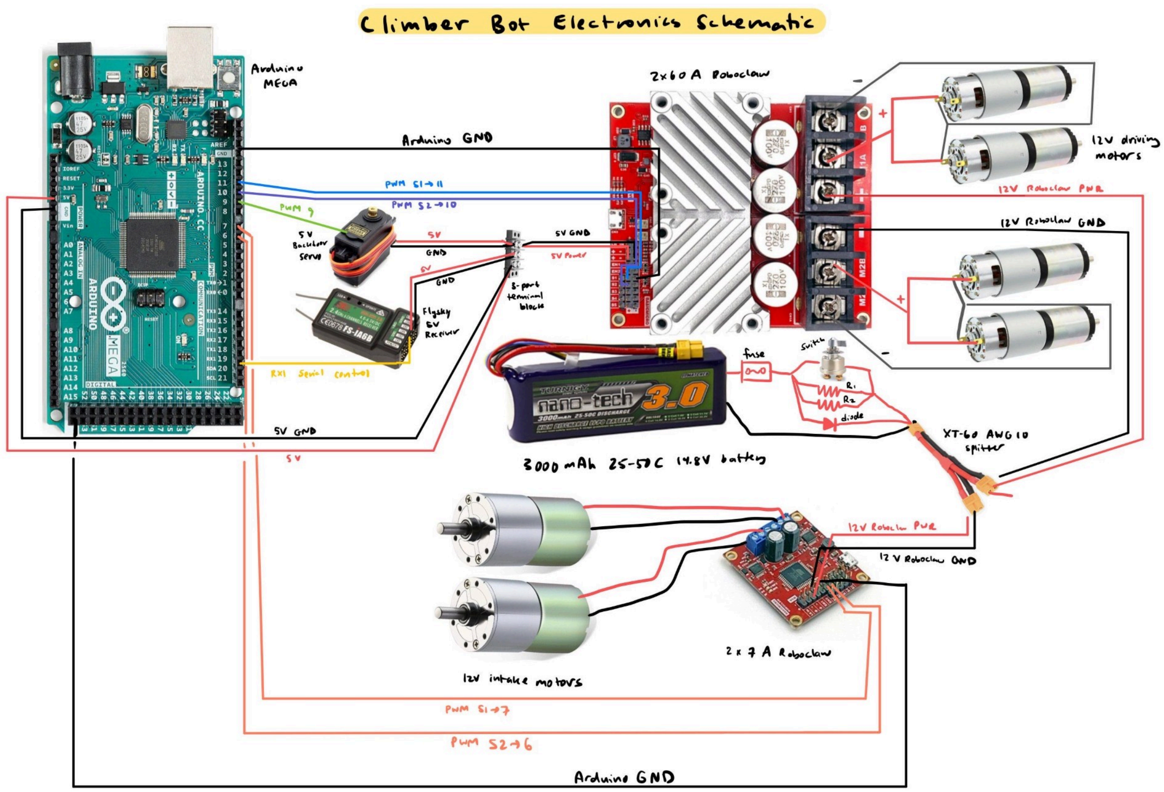
We also discussed cutting down the heights of the outside walls in order to cut the amount of aluminum (and thus cost) we need. We also decided to instead make the ramp and top plate 3D printed so that we can save cost on aluminum.

11/1 - Decided on L298 H-Bridge intake motor controller

Electronics todo:

- replace mosfets with motor controllers (free!)
- confirm 12 V manual switch choice
- confirm fuses
- confirm terminal ports
- go over schematic w david

We were able to find an LN298 H-Bridge in the shop, and have elected to use this instead of mosfets for the intake motors, since we will be able to control the speed of the motors, making it easier to test the intake mechanism and make changes where they are needed. We updated the electronics schematic to reflect these changes, as can be seen here:



Electronics schematic with H-bridge instead of mosfets.

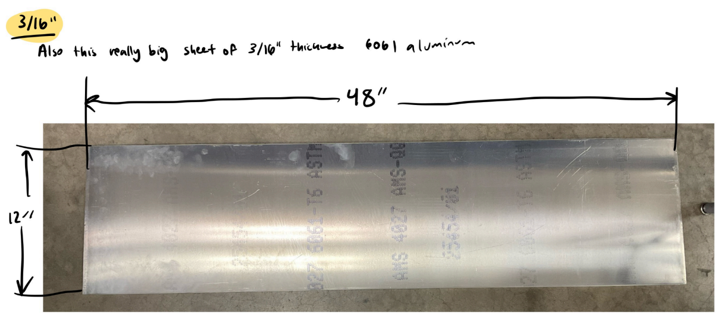
11/4 - Measuring aluminum sheets and resistor selection

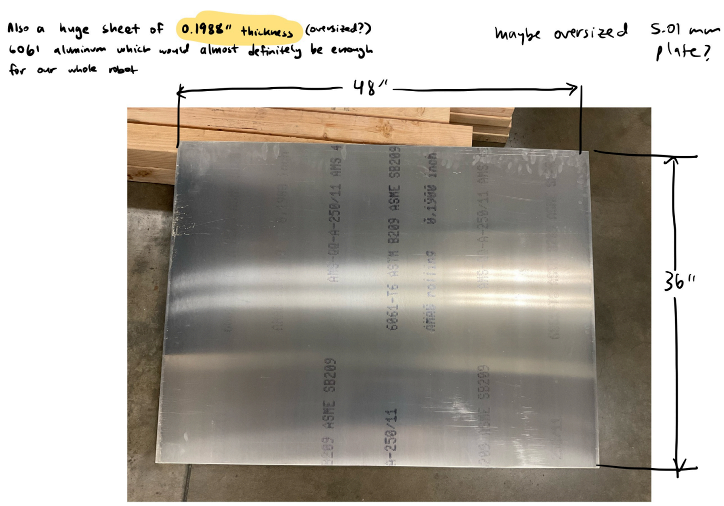
Before my morning class, I came into the shop to measure the dimensions of the available aluminum plates in the shop so that we can use the sheets of aluminum at half price. I plan to finish measuring the dimensions of the plate after class.

anya todo in shop after pe:

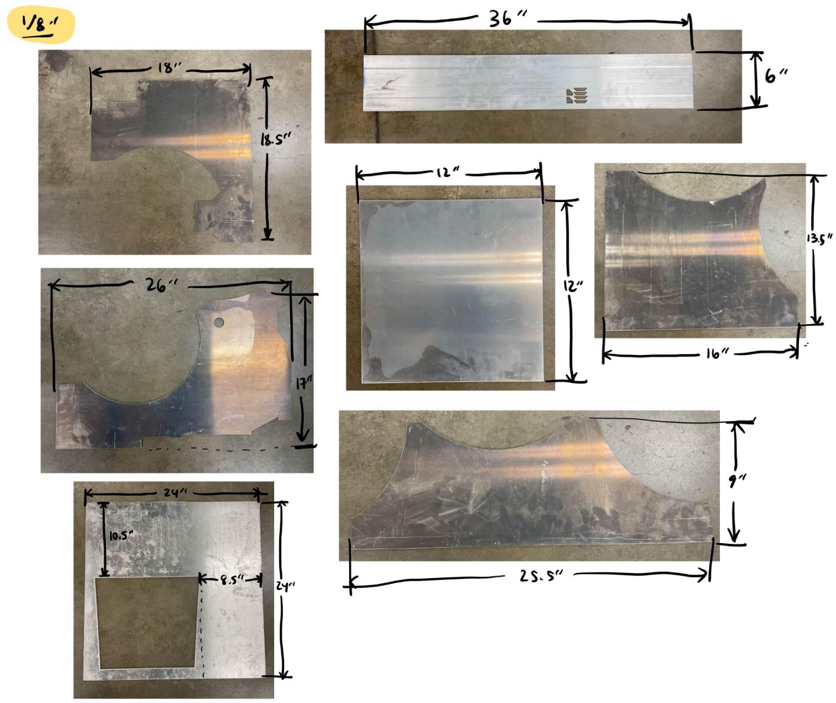
- measure aluminum extrusions
- measure 1/8" plate dimensions
- look for resistor for battery in shop
- look for the awg wire we need in shop
- put switchback and fuse diode on bom

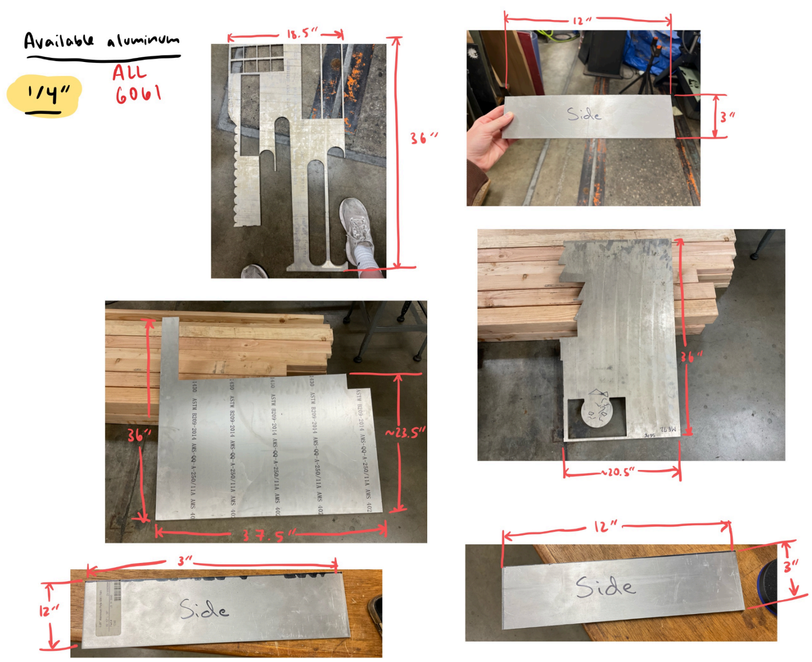
The dimensions of the plates are in the following pictures. I sent these to the manufacturing team so they can try to waterjet plates early before the available aluminum runs out.





11/4





Later in the afternoon, I came back in to figure out which resistors to use across the switch. In the roboclaw manual, the instructions were a bit confusing about how to pick the resistance and power ratings of the resistor. Daniel is going in later, so he will be asking Trent:

11/4

- why the placement of the diode is slightly different between the two diagrams
- how we are supposed to know the resistor specs since it lists it for a different voltage robotclaw

Daniel responded about the questions, and said:
1.) the wiring in the shop is free to take as we please, they have 12awg and 10awg
2.) Trent says 12awg seems reasonable for the 48amp peaks we expect from the motors, trent recommends silicon 12awg because better at higher temps
3.) The resistor will be different, he said it has something to do with the capacitor. He said the safe thing is to meet the resistor they have but we can likely get a way with a 1k, 1/4W resistor or maybe even two 2k, 1/4 in parallel.
4.) He said he isn't too sure on why the diode is in parallel vs in series with the resistor between the two manuals. His intuition is that it would be better to have the diode in series with the resistor but we can email him and he'll look into it for us, OR we can even email roboclaw themselves because apparently they are good at responding

I ended up going into the shop again and finding the resistors that are available for anyone to take. I talked to Trent about how to select one again, and found that power adds in parallel so 2 of the 2.2 kOhm resistors in parallel with have a total resistance of 1.1 kOhm and total power of 1/2 W, which is sufficient for our roboclaw.

TODO: priority (tonight)

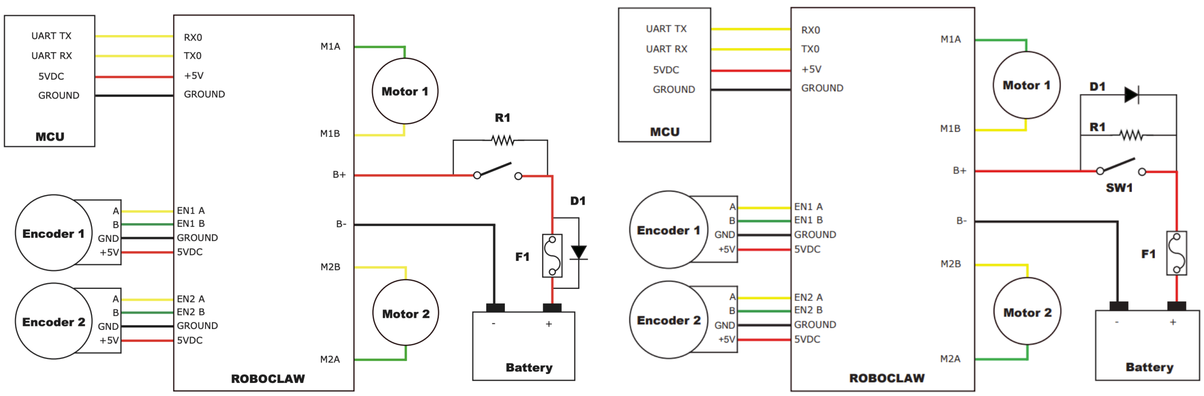
- reconsider 12 AWG now with the shorter wires bc of fear of melting and lighting machine shop on fire
- based on this decision, pick the fuse (consider the above FACT)
- ~~email trent above the above + roboclaw schematic difference questions (location of diode) + our updated schematic with the resistors, diode, switch. ask if we can possibly get the fuse paid for by the shop since everyone has the same battery~~

end of this week

- IF motors arrive, start working with motion studio and figure out how roboclaw interface works
- either way, research into how to map controls -> motor motion
- maybe start basic wiring with a breadboard and the arduino

11/5 - Sorting out Roboclaw manual discrepancy

We noticed a discrepancy in the two wiring diagrams between the Roboclaw manual for a 2x60 A roboclaw, which is what we are using, and the general user guide for all roboclaw user manuals. In the general Roboclaw manual, the diode is placed in series with the resistor. In the 2x60A Roboclaw manual, the diode is in parallel with the resistor. This is shown below.



Trent was also not sure, so he emailed the roboclaw company for us and confirmed that the fuse should be in series with the switch, while the resistor and diode should indeed be in parallel with the switch. This helped us confirm our electronics schematic and move forward with the wiring process.

