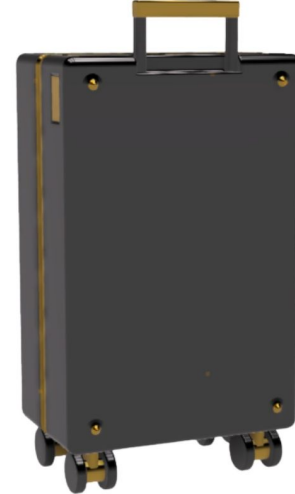# Sanitable

An automatic table sanitizing device

Design Review by Yuki Oyama

Context

Cornell MAE 4340

Innovative Product Design via Digital Manufacturing
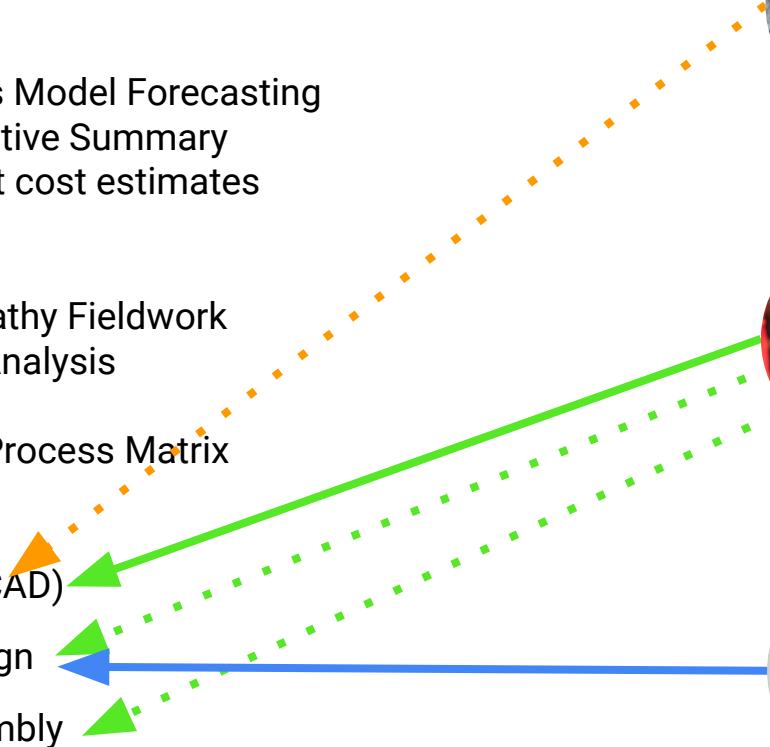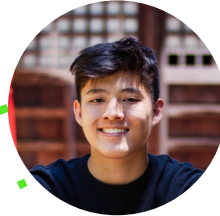
Context | 7 Person Project

Business:
- Market Analysis/Bass Model Forecasting
- Mock Financial Executive Summary
- Mass Production/Unit cost estimates

Human Centered Design:
- User Interviews/Empathy Fieldwork
- Competitor Product Analysis
- Conjoint Analysis
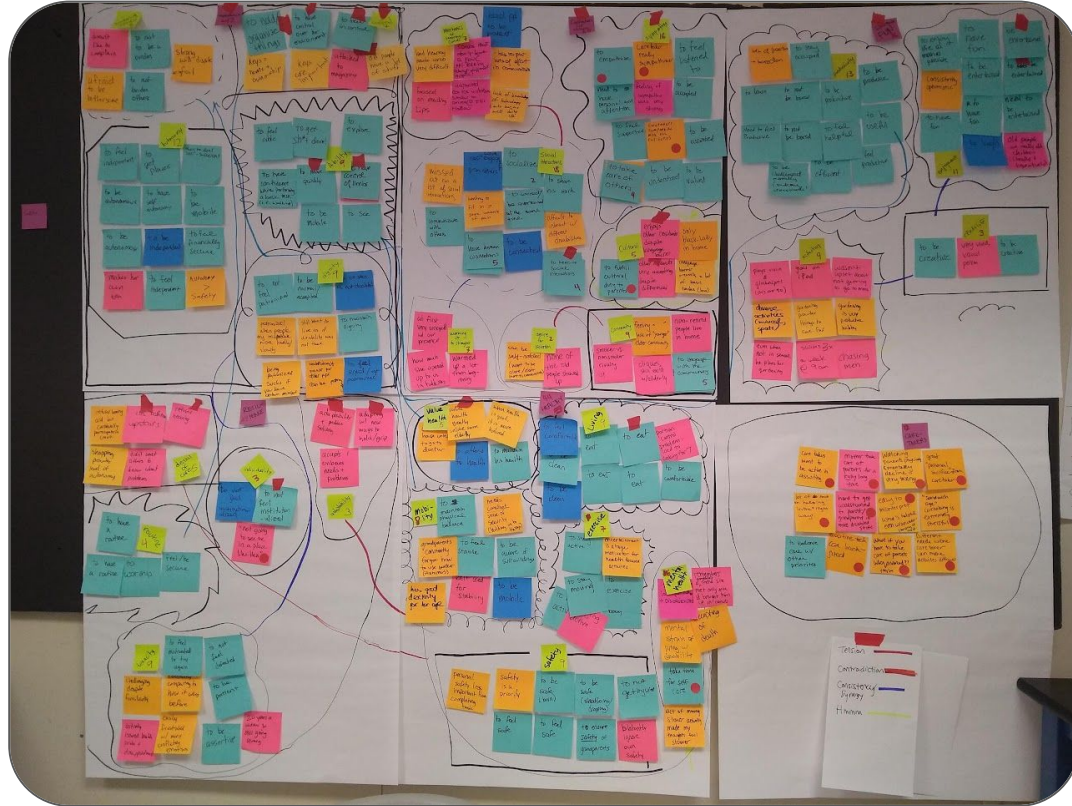- Analytical Hierarchy Process Matrix

Mechatronic Design:
- Mechanical Design (CAD)

- Electrical Circuit Design

- Manufacturing/Assembly

User Interviews

1st P. Who: Where: When:
Penn State Football Tailgate Immersion
9/18/21

What: How:
- People from my childhood reconnected for the first time in a while
- I/we were not concerned about COVID
- I felt like the new normal was the same as before

Why:
- I felt at-home and comfortable in the "new normal" environment even with lack of precautions
- One of those "can't miss" events for me
- Does it make sense for PSU students to wear masks in classrooms after a massive gathering like this?

N: Socialization, reconnection, normalcy, fun, map/sense of directio[...]
[...]gy to make it through a long day

[...]nic for a day, should I have been mo[...]
[...] normal

[...] covid, no masks, Auburn fans are fri[...]

2nd P. Who: Where: When:
3 kids(10, 13, 16), cat cafe, at 2pm on 9/12.

What: How:
Became friends with one person in maryland through playing Call of Duty, separated from pretty much all "irl" friends due to isolation, but snapchatted the CoD friend everyday.

"Covid didn't affect me because I was isolated to begin with"

N: relaxing, having fun, Connect with people

I: cat can provide a 'blank slate' identity for introverted people to interact with, COVID has lead to tension within families, kids have found unique friend groups outside of school thanks to COVID

S: unexpected friend loss, large age difference, being at a cat cafe

Why:
- You feel strong feelings of isolation during Covid
- You have difficulties forming strong friendships
- You aren't used to interacting with your friends who you would see in person online, and it's a really different dynamic

tensions/contradictions/consistencies/synergies/

2nd P Who: Where: When:
Roommate Max, Apartment
- info science major that plays frisbee

What: How:
-Interned at office mon-thurs and virtual rest of time, read articles & met w/ other people
-Food trucks would come on thursdays and could meet other people more easily
- Worked from home with family
-Went to friend's house to play videogames

Why:
Difficult to establish boundaries with parents due to covid restrictions
Relieving to be able to leave the house and hang out with friends
Had to intentionally make time to spend with girlfriend

N: to be able to escape, balancing working from home and in-person, have [...] people

I: maintaining relationships & friendships are difficult when in person interac[...] in-person/remote work environment is becoming more common; certain rela[...]

S: Despite both working from home didn't really interact with mother; relatio[...] that in person workers felt welcome

Who: Where: When:
3rd P. Hotel Lobby, Friday afternoon

What: How:
- After hotel breakfast, lobby is relatively empty
- People kept coming to lobby for food but then saw breakfast was over
- Teammates studying in lobby
- People came and grabbed coffee and tea [...]t by the entrance
[...]re was only a small water dispenser
[...]he guests didn't know where to drop
[...]r keys after the basket were emptied

[...]to have a convenient place to drop keys; need to drink water; need to fill tall water

[...] get really thirsty in hotels; Front desk workers don't often know when coffee is empty

[...]was no water fountain in hotel

Why:
- People were frustrated at how hard it was to fill up water
- Filling up water was slow
- Water container was short so people had to fill up cups then pour into water bottles to fill up bottles

tensions/contradictions/consistencies/synergies/

tensions/contradictions/cor[...]
adictions/cor[...]

