CARE: COVID-19 Abatement Return to Education

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Executive Summary

The COVID-19 pandemic poses new challenges in many aspects of life and society. Being that the prime ethical responsibility of engineers is to keep people safe, our sponsor, John Nielsen, asked us to develop a solution that addresses a current or anticipated need related to the ongoing COVID-19 pandemic. We entered a needs-finding phase to search for problems caused by COVID-19 that people want or need to be solved. We identified K-12 education as an area that has undergone drastic changes due to the pandemic. After conducting interviews with educators, we found that K-12 teachers need a way to return to the classroom safely without relying on the decisions of their students. Our project addresses the following problem statement: K-12 teachers need a way to feel safe during the COVID-19 pandemic so that they can return to in-person teaching.

Based on our interviews, guaranteeing the enforcement of safety protocols makes K-12 teachers feel safe. We decided to build a toolbox of devices to help teachers enforce sanitation and personal protective equipment (PPE) protocols. The sanitation device is an automatic disinfecting spray placed above high touch surfaces, like doorknobs, that automatically sanitizes the desired surfaces after any individual touches it. The PPE device is a face shield with a microphone and speaker that enables teachers to overcome the tiring and difficult task of speaking over a face covering.

For our toolbox prototype, we purchased or 3D printed all the components. Our automatic disinfecting spray prototype uses a motor and cam controlled by a microcontroller to actuate a nozzle that sprays liquid sanitizer. The system can attach to doors or other flat surfaces via an adhesive mount and adjustable arm. The face shield prototype consists of a microphone and speaker attached to a shoulder-mounted face shield.

As we manufactured and assembled our toolbox, we tested individual components and subassemblies to ensure that they operated as expected and would properly integrate into each system. In addition, we performed usability testing for the completed components with teachers and friends. The responses from our user testing indicated the face shield was easy to operate and effective. While the disinfecting spray could use improvements in usability, it functioned as expected.

Based on feedback from our usability testing, we recommend reducing the bulkiness of the overall disinfecting spray system and improving the adjustability of the mounting. We also recommend further testing in a wider range of environments to ensure all use cases of the toolbox are covered. We need further nozzle and adhesive testing for the disinfecting spray as the current nozzle tends to leak and the adhesive leaves behind a sticky residue when removed. Moving forward, to reduce the toolbox cost, we recommend pursuing mass manufacturing including purchasing components in bulk and injection molding instead of 3D printing. We also recommend replacing breadboard and wire circuits with custom PCBs for cleaner packaging and less unnecessary electronics parts.

Overall, the face shield and automatic disinfecting spray toolbox allows teachers to focus their attention on what really matters, teaching, while maintaining a safe environment.

Chapter 1: Introduction

The recent pandemic caused by SARS-CoV-2 (COVID -19) in the spring of 2020 has already led to almost 600,000 deaths in the United States alone [1]. COVID-19 is most commonly spread through human-to-human contact through respiratory pathways such as from coughing, sneezing, or talking. Transmission is most likely to occur when people are within close proximity to one another. Spread may also occur through contact with contaminated surfaces, although surfaces are less likely sources of infection [2]. Leading experts and governing bodies are advocating for social distancing practices and wearing masks over one's mouth and nose to slow the rate of transmission. These new practices in addition to countless other changes have led to new problems affecting individuals and institutions.

Our sponsor, John Nielsen, is a mechanical engineering graduate who remains an active member of the Cal Poly community. He created the Mustang '60 Machine Shop and is a member of the Mechanical Engineering Industrial Advisory Board (IAB). Being that the prime ethical responsibility of engineers is to keep people safe, our sponsor asked us to develop a solution that addresses an issue related to the ongoing COVID-19 pandemic. We were tasked to research the current and anticipated future needs of our global fight against the virus. By identifying critical problems associated with fighting the virus, we will select one and develop the necessary technology to address it. Possibilities include a local solution for the Cal Poly or San Luis Obispo community, a more general solution such as redesign of an existing solution, or a solution for those who are having long term effects of the virus.

With this goal in mind, we entered a needs-finding phase to search for problems caused by COVID-19 that people want or need to be solved. We generated a bug list including our own annoyances related to COVID-19 as well as the issues of other members of the community, organizations, and people of various professions. One aspect of everyday life that has undergone drastic changes as a result of the pandemic is education. Schools across the nation rapidly transitioned to remote learning in the spring of 2020 and are currently facing countless issues to provide the highest quality education in an equitable manner. Once we narrowed in on education, we conducted additional interviews with educators to gain a greater understanding of their needs. For our project, we would like to provide teachers with a way to return to the classroom safely without relying on the decisions of their students. We generated the following problem statement: teachers need a way to feel safe during the COVID-19 pandemic so that they can return to in-person teaching.

Chapter 2: Background

To better understand issues in education brought on by COVID-19, we divided research into three categories: special education, K-12 education, and university/college education. In times of emergency, special education students are often the first to fall behind and the last to be re-integrated into the classroom [3]. The most important factor in determining special education student success is the school's or teacher's ability to maintain relationships with the students [3]. This means going out of their way to reach out and gain an understanding of what their home situation is like so they can determine how to best cater to each students' needs. This is difficult to achieve as students have varying degrees of access to Wi-Fi and technological devices as well as desires to maintain privacy [3]. Some students require teachers to make individual phone calls or deliver homework packets directly to students' homes [4]. Other students' needs simply cannot be met in a virtual environment [4]. In cases where these needs cannot be accommodated, special education students fall behind and are not able to catch up. For teachers, the transition to online learning and the subsequent changes to the student teacher relationship is leading to a general feeling of burnout [3].

As part of our needs-finding we had the opportunity to interview three teachers. Satia Widmann form the Montessori Children's School of San Luis Obispo, Yolanda Hopkins from Lemonwood Elementary School in Oxnard, as well as the Principal of San Luis Obispo (SLO) High School, Leslie O'Connor. In all three cases the educators expressed frustration with the logistics of providing an effective virtual learning experience [5]. There was a divide between the approaches taken by the public schools and the Montessori school. The Montessori school is using a hybrid schedule with groups of students alternating between coming to school in-person and attending virtually. In an interview with Satia Widmann, the small student body was cited as the primary reason for a hybrid model being possible. Lemonwood Elementary and SLO High School are both operating in a virtual format, although sports have resumed at SLO High School with students separated into cohorts. The primary barrier to a return to in-person instruction at the public schools was the inability for teachers to return to the in-person classroom environment safely and comfortably. With a large student body, it is difficult to ensure that all students are following appropriate COVID-19 protocols. Until all students are following proper protocols or teachers have a way to be safe independently of the choices of their students, a return to in-person instruction is unlikely.

University settings pose an additional set of challenges stemming from the fact that students generally travel from different communities to attend school and participate in more social actives, increasing the likelihood of spreading COVID-19. Epidemiological computational models performed to assess the best methods to reopen schools pointed to the need for increased frequency of testing for COVID-19 [6]. Contact tracing and frequent testing are the two most essential methods to prevent an outbreak on university campuses.

At Cal Poly San Luis Obispo, contact tracing is performed at the county level and testing protocols are changing as the Universities' testing capacities grow. At the beginning of the school year, both staff and students had to provide negative test results before entering campus. As of October 2020, staff and students must undergo testing every two weeks to remain on campus. Smaller student groups such as music groups, athletes, and on campus residents have their own testing protocols. Dr. Crocket, Assistant Dean of The College of Engineering, noted challenges currently being addressed at the university to ensure the safety of all staff and students but compared to other institution in the surrounding community, Cal Poly has far more resources to ensure the safety of all personnel. Other Universities are also choosing to return to some in-person classes and are facing a variety of issues but as Dr. Crocket noted, Universities have more resources than other local establishments to navigate the changing dynamics of a global pandemic.

Based on our interviews across the different levels of education, we decided that we could make the most impact in the K-12 environment, as K-12 schools lack the resources and funding available to universities. Due to the setbacks that come with virtual learning, most K-12 teachers have a common desire to return to in-person teaching, but they need to do so safely. We conducted a second round of interviews specifically with K-12 teachers to identify factors that create an unsafe classroom environment, and changes that would improve classroom safety. Across the board, concerns with classroom safety revolve around teachers' ability to enforce proper procedures and protocol.

To help teachers enforce safety protocols, we researched protocols they are required or suggested to follow. We looked at the Santa Clara County Office of Education guidelines, a county known to have extensive, detailed COVID-19 guidelines for schools [7]. In summary, the Santa Clara guidelines contain five main requirements:

- Ensure students & teachers with fever / respiratory symptoms stay home
- Students & staff wear face coverings
- Sanitize frequently
- Staff maintain 6 ft distance between each other and visitors or volunteers
- Monitor ventilation and air flow. Replace HVAC filters frequently

We identified existing solutions that satisfy these five main requirements: screening for symptoms, personal protective equipment (PPE), disinfecting surfaces, physical distancing, and air circulation. Screening for symptoms can be either done through self-reporting or through measurements taken before entering enclosed public spaces such as stores, schools, or gyms. Health screening stations are set up at the entrance of an establishment where a no contact infrared thermometer is used to record the body temperature of an individual before they are allowed entry. Symptom screening is intended to identify potentially infected individuals from a public setting before those around them are infected.

Source: Adapted from [8]

PPE encompasses masks, face shields, gowns, gloves and many other products that are worn by an individual to create a physical barrier between themselves and the outside environment. Cloth masks, single-use surgical masks, and N-95 respirators are the most widely used face coverings and are ideally worn by everyone. Masks serve three purposes: protect the wearer from other people, protect other people from the wearer, and protect the wearer from themselves by discouraging face touching. Masks create a barrier for the movement of airborne particles and liquid droplets. In the image below the airflow of a man coughing without a mask, on the left, and with a mask, on the right, is shown. Without a mask the velocity of airflow and the distance travelled by the man's exhale is far greater than when a mask was worn. Although a mask does not eliminate the potential for virus transmission it does contain some of the spread of airborne particles and water droplets.

Source: Adapted from [11]

N-95 masks are more effective at preventing the spread of COVID-19. N-95 masks remove 95% of non-oil 0.3+ micron particles protecting the wearer from COVID-19 [9]. N-95 masks with a valve protect the wearer but not bystanders as the valve allows for unfiltered exhaled air to be released. A growing area of research in PPE is recharging N-95 respirators. N-95 masks contain a polypropylene electret fiber layer that traps particles through electrostatic or electrophoretic effects, this effect is lost after washing and usage lowering the efficacy of N-95 masks over time. However, the efficacy of N-95 respirators can be regained by recharging the polypropylene electret fiber layer with a high voltage [10].

Source: Adapted from [11]

Nonstandard face masks are being developed to be more comfortable for children, to allow for better communication through lip reading, and to prevent glasses from fogging.

Source: Adapted from [12]

Face shields provide an additional barrier and level of protection.

Source: Adapted from [13]

Disinfecting surfaces is another area of technological development to limit the spread of COVID-19. The CDC recommends disinfecting high contact surfaces with EPA registered disinfectants [10]. UV radiation can also be used to disinfect surfaces, air, and water. Portable UV light or UV wand sanitizers are alternative technologies to traditional methods of spraying ethanol or bleach to kill a virus.

Source: Adapted from [14]

Physical distancing protocols and measures are another crucial aspect of limiting the spread of COVID-19. Plexi glass dividers are frequently used in crowded spaces to create physical barriers between people. Contact warning devices and contact tracing devices are being developed to enforce physical distancing in high contact organizations. KINEXON's SafeZone is a wearable wrist device that tracks real time encounters between users and allows for contact tracing to be performed more accurately through precise tracking of person-to-person interactions. The SafeZone device is being used by sports teams, at events, and by employers to keep individuals safe. Another physical distancing technology is the Perividi app which notifies employees when they are too close together [15]. This smart phone app is intended for construction sites, oil rigs, and other workplaces where close contact may occur.

Source: Adapted from [16]

Air circulation is another area of development to reduce transmission rates inside buildings. The World Health Organization is encouraging updates to ventilation and air conditioning systems in public spaces and building to reduce recirculation of air and improve filtration systems [17]. Two types of technologies could be translated to the K-12 setting to address air circulation concerns inside the classroom. The first is high efficiency particulate air (HEPA) filters which are used in airplanes and hospitals to filter air. CO2 indicators can be used as a measure of airflow rates and direction to evaluate the air circulation of an enclosed space.

Source: Adapted from [18]

New technologies and existing technologies are being adapted across sectors and around the world to address the pressing needs of the pandemic.

Chapter 3: Design Development

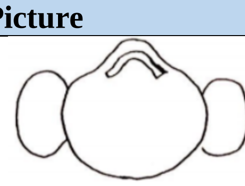
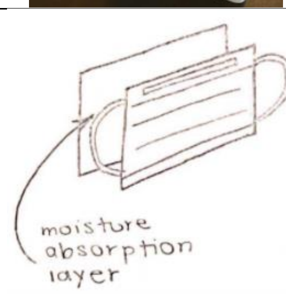
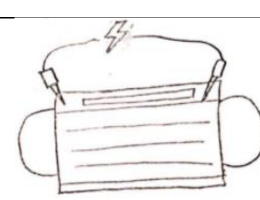
After researching existing solutions, we brainstormed our own solutions for the five categories of safety protocols outlined by the Santa Clara County. After generating solutions, we decided not to focus on monitoring symptoms because effective solutions already exist, and the only way to improve upon symptom monitoring is to implement rapid COVID testing, which is beyond the scope of this project. We also decided to remove HVAC monitoring from our scope because any changes to HVAC systems would not be an opt-in solution that an individual teacher could implement. It would require substantial infrastructure changes that would require approval from the district. This left us with three areas of focus: PPE, physical distancing, and sanitation. Considering that our main priority is to make teachers feel safe in an in-person classroom environment, we decided to pursue all three areas to address as many teacher concerns as possible, rather than pursuing a single solution. Our final solution is a toolbox approach with three products. Each product will help teachers enforce the PPE, sanitation, and physical distancing protocols effectively in the classroom.

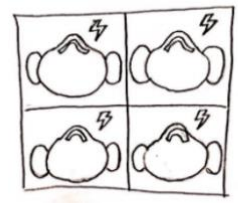
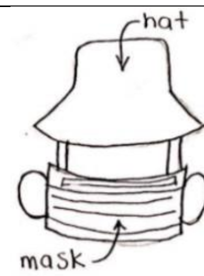
<u>PPE</u>
We determined the following customer requirements to ensure that our solution helps teachers enforce the PPE safety protocol:

1. Enforcing protocol
2. Opt-in product for teachers to use at their own discretion
3. Low cost
4. Easy to use and easy to maintain
5. Does not need active user operation
6. Improves classroom engagement
7. Allow use of lab equipment, sports equipment, art supplies
8. Allow for group activities
9. Addresses teacher's concerns

Next, guided by our customer requirements, we generated the solutions in Table 1.

Table 1. PPE solutions generated

Idea	Description	Picture
A	<u>N95 mask</u> We chose an N95 mask to be our datum because they currently provide the most protection from inhaling COVID-19 particles than other face coverings.	
B	<u>Nose clip mask</u> We prototyped this mask to prevent glasses from fogging up. The nose clip provides a snug fit between the mask and nose so that breath cannot rise from the top of the mask and cause glasses to fog up. The mask also has a covering made of the same material as the rest of the mask to cover the clip and make it more visually appealing.	
C	<u>Moisture absorbing mask</u> Part of what makes masks uncomfortable to wear is that they trap the moisture and heat of breath inside. To make a more comfortable, kid-friendly mask, we came up with a mask that better absorbs the moisture from breath and allows it to evaporate.	
D	<u>Dog cone</u> A face shield in the shape of a dog cone makes it more difficult for users to involuntarily touch their face and possibly intake COVID-19 particles.	
E	<u>N95 mask charger</u> While much of N95's effectiveness comes from their material properties, part of their effectiveness comes from their electrostatic properties. We want to find a way to give any mask the same electrostatic properties as an N95.	

F	<u>Shoulder face shield with microphone and speaker</u> A face shield that attaches at the shoulders prevents the user from involuntarily touching their face and prevents their own breath droplets from falling onto surfaces. A microphone and speaker system also address the issue that masks and face shields make it very difficult to hear people speaking and forces the speaker to strain themselves to be heard.	
G	<u>Scuba mask face shield</u> The scuba mask face shield combines a face shield and mask into one device by creating a barrier that surrounds the whole face while enabling the user to breathe through a respirator.	
H	<u>Class set of rechargeable N95 masks</u> Because N95 masks are limited in supply and should be consumed by first responders, recharging N95 masks make them a one-time purchase for the whole school year. Teachers have cubbies to recharge student masks at the end of the school day, restoring the N95 electrostatic properties, and having them ready for use the next class.	
I	<u>Mask hat combo</u> In a mask hat combo, the mask cannot be taken off without first taking off the hat, and the hat cannot be on without first putting on the mask. This way, teachers can easily identify when a student has taken off his or her mask.	

We created the Pugh matrix in Table 2 to compare how well our brainstormed solutions satisfy our customer requirements. In our Pugh matrix, we weighted requirements on a scale of one to four, one being the least important and four being the most important. We chose the best existing idea to be our datum. Then, we scored the other ideas in comparison to the datum, with + being better than the datum, – being worse than the datum, and S being same as the datum. The highest scoring ideas best satisfy our requirements.

Table 2. PPE Pugh matrix

Pugh Matrix – PPE – Type of approach										
Requirement	**Weights**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
1	4		S	S	S	S	S	S	S	S
2	3		S	S	S	S	S	S	-	S
3	2		+	-	+	-	-	-	-	-
4	2		S	S	-	S	-	S	-	S
5	2	D	S	S	S	-	-	S	S	-
6	2	A	+	+	-	S	+	-	S	S
7	1	T	S	S	-	S	-	S	S	S
8	1	U	S	S	S	S	S	S	S	S
9	4	M	-	-	-	S	+	-	S	-
Sum(+)			4	2	2	0	6	0	0	0
Sum(-)			4	6	9	4	7	8	7	8
Sum(S)			13	13	10	17	8	13	14	13
Weighted sum			0	-4	-7	-4	-1	-8	-7	-8

We set the N95 mask as our datum because that is currently the most effective solution for preventing inhalation of COVID particles. Looking at our Pugh matrix results, we compared our top ideas, the datum N95 mask, the nose clip mask, and the shoulder face shield with microphone and speaker. Because the nose clip face mask addresses a very specific problem that does not apply to all teachers, we decided not to pursue this idea. For the PPE top concept, we decided to combine a PPE device with an added microphone and speaker.

After narrowing down which type of product we want to pursue for the PPE protocol, we went through another iteration of more specific customer requirements and translated those into engineering specifications using Quality Function Deployment (QFD). For each solution, we addressed all customer requirements with an engineering specification and did not create any unnecessary specifications. The house of quality, see Appendix B, shows the correlation between our customer requirements and engineering specifications. We also rated competitor solutions against our criteria to ensure our product better solves our customers' needs and created targets for our engineering specifications that put us ahead of the competition. Our competitors are listed in Appendix B. We also weight the importance of our engineering specifications in relation to each other. We summarize the house of quality results in Table 3.

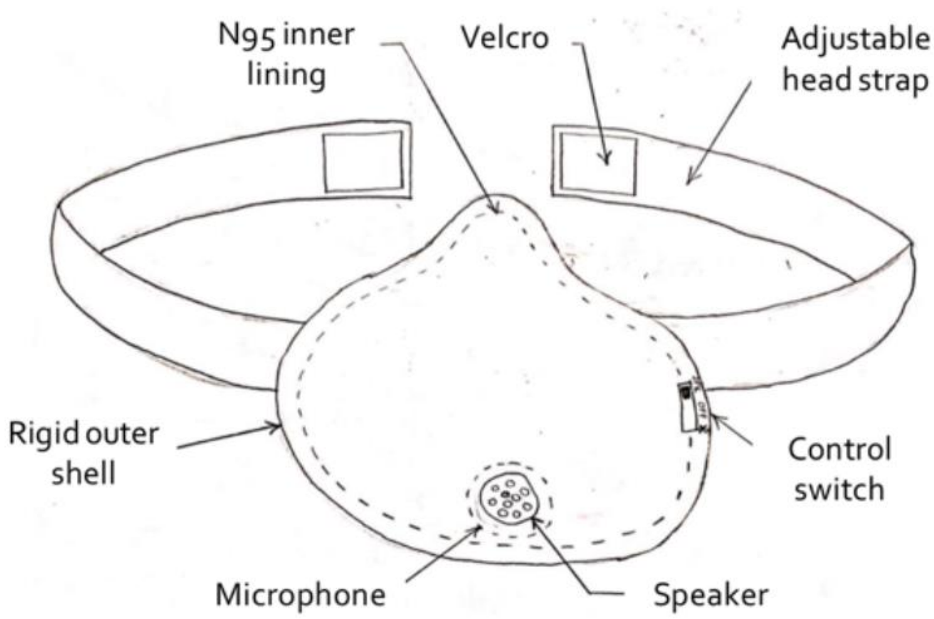
Table 3. Face shield with microphone and speaker engineering specifications

	Formal Design Requirements – Face Shield with Microphone and Speaker				
Spec. #	**Category**	**Parameter Description**	**Requirement or target (units)**	**Tolerance**	**Risk**
1	Cost	Cost to purchase	$40	Max	M
2	Life	Battery life	12 hours	Min	M
3		Product life	10 years	Min	L
4	Safety	Electrical insulation	3.7 V	Min	H
5		Thermal insulation	0.036 °F temperature increase	Max	H
6		Mask compatibility	N95, surgical, and cloth mask fit underneath	Min	H
7	Comfort	Weight	4.16 oz	Max	H
8		Strap	Straps around head and/or neck, not ears	Min	M
9		Material	No sharp edges where mask contacts user	Min	M
10		Breathability	Mask outer surface contacts outside air	Min	H
11	Sound	Speaker volume	60 – 70 dB	Range	M
12		Microphone sensitivity	50 Hz– 70 kHz	Range	M
13	Misuse	Drop height	3 ft	Min	L
15	Maintenance	Serviceability	Assemble & disassemble without breaking any components	Min	M

16		Cleaning	Compatible with ethanol, hydrogen peroxide, and quaternary ammonium	Min	H

For our competitor solution, we chose a microphone pack with a speaker paired with a face shield because this solution currently best addresses this specific problem. We derived many specification targets by comparing to this solution. To determine maximum cost, we looked at average prices for a microphone speaker pack and face shield, which added up to around $40. A speaker pack battery life lasts for 12 hours. Although our competitors did not provide product life, we estimated product life based on what we assume our customers expect. Next, to determine the size of our battery, we determined the power requirements of our microphone and speaker. Based on typical volume levels of the human voice and classrooms, we estimated our microphone sensitivity and speaker output volumes [20]. After determining sound requirements, we sized the battery. Based on our battery size, we determined our mask must provide insulation for minimum of 3V. Our thermal insulation requirement comes from the minimum temperature difference detectable by human skin [21]. Our estimate for maximum weight comes from the typical weight of respirators on Amazon. Respirators weigh more than casual face coverings, but users can comfortably wear them for long periods of time. When considering product misuse, we selected a drop height of 3ft, a typical height of tables and counters.

Using our customer requirements and engineering specifications, we performed high-level analysis to prove that our top concepts will satisfy our problem needs. Figure 1 shows a preliminary sketch of our initial concept before prototyping which consisted of an N95 mask as the frame rather than a face shield. For this iteration, we included two modes of operation: on/off. The mask consists of a rigid outer shell that holds the electrical components, including the microphone, speaker, battery, circuit board, and switch.



. Figure 1. N95 mask with microphone and speaker

Our concept satisfied some of our engineering specifications, while other specifications required further testing. After assessing the usability of a face mask device, we noted it was uncomfortable to wear, difficult to breathe through, and bulky. This led to the design transitioning to a face shield to provide the frame for the electronic components and to protect the user from COVID-19. A face shield provides more rigidity and is more comfortable to use for extended periods of time than a face mask. We reevaluated our design and updated our conceptual design to the face shield in Figure 2.

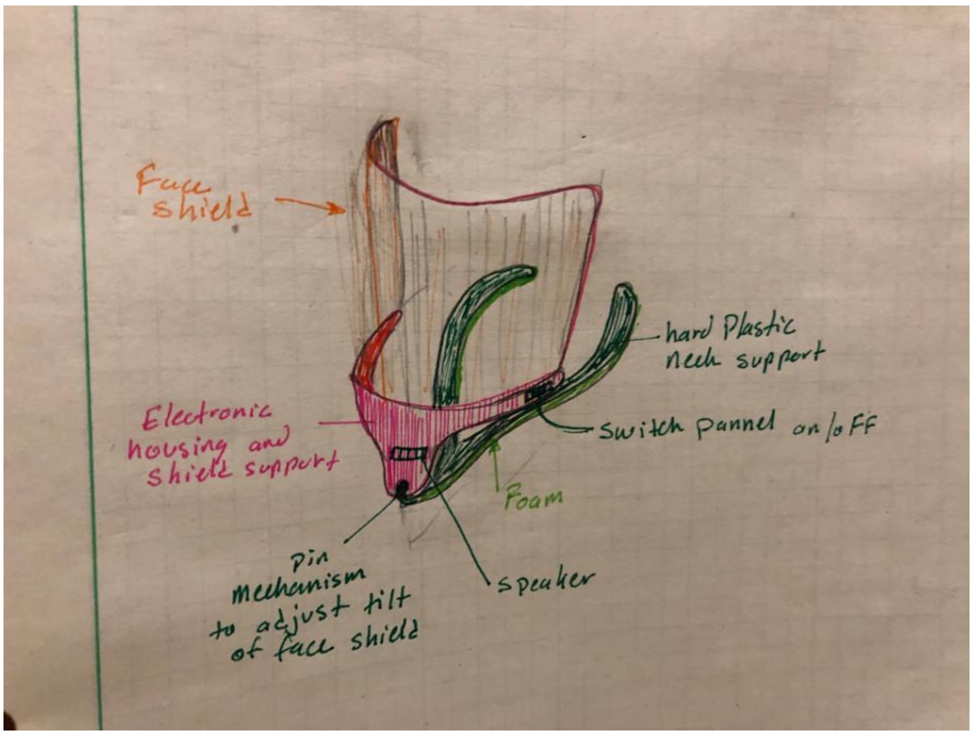


Figure 2. Face Shield Conceptual Drawing

In response to the feedback, we shifted our design from a hard shell worn on the face and strapped to the head to a face shield that rests on the shoulders. By resting on the shoulders, the weight is distributed which will result in a more comfortable user experience. The electronic housing that will contain the microphone and speaker will be attached to the face shield near the neck. The face shield consists of a clear visor to provide some protection against COVID-19 and a frame to support the device and keep it secure around the user. The user will still be expected to wear a mask as face shields alone are not an effective measure against COVID-19.

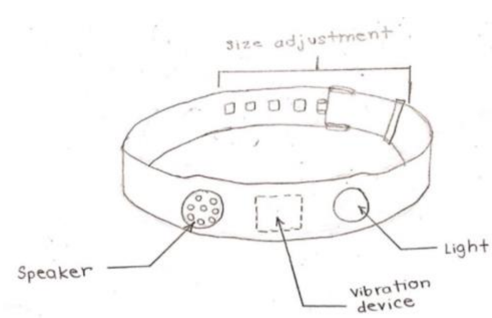
Physical distancing

We determined the following customer requirements to ensure that our solution helps teachers enforce the physical distancing safety protocol:

1. Enforcing protocol
2. Opt-in product for teachers to use at their own discretion
3. Low cost
4. Easy to use and easy to maintain
5. Does not need active user operation
6. Improves classroom engagement
7. Allow use of lab equipment, sports equipment, art supplies
8. Allow for group activities
9. Addresses teacher's concerns
10. Suitable for indoor and outdoor environments

For physical distancing, we added the additional “suitable for indoor and outdoor environments” criterion as schools are a mix of indoor and outdoor environments that students move between throughout the day. We brainstormed the solutions in Table 4.

Table 4. Physical distancing solutions generated

Idea	Description	Picture
A	**Wristband Sensors** – A class set of approximately 30 that notify users if they are violating physical distancing protocols. Wearers would be notified of small violations with a vibration. In the event of serious violations, the speaker would emit a sound.	

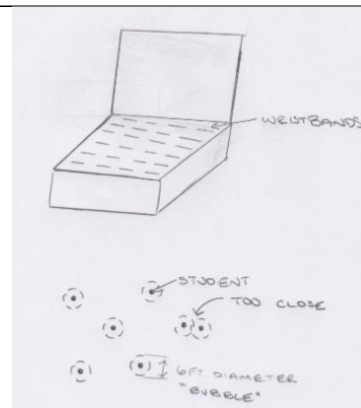
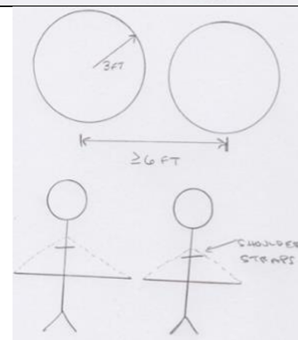
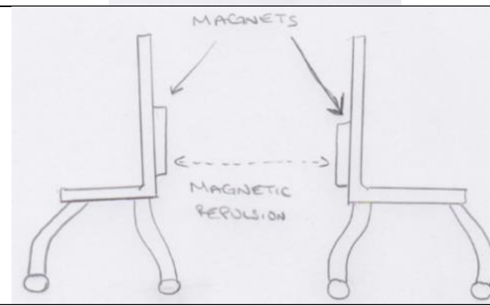
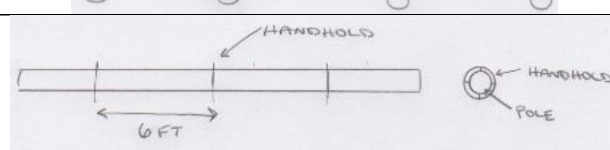
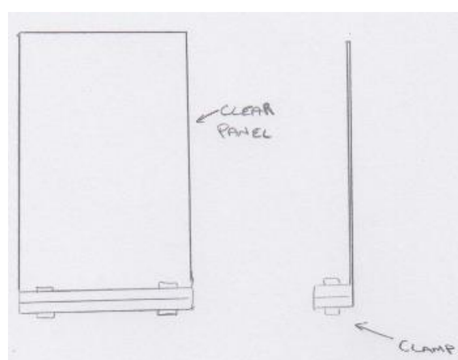
		
B	**<u>3ft Radius Hoop</u>** – Hoops worn by students will ensure at least 6 ft physical distance. The hoops will collide or visibly overlap when students are too close together.	
C	**<u>Magnetic Repulsion</u>** – The magnetic repulsive forces from the magnets attached to the chairs will keep students distanced from one another.	
D	**<u>Line Organizational Pole</u>** – A pole with handholds spaced at 6 ft apart would ensure that students remain physically distant while moving as a group.	
E	**<u>Movable Divider</u>** – Dividers that can be clamped to tables provide a degree of protection when 6 ft physical distancing is not practical. Dividers could also be placed on other sufficiently level surfaces.	

Table 5. Physical distancing Pugh matrix

Pugh Matrix – Physical Distancing						
Criteria	Weight	Class set wristband sensors	**3ft radius hoop**	Magnetic repulsion	Line organizational pole	Easy move dividers
1	4	-	D A T U M	S	-	-
2	3	S		S	S	+
3	2	-		-	+	-
4	2	-		-	S	S
5	2	S		S	S	S
6	2	S		-	S	S
7	1	+		-	-	S
8	1	+		-	-	-
9	4	+		S	-	S
10	4	+		S	S	S
Sum(+)		4 (10)		0 (0)	1 (2)	1 (3)
Sum(-)		3 (-8)		5 (-8)	4 (-10)	3 (-7)
Sum(S)		3 (0)		5 (0)	5 (0)	6 (0)
Weighted Sum		2		-8	-8	-4

For the physical distancing Pugh matrix in Table 5, we chose the 3 ft radius hoop as our datum because we considered it the most straight forward way to ensure at least 6 ft of physical distance, if the hoops are not overlapping there is sufficient distance between students. For physical distancing the Pugh matrix provided a clear path forward with the class set of wristband sensors edging out the datum and the other options performing moderately to significantly worse than the datum.

After narrowing down which type of product we want to pursue for the physical distancing protocol, we went through another iteration of more specific customer requirements and translated those into engineering specifications using QFD. We summarize our house of quality specifications in Table 6.

Table 6. Physical distancing monitor engineering specifications

Formal Design Requirements – Physical Distancing					
Spec. #	**Category**	**Parameter Description**	**Requirement or target (units)**	**Tolerance**	**Risk**
1	Cost	Cost to purchase	$20/unit	Max	L
3	Time	Operating Time	20 minutes/day	Max	L
4		Battery Life	10 hours	Min	L
5		Product Life	5 years	Min	L
4	Comfort	Weight	5 oz	Max	L
5		Material	Non skin irritant	Min	M
5	Notification	Speaker Volume	75-80 dB	Range	M
6		Vibration Intensity	130-180 Hz	Range	M
7	Durability	Water Resistance	IPX4	Min	L
8		Drop Resistance	3 ft Drop Test	Min	L
8	Number	Class Set	30 units	N/A	L
10	Measurement	Range	0-10 ft	Range	M
11		Accuracy	± 1 ft	Max	M

A comparable product produced by Ultimaxx costs $33 for a single unit, and $24 per unit in a group of 10. For a class set of 30, our goal is to provide a product that is slightly less expensive per unit at $20. The average school day is between 6-7 hours; to provide a degree of leeway the wristband battery should last at least 10 hours [22]. The wristband must be water resistant, so it does not have to be removed for the wearer to wash their hands. IPX4 is a water resistance designation that indicates the product can withstand water splashes. The vibration intensity was determined from the range commonly used in mobile phones, which is comparable to the desired vibration intensity [23]. The wristband should be capable of at least withstanding a drop from 3 ft, equivalent to if it fell off a table. To ensure that the sound emitted by the wristband is perceptible from across a room, it should be approximately 75-80 dB, which is about as loud as an alarm. Sounds over 85 dB can be damaging over an extended period [24].

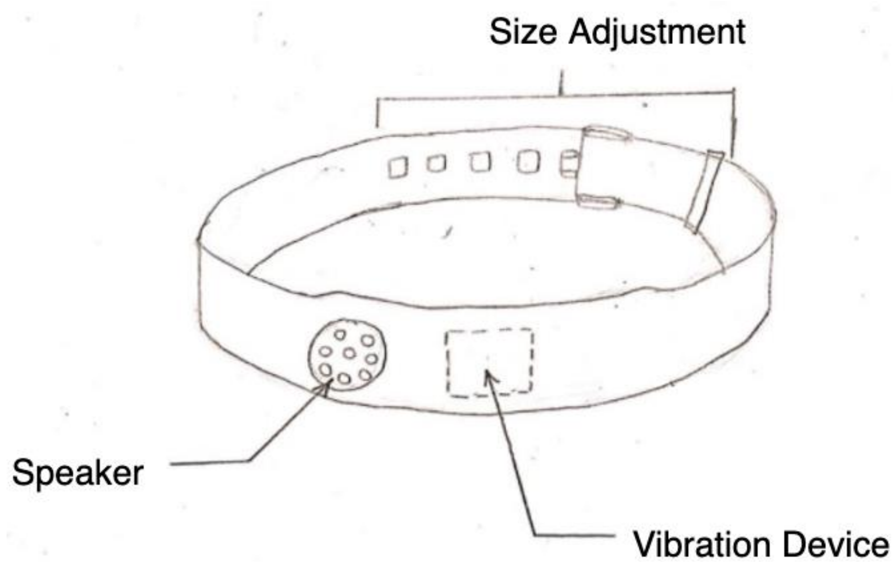


Figure 3.Physical Distance Monitoring Wristband

We have outlined the development plan for the physical distancing monitoring wristband to address the physical distancing protocol. Figure 3 shows a sketch of the concept that including key components and the preliminary appearance of the device. The vibration device and speaker provide feedback if the wearer is too close to others. If physical distance protocols have not been seriously violated, for example standing five feet apart instead of six, the band will vibrate to inform the wearer that they need to move farther away from others. If protocols have been seriously violated, for example standing one foot apart, the speaker will emit a sound to notify the wearer, those near them, and the teacher that students are much too close to one another. The standard recommended safe distance is six feet, however, there are situations where it is simply not possible to maintain a six-foot distance due to the size of the space and the number of students present. With that in mind, the distance between wearers will be a value that would be set by the teacher.

The exact method by which the wristbands will interact with one another to determine how close wearers are to each other is still outstanding; two potential solutions are Bluetooth connectivity or radio-frequency identification (RFID) tags, but more research is required [26][27]. Charging is an additional aspect of the device that requires further consideration. Consumable batteries would need to be long lasting, or teachers would have to frequently replace the batteries, adding the additional work of having to ensure there is an adequate store of batteries at the school and having to replace each battery individually. Rechargeable batteries would not have to be as frequently replaced, but if they required wired recharging the teacher would have to plug in each wristband separately. Conceptually, a potential solution that would include rechargeable batteries but would be easy to recharge is wireless charging. However, more research is required to determine if this is a practicable solution.

The COVID-19 situation globally has been changing throughout the duration of this project. Several vaccine candidates have been approved for use by the FDA and over one million vaccines are being administered in the United States daily. With this is mind, we have chosen to narrow the scope of the project to focus on solutions which are more broadly applicable in a post-COVID-19 world and remove the physical distancing bracelet from our toolbox. The conceptual design development of the physical distancing device remains included in this report for completeness.

Sanitation

We determined the following customer requirements to ensure that our solution helps teachers enforce the sanitation safety protocol:

1. Enforcing Santa Clara County protocol of sanitizing frequently
2. Opt-in product for teachers to use at their own discretion
3. Low cost
4. Easy to use and maintain
5. Does not need active user operation
6. Safe for use in classroom environment
7. Addresses teacher's safety concern of sanitizing high contact surfaces

Guided by our customer requirements, we generated the solutions in Table 7. Then we compared them using the Pugh matrix in Table 8.

Table 7.Sanitization solutions generated

Idea	Description	Picture
A	**UVC Classroom lights** – Far UVC lights hung on the ceiling of classrooms to provide broad range of disinfecting.	
B	**UVC dunk box** – A UVC light sanitizing box would be used to sanitize shared classroom supplies such as art supplies, games, and other miscellaneous objects. The solid box would contain UVC lights on the interior to quickly and easily sanitize all objects placed inside of it.	