11/7 - Researching RC Controller & Testing RC Controller

Yesterday, Daniel found a tutorial on the Flysky RC controller and how to wire the receiver and began taking notes in a separate Google doc. He used the following video to start a tutorial on RC controllers and plan out how we are going to start testing with the controller and receiver:
https://www.youtube.com/watch?v=BACBNgaCnJU&list=PLWNDWPAClRVoIZzsX-SkR5Br0_ZtRscxZ&index=12

To do:

- ~~anya download motion studio~~
- ~~anya download arduino~~
- ~~install libraries to read ibus and for motion studio code~~
- test motors manually in motion studio
- ~~connect rc controller to servo motors~~
- redo roboclaw tutorial from me 14
- ~~go through lipo safety document again~~
- charge the lipos we will be using
- ask trent for battery monitor for us to use/look in closet
- do some tests on the batteries we are using (checking capacity, etc.)
- from trents email decide fuse

Notes on RC controllers:

Helpful Video: RC Robot Car - RC Controls and Arduino - DroneBot Workshop
https://www.youtube.com/watch?v=BACBNgaCnJU&list=PLWNDWPAClRVoIZzsX-SkR5Br0_ZtRscxZ&index=9
Article based of video: Radio Control – Use the Flysky FS-I6X with Arduino & Build an RC Car
https://dronebotworkshop.com/radio-control-arduino-car/

RC control model: FS-i6x Flysky
User Manual: https://files.banggood.com/2016/09/FS-i6X%20User%20manual.pdf

Receiver model we NEED for iBUS Product Model: FS-iA6B
Specifications: https://www.flysky-cn.com/ia6b-canshu

Side notes:

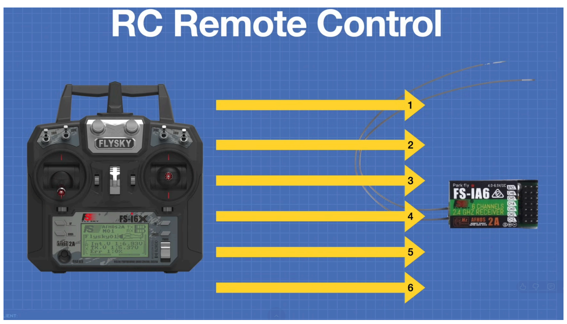
- Old units/models require unique channels/frequencies to avoid interference
- New units (that use 2.4Ghz) require line of site operation

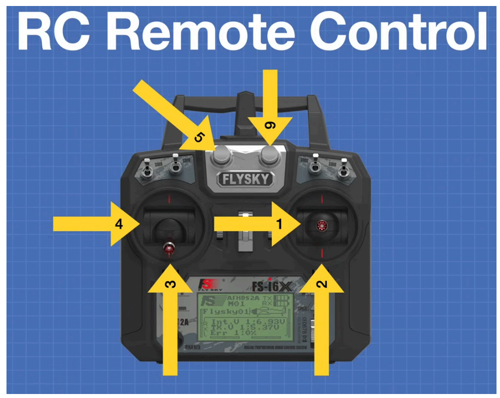
11/7

- If you’re using the Flysky FS-I6X, you will need to be sure that you power up the receiver AFTER the transmitter, this is true for many other RC Controllers as well. You’ll also need to have all the switches in the up position and the throttle control (left stick) down all the way. Both of these requirements are safety precautions to avoid an uncontrolled vehicle or one that starts with the motors running.

Controller Channels:

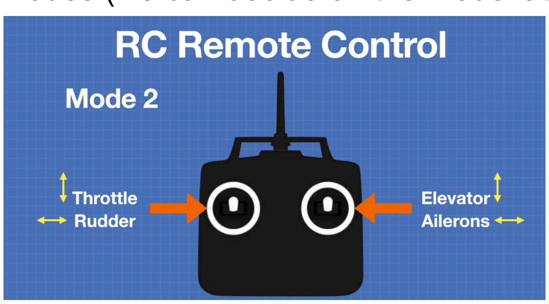
- 6 Channels, (video mentions that firmware update can possibly update the controller to have 10 channels but that would require a new receiver that has 10 outputs? Unsure how this works if we plan on using iBUS)





- Receiver has 6 3-pin outputs with PWM or PPM
- We should use iBUS serial output & input (already in wiring schematic) since iBUS will only require us to connect one wire making the setup cleaner. It is also apparently faster at communicating.
    - These outputs are at the top (two outputs out at the top)

Modes (we can decide on the mode later):



Basic mapping of controls (need to look at the manual)

- By default the 5th and 6th channels go to the pucks which seems useful for opening/closing or controlling the speeds of the back door motors as well as the intake motors. If we instead want to make it so that the backdoor motor only needs to turn on and off, we can map one of the switches (next to the pots) to that channel. The instructions for this are in the manual.

11/7

Wiring

- Can confirm that the wiring on the schematic is correct. iBUS DATA connected to -> 19 (RX1) on arduino.
- However, according to some sources online, you can connect both iBUS output and PMW channels at the SAME time.

Notes & Code: Roboclaw -> Motors (bypassing arduino)

- There's been increasing suggestions to ignore the arduino and connect/code directly in roboclaw/motion studio. While I argue that we should use the arduino in our final design (further research pending) this could be used for prototyping between the motors, roboclaw, and receiver/controller directly.

- Ultimately it seems that we will for sure need an arduino to be able to run the autonomous robot.

Possible tutorial here:
https://resources.basicmicro.com/roboclaw-rc-controlled-differential-drive-setup/

Notes & Code: Arduino -> Motors

- First download Arduino IDE & Basic Micro Motion Studio

SETUP

Within Arduino IDE:
- We require a library to read the ibus data and to interact with Roboclaw
    - IBusBM Library:
        - Go to Tools -> Manage Libraries -> download IBusBM
    - Roboclaw Arduino Library: link here
        - Download 2x60a Arduino Library and Examples from the link above
        - Go to Sketch -> Include Library -> Add .ZIP Library -> arduino.zip (what you should have downloaded)

Prototyping:

These initial tests will be to make sure we know what the fuck we are even doing. #1 seems pretty chill to do since we don't need the motors to be here so we can test it out with any battery?

1.) Test motors manually in motion studio (connect solely the motors and the roboclaw to a laptop?)

1.5) Test receiver by connecting to small servo motors directly

11/7

2.) Test that the RC controller is connected to the arduino using iBUS (just use RC and arduino) * NO MOTORS

3.) Test the motors directly from the RC controller (connect the motors to the roboclaw to the receiver, and link receiver to the controller)

n.) Test the entire set up without the intake and servos (connect the motors to the arduino to the roboclaw, to the receiver, to controller

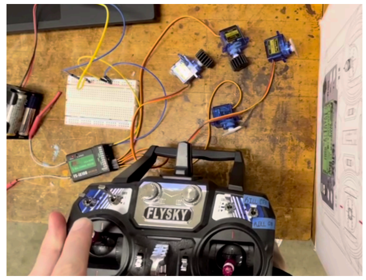
---

We got through a large portion of the tutorial, but quickly ran into the issue of how to power the receiver. At first, I couldn't find a 5 V battery pack to power the receiver, so I decided to power it using the 5 V output of our arduino MEGA. After wiring with the arduino, I was unfortunately not able to get the arduino MEGA to connect to my computer. I came to the conclusion that the arduino was not working properly. I'm not sure why it was left in the shop cabinet, but I added it to one of our team's drawers and labeled it as faulty. I found another off-brand arduino which has almost all of the same pins and seems to be based off of the arduino MEGA design. This one connected to my computer when I plugged it in and we plan to continue using this arduino.

As a preliminary test, as the video follows, I wired the receiver to four small microservo motors to see if I could control the microservo motors using the receiver. As I mentioned, I initially powered the receiver from the arduino 5V output. However, after looking at an online forum, I realized that this could overdraw current from the arduino and brown it out since even though the receiver requires less than the 3A the 5V output of the arduino supplies, the microservo motors connected to the receiver will draw additional currents. To fix this, Daniel came to the shop and ended up finding a battery pack that I did not see in the shop cabinet and instead using that to power the receiver.

We were able to successfully control all four microservo motors using the RC controller and receiver and got more comfortable with the settings of the RC controller. We also performed a test (as the video did) where we read PWM input from the receiver to the arduino and printed it in the console log of the arduino application and read the output signal magnitudes as we moved the joysticks of the RC controller, and this worked as expected.

11/7



Using the RC controller to control each of the four microservo motors.

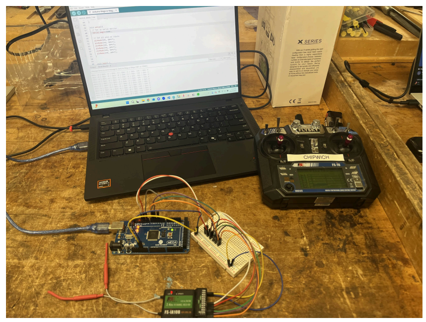


Image of wiring of receiver to arduino, used for intermittent testing.

We also noted that IBUS channels have faster response times, so we eventually plan to use these channels for the driving motors and the PWM channels for the intake and dumping motors, but we are constrained by only 2 available IBUS channels.

tonight:

- put fuse and diode on BOM

weekend:

- read up on roboclaw manual
- get basic understanding of arduino code -> roboclaw (from video ?)

monday:

- redo me 14 roboclaw tutorial
- control small intake motor using small roboclaw + receiver so lily can test intake with arduino
- check on saved lipo voltages + re-learn how to charge

11/8 - Picking diode

Today, Daniel and I were able to pick out a diode and found the link to the intake motors that we found in the shop. We confirmed the choice with Trent and are ready to order.

diode:
https://www.digikey.com/en/products/detail/littelfuse-inc/5KP24A/286072?gclsrc=aw.ds&gad_source=1&gad_campaignid=20228387720&gbraid=0AAAADrbLlhCnEXK04DA8-hYVo5VX48ox&gclid=CjwKCAiA8bvIBhBJEiwAu5ayrIc-oyMqTZhiQDzo-ebMkL1JrX-G9784uo9eUs1tNLAw3r4jAeEQrRoCJLAQAvD_BwE

intake motors: https://www.handsontec.com/dataspecs/motor_fan/550-Motor.pdf

11/14 - Lipo charging and intake motor prototyping

I went into the shop briefly this morning to re-learn the lipo charging procedure. I read through the handbook and also had one of the TAs re-explain the procedure so that we could avoid making mistakes when charging and damaging the lipo battery.

LIPO CHARGING PROCEDURE:

- plug sensor into 4S port
- plug main thing into channel
- go to current, set to 2.2 A (general rule of thumb is 1 C charge rate to not damage longevity of battery, and 1 C * 2.2 Ah capacity = 2.2 A charge rate)
- note: max current it can be charged at is 8*2.2 = 17.6 A, but this is the maximum and can still damage the battery life. only would get to a higher charge rate if we needed the battery charged faster.
- should take ~1-2 hrs to go from fully dead to fully charged
    - the max voltage our battery can be charged to is 4.2 V * 4 S = 16.8 V

Daniel also found these videos, which we began working through about H-bridge motor controllers:

https://www.youtube.com/watch?v=ygrsIqWOh3Y

https://www.youtube.com/watch?v=_I-7XYaAtAo

We wanted to start with the H-bridge motor controller before working with the roboclaws because they are less likely to get damaged and because the intake subteam is a bit bottlenecked since they do not have motors to work with yet. We started by finding a 12 V battery pack (which was rather difficult to find in the shop) and connecting that directly to the motors without the H-bridge and were able to get the intake motors to spin so that the intake team could start prototyping with them.

Next, we wanted to confirm that the default jumper wires were sufficient to connect to the H-bridge without melting. We consulted Trent and he told us to confirm that the voltage drop should have at most a 3-6% voltage drop across them. We looked up how to measure the voltage drop across a multimeter (which was a bit harder than we thought) and confirmed that the jumper wires only had a voltage drop of 2% across them, which satisfied the voltage drop requirement.

We also determined the diode we will be using between the lipo and the roboclaw, and determined that the diode will be in parallel with the switch, and added this to our next BOM and submitted it in the weekly report.

11/14

Rough Electronics Timeline:

Week 8 (11/17-11/21):

- Monday: Finish Intake Mechanism wiring and add option to control speed of motor for intake prototyping
- Tuesday-Wednesday: Prototype 2x60A roboclaw + LiPo + Motors along with writing out the code on motion studio
- Thursday-Friday: Begin creating a more complete set of code + wiring layout necessary for proper driving. Begin integrating the RC controller and receiver into the wiring.

Week 9 (11/24 - 11/28):

- Monday-Wednesday: Continue working on the complete roboclaw + RC controller set up.
- Thursday - Friday: Finish roboclaw + RC controller setup and begin investigating the layout/setup on the robot. (what 3D holders need to be printed, how will the wiring be organized).

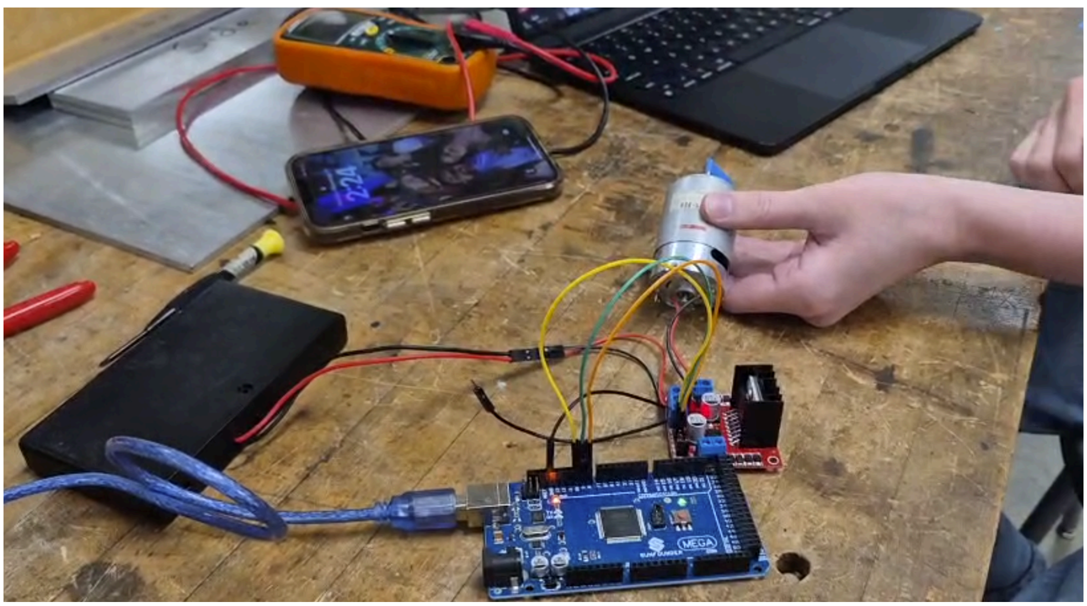
Week 10 (12/1 - 12/3):

- Complete electronics -> chassis integration

11/17 - Completing H-Bridge tutorial

Today is our final day of working with the LN298 H-bridge to create a prototype with working code that can be used for the testing of the intake mechanism. When we plugged in the H-bridge, we found that it couldn't connect to my computer. We were very confused by this and did some testing to see if the issue was with the arduino or the H-bridge. After performing some tests, we found that the issue was with the H-bridge. We replaced the H-bridge with a different one we found in the shop and labeled this faulty H-bridge and placed it in our team drawer.

Once we replaced the H-bridge, we were able to get code provided from the tutorial video running with some of our own modifications that made the intake motor start off, then slowly increase in RPM to the maximum value, stay there, slowly decrease to 0 RPM, pause, and repeat. Now that we completed this, we showed our team so that the intake subteam could start working on their prototype.