Who: Where: When:
[...]
[...]pokelava (weekday lunch

What: How:
Line length varies a lot
Mobile orders interspersed with people ordering

What: [...]
much (short on weekday, much slower on friday evening)

Why:
-

N: separate mobile orders from in person line, increase flow of customers through store, more space in waiting area, More staff to prepare food

I: having the toppings customizable slow, speaking thru window difficult for communication, doing multiple mobile orders at once saves time

S: Weekday lunch hours do not mean a long line; mobile orders are starting to outpace ordering in line; mobile orders are prepared in the same space as the people's in line

tensions/contradictions/consistencies/synergies/

Who: Where: When:
2nd P. , Transgender Artist living in San Francisco, 9/10/21
What: How:
-Works at a nonprofit "Pirate Store" that sells products to fund education for kids that come to learn at the store. The kids even get to publish their own books that get sold in-store.
-Thinks COVID has made people appreciate social interaction more- enjoyed seeing kid and parent enjoy the inside his shop
-COVID affected them a lot being alone in the shop, since they love being around people
-Feels super stressed out in public transport because of homeless people that are less likely to be vaccinated
-Really enjoys wearing masks (of different types), and thinks they are attractive **Extreme User!**

Why:
- You want [...]
though it is [...]
want to co[...]
seeing pe[...]
- You under[...]
consequen[...]
have acce[...]
afraid of c[...]
students a[...]
- You find c[...]
have ever[...]
appear wit[...]
doing it for[...]
so.

N: Social distancing, creating art, interacting with people, staying in touch with family
I: Areas of highly concentrated people can cause significant anxiety and stress for people that are extremely COVID-safe, and can affect their mood over the next few days (or longer), Public transport specifically seems to be the primary source of COVID stress, Some people have become used to masks, People appreciate social interaction more because of COVID
S: User enjoys wearing masks and collects different styles of them,

Who: Where: When:
3rd p. Cornell
Law School
Vlog

What: How:
Law school assigns a lot of reading which takes up much time and is expensive
Tried to get work done consistently throughout day

Why:
-Excited for starting law school
-Interested in getting to know the professors
-Not stressed, but is early in the semester

N: manage time and increase reading speed, balance work with socializing; find times where her buffs mature are free simultaneously

I: Speed at which work can be done is as important as the volume of work assigned, to socialize all people need simultaneous free time; personal connections to instructors much harder remote than in person

S: People still need to buy books making carrying difficult, disperses reading throughout the workday, law school student priorities different than undergraduate student

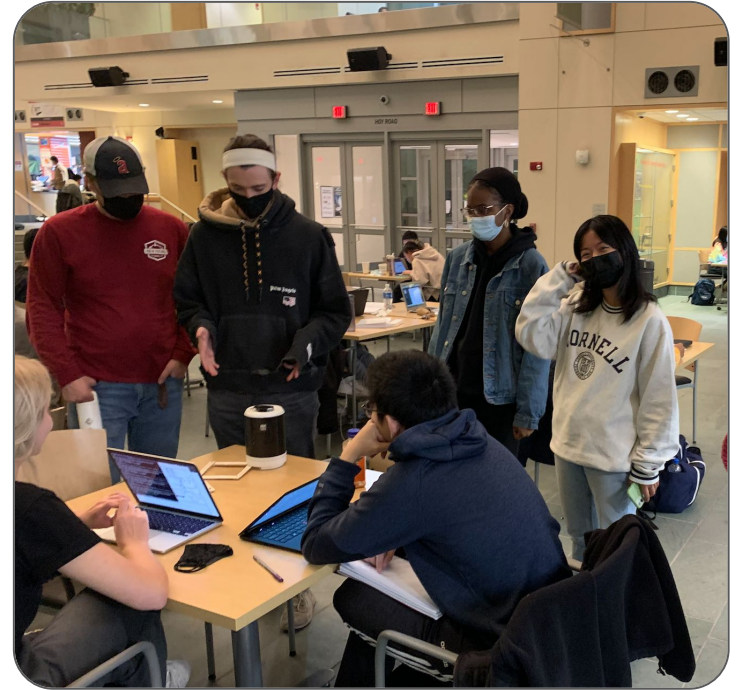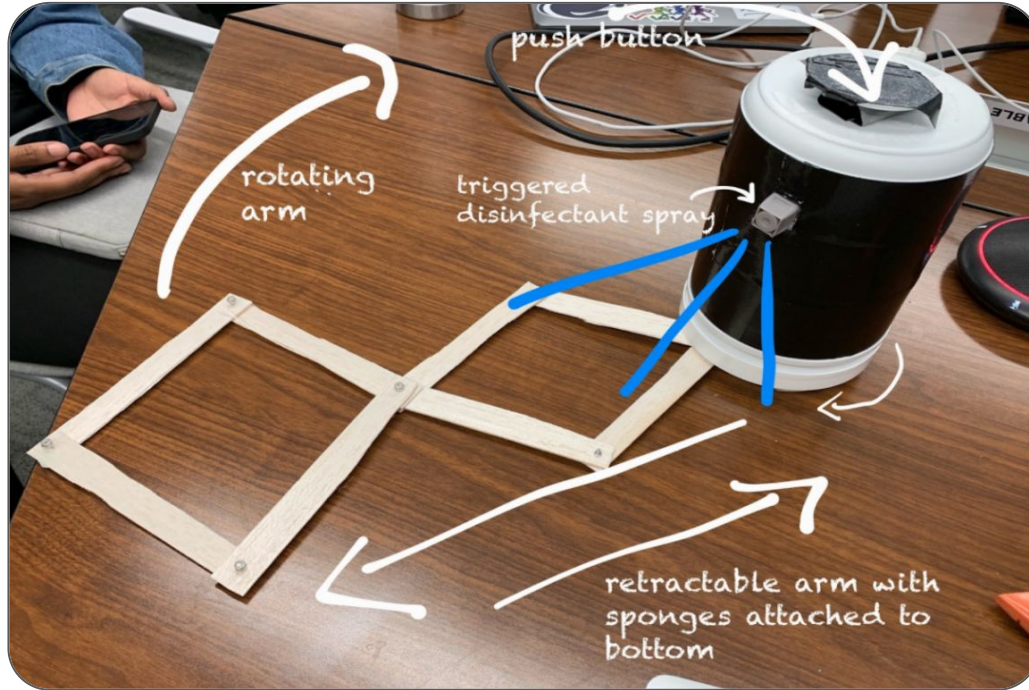tensions/contradictions/consistencies/synergies/

Brainstorming

Problem Discovery

Food service workers find it extremely inconvenient to **constantly sanitize tables** after every use and cumbersome to flip "safe to use" cards over and over.

v0 Prototype | Early Prototyping

rotating arm

push button

triggered disinfectant spray

retractable arm with sponges attached to bottom

Common Table Sizes

	2 seater dining table size	4 seater dining table size	6 seater dining table size	8 seater dining table size	10 seater dining table size	12 seater dining table size
Round dining table sizes	Min: 2'6" Ideal: 3ft	3ft (92cm) 4ft (122cm)	4'6" (137cm) 5ft (152cm)	5ft (152cm) 6ft (183cm)	7ft (213cm) 8ft (244cm)	8ft (244cm) 9ft (274cm)
Rectangle/Oval dining table sizes	2×2'6" (61x76cm)	4x3ft (122x91cm)	6x3ft (183x91cm)	8×3'6" (244x110cm)	10x4ft (305x120cm)	12×4'6" (366x135cm
Square dining table sizes	2'6" (76cm)	3–5ft (92cm)	4–6ft (122cm)	6ft (183cm)	7ft (213cm)	8ft (244cm)

Requirements & Priority

	Improvement Direction	↑	↓	↓	↓	↑	↑	↓	↑	↓	↓	↓	↑
	Units	n/a	m^2	s	W	MPa	n/a	s	s	s	m^3	n/a	n/a	n/a
	Importance Weight Factor	Spray Warning	Cleaning Area	Time to clean	Power consumed per clean	Material Rigidity	Water Resistance	Time to install	battery life	Time to service	Profile and size	Number of moving parts	Stationary	Adaptability to table size
Customer Requirements														
Avoid getting sprayed	4													
Table clean	5											3		9
Table dry after	4		9	1								3		9
Don't get hurt													3	
Easy install	2							9				3	1	
Maintenance	3									9				
Low power									3			3	3	
Non-obtrusive												9	3	
Doesn't break easily						3	3					3	3	
Mostly automated														3
Water Resistant	2						9							
Raw Score		38	83	9	18	14	32	21	6	27	60	30	17	90
Relative Weight (%)		8.54	18.65	2.02	4.04	3.15	7.19	4.72	1.35	6.07	13.48	6.74	3.82	20.22
Rank Order		4	2	12	9	11	5	8	13	7	3	6	10	1

Takeaway
(Highest Priority Requirements)