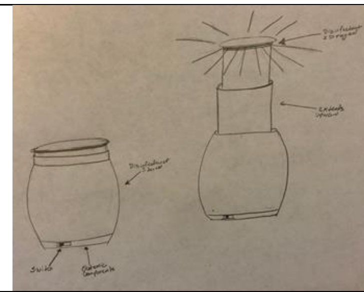
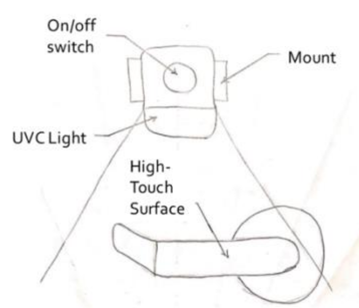
C	**<u>Sanitizing spray sprinkler</u>** – Device is placed around the classroom and when activated, the device extends upward and sprays a mist of disinfecting solution.	
D	**<u>Clean sensor</u>** – Use visible light fluorescence spectroscopy to scan surfaces to detect signs of viruses and bacteria. This device could be used to check the cleanliness of the classroom after it has been cleaned or used during the day near high contact surfaces to notify the teacher when the surface needs to be cleaned.	
E	**<u>Targeted disinfecting spray</u>** – Similar to an automated air freshener, this device would spray disinfecting solution onto high contact surfaces such as doorknobs or computer keyboards at a set interval or after each use. The device would come with mounts ranging from strong adhesive stickers to gorilla tripods so teachers can move the product as needed	
F	**<u>Targeted UVC lights</u>** – A small far UVC light is mounted above high contact surfaces such as doorknobs, faucets, and communal tables to thoroughly disinfect the surfaces.	

Table 8. Sanitization Pugh matrix

Pugh Matrix – Automated Disinfecting Devices – Type of approach							
Requirement	Weights	UVC classroom lights	UVC dunk box	Sanitizing spray sprinkler	Clean Sensor	Targeted disinfecting spray	Targeted UVC lights
1	3	DATUM	-	S	-	S	S
2	2		+	S	+	+	+
3	1		+	S	+	+	+
4	1		S	S	S	-	S
5	1		-	S	-	S	S
6	4		S	+	+	+	S
7	3		-	S	-	+	+
Sum(+)			3	4	7	9	7
Sum(-)			7	0	8	1	0
Sum(S)			5	11	1	5	9
Weighted sum			-4	4	-1	8	7

After analyzing potential solutions to enforce disinfection protocols and to enable teachers to feel in control and safe in their classrooms, we narrowed our device concepts to the highest scoring ideas: automated targeted disinfecting spray and automated targeted UVC lights. Disinfecting spray and UVC lights are both effective at inactivating COVID-19, a key design requirement. The automated aspect of the designs ensures surfaces are frequently disinfected without active user operation. The combination of automated and targeted disinfecting will allow teachers to feel safer navigating the classroom environment.

Now to decipher between the two effective solutions, targeted disinfecting spray or targeted UVC lights, we looked at drawbacks of each potential solution. After disinfecting spray is applied to a surface, such as a doorknob, the spray must be wiped off to avoid skin irritation. As a result, the targeted disinfecting spray device needs an additional tool to wipe off the given surface after the disinfectant is sprayed. This additional wiping tool would need to be automated to ensure the device is easy to use and adjustable to account for various device placements in the classroom. Although an automated wiping tool is possible, it adds a level of complexity, adding more costs and more potential to break.

To understand the drawback of the targeted UVC light we need to differentiate between two types of UVC light, Germicidal UVC light and far-UVC light. Germicidal ultraviolet light, typically at 254 nm, when used directly, is effective at killing pathogens but poses health hazard to skin and eyes. By contrast, Nature, a highly reputable scientific journal, and countless other scientific publications have shown far-UVC light, 207 – 222 nm, effectively kills pathogens without harm to exposed human tissue [19]. Although far-UVC is the better option in regard to safety, far-UVC lights costs around $1000 making it impossible to meet the low-cost requirements. Thus, we will be proceeding with the automated and targeted UVC lights using germicidal with mechanical safety features.

After further consideration of the benefits and drawbacks of UVC light we concluded that it would be imprudent to continue pursuing UVC as our sanitizing method. We performed another iteration of customer requirements with corresponding engineering specifications as shown in Table 9. All parameters related to UVC lights are based on standard set by the CDC and from peer reviewed research papers [19][25].

Table 9. Classroom UVC lights engineering specifications

Formal Design Requirements – UVC Light Disinfecting Surfaces					
Spec. #	**Category**	**Parameter Description**	**Requirement or target (units)**	**Tolerance**	**Risk**
1	Cost	Cost to purchase	$30	Max	M
2		Cost to operate	$10	Max	M
3	Time	Operating time	Operator time spent 15 mins / day	Max	M
4		Ease of learning	1 hour set up time	Max	M
5		Time between maintenance	1 week	Min	M
6		Battery Life	1 week of classroom use	Min	M
7		Product Life Span	1 year	Min	M
8	Efficacy	Inactivates COVID-19 virus	99% of virus on given surfaces	Min	H
9		Safety	Output poses no harm to humans	Max	H
10		Durability	Pass drop test	N/A	H

11	UVC Light	Light wavelength	207 – 254nm	Range	H
12		Duration of light exposure	10 mins	Max	H
13		Dose strength	1.2 – 3 mJ/cm^2	Range	H

Using our customer requirements and engineering specifications, we performed high-level analysis to prove that our top concepts will satisfy our problem needs. The final concept to address sanitation concerns in the classroom uses germicidal UVC light, 254 nm light, to inactivate COVID-19. The main components of the targeted UVC light are a safety guard, adhesive mount, battery, and controls feature. The safety guards around the light bulb direct the light downward at the targeted surface for cleaning ensuring the light does not shine in anyone's eyes. The adhesive mount allows the device to be moved around the classroom as needed and easily mounted above high contact surfaces. The battery needs more consideration and at this moment we are unsure of whether it will be rechargeable, with or without a cord, or if it will rely on disposable batteries. Another area of further development is in the controls schematic and when the device will be used to balance safety concerns and the need for frequent sanitation.

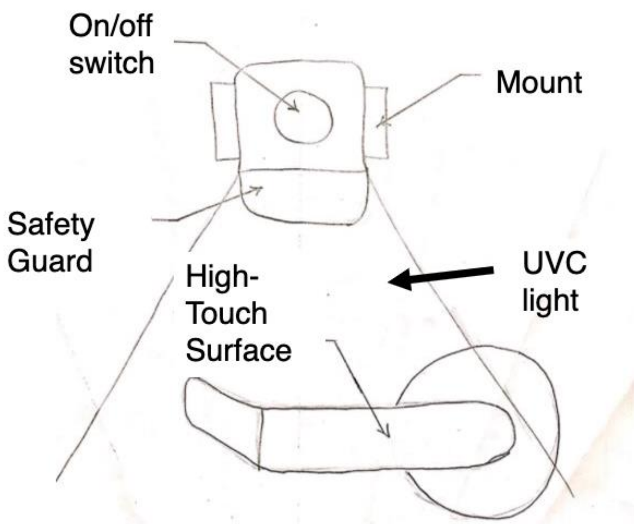


Figure 4. Targeted UVC light device.

The targeted UVC light meets the project requirements by ensuring teachers feel safe returning to in person classrooms by being confident in the level of cleanliness of high touch surfaces around the classroom. Seen in Figure 4, the device is designed to be an opt-in product at an affordable cost for teachers.

After further consideration of the safety concerns of UVC light, we concluded that we could not develop safety measures we felt would eliminate the risk of accidental exposure. Since this product is intended to be used in school setting, student safety is important. This necessitated a conceptual redesign of the sanitation component of our toolbox. We have decided to opt for a liquid-based sanitizer instead of using UVC.

We revisited our customer requirements and engineering specifications and adjusted them for a liquid sanitizer disinfecting spray application. When determining our cost goal, we could not find existing products to price match off of, so we looked at costs of similar products like automatic hand sanitizer and automatic soap dispensers. If we had more time, we would conduct surveys with potential customers to get a more accurate cost target. We want to make our product geared towards doorknobs and faucets, which is how we determined the spray area requirement.

Table 10. Liquid sanitizer spray requirements and specifications

Customer Requirement	Engineering Specification
Low cost	Cost < $40
Minimize frequency of battery replacement	Lithium-ion rechargeable battery
Minimize need to replace product	Individual components replaceable, design for assembly & disassembly
Kill COVID-19 particles living on surfaces	Spray adequate amount of sanitizer to fully cover surface
Does not spray on people	Implement controls system with sensors (motion, distance, etc.) to ensure people do not get sprayed
Applicable for doorknobs & faucets	Spray area > 4" L x 2" W
Minimize frequency of refilling sanitizer	Refill < 1 time per week
User can choose which sanitizer they want to use	Refillable reservoir compatible with common liquid sanitizers
Easy to refill	Minimize steps required to refill
Easy to set up in various parts of classroom	Mountable to common classroom surfaces (doors, counters, desks, etc.)
Safe for classroom use	No sharp edges, no exposed electrical components, no chance of falling

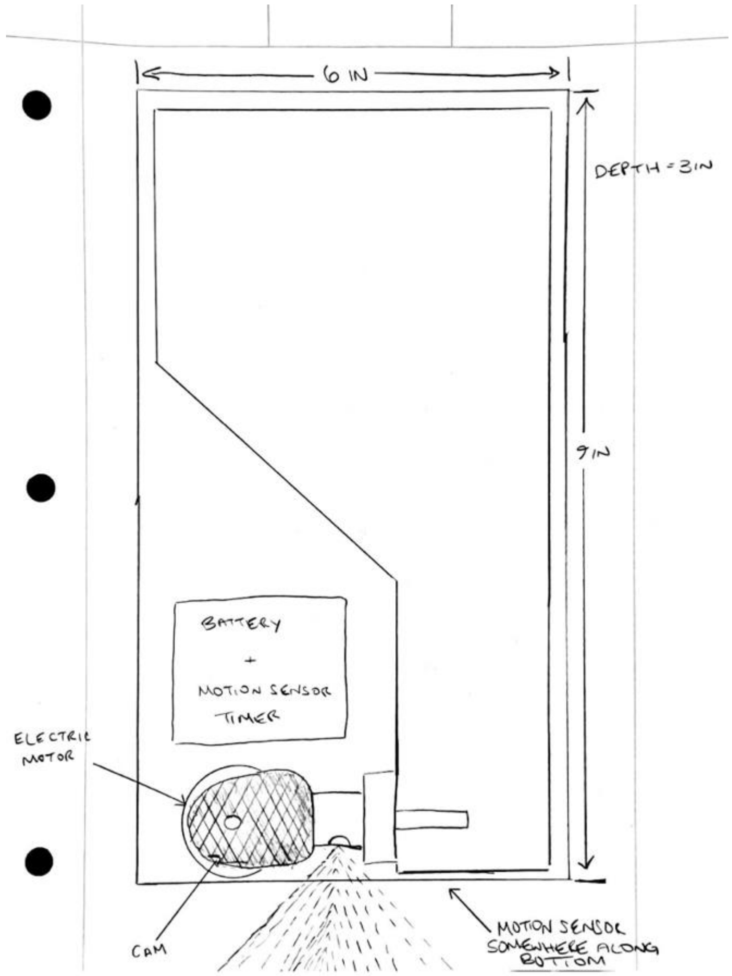


Figure 5. Sanitation Module Conceptual Drawing

Figure 5 shows the conceptual design of the sanitation module. The main components of the device are a reservoir to hold the disinfecting solution, a spray nozzle to dispense the liquid, an electric motor and cam, a battery, a fan, and a control system. After deciding that we would no longer be using UVC light, we compared liquid disinfectant and aerosolized disinfectant. Our research found that aerosolized disinfectant was typically several times more expensive than liquid disinfectant. To promote disinfectant evaporation and avoid dripping, a fan on the bottom of the sanitation module will turn on after the solution has been sprayed. Conceptually the general operation of the system will be as follows, a motion sensor will detect the motion of a hand opening a door, the system will then wait several seconds or until the hand is no longer present, the motor will spin the cam, the cam will depress the nozzle and spray the disinfectant, and then the fan will run. The system is not intended to sanitizer hands, it disinfects high touch surfaces after they have been used.

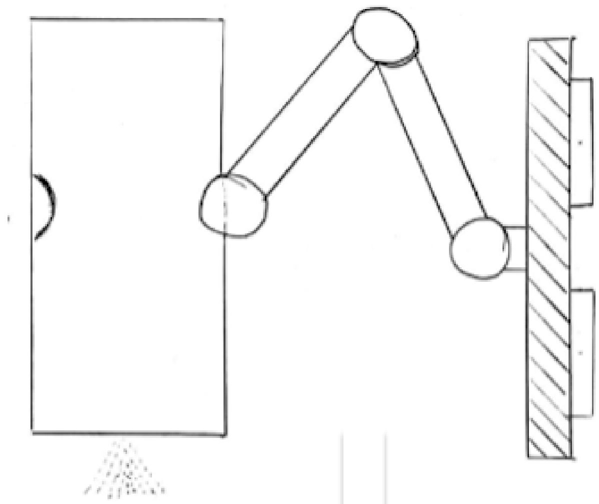


Figure 6. Mount and Articulating Arm Conceptual Drawing

We also further developed our mounting concept. The system is intended to be relatively easy to mount while also remaining firmly attached to the surface to which it is mounted. To achieve this the mount will consist of a heavy-duty suction cup that will be able to hold the system in a variety of positions as shown in Figure 6. Since we cannot anticipate the specifics of every situation the automatic disinfecting spray will used for, it is important that the system can be moved around while it is mounted. The sanitation module will be connected to the mount with an articulating arm to provide greater flexibility in use.

Chapter 4: Description of the Final Design

4.1 Overall description / layout

Our final design for the sanitization protocol is an automatic disinfecting spray that will spray high-touch surfaces, specifically door handles and faucet handles. After someone opens the door or finishes using the faucet, the spray will acuate to sanitize the high-touch surface before the next user. The system will include a sensor and controls system to ensure that users do not get sprayed with the sanitizer.

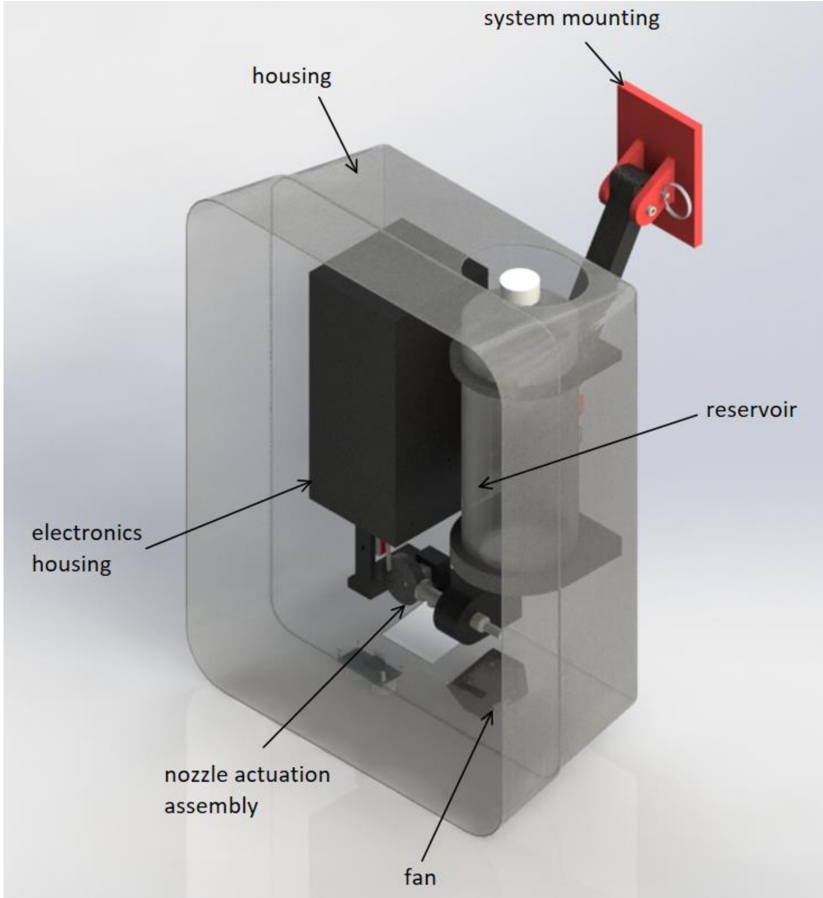


Figure 7. Automatic Disinfecting Spray Assembly Layout

Figure 7 shows the CAD assembly for the automatic disinfecting spray. All the components are enclosed inside of a clear plastic housing so that users can monitor the level of sanitizer in the reservoir. For visibility purposes, the front cover of the housing is not shown. The system mounting can mount to doors, counters, mirrors, or other flat surfaces above the high-touch surface. The mounting is also adjustable to ensure the device accurately sprays on the desired surface. A refillable reservoir stores the liquid sanitizer chosen by the user. The reservoir connects to the spray nozzle through a plastic tube. A motor and cam assembly controlled by a microcontroller and sensor actuates the nozzle. A small fan helps more quickly dry the high-touch surface so that users do not get wet when they touch the surface. The electronics components are stored in a housing to protect them from accidental sanitizer spills.

The face shield design consists of a modified Z shield, a commercially available face shield that is supported on the shoulders. By adding a microphone and speaker to the current face shield design teachers can more effectively deliver lectures with more comfort and ease while keeping themselves safe. By using a face shield that rests on the user's shoulder, the user will be able to support the weight of the added electronic components without straining their neck and shoulders like with a forehead supported face shield. In addition, teachers in a K-12 setting frequently work with children who are shorter than them. Thus, a shoulder supported face shield also provides coverage from airborne particles travelling from underneath the face shield. The addition of a microphone and speaker allows teachers to overcome the strain of wearing a mask and projecting loudly while talking. Teachers are talking for extended periods of time in a classroom and to be able to do so day to day they need to find a way to teach comfortable. Our device allows the teacher to talk at a normal volume and the face shield will project their voice louder to the entire class, even students sitting at the back of the classroom will be able to clearly hear the lecture.

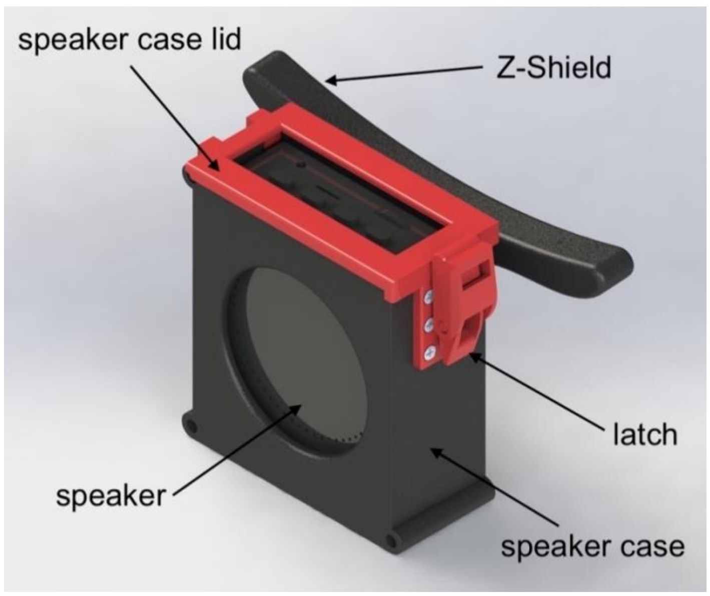


Figure 8. Face Shield Assembly Layout

The face shield design shown in Figure 8 consists of a modified Z shield, a commercially available face shield that is supported on the shoulders. By adding a microphone and speaker to the current face shield design teachers are able to more effectively deliver lectures with more comfort and ease while keeping themselves safe. By using a face shield that rests on the user's shoulder, the user will be able to support the weight of the added electronic components without straining their neck and shoulders like with a forehead supported face shield. In addition, teachers in a K-12 setting frequently work with children who are shorter than them. Thus, a shoulder supported face shield also provides coverage from airborne particles travelling from underneath the face shield. The addition of a microphone and speaker allows teachers to overcome the strain of wearing a mask and projecting loudly while talking. Teachers are talking for extended periods of time in a classroom and to be able to do so day to day they need to find a way to teach comfortable. Our device allows the teacher to talk at a normal volume and the face shield will project their voice louder to the entire class, even students sitting at the back of the classroom will be able to clearly hear the lecture.

4.2 Detailed design

The automatic disinfecting spray uses a motor and cam to actuate a spray nozzle.

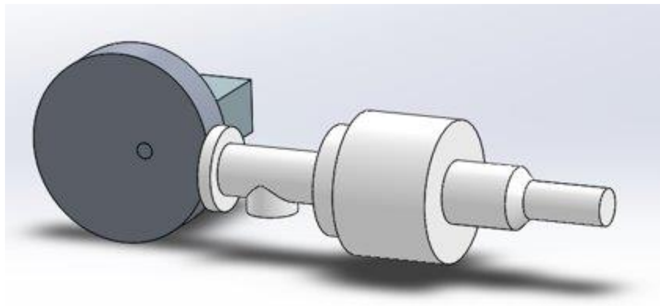


Figure 9. Initial cam & motor subassembly

Figure 9 shows our initial cam and motor assembly. The motor has a D-shape shaft, and the cam has a D-shape hole to ensure that the cam rotates with the motor shaft. A set screw goes through the cam and tightens onto the flat surface of the D-shaped motor shaft to fix the cam's longitudinal position along the shaft.

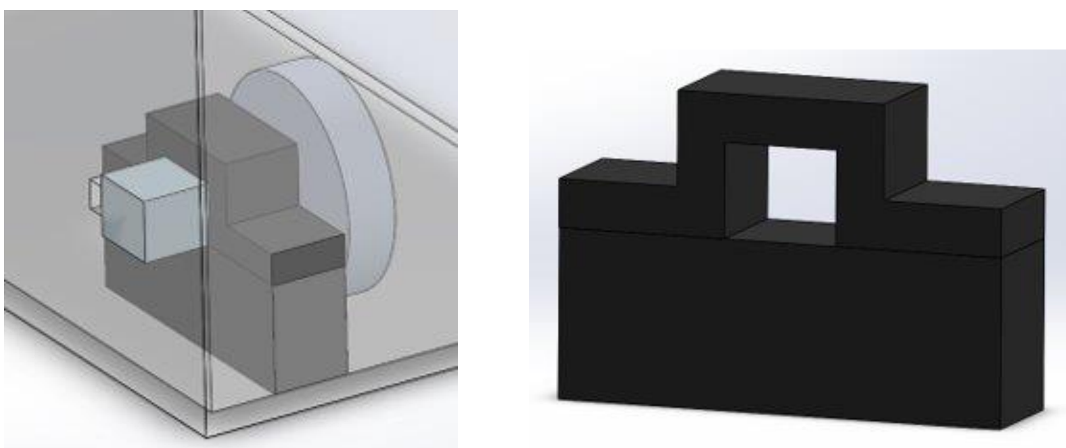


Figure 10. Initial motor mounting

For mass manufacturing of the disinfecting spray, we would injection mold the housing to include mounts for the internal components. For prototyping, we decided to use a plastic box to act as the housing, and 3D print mounts that will screw into the housing to hold the internal components.

We must mount the motor and cam such that the cam has enough clearance to fully rotate. Figure 10 shows the initial design for the 3D printed mount for the motor. The mount allows the cam to fully rotate without contacting the housing. This mount screws into the floor of the housing.

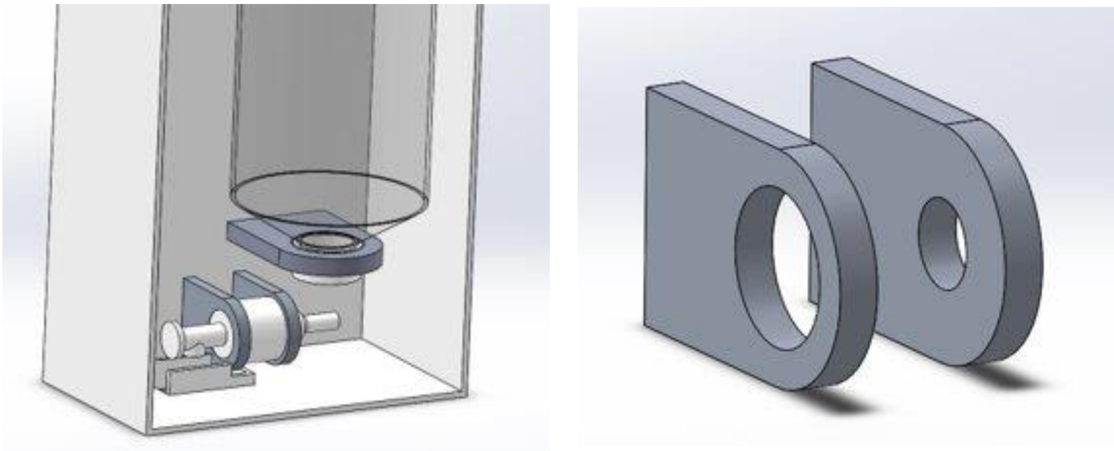


Figure 11. Initial nozzle mounting

Initially the nozzle mounted to the housing with two tabs seen in Figure 11. The tabs screw into the back face of the housing. The nozzle has two mounting tabs to prevent translation in any direction. The reservoir has one mount around the cap to hold its position vertically and one mount above to prevent the reservoir from tipping over in any direction.

After prototyping these initial mounts, we found that the nozzle and cam did not make proper contact. Because the bottom of the housing is not perfectly flat, mounting the motor to the bottom of the housing caused the cam to be at an angle to the nozzle. In addition, due to tolerance stack-up between all the mounts, the cam and nozzle did not contact.

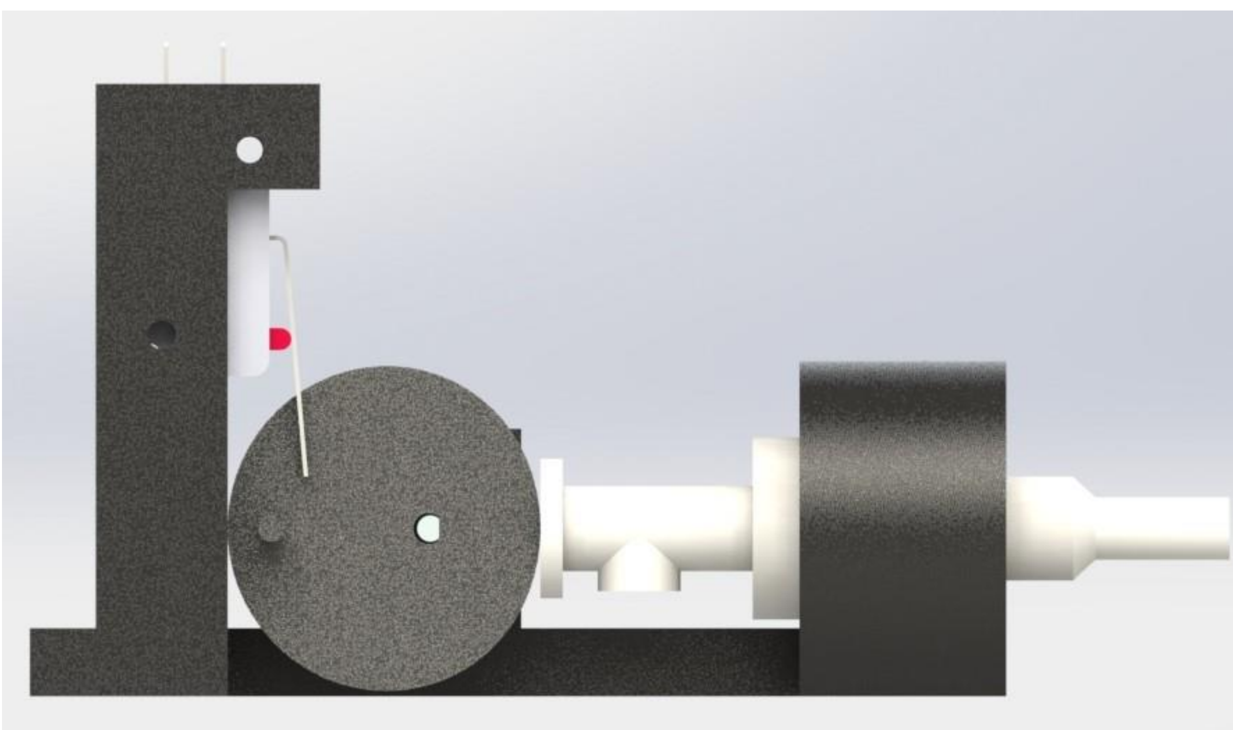


Figure 12. Final nozzle actuation subassembly design

To address these issues, we redesigned the nozzle actuation assembly in Figure 12. This mount screws into the flat back of the housing instead of the angled bottom of the housing, so all the components line up. By mounting all the components on a single part, we reduce the tolerance stack-up and ensure that all the components interact properly. The final subassembly also has a spot to mount the limit switch, which senses the cam position.

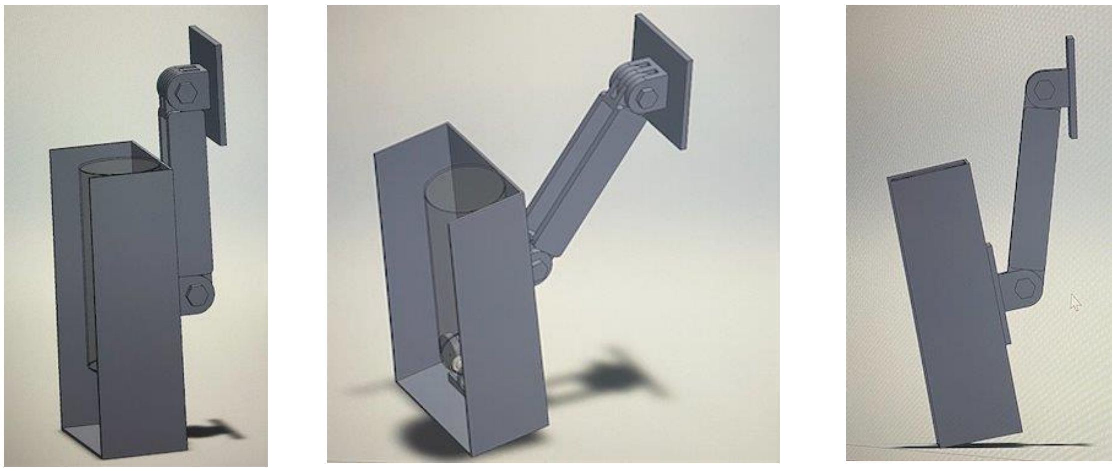


Figure 13. System mounting initial design

Figure 13 shows our initial design for the overall system mounting. The mount can stick onto flat surfaces like doors, mirrors, or counters using suction cups. Suction cups allow the system to be easily removed or adjusted. An arm can extend, or collapse based on the distance from the mounting surface to the high-touch surface. This arm allows for more flexibility regarding the application of the system to different high-touch surfaces. The arm stays in place using the friction of two tightened bolts.

After performing some tests, we realized our initial system mounting design could not support the weight of the full reservoir and electronics components. The suction cup could not support the moment created by the weight of the housing, and the bolts could not produce enough clamping force or friction to prevent the arm from rotating. The bolts also required tools to tighten and loosen, which became time consuming.

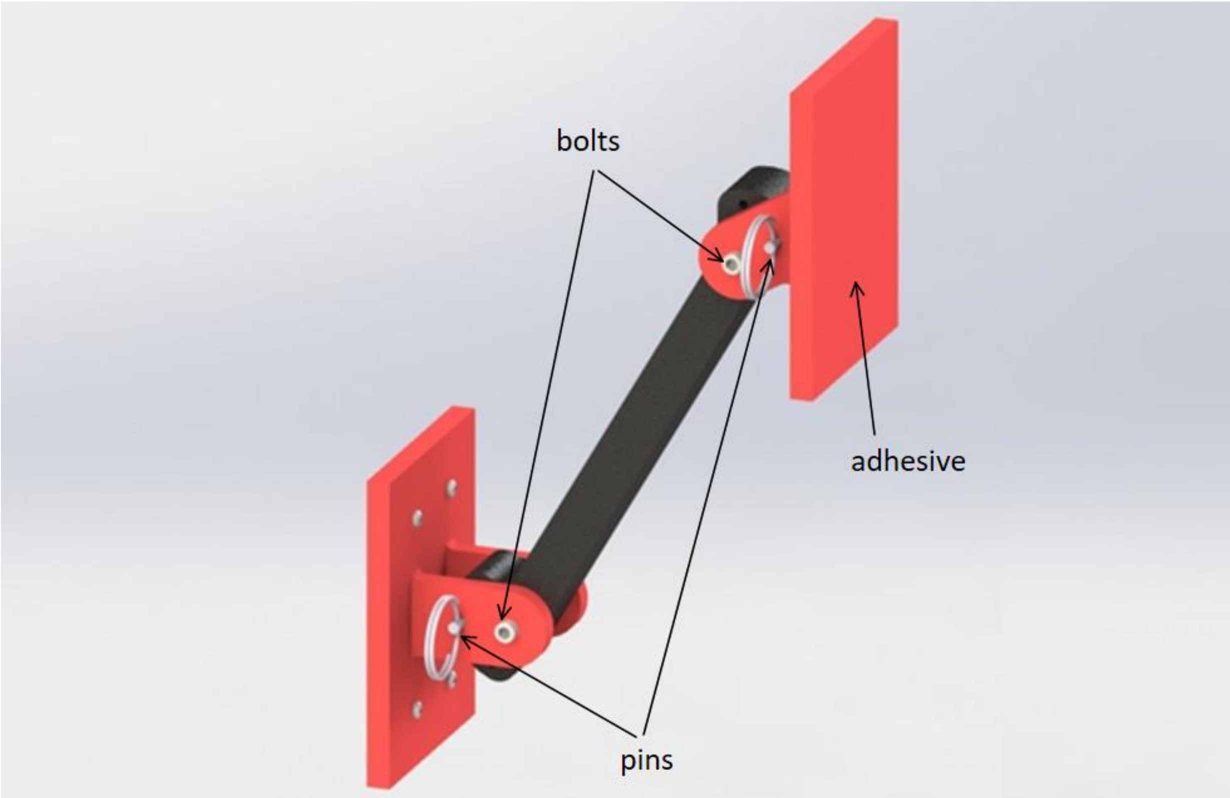


Figure 14. Final system mounting design

We improved upon these points to come up with the final design in Figure 14. We replaced the suction cup with a strong adhesive mount. Instead of using friction to lock the arm in place, we used two bolts and two pins to lock each end of the arm in place. The bolts can be screwed in by hand, and the pins are quick release. The arm has discrete holes for placing the pins, so the arm can only be adjusted to specific positions. While this might be a drawback compared to the infinitely adjustable friction design, this design can hold the full weight of the housing, which is more critical to the product's success.

For refilling, Figure 15, the housing has a hole at the top to easily access the reservoir cap. Due to the small cap size, we recommend using a funnel during the refilling process to mitigate spilling.

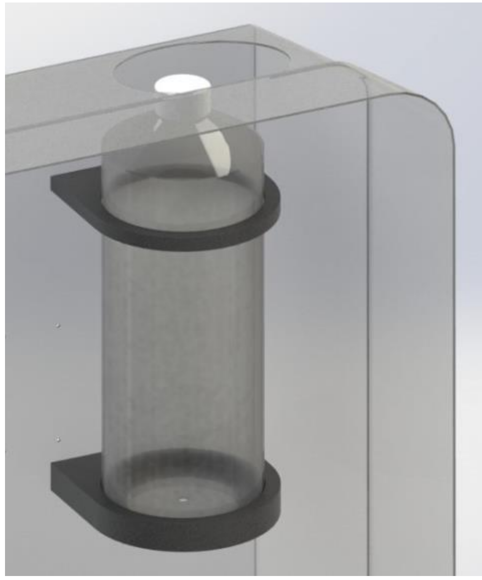


Figure 15. Reservoir refilling

To protect the electrical components from sanitizer spills or leaks, we designed the electronics housing in Figure 16. We put in blocks to approximate the amount of space taken up by the batteries, motor driver, and microcontroller bread board. The housing cover can be removed by pulling up then out and vice versa to replace the cover.

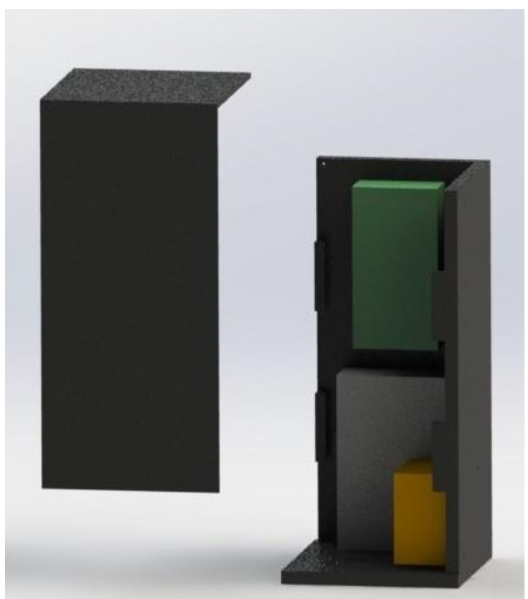
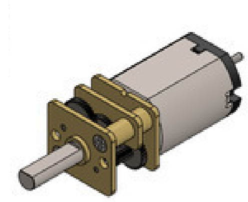
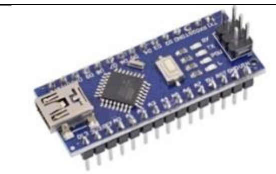
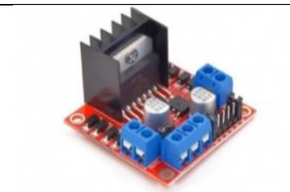


Figure 16. Electronics housing design

A sensing and timing control system will control the actuation of the motor. An ultrasonic sensor will be used to detect the presence of a hand as it turns a knob or handle. The electronics control system underwent iteration and serious redesign, components of the original and updated design are discussed for completeness. Table 11 shows the electronic components that make up the final controls circuit.