Working intake motor prototype with an LN298 H-Bridge and an Arduino MEGA

Finally, since we anticipate needing to write arduino code either by the end of this term or at the start of next term, we created a GitHub repository and cloned it to our laptops and Daniel uploaded his Arduino code to the repository.

https://github.com/anyamischel/me-72-pharaobots

11/18 - Testing receiver and completing roboclaw tutorial

Today, I went into the shop to work on testing the receiver connections and followed this youtube video to understand how the receiver connects to the Roboclaws: https://www.youtube.com/watch?v=7mKcj2DIFhY

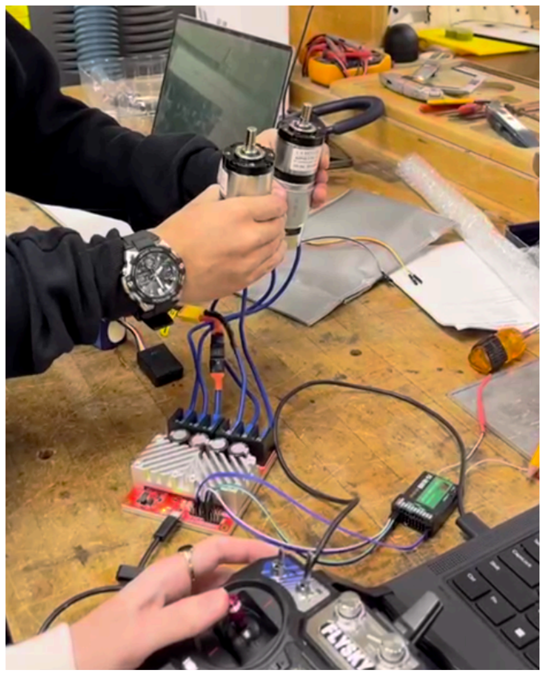
We are still not sure about certain details of the wiring such as if we should wait to solder the resistors until we have finalized the layout. We also redid the ME 14 Roboclaw tutorial to make sure that we are not going to damage the roboclaw and felt much more confident using the roboclaw after we finished these tutorials.

Remaining questions:

- Should we solder the resistors now?
- Can you solder two things in parallel onto one wire?
- Is it alright to use 12 AWG wire?
- Is Trent still ordering more 12 AWG wire?

11/19 - Connect receivers and electronics redesign

Today, we came into the shop to finish the electronics setup with the receiver and the 2x60 A roboclaw. First, we installed the drivers so that we could connect to the roboclaw. This allowed us to connect to it. Then, I plugged it into my computer and set current limits at the stall current for each of the motors and set the minimum close to 0. I was able to control 2 motors using the sliders on my computer and Daniel and I crimped the small ring terminals onto the 12 AWG wire and connected that to the screw terminals of the 2x60 A roboclaw. We had also connected the receivers to the 2x60 A roboclaw and demonstrated the ability to control two motors with the RC controller.



Controlling the motors attached to the Roboclaw using the RC controller

While this was good news, we next planned to wire the other two motors to the roboclaw and asked Trent to double check how to wire two motors in parallel out of one output of the Roboclaw. When we asked him, he looked at our wiring diagram and realized an important problem which had not been brought to our attention during the PDR or CDR. He pointed out that having two motors wired in parallel out of one roboclaw output will create issues when one of the motors experiences a higher load than the other. He said that the roboclaw will end up sending most of its current to whichever motor has a lower load, effectively only turning the wheel under less load. This would create huge problems when driving over bumpy surfaces, where one of the wheels might just end up free-spinning while the other might end up stuck and unable to get over the object. Daniel and I asked if there were any other roboclaws available in the shop, and Trent got us an extra 2x30 A roboclaw and a 2x45 A roboclaw which we can use instead of a singular 2x60 A roboclaw. This eliminates our design issue entirely,

11/19

since now we can have one motor per output channel of the roboclaw. We will have to double check the wire we need and rewire and change the way we mix/control the mappings between the receiver and the roboclaw, but that shouldn't be too big of an issue. We started working on this but will continue with it tomorrow.

To do before end of weekend:

- Change mapping of receiver controls
- Calculate if we can use a higher AWG wire
- Double check resistor's value, but check with trent
- Set up 4 motors with 2 of the 2x30 A roboclaws
- If assembly is done, combine with chassis for prototype and determine location of electronics in chassis

11/20 - Wiring progress for 2 roboclaws

I did not have as much time today, but I came back into the shop to work on the electronics wiring. We talked to Trent and determined that we should be able to use 14 AWG wire for our battery and lipos. We restripped the 14 AWG wires and began wiring. We wrapped the leads around the switch temporarily and soldered the resistors and diode in parallel so they could be placed across the switch. We also just bent the ends of these leads around the switch since we do not have ring terminals yet.

11/21 - Soldering Y-split on battery wire

Since we are now using two roboclaws, we now need the main wire from the battery to split after the fuse into two paths which lead to the separate roboclaws. We do not have to solder the positive leads together since we can just purchase two ring terminals (1/positive wire) that come out of the switch so there are fewer failure points. We do have to solder the ground wires that go back into the battery together, though, since those do not pass through the switch. I came into the shop to solder those wires together briefly and shrink wrapped them. I ensured that I could still plug everything into the battery and that the connection was strong by tugging on the wires.

11/24 - Switching out wires, using electronics box

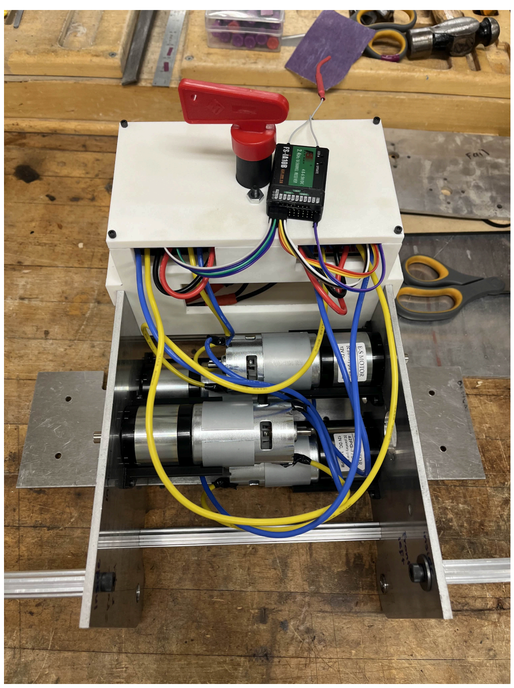
Morning:

We placed an order for 5 ring terminal connectors for M10 stud circular 10-14 AWG crimp from Digikey with the plan of using one from the battery to the switch, 2 from the parallel output from the switch to the roboclaws, and one for either end of the diode/resistors across the switch.

Since we made the switch from the larger roboclaw to the two smaller ones, I went into the shop and stripped a new set of 14 AWG wires after the switch while preserving the 12 AWG wire from the battery to the switch. I couldn't quite finish crimping the small ring terminals onto the other ends of the wires leading to the Roboclaws, so Daniel did this when he came into the shop. Daniel also wrapped the wires around the ends of the switches and secured it using electrical tape. Daniel confirmed that turning on the switch and the controller caused the roboclaws to turn on and flash, indicating that they worked as expected.

Evening:

I came into the shop again to put all the electronics inside the electronics box which Hannah 3D printed. The box fit the electronics well and made it much easier to use the switch. However, the lid was also 3D printed which made it difficult to see the lights of the roboclaw, so Hannah suggested changing it to be made out of acrylic. I tried to find velcro to secure the roboclaws to the box but couldn't. Luckily Daniel was able to and we finished securing the electronics.



Electronics box housing the two roboclaws, switch base, wires, and lipo battery.

11/25 - Remixing for total driving

In the morning, I went into the shop and plugged the lipo into the electronics and turned on the RC controller and tried to control the motors with the controller. After a few seconds, I had difficulties where two of the motors stopped moving entirely or only moved a little bit and made a weird buzzing noise. I originally thought this was because the resistors and diode in parallel with the switch allowed the current to flow through them which causes the Roboclaw lights to be lit for a brief period, even when the switch isn't turned on. I was also having issues where the error light and all others were blinking rapidly which made me suspicious that there were further issues with the Roboclaw.

Daniel came into the shop with me and we reconnected to the Roboclaws using a microusb to our computers and found that if we disconnected the second output channel on both roboclaws for the motors that weren't spinning, we could turn on mixing on Motion Studio and move two motors with one controller.

We changed the endpoints on the RC controller's settings so that the motors on the same side no longer spun in opposite directions. Frustratingly, when we put all of the electronics back into the box, the mixing seemed to have turned off and only one motor was running per input. We figured that either we did not save the settings to the controller correctly or the roboclaws reset the mixing when we connected to them with the microusb cable.

Default joystick → channel mappings from the RC controller to the roboclaw.

11/25

We also noticed after more testing that one of our motors started smoking and producing a bad smell and buzzing. We consulted Trent and he inspected our motors for damage and confirmed that they were fine but that the brushes had not been fully worn in and suggested we run the motors at 20% speed for around 5-10 minutes.

We eventually decided to connect S1 and S2 to all channels on the receiver.
We decided to connect S1 on the left roboclaw to CH4 so that both wheels on the left side move in the same direction for inputs on CH4. We then changed the endpoints on CH3 to go from 0% → 0% only when all other electrical components are turned off.

We then connected S1 on the right roboclaw to CH2. That way, both wheels on the right side moved in the same direction for inputs on CH2. We then changed the endpoints of CH1 to be 0% → 0%. This configured the robot to have tank controls (CH4 controls the robot's left wheels, CH2 controls the robot's right wheels).

We also tried driving with this but it was not very intuitive, especially because CH 4 is horizontal while CH 2 is vertical, so driving straight does not just equate to both joysticks forward. Having one joystick to the side while the other was forward in order to drive straight did not make much intuitive sense so we want to switch this next week.

To do next week (break because of Thanksgiving):

- Look into both elevon
- Look into mixing using only the roboclaw
- If we still can't figure it out by the demo, go back to the controls we currently have.

12/1 - Adding elevon & soldering wires to motors

I came into the shop to cut the lengths of the wires between the motors and the roboclaw. I marked where on the wires I needed to cut them and then cut them using the wire cutters and soldered them directly onto the motors. I had some difficulty with getting the wire to stay attached to the motor's leads and probably should have been using a clip but eventually got it working with some effort. I shrink wrapped the outside of the leads and used electrical tape to patch up any other exposed areas of metal. I connected the RC controller and confirmed that driving worked as expected.

https://www.youtube.com/watch?v=fU0cFLLZ7jY

Later, Daniel and I watched the video on Elevon for an RC plane (linked above) and adjusted the settings on our own RC controller. We did the following steps.

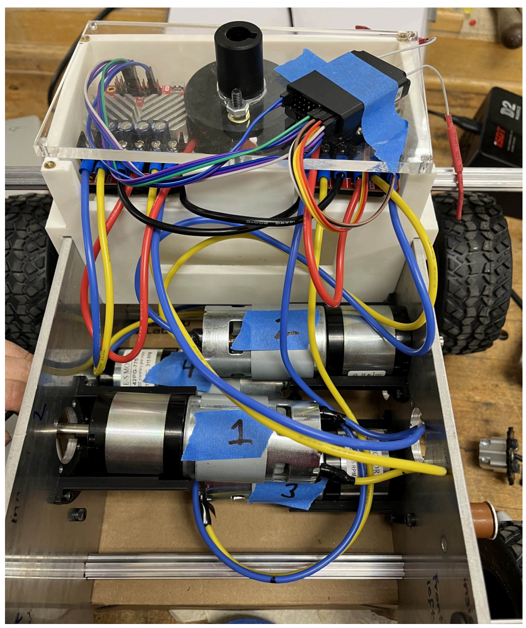
Solution to driving:
-Physically switched Channels 2 and 4 on the receiver
-Changed end points of Ch3 and Ch4 to be 0% - 0%
-Reversed just channel 1
-Enabled Elevon with the configuration: CH1: -100% and CH2: 100%
-Then realized that our turning was flipped so we physically switched CH2 and CH1 on the receiver

12/2 - Soldering ring terminals, fixing mixing, testing climbing

<u>Morning:</u>

The ring terminals arrived, so I went into the shop in the morning and removed the electrical tape around the switch. I stripped the wires to be a bit shorter and soldered the wires onto the ring terminals and used heat shrink to protect the exposed wire. I re-fastened the ring terminals onto the switch and placed everything back into the electronics box. I noticed that some of the threaded inserts in the electronics box were starting to come completely out, which is making it difficult to screw the lid into the box.

Soldering the wires onto the ring terminals was actually quite difficult and took much longer than I expected. I'm not sure if the ring terminal material is different from the wires I was using, but it seemed to do a much worse job at sticking to the solder. It felt like my connections were not as good as a result, but tugging on the wires did not seem to loosen anything, so I left it. I connected the RC controller and confirmed that everything worked as expected.



Electronics box.

<u>Night:</u>

The manufacturing subteam caught up in assembly and was ready to test, but Daniel was in the shop with them and was having some issues with testing because it seemed that the RC controller settings had been reset when he updated the roboclaw. However, he figured out what the old settings were and we conducted some tests of the driving and ensured that it worked as expected. We ended up using mixing and elevon on the RC controller only and this was able to map the joysticks to the controls we wanted.

12/2
We also tested the robot's ability to climb up the pyramid. We found that no matter the speed we drove the robot at the pyramid, it did not seem to gain enough traction to pull itself up the pyramid. We added some normal force to the robot by pushing directly on the robot into the ramp and found that under this situation, the robot could climb the pyramid. We taped small aluminum blocks onto the robot to test if that allowed it to climb the pyramid, and while this helped, it did not seem to entirely fix the issue. We determined that we needed to create a box to contain additional weights since using masking tape was also not properly holding up the weights.

Pictures from testing of the robot attempting to climb the hill (with some help)

12/3 - Additional testing of climbing

We came into the shop for a few more hours to try additional testing of the robot's ability to climb. We now have the 3D Printed box with the extra weight installed in the front bottom of the robot, but this alone did not seem to be enough to allow the robot to drive. We tried adding additional weights and tried putting weights on top of the bottom plate in between the front and back wheels, but this didn't really seem to fix the issue. We noticed that driving on wood is a bit easier than on the steel plates. We also found that using only 2 additional weights in the front was the best driving situation, so we will be keeping that for the mobility demo. Tomorrow, we will try incorporating rubber bands onto the wheels' surfaces to see if that increases traction. We are currently brainstorming ways to increase traction for next term. Some ideas are a higher gear ratio, different wheels which have better surface area contact (since our wheels are made more for rough terrain applications than smooth surfaces), and a lower center of mass. However, all of these are not changes we can make within one night, so we hope that using rubber bands tomorrow will help with traction.

12/4 - MOBILITY DEMO DAY

Before the demo:

Today was the mobility demo. I went into the shop at 1 PM with hopefully some time to do final testing before the mobility demo at 4 PM. Lily mentioned that she had rubber bands, so we disassembled our outer walls and stretched a lot of rubber bands all over our wheels to try and completely cover the surface area in an effort to improve traction. We put the outer wall back onto our robot and then tested driving with it. We first tried driving forward and didn't notice any major issues like the rubber bands sliding off or getting caught in the chain. Afterwards, we tested climbing, but were still not successful. This was pretty frustrating because last night we felt like we had tried every possible combination of center of mass rearrangements and increases in weights, but nothing seemed to be working. We gave up on the rubber bands and cut the rubber bands off our robot to disassemble it.