1. Adaptability to table size
2. Maximizing Cleaning Area
3. Minimizing Profile and Size

Design Brainstorm

Removable Cap

spray

Spray

Bottom View

VHB adhesive

Top View (Uncapped)

Dynamic

static

Sprays as dynamic section rotates

Bottles containing disinfectant

Brush actuates down

Bearings

Chain

Motor

Disinfectant Fluid
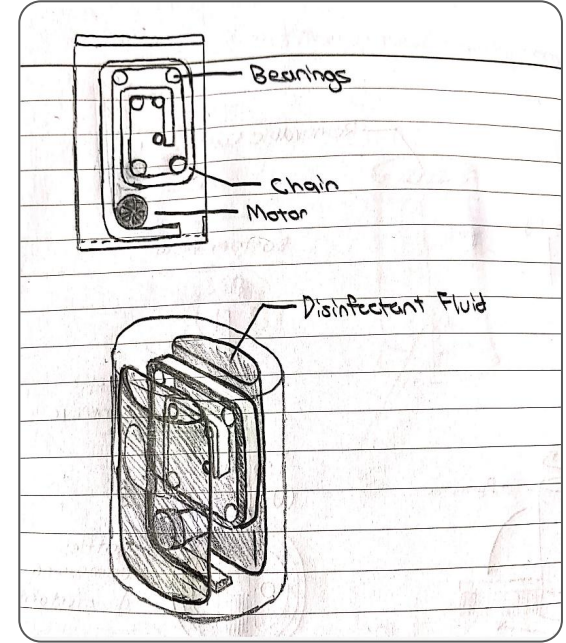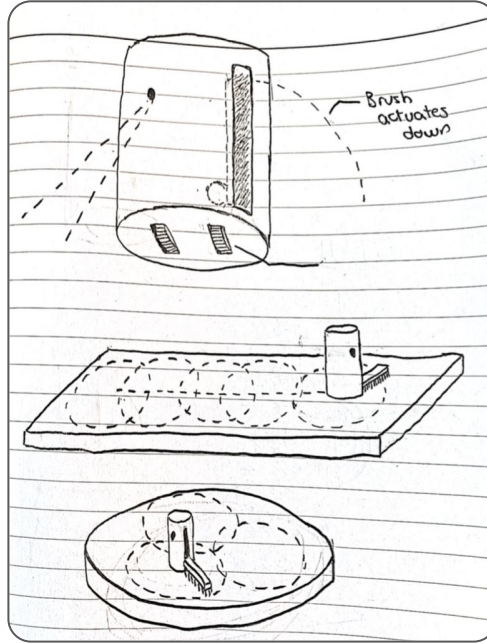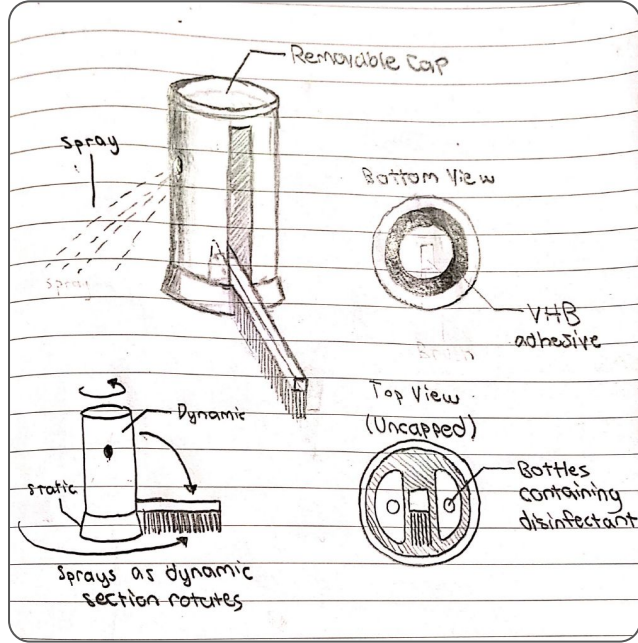
Design Choice
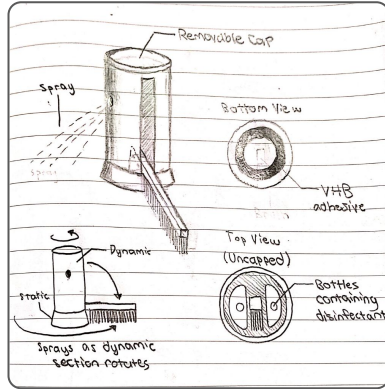
Pros	Cons
Simple mechanical design	Lack of table size adaptability
Simple Maintenance	Large {Product Size]-[Area Cleaned] Ratio
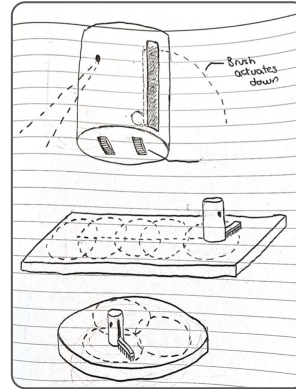
Pros	Cons
Table Size Adaptability	Electromechanically complex
Smallest [Product Size]-[Area Cleaned] ratio	Power consumption
	Slow to clean
	Reliability concerns (drop, water/dust proofing, theft, etc.)
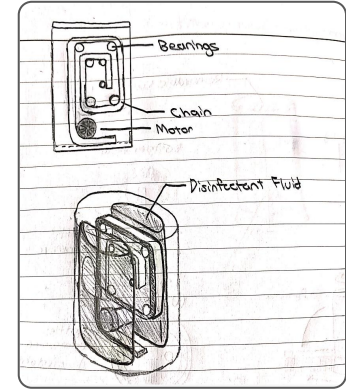
Pros	Cons
Table Size Adaptability	Mechanically complex
Small [Product Size]-[Area Cleaned] Ratio	Difficult maintenance
Fast to clean	

Product Vision/Concept | Key Features

Minimal ID

- White cylinder
- Button on top to actuate cleaning motion
- Easily removable cap on top

Stationary Sweep

- Extension of wiper to edge of a table
- Extension can be programmed for square or circular
- Sits in the middle of table and sweeps in circular motion

Disinfectant Deployment

- Equipped with internal disinfectant supply
- Tube passing through black wiper deploys disinfectant

Product Vision/Concept | Functional Decomposition
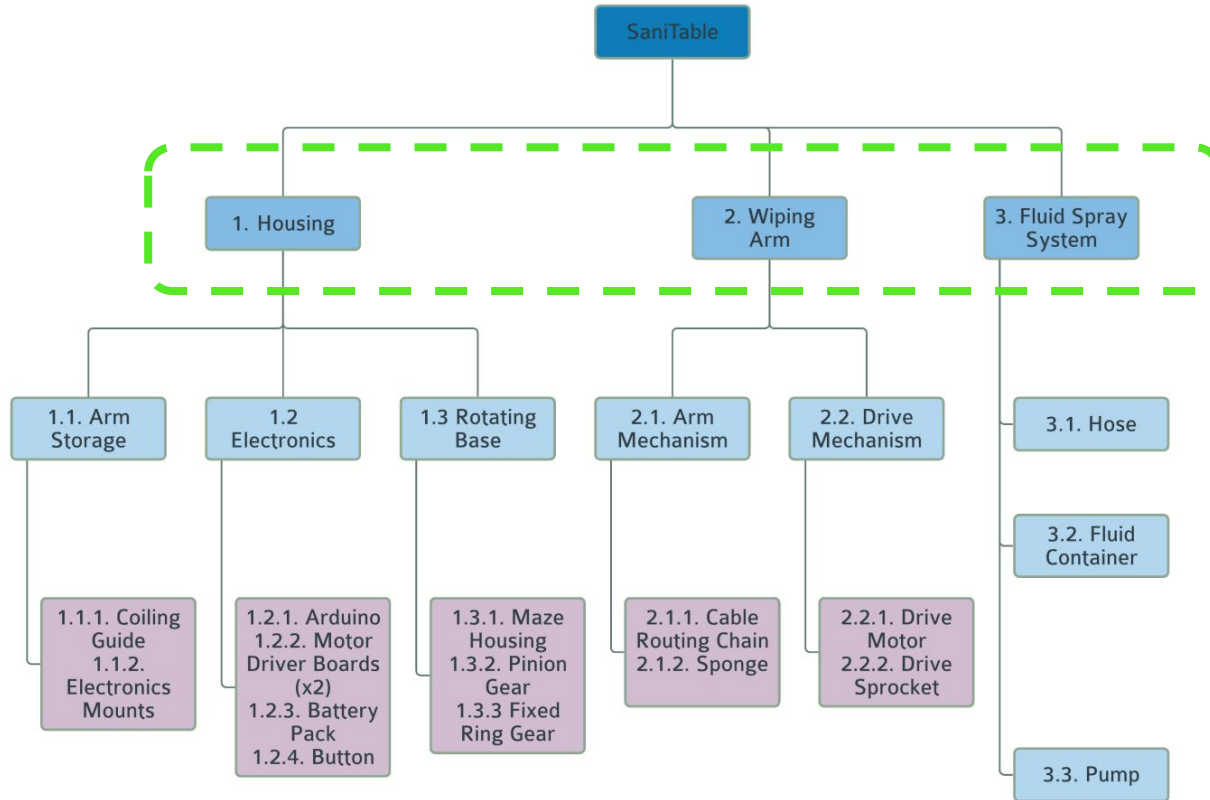
Rotation (Sweep)