Table 11. Automatic Disinfection Spray Circuit Components

Automatic Disinfecting Spray Main Electronic Components and Key Specs	
Motor Specs: Supply Voltage: 6 V Current: 0.7 A	
Arduino Nano Specs: Supply Voltage: 5V Current: 17 mA	
Motor Driver Driver Voltage: 5-35V Driver Current: 2A (Single Bridge) Logic Voltage: 5V Logic Current: 0-36 mA	
Sensor Specs: Supply Voltage: 5 V Current: 15 mA	
Battery Pack Specs: Rechargeable Li-Ion Battery life: 3 Days Voltage: 7.4 V Capacity: 3000 mA	
Fan Specs: Supply Voltage: 3-5.8 V Supply Current: 0.18A	
Limit Switch	

The electrical components for the automatic sanitizer will be powered using a battery pack with two rechargeable 3.7 V lithium-ion batteries. The benefit of using 3.7 V batteries is that they are inexpensive and widely available. The two batteries provide a combined 7.4 V; however, the motor driver has internal resistance so the voltage that is available to the motor and fan at their respective terminals is appropriate for their requirements.

Originally our electronics design called for a Si1102 optical proximity sensor to detect the presence of a hand interacting with the high touch surface. The sensor operates with a simple on/off digital output with the state based on the comparison of reflected light against a set threshold. The LED outputs light pulses whose reflections are processed by the sensor. If a hand is present the reflected light will exceed the detection threshold and indicate proximity. A schematic of the Si1102 is shown in Figure 18.

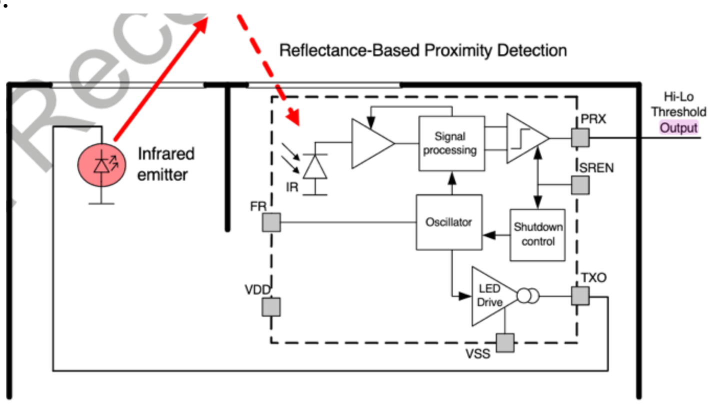


Figure 17. Si1102 Functional Schematic

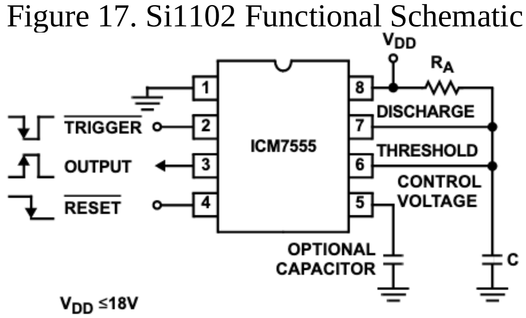


Figure 18. ICM7555 Timer Schematic

Our initial design required an independent 555 timer to execute the delay. The timer will be used in monostable, or one-shot operation. In monostable operation the timer can be triggered to generate a pulse for a preset amount of time depending on the values of resistor R_A and capacitor C seen in Figure 13. The sensor detecting the proximity of a hand will trigger the timer to begin its 5 second pulse. If the proximity sensor still detects the presence of a hand at the end of the pulse, the timer will be retriggered for another pulse. An in-depth description of the specifics of this operation can be found in Appendix D.

Our initial sensing and control system for the automatic sanitizer had the advantage of being very simple conceptually and avoids using more complicated components like a microcontroller. We had considered using a microcontroller early in our design process but moved on to other ideas due to its complexity. However, the simplicity of the system made it more difficult to implement and required electrical expertise beyond our abilities. Although a microcontroller is a more complex piece of technology, it is more user friendly, and we have previous experience working with microcontrollers. We selected the Arduino Nano shown in Figure 19 as our microcontroller because of its small form factor and inexpensive cost. Other benefits of using an Arduino are its relative user friendliness and the open-source nature of the platform. Using the Arduino Nano also eliminated the need for a separate 555 timer for the five second delay between detection and motor actuation. The five second delay can be created within the Arduino program using a few lines of code.

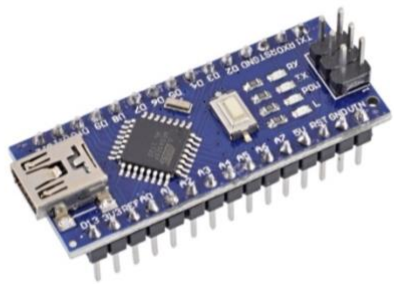


Figure 19. Arduino Nano

Shifting to a microcontroller-based system also required utilizing a sensor that could easily interface with the Arduino. A HC-SR04 Ultrasonic Sensor operates by emitting a high frequency sound wave, beyond the capability of human hearing. When the sound wave hits an object, it is reflected to the sensor which uses the time elapsed between the emission and receipt of the sound wave to determine the distance of the object. The operation of the sensor can be seen below in Figure 20.

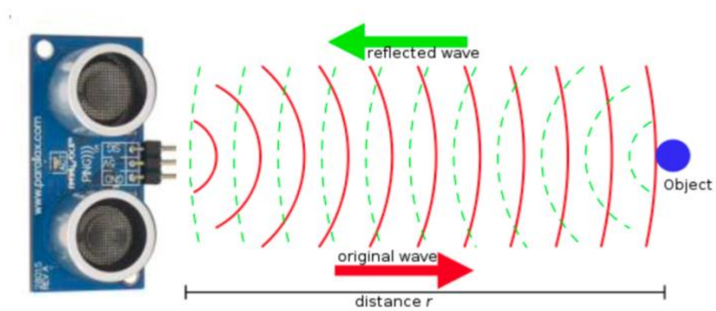


Figure 20. Ultrasonic Sensor Operation

To control the micro-metal gear motor with the Arduino we also require a motor driver. Using pulse-width modulation (PWM) and motor control pins the motor driver allows the Arduino to control the speed and direction of motor rotation. Since the motor is dual-channel the set of pins not occupied by the motor will be used to control the fan. The motor driver also has a 5V output port which we can use to power the Arduino during system operation. The L298N Dual-Channel H-Bridge Motor Driver we used can be seen below in Figure 21.

Figure 21. L298N Dual-Channel H-Bridge Motor Driver

To ensure that the sanitizer is dispensed is a consistent manner we need to the location of the motor each time it is actuated. If the motor does not have a consistent rotation the final motor position could prevent the nozzle from depressing properly. The motor does not need to complete a full revolution to depress the nozzle. Instead, the motor reverses direction each time runs, only rotating enough to depress the nozzle each time it cycles before stopping and rotating the other direction the next time it cycles. This system works because the limit switch's lever is long enough that the cam impacts the lever at the top and bottom of its rotation. A long lever limit switch can be seen in Figure 22.

Figure 22. Limit switch

The full electronics schematic for the automatic sanitizing spray with brief descriptions of each component can be seen in Figure 23.

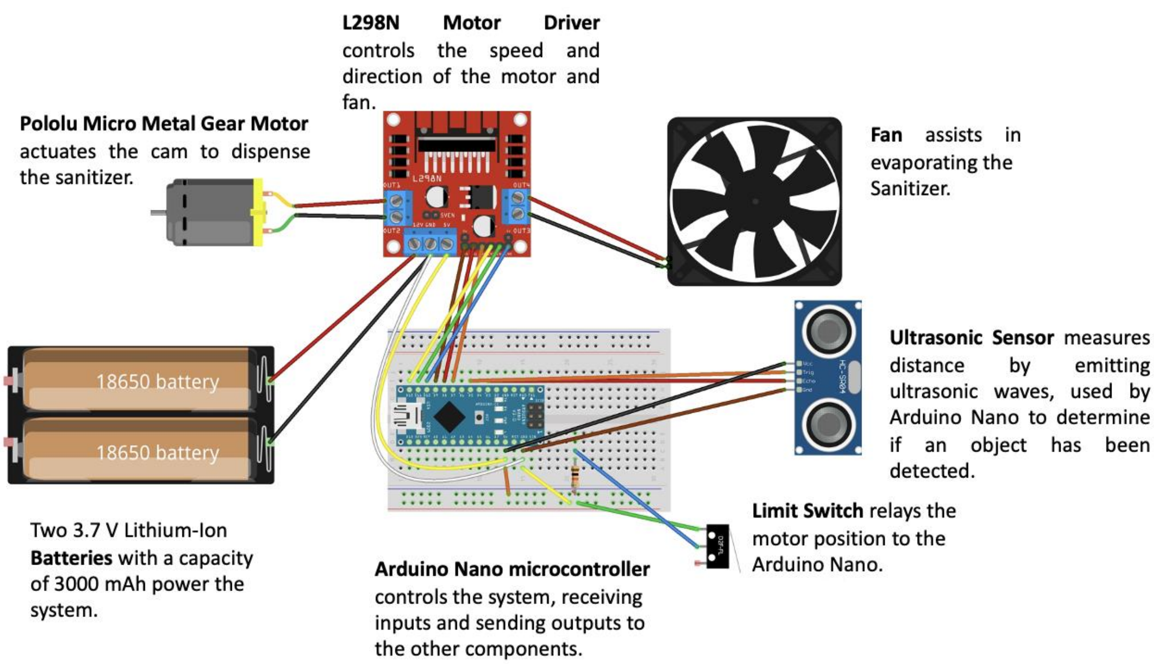


Figure 23. Automatic Sanitizing Spray Electronics Schematic

The Arduino Nano code that controls and interfaces all the electronic components follows the flowchart that is shown below in Figure 24. When the system is initially turn on the motor and sensor both begin with calibration sequences the ensure the motor begins in the correct position and that the sensor takes calibration measurements so the Arduino can determine how far away the surface to be sanitized is from the automatic sanitizing spray. If the sensor takes a measurement more than fifty percent less than the calibration distance an object is considered detected, beginning a five second countdown. If an object is still detected at the end of the five second delay, the delay starts again to avoid spraying a person's hand if they are utilizing the surface to be sanitized. The complete paths of the code can be seen in the flowchart. The full Arduino Nano code can be found in Appendix D.

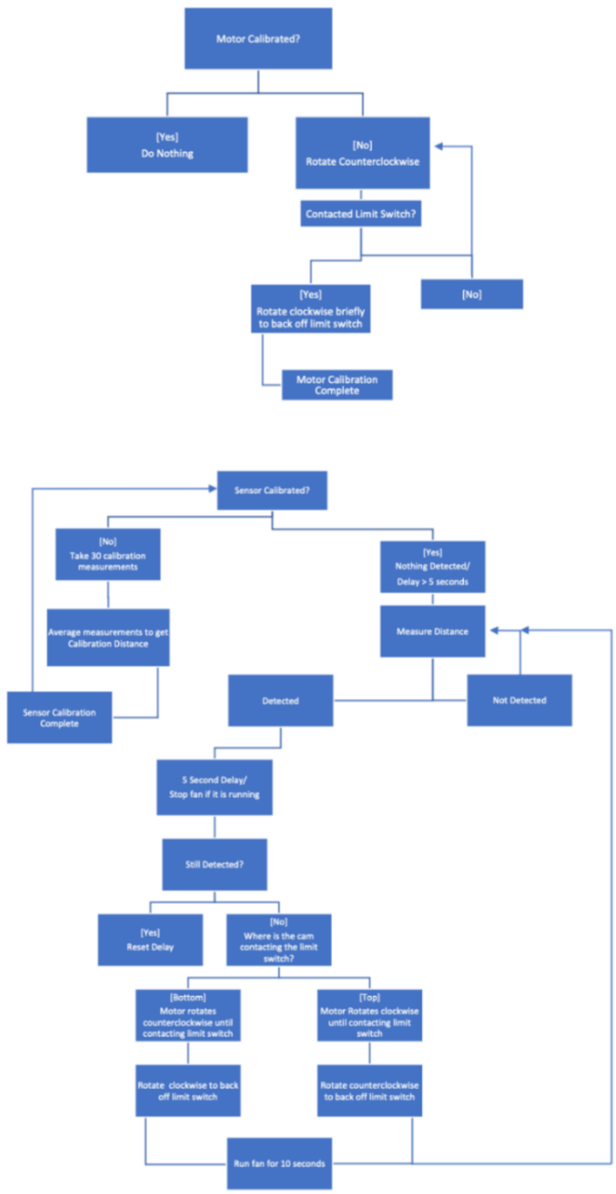


Figure 24. Arduino Code Flowchart

The face shield contains an electronic system to allow teachers to more comfortable teach and overcome the limitations of wearing a face mask. three primary electronic components: microphone, speaker, and battery. The below microphone and speaker will be used in the circuit. The main selection criterion for the microphone was ensuring the microphone could pick up all frequencies of human speech, 15 Hz to 17 kHz. The main selection criterion for the speaker was ensuring the speaker could be heard clearly by students in the back of the classroom. The battery was chosen to be rechargeable for sustainability and user-friendly purpose as well as meeting the required voltage output. We utilized a Zoweetek rechargeable voice amplifier. Figure 25 shows the breakdown of the internal components of the voice amplifier.

Figure 25. Zoweetek portable rechargeable mini voice amplifier

In addition to electronic parts, the face shield utilizes a modified commercially made face shield called the Z shield. The below table outlines the mechanical parts of the face shield.

Table 12. Decomposition of Z shield Design

Fully assembled face shield supported by the chest. 	Polyethylene terephthalate glycol (PETG) clear visor provides protection from COVID-19 particles. 
Shoulder support piece allows for the distance between the clear visor and the user's face to be adjusted. 	Original visor holder which will be supplemented to allow the speaker case to mount 
Speaker Case Design 	

Part specification sheets can be found in Appendix F.

4.3 Analysis Results

To size the system mounting, we used the Solidworks model to estimate the weight of all the components and added 2 lb to account for the full 32 oz reservoir. This gave us a 3.2 lb weight estimate for the full system. Based on the free body diagram in Figure 26, we used this load to size the system mounting components. Appendix G shows detailed free body diagrams and stress calculations for the adjustable arm, bolts / pins, and mounting tabs.

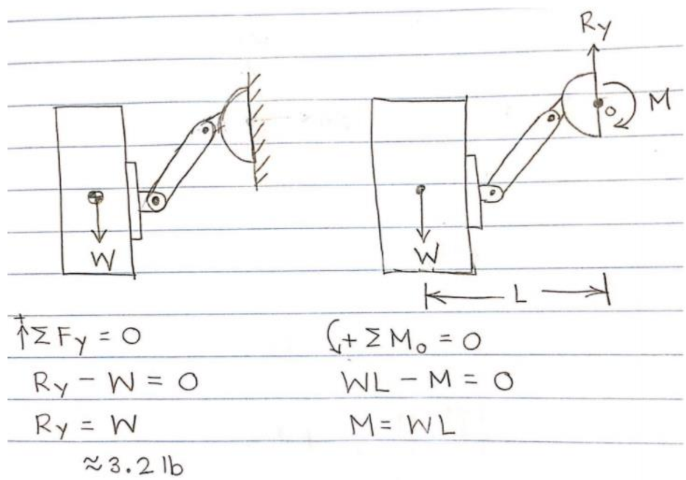
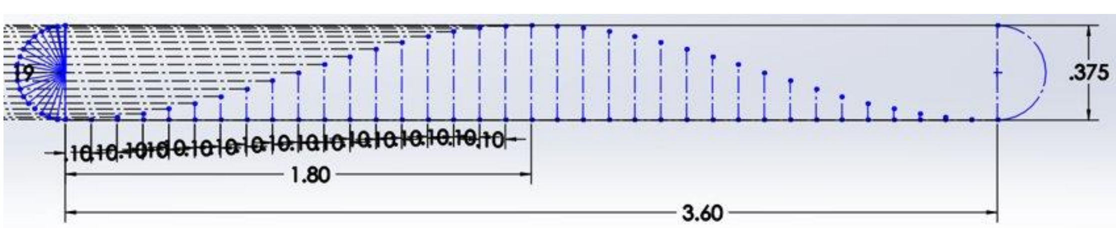


Figure 26. System mounting free body diagram

To create the cam profile, we first sketched in SolidWorks the displacement diagram in the top image of Figure 27. Each time the nozzle sprays, the cam goes through one rotation, so we used a simple harmonic motion displacement diagram. The x-axis is the cam's angle of rotation from 0 to 360 degrees, and the y-axis is the cam displacement in inches. From rest to fully depressed, the nozzle undergoes .375" of displacement. So, the displacement diagram goes from a minimum displacement of 0" to a maximum displacement of .375". We divided each half of the diagram, 180 degrees, into 18 equal increments, so we plotted one point for every 10 degrees of cam rotation. We plotted the points from 0 to 180 degrees and used the mirror tool in SolidWorks to plot the points from 180 to 360 degrees. We then projected the points from the displacement diagram around a circle to get the cam profile shown in yellow on the bottom image of Figure 27. We extruded this yellow cam profile to create the cam part.



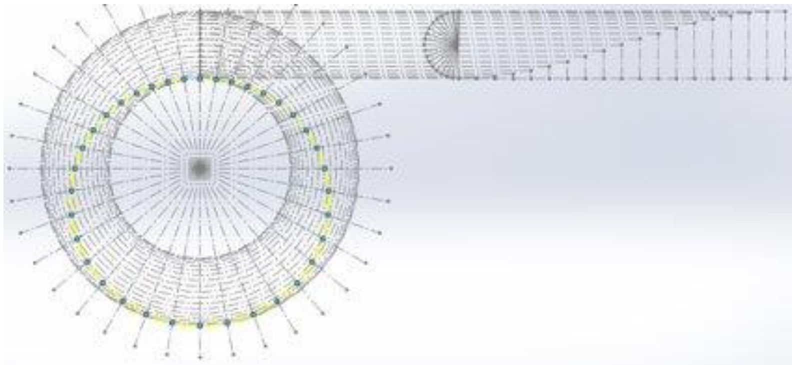


Figure 27. Cam geometry

To determine the torque required by the motor, we needed the maximum moment generated by the normal force and friction force of the nozzle on the cam. Using a force gauge, we determined that the nozzle requires 18 – 24N of force to fully depress. We estimated the friction force using the 24N normal force and the static coefficient of friction for plastic on plastic. A 1" prime circle and .375" maximum displacement gave us a .875" maximum moment arm for the friction force. We found the maximum moment arm for the normal force in Figure 28. Because the nozzle force always acts perpendicular to the cam profile, we sketched a line perpendicular to the cam profile and rotated it around the cam until we found the maximum distance between the force's line of action and the center of the cam, which is approximately .18". We added the effects of these two moments to get a motor torque requirement of 2.2 kg-cm. See Appendix G for detailed calculations.

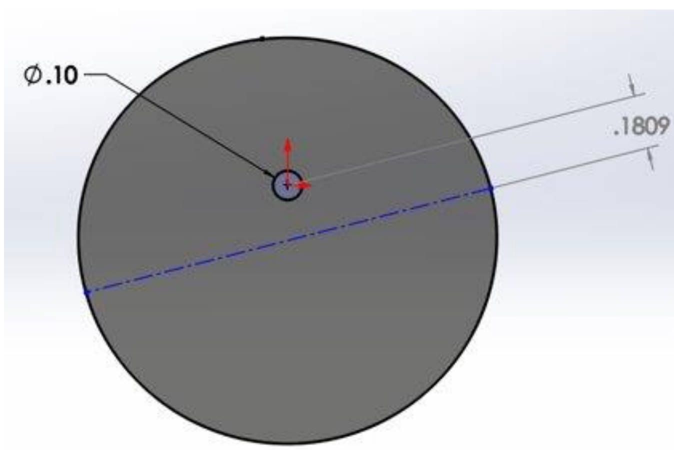


Figure 28. Moment arm for torque exerted on motor shaft

An issue we encountered when determining which motor we would use was finding a motor with sufficient torque. Many of the electric motors we found during our research were inexpensive and matched the battery voltage, however their torque capabilities were far below our requirements. Following further research, we identified micro-metal gear motors as a potential solution to our problem as they have much higher torque output. The specific micro-metal gear motor we selected has a stall torque of 5.5 kg-cm, so the torque required is well within the motor's capabilities. Under that load, the motor speed is approximately 50 RPM, and the motor is expected to draw 0.69 A of current. Detailed calculations can be found in Appendix G.

When sizing the battery, we had to consider the current draws from each of the electrical components in the system. We also had to take into consideration the amount of time we expected each component to be in operation during each day. Our analysis indicated that if the system would have a battery life of approximately 72 hours, or if the system was plugged into the battery 24 hours a day and were in active operation 12 hours a day the battery would last approximately 6 days. The specific analysis can be found in Appendix G.

4.4 Cost breakdown

Table 13 shows the cost estimate for our toolbox. Both prototypes exceeded our specified target of $40. However, we expect mass manufacturing to decrease the unit cost because we can buy components for cheaper in bulk. For the automatic disinfecting spray, we estimated the cost of mounts based on the amount of 3D printer filament we used. For mass manufacturing, we would injection mold the mounts, which would have a large initial cost but significantly reduce the unit cost over time. We also based our $40 target off of similar products, like automatic hand sanitizer dispensers, but not competing products. Since we do not have existing products to price match, to get a more accurate cost requirement, we would have to conduct surveys with potential customers.

Table 13. Toolbox cost estimate

Automatic disinfecting spray		**Face shield**	
Component	**Cost**	**Component**	**Cost**
Housing	$2.00	Frame	$19.99
Spray bottle	$1.00	Visor	$4.00
Nozzle	$0.40	Mini voice amplifier	$26
Motor	$16.00		
Electronics	$20.00		
Fasteners	$8.00		
Mounts	$8.00		
Total Cost	**$55.40**		**$49.99**

4.5 Material, geometry, component selection

We purchased most of the components for both prototypes. The specifications and datasheets for our purchased components can be found in Appendix F. For the automatic disinfecting spray, we selected a spray bottle to act as our reservoir because the long, vertical shape could be easily packaged, and it's compatible with sanitizers. We selected a relatively flat fingertip nozzle for easy actuation using a cam. Based off size estimations for all of the internal components, we determined the minimum length, width, and height of the housing, which is 4.5" W x 3.2" D x 11.5" H. We selected a plastic enclosure that meets or exceeds these dimensions to ensure all the components will fit. We sized the fasteners based on the load they have to take.

For the face shield, the electronic components were selected by balancing cost and performance. The primary performance criteria centered around selecting microphones, speakers, and batteries to be applicable in a classroom setting. Meaning the microphone can pick up frequencies of human speech and the speakers are load enough to be heard at the back of the classroom.

We 3D printed all of the manufactured components using PETG including the automatic disinfecting spray mounts, cam, and electronics housing as well as the electronics housing for the face shield. Their part drawings can be found in Appendix C. We sized the mounts to have loose fit clearance with the components they hold for easy assembly without too much movement, taking into consideration the 0.5 mm tolerance of the 3D printer.

4.6 Safety considerations

We identify product hazards in the checklist in Appendix H. For the automatic disinfecting spray, our main concern is with the system mounting. A full 32 fl-oz bottle weighs around 2 lb, which could cause injury if it falls. To eliminate this concern, we sized our mounting with enough weight capacity and performed testing to confirm it meets specifications. Another concern is preventing the liquid sanitizer from contacting exposed electronics. To combat this, we designed an enclosed electronics housing and can heat shrink or use electrical tape to protect wires. Sanitizer can also be harmful upon consumption. However, our controls system will mitigate people's exposure to the sanitizer by preventing the system from actuating when it senses a person nearby.

The primary safety consideration in the face shield design is ensuring the speakers do not cause any auditory harm to the users. Hearing damage occurs when a user is exposed to 90 dB for a prolonged period. The speakers we selected emit noise within a safe volume range.

During the manufacturing process, our electronic circuit components require soldering, which can be harmful. When soldering, we make sure to stay in well-ventilated or open-air spaces.

4.7 Maintenance and repair considerations

The automatic disinfecting spray's maintenance consists of refilling the reservoir and recharging the battery. For easy refilling, we added a hole at the top of the housing to make the reservoir cap accessible. By using a funnel when refilling, the user can also minimize accidental spills inside the housing. A clear housing also allows the user to monitor the amount of sanitizer in the reservoir so the user does not overfill the reservoir. We designed the mounting such that the user can quickly and safely remove the battery for recharging. The user simply removes the cover to the electronics housing, and within the housing, the battery is in the user's direct line of sight. With regards to repairs, all of our internal components can be removed without breaking anything. The front face of the housing will be removable for easy access to the internal components. Because the mounts screw in, individual components can be easily removed and reassembled.

The maintenance for the face shield consists of recharging the battery every 5 hours of use, roughly every two days. Teachers use the face shield primarily during presentations to the entire class limiting the daily usage to a couple hours. The face shield will also need to be cleaned periodically for sanitary purposes. Finger smudges will appear on the clear protective visor which will need to be cleaned on an as needed bases.

Chapter 5: Product Realization

5.1 Manufacturing processes

For both the face shield and the automatic sanitizing spray we primarily used 3D printing to manufacture the components we did not purchase. The parts were printed polyethylene terephthalate glycol (PETG) filament. Polylactic acid (PLA) is the most common filament type, but we opted for PETG because it is generally strong and is also commonly used. We used the two 3D printers shown below in Figure 29 to print our parts. To print parts from our SolidWorks models we converted our SolidWorks files into stereolithography files (STLs). The STLs were then run through PrusaSlicer to convert the STLs into command code for the 3D printer. During manufacturing we used each of the 3D printers in different situations depending on the part we needed printed and how quickly we needed it finished. The Ender 3 is a significantly smaller printer than the Ender 5 with only a quarter of the build volume and a 0.4 mm nozzle compared to the 0.8 mm nozzle of the Ender 5 Plus.

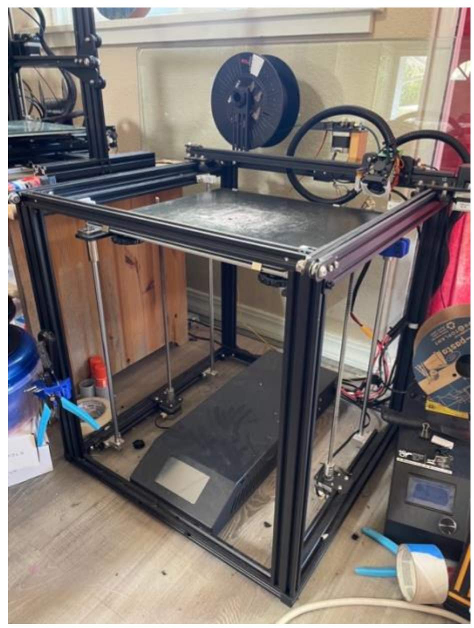



Figure 29. Creality Ender 3 and Ender 5 Plus 3D Printers

Due to its larger nozzle diameter and build volume, the Ender 5 Plus lent itself to printing parts that were larger or smaller parts that needed to be printed quickly. We used the Ender 5 Plus to print most of our components because, except for the cam or the speaker box lid and latch, precise tolerancing was not a significant issue. Tolerancing problems do not arise because the 3D printer is not precise, but rather because of the 3D printing process. Filament is melted as it is extruded through the nozzle and then cools and hardens into the layers of the part. When large volumes of filament are coming out of the nozzle quickly as happens on the Ender 5 Plus the cooling and hardening process can be less than perfect. Figures 23 and 24 show parts printed using the Ender 5 Plus for the automatic sanitizing spray and the face shield respectively.

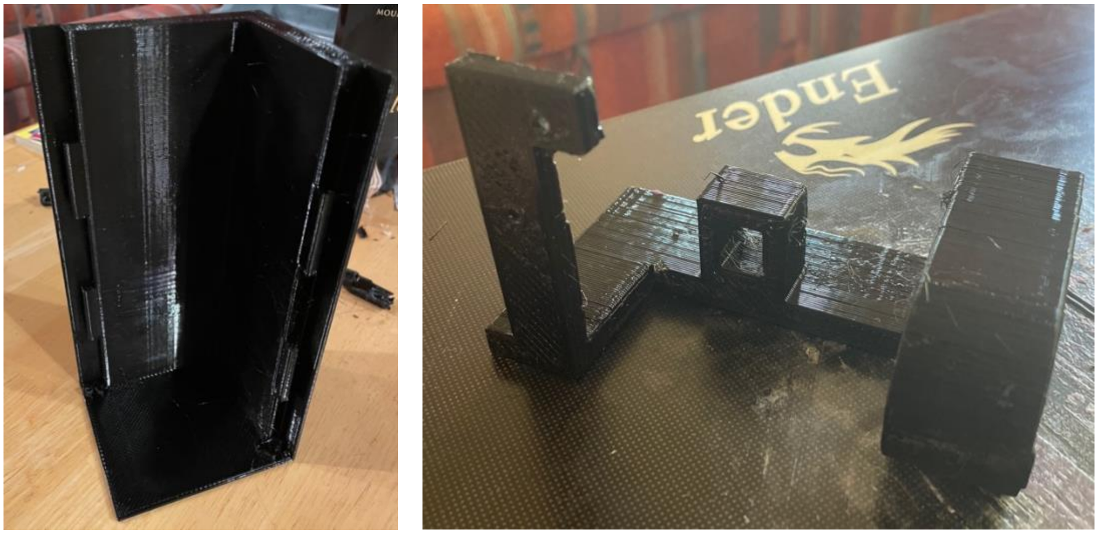


Figure 30. Electronics Housing and Motor Mount for Automatic Sanitizing Spray

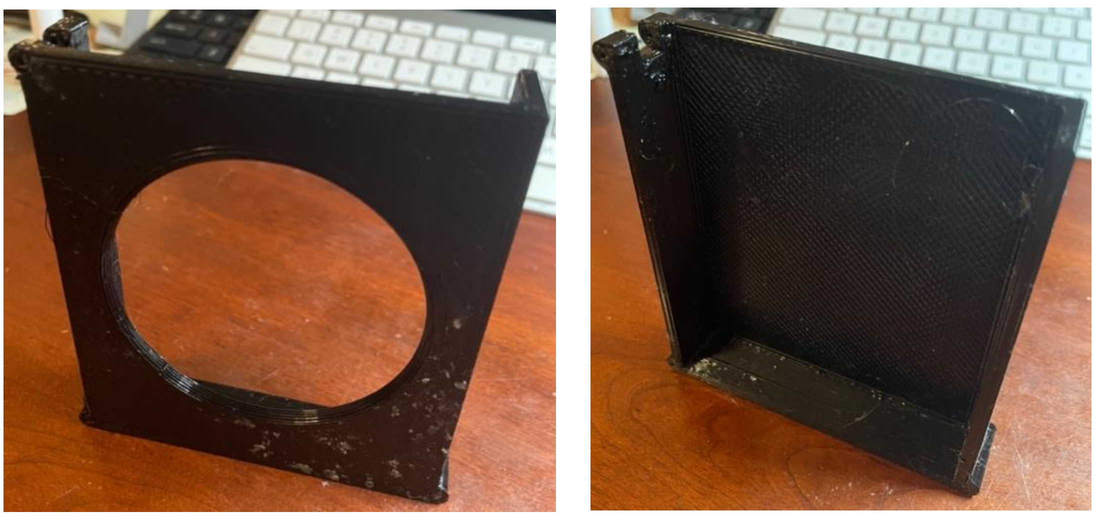


Figure 31. Front and Rear Halves of the Speaker Case

For parts that required tighter tolerances we used the Ender 3, see Figure 32 for pictures of the cam and speaker case latch that were printed with the Ender 3.

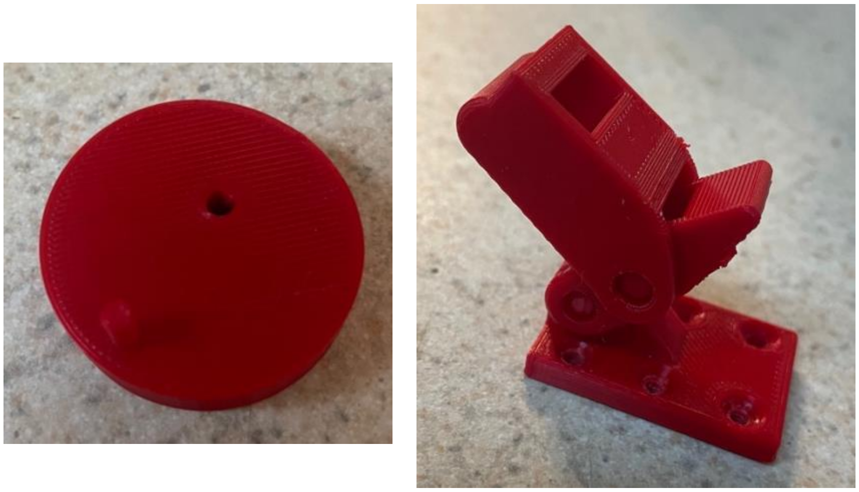


Figure 32. Cam and Speaker Case Latch

Many of the holes in our 3D printed parts needed to be threaded so machined screws could be screwed in. We sized the holes in our parts so that they could be tapped without having to be drilled out. 3D printed parts can be tapped easily with a hand tap and results in threads that successfully interface with screws. Figure 33 shows one of the holes in the front of the speaker case being tapped.

Figure 33. Tapping

With a few exceptions our electronics did not require additional manufacturing, with only simple jump wires required to connect between components. When soldering was required, we used the kit shown in Figure 34. When soldering flux is first applied to the joint, the joint is heated up using the soldering iron, and then solder is applied to the joint. The fan should be on to help ventilate the area being soldered.

Figure 25. Soldering Kit

The electronics the required soldering were the header pins on the Arduino Nano, the micro-metal motor tabs, the limit switch, as well as joints in the wires from the battery to the motor driver. Figure 35 shows the soldered Arduino Nano header pins and the joints on the motor.

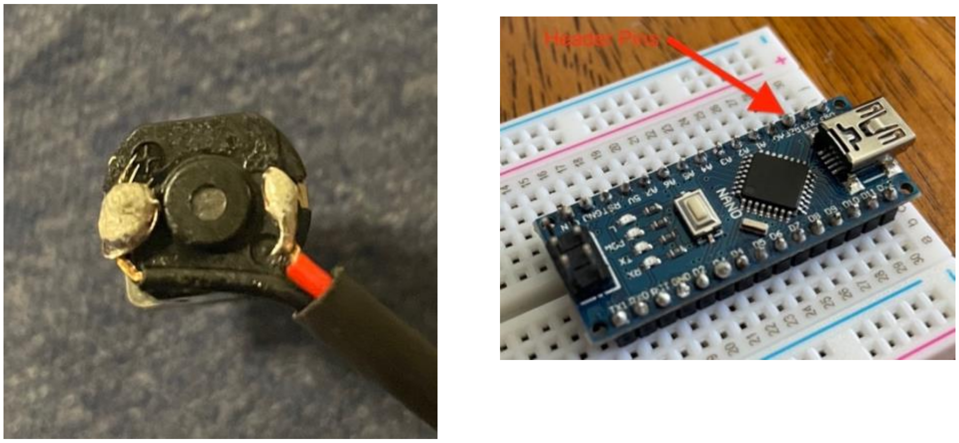


Figure 26. Soldered Motor Joints and Arduino Nano Header Pins

5.2 Prototype

Arriving at our final prototype involved some iteration. Figure 36 shows our first prototype for the automatic disinfecting spray housing. We used a suction cup to mount the system. We used bolts at each end of the adjustable arm to clamp the arm in position. To refill the reservoir, we used a Dremel to cut a hole in the top of the reservoir and used a plug to seal the hole. We used a silicone seal to secure the tube into the reservoir. The nozzle actuation assembly had three mounts, two for the nozzle and one for the motor.

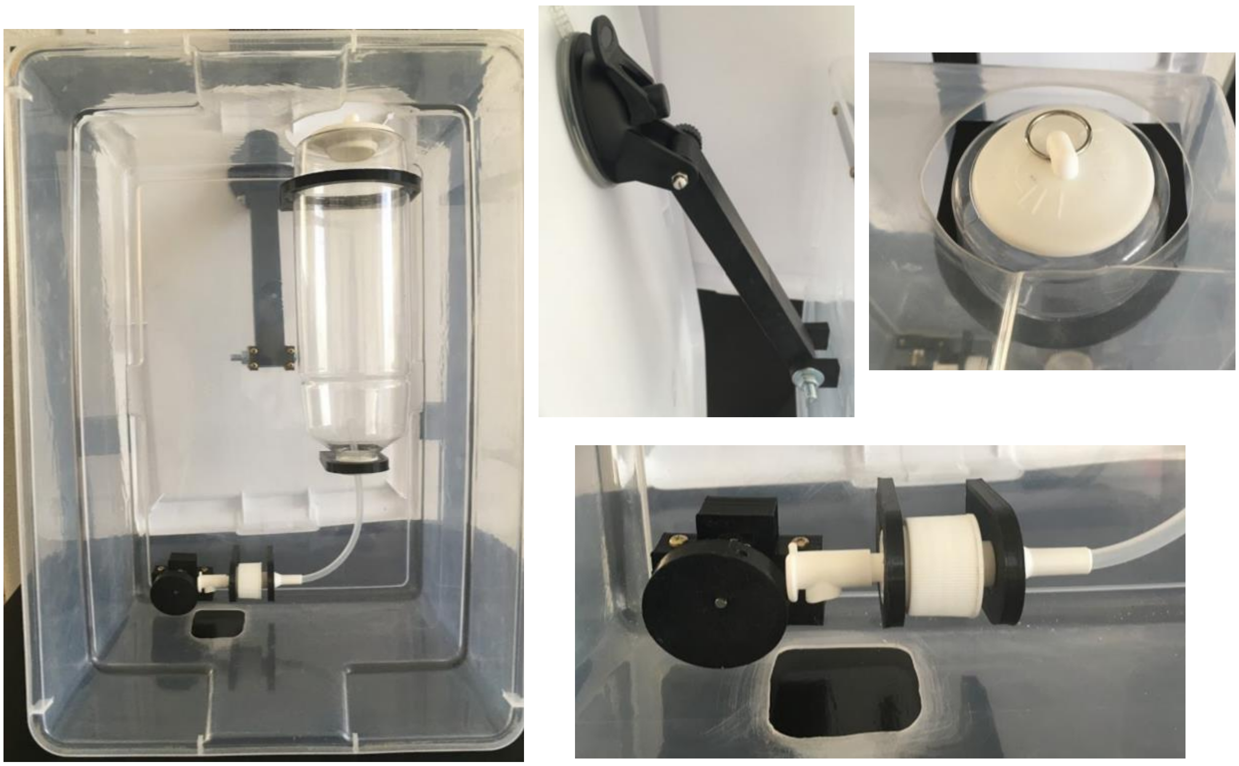


Figure 27. Automatic disinfecting spray housing initial prototype

For this initial prototype, we had difficulty cutting a clean circle in the top of the reservoir using a Dremel, so a significant amount of sanitizer leaked out of the plug. The silicone seal around the tube also became easily undone and caused leaking. As you can see in Figure 36, due to difficulty accurately mounting to the housing, the nozzle and cam did not make proper contact, so the nozzle could not follow the cam profile and actuate. The system mounting also could not hold the full weight of the reservoir when fully extended.