Then, until the rest of our team arrived for the mobility demo, we practiced driving and turning. We noticed that after the rubber bands, there were some new issues with the robot. The driving felt a bit less efficient than before, and the turning acted very strangely/unexpectedly. We did normal tests of turning and discovered that right turns acted normally but seemed to be happening less efficiently. However, we found that on left turns, the front left wheel would stall and jerk, which was not how it was behaving last night. This made it so that the robot would pivot about the back left wheel when it was turning left, so the robot could no longer turn in place like we had hoped. We tested different parts of the drivetrain not being fixed properly to the shaft by rotating them manually with our hands, but it seemed that additional tightening on the shaft collars did not do much. We were not able to fix our turning entirely or climb before the demo.

Results of the demo:

We were able to complete the straight driving and driving around cones tests rather easily, but were not able to climb the pyramid during this part of the demo. We cleaned our robot's wheels and the pyramid's surface before the climbing portion and that allowed us to climb around a foot before slipping and falling back down. Jimmy looked at our robot more and noticed that the motor of the front wheels were spinning, but the motors themselves were not. At first, we thought this was an issue with having 3D printed hubs for the wheels and began planning how we would try to lathe new hubs out of aluminum before winter break starts. However, Jimmy noticed that the problem was actually that the inside of the wheel was spinning with the shaft, while the outside part of the wheel was fixed. He demonstrated this by holding the front wheels fixed with his hand while driving the motors forward, and seeing that the motors and inside of the wheel spun. Thus, the wheels we are using are not sufficient for the high torque application of this competition and we decided that we need to get new wheels.

12/4

We began researching wheel types and found that colson wheels might work. We found two wheels in the shop cabinet that we could test that are both 4” (which is too small for our breakover angle) that we could test with. We found that these wheels are on the Andymark website and are called Sushi & stealth wheels. The gray and blue wheels correspond to the higher durometer values, so they are the hardest out of the wheels in this link:
https://andymark.com/products/stealth-and-sushi-wheels

I asked Jimmy more about wheels and he recommended against compliant wheels since they are specialized for intake. He mentioned colson wheels or the above sushi/stealth wheels. We will need to do further research into the wheels but would like to at least like to try these wheels. We sent an email to Professor Mello about discovering our issue with the robot, and plan to purchase new wheels before the end of the term. Later at night, I also started designing a way to integrate magnets into the chassis design. One of the biggest issues with magnets which had caused us to not consider them was that any location we could have put them on our chassis would have been too large of a distance from the ground the robot drives on to have any real magnetic force to keep the magnet on the pyramid. We had also tried seeing if taping them to the wheels would help with driving, but even an inch of clearance is too big. I started designing a small mount which could be drilled into the inner wall and house the magnets a few millimeters off the ground. We may try 3D printing these before winter break to test if they could help increase the normal force between the robot and the surface of the pyramid.

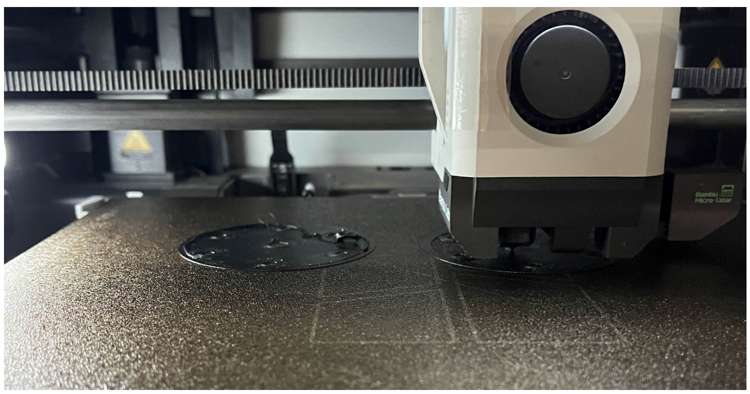
To do:

- CAD new hubs for the 4” wheels (gray and blue, should be the same)
- 3D print new hubs for the wheels
- Test new wheels by taking off the old ones and replacing them with the shop wheels
- Test driving with the new wheels

12/5 - 3D printing new wheel hubs & designing magnet mounts

Today I 3D printed wheel hubs for the new shop's wheels. These wheels are 4" in diameter and are "stealth and sushi wheels". There are both gray wheels and blue wheels, but we are planning to use the blue wheels since they have a slightly lower durometer than the gray wheels.

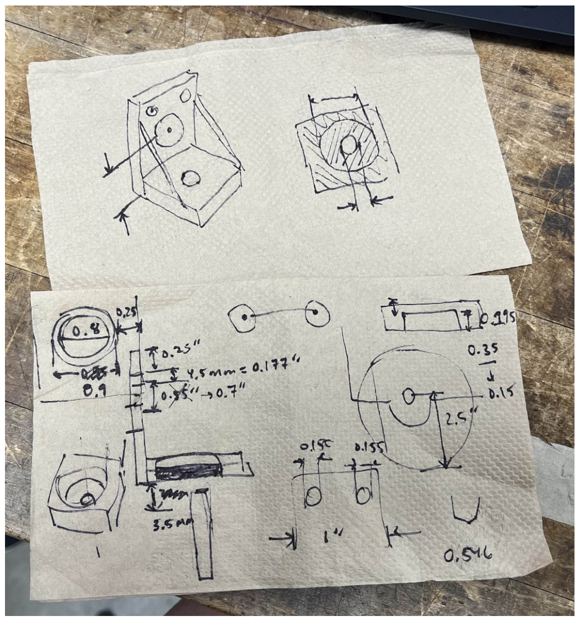
Miina had made a copy of the old wheel hub CAD and adjusted the location of the attachment holes last night, so this morning I uploaded the STL file she linked in the ME 72 Google drive and printed the hubs. Unfortunately, the first 2 times of printing did not work and the PLA was peeling off of the bed. I tried washing the plate with soap and water in the back of the shop but this didn't help that much since one of the wheel hubs on the third print failed, so I had to skip it while it was printing and print the last wheel hub by itself later in the day.



Once I had all the wheel hubs, I came back into the shop in the evening and attached the wheel hubs to the shop wheels and hand tightened them. After this, I began disassembling the robot by unscrewing the churros and then removing the outer walls, and afterwards taking the shafts out of the inner wall's bearings. I tried to remove the old wheels from the shaft by unscrewing the wheel hub from the old wheels, but I couldn't fit the allen key in the space between the sprocket and wheel hub. Because of this, I decided to instead move the shaft collar so that I had more room to remove the wheel, but got the allen key stuck in the screw for a while. I talked to Ana about this and she said that the manufacturing subteam had been having consistent problems with the allen key getting stuck in the same screw for multiple weeks. I was able to get one of the wheels off by moving it towards the sprocket and then loosening the shaft collar. However, I had much more difficulty with the other wheels and realized that this was because the wheel hubs were press fitted onto the shaft, and the wheel that I was able to take off was not press fitted very well onto the shaft. Because the bigger press fit removal machine was not on the student benches and the shop was closed, we decided to work on replacing the wheels on Monday.

12/5

Daniel was also in the shop with me in the evening working on the disassembly of the robot. We also discussed the idea that I had the previous night about how to incorporate magnets to the chassis design through 3D printed mounts. We were looking for which bolts to use but are deciding between #8 screws and M4 screws, but since we didn't have access to the shop, we couldn't go in and check what was available. We began making the CAD of the magnet holder mount for the 5" wheels, but we will probably need to print magnet holder mounts for both the 5" wheels and the 4" wheels so that we can test with the 4" wheels, but we will probably eventually drive with 5" wheels once we can order some new ones.



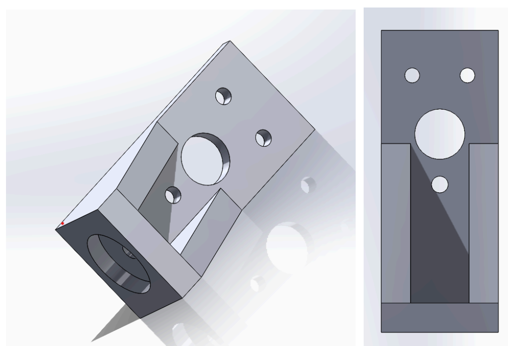
Quick drawings/sketches of the magnet mounts for the improved robot.

12/7 - Adjusted CAD of magnet mounts

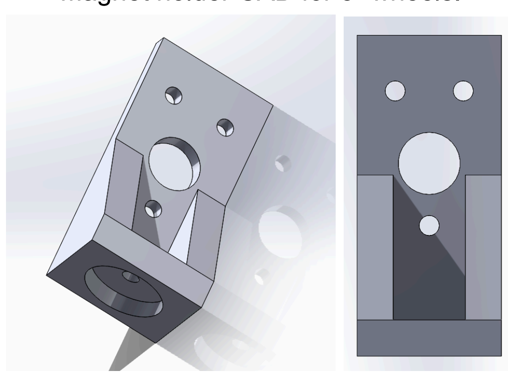
Today, I worked on fixing the CAD of the magnet mounts with the 5” wheels, and also made the CAD of the magnet mount for the 4” wheels so that we could test the mobility demo this week. I had some difficulties getting used to some of the features since I have not used SolidWorks in a while.

All fasteners for the magnet mounts will be #8 bolts with nuts.

Each mount needs 4 of these bolts (assuming Trent confirms that adding the extra hole is alright), totaling 4x4 = 16 bolts for the robot.



Magnet holder CAD for 5” wheels.



Magnet holder for CAD 4” wheels.

While designing this, I set the dimension from the center (shaft) hole to the hole into the inner wall to be something arbitrary since the shop is closed over the weekend and I was not able to measure the width of the aluminum around the shaft hole.

<u>Plan for tomorrow:</u>

- MORNING:
    - ask Trent about the third hole and infill of print
    - measure location of it and fix in cad
    - start print of magnet mounts
- AFTERNOON AND TUESDAY (after prints are done):
    - go in with Miina to replace wheels and mill holes

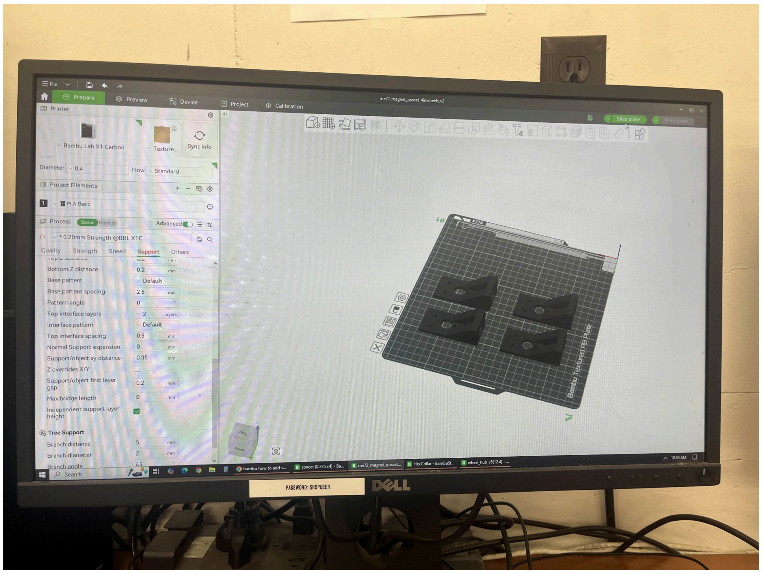
12/8 - Added magnet holders, replaced wheels, & successfully climbed

Morning:

Today I am 3D printing the magnet holders. I asked Paul about whether we have enough space between the shaft hole and the bottom of the plate and he confirmed that it should be alright since the load per magnet is only ~2 lbs. We plan to use 6-32 screws instead of 8-32 screws per his recommendation as well since it will save us some space. I adjusted the CAD of the magnet holders to adjust for the new screw size but kept the hole size of the magnet's bolt the same since those fit the magnets. I picked out twelve 6-32 screws and nuts for all four magnet holders. I also adjusted the width of the gussets on the holders so that there is a 0.1" clearance for the nut so that I don't have to fit a wrench when tightening the screws.

I found online that the width between flats of an 8-32 nut is 0.344". Thus, with the 0.1" clearance, the gussets should be 0.444" apart. Thus width of each gusset is (plate width - distance between gussets)/2 = (1.4-0.444)/2 = 0.478"

I started prints of both the magnet holders for the 4" wheels and the 5" wheels.



Magnet holders for 4" wheels loaded in Bambu

To do this afternoon:

- Remove wheels from shafts
- Press fit new wheels onto shafts
- Take off inner walls
- Drill holes in inner walls
- Reassemble if time allows. If not, reassemble tomorrow
- Get VPN for CAD

Afternoon:

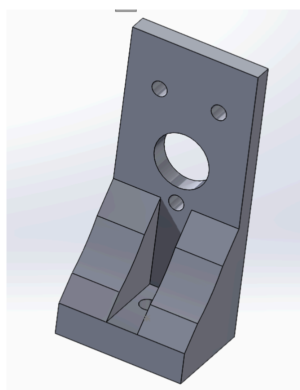
12/8

I got the printed 4” wheel magnet mounts out of the printer, but they have some issues which I will address and hopefully re-print before Miina and I machine the holes and switch the wheels tonight.

Problems with current magnet mounts:

- Shaft hole should be bigger to accommodate for shaft collar
- Gussetts are running into sprocket
- Gussets too far apart, screwing in nut is hard
- Clearance from ground should probably be 3 mm, losing quite a bit of force from the extra 0.5 mm

Need 0.345” between gussets now. Width of each gusset: (1.4-0.345)/2 = 0.5275”



Updated CAD of magnet mount for 4” wheels

Evening:

We went back into the shop once the magnet holders were printed. We took them out and aligned them with the shaft and realized that the bottom of them was sticking too high up and running into the sprockets. To fix this, I used the vertical band saw to make cuts into the mounts to make more space for the sprocket. We will eventually 3D print the mounts again, but this temporary solution was just used so that we could test the climbing of the robot. In the meantime, Miina undid the press fits on the old wheels and then redid them with the 4” wheels we found in the shop.

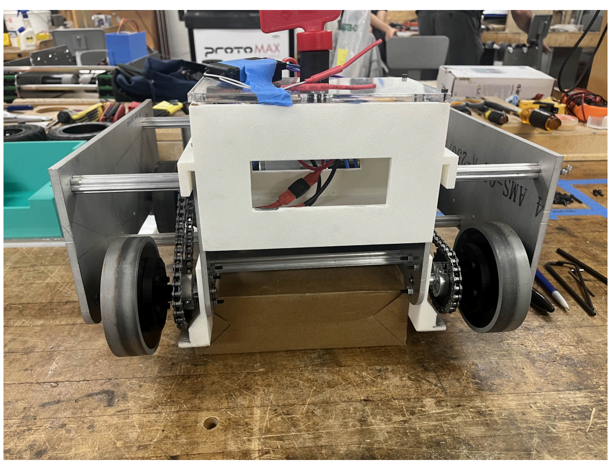
We first tested driving with the new wheels before committing to adding the magnet mounts. The robot was able to climb around 2-3 inches before slipping and falling back again, so we decided to add the magnets.