Base plate

- Remains static w.r.t. table

- Adhered to table via VHB Pads

- Secures device in the center of table

Internal Gear Mechanism

- Motor attached to top enclosure

- Spur gear on motor interfaces with internal gear
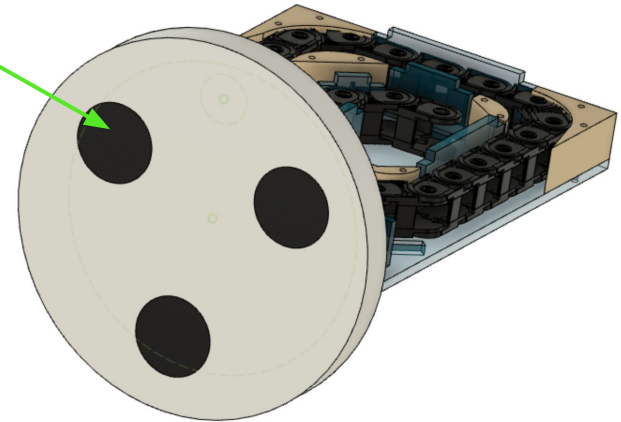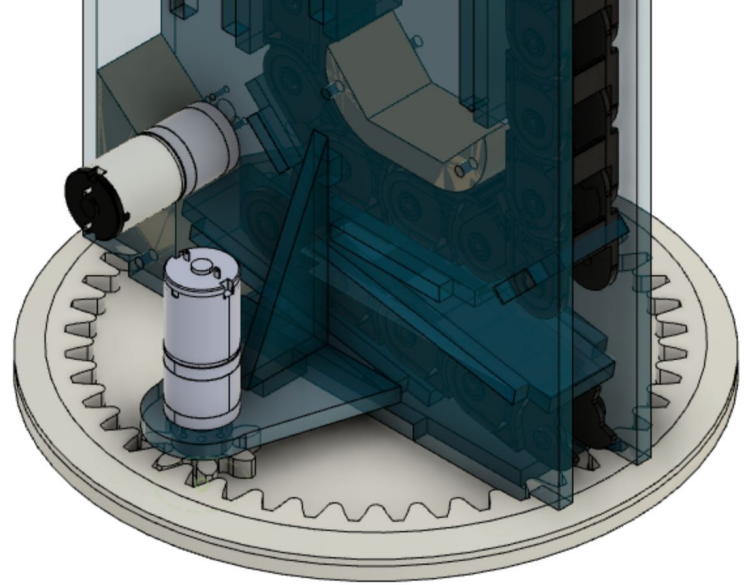
Rotation (Sweep) | Details

Point of Contact

- Contact only at the perimeter of the base plate

- Minimizes friction, while distributing load
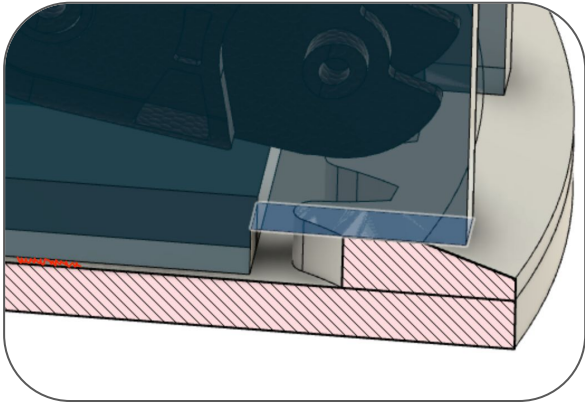
Centering & Mounting

- Press fit axle in bottom plate

- Interfaces with through hole on wiper storage component keeping rotating assembly centered
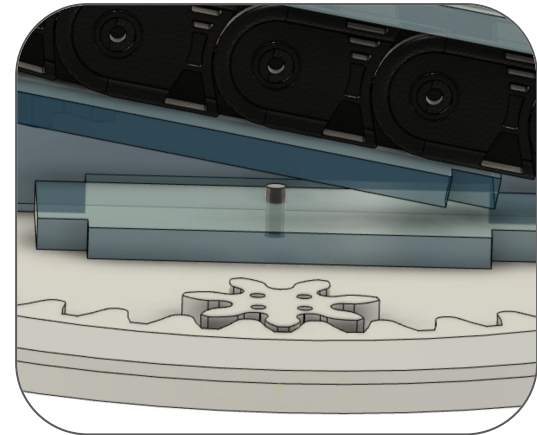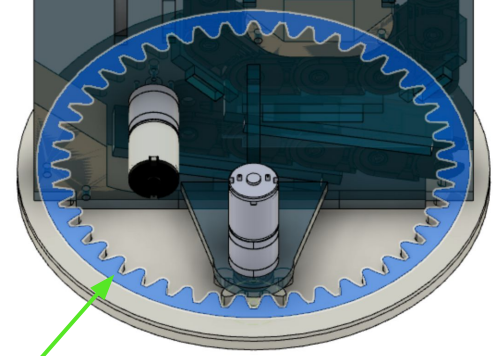
Rotation (Sweep) | Motor Assembly

Supported motor mount

- Cantilever mount coming off of wiper storage component

- Important that spur gear meshes -> triangular laser-cut support to minimize bending
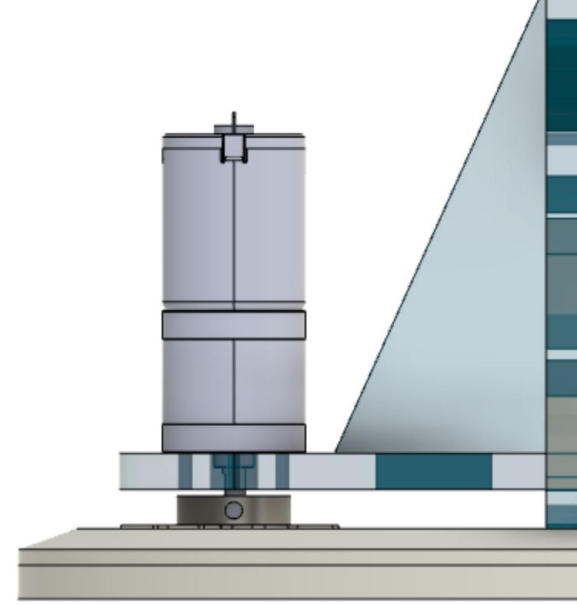
Motor axle - Gear Connection

- Aluminum motor hub with a d shaft + worm screw (prevent slipping of gear on axle)

- Counterbored holes in spur gear to securely attach to the spur gear to motor hub
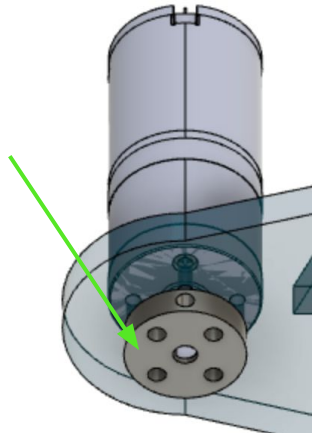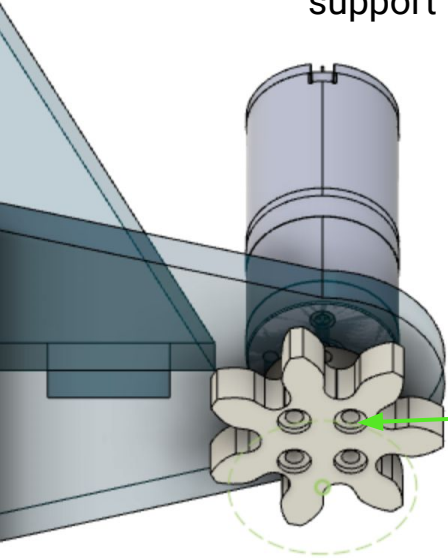
Rotation (Sweep) | Motor Selection

Reaction force between **spur gear** and **internal gear** can be determined by calculating **total frictional force** acting against rotation.