To solve these issues, we iterated our design and manufactured the final prototype in Figure 37. We flipped the orientation of the reservoir so that the bottle's cap acts as the removable lid. We drilled a hole into the bottom of the bottle, and instead of silicone sealant, we used super glue to secure the tube into the bottom of the reservoir. These modifications removed any leaking from the reservoir. To ensure that the nozzle can properly follow the cam profile, we combined the motor and nozzle mounts into a single mount. This greatly reduced tolerance stack-up. We also strengthened the system mounting by replacing the suction cup with a 3D printed mount and 3M adhesive tape. Because the 3M tape does not stick well to plastic, we had to super glue the tape to the mount. This means that the mount and adhesive function as a single part, and both must be replaced at a time. Rather than using the clamping force of a single bolt, we use a bolt and quick-release pin to secure the arm in place. Both can be removed and replaced without tools. The quick-release pin fits into discrete holes in the arm. This means that the arm is not infinitely adjustable, but the load capacity of this mounting method outweighs this downside.

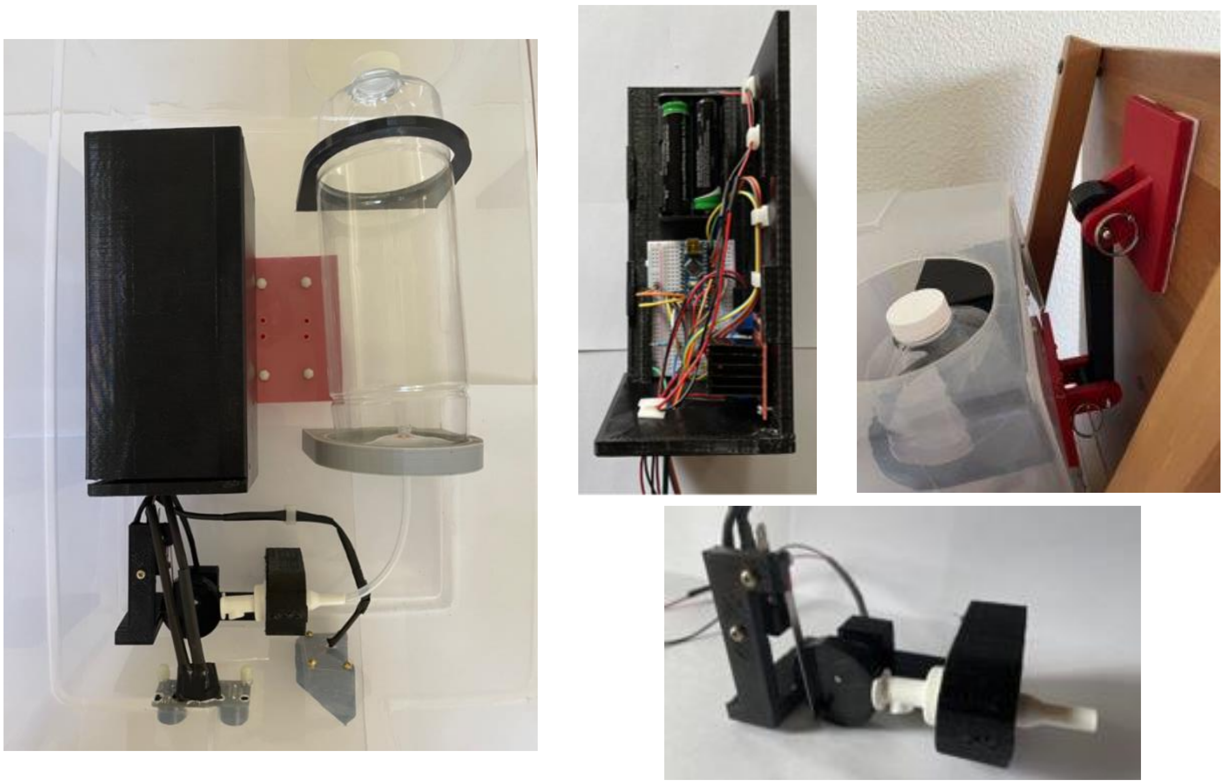


Figure 28. Automatic disinfecting spray final prototype

Our final prototype also included the electronics housing to protect the main circuit components from spilled sanitizer. We used wire clips to secure the wires to the side of the housing to improve accessibility to the batteries. Outside of the electronics housing, we wrapped all of the wires in heat shrink and electrical tape to keep them protected.

Figure 38 shows the final design of a face shield with an external microphone and speaker attached. The electronic components contained in a holder attached to the face shield. The face shield design consists of three mechanical components and three main electronic components. The mechanical components consist of a frame, speaker holder, and protective shield. The main electronic components consist of a microphone, speaker, and battery.


Figure 29. Face shield with microphone and speaker

5.3 Future recommendations

For mass manufacturing the 3D printed components would instead be injection molded. 3D printing is excellent for prototyping since it allows for rapid design iteration and inexpensive for limited production. Unfortunately, 3D printing can be time consuming and expensive per unit produced, especially for larger parts. Injection molding has larger upfront costs to design and build the injection mold, but over time it is the quicker, cheaper option. We would also recommend injection molding the reservoir and nozzle tube into a single piece due to the difficulty we experienced creating a leakproof seal. Injection molding the housing to include holes for refilling, dispensing sanitizer, and mounting screws would also eliminate the need to drill, Dremel, or cut holes into the housing. We also spent a lot of manufacturing time drilling pilot holes and tapping, so including threaded holes in the injection mold would further reduce manufacturing time.

In terms of the electronics, it would be beneficial to investigate creating a printed circuit board (PCB) microcontroller for this application instead of using an Arduino Nano. A purpose-built PCB microcontroller could have tailored functionality limited to only what the system needs. A PCB would also reduce the size of the electrical components and number of wires. We would also recommend using more exact wire sizes to keep the electronics housing less cluttered. Additional time should be spent determining if a peristaltic pump might be a preferable sanitizer dispensing mode instead of the motor-cam-nozzle system.

Table 14 summarizes the manufacturing processes, vendors, and materials for our mass manufactured and prototyped product. For mass manufacturing the automatic disinfecting spray, our largest manufacturing processes include injection molding the housing, mounts, and reservoir, water jetting the cam profile, and soldering the electrical components. For prototyping, we will purchase a plastic box to act as the housing. We will 3D print the mounts and screw them into the plastic housing box. We will also 3D print the cam. We will purchase the rest of our components and slightly modify them to fit into our system, such as cutting tubing and wires to length.

Table 14. Details for mass & prototype manufacturing

Component	Mass Manufacturing	Vendor/Material	Prototype	Vendor/Material
Automatic disinfecting spray				
Housing	Injection mold	Plastic	Purchase, drill, Dremel, & cut	Target
Reservoir	Injection mold	Plastic	Purchase, drill & glue	US Plastic
Nozzle	Purchase	US Plastic	Purchase	US Plastic
Motor	Purchase & solder	Pololu	Purchase & solder	Pololu
Electronics	PCB	Various vendors	Purchase, solder, circuit assembly	Various vendors
Cam	Waterjet	Aluminum	3D print	PETG
Adhesive	Purchase & epoxy	3M	Purchase & super glue	3M
Fasteners	Purchase	McMaster-Carr	Purchase	McMaster-Carr
Mounts	Injection mold	Plastic	3D print, drill & tap	PETG
Face Shield				
Frame	Injection mold	ASB	Purchase	Z shield
Visor	Purchase & cut to length	US Plastic	Purchase	Z shield
Microphone	Purchase	Mouser	Purchase	Mouser
Speaker	Purchase	Mouser	Purchase	Mouser
Battery	Purchase	AliExpress	Purchase	AliExpress
Additional electronic components	Purchase	Mouser	Purchase	Mouser

Chapter 6: Design Verification

6.1 Test Descriptions

As we manufactured and assembled our toolbox, we tested individual components and subassemblies using a Digi-Key Analog Discovery 2 to ensure that they operated as expected and would properly integrate into each system.

For the automatic disinfecting spray, we had to ensure that the nozzle could fully spray a typical faucet handle or doorknob surface area. The nozzle must also spray from a large enough distance such that a hand can still fit under the device. We also need to determine how much sanitizer gets released with each spray to determine how often the user will have to refill the reservoir. Figure 3 shows pictures from our nozzle testing. We determined that our specific nozzle can fully coat an approximate area of 4” x 3.5”, which exceeds our 4” x 2” minimum specification. It fully coats this area from a distance of 4.5”, which leaves plenty of room for a hand to fit under. With each actuation, the nozzle dispenses 0.02 oz of fluid, so the system can run through 1600 cycles before refilling the reservoir.

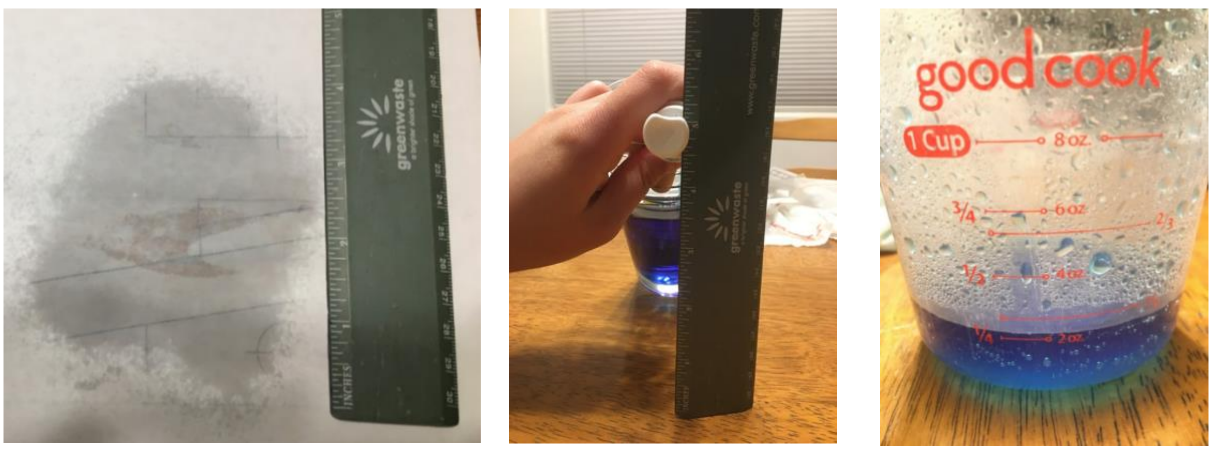


Figure 30. Nozzle testing

Another component critical to the safety of the disinfecting spray is the system mounting. For use in a classroom, we cannot risk the possibility of having the housing fall on someone. We tested the system mounting with all the components installed and the reservoir full, the maximum load case that it will experience. Our first prototype with the suction cup and friction style mounting failed and could not even hold the empty reservoir. For our following prototypes we replaced the suction cup with a 3D printed mount and adhesive. Our second system mounting prototype had two mounting tabs screw into the housing, which induced a lot of bending in the housing and caused the housing to hang at an angle as you can see in Figure 40a. For our final system mounting prototype in Figure 40b, we combined the two tabs into a single mount with a larger surface area, which significantly reduced the bending in the housing and allowed it to hang more vertically. An opportunity for improvement we discovered in our testing is the residue left behind by the adhesive seen in Figure 40c. We recommend further testing of different types of adhesives to find one with the right balance between strength and removability.

(a) Two mounting tabs (b) Single mounting tab (c) Adhesive residue

Figure 31. System mounting capacity testing

Throughout the process of writing the Arduino code and integrating all the electrical components into one system we had to test the code for each component individually as well conduct tests as the code was integrated to operate multiple components. Testing the ultrasonic sensor was critically important since the distance measurements produced from the outputs of the sensor serve as the first step that begins the process of system actuation. To test the ultrasonic sensor's measurement capabilities, we set objects at known distances and directed the sensor towards the object. We tested objects at 1 in, 3in, 6in, and 12 in which span the range from the minimum effective measurable distance for an ultrasonic sensor to the maximum expected range for the use cases of this system. For all the test distances the ultrasonic sensor measured the distance of the object accurately to within a centimeter. Ultrasonic sensors report distance in centimeters so there was some degree of rounding present in the reported measurement. Although our formal testing was limited to 12 in, ultrasonic sensors are rated to measure up to 400 cm (~160 in) so longer measurement distances are feasible using the sensor. An example of a measurement test can be seen below in Figure 41.

Figure 32. Ultrasonic Sensor Measurement Test

The code associated with the ultrasonic sensor has importance to the system beyond simply measuring distance, it is also integral to calibrating the system. Since the electronic controls system would be reset and recalibrate every time the automatic sanitizer was repositioned testing the calibration and detection code was important. Rather than use set locations like during measurement testing, we tested in a variety of different location to see how the sensor calibration would react in different settings. During calibration and detection testing we discovered an interesting failure mode; if the sensor was laying on a flat surface it would occasionally erroneously detect the surface it was resting on as a new object. This was interesting to learn but this problem did not necessitate a redesign because during system operation the sensor is several inches away from surfaces that it could pick up in a similar way. Figure 42 shows the sensor oriented vertically for calibration and detection testing as it would likely be during operation.

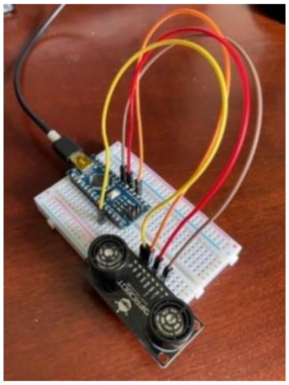


Figure 33. Calibration and Detection Test

To test that the motor and cam would be able to sufficiently depress the nozzle to dispense sanitizer we developed a test fixture to hold the motor and the nozzle which can be seen in Figure 43. The nozzle depression test confirmed that the motor we had selected had sufficient torque to depress the nozzle using the cam, However, we did find that the cam we used for the test was slightly too small to depress the nozzle all the way. To achieve complete depression of the nozzle we had to size up the cam so that the displacement at the point of contact throughout the rotation of the cam could completely depress the nozzle without causing it to bottom out.

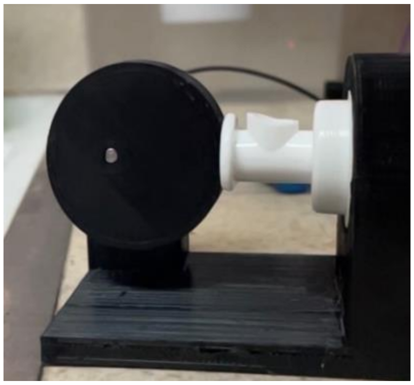


Figure 34. Nozzle Depression Test Fixture

In addition to calibrating the sensor we also had to test our motor calibration system to ensure that the motor would operate as expected. The most important aspect of this test was determining the optimal duration of time for the motor to rotate so that the cam would just back off the limit switch so the switch would become open. If the motor did not rotate long enough the limit switch would remain closed and if the motor rotated for too long it might begin to depress the nozzle again. This test process was primarily trial and error, testing different lengths of times and comparing the results. The test resulted in 50 ms allowing the motor enough time to back off the cam without rotating far enough to depress the nozzle. In Figure 43 the cam can be seen contacting the limit switch before it rotates to back off.

Figure 35. Motor Calibration Test

Figure 36. Face Shield Speaker User Testing

To ensure the toolbox solution was fully functional and met the needs of our users, K – 12 teachers, we conducted a usability study. Two teachers were given the face shield to use during their everyday classroom activities. The teachers noted the user interface was simple to learn and were able to easily operate the microphone and speaker components which included turning it off/on and adjusting the volume levels. The face shield was tested in both large and small student groups. The device was most helpful during large group activities as it aloud the teachers to more comfortable project their voice through their face covering. In small groups, the additional voice amplification was not necessary. After wearing the face shield off and on throughout the day based on group size, the teachers noted the face shield was comfortable to wear. The major takeaways from the usability study were the use cases. Teachers used the face shield on an as needed bases, primarily during large group activities, instead of wearing the face shield through the entire day as we initial assumed would be the case. An important piece of feedback was that the angle of the speaker case was too severe and that the bottom back edge of the box would dig into the user's upper chest which can be seen in Figure 44. We used this information to redesign the interface between the face shield and the speaker box to bring the back bottom edge of the case forward away from the user's chest.

Figure 37. Automatic Sanitizer User testing

Due to the residue left by the mounting adhesive, we decided to mount the automatic disinfecting spray to a board for testing purposes. As we did not want to ruin any classroom surfaces, we had our friends and roommates try setting up and running the system to get usability feedback. The system was able to calibrate successfully, detect, and actuate as well as delay actuation in the even a hand was still present as shown in Figure 45. Common points for improvement included difficulty locating the pin holes when adjusting the system mounting, leaking from the nozzle, and bulkiness. We recommend addressing these issues in future iterations of the product.

6.2 Test Results

Table 15 summarizes the tests we performed including general procedure, equipment, acceptance criteria, and results. Almost all our test results met our acceptance criteria. Our initial disinfecting spray prototype used a grommet to connect the nozzle tube to the reservoir, but the grommet leak test failed. However, our final prototype using super glue to seal the tube connection passed with no visible leaks. The face shield battery life also did not meet our 8-hour goal, currently sitting at 5 hours. However, based on the feedback we received from our usability testing; teachers will not use the face shield throughout the entire school day. Rather, they only use it when speaking to the whole class. So, we expect a 5-hour battery life will last teachers the whole school day.

Table 15. Toolbox test results

Test Name	Test Description	Equipment	Acceptance Criteria	Results
Automatic Disinfecting Spray				
Sensing distance	Measure min. & max. distance at which sensor reads a hand	Tape Measure	Up to 12 in	Pass
Battery life	Run system from battery fully charged to battery drained	Test System	72 Hours	Pass
Motor torque	Check motor has sufficient torque by testing if it can depress the nozzle	Motor Driver, Motor, Arduino Nano, Nozzle	Can Depress Nozzle	Pass
Motor & cam subassembly	Rotate motor & cam together & visually verify that nozzle gets fully depressed	Motor, cam, & nozzle subassembly	Visual pass	Pass
Cam displacement	Measure difference between min. & max. radius of cam	Calipers	.375” +/- .010”	.375” +/- .010”
Spray distance	Measure max. distance between nozzle & surface with fully coated area	Ruler	> 3”	4.5”
Spray area	Measure max. surface area fully coated by one spray. Dye water & spray on paper towel for easy visual	Ruler, food coloring, paper towel	> 4”x2”	4” x 3.5”
Spray volume	Measure volume of N sprays. Calculate volume of one spray	Measuring cup	< 0.04 oz	0.02 oz

Glue seal leak test	Make sure liquid does not leak out of reservoir	Sanitizer	Visual pass	Pass
Grommet leak test	Make sure liquid does not leak out of grommet	Sanitizer	Visual pass	Fail
Refilling	Fill reservoir with liquid sanitizer	Funnel	No sanitizer spilled	Pass
System mount capacity	Ensure system mounting can hold all components including full reservoir	Full system	Visual pass	Pass
Sharp edges inspection	Visual and physical inspection to ensure no sharp edges or physical components can cut the user	Full system	No sharp edges found	Pass
Components replaceable	Assemble & disassemble full system	Phillips screwdriver	No components broken	Pass
Cost	Add cost of components	N/A	< $40	$55
Face Shield				
Battery voltage & current	Measure voltage drop across components & current draw through components	Voltmeter, ammeter	Matches component specifications	Results in Table 17
FS Physical Safety - Sharp edges	Visual and physical inspection to ensure no sharp edges or physical components that can cut the user		No sharp edges found	Pass
FS Physical Safety - Touch Temp test	After device has been on for 3 hours, perform physical inspection that no user facing components heated up above room temp		Touch pass	Pass
FS Physical Safety - Touch Current test	Ensure no exposed wires or conductive materials exposed to user		Visual Check	Pass
FS Physical Safety - COVID-19 Protection	Test face shield protection from aerosol droplets by assessing perceived safety of user and spraying water at the user	Spray bottle with food coloring to mimic student sneezing	Substantially equivalent to coverage provided by traditional forehead face shield	Pass

FS Sound - Audio Clarity	Ensure user can be understood from the back of a classroom. Have someone stand 30 feet away and have them transcribe what they think the wearer is saying	Digi-Key Analog Discovery 2 and human interpretation	Listener can transcribe the wearer's conversation with 100% accuracy	Pass usability testing
FS Sound - Frequency Range	Ensure audible intonations can be heard from the back of a classroom (15 Hz - 17 kHz). Use analog discovery 2 to play range of frequencies	Digi-Key Analog Discovery 2	output of full system can be within the 15Hz - 17 kHz range	90 Hz – 18 kHz
FS Sound - Volume	Ensure speaker can be heard from back of a classroom (60 - 70 dB)	Digi-Key Analog Discovery 2	output of full system can be within the 60 - 70 dB range	Pass usability testing
FS Sound - Mic pickup	Mic can pick up all frequencies of a conversation (15 Hz - 17 kHz). Use analog discovery 2 to play range of frequencies as input	Digi-Key Analog Discovery 2	Signals between 15 Hz - 17 kHz picked up	90 Hz – 18 kHz
FS Sound - Feedback	No noticeable audio/ sound feedback when user is talking	Digi-Key Analog Discovery 2	no auditory feedback observed	Pass
FS Drop test	Drop device from 4 ft above ground	Tape measure	No visual signs of damage, functional	Pass
FS Usability Study	Five people wear the face shield for three hours consecutively and evaluate the face shield comfort and usability	Users, fully assembled face shields	No hot spots, rubbing, or discomfort reported from users	Pass usability testing
FS Output Power	Measure output power of whole system	Digi-Key Analog Discovery 2	10 W	10 W
FS Output impedance	Measure output impedance of whole system	Digi-Key Analog Discovery 2	4 ohms	4 ohms
FS Use time	Ensure face shield can be used for an entire school day		8 hour min	5 hours
FS Weight	Ensure Face shield is comfortable to wear		1.85 lb max	1.2 lb

Table 16. Face Shield electrical component results

Microphone specs testing results:	Sensitivity: −26 dB FS ±1 dB Current: 185 µA Voltage: 1.65 V to 3.63 V
Speaker specs:	Frequency: 600 ~ 20,000 Hz
Battery specs:	Rechargeable Li-Ion Battery life: 14 hours 50 × 34 × 5.2 mm Voltage: 3.7V Capacity: 1000 mAh

6.3 Specification verification checklist

Table 18 shows how our test results discussed in section 6.2 meet our engineering specifications. Our final prototype meets all of our requirements besides the cost, which as discussed previously can be met through mass manufacturing.

Table 17. Engineering specification & corresponding test

Functional Requirement/specification	Test	Pass/Fail
Automatic Disinfecting Spray		
Minimize battery replacement	Battery life	Pass
Minimize full product replacement	Components replaceable	Pass
Controls	Timer functions as expected, sensing distance	Pass
Fully coat surface with sanitizer	Spray surface area	Pass
Doorknobs & faucets	Spray surface area & distance	Pass
Refill < 1 time per week	Spray volume	Pass
Easy to refill	Refilling	Pass
Compatible with common sanitizer	Reservoir & nozzle material selection	Pass
Safe for classroom use	Sharp edges inspection Mounting load capacity	Pass Pass
Cost < $40	Cost	Fail
Face Shield		
Battery life lasts a school day	Battery life	Fail
Protects user from respiratory droplets	FS physical Safety – COVID-19 Protection	Pass
Allow user to easily take on/ off device	Usability Study	Pass
No fogging or visual impairments	Usability Study	Pass
Volume loud enough to be heard at the back of a classroom	Sound - Volume	Pass
Audio is clear	Sound – mic pick up, Sound – feedback	Pass

Chapter 7: Conclusions and Recommendations

The toolbox solution effectively equipped teachers with the resources to manage their safety and comfort when returning to in-person education during the COVID-19 pandemic. The toolbox meets the goal of executing safety procedures while allowing teachers to focus on teaching. The face shield amplifies the user's voice reducing the strain of talking loudly over a face mask for extended periods of time. The disinfecting spray sanitizes surfaces below it after someone touches the surface. The responses from our user testing indicated the face shield was easy to operate and effective. While the disinfecting spray could use improvements in usability, it functioned as expected.

Moving forward, we recommend pursuing mass manufacturing of the toolbox. Mass manufacturing would reduce the unit cost of the toolbox by allowing us to purchase components in bulk. We also recommend using injection molding instead of 3D printing. Despite the high upfront cost of creating the molds, injection molding would reduce costs in the long run. Including the tapped holes in the injection molded mounts would also significantly reduce the manufacturing time required to pilot drill and tap the holes. We also recommend replacing the breadboard and wire circuits with custom PCBs for cleaner packaging and less unnecessary electronics parts.

Based on our usability feedback, aspects of the toolbox could still use further iteration and testing. We recommend conducting tests in a wider range of environments to ensure all use cases of the toolbox are covered. Additional uses case may include wearing the face shield in a large auditorium to ensure no feedback occurs from the echoing present in some auditoriums. Additional use cases for the automatic disinfecting spray include testing the mounting capabilities over faucets and other high contact surfaces beyond doorknobs. We would also recommend testing more nozzles and adhesives for the disinfecting spray. The nozzle we selected tends to leak due to its sideways orientation, so other nozzles might be better suited for this application. Our current adhesive leaves behind a sticky residue when removed, so we recommend finding an alternative adhesive with the proper strength and removability. Users also had trouble placing the pins when adjusting the system mounting. For the arm, possibly using a more frictionless material and tapering the holes would make the pin easier to place. The overall size of the housing is bulky, so we recommend repackaging the components for a more compact result.

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Appendix B: House of Quality

House of Quality – Face Shield

Customer (Step #1) Requirements (Whats)	Weighting (1 to 5)	Engineering Requirements (HOWS): Cost	Battery life	Product life	Electrically insulative material	Maximum temperature differential	Fit N95, cloth, and surgical masks	Weight	Strap around head/neck	Soft material where contact user	Substantial air flow	Speaker volume	Microphone sensitivity	Withstand drop height	Waterproofing	Serviceable	Compatible with sanitizers				Benchmarks: Microphone & speaker pack & N95
Low cost	3	9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1				Y
Long battery life	3	1	9		1			1				1	1			1					Y
Long product life	2	1		9				1	1	1		1	1	3	3	3	1				Y
Cannot shock user	5	1	1	1	9		1	1	1	1		1	1	1	1	1	1				Y
Cannot heat up	5	1	1	1		9	1	1	1	1		1	1	1	1	1	1				Y
Protect from COVID	5	1		1			9	1	1		1						3				Y
Low weight	4	1	1	1	1	1	1	9	1	1	1	1	1	1	1	1	1				Y
Comfortable to wear	3	1			1	3	1	3	9	9	1										N
Comfortable to breathe	4	1			1	1	1	1		1	9		1								Y
Good speaker volume	3	1	1					1				9									Y
Mic. detects voice	3	1	1				1	1					9								Y
Accidental drops ok	1	1		3	1	1		1	1			1	1	9							Y
Accidental spills ok	1	1	1	3	1	1		1	1	1	1	1	1		9		1				Y
Easily replace compon	2	1	1	1				1	1	1	1	1	1	1	1	9					Y
Easy to clean	4	1	1	1	1	1	1	1	1	1	1	1	1		1		9				Y
Units		$	hr	yr	V	°C	-	oz	-	-	-	dB	dB	ft	-	-	-				
Targets		40	12	10	6	.02	Y	4.2	Y	Y	Y	60	30	3	Y	Y	Y				
Mic pack & N95		S	S	?	?	?	S	-	+	S	+	S	S	?	?	-	-				
Importance Scoring		72	39	34	65	71	76	81	58	56	58	52	58	31	41	44	72	0	0	0	
Importance Rating (%)		89	48	42	80	88	94	100	72	69	72	64	72	38	51	54	89	0	0	0	

Y	Yes, satisfies requirement
N	No, does not satisfy requirement
S	Does the same as specification
+	Does better than the specification
-	Does worse than the specification
?	Questionable
● = 9	Srong Correlation
○ = 3	Medium Correlation
Δ = 1	Small Correlation
Blank	No Correlation

House of Quality - Sanitation

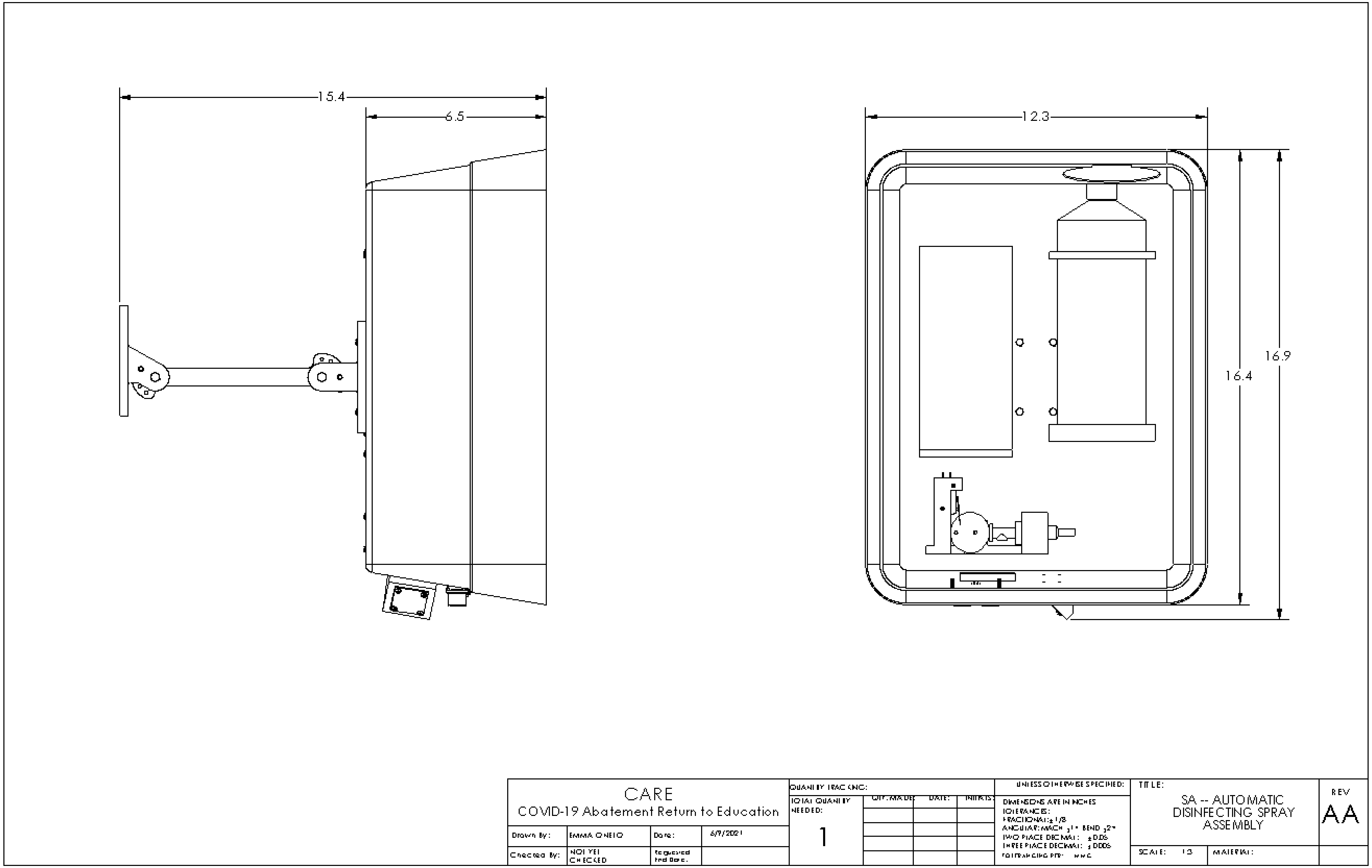
Customer (Step #1) Requirements (Whats)	Weighting (1 to 5)	Cost to purchase	Cost to operate	Operating Time	Time to learn operations	Time between maintaince	Innactivates COVID-19	Exposure Limit	Product Life	Irradation Area	Light wavelength	Dose strength	Durability - withstand drop test	Mount type	UVC Stand up ilghts
		Engineering Requirements (HOWS)													**Benchmarks**
Customer Requirements(2)															
Low Cost	5	9	9								3	3	3		N
Easy to Use	3	3			9	3									Y
Easy to Maintain	3	3				9									Y
Innactivates COVID-19	5	3					9	9		3	9	9			Y
Safe in classroom	5	3						9		3	9	9	3		Y
Opt-in Product	4	3													Y
Withstand chaos of classroom	3	3											9		Y
Does not need active user	3	3		3	3	3			9						Y
Easy to manuever	2	3												9	Y
Units		$	$	min	hr	weeks		min	years	sq ft	nm	mJ/cm2			
Targets		50	10	15	1	1	Y	10	1	1	254	2.2	Y	Y	
Benchmark #1		200	0	15	0	52	Y	10	1	700	254	3	Y	Y	
Benchmark #2															
Importance Scoring		135	45	9	9	36	45	90	27	30	105	105	57	18	
Importance Rating (%)		100	33	7	7	27	33	67	20	22	78	78	42	13	

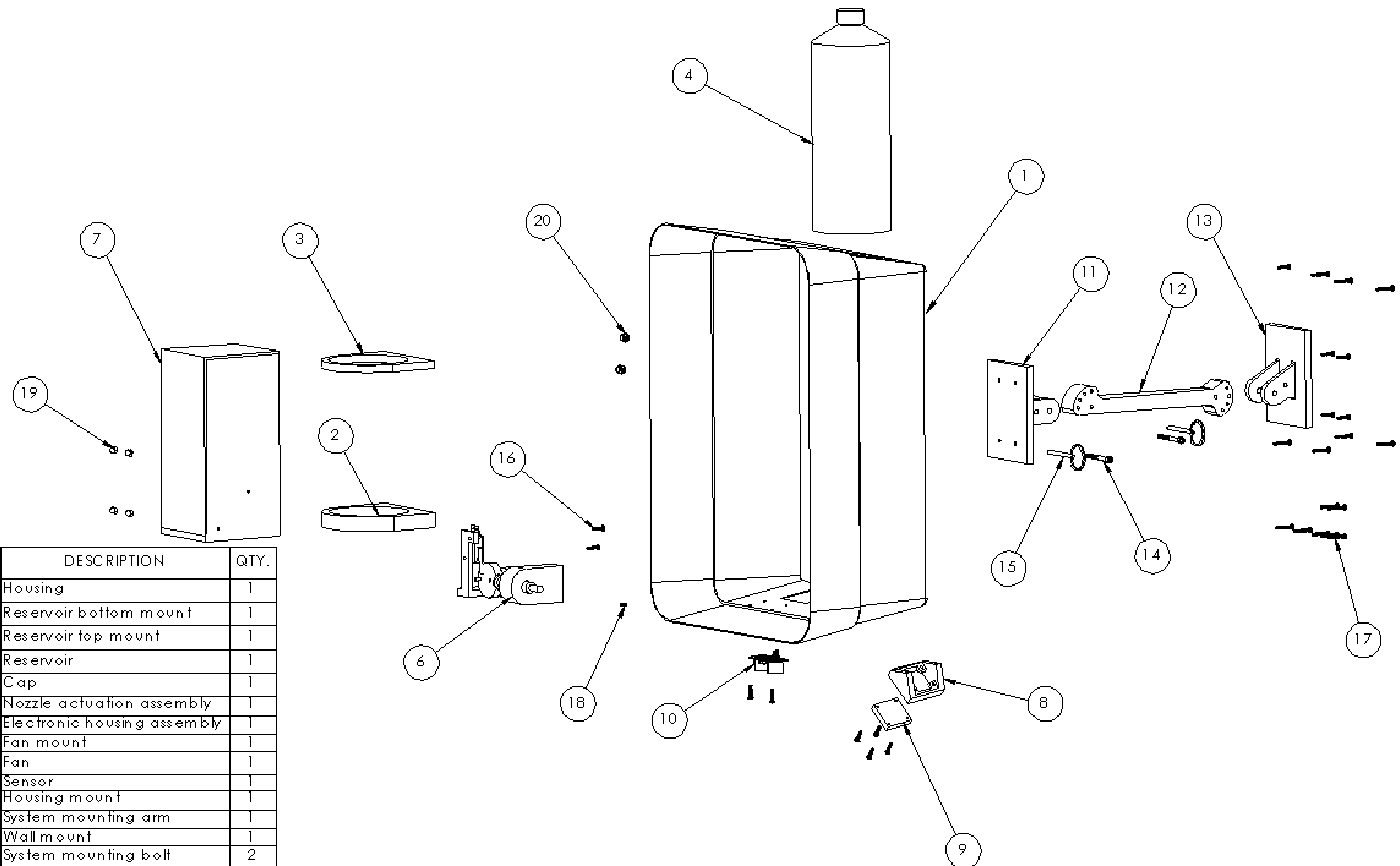
House of Quality – Physical Distancing

Customer Requirements (Step #2)	Weighting (1 to 5)	Cost	Battery Life	Product Life	Operator Time	Weight	Non-irritant Material	Speaker Volume	Vibration Intensity	Water Resistance	Drop Resistance	Range	Measurement Accuracy	Class Set	Benchmarks: Ultimaxx
Low Cost	3	9	1	1			1	1	1	1	1	3	3	9	Y
Easy to Use	3	3	1	1	9										Y
Battery Lasts a School Day	5	3	9			1		1	1						Y
Lightweight	4	1	1			9									Y
Comfortable	3	1				3	9								Y
Notifies Wearer and Teacher	3	3	1					9	9						N
Durable	3	1		9						9	9				Y
Measures Distance	5	3	1									9	9		Y
Enough for a Class	3	3		1										9	Y
Easy to Repair	2	1	1	9	1										?
Units		$	hr	yr	min	oz	-	dB	Hz	-	-	ft	ft	-	
Targets		20	10	5	15	5		80	150			10	1	30	
Ultimaxx		-	+	?	?	S		N	?			-	?	Y	
Importance Scoring		96	65	54	29	50	30	35	35	30	30	54	54	54	
Importance Rating (%)		100	68	56	30	52	31	36	36	31	31	56	56	56	