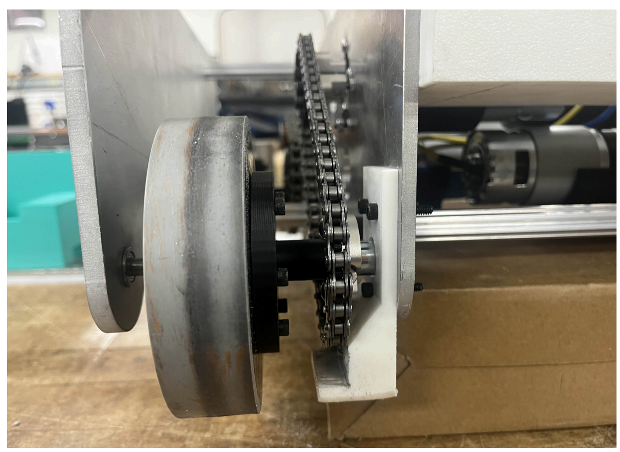
Miina and I disassembled the robot and drew marks for the holes on the inner wall for the mount and took the inner walls to the drill press and drilled these holes. One of them

12/8

we accidentally used too big of a drill bit, but it still worked to keep the magnet holders in place. We didn't anticipate very much force on each of the holders (~2.8 lbs/magnet). All of the holes were aligned sufficiently and we screwed the mounting holes into the inner wall.

After this, we reassembled the robot. This took a while since we had difficulty getting the motors screwed into the inner plate. Once we got the motors screwed in, we tested driving. Driving seems to be less smooth on the new wheels, and the new wheels seem to collect dust extremely easily. Because of this, we would like to eventually use lower durometer wheels since the new ones we tested have a durometer of 80, which is rather higher. We then tried climbing and were able to climb and interestingly much better in the forwards direction than in the reverse direction. We believe this is because the back left wheel is the pivot point when turning due to the way we made mixing work on the RC controller, so having this wheel in the back instead of the front allows the robot to still drive up the ramp while it is driving. Driving it backwards up the ramp and also turning to the right would cause the robot to slip backwards because of this stationary wheel. We also weren't able to get all the way to the top of the pyramid because of the breakover angle with the smaller wheels, so we would like to order softer 5" wheels.





Robot chassis with magnet holders installed (see cuts in gussets) and 4" wheels

To do for robot:
- Order 5" wheels with lower durometer
- Adjust CAD of magnet holder mounts for 5" wheels
    - Make sure plate is smaller to avoid clearance issues
    - Remove part of gusset or extrude rectangle into it to avoid interference with sprockets

12/9 - Demonstrated climbing again

Today I went into the shop in the afternoon to charge the lipo batteries and redo the climbing section of the mobility demo. After last night, we were confident that the robot would drive correctly. We demonstrated that the robot could climb up and get down the pyramid easily and demonstrated the robot turning around on the top of the pyramid a few times to show Professor Mello that we could turn within small spaces. The largest limiting factors seem to be the wheels and the mixing, causing the back left wheel to be stationary as the robot turns in either direction. As mentioned yesterday, this is why the robot works better driving up the ramp forwards and not turning around at the top. We took three time trials of the robot driving up and down the ramp and the times are as follows:

- Trail 1: 16.35 s
- Trial 2: 11.70 s
- Trial 3: 11.60 s

My driving definitely improved for the last two trials. I also tried standing on the stool so that I could see the top of the pyramid and that also made it a lot easier to drive since I wasn't as worried about driving the robot off the top of the pyramid.

Driving the robot to the top of the pyramid.

*** End of fall term**

12/26 - Updated magnet mount CADs

Today, I updated the magnet mount CAD for the 4” wheels, and created a new CAD for the magnet mounts for the 5” wheels. The adjustments are as follows:

- Made the side supports into small fillets.
- Made the width of the mount thinner.
- Made the back plate thinner.
- Changed the clearance from 4 mm to 0.15” (slightly smaller than 4 mm) since we can afford this smaller clearance, and since we want to work entirely in customary units moving forwards.
- Confirmed the fasteners for the magnet are #8 bolts, while the fasteners into the inner wall are #8 bolts (all customary).
- Ensured the top holes are still 0.66” apart for the 5” wheel version.

I also drafted a spreadsheet for the weekly hours tracking to address the problem we had last term, but didn’t realize Daniel had also created one and I think his is more effective.

1/6/26 - 3D Printing Magnet Mounts, Wheels Research, and CAD

Today I went into the shop in the morning and 3D printed the new magnet mounts for the 5” wheels and the 4” wheels so that we could reassemble the robot as soon as possible with the glued 5” wheels. I also spoke to Paul and asked him about glue options for the rubber 5” wheels and he said it was based on the material of the wheels. I looked into the Studica website for the wheels (Studica), but they do not list the material of the outer tire or the inner rim anywhere. I contacted Studica using their online form and found the type of glue that is best suited for the wheel type. Their response is below.

Question about Studica 125mm All-Terrain Robotics Wheel Set Summarize

JE Janet Ebert<janete@studica.com>

To: Mischel, Anya B.

Tue 1/6/2026 11:17 AM

Hi Anya,

Thanks for reaching out. The inner hub is PC+ABS and outer portion is rubber although I am not sure of the exact rubber composition. They are intentionally not attached as they were designed allow the inner foam to be changed if desired. If you would like to glue them, our suggestion would be to use a Medium/Thick Rubber CA Tire Glue, a type of cyanoacrylate (super glue) with added rubber reinforcement and increased viscosity, specifically designed for bonding rubber RC tires to plastic wheels. You can find many options if you do a Google search for Medium/Thick Rubber CA Tire Glue.

Regards,

Janet Ebert
Studica, Inc.
888.561.7521

Studica, Inc. - **Uniting Education and Technology Since 1985**

I asked Trent about it and we decided to use a silicone adhesive, which is not as good as the glue that Studica recommended, but should still work well enough. I also asked Trent about the best way to go about machining our walls, now that they are larger in size than the area of the waterjet. Unfortunately the big waterjet will not be fixed by the

1/6/26
end of the year, so we decided that it would be best to conversationally mill all four walls since we can cut out the shape of the walls using this method, and it will fit on the mills without an issue.

I was able to remove the outside tire of the wheels with some difficulty and sanded them down using brass wool. Miina and I later came into the shop to glue the wheels. This was very difficult since the glue got everywhere and it was hard to get it into the crevices. After gluing, we waited for the wheels to dry for 24 hours. Tomorrow, Lily and Sophia will disassemble the robot and reassemble with the old glued wheels so that we can test them.

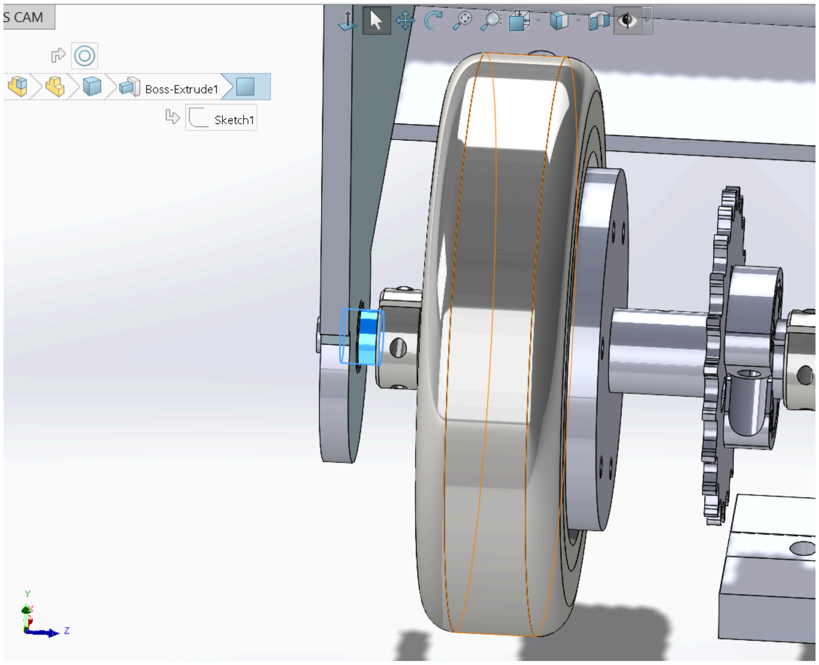
1/7 - Testing reassembled robot with glued wheels & CADding new robot

Today, I came into the shop briefly to help with testing the robot with the old, glued wheels. Unfortunately, when testing climbing, the wheels quickly slipped and did not regain traction like we had hoped. We noticed that the glue was not sufficiently securing the tires to the hubs and that it would not work, so we decided that we will be going back to the old shop wheels that are 4”.

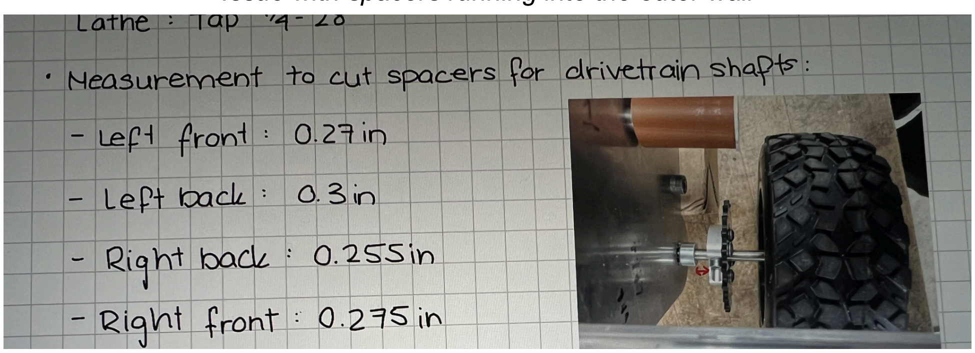
In addition to working on the testing, I was mostly focused on finishing the CAD of the new robot. Ideally, we only wanted the CAD to have longer inner and outer walls, without changing much of the other parts of the CAD. However, this was quite difficult to do, since I found that there were a lot of mating issues with the old assembly. Furthermore, I noticed that the way that the inner and outer walls were CADded did not make the most sense and would be a bit hairy to make adjustments. Instead, I decided to create new CAD models for the inner and outer walls from scratch. This was pretty time-consuming but ultimately a very good decision, because it revealed other mistakes that were previously made with our CAD models which had shown up in the misalignment of holes in the first robot that I could now correct.

1/8 - Fixing mates and adjusting CAD model

I realized some issues with the mating, such as spacers running into the bearing holes. I also found that the holes of the motor mounts and the locations of the holes were incorrect, which had created issues with the first robot. I fixed these issues by deleting all the old mates and re-adding mates with my new inner and outer walls axially. I had to set some new distance mates, which I got from Hannah.



Issue with spacers running into the outer wall



Measurements for spacer lengths for the old drivetrain

CAD to do:

- replace other inner wall
- fix mating on bottom plate
- fix spacers
- finish mating of things on shaft axially after choosing spacer lengths
- fix distances between holes for the chain length thing

1/12 - Continuing to work on mates and adjusting holes

We had a group meeting, and Miina and I talked about the location of the motor holes and we determined the locations they needed to be. She sent me a picture of them, which is below:

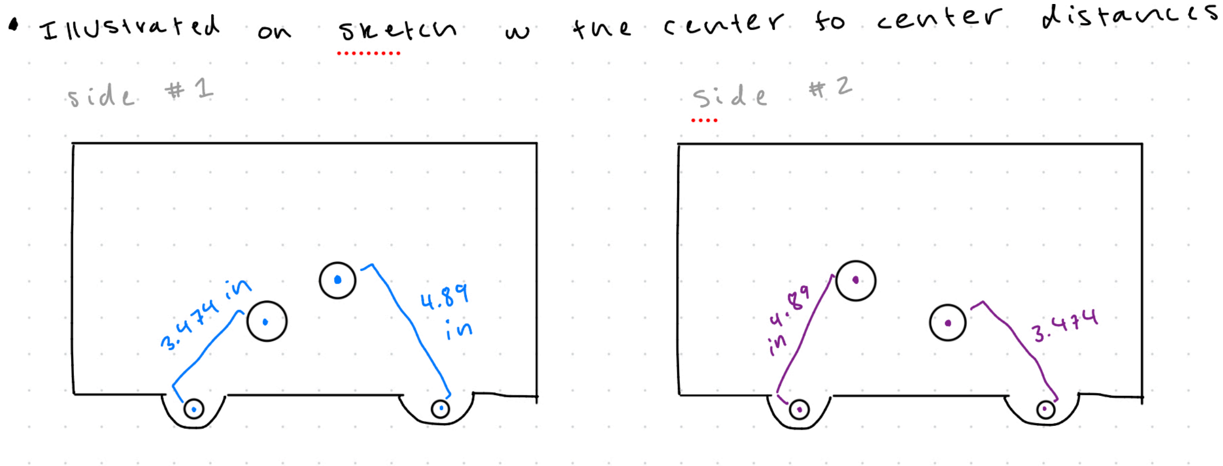


Diagram of the location that the motor holes need to be on the inner walls.

Miina also told me: “the 4.89 results in 50.1 links which we used on one side on the old robot (and it worked ok) and the 3.474 should now result in 42.1 links for the other motor”. Miina also showed me a picture which shows the spacing needed between the inner and outer walls, which is below:

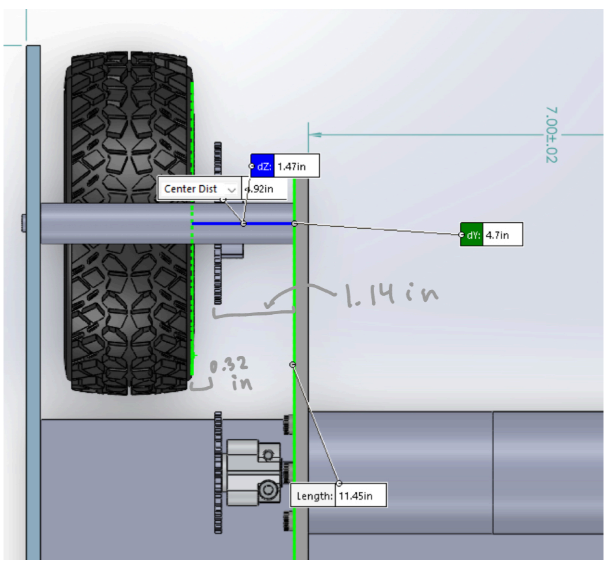


Image of the drivetrain between the inner and outer walls from Robot 1’s CAD to be replicated.

This informed the matings for the new assembly with the updated walls. I also adjusted the motor mounts so that they could be slightly lower, which would allow for the ramp to have a bit more space and not need to be as steep. I made these adjustments and then uploaded the new assembly to the drive.

1/12

ASSEMBLY CAD TO-DO.