Operating Motor Torque: 0.295 N*m
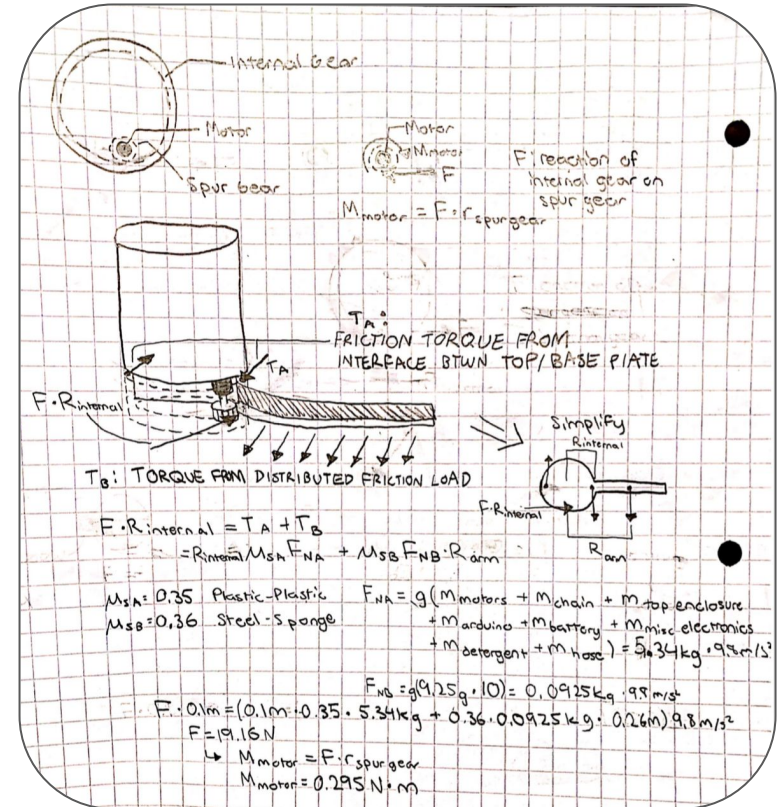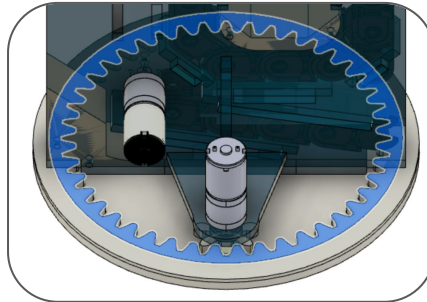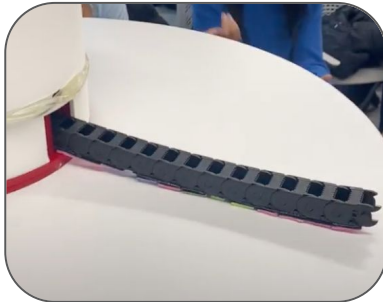
Rotation (Sweep) | Motor Selection

Extrapolation for 0.295N*m=3 kg*cm
39 RPM

7 teeth spur gear, 44 Teeth Internal Gear
44/7=6.286rotations

6.286 rotations / (39 RPM) = 0.16min

=9.6s to sweep table

AT Load		
Torque	SPEED	Current
KG.cm	RPM	A
0.1	1000	0.45
0.22	450	0.45
0.5	220	0.45
0.8	130	0.45
1	100	0.45
1.8	60	0.45
2.4	46	0.45
4	27	0.45

Wiper | Brainstorm

Considerations

- Serviceability
- Lateral rigidity
- Carry/deploy disinfectant
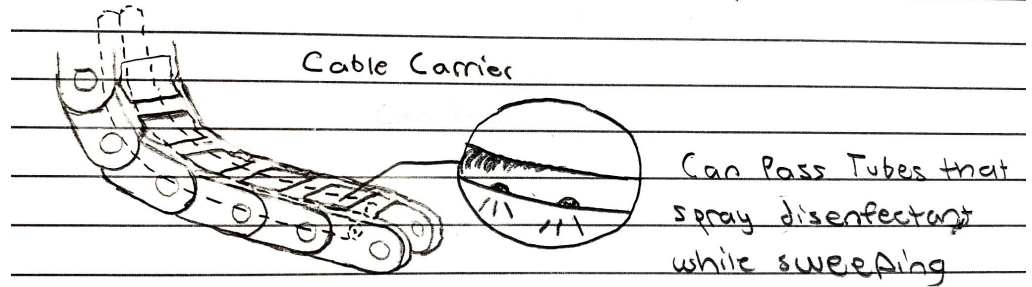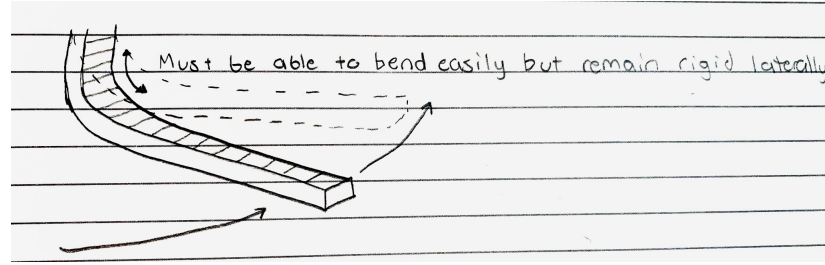
Wiper

Cable Carrier Design

- Internal space allowing for passage of a disinfectant hose

- "Rolls up" but is laterally rigid

Sponge

- Velcroed on

- Provide cleaning interface between table and wiper

- Can be easily removed and replaced for servicing purposes

Housing | Wiper Storage

Compact

- Minimize space taken up by the wiper while maximizing cleaning range of device by coiling cable

Deployable

- Curved turns to prevent catching during deploying and retracting

- Continuous path to ensure wiper can retract well

- Exit at the bottom where wiper is deployed onto table
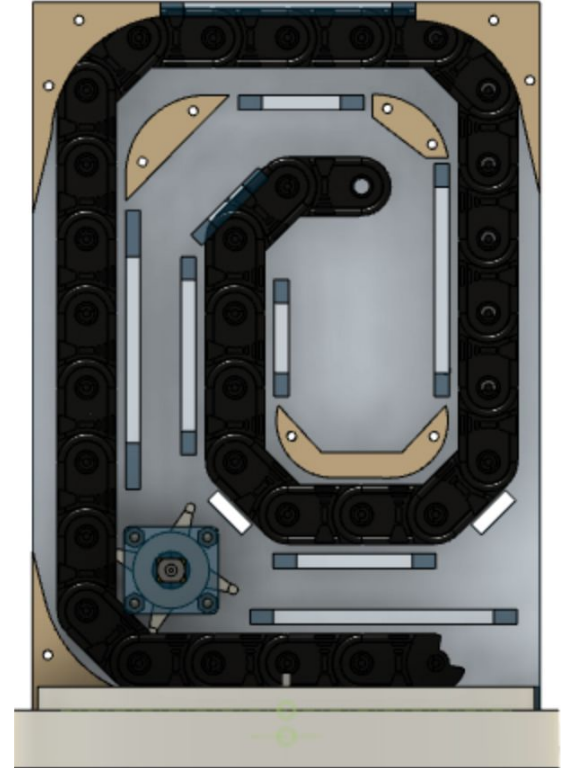
Housing | Design Iteration
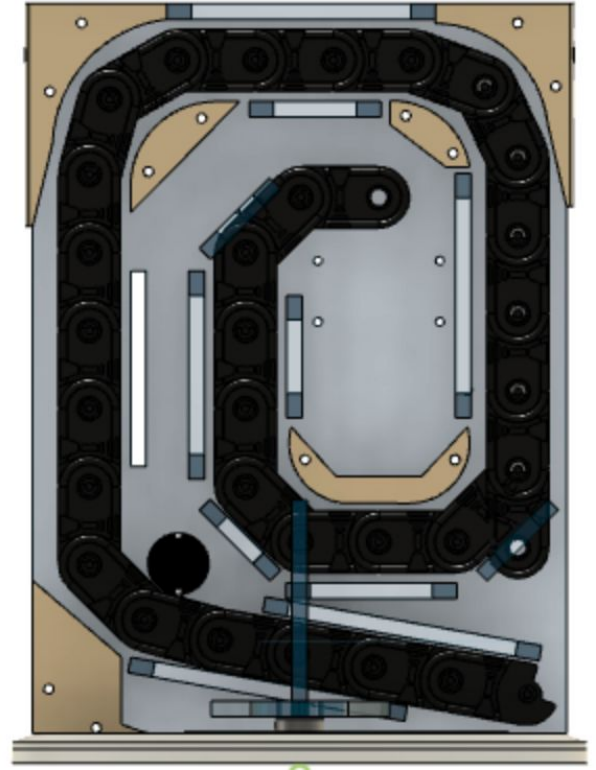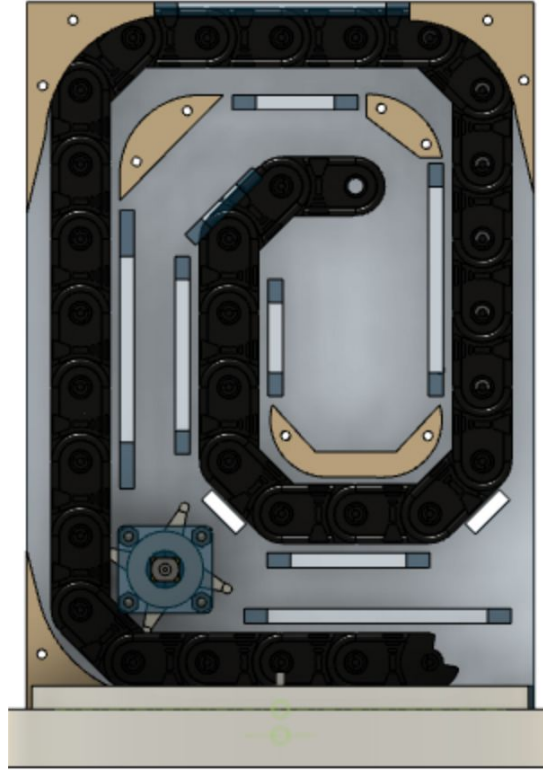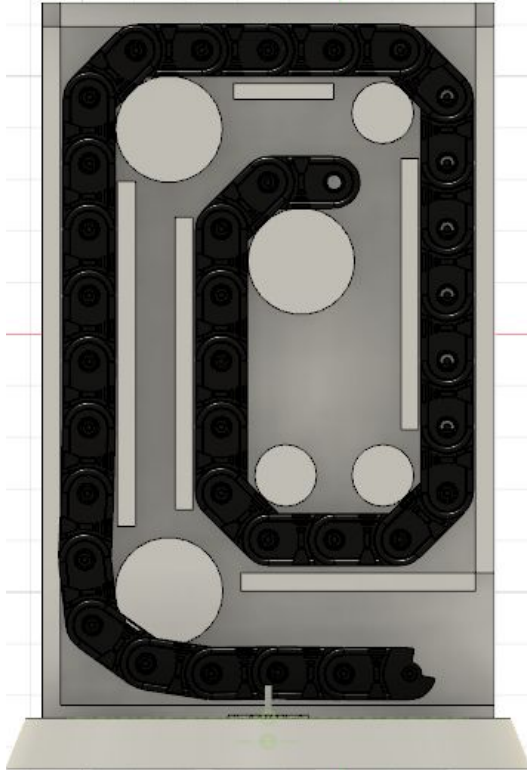
Housing | ID