Customer (Step #1) Requirements (Whats) · Engineering Requirements (HOWS) · Benchmarks

Appendix C: Final Drawings





ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	SA -- 001	Housing	1
2	SA -- 012	Reservoir bottom mount	1
3	SA -- 011	Reservoir top mount	1
4	SA -- 002	Reservoir	1
5	SA -- 010	Cap	1
6	-	Nozzle actuation assembly	1
7	-	Electronic housing assembly	1
8	SA -- 024	Fan mount	1
9	SA -- 007	Fan	1
10	SA -- 008	Sensor	1
11	SA -- 018	Housing mount	1
12	SA -- 017	System mounting arm	1
13	SA -- 019	Wall mount	1
14	SA -- 028	System mounting bolt	2
15	SA -- 029	System mounting pin	2
16	SA -- 031	Screw 4-40 x .5	13
17	SA -- 030	Screw 4-40 x .75	14
18	SA -- 032	Cam set screw	1
19	SA -- 027	Cap nut 4-40	4
20	SA -- 026	Cap nut 8-32	2

CARE COVID-19 Abatement Return to Education			
Drawn By:	EMMA ONEIO	Date:	6/7/2021
Checked By:	NOT YET CHECKED	Requested End Date:	

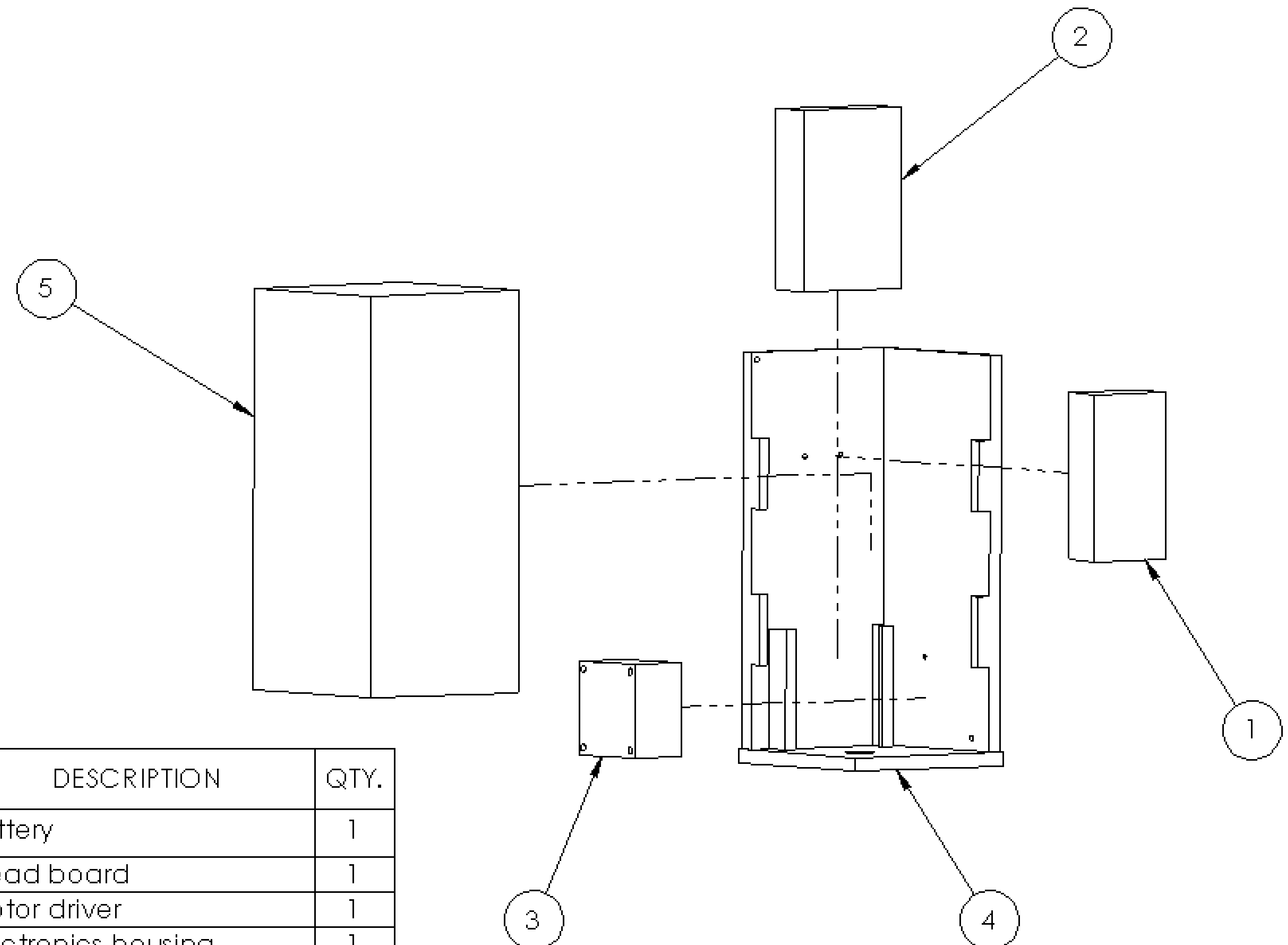
QUANTITY TRACKING:			
TOTAL QUANTITY NEEDED:	QTY. MADE	DATE:	INITIALS:
1			

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL: ± 1/8
ANGULAR: MACH ± 1° BEND ± 2°
TWO PLACE DECIMAL: ± 0.05
THREE PLACE DECIMAL: ± 0.005
TOLERANCING PER: NWC

TITLE: SA -- AUTOMATIC DISINFECTING SPRAY ASSEMBLY

REV: AA

SCALE: 1:4 MATERIAL:



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	SA -- 005	Battery	1
2	SA -- 020	Bread board	1
3	SA -- 021	Motor driver	1
4	SA -- 022	Electronics housing	1
5	SA -- 023	Electronics housing cover	1

CARE

COVID-19 Abatement Return to Education

Drawn By:	EMMA ONETO	Date:	6/9/2021
Checked By:	NOT YET CHECKED	Requested End Date:	

QUANTITY TRACKING:

TOTAL QUANTITY NEEDED:	QTY. MADE:	DATE:	INITIALS:
1			

UNLESS OTHERWISE SPECIFIED:

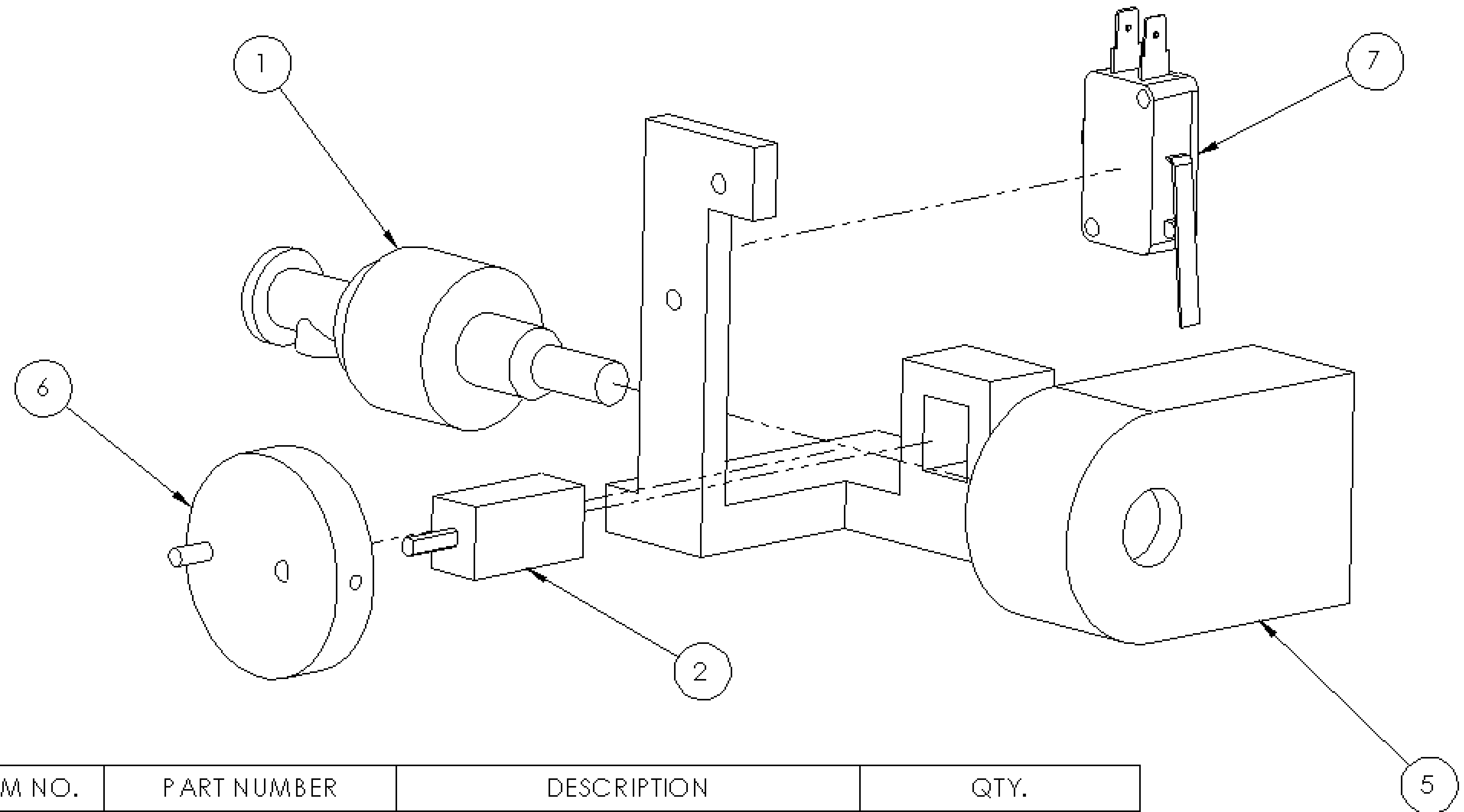
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL: ± 1/8
ANGULAR: MACH ±1° BEND ±2°
TWO PLACE DECIMAL: ± 0.05
THREE PLACE DECIMAL: ± 0.005
TOLERANCING PER: MMC

TITLE: SA -- ELECTRONICS HOUSING ASSEMBLY

REV AA

SCALE: 1:3 MATERIAL:

1 OF 1



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	SA -- 003	Nozzle	1
2	SA -- 004	Motor	1
5	SA -- 033	Motor mount	1
6	SA -- 006	Cam	1
7	SA -- 025	Limit switch	1

CARE

COVID-19 Abatement Return to Education

Drawn By:	EMMA ONETO	Date:	6/9/2021
Checked By:	NOT YET CHECKED	Requested End Date:	

QUANTITY TRACKING:

TOTAL QUANTITY NEEDED:	QTY. MADE:	DATE:	INITIALS:
1			

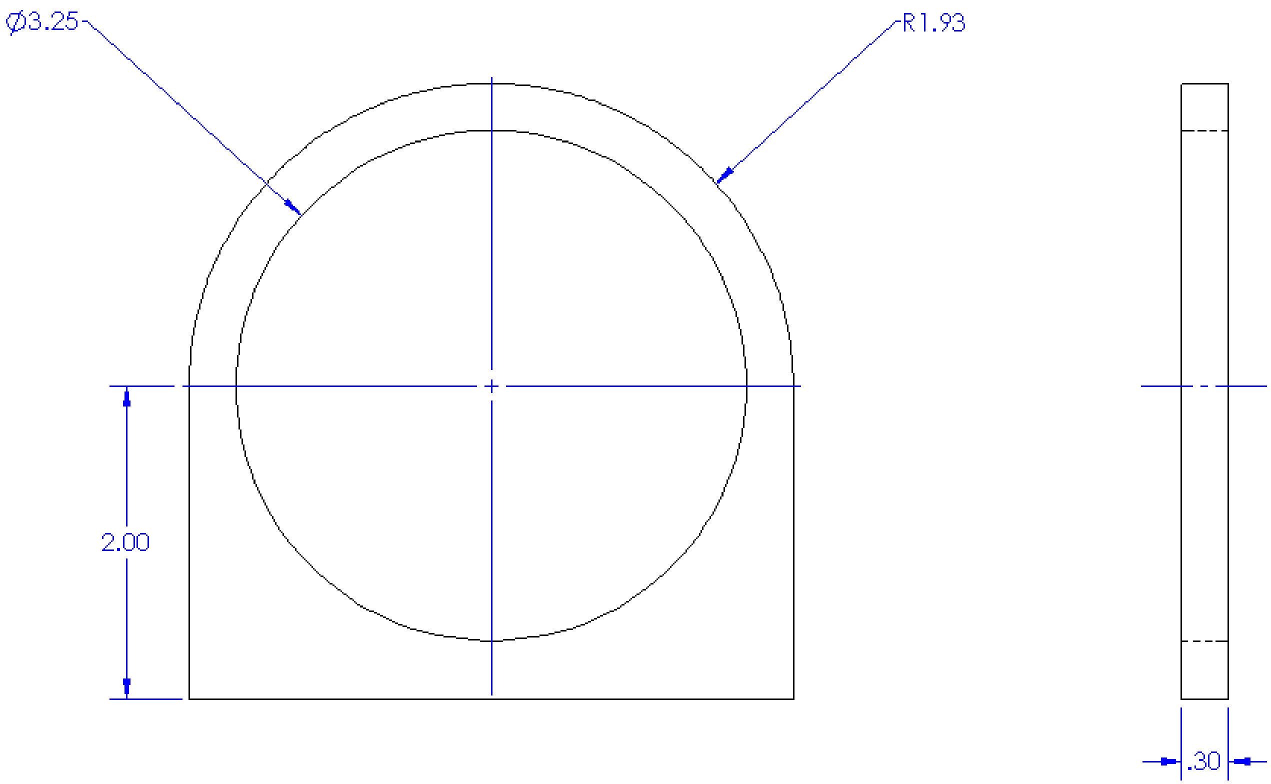
UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL: ± 1/8
ANGULAR: MACH ±1° BEND ±2°
TWO PLACE DECIMAL: ± 0.05
THREE PLACE DECIMAL: ± 0.005
TOLERANCING PER: MMC

TITLE: SA -- NOZZLE ACTUATION ASSEMBLY

REV: AA

SCALE: 1:1 | MATERIAL: | 1 OF 1



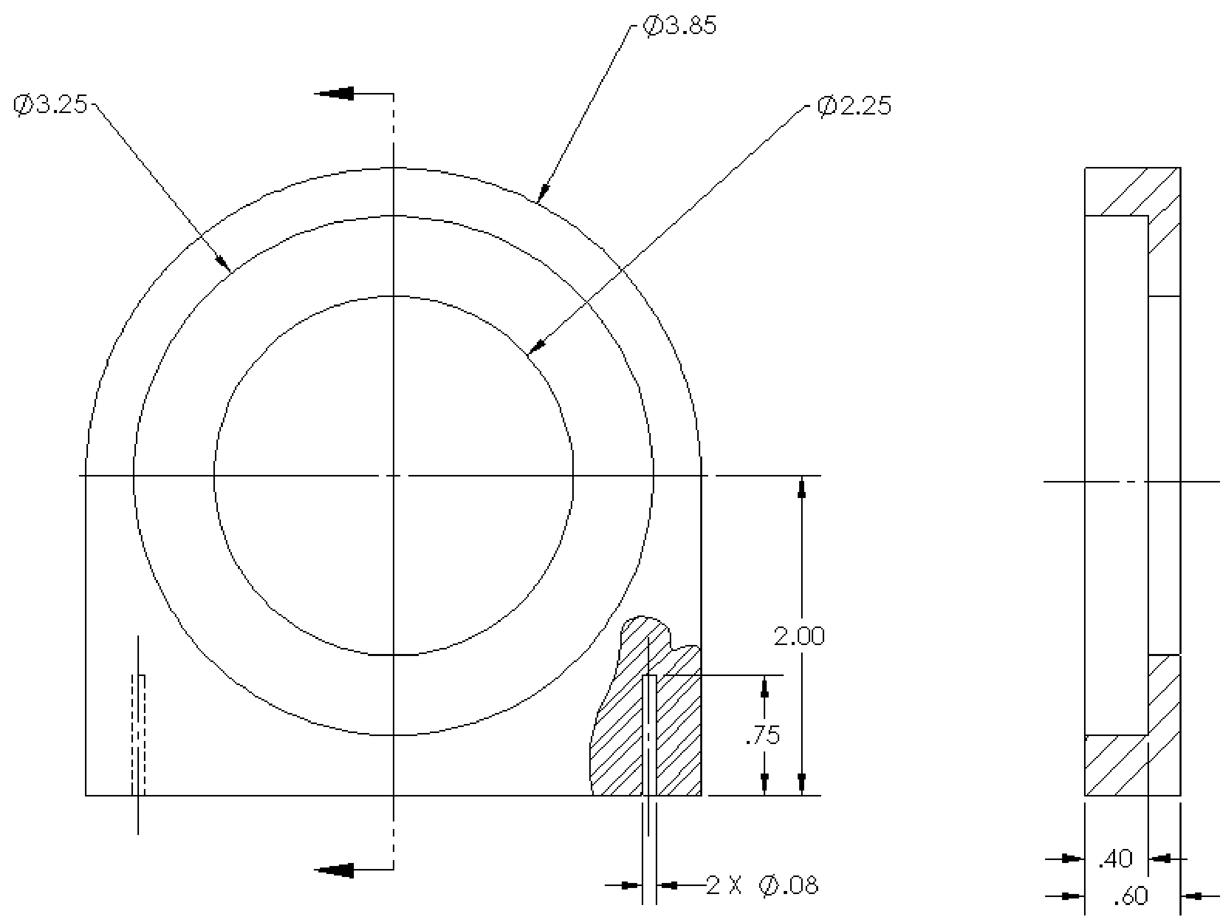
CARE COVID-19 Abatement Return to Education					
Drawn By:	EMMA ONETO	Date:	2/21/2021		
Checked By:	NOT YET CHECKED	Requested End Date:			

QUANTITY TRACKING:			
TOTAL QUANTITY NEEDED:	QTY. MADE:	DATE:	INITIALS:
1			

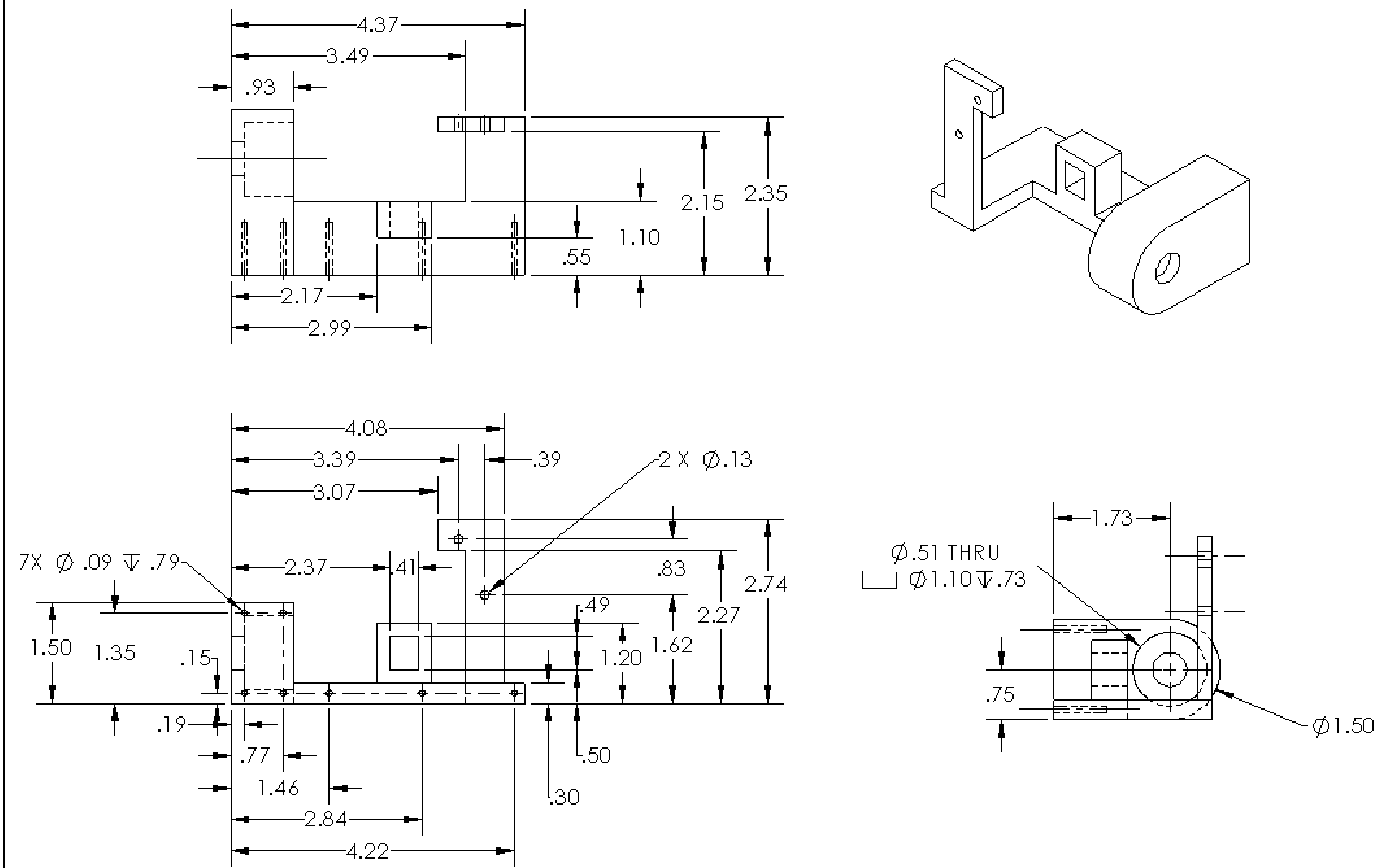
UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL: ± 1/8
ANGULAR: MACH ±1° BEND ±2°
TWO PLACE DECIMAL: ±0.01
THREE PLACE DECIMAL: ±0.005
TOLERANCING PER: MMC

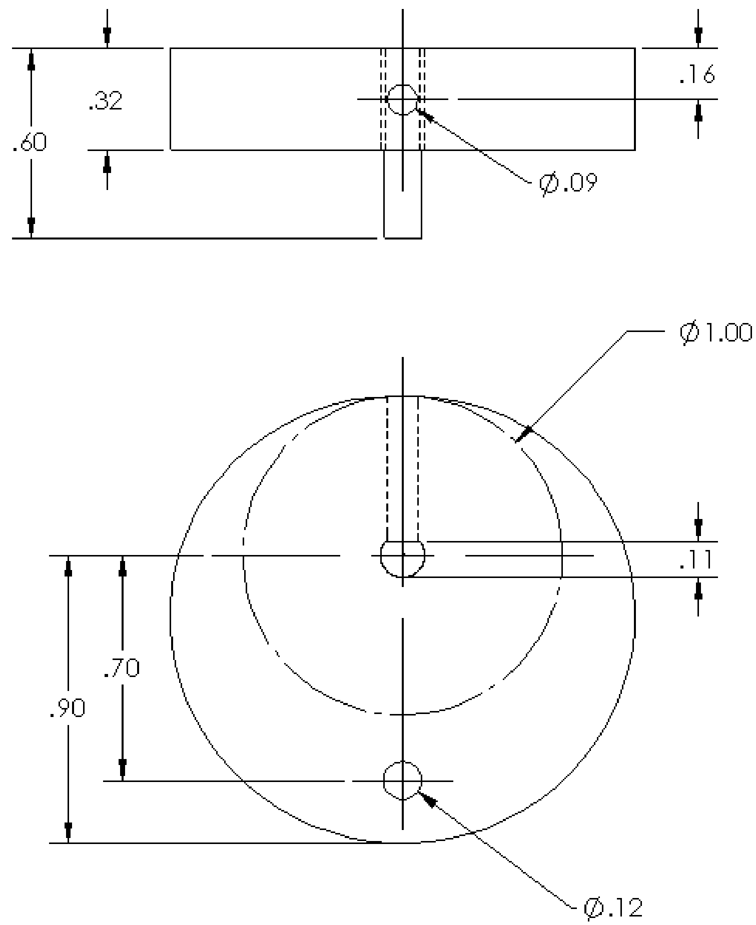
TITLE:		REV
SA -- 011 RESERVOIR TOP MOUNT		AA
SCALE: 1:1	MATERIAL: PETG	1 OF 1



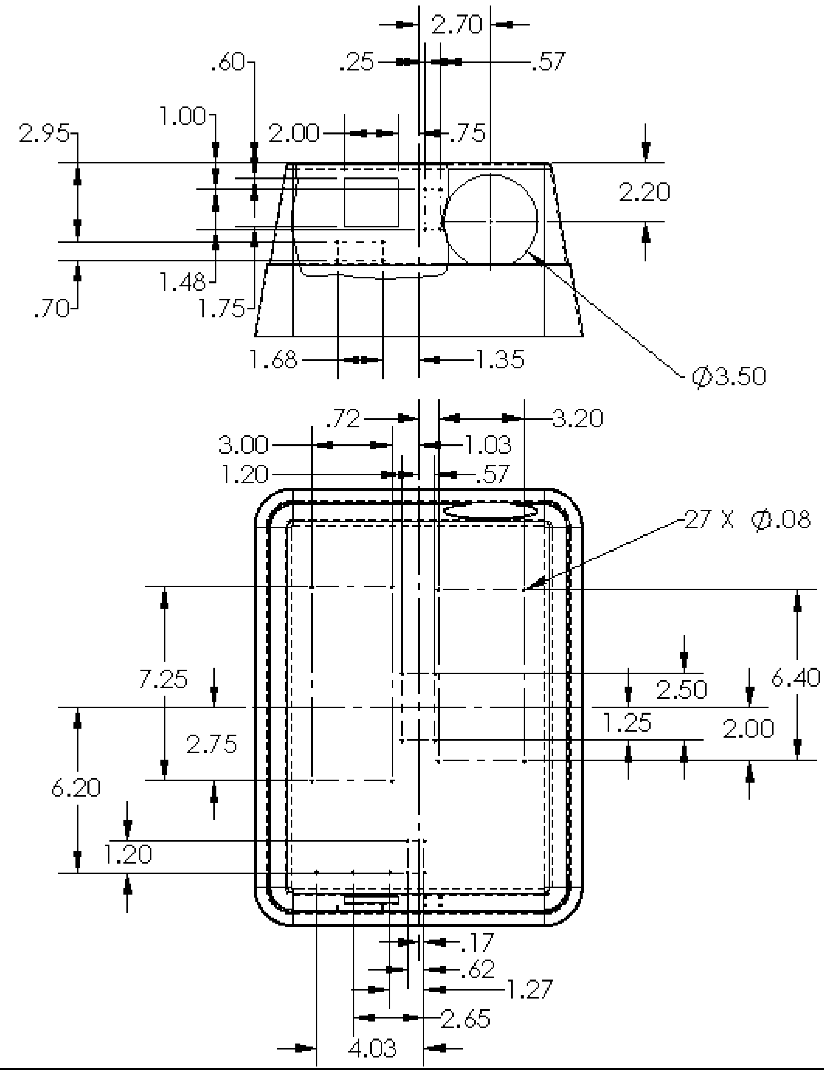
CARE COVID-19 Abatement Return to Education				QUANTITY TRACKING:				UNLESS OTHERWISE SPECIFIED:	TITLE:	REV
Drawn By:	EMMA ONETO	Date:	6/9/2021	TOTAL QUANTITY NEEDED: 1	QTY. MADE:	DATE:	INITIALS:	DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL: ± 1/8 ANGULAR: MACH ±1° BEND ±2° TWO PLACE DECIMAL: ±0.05 THREE PLACE DECIMAL: ±0.005 TOLERANCING PER: MMC	SA -- 012 RESERVOIR BOTTOM MOUNT	AA
Checked By:	NOT YET CHECKED	Requested End Date:							SCALE: 1:1 / MATERIAL: PETG	1 OF 1



CARE COVID-19 Abatement Return to Education	QUANTITY TRACKING:				UNLESS OTHERWISE SPECIFIED:	TITLE: SA -- 033 MOTOR MOUNT	REV AA
	TOTAL QUANTITY NEEDED: 1	QTY. MADE:	DATE:	INITIALS:	DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL: ± 1/8 ANGULAR: MACH ±1° BEND ±2° TWO PLACE DECIMAL: ± 0.01 THREE PLACE DECIMAL: ± 0.005 TOLERANCING PER: MMC	
Drawn By: EMMA ONETO | Date: 6/10/2021						SCALE: 1:2 | MATERIAL: PETG	1 OF 1
Checked By: NOT YET CHECKED | Requested End Date:						

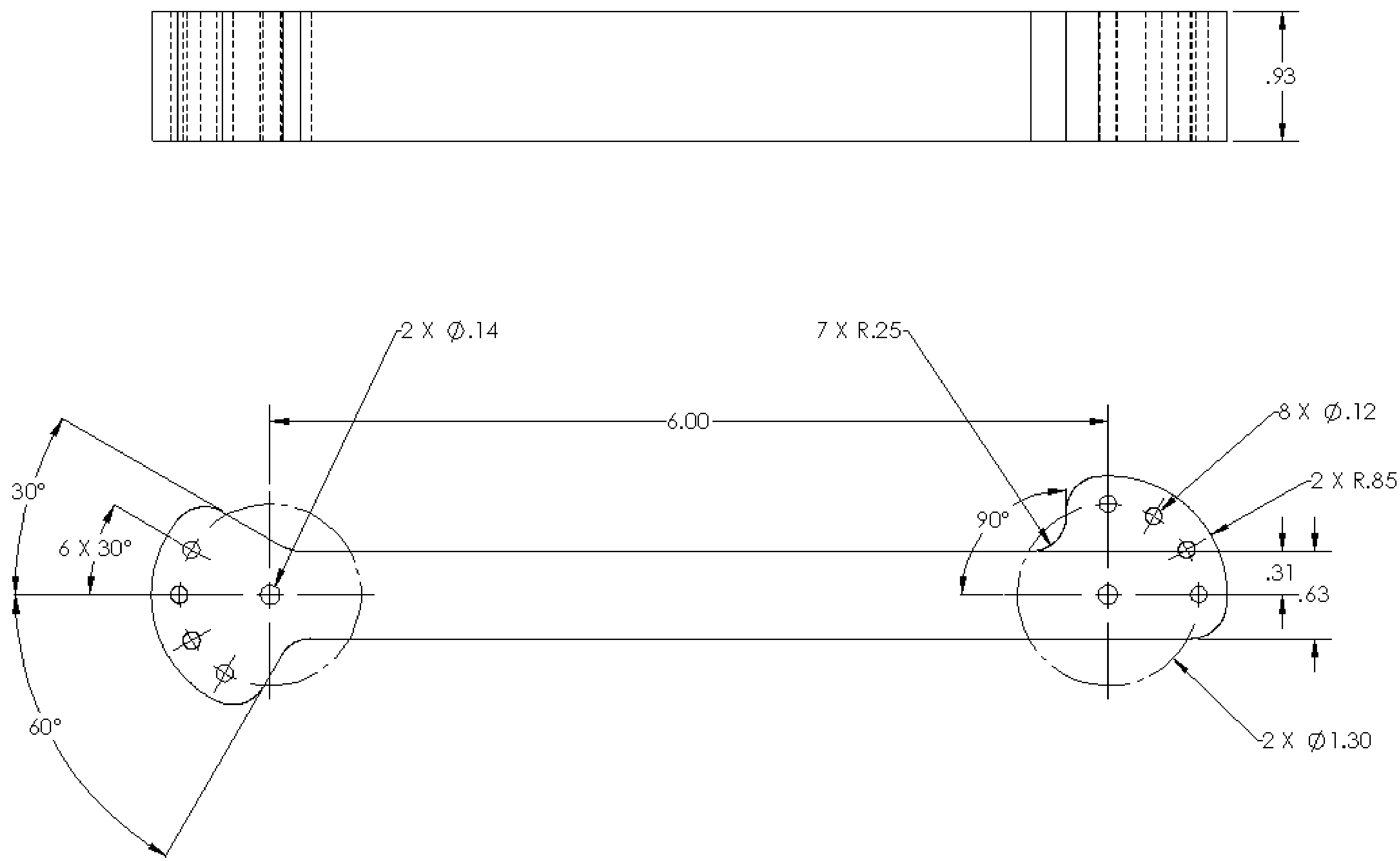


CARE COVID-19 Abatement Return to Education				QUANTITY TRACKING:				UNLESS OTHERWISE SPECIFIED:	TITLE: SA -- 006 - CAM		REV AA
Drawn By:	EMMA ONETO	Date:	6/10/2021	TOTAL QUANTITY NEEDED: 1	QTY. MADE:	DATE:	INITIALS:	DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL: ± 1/8 ANGULAR: MACH ±1° BEND ±2° TWO PLACE DECIMAL: ±0.05 THREE PLACE DECIMAL: ±0.005 TOLERANCING PER: MMC	SCALE: 2:1	MATERIAL: PETG	1 OF 1
Checked By:	NOT YET CHECKED	Requested End Date:									

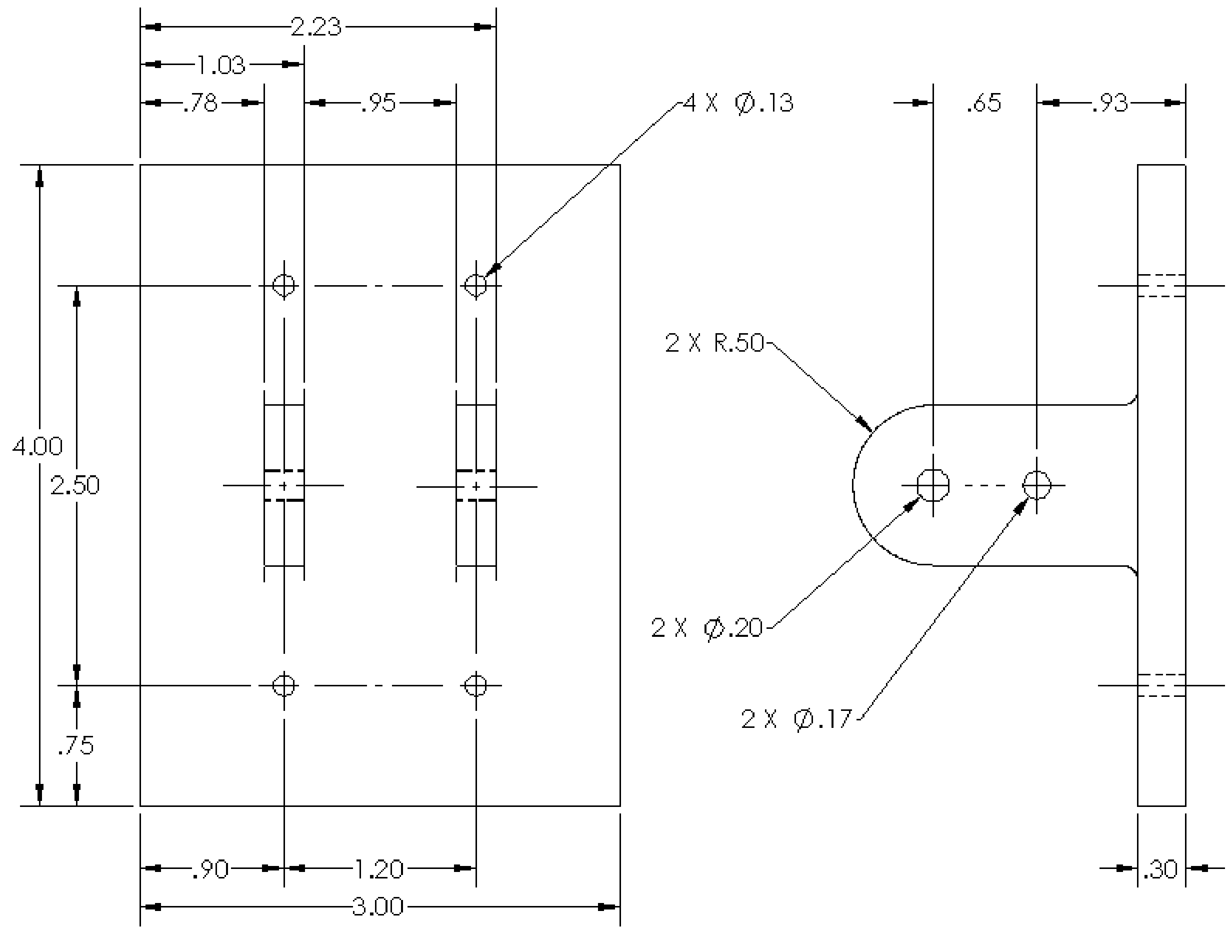


CARE COVID-19 Abatement Return to Education				QUANTITY TRACKING:			
Drawn By:	EMMA ONETO	Date:	6/10/2021	TOTAL QUANTITY NEEDED: 1	QTY. MADE:	DATE:	INITIALS:
Checked By:	NOT YET CHECKED	Requested End Date:					