- confirm size of spacers so i can fix axially
- ~~fix holes for motors~~
- ~~upload new magnet holders (this is why mating isnt working rn)~~
- ~~fix discrepancy between motor mount and inner wall holes fix sizing of holes for motor mounts make sure sprockets are in line make sure spacing between wheel and sprocket is correct and sprocket and wall are correct make sure motors on the same side are diagonally at least 96.4 mm apart make some of the mounts flush with the ground~~
- add bottom plate
- add front plate

1/25 - Team Meeting & Catch Up

I unfortunately missed almost two weeks of time due to a family emergency, as I had to fly home and was not able to work very much besides slight CAD adjustments until I returned. I was caught back up to speed with my group on Sunday, and when reviewing the updates to the CAD, we realized that the location of the intake rods were not far enough away from the ramp to allow for sufficient clearance when collecting the EC's.

1/26 - Disassembling Robot 1

This morning, I went with Hannah to help 3D print some of the inner walls for the intake. Afterwards, I went to the machine shop and disassembled the rest of Robot 1. I also replaced the gray wheels with the blue wheels and tightened everything and labeled some of the parts so that they are ready for reassembly on Wednesday with the new inner and outer walls. We discussed the solution to the intake clearance and front plate and determined that in order to still fit within the size limit, we would have to initially bend some of the front row of spindles.

1/27 - Making new chains for Ramses

Today, I went into the shop to make new chains for Ramses. The chains were cut to lengths of 40, 48, 50, and 56 links. The goal of this was to eliminate the need for tension rods since Miina calculated the exact location the motor mounts needed to be in order to keep the chains at the correct tension. I used old chains that we had already ordered and used the dremel to remove the top part of the link which keeps the flat part of the link on the two rods and used the chain cutter to entirely remove the link. I counted the number of links and attached the master link to complete the chains. In the process of making the chains, I accidentally bent one of the links, so using this chain set would require using two master links and cutting out the broken link.

Cut chains for Ramses

1/28 - Preparation for Intake Demo

Today, I worked on the disassembly of the robot and began reassembly of the upper assembly with Hannah for the intake demo. I noticed that the magnet mounts that we printed for the intake demo had incorrectly sized holes, so we will need to change them in the CAD and reprint them. I installed the chains, but realized that the tension rods are a little bit smaller than expected, so we will be printing new ones that create more tension than the current brown ones. I also CADded a mount for the intake motor and began printing it in the machine shop so that it could be ready for the morning. Lily is printing one as a back-up as well.

1/29 - Intake Demo Day

Today, we worked on assembling the intake for the intake demo in the afternoon. I 3D printed a prototype of the front wall so that the intake subteam could test the amount of resistance it adds.

In the morning, we noticed that the spindles for the intake were cut too short and did not reach the pellets when on the drivetrain sitting on the ground. This mistake occurred because the intake subteam cut the lengths assuming the plastic intake ramp was flush with the ground and did not account for its location off the ground due to the presence of the rubber ramp. Thus, we faced a significant challenge of how to increase the lengths of the spindles for the intake demo later that day.

We made the decision to increase the spindle length for testing by using paper towels and electrical tape to extend the lengths of the spindles. We spent the rest of the day reassembling the robot. During the demo, we were not able to pick up many pellets, especially ones that were close to the base of the pyramid. Through testing later in the day, we determined that the addition of more rigid, plastic tubing improved the efficiency of intake. Furthermore, we noticed that during the demo, pellets would often get stuck in the gap between the ramp and the wheels and that the robot would frequently drive over pellets, which caused the intake to no longer be flush with the ground and thus not be able to pick up pellets. We think having an additional rubber ramp which helps gather pellets into the intake ramp would fix this issue and make the intake more efficient. Finally, we noticed during the demo that the chains still seemed to skip links occasionally on the drivetrain, so we will be reprinting these.

DRIVETRAIN post demo tasks, ROBOT 2:

- make sure everything in the CAD is up to date. fix suppressed parts and errors
- add screw holes in the CAD for the front plate. rethink how we are making the front plate --> based on the demo today, is it possible to lower the height of the

1/29

plate based on the size of the ECs and pellets? Should we make the front plate any taller?

- cut churro for front left top since it's currently missing. Actually since our plates should all be fixed distance apart, it might be be better to have exactly the same length of churros. I imagine having different lengths and tightening all as much as possible is causing the plates to bend a tiny amount, it might be negligible but since we have to recut churros for the second robot anyways
- bottom plate? + holes on walls for bottom pate
- add more churros for reinforcement

post demo tasks, remaking ROBOT 1:

- Assuming we are reusing the chains from last term, recalculate chain length --> motor mount positions for robot 1
- cut new churros
- cut new shafts
- print new wheel hubs for second set of wheels
- remake walls. but this should be later honestly because its better if intake stuff is fully tested and finalized so we don't have to go in and make changes

----

things that need to be fixed: INTAKE/UPPER ASSEMBLY WALLS:

- holes for the intake motor in the CAD -- or better, just have big hole where the motor goes so we don't have to screw through both plates
- have slot for magnet mounts, hole for tension rods

RAMP:

- make cutout for motor bigger and put in CAD

INTAKE:

- make spindles longer for first row, fix issue with overlap to the next row. more prototyping is needed to determine how long they can be without friction issues. maybe we can shorten the middle row instead of shortening the front row?
- cut the shafts at least for the first and third rows and the non-gear side of the middle row so that the shafts don't have to extend through the drivetrain walls. move the shaft collars accordingly. def do this in the CAD and we can confirm in full CAD meeting before committing to cutting them

DRIVETRAIN:

- fix motor mount holes to be for M4 screws
- back square cutout for back door motor on inside wall of right side

EVERYONE:

- meet and go over CAD with these changes

1/29

Ideas for intake tests:

- take intake off of robot and test pellet collection.
- ***very important one: use something to act as a front plate and check intake of pellets and ECs on the table. This is rly rly important so we can be confident on front plate location. We might have to think abt moving the first row back if this is a big issue.
- with intake off of robot, try adding screw at other end of all tubes to add weight to end
- trying more rigid tubing, or maybe trying rigid alternating every other row on the first row of intake? There is vinyl tubing in the shop. PVC is even harder. This can also be done on the table
- Other tests:
- adding hot glue to ends to make more textures as at ends
- adding criss cross cuts at ends of tubing for friction issue

Other ideas for improvement:

- Using squeegee (?) at bottom of robot for making a front funnel. We can't make our intake wider, but we could make the gathering wider so that it funnels into the ramp. Maybe making the bottom of the inner walls a bit shorter in length and then having an extended part which funnels them into the intake. Could also be 3d printed but have a small clearance off the ground as long as it is high enough to still push pellets, I just don't know how it would impact ramp clearance yet.

1/30 - Team Meeting

Today we met as a team to discuss what went wrong during our intake demo and how we can keep better track of changes. One of the sources for our issues during the intake demo was a discrepancy between versions of the CAD, where one version that the intake subteam was using had changes that were not consistent with the version that the upper assembly subteam had. I decided to work with the CAD to fix the assembly and all mating errors and manage the CAD.

2/3 - Disassembling Ramses and Preparing to fix CAD

This morning, I went to the shop to disassemble Ramses so that the intake subteam could disassemble the robot and replace the spindles with longer versions from the additional rubber tubing. I also compiled the two different versions of the CAD from the intake and upper assembly subteams and began resolving the mating issues between the two versions of the CAD.

2/6 - Redoing assembly and lathing new set of shafts

The distance between the outer side of the intake walls is 7 in, so I'm cutting the shafts to 6.98 in, just so there's a bit of a clearance there if we need to change the location of the intake shaft holes ever so that there's no chance they can run into the drivetrain walls.

Over the past few days, I completely redid the assembly of the CAD and reorganized the hierarchy of the CAD. Previously, the main assembly had the following subassemblies:

- Drivetrain
- Upper Assembly
    - Intake Subassembly
    - Back Door Assembly

Furthermore, there were numerous mating issues and some parts were fully fixed in the CAD, so making any adjustments completely broke the assembly. To fix this, I remade the assembly with the following new hierarchy:

- Drivetrain
- Upper Assembly
    - Back Door Assembly
- Intake Row 1
- Intake Row 2
- Intake Row 3

I also redid all of the mates and only fixed the drivetrain in the main assembly so that all of the other parts were mated to this assembly instead. Furthermore, I redid the middle row intake sub assemblies to fix the mating errors so that I could get correct locations for the holes for the intake motor mounting for *Cleopatra*. I met with the rest of our team to discuss the changes and we agreed that I would manage the CAD so that there were not multiple versions of the CAD floating around.

Lastly, the intake subteam performed tests on the lowest possible height the front plate could extend down over the front row of spindles while still spinning and we determined this height and put it into the CAD.

In the evening, we tested our robot going down the brachi with the new second drivetrain and churros and found that if the robot went down the brachi with the front facing down the brachi, it went down smoothly, while the robot flipped multiple times when trying to descend backwards. We also found that the robot flipping over multiple times loosened the churros a lot, which confirmed our need for a front and back plate.

2/8 - Team Meeting

things we have to do this week (PRIORITIZED):

1. check number of bearings in shop and submit BOM with that and magnets, rename cad files and re-upload, update budget for intake
2. machine back plate
3. cut intake shafts to the correct length and reassemble for electronics testing
4. integrate backdoor mechanism
5. reprint ramp and upper assembly walls
6. add holes on drivetrain walls (ask trent how to do this on mill)
7. reprint electronics box
8. test the rubber part of ramp, test brachi with extra magnets, test with different tension rods and magnet mounts
9. machine front plate, start next robot walls

SCHEDULE FOR WEEK: monday:

- cut churros and shafts
- put holes in drivetrain walls for front and back plates
- machine back plate

middle shaft length needs to be 7.74 in (maybe cut to 7.75 and see if it works so the shaft isnt too short), the other two need to be 6.98 in

2/9 - Cut churros

today in our meeting we should ask mello:

- if our size with the intake sticking out is fine
- if the pushing on the pyramid is only in the last 60 seconds or if he has decided to make it the entire duration

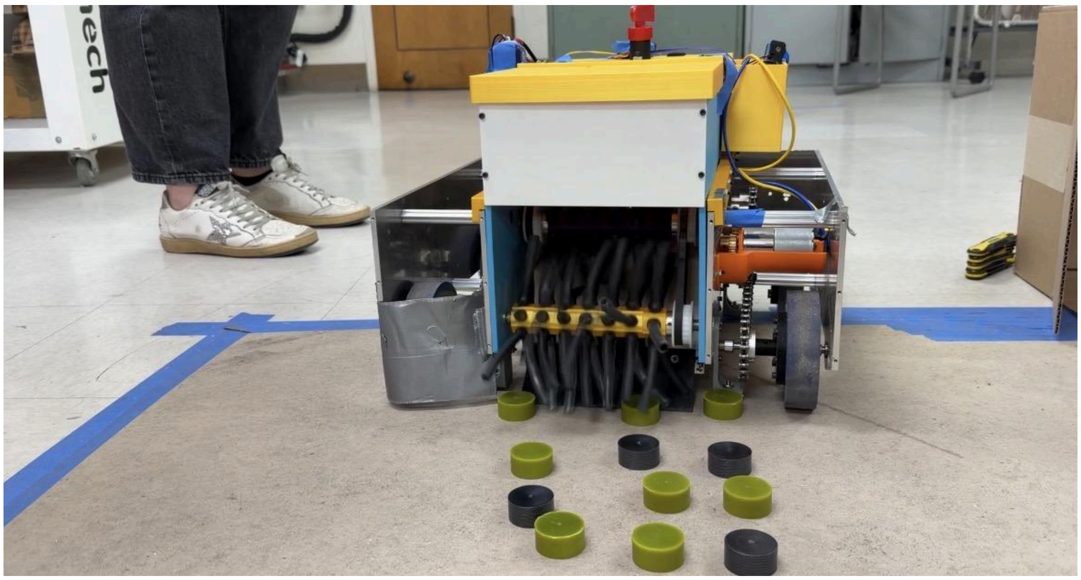
Cut new churros to 6.34 in and started tapping but didn't finish, will finish in the morning and cut shafts
Also 3D printed many parts at the tech hub for the Intake & Mobility Demo II

2/10 - Tapped churros and found shaft stock

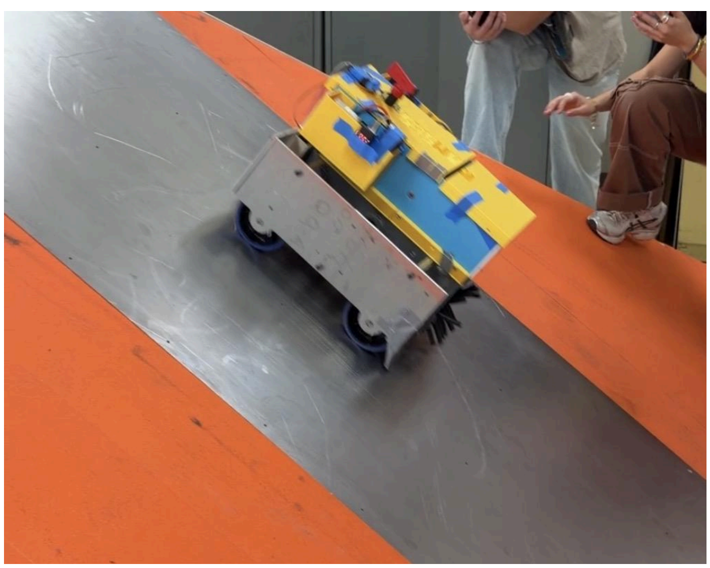
Today I finished tapping all the churros and found stock for the shafts. I realized there were not enough aluminum shafts, so we will be using stainless steel for Cleopatra. Also, since there is a limited supply of churros, we will be making the distance between the inner and outer walls for Cleopatra 3.5 in instead of 3.64 inches like for Ramses. I also set up the back plate for milling and created a version of the CAD drivetrain for Cleopatra.

2/12 - Mobility and Intake Demo II

Today we had our mobility and intake demo II. We found that rougher spindles alternating worked much better and we were able to pick up both ECs and pellets this time compared to the first intake demo. We were also able to climb but noticed that we had some difficulty climbing the first few tests because one of the magnets was loose inside the mount, and another time one of the magnets was repelling from the steel surface and making it harder to climb. We fixed these issues and were eventually able to intake (though, not the most efficiently), climb the pyramid, deposit, and go down the brachi by the end. Pictures from the demo are below.