Outer cylindrical cover

- Mounting holes to the wiper storage

- Sits on top of base plate

- Groove for disinfectant spray hose

Removable cover

- Sits on top of cylindrical cover

Wiper Deployment | Motor Assembly

Motorized deployment

- Motor drives sprocket gear

- Driven at the bottom of the enclosure near the exit of the enclosure

- Attaches to aluminum motor hub & acrylic plastic wiper storage housing
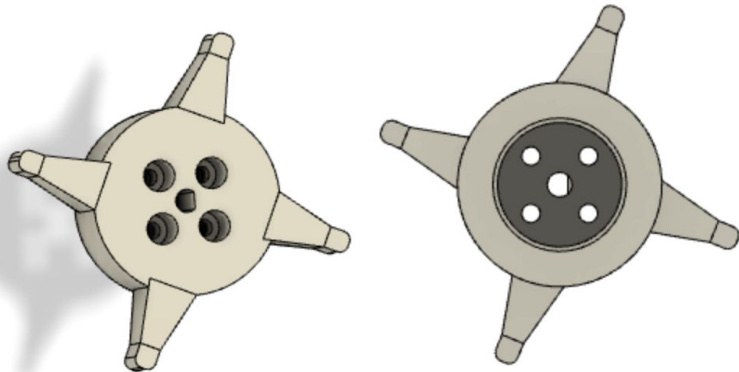
Sprocket

- Designed to mesh into cable carrier grooves

- Interfaces with an aluminum motor hub
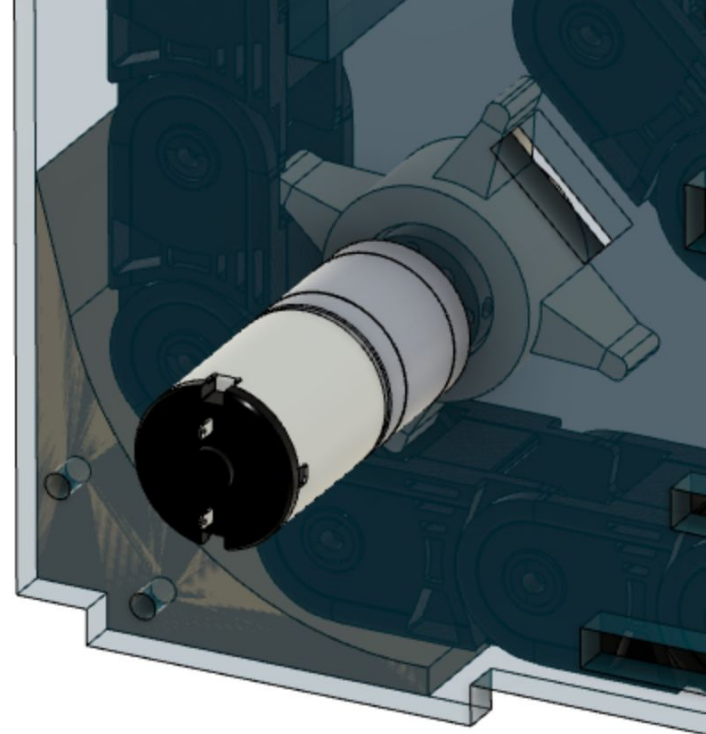
Wiper Deployment | Motor Selection
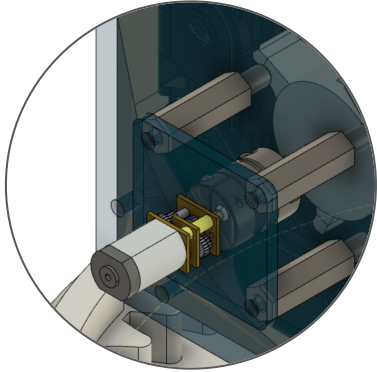
Initially Motor choice

- Utilized low torque motor available in lab

- Axle adapter to lengthen motor axle and attach to the Sprocket

- Lasercut, standoff supported motor mount
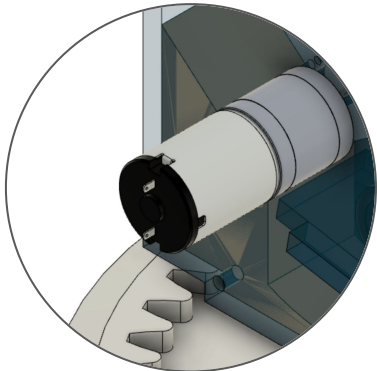
Conservative Motor Choice

- Frictional forces from chain links is significantly lower than the frictional forces experienced by sweep motor

- Weight of single chain element is 9.25g
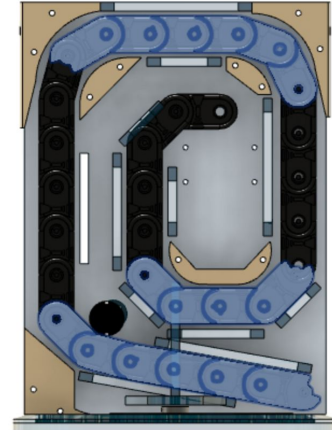
Disinfectant Storage

Water Bottle

- Zip Tied Water Bottle to dynamic top assembly

- Stores disinfectant, and can be easily filled
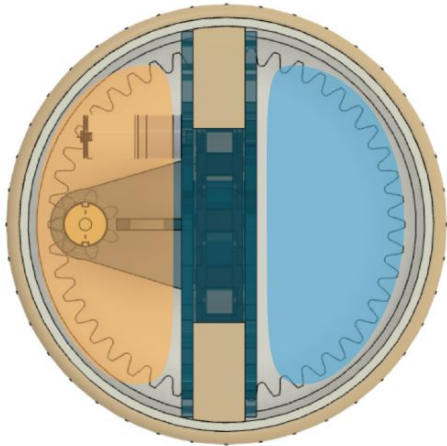
Waterproofing

- All electronic components (besides the pump) on the opposite side of wiper storage from water bottle

- Avoid failure from leaks in bottle
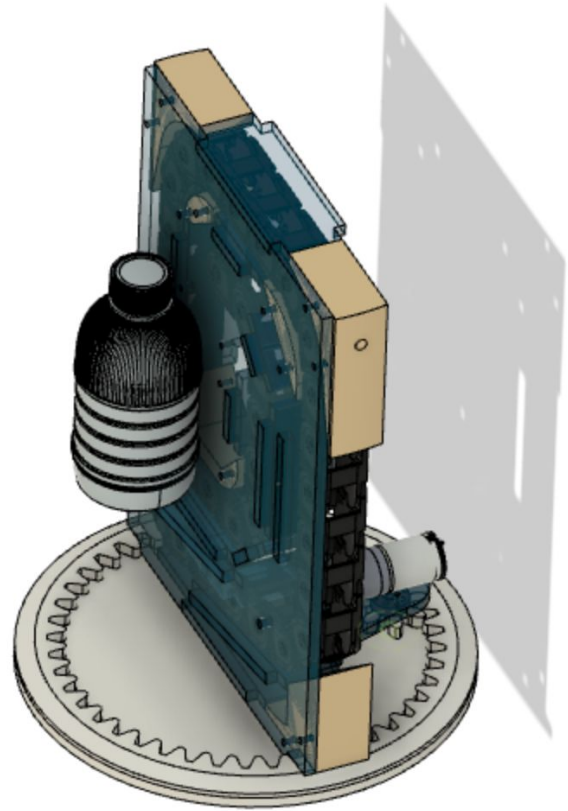
Disinfectant Deployment