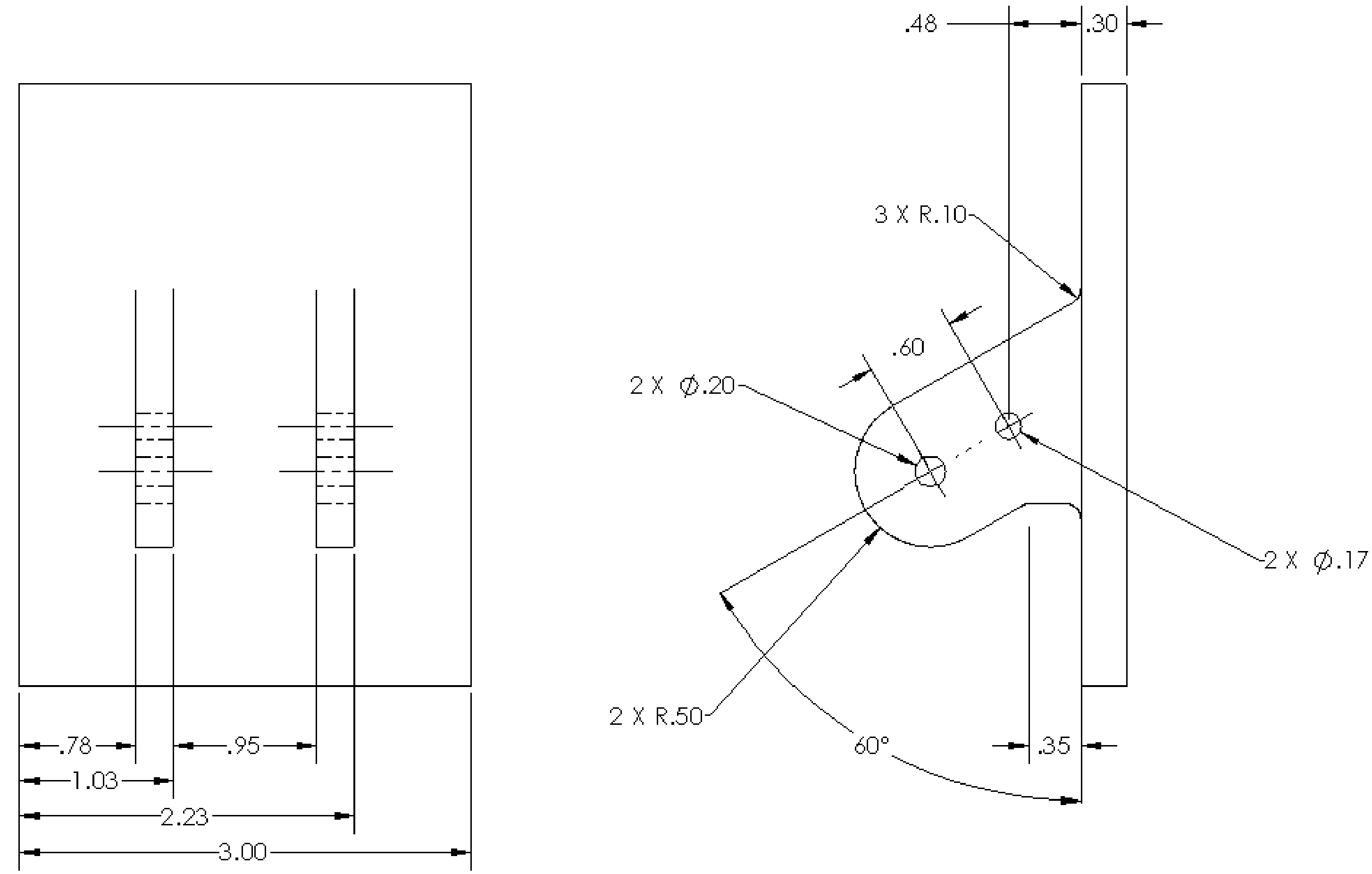
UNLESS OTHERWISE SPECIFIED:	TITLE:			REV
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL: ± 1/8 ANGULAR: MACH ±1° BEND ±2° TWO PLACE DECIMAL: ±0.05 THREE PLACE DECIMAL: ±0.005 TOLERANCING PER: MMC	SA -- 001 - HOUSING			AA
	SCALE: 1:6	MATERIAL: PLASTIC		1 OF 1



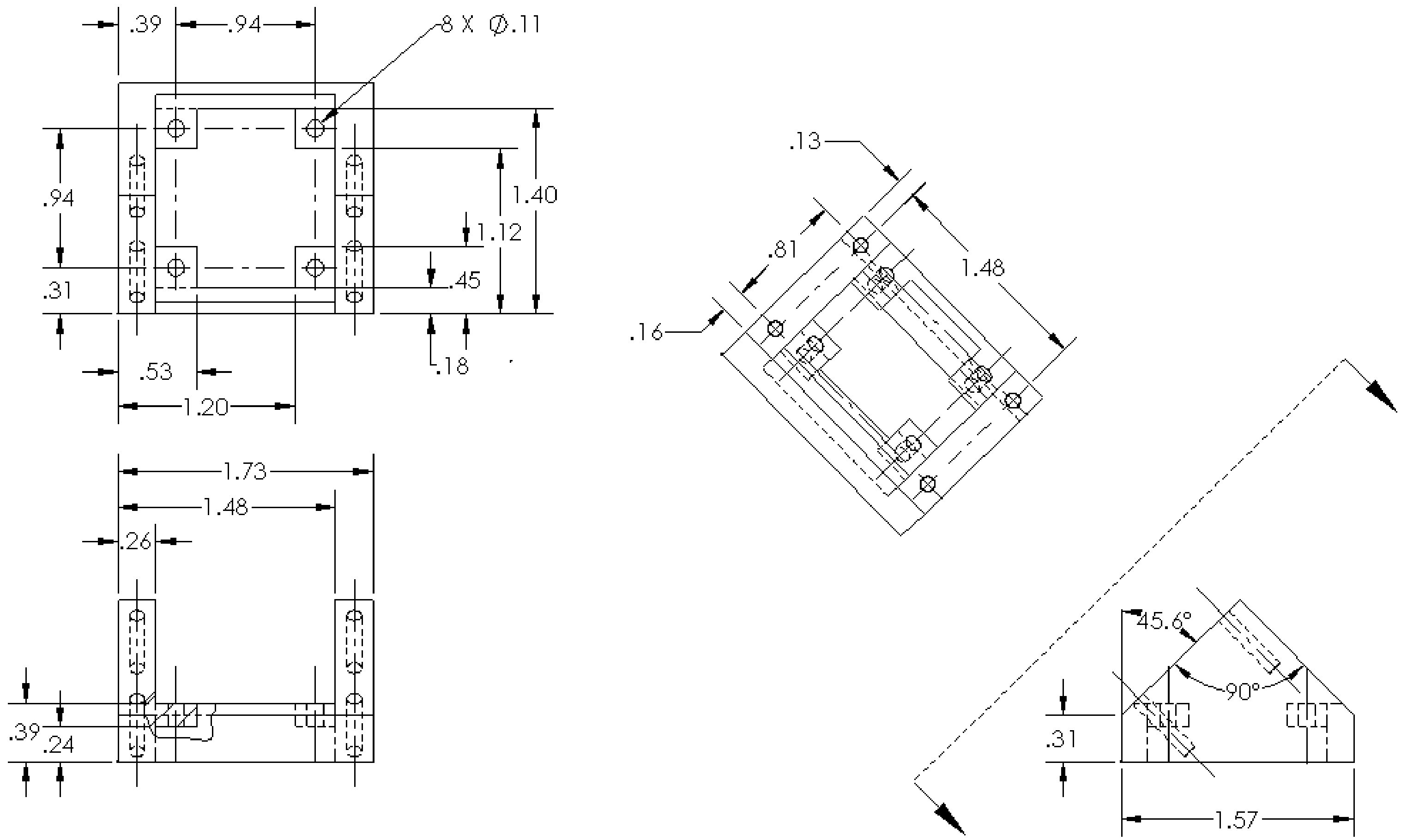
CARE COVID-19 Abatement Return to Education				QUANTITY TRACKING:				UNLESS OTHERWISE SPECIFIED:	TITLE: SA -- 017 SYSTEM MOUNTING ARM	REV AA
				TOTAL QUANTITY NEEDED: 1	QTY. MADE:	DATE:	INITIALS:	DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL: ± 1/8 ANGULAR: MACH ±1° BEND ±2° TWO PLACE DECIMAL: ±0.05 THREE PLACE DECIMAL: ±0.005 TOLERANCING PER: MMC		
Drawn By:	EMMA ONETO	Date:	6/10/2021							
Checked By:	NOT YET CHECKED	Requested End Date:							SCALE: 1:1 | MATERIAL: PETG	1 OF 1



CARE COVID-19 Abatement Return to Education				QUANTITY TRACKING:				UNLESS OTHERWISE SPECIFIED:	TITLE: SA -- 018 SYSTEM MOUNTING TAB		REV AA
Drawn By:	EMMA ONETO	Date:	6/10/2021	TOTAL QUANTITY NEEDED: 1	QTY. MADE:	DATE:	INITIALS:	DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL: ± 1/8 ANGULAR: MACH ±1° BEND ±2° TWO PLACE DECIMAL: ±0.05 THREE PLACE DECIMAL: ±0.005 TOLERANCING PER: MMC			
Checked By:	NOT YET CHECKED	Requested End Date:							SCALE: 1:1	MATERIAL: PETG	1 OF 1



CARE COVID-19 Abatement Return to Education				QUANTITY TRACKING:				UNLESS OTHERWISE SPECIFIED:	TITLE:
				TOTAL QUANTITY NEEDED:	QTY. MADE:	DATE:	INITIALS:	DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL: ± 1/8 ANGULAR: MACH ±1° BEND ±2° TWO PLACE DECIMAL: ± 0.05 THREE PLACE DECIMAL: ± 0.005 TOLERANCING PER: MMC	SA -- 019 WALL MOUNT
Drawn By:	EMMA ONETO	Date:	6/10/2021	1					REV AA
Checked By:	NOT YET CHECKED	Requested End Date:							SCALE: 1:1 · MATERIAL: PETG · 1 OF 1

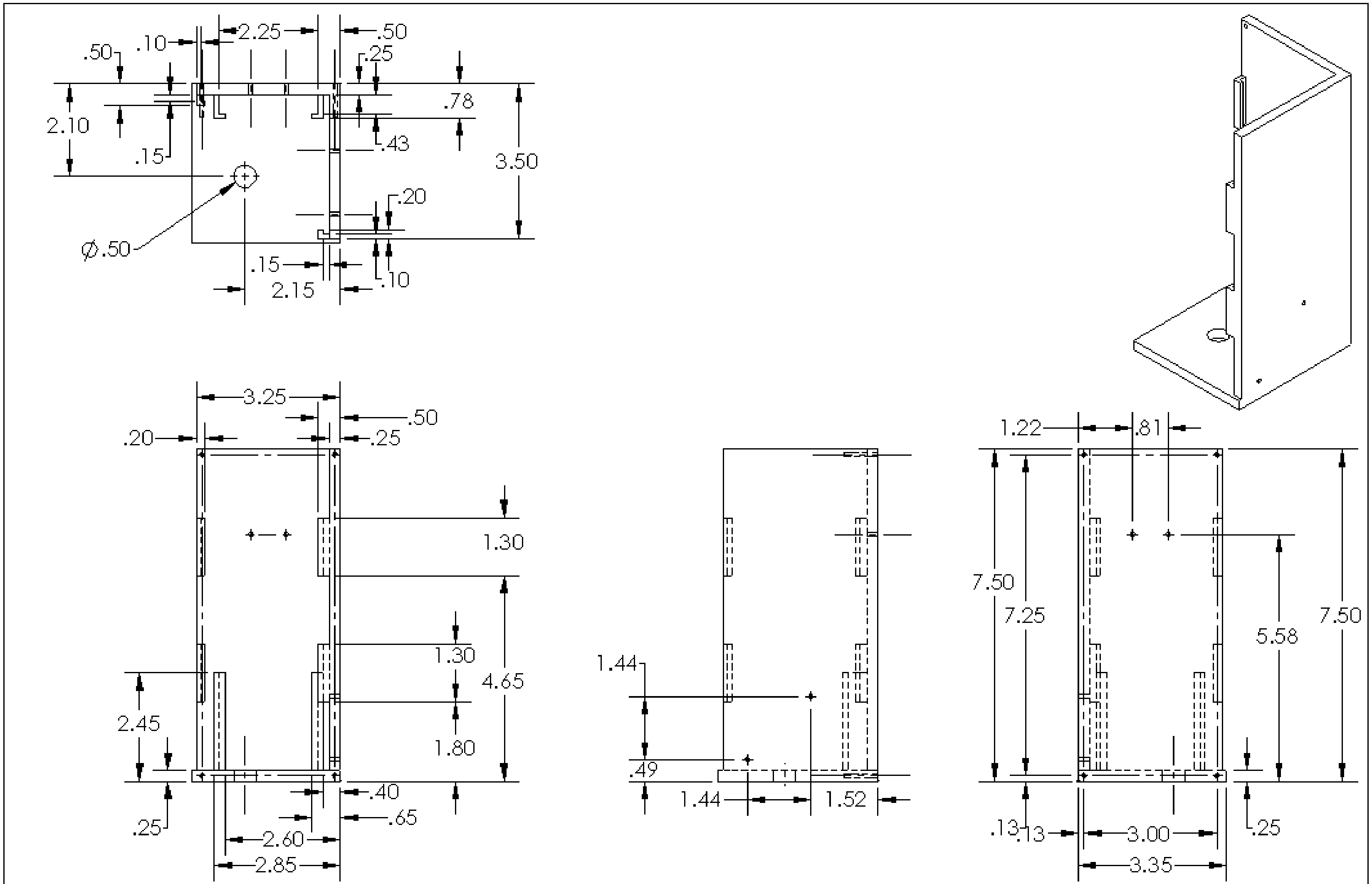


CARE COVID-19 Abatement Return to Education			
Drawn By:	EMMA ONETO	Date:	6/10/2021
Checked By:	NOT YET CHECKED	Requested End Date:	

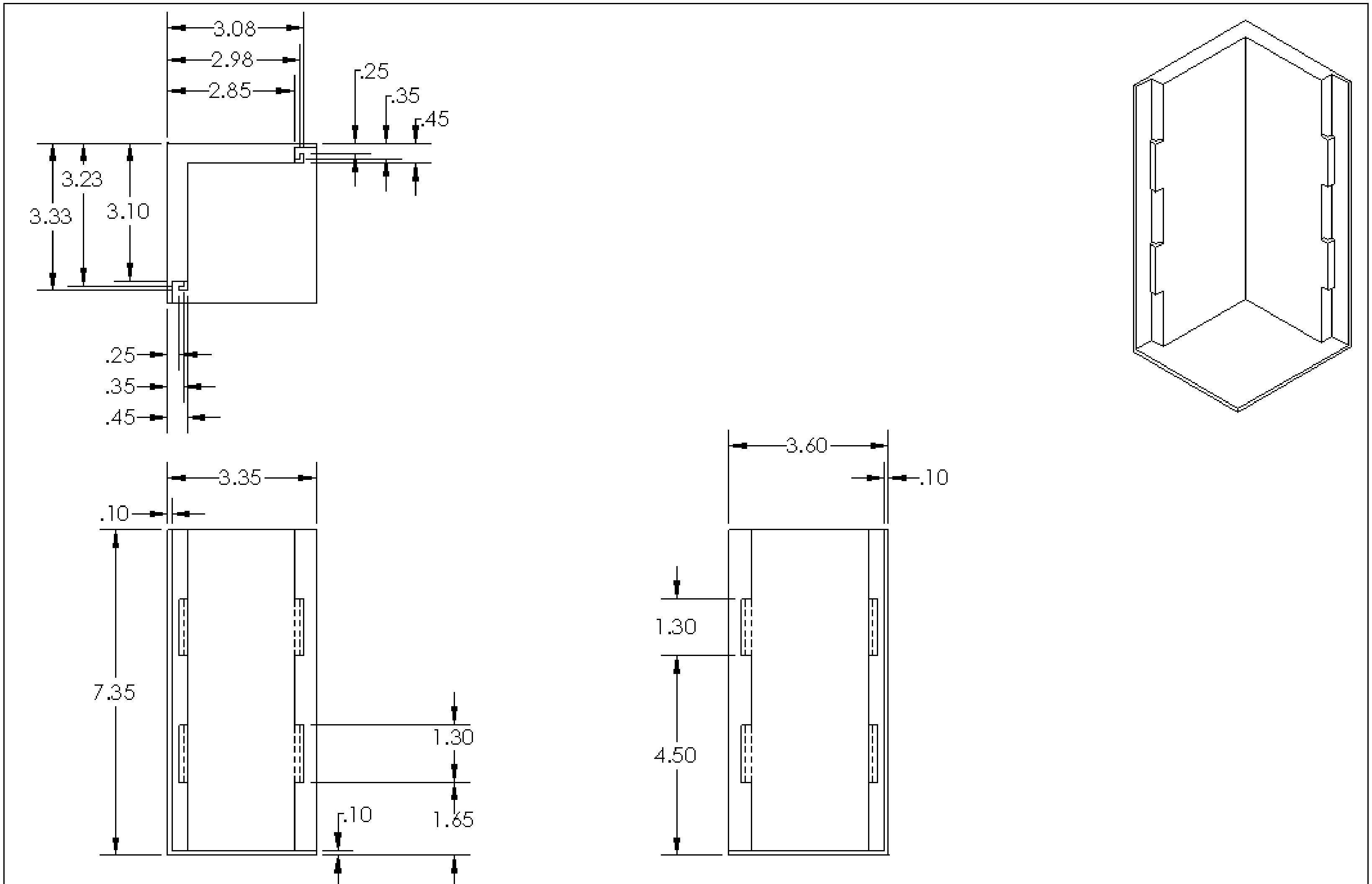
QUANTITY TRACKING:			
TOTAL QUANTITY NEEDED:	QTY. MADE:	DATE:	INITIALS:
1			

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL: ± 1/8
ANGULAR: MACH ±1° BEND ±2°
TWO PLACE DECIMAL: ± 0.05
THREE PLACE DECIMAL: ± 0.005
TOLERANCING PER: MMC

TITLE:		REV
SA -- 024 - FAN MOUNT		AA
SCALE: 1:1	MATERIAL: PETG	1 OF 1



CARE COVID-19 Abatement Return to Education				QUANTITY TRACKING:				UNLESS OTHERWISE SPECIFIED:	TITLE: SA -- 022 ELECTRONICS HOUSING	REV AA
Drawn By:	EMMA ONETO	Date:	6/10/2021	TOTAL QUANTITY NEEDED: 1	QTY. MADE:	DATE:	INITIALS:	DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL: ± 1/8 ANGULAR: MACH ±1° BEND ±2° TWO PLACE DECIMAL: ± 0.05 THREE PLACE DECIMAL: ± 0.005 TOLERANCING PER: MMC	SCALE: 1:3 MATERIAL: PETG	1 OF 1
Checked By:	NOT YET CHECKED	Requested End Date:								



CARE COVID-19 Abatement Return to Education			
Drawn By:	EMMA ONETO	Date:	6/10/2021
Checked By:	NOT YET CHECKED	Requested End Date:	

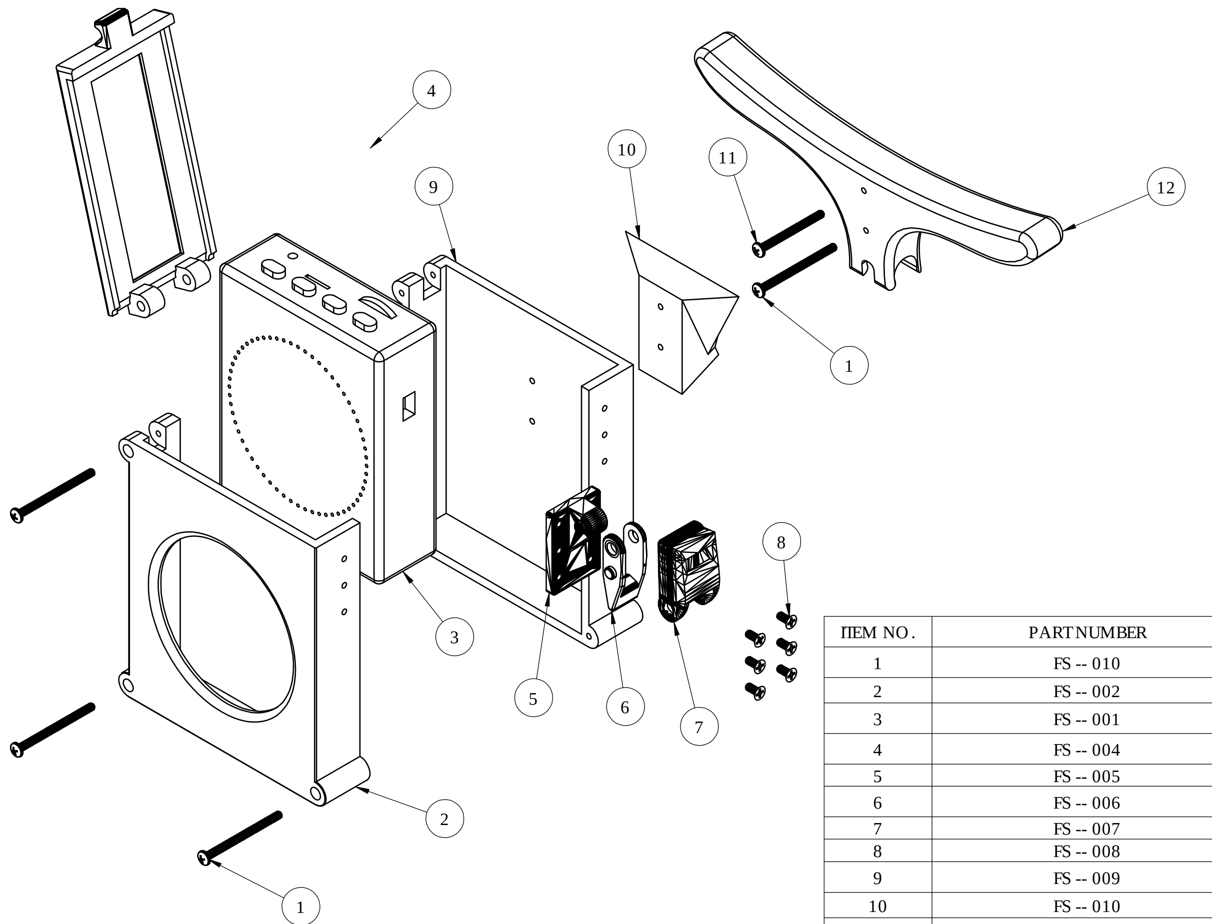
QUANTITY TRACKING:			
TOTAL QUANTITY NEEDED:	QTY. MADE:	DATE:	INITIALS:
1			

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL: ± 1/8
ANGULAR: MACH ±1° BEND ±2°
TWO PLACE DECIMAL: ±0.05
THREE PLACE DECIMAL: ±0.005
TOLERANCING PER: MMC

TITLE:
SA -- 023 - ELECTRONICS HOUSING COVER

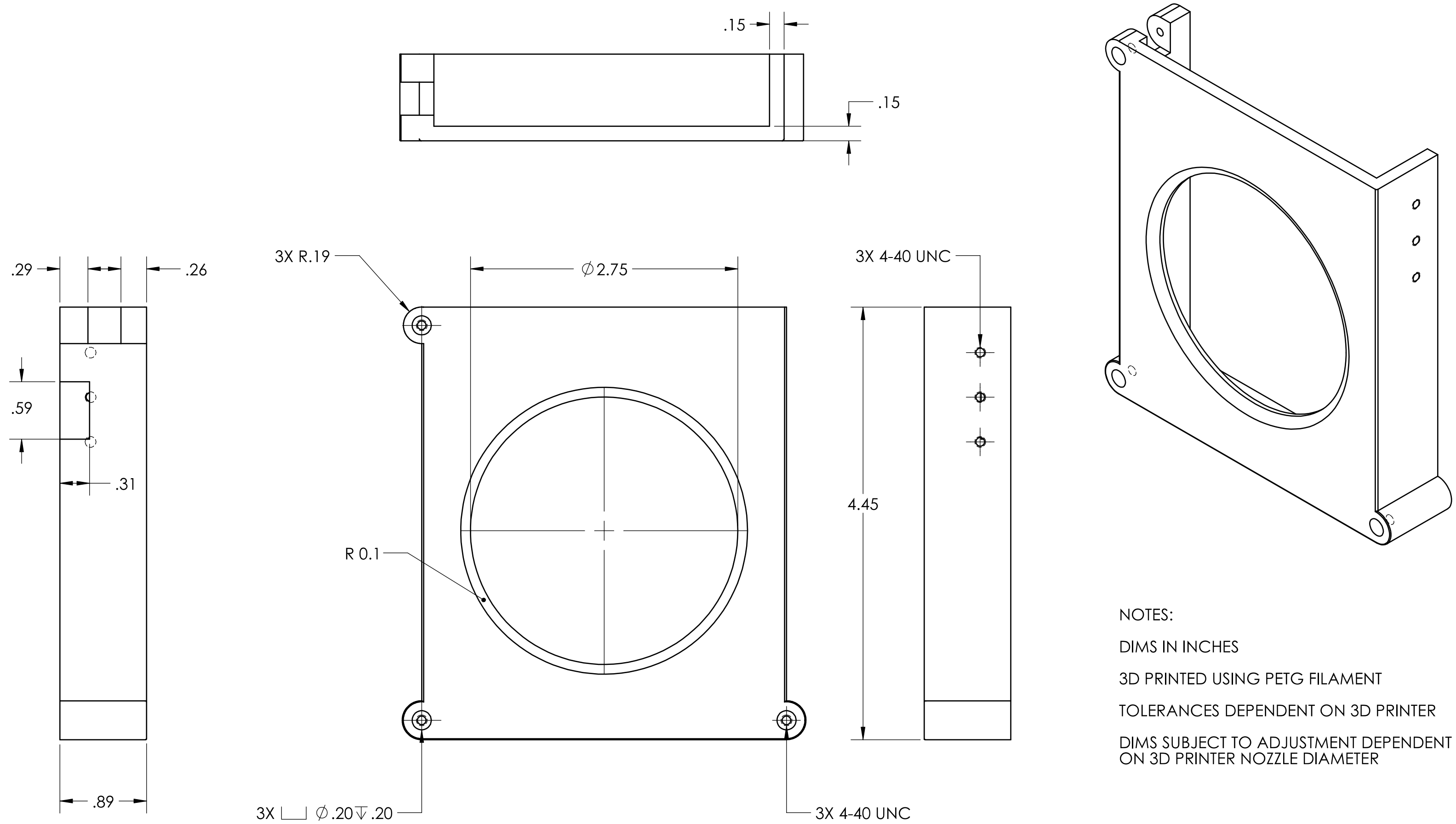
REV AA

SCALE: 1:3 | MATERIAL: PETG | 1 OF 1



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	FS -- 010	1.5 IN 4-40 SCREW	4
2	FS -- 002	SPEAKER CASE FRONT	1
3	FS -- 001	SPEAKER	1
4	FS -- 004	SPEAKER CASE LID	1
5	FS -- 005	LATCH MOUNT	1
6	FS -- 006	LATCH ARM	1
7	FS -- 007	LATCH CLOSURE	1
8	FS -- 008	0.25 IN 4-40 SCREW	6
9	FS -- 009	SPEAKER CASE REAR	1
10	FS -- 010	SPEAKER MOUNT	1
11	FS -- 011	1.25 IN 4-40 SCREW	1
12	FS -- 012	Z-SHIELD	1

Cal Poly ENGR 461	Lab Section: 03	Assignment	Title: SPEAKER EXPLODED VIEW		Drwn. By: MATTEO MARSELLA
	Dwg. #:	Nxt Asb:	Date: 06/03/2021	Scale: 1:1.5	Chkd. By:



NOTES:

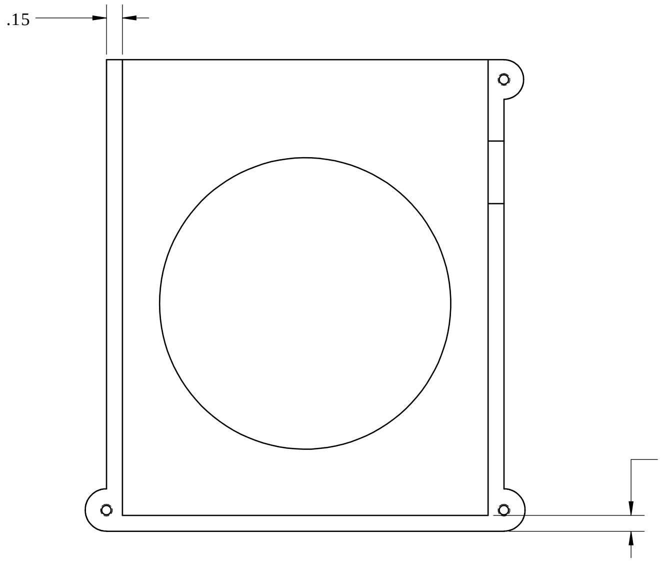
DIMS IN INCHES

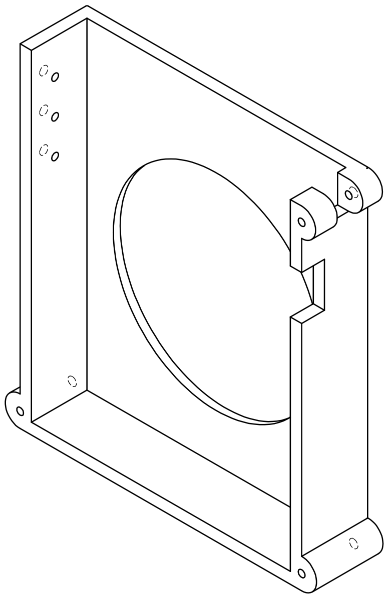
3D PRINTED USING PETG FILAMENT

TOLERANCES DEPENDENT ON 3D PRINTER

DIMS SUBJECT TO ADJUSTMENT DEPENDENT ON 3D PRINTER NOZZLE DIAMETER

Cal Poly	Lab Section: 03	Assignment	Title: SPEAKER CASE FRONT PART 1		Drwn. By: MATTEO MARSELLA
ENGR 461	Dwg. #:	Nxt Asb:	Date: 06/02/2021	Scale: 1:1	Chkd. By:





NOTES:

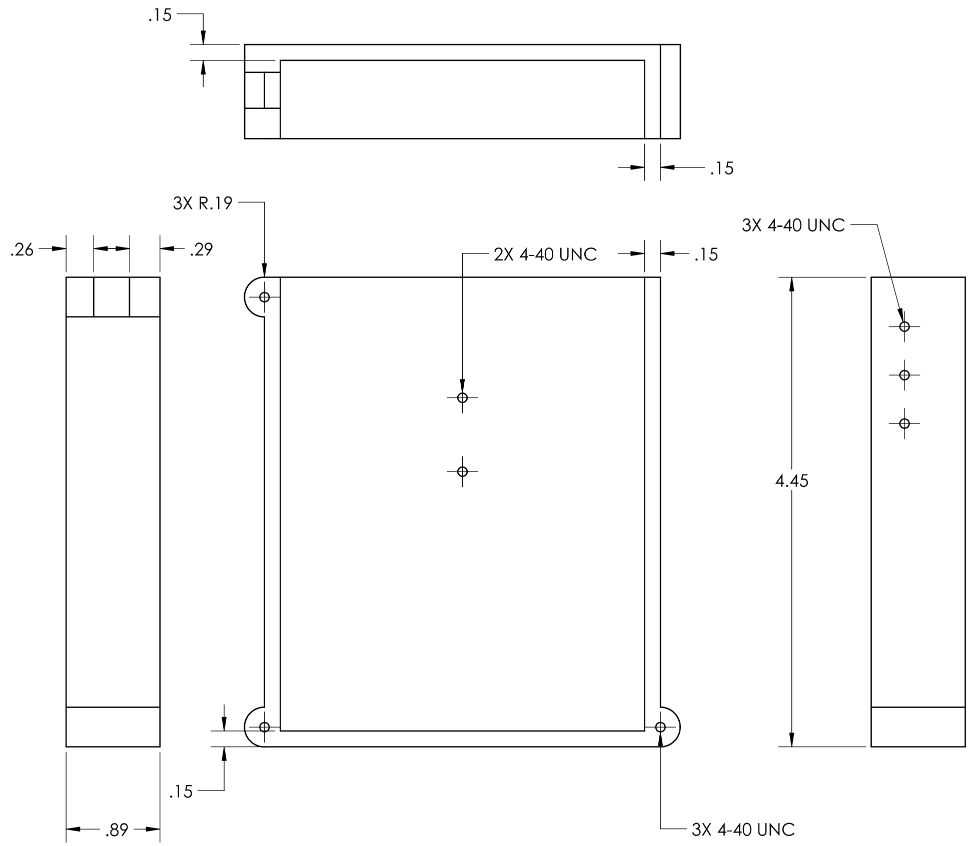
DIMS IN INCHES

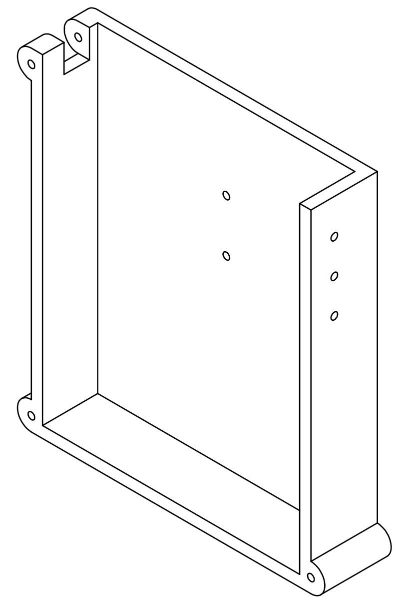
3D PRINTED USING PETG FILAMENT

TOLERANCES DEPENDENT ON 3D PRINTER

DIMS SUBJECT TO ADJUSTMENT DEPENDENT ON 3D PRINTER NOZZLE DIAMETER

Cal Poly ENGR 461	Lab Section: 03	Assignment	Title: SPEAKER CASE FRONT PART 2		Drwn. By: MATTEO MARSELLA
	Dwg. #:	Nxt Asb:	Date: 06/02/2021	Scale: 1:1	Chkd. By:





NOTES:

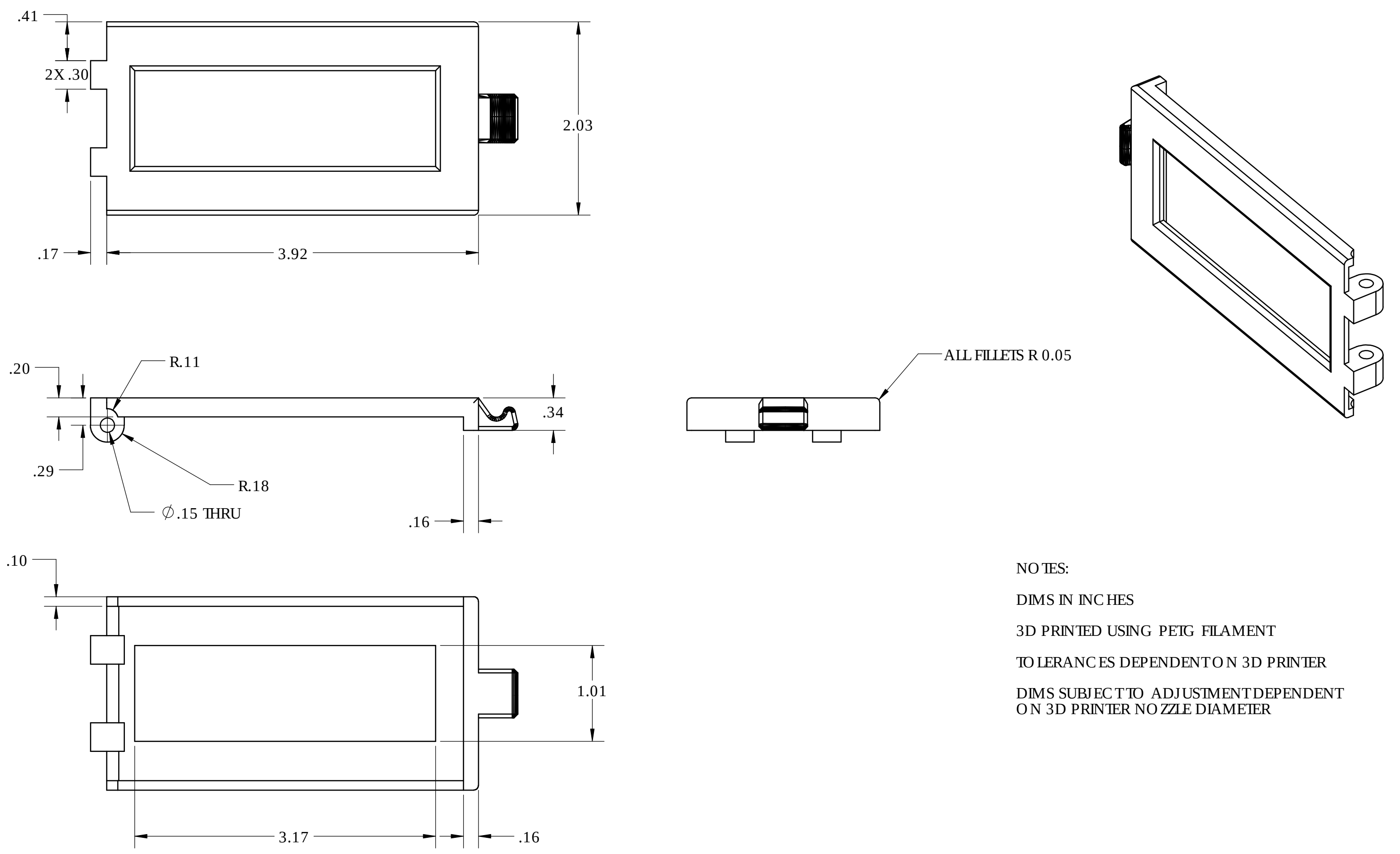
DIMS IN INCHES

3D PRINTED USING PETG FILAMENT

TOLERANCES DEPENDENT ON 3D PRINTER

DIMS SUBJECT TO ADJUSTMENT DEPENDENT
ON 3D PRINTER NOZZLE DIAMETER

Cal Poly ENGR 461	Lab Section: 03	Assignment	Title: SPEAKER CASE REAR		Drwn. By: MATTEO MARSELLA
	Dwg. #:	Nxt Asb:	Date: 06/02/2021	Scale: 1:1	Chkd. By:



NOTES:

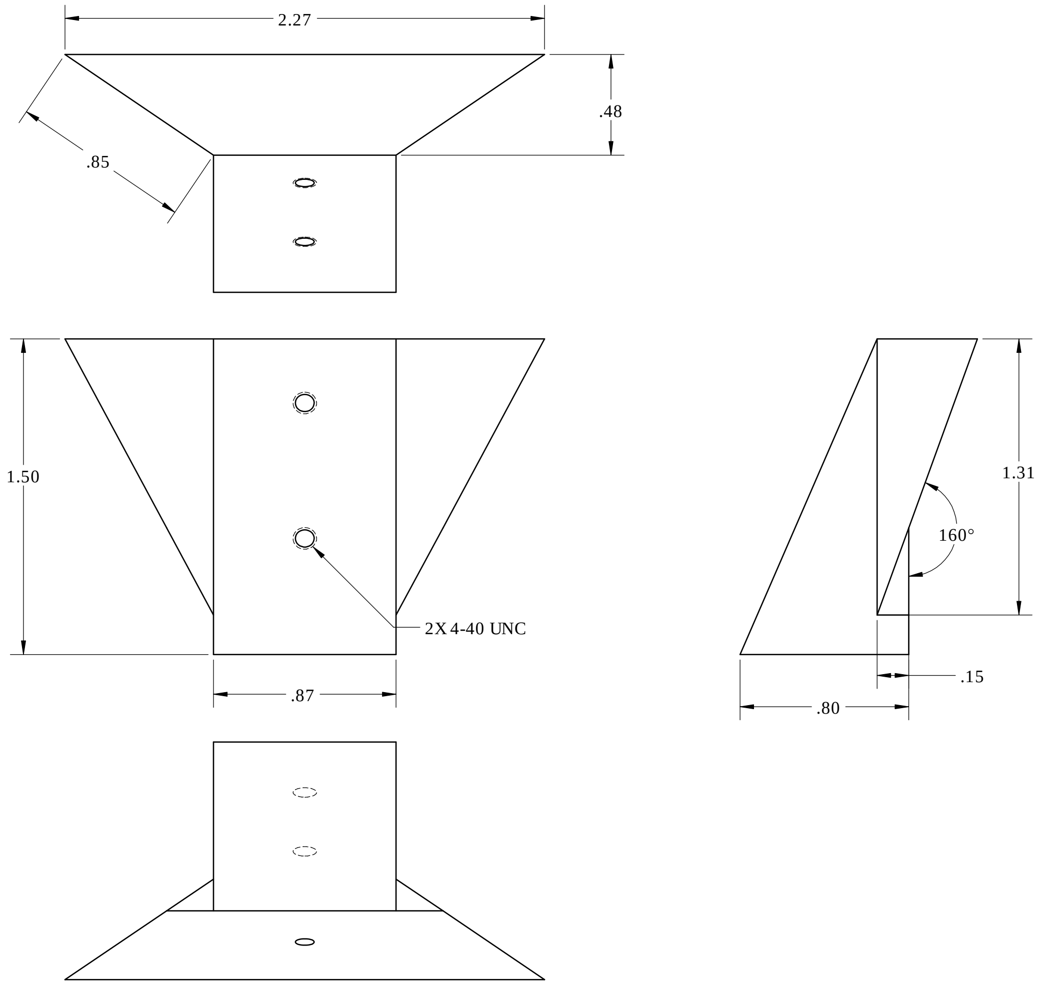
DIMS IN INCHES

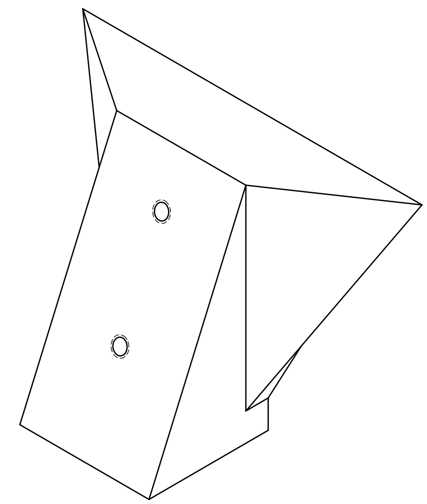
3D PRINTED USING PETG FILAMENT

TOLERANCES DEPENDENT ON 3D PRINTER

DIMS SUBJECT TO ADJUSTMENT DEPENDENT ON 3D PRINTER NOZZLE DIAMETER

Cal Poly ENGR 461	Lab Section: 03	Assignment	Title: SPEAKER LID		Drwn. By: MATTEO MARSELLA
	Dwg. #:	Nxt Asb:	Date: 06/02/2021	Scale: 1:1	Chkd. By:





NOTES:

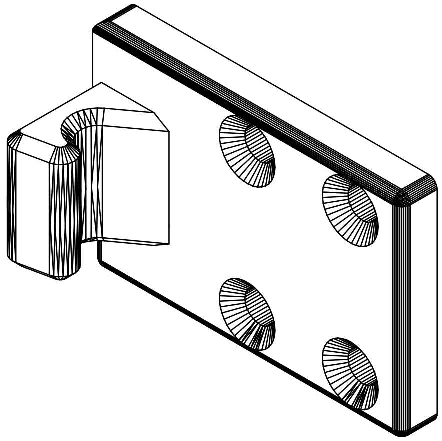
DIMS IN INCHES

3D PRINTED USING PETG FILAMENT

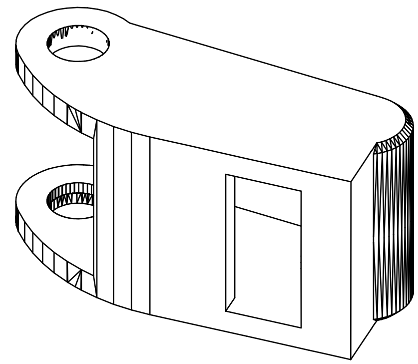
TOLERANCES DEPENDENT ON 3D PRINTER

DIMS SUBJECT TO ADJUSTMENT DEPENDENT
ON 3D PRINTER NOZZLE DIAMETER

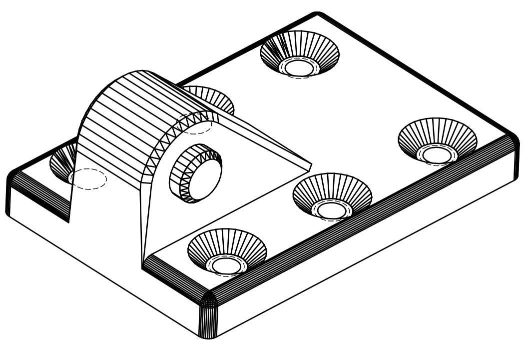
Cal Poly	Lab Section: 03	Assignment	Title: SPEAKER MOUNT		Drwn. By: MATTEO MARSELLA
ENGR 461	Dwg. #:	Nxt Asb:	Date: 06/01/2021	Scale: 2:1	Chkd. By:



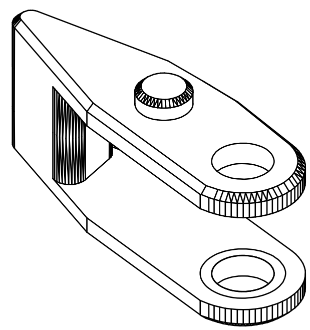
FS -- 013 - LATCH CATCH



FS -- 007 - LATCH CLOSURE



FS -- 005 - LATCH MOUNT



FS -- 006 - LATCH ARM

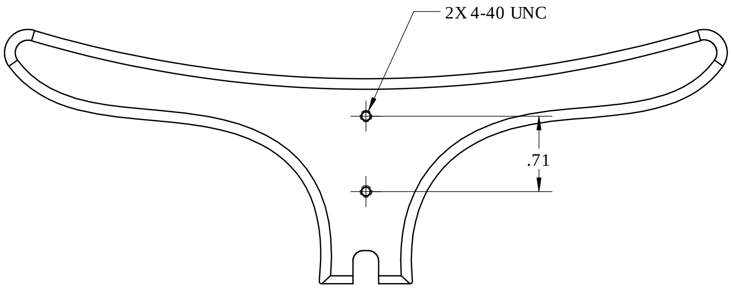
NOTES:

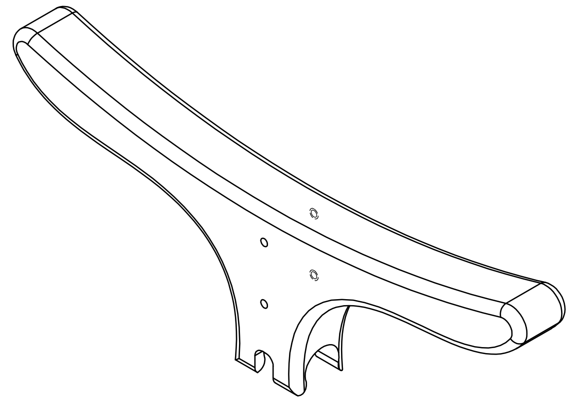
3D PRINTED IN PETG

DESIGNED BY THINGIVERSE USER ARTEAN

THING: 4609397

Cal Poly	Lab Section: 03	Assignment	Title: THINGIVERSE PARTS		Drwn. By: MATTEO MARSELLA
ENGR 461	Dwg. #:	Nxt Asb:	Date: 06/03/2021	Scale: 3:1	Chkd. By:





NOTES:

ALL DIMS IN INCHES

THIS IS AN APPOXIMATION OF THE Z-SHIELD

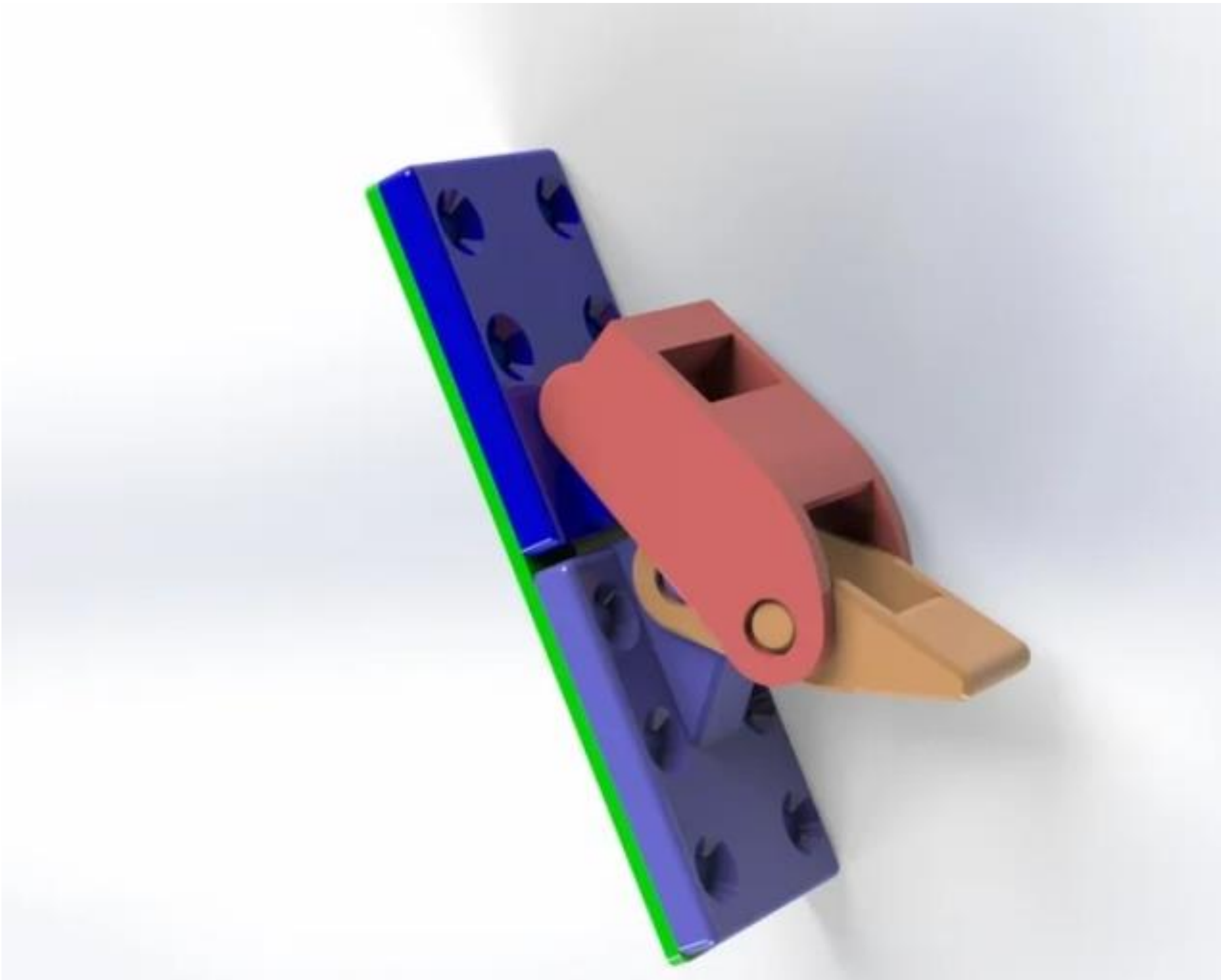
THE HOLES MUST BE ADDED TO THE PUCHASED Z-SHIELD

Cal Poly	Lab Section: 03	Assignment	Title: Z-SHIELD		Drwn. By: MATTEO MARSELLA
ENGR 461	Dwg. #:	Nxt Asb:	Date: 06/02/2021	Scale: 1:1	Chkd. By:

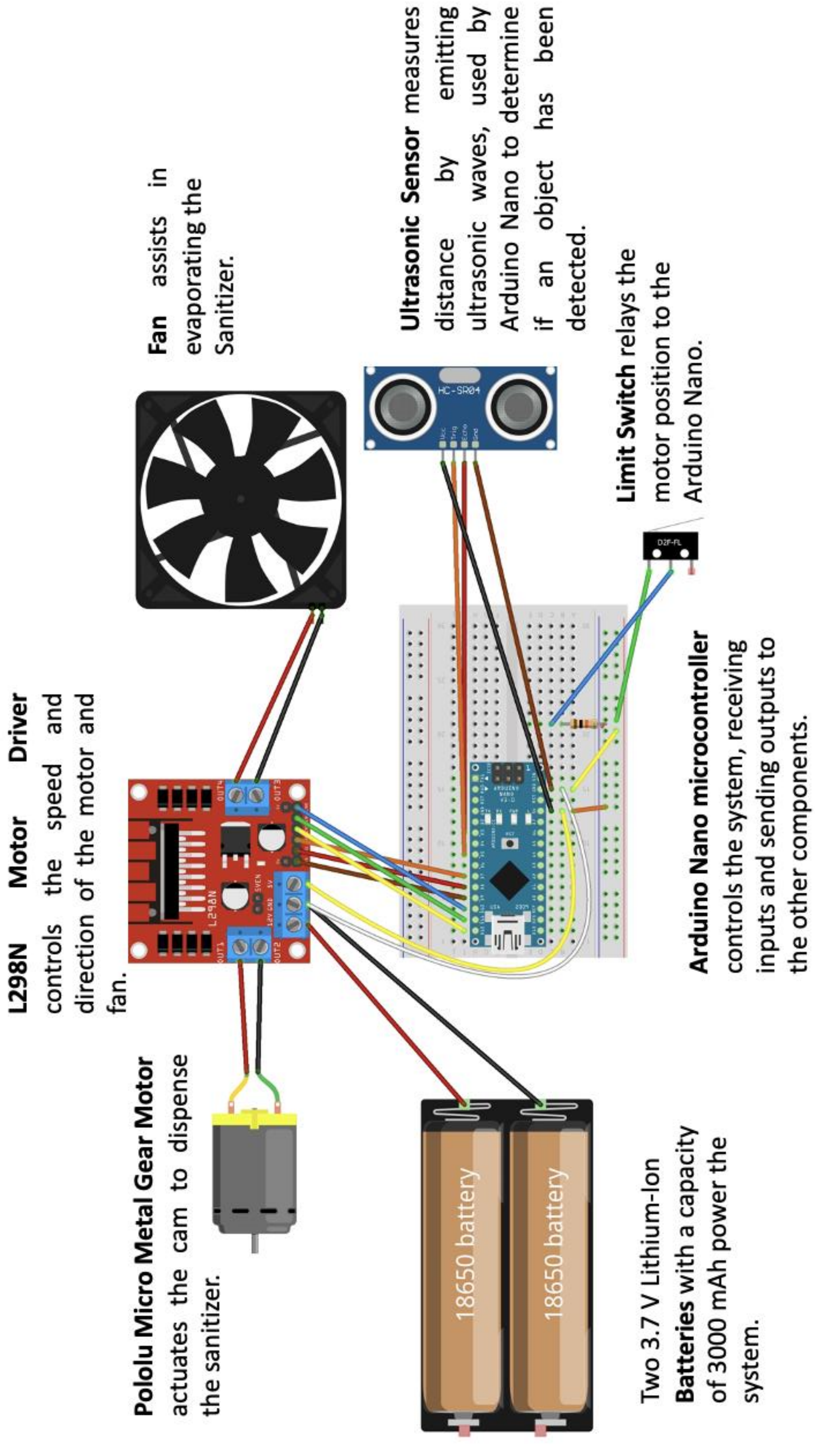
Speaker Case Latch

Adapted from a design by Thingiverse user Artean

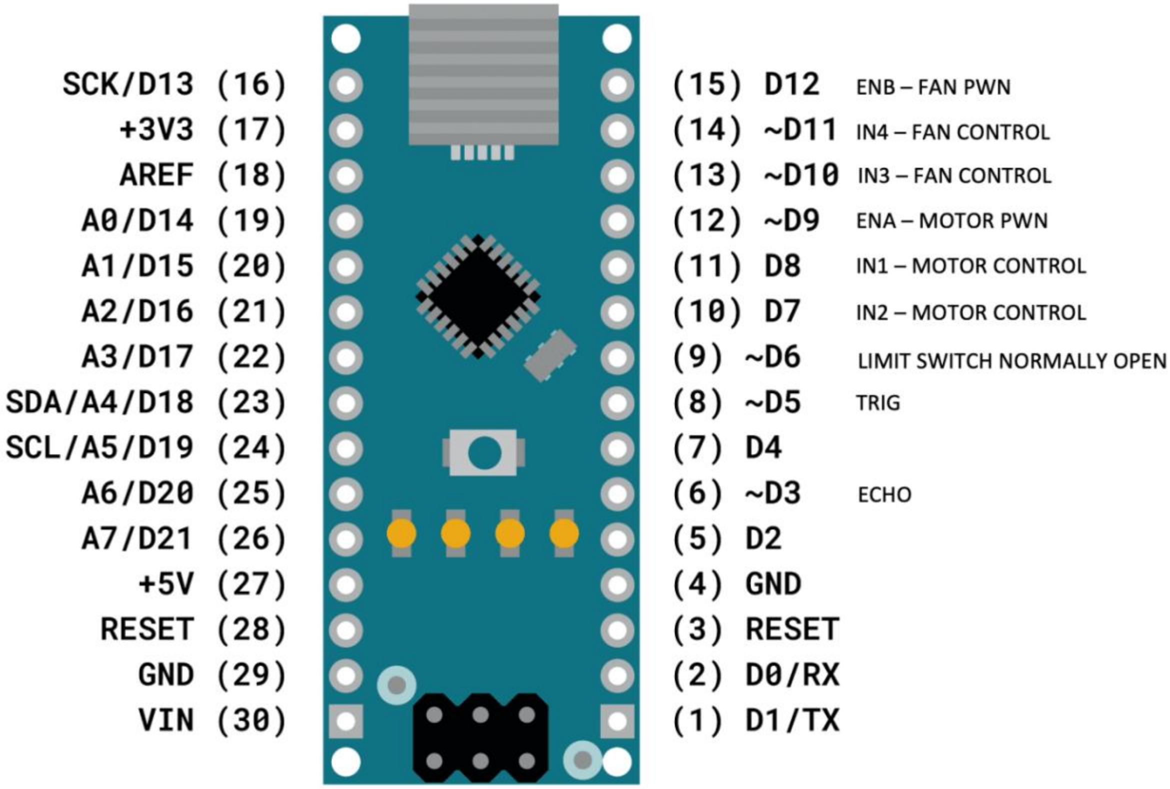
https://www.thingiverse.com/thing:4609397



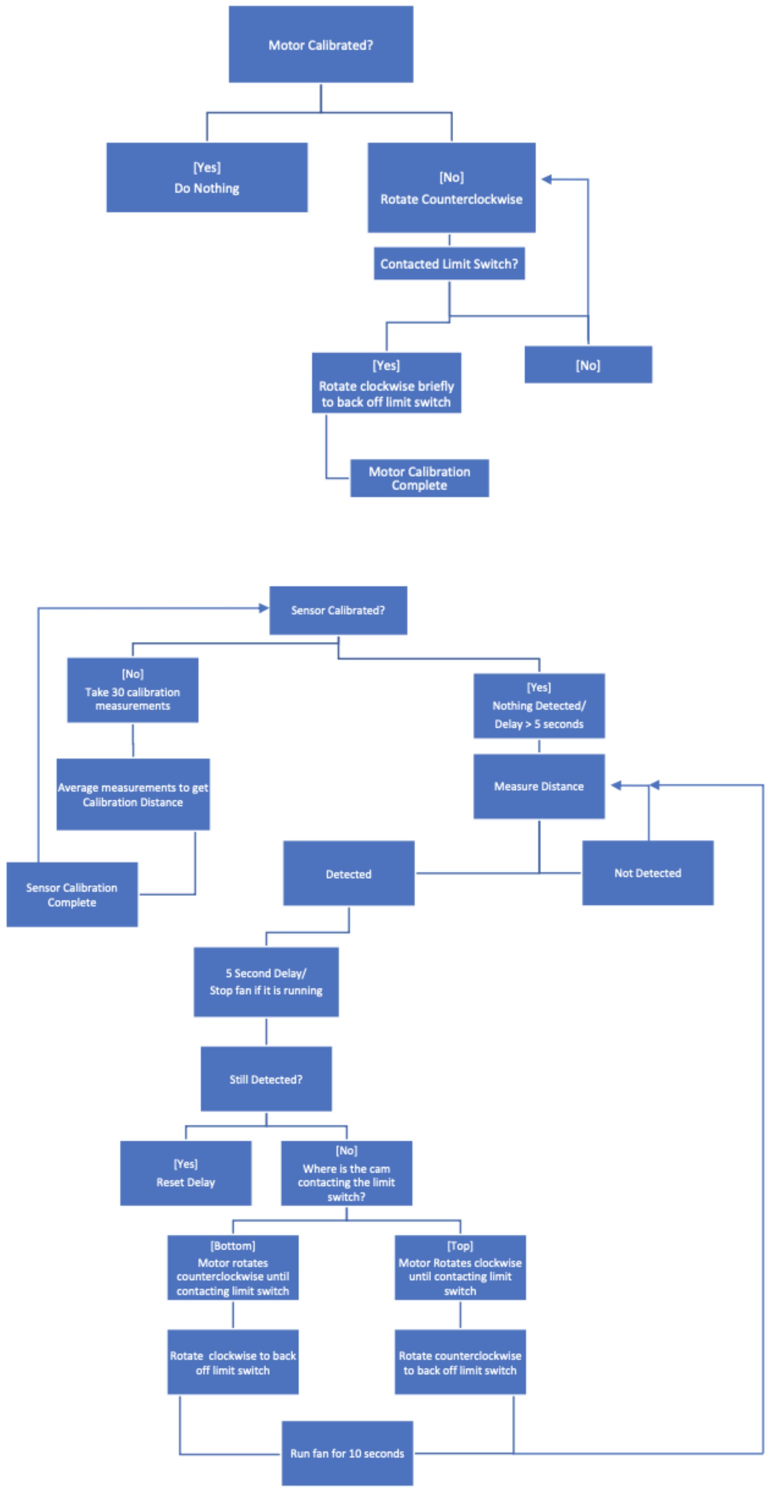
Automatic Sanitizing Spray Electronics Schematic



Appendix D: Arduino Nano
Arduino Nano Pinouts



Arduino Code Flowchart



Arduino Nano Code

```
// CARE: COVID-19 Abatement Return to Education
// By: Matteo Marsella with special thanks to Scott Mangin

// Define Variables + Assign Values


//Sensor

const int URECHO = 3;                   // PWM Output 0-25000US,Every 50US
represent 1cm
const int URTRIG = 5;                   // trigger pin
const int threshold = 5000;             // 5 second timer

                                        // set all to zero to begin
int calibrated = 0;                     // reports if system is calibrated or not
int count = 0;                          // keeps track of time in milliseconds
unsigned int DistanceMeasured = 0;      // distance measured by the sensor during
operation
unsigned int CalibrationMeasure = 0;    // measured distance during calibration
period
unsigned int CalibrationSum = 0;        // sum of calibration distances
unsigned int CalibrationDistance = 0; // calibraton distance to compare against,
CalibrationSum divided by number of measurements
unsigned int Difference = 0;            // difference in value between
CalibrationDistance and DistanceMeasure
float DifferencePercent = 0;            // percentage difference change between
calibration measurement and current measurement, determines sensor detection
bool Detected = 0;                      // flag for if the sensor has detected
something

unsigned int Position = 1;              // cam impact with limit switch, 1 = Bottom
Position / 2 = Top Position
unsigned long LowLevelTime;             // time from sensor results in distance
measurement

unsigned long tdelay = 0;               // set sensor variables to zero
bool firsttime = 0;
unsigned long tref = 0;
unsigned long tnew = 0;

unsigned long tdelayf = 0;              // set fan variables to zero
bool firsttimef = 0;
unsigned long treff = 0;
unsigned long tnewf = 0;
const int thresholdf = 5000;            // 5 second timer
```

```
//Motor
const int IN1 = 8;                     // motor control pin 1
const int IN2 = 7;                     // motor control pin 2
const int EN1 = 9;                     // PWN motor pin
const int Mspeed = 255;                // motor speed

//Fan
const int IN3 = 10;                    // fan control pin 1
const int IN4 = 11;                    // fan control pin 2
const int EN2 = 12;                    // PWN fan pin
const int FSpeed = 255;                // fan speed
bool fanflg = 0;

//Limit Switch
const int LS = 6;                     // limit switch pin, set to normally open


void setup()                                  // runs once
{
  delay(1000);
  bool red = 0;                               // set to zero to make sure code
runs so motor is in the correct position

  //Sensor
  Serial.begin(9600);                         // sets the baud rate to 9600
  pinMode(URTRIG, OUTPUT);                    // low pull on pin COMP/TRIG
  digitalWrite(URTRIG, HIGH);                 // set to HIGH
  pinMode(URECHO, INPUT);                     // sending Enable PWM mode command
  delay(500);
  Serial.println("Init the sensor");

  //Motor
  pinMode(IN1, OUTPUT);                       // set motor pins as outputs
  pinMode(IN2, OUTPUT);
  pinMode(EN1, OUTPUT);
  digitalWrite(IN1, LOW);                     // set motor control pins at low,
i.e. motor is stopped
  digitalWrite(IN2, LOW);

  //Limit Switch
  pinMode(LS, INPUT);                         // set limit switch as an input

  // Motor Setup
  analogWrite(EN1, Mspeed);                   // set PWN pin to motor speed
```

```
calibration distances
    count = count + 1;                                          // number of
calibration distances taken

    if (count >= 30) {                                          // run if 30 or more
calibration distances have been taken
      CalibrationDistance = CalibrationSum / count;       // average
CalibrationSum to find CalibrationDistance
      calibrated = 1;                                           // sensor is now
calibrated
      Serial.print("Calibration Distance is");
      Serial.print(CalibrationDistance);
      Serial.print("cm");
    }
    else
    {
      delay(200);
    }
  }

  else

  {

    if (Detected == 0 || tdelay > threshold)  // run if nothing has been detected
or delay has exceeded 5 seconds
    {
      //Serial.print("Distance=");
      digitalWrite(URTRIG, LOW);              // set trigger (signal emitter) to
low (not emitting)
      digitalWrite(URTRIG, HIGH);             // set trigger to high (emitting)

      LowLevelTime = pulseIn(URECHO, LOW);    // time for sensor to receive
emitted frequency
      if (LowLevelTime >= 50000)              // the reading is invalid
      {
        Serial.println("Invalid");
      }
      else
      {
        DistanceMeasured = LowLevelTime / 50; // every 50us low level stands for
1cm
        // Serial.print(DistanceMeasured);
        // Serial.println("cm");
        // Serial.println(CalibrationDistance);
```

```
        Difference = CalibrationDistance - DistanceMeasured; //difference between
calibration distance and currently measured distance
        //Serial.println(Difference);
        DifferencePercent = (float) Difference / (float) CalibrationDistance; //
the difference represented as a percent of the calibration distance
        //Serial.println(DifferencePercent);

        if (DifferencePercent >= 0.5) {          // run if the difference
represents 50% or more of the calibration distance
          if (Detected == 1)                     // run if the sensor is
detecting something
          {
            Serial.println("Repeat Countdown");
            tdelay = 0;                          // set delay back to zero and
repeat the countdown if something is detected at the end of the initial countdown
          }
          else if (Detected == 0 && tdelay == 0) // run if nothing is detected or
the delay is zero
          {
            Serial.println("Detected");
            Detected = 1;                        // something has been detected
          }
        }
        else {                                   // run if the difference does
not represent 50% or more of the calibration distance
          if (Detected == 0 && tdelay == 0)      // run if nothing is detected
and delay is zero
          {
            Serial.println("Not Detected");
          }
          else if (Detected == 1)                // run if something has been
detected
          {
            Serial.println ("Position: ");
            Serial.print(Position);

            if (Position == 1)                   // run if limit switch is in
bottom position
            {

              digitalWrite(IN1, LOW);            // motor spins clockwise at
given speed
              digitalWrite(IN2, HIGH);
              analogWrite(EN1, Mspeed);
```

```
            delay(50);  //Subject to change 150
            analogWrite(EN1, 0);
            analogWrite(EN2, FSpeed);
            fanflg = 1;
          }

          tdelay = 0;                               // reset delay
          Detected = 0;                             // reset detection
          Serial.println(Position);
        }
      }
    }
    delay(200);
  }
  else if (Detected == 1)                           // run if something has been
detected
  {
    if (firsttime == 0)                             // run if this is the first time
through
    {
      tref = millis();                              // set reference time
      firsttime = 1;                                // set so it is no longer the
first time through
    }
    tnew = millis();                                // set new time
    tdelay = tdelay + tnew - tref;                  // count up the delay time
    tref = tnew;                                    // make the new time the next
reference time
    Serial.println(tdelay);
    if (tdelay > threshold)                         // run if the delay exceeds the
5 second threshold
    {
      firsttime = 0;                                // reset to first time
    }
    delay(100);
  }
}

if(fanflg == 1)
{
  if(Detected == 0)
  {
    if (firsttimef == 0)                             // run if this is the first
time through
    {
```

```
        treff = millis();                          // set reference time
        firsttimef = 1;                            // set so it is no longer the
first time through
      }
      tnewf = millis();                            // set new time
      tdelayf = tdelayf + tnewf - treff;              // count up the delay time
      treff = tnewf;                                // make the new time the next
reference time
      if (tdelayf > thresholdf)                     // run if the delay exceeds
the 5 second threshold
      {
        analogWrite(EN2, 0);
        firsttimef = 0;                            // reset to first time
        treff = 0;
        tnewf = 0;
        tdelayf = 0;
        fanflg = 0;
      }
    }
    else if (Detected == 1)
    {
      analogWrite(EN2, 0);
      firsttimef = 0;                              // reset to first time
      treff = 0;
      tnewf = 0;
      tdelayf = 0;
      fanflg = 0;
    }
  }

}
```

Appendix E: List of Vendors, Contact Information, and Pricing

Part No.	Part Name	Vendor	Contact Info / Website	Pricing per ct
Automatic disinfecting spray				
001	Housing	Target	https://www.target.com/p/sterilite-6-qt-clear-view-box-clear-with-latches-purple/-/A-13794493#lnk=sametab	$1.99
002	Spray bottle	US Plastic	https://www.usplastic.com/catalog/item.aspx?itemid=129116&catid=556	$1.16
003	Nozzle	US Plastic	https://www.usplastic.com/catalog/item.aspx?itemid=129253&catid=1376	$0.40
004	Motor	Pololu	https://www.pololu.com/product/4794	$15.95
005	Battery	Newegg	https://www.newegg.com/garberiel-jbl3124-rechargeable-battery-army-green/p/054-03G7-00005	$4.00
007	Fan	Amazon	https://www.amazon.com/Oak-Pine-3-3V-Raspberry-One-Two/dp/B07PRKCCSL	$1.70
008	Ultrasonic Sensor	Adafruit	https://www.adafruit.com/product/3942	$3.95
010	Spray bottle cap	US Plastic	https://www.usplastic.com/catalog/item.aspx?itemid=129709	$0.08
020	Arduino Nano	Amazon	https://www.amazon.com/gp/product/B07HRM2L3M/ref=ppx_yo_dt_b_asin_title_o02_s00?ie=UTF8&psc=1	$4.46
021	Motor Driver	Amazon	https://www.amazon.com/gp/product/B01M29YK5U/ref=ppx_yo_dt_b_asin_title_o04_s00?ie=UTF8&psc=1	$4.45
025	Limit Switch	Amazon	https://www.amazon.com/Cylewet-V-153-1C25-Straight-Arduino-CYT1068/dp/B071NSRHK3/ref=sr_1_5?dchild=1&keywords=Micro+Switch&qid=1623364235&sr=8-5	$1.17
026	Cap nut 8-32	McMaster-Carr	https://www.mcmaster.com/91855A440/	$0.53
027	Cap nut 4-40	McMaster-Carr	https://www.mcmaster.com/99022A101/	$0.68
028	System mounting bolt	McMaster-Carr	https://www.mcmaster.com/91864A027/	$1.32
029	System mounting pin	McMaster-Carr	https://www.mcmaster.com/98404A107/	$2.06
030	Screw 4-40 x .75	McMaster-Carr	https://www.mcmaster.com/96880A246/	$0.34

031	Screw 4-40 x .5	McMaster-Carr	https://www.mcmaster.com/96880A233/	$0.32
032	Cam set screw	McMaster-Carr	https://www.mcmaster.com/92158A135/	$0.47
033	3M adhesive	Home Depot	https://www.homedepot.com/p/3M-1-in-x-50-in-Indoor-Mounting-Tape-MMM114/304571478	$4.27
-	PETG Filament	Amazon	https://www.amazon.com/gp/product/B07T4X4D2C/ref=ppx_yo_dt_b_asin_title_o02_s00?ie=UTF8&psc=1	$21.99
035	Breadboards	Amazon	https://www.amazon.com/gp/product/B07DL13RZH/ref=ppx_yo_dt_b_asin_title_o00_s00?ie=UTF8&psc=1	$9.99
036	Jumper Wires	Amazon	https://www.amazon.com/gp/product/B08151TQHG/ref=ppx_yo_dt_b_asin_title_o09_s00?ie=UTF8&psc=1	$7.99
Face shield				
015	Z shield	Amazon	https://www.amazon.com/ZShield-Flex-Reusable-Lightweight-Coverage/dp/B08L46BPFY/ref=sr_1_2?dchild=1&keywords=z+shield&qid=1610662868&s=hi&sr=1-2	$18.95
016	Zoweetek Portable Voice Amplifier	Amazon	https://www.amazon.com/Rechargeable-Amplifier-Microphone-Waistband-Presentation/dp/B06XWV9CCQ	$35.99

Appendix F: Vendor Supplied Component Specifications and Data Sheets

Housing

Highlights

- Overall Assembled Size: 14 1/8" x 7 3/4" x 4 7/8"
- Provides solutions to a variety of household storage needs
- Clear lid and base for easy identification of contents
- Colorful latches secure lid to base, keeping contents safely stored inside
- Indexed lids allow for storage boxes to stack neatly on one another
- Proudly made in the USA

Specifications

Number of Pieces: 1

Dimensions (Overall): 14.12 Inches (L), 4.88 Inches (H) x 7.75 Inches (W)

Closure Type: Latches

Used For: Storage, Organizing

Features: Nesting, Handles, Portable, Lidded, Stackable

Capacity (Volume): 6 Quart

Assembly Details: No Assembly Required

Primary item stored: Universal Storage

Material: Plastic

Care & Cleaning: Spot or Wipe Clean

TCIN: 13794493

UPC: 073149751171

Item Number (DPCI): 002-02-0403

Origin: Made in the USA

If the item details above aren't accurate or complete, we want to know about it. Report incorrect product info.

Description

Keep yourself organized with the contemporary styling and seven useful sizes of the Sterilite ClearView Latch™ Box line. The 6 Quart ClearView Latch™ Box is ideal for storing shoes, toys, crafts and other small items around the home, and conveniently fits on 16" wire shelving, great for closet organization. The clear base and lid allow contents to be easily identified from any angle. Color accented latches secure the lid to the base, yet are still easy to unlatch. The indexed lids allow same size storage boxes to stack neatly on top of each other to use vertical storage space efficiently. The overall assembled dimensions of this item are 14 1/8" L x 7 3/4" W x 4 7/8" H.

Spray bottle

← Back to Group

32 oz. PET Round Spray Bottle with 28/400 Neck (Sprayer or Cap Sold Separately)

Find caps | Find sprayers

Item #: 71495

In Stock

$1.16/Each

- 1 +

Add to Cart

Overview

These round PET bottles are a unique option as a sprayer bottle.

- PET
- For use with sprayers with 9-1/4" dip tubes
- Dimensions: 3.125" Dia. x 9" Hgt.
- Meets FDA standards
- **Caps & sprayers sold separately**

Item Information

Item Number: 71495

Catalog Page Number: P-40

Manufacturer: Not Listed

Manufacturer Part #: BTL 32OZ PET

Country of Origin: USA

Tech Specs

Material: PET

Shape: Round

Color: Clear

Capacity: 32 oz.

Mouth: 28/400

Style: Spray

Weight: 0.098 lbs

Nozzle

← Back to Group

24/410 White Ribbed Finger Sprayer - 7-5/8" Dip Tube & 0.7mL Output

Item #: 68679

In Stock

$0.40/Each

- 1 +

Add to Cart

Overview

These finger sprayers are perfect for applications requiring a fine mist spray.

- Hood & dip tube included
- Look great with a variety of bottles
- Great for personal care products
- Finger pumps are ergonomical & easy to use
- Bottles sold separately

Item Information

Item Number: 68679

Catalog Page Number: P-44

Manufacturer: Not Listed

Manufacturer Part #: USP 68679

Tech Specs

Material: Polypropylene

Color: White

Mouth: 24/410

Style: Sprayer

Weight: 0.023 lbs

Spray Bottle Cap

← Back to Group

28/400 White Polypropylene Unlined Ribbed Cap

Item #: 62945

Out Of Stock (Extended)

$0.08/Each

This item is not currently available. Please check back later or fill out our Information Assistance form for an estimate of when it will be back.

Overview

The ribbed sides on these caps allow for easy removal. These caps are ideal for a wide variety of bottles and jars to be used in the food industry and health and beauty products.