Ramses intake pellets with a temporary side gathering ramp



Ramses climbing the pyramid backwards

2/13 - Meeting to discuss end of term plan

To do: cad:

- ~~slot in the drivetrain for intake shaft up~~
- electronics container, redesign part of lid in order to work with new electronics management
- change mount for intake motor (through hole,
- ~~change ramp so the speed bump has a smooth protective semicircle bump~~
- ~~add churro to front (+ cutout)~~
- extend funnel walls and add cutout for screwing
- extrude hole for back top churros through the back funnel walls
- add magnet holder for bottom of ramp for magnet to be flat
- ~~add holes to attach system integration through the drivetrain~~
- add holes for top back plate into upper assembly thickness
- ~~update hole miina changed~~
- wider slot for tension rod screw
- change holes for magnet mounts to be smaller

testing:

- test height of front plate (urgent!! - tuesday)
- back door, especially w magnets and secure servo better
- figure out what length the ramp should be with robot full assembled
- see if we have the budget for harder tubing. or just find a way to make the tubing harder

machining:

- fix back plate, and add holes to attach to upper assesmbly
- fix left inner wall old robot for slot
- add other churro holes
- outer wall intake motor holes
- reprint motor mount with motor back a bit for more clearance for gears, also so it doesn't hit the chain
- drill system integration into inner drivetrain side walls
- reassemble old robot
- machine 5 more tension rod holders

bom things:

- more churros
- intake stuff second robot
- harder intake material?

2/17 - Planning for end of term

to do this week: ROBOT 1

- make tension rods
- measure and make sure all the churros are the same length. update the cad to have 2nd robot with longer walls, leave some margin for screws, as well as for a narrower outer to inner wall gap.
- cut churros to correct length
- machine the drivetrain walls
- machine back plate
- press fit things onto shafts

ROBOT 2

- make sure to test front plate height and ask about cost of more rigid tubing first before disassembly
- fix hole locations on back plate. consider adding L brackets

tonight:

- discuss budget
- subteam reintegration
- timeline for rest of term

We met as a team to discuss everything left before the mock (and actual) competition). Below are the TODO's:

Electronics:

- Design new electronics box
    - Organize wires
- Figure out position and design IR sensor holders
- Calibrate driving code (if necessary)
- Calibrate autonomous driving code
- Solder every single connection (including IR sensor to breadboard)

Drivetrain:

- Machine new walls
- Order new churros, two new short churros and two new long churros (+ tapped)
- Lathe down old churros to
- Press-fit wheels to wheels hubs
- Lathe 5 new tension rods
- New chains for robot 2/cut down old chains from Robot 1/see if there are more chains in shop
- Update robot 1 walls → intake motor mount holes + another churro hole + fix back plate + slot up from intake hole
- More spacers

2/17

Intake:

- Final tests with rigid vs flexible tubing
- Fix side slot issue
- Assemble intake for second robot
  - Cut new shafts
  - Print new hubs
  - Make spacers
  - press fit onto shaft
  - Locktight and zipties
  - Repeat for second set

Upper Assembly:

- ~~Update the whole CAD with things noticed at demo~~
- ~~Make new electronics storages~~
- ~~Add cut extrude for all nits (hexagon)~~
- Compile list of specific assembly order.
- Print all the parts.
- ~~Machine back plate for robot 2~~
- Fix back plate for robot 1
- Decide on Front plate
- Machine front plate
- ~~Change back upper assembly walls~~
- ~~Change CAD of dumping door to account for magnets~~
- Make servo not move in box
- Lock nuts everywhere
- ~~Print new back doors~~
- ~~Extend funnel walls~~
- ~~Change back ramp to account for magnets~~
- ~~extrude hole for back top churros through the back funnel walls~~
- ~~add holes for top back plate into upper assembly thickness~~
- ~~wider slot for tension rod screw~~

2/19 - Electronics box/upper assembly design and new magnet mount design
goals for today (anya):

- assemble old robot for electronics testing
- new chains
- new tension rods
- prototype gathering area w cardboard

I ended up working on the CAD of the new magnet mounts to include a small area for filling the gap between the old magnet mounts and the ramp where the pellets were getting stuck. This geometry was pretty complicated so this was rather challenging. I started the print for them at night in the tech hub. I also CADded a quick prototype for a 3D printed attachment on the front wall for the gathering ramp which would prevent the robot from driving over the pellets and help the pellets get into the intake ramp.

I also discussed the electronics container redesign with Hannah and Daniel to find a way to keep the wire management as simple as possible. We found a solution that did not involve mounting the switch to the lid of the robot, which was extremely helpful because it allows us to open the lid without being constrained by the length of the wires. We are also now having the electronics boxes be a part of the upper assembly walls.

2/20 - Testing front gathering area
Today I worked with Ana to test the intake with a prototype of the gathering area mount. This seemed to work much better, and the magnet mounts seemed to work really well to fill the gap. I also adjusted the CAD of the front ramp so that the additional piece of rubber could be added so that there are no gaps that the pellets could get stuck in.

2/24 - Testing 3D printed parts and CADding last parts

I added some other things to be printed. the order of priority on printing these is:

- new front ramp with shifted holes for rubber ramp
- new intake motor mounts for both ramses and cleopatra
- gathering area holder prototypes for ramses. these are still for testing sizing (don't account for IR sensors' locations)
- 0.886 in clearance magnet mounts (need 2 printed)
- magnet mount that fill gap for both sides of cleopatra

I also disassembled the robots

To do:

- Update front wall cutout height to 3.75
- design top button presser for lid
- Add holes and hexagon for both lids for mounting

TODO:

- adjust front ramp because bump is to small
- print new front ramp
- check if new electronics cover works
- print 3 new covers
- put holes for button pusher in front of lid
- print both front lids
- adjust back plate holes

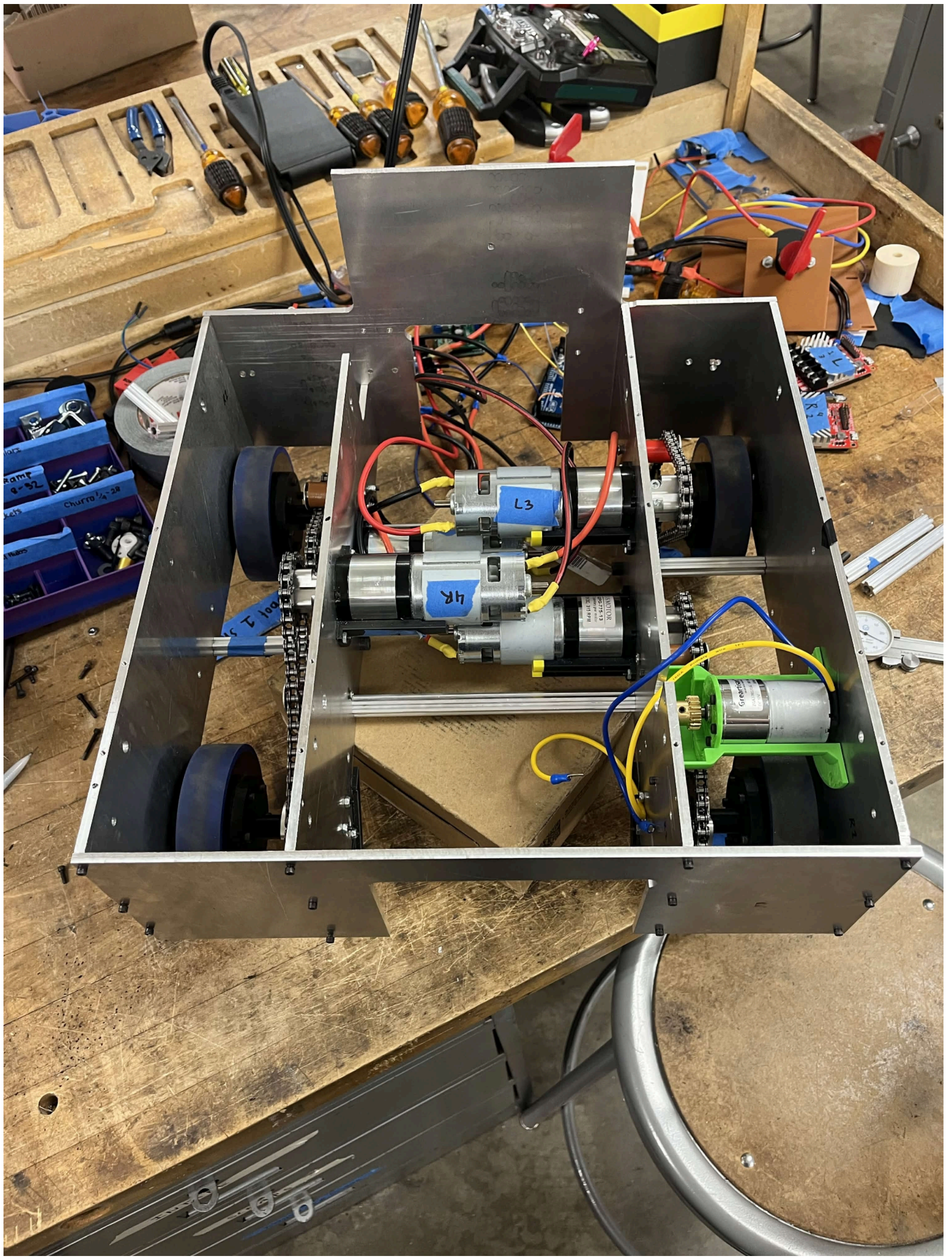
2/25 - Picking up prints and preparing to mill front plates

I picked up the below prints for the mock competition:

3D printed parts for Ramses

I also adjusted the CAD of the front plates for Ramses and Cleo because the side that the pulley was on for the intake switched, so I increased the width of the protection part for the side with the pulley and decreased it for the other side. Then, I measured and sketched the area of the front plates on the sheets of aluminum we had and did rough cuts for both front plates.

2/26 - Milling front plates
I used the mill with two vices to make both front plates for both robots and tested mounting them on both robots. The holes all seemed to align well for Ramses and Cleopatra and worked well when we tested with the side drivetrain wall and front and back plates. An image of the drivetrain assembly is below. We began full assembly with the upper assembly and found that when the upper assembly and intake was not a part of the full assembly, everything seemed to fit together better.



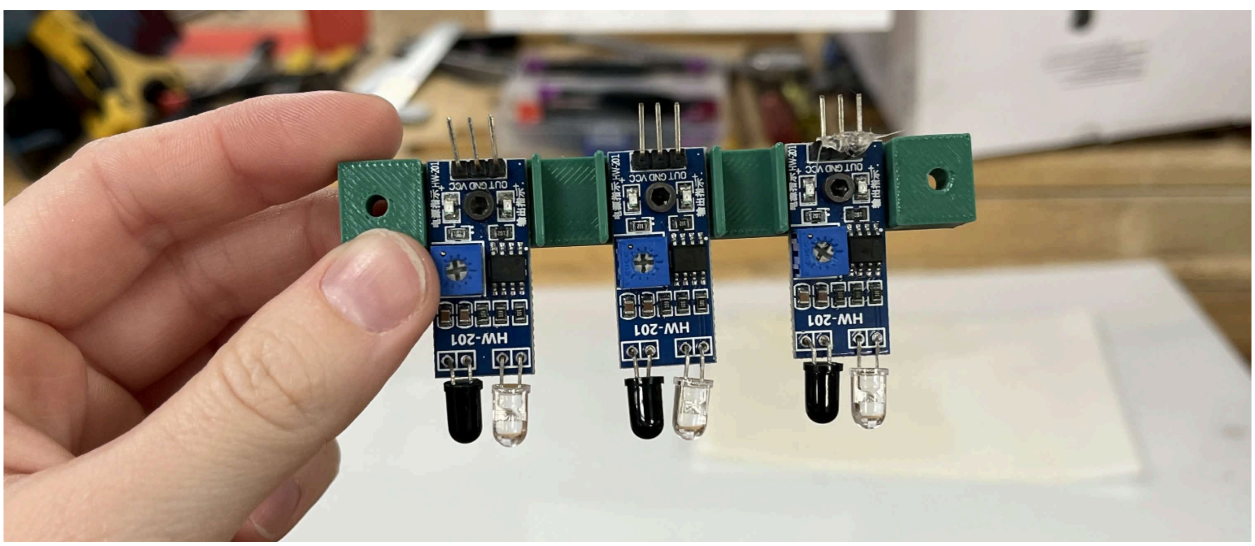
Assembled Ramses drivetrain with front and back plates

2/27 - Full reassembly and testing of intake

We spent the whole day reassembling Ramses and Cleopatra and testing the intake in preparation for the mock competition. We noticed that the original mounts designed for the intake motor seemed to not be sturdy enough to keep the intake motor running without movement and resulted in the gear between the intake motor and the second row of intake not meshing and the motor stalling. I redesigned the mount for the motor to have the motor closer to the intake row and to reinforce the mount by having it screw into the outside drivetrain wall as well and have thicker walls so that the motor is less likely to move and began the print of this robot.

During the reassembly, we encountered many problems. Once we put the upper assembly into the drivetrain for the full assembly, we noticed that the holes that went into the front and back walls did not fit as well. We had to put a lot of strength in to compress the walls to screw anything in. We were able to replace the intake motor mounts, but noticed that the intake motor got extremely hot still when intaking pellets and that the pellets frequently got stuck when going up the ramp.

We also 3D printed the beacon presser for Ramses and the IR sensor holder which I designed with Daniel earlier in the week and installed them on Ramses.



IR sensor mount for Ramses and Cleopatra

2/28 - Mock Competition

TO DO for BEFORE 1 PM

- finish assembling both robots. We need to test intake in iterations
- to assemble:

CLEO: (blue and yellow motor cables)

- add motor mount to Cleopatra: This means removing the left OUSIDE WALL entirely to prevent breaking the mount. Also, Please don't lose SPACERS and keep in mind where they each go on what wheels. If you need to label, do so. also please keep in mind all bearings so they don't pop out.
- put front and back plates on (because you need to take these off to put take off the outside left wall)

RAMSES:

- change the motor mount if needed. (same process)

We also installed flat heat sinks on the intake motors (we could not find circular heat sinks) in an attempt to cool down the intake motors.

Mock competition results:

Since we did not have access to a testing area for the autonomous portion, we had to hard-code the autonomous portion which seemed to work well. The intake unfortunately stalled frequently during the competition and we were not able to pick up pellets for a good portion of the competition. Additionally, wires frequently fell out during collisions, resulting in a loss of control from the RC controllers. Overall, the mock competition did not go as we had hoped and we will be focusing our attention towards fixing the intake leading up to the actual competition.