Pump

- 6-12V DC Diaphragm Pump, Max flow rate of 1.8L/min

- Mounted with OTS mount to holes in the wiper storage
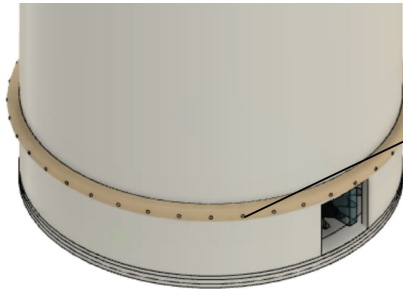
Hose

- Wrapped around rotating enclosure, spraying omnidirectionally as device sweeps

- Original passage through cable carrier too complex
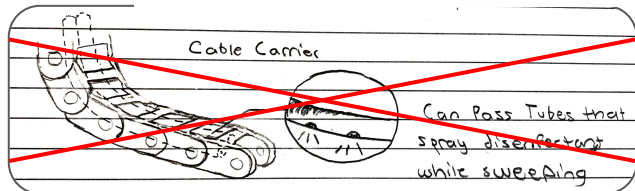
Finite Element Analysis

Small Loads Expected

Worst case scenario:
Impeding Object with Frictional Force >
Sweep Motor Stall Torque

Conservative force on link: 47.218N =
10.77 lbf

R_x, R_y: Pin Reaction Forces

F_{object}: Reaction force from object

F_{gear}: Reaction force from internal gear

F_{object} determined by F_{gear}, the stall torque force

$F_{gear} \times r_{spur gear} = T_{stall motor} = 0.8 \, N \cdot m$

$F_{gear} \times 0.0154 m = 0.8 \, Nm$

$F_{gear} = 51.95 \, N$

$\sum M_{/pin} = F_{gear} \times R_{internal gear} - F_{object} \times R_{min}$

$0 = 51.95 N \times 0.1 m - F_{object} \times 0.11 m$

$F_{object} = 47.218 \, N$

↳ Conservative Loading Case
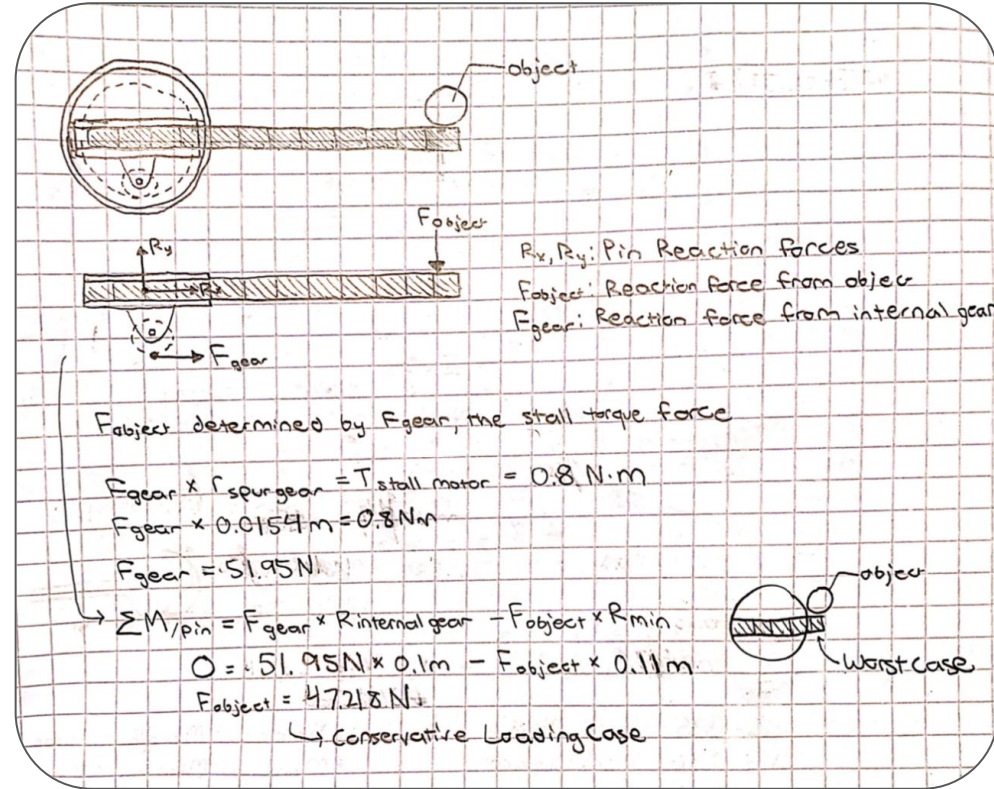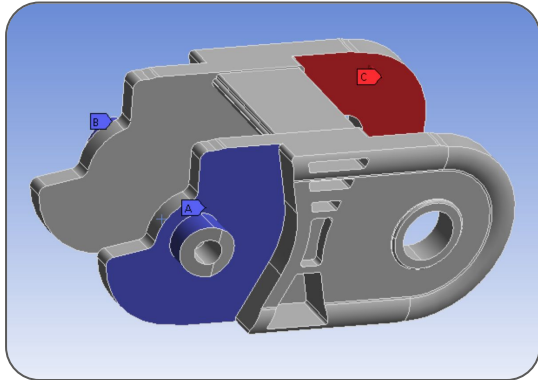
Finite Element Analysis

Max Principal Stress:
4272.1 psi = 29.1 MPa

Yield Stress of Polycarbonate: 80 MPa

Factor of Safety: 2.74

Max Deformation: 0.68mm
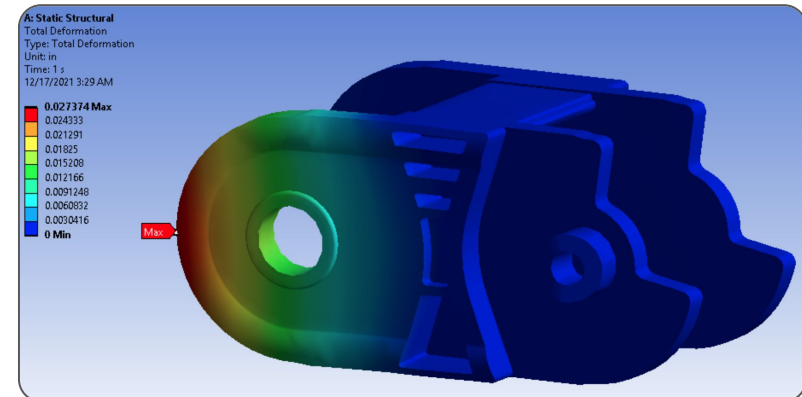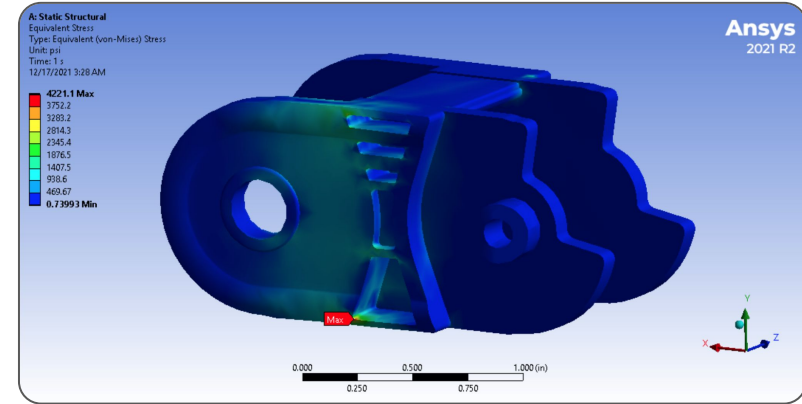
Mechanical Design |
Summary

Access Hatch

An uncrewable top access hatch equipt with a button that actuates the cleaning process can be easily removed to service the pump

Disenfectant Deployment

Tubing that routes to a pump & disinfectant supply inside Sanitable spray down the table in 360 degrees before the wiping procedure begins
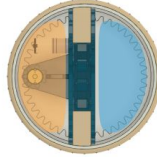
Waterproofing

All electronics are isolated on one half of the enclosure (orange half) separate from the disinfectant container (mounted on blue side)
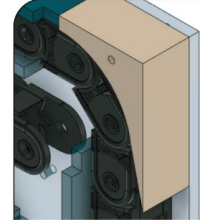
Wiper Storage