3/2 - Intake motor selection and planning

MONDAY:

- ~~new intake motor order and bevel gears~~
- ~~test intake and gathering area. check if we need to make new ramp~~
- ~~test driving up pyramid with both (check chains, retighten tension rods)~~
- ~~print new wheel hubs at tech hub~~
- ~~start dissassembling~~

TUESDAY:

- cut, lathe, and tap long rods for tension rod and put holes in drivetrain
- cut more spacers on drivetrain (for Ramses) and for intake
- ~~cut rubber ramp and glue. find solution to it ripping where the holes are~~
- replace wheel hubs and switch to gray wheels for the beaten down ones
- figure out magnet mounts on Cleo because it is not sticking to ramp
- purchase new battery pack
- add holes to front plate for gathering area. cut and glue new rubber for that
- test line following ?
- (morning) CAD with new intake motor mount out of aluminum. waterjet plate to face mount the motor. test with shop bevel gears
- (night) 3D print new integrated gathering area

WEDNESDAY:

- finish making intake motor mount and testing intake
- test new gathering area
- integrate new battery pack
- test line following

THURSDAY:

- pyramid climbing demo in gym 3 - 5:30 PM
- hot glue wires better

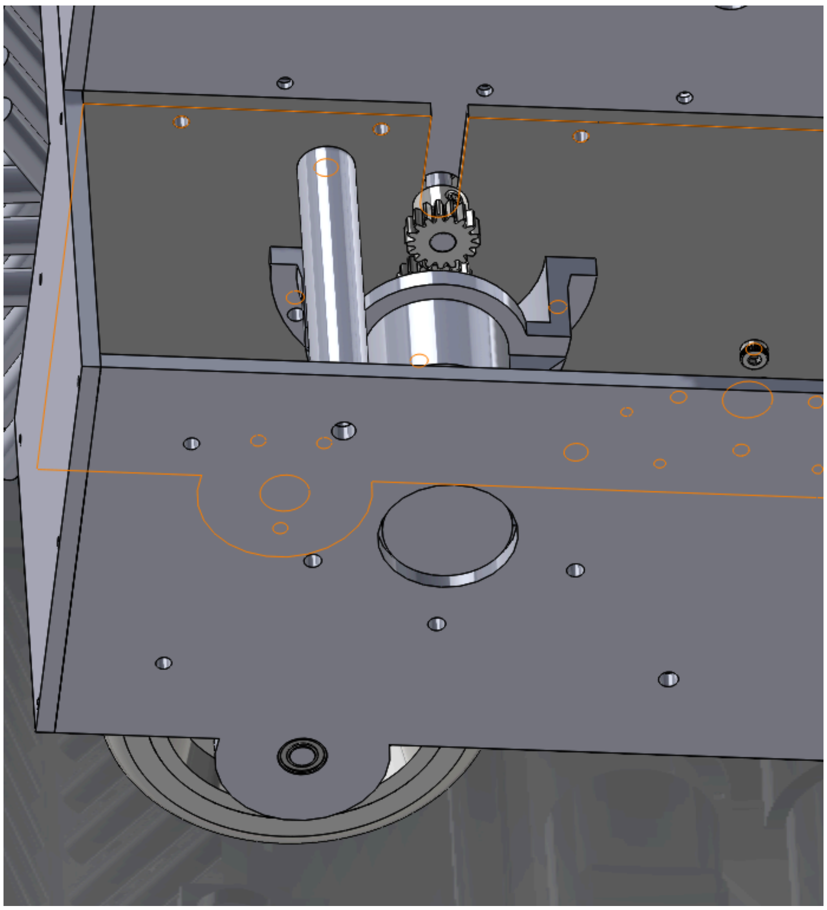
FRIDAY:

- buffer ?

I spent much of the time today researching a new motor to replace the original intake motor so that we could correctly spec the motor. We met with Prof. Mello and he graciously allowed us to go a little bit over budget to purchase two new intake motors. I also went into the shop with Ana to test the intake and determine the best way to mount the motor options that we had.

3/4 - CADding motor mounts

Today we decided the motor mounts that we will be using for the intake motors and made the walls much thicker with improved support. I began the 3D print for this motor mount. We realized that with the new motor, we would have to put a small hole in both outer drivetrain walls so that the motor could stick out of the wall. Miina worked on making this while I made the CAD. I also worked on the CAD of the gathering area rubber ramp mount and realized that it would be best to install the rubber flat on the outside of the front plate for the side with the IR sensor mount since the is very limited space between the front plate and wheels.

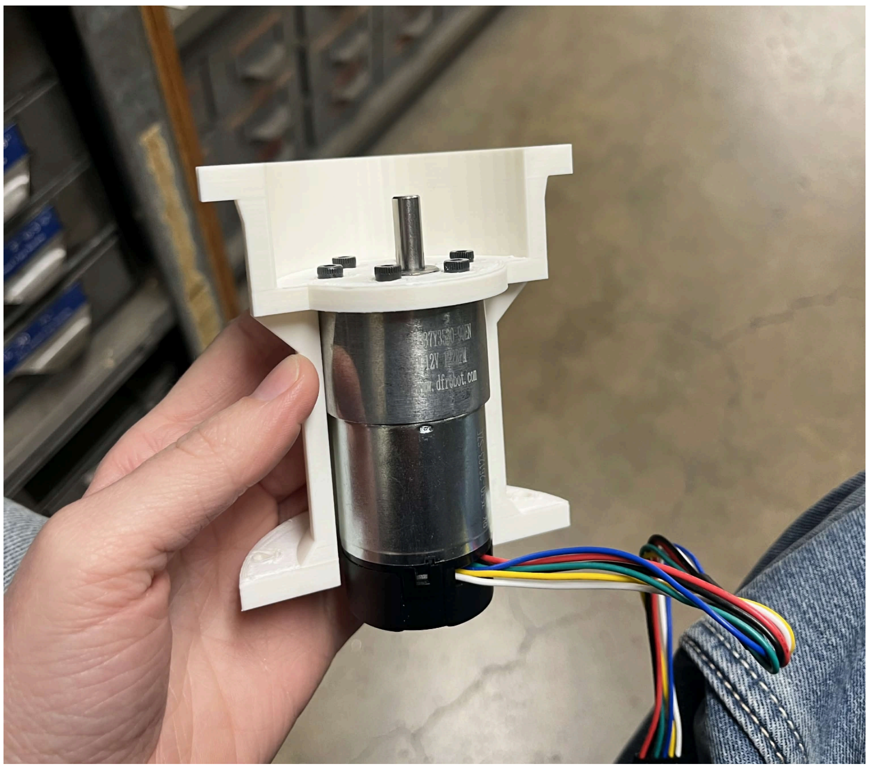


CAD showing hole in the outside drivetrain wall where the intake motor will be sticking out a bit from.

Unfortunately, the first version of the 3D print for the new motor mounts was overconstrained and we could not fit the intake motor into it, so I had to adjust the CAD and reprint them. We had tried shaving down the 3D print but it was not worth the time since it was quite difficult.

3/5 - New intake testing

I picked up the new intake motor mount print and the intake motor successfully fit in the print. We partially disassembled it in order to install the new intake motor and we found that the new intake motor worked *much* better than the old one. We ran the motor for four minutes straight intaking pellets and it did not stall once, which confirmed our selection of the motor with the stall torque and RPM. The motors did get a little hot at the last minute but still not as bad as the first motor. The motor also ran well even when not at max RPM so Daniel suggested having like an "eco friendly" mode where it runs a bit lower than max rpm



New intake motor in 3D printed mount

The rest of the day was spent reassembling and testing. I also lathed and tapped mini churros which screwed into the outer wall of the drivetrain on both robots which stuck out further than the amount the intake motor stuck out of the drivetrain so that it protected the intake motor from collisions.

3/7 - Magnet mount redesign

In the morning, we realized that something went wrong during reassembly causing both robots to not be able to climb the pyramid. We conducted many tests of climbing and found that the root cause of the issue was that the magnets were mounted not directly below the drivetrain wall but rather to the side of it, which caused the magnet mounts to torque a bit and change clearance off of the ground for different mounts, which caused the driving to veer a bit when climbing. To fix this, I redesigned the magnet mounts to sit directly below the drivetrain wall instead so that there is no torque on the mounts which would prevent bending. I also changed the mounting for the magnet mounts to make them a slot rather than going around the driving shaft so that they could be swapped out without disassembling the robot.

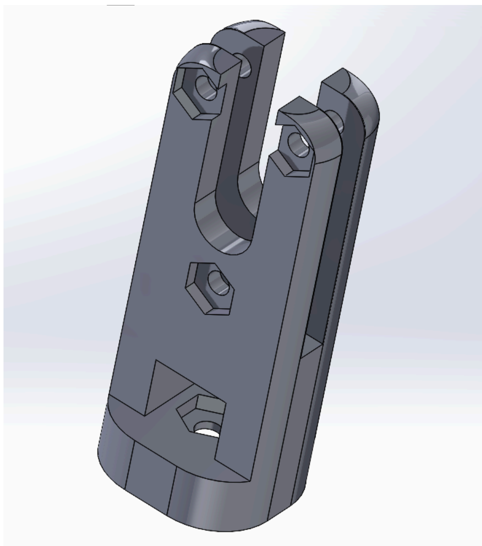
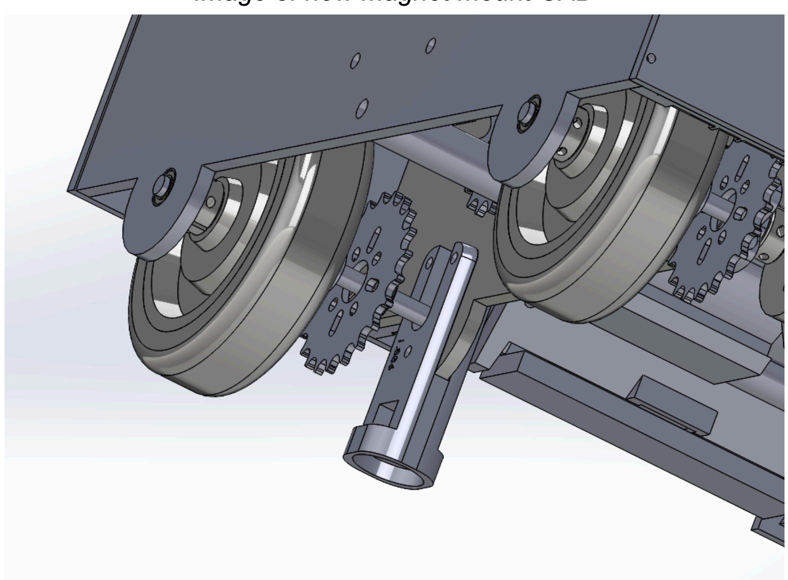


Image of new magnet mount CAD



Magnet mounts in the full robot assembly.

3/8 - Magnet mount reinstallation

We spent all day disassembling to remove the old magnet mounts, adjusting the new ones, and reinstalling the new magnet mounts onto the drivetrain. We noticed that the tolerance on the prints was a bit too small and resulted in making the installation of the magnet mounts very difficult. Additionally, someone had glued the magnets into the old mounts which also made removing them difficult. We also realized that because of the flange, the slot for sliding in the mount was too small and it broke on one of the mounts when we tried to install it. To fix this, we sawed off half of the magnet mount's wall attachment and that seemed to fix the issue. Lily also printed a version of the magnet mounts with this cut already present so we didn't have to saw the second set of mounts, as shown below.

3D printed adjusted magnet mounts

At night, we tested driving up the pyramid with the swapped mounts and climbing was successful. At the end of the night, we tested climbing with driving forwards, which also worked. However, when driving down the pyramid in the other direction, we unfortunately drove too fast and the robot flipped over and the upper assembly walls cracked. This was very unfortunate, but none of the bearings were damaged. Since the entire upper assembly was glued and we did not have time to reprint or reassemble before the competition, we taped the wall back together and brainstormed a way to reinforce the walls.

3/9 - Rubber gathering ramp installation and upper assembly wall reinforcement

- put on gathering area mount. cut rubber for last piece
- glue magnets ?
- screw in back side of intake motor mount into the outside drivetrain walls
- fix cleo front plate and add 4-40 washers
- add back weights to robots
- add churro bumper to protect intake motor sticking out
- practice driving and discuss strategy
- pack bag for the competition

In the morning, we went to the shop and water jetted two triangular pieces of aluminum with scrap metal we had from earlier in the term and screwed it into the front plate to reinforce the upper assembly walls on both robots, especially the one that flipped and cracked last night. We also 3D printed backup parts for a few other parts of the upper assembly. I also cut the rubber pieces for the gathering area, screwed them into the mounts and screwed the mounts into the front plate on both robots, and tested in the intake with these and they seemed to help a lot. We also zip tied the heat sinks on the new intake motor in case of overheating during the competition.

In the evening, we took the robot to the gym to test climbing up the pyramid. The tests of intake and line-following seemed to work very well. Unfortunately, the test of climbing worked at first but later failed because one of the 3D prints scraped against the ground and cracked. To fix this issue, I once again changed the design of the magnet mounts to be much thicker so the 3D print was less likely to fail and printed two sets of them, one to replace in the morning, and one as a back up in case any other prints cracked in the competition.

3/10 - Competition Day

In the morning, we showed up at the gym early to swap out the broken magnet mounts for the ones that I printed. We also trimmed the rubber from the gathering areas slightly and tested that the intake worked as we expected.

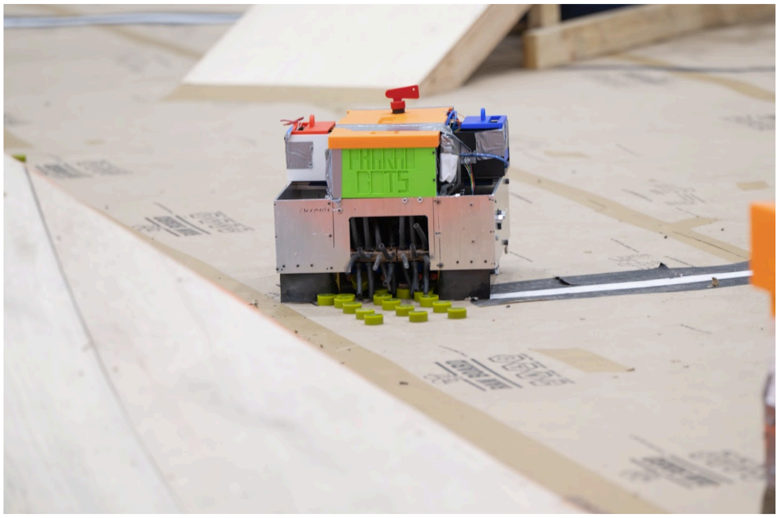
The competition went much better than we had expected. Our intake was consistent, our game strategy was extremely effective, and we were able to it the beacon first all but one of the rounds of the competition. We still encountered some problems during the competition, but we were able to effectively find quick solutions for these. At one point, our robot rolled down the face of the pyramid and the switch handle broke, but we had another as backup and an extra 3D printed part for the upper assembly that we could replace during our time out. Another time, the AA battery pack we had for the Arduino died, so we used a portable battery back to power the arduino for the rest of the competition. In another instance, another one of the magnet mounts (that we *hadn't*) replaced that morning broke off, so we replaced them with the second set that I printed the night before.

In between the round-robin stage and the semifinals, our wheel hubs came loose from the shaft as the press fit wore down. This was pretty expected since the wheel hub was 3D printed due to lack of time and budget to machine them out of aluminum. Luckily, we had a second set of backup 3D printed wheel hubs. We called our third and last time out to disassemble the outside of our robot, remove the shafts, and switch out the wheel hubs. This was very difficult to do in the time constraint and we had difficulty getting one of the shafts back into the bearing, but it held up for the rest of the competition.

Due to our strategy, consistency, and quick thinking when problems arose, we ended up earning the highest score out of any of the teams that day and won the entire competition.

Ramses descending the pyramid

3/10



Cleopatra intaking pellets in the autonomous portion

Team victory!