A maze of curved and linear pathways compatcly stores the wiper, which can extend up to 2.5ft.
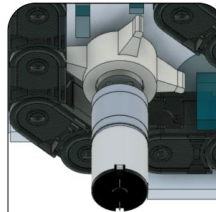
Wiper Deployment

The wiper is automatically deployed by a motorized spur gear that extends the wiper out of the device to the edge of the table. This feature allows our device to function for a wide range of table sizes
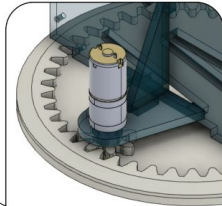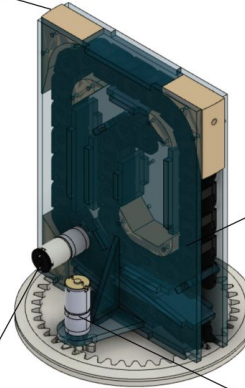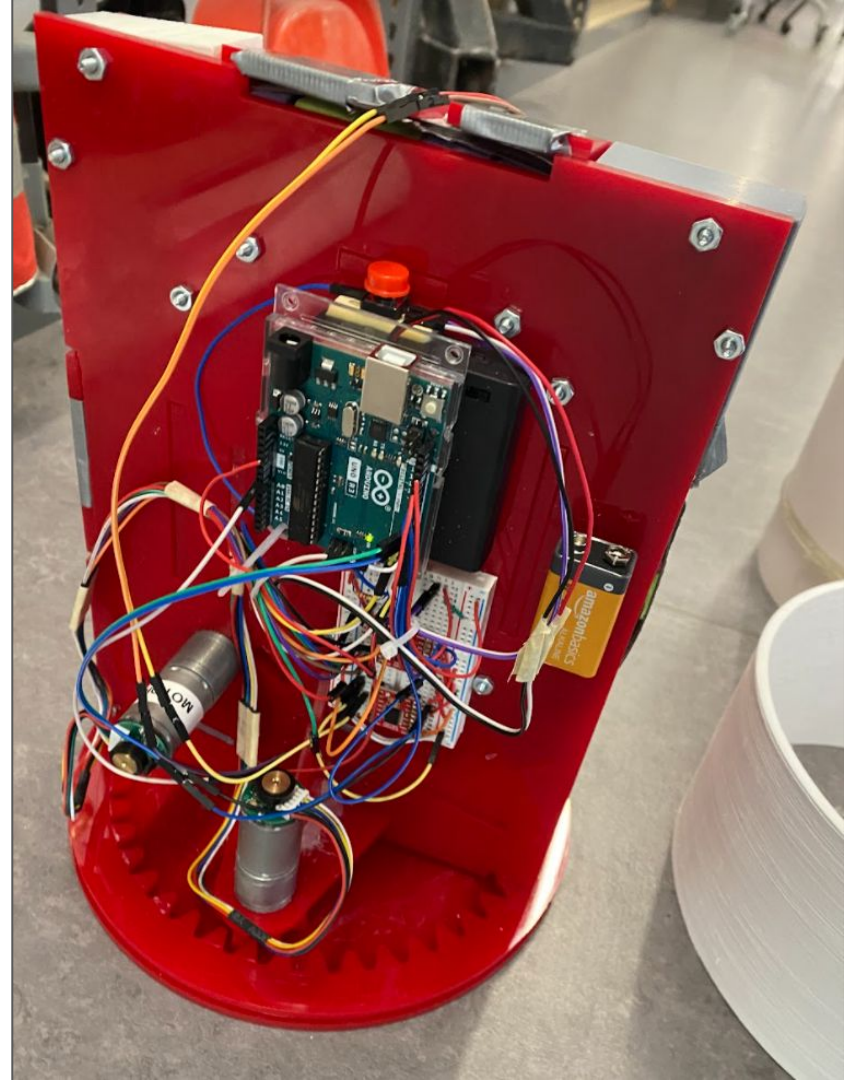
360 Degree Motion

An internal motorized rotational mechanism allows Sanitable to spin a full 360 degrees in order to ensure the table is completely wiped down

Electronics

****Was not my direct contribution***

1. Arduino

2. Motors + encoders

3. Pump

4. Push button actuation
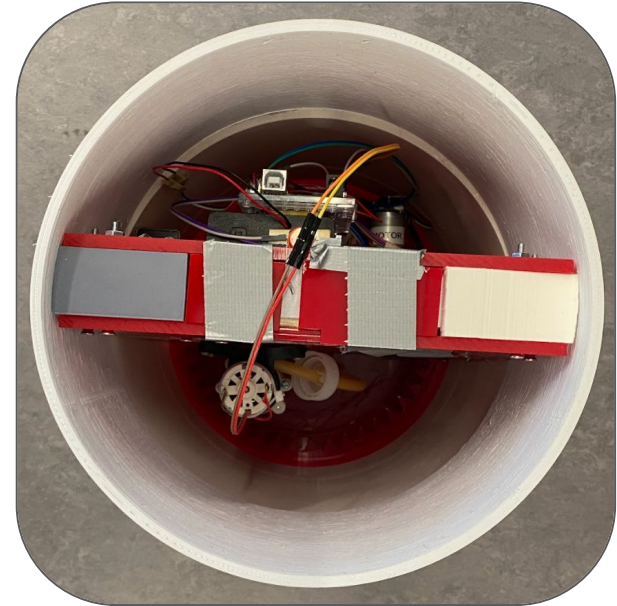
5. 9V battery

Final Prototype Assembly

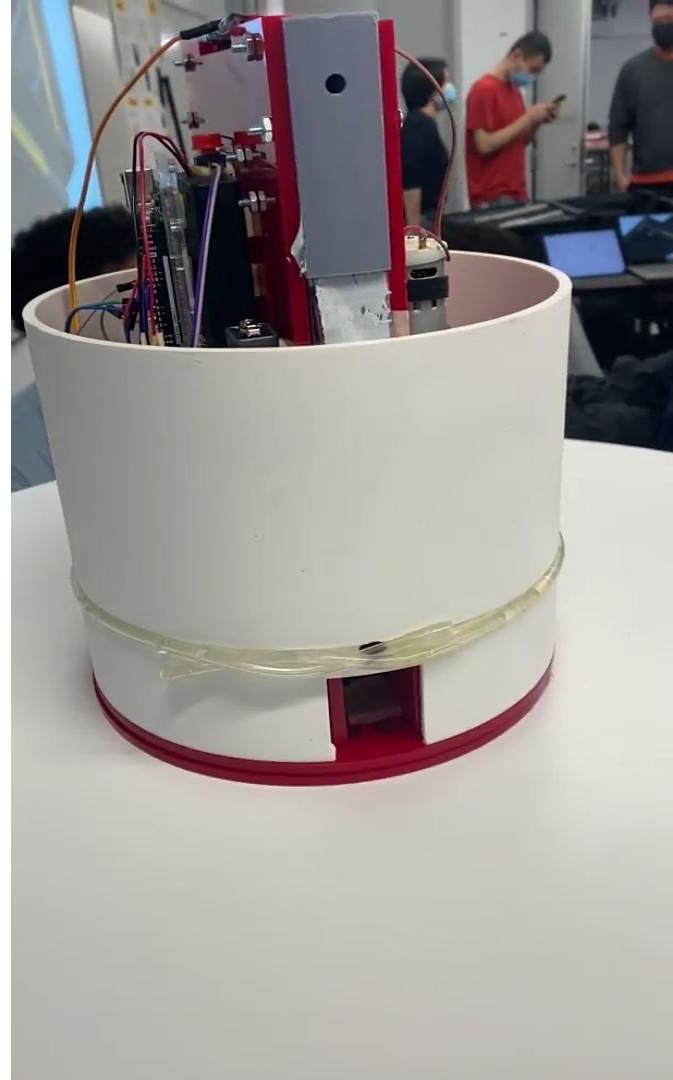Laser-cut Wiper Housing

3D Printed Outer Casing

Electronics mounted securely to housing

Detergent container mounted

Disinfectant hose connects to container and wraps around
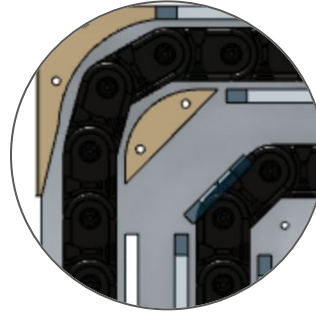
Final Functional Demonstration

Areas of Improvement
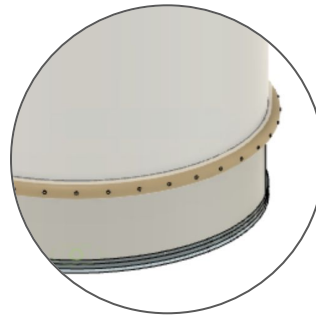

Access Hatch

Screwable
Actuation
Water proof

Wiper + Storage

Smaller Profile
More compact coil
Servicing Method

Adjustability

Rectangular Tables
"Setup Mode"

Hose

Pass through wiper
Reeling mechanism

Thank you.
Questions?