- Polypropylene
- Unlined

Item Information

Item Number: 62945

Catalog Page Number: P-30

Manufacturer: Not Listed

Manufacturer Part #: USP 62945

Country of Origin: USA

Tech Specs

Material: Polypropylene

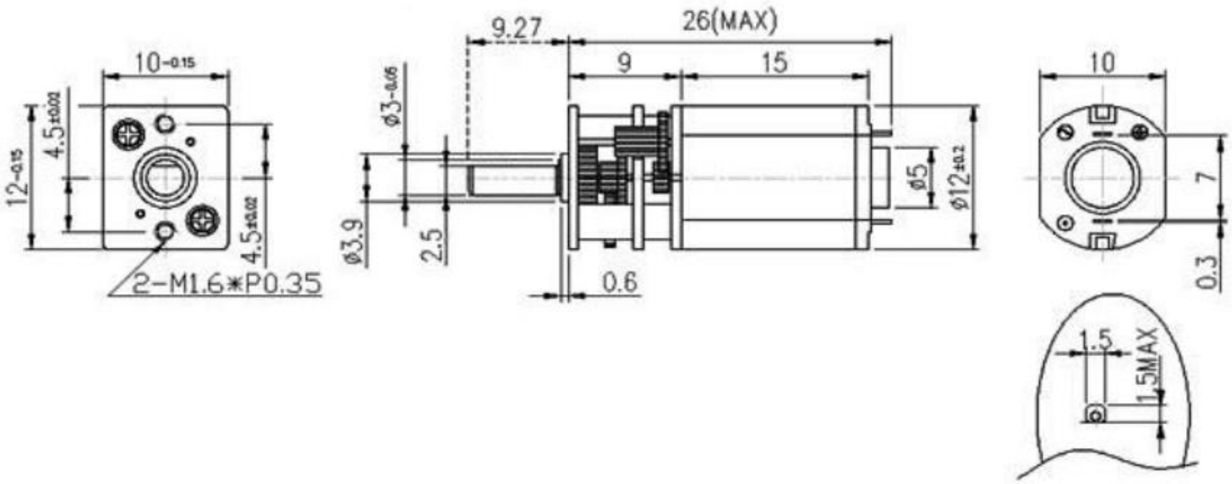
Color: White

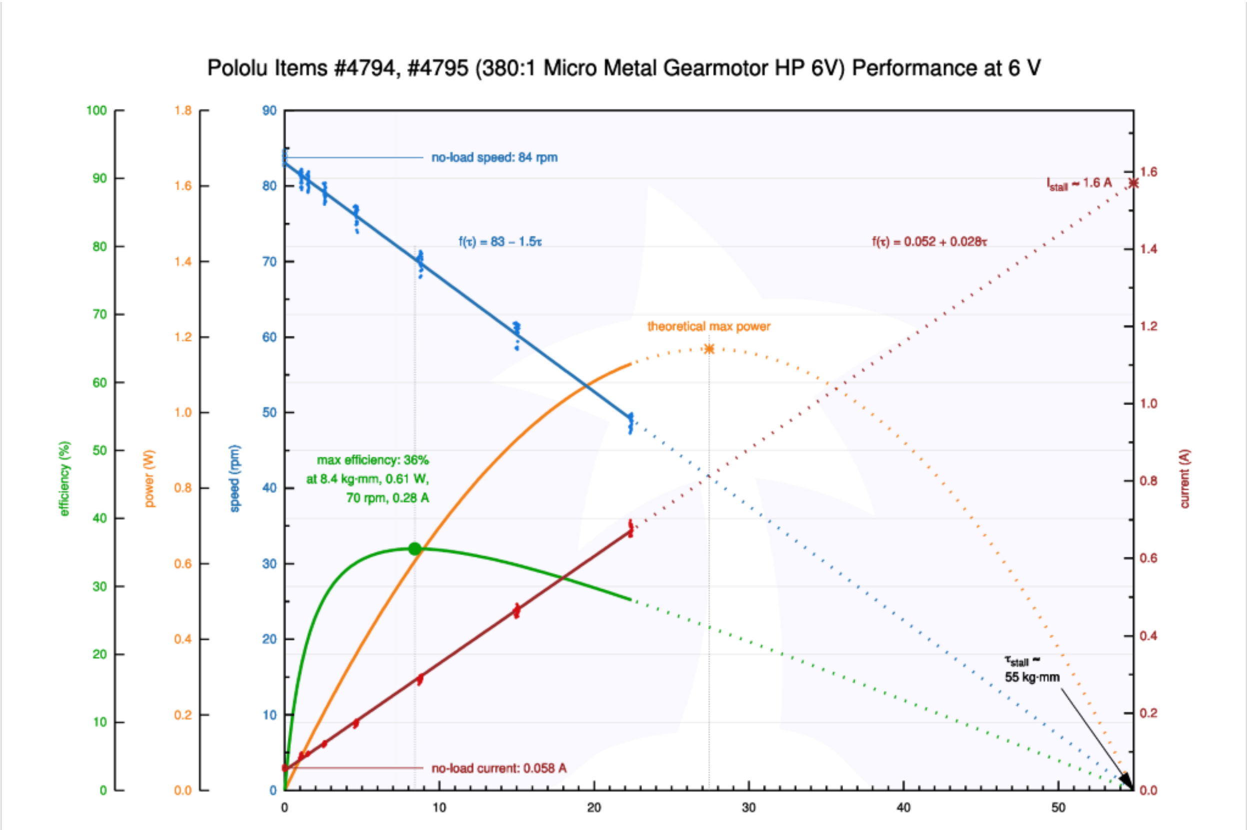
Style: Cap

Mouth: 28/400

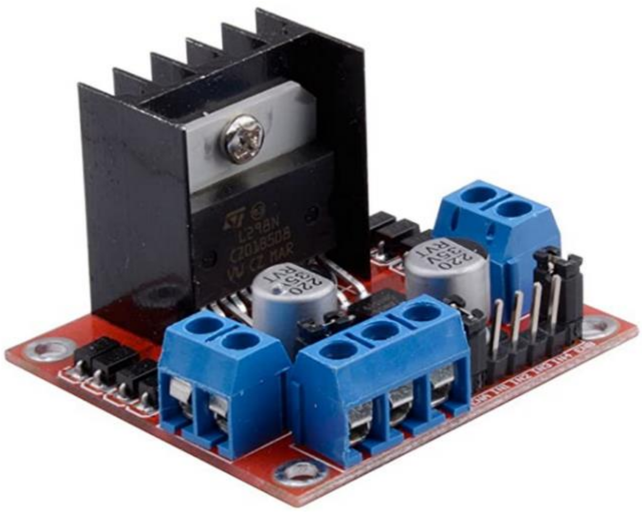
Weight: 0.005 lbs

380:1 Micro-Metal Gear Motor





Motor Driver



- **Specification:**
- Chip: L298N
- Logic voltage: 5V
- Logic current 0mA-36mA
- Storage Temperature: -20 °C to °C to +135
- Operating mode: H-bridge driver (dual)
- Drive voltage: 5V-35V
- Drive current: 2A (MAX single bridge)
- Maximum power: 25W
- Dimensions: 43x43x27mm

Note:

- This module has a built-in 5v power supply, when the driving voltage is 7v-35v, this supply is suitable for power supply
- DO NOT input voltage to +5v supply interface, however ledding out 5v for external use is available.
- When ENA enable IN1 IN2 control OUT1 OUT2
- When ENB enable IN3 IN4 control OUT3 OUT4

Qunqi 2Packs L298N Motor Drive Controller Board Module Dual H Bridge DC Stepper For Arduino

Brand: Qunqi

247 ratings

Amazon's Choice in Motor Speed Controllers by Qunqi

Price: $8.89 prime & FREE Returns

Extra Savings Buy 5, save 3%. 1 Applicable Promotion

- Dual-channel H-bridge driver working mode creates higher working efficiency,L298N as main chip.Can drive one 2-phase stepper motor, one 4-phase stepper motor or two DC motors.
- To avoid damage the voltage stabilizing chip, please use an external 5V logic supply when using more than 12V driving voltage
- Use large-capacity filter capacitors and diode with freewheeling protection function, increasing reliability
- High working power to 35v,large current can reach 3A MAX and continue current is 2A, power to 25w.
- Large capacity filter capacitance,afterflow protection diode, more stable and reliable.

Automatic Sanitizing Spray Battery

- Specification:
- 1.Voltage:3.7V
- 2.Net Weight:355g
- 3.Dimensions:6.5X1.8cm
- 4.Type of Battery:Lithium Battery
- 5.Whether to Charge:Rechargeable
- 6.Protection Board:X1
- 7.Color:Green

Fan

Product description

This Pi fan does not only support Pi 2/ Pi 3/ 3B+ and Pi Zero/ Zero W, but also compatible with other development boards.
Its connector is separating, One-to-Two interface, can choose 3.3V or 5V.
Rated voltage: DC 5V
Working voltage: 3.0- 5.8V
Current: 0.18A
Air volume: 5m^3 / h
Number of revolutions: 13200RPM
Noise: 18dB
Package Includes:
6 * PI Fans
24 * Screws M2.5 * 14mm
24 * Nails M2.5

Roll over image to zoom in

TeOhk 3.3V 5V Pi Fan Kit - CPU Cooling Fan with Screws One-to-Two Interface Heatsink Cooler Fan for Pi 2/ Pi 3/ 3B+ and Pi Zero/ Zero W, 30x30x7mm, Set of 6

Brand: Oak-Pine
24 ratings

Price: $9.99 ✓prime FREE One-Day & FREE Returns

5% back on all purchases with an eligible Prime membership for the first 3 months with the Amazon Prime Rewards Visa Card. No annual fee. Terms and cap apply.

- Working in Silence. This fan gives a smooth and quick working performance, which will provide you a perfect working space.
- Efficiency. Quickly dissipate heat for your Pi or other experimental tools to and extend the lifespan of your Pi or other development boards.
- Screws Included. Fast installation in seconds.
- One-to-Two interface, can choose voltage 3.3V or 5V according to your needs; Working voltage: 3.0-5.8V; Current: 0.18A. Air volume: 5 m^3/ h; Number of revolutions: 13200RPM.
- Compatible with: Pi fan, Pi zero w heatsink, Pi 2/ Pi 3/ 3B+ and Pi Zero/ Zero W, Retroflag NESPi case and Nespi Case, robot etc.

Ultrasonic Sensor

TECHNICAL DETAILS

- Power & Logic Voltage: DC 5V
- Current during measurment: 15mA
- Ultrasonic Frequency: 40 KHz
- Measuring Angle: 15°
- Trigger Input Signal: 10uS high pulse
- Sensor dimensions (excluding header): 45.5 x 20 x 15.5mm
- Weight: 8.7g

Limit Switch

Cylewet 6Pcs V-153-1C25 Micro Limit Switch Long Straight Hinge Lever Arm SPDT Snap Action LOT for Arduino (Pack of 6) CYT1068

Brand: Cylewet

351 ratings | 15 answered questions

Price: $6.99 prime & FREE Returns

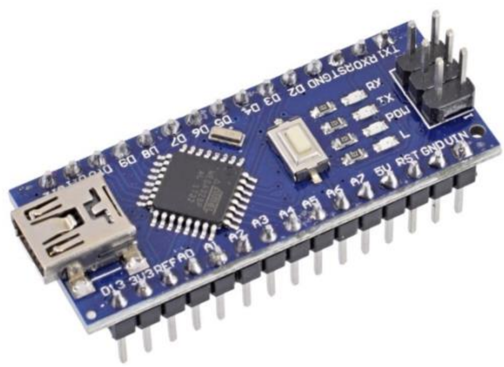
Brand	Cylewet
Switch Type	Limit Switch, SPDT
Terminal	SPDT
Material	Plastic, Metal
Circuit Type	1-way
Actuator Type	Hinge Lever
Current Rating	15 Amps

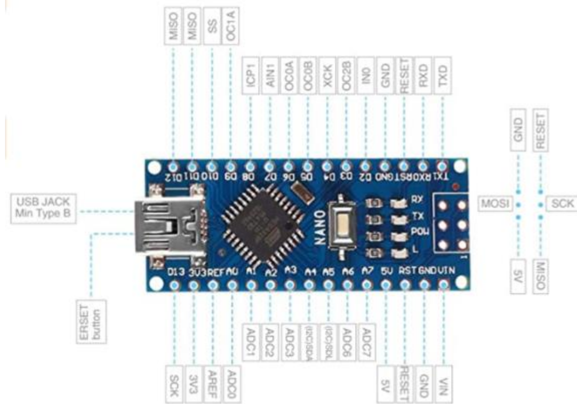
See more

About this item

- Material: plastic and metal
- Color: red, black and silver
- Actuator Action: momentary
- Actuator Type: long straight hinge lever
- Rating: 15A, 1/2Hp, 125/250Vac; 0.6A,125Vdc; 0.3A, 250Vdc; 0.6A,125Vdc; 0.3A, 250Vdc

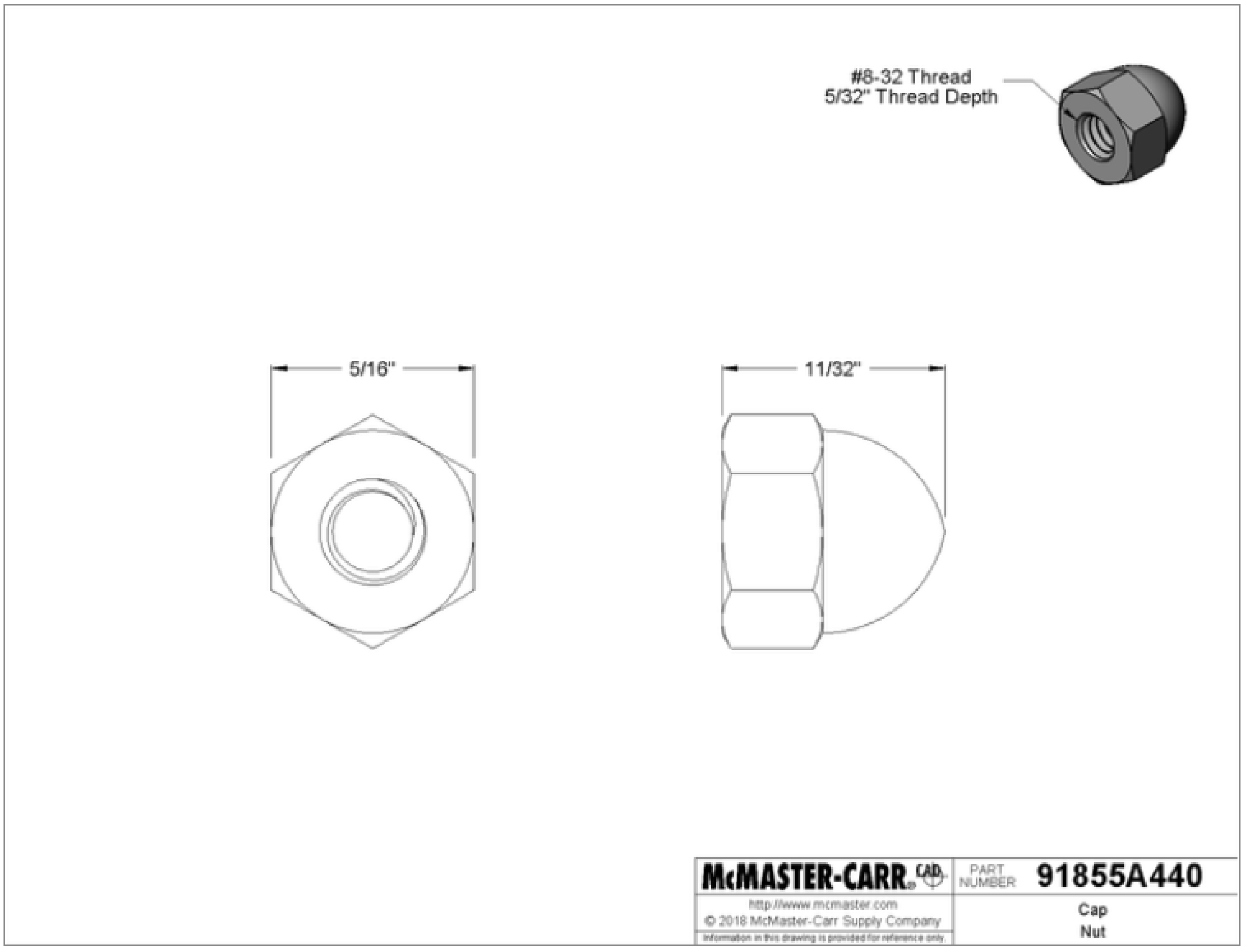
Arduino Nano





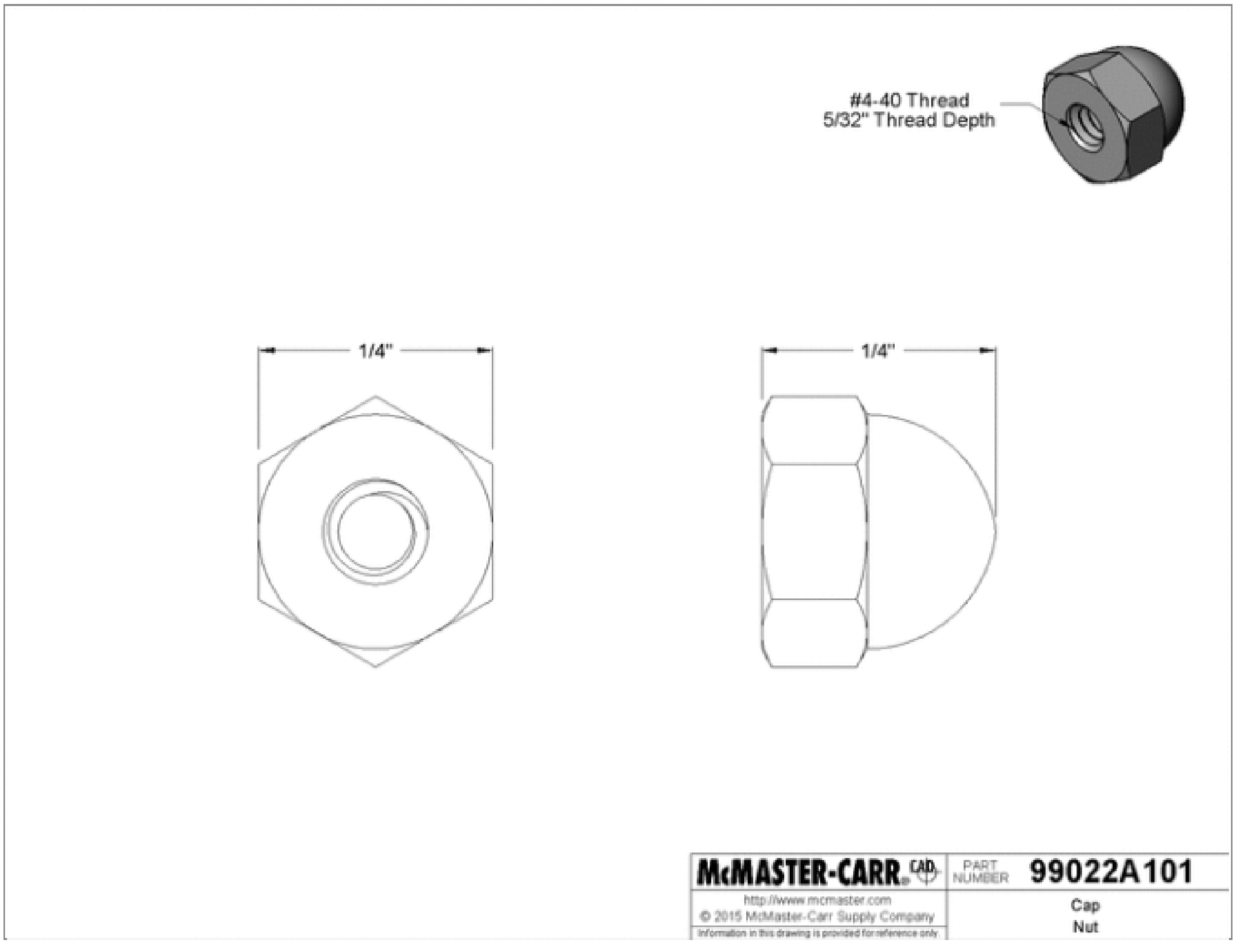
- The Nano is using the chips ATmega328P and CH340, Replace FT232RL.
- *It is a smallest, complete, and breadboard friendly board. It has everything that Diecimila/Duemilanove has (electrically) with more analog input pins and onboard +5V AREF jumper.
- Comes with 3 packs of Nano V3.0 Micro Controller Module, each Nano V3.0 Micro Controller module is equipped with 3pcs pin headers (2pcs 15pin headers +1pcs 6pin headers), no welding needed. You can download CH340 Driver from download link in the product description below. also it has 1 cable
- Uses the CH340G instead of the FTDI FT232RL IC which can improve the transfer speed, increase the stability in windows and solve the issues with FTDI drivers bricking non-original chips, ATMEGA328P offers even more programming and data memory space.

Cap nut 8-32



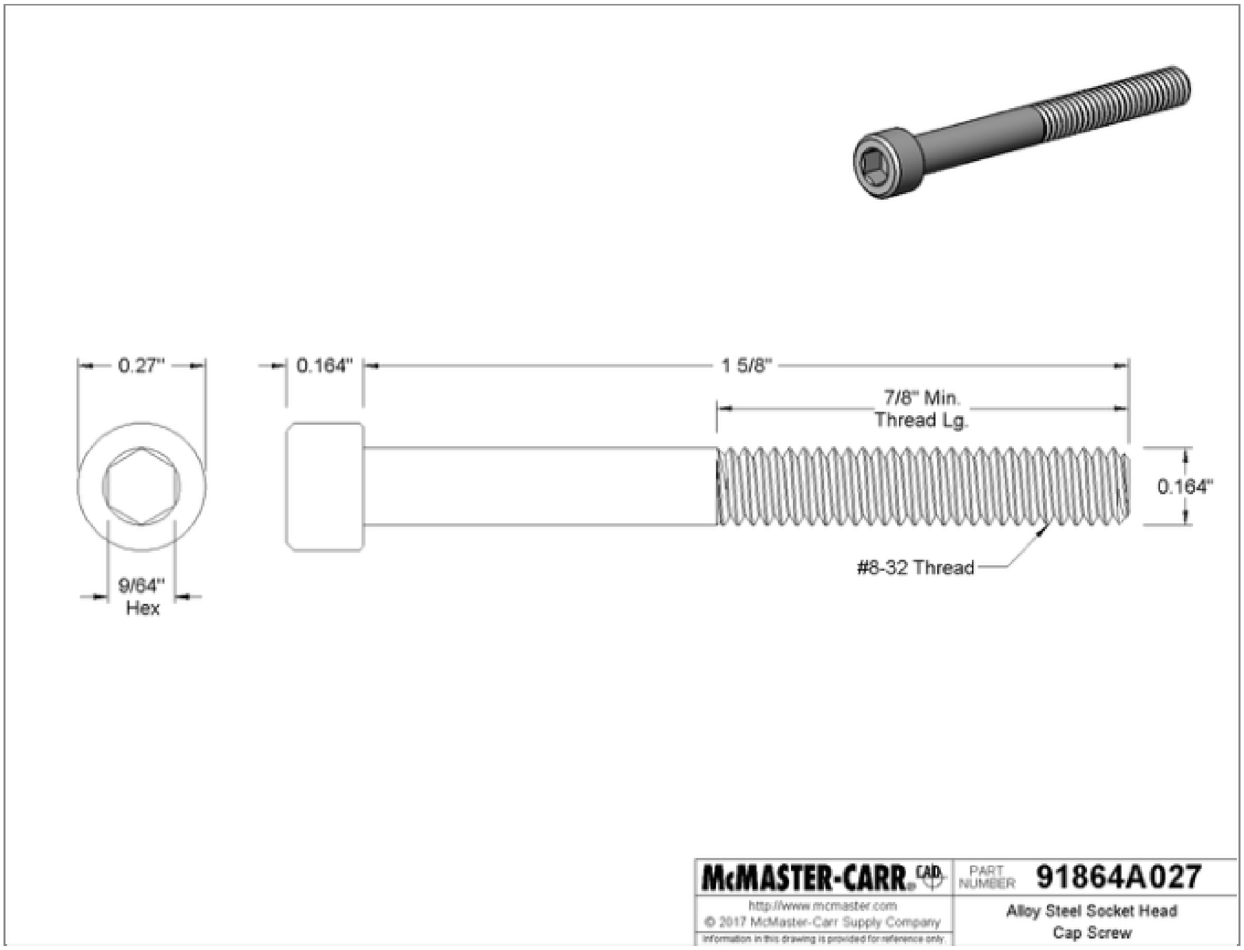
Material	18-8 Stainless Steel
Thread	
Size	8-32
Type	UNC
Spacing	Coarse
Fit	Class 2B
Depth	5/32"
Direction	Right Hand
Width	5/16"
Height	11/32"
Drive Style	External Hex
Nut Type	Cap, Hex
Cap Nut Profile	Standard
System of Measurement	Inch
RoHS	RoHS 3 (2015/863/EU) Compliant
REACH	REACH (EC 1907/2006) (01/19/2021, 211 SVHC) Compliant
DFARS	Specialty Metals Compliant (252.225-7009)
Country of Origin	United States
USMCA Qualifying	No
Schedule B	731816.0000
ECCN	EAR99

Cap nut 4-40



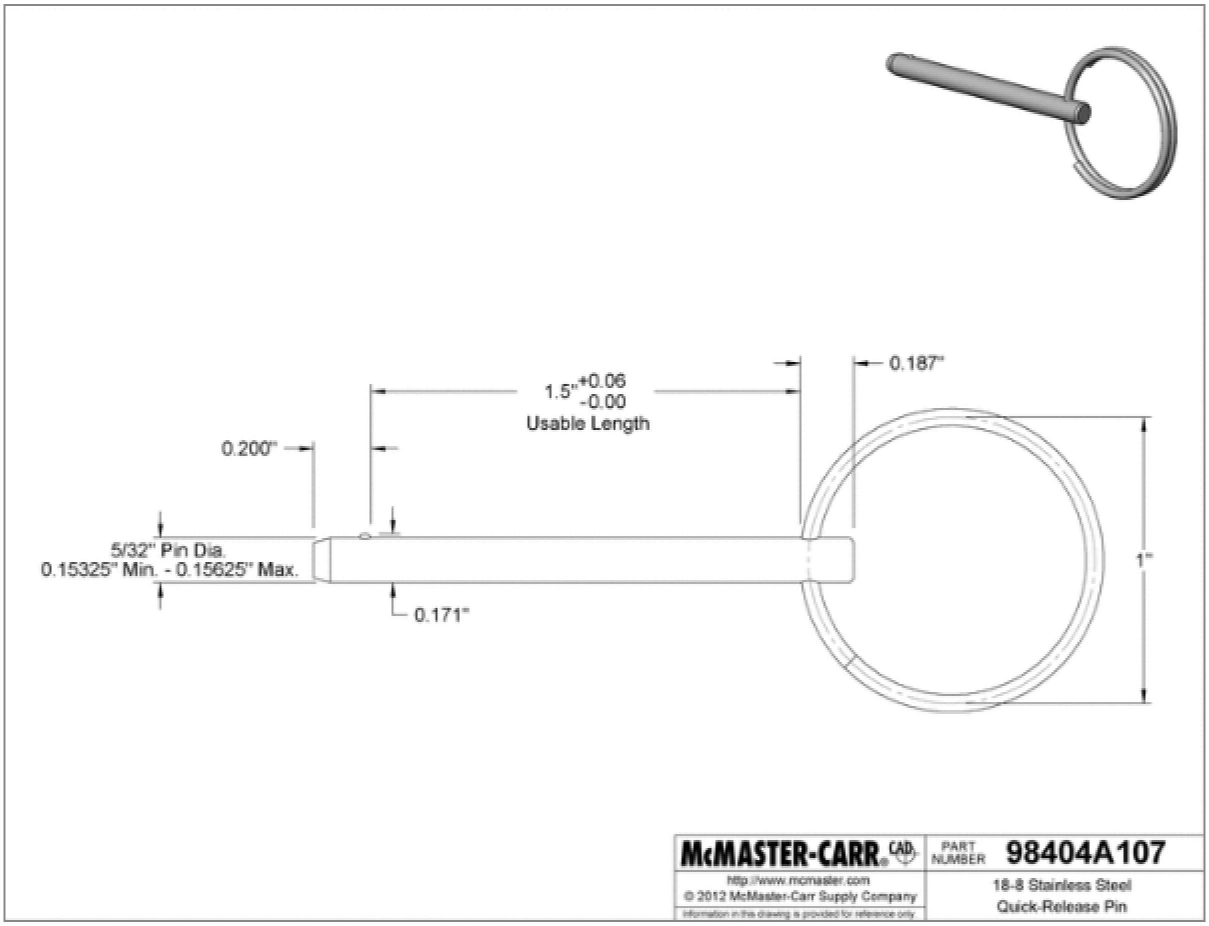
Material	18-8 Stainless Steel
Thread	
Size	4-40
Type	UNC
Spacing	Coarse
Fit	Class 2B
Depth	5/32"
Direction	Right Hand
Width	1/4"
Height	1/4"
Drive Style	External Hex
Nut Type	Cap, Hex
Cap Nut Profile	Standard
System of Measurement	Inch
RoHS	RoHS 3 (2015/863/EU) Compliant
REACH	REACH (EC 1907/2006) (01/19/2021, 211 SVHC) Compliant
DFARS	Specialty Metals Compliant (252.225-7009)
Country of Origin	United States
USMCA Qualifying	No
Schedule B	731816.0000
ECCN	EAR99

System mounting bolt



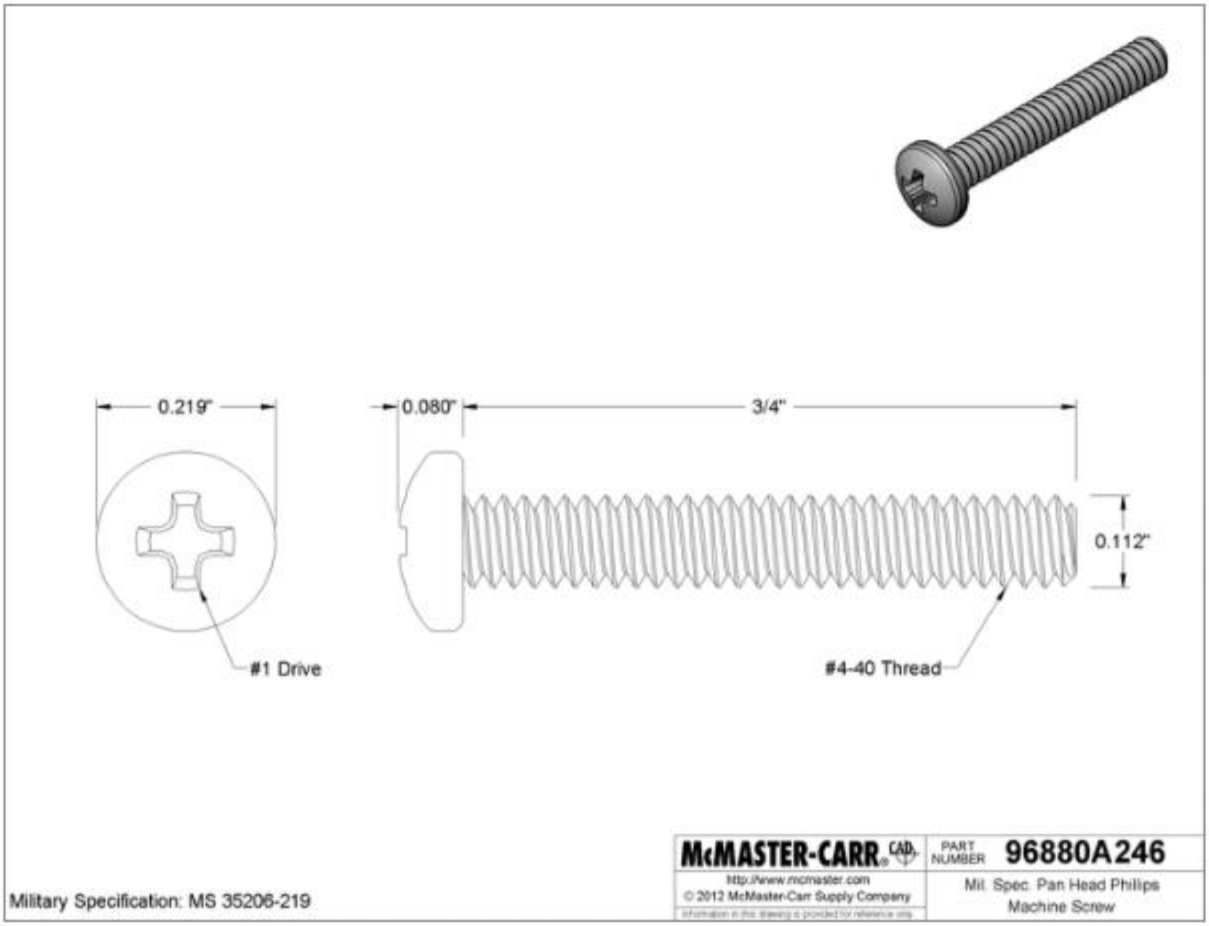
Head Type	Socket
Socket Head Profile	Standard
Drive Style	Hex
System of Measurement	Inch
Thread Direction	Right Hand
Thread Size	8-32
Screw Size Decimal Equivalent	0.164"
Thread Type	UNC
Thread Fit	Class 3A
Length	1 5/8"
Threading	Partially Threaded
Min. Thread Length	7/8"
Thread Spacing	Coarse
Head	
Diameter	0.27"
Height	0.164"
Drive Size	9/64"
Material	Black-Oxide Alloy Steel
Tensile Strength	170,000 psi
Hardness	Rockwell C37
Specifications Met	ASTM A574
RoHS	RoHS 3 (2015/863/EU) Compliant
REACH	REACH (EC 1907/2006) (01/19/2021, 211 SVHC) Compliant
DFARS	Specialty Metals Compliant (252.225-7009)
Country of Origin	United States
USMCA Qualifying	No
Schedule B	731815.9000
ECCN	EAR99

System mounting pin



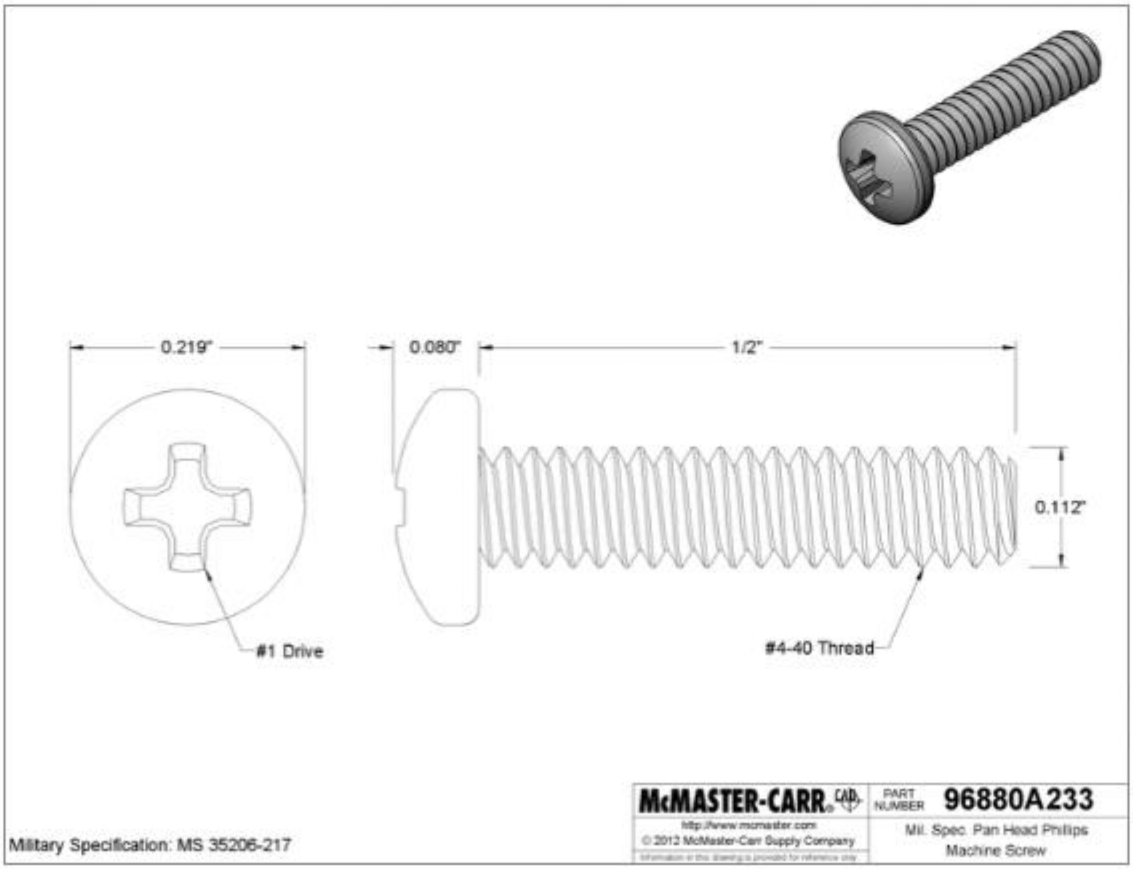
Pin Type	Quick Release
End Type	Spring-Loaded Ball
Head Type	Ring
Shaft Type	Plain
End Shape	Chamfered
System of Measurement	Inch
Material	18-8 Stainless Steel
Usable Length	1 1/2"
Diameter	5/32"
Diameter Tolerance	-0.003" to 0"
Diameter at Extended Ball Height	0.171"
Min. Hardness	Rockwell B85
Breaking Strength	Not Rated
Number of Retaining Balls	1
Ball Material	316 Stainless Steel
Spring Material	316 Stainless Steel
Handle Material	316 Stainless Steel
Lock Type	Nonlocking
Passivation	Not Passivated
RoHS	RoHS 3 (2015/863/EU) Compliant
REACH	REACH (EC 1907/2006) (01/19/2021, 211 SVHC) Compliant
DFARS	Specialty Metals Compliant (252.225-7008, 252.225-7009)
Country of Origin	United States
USMCA Qualifying	No
Schedule B	731829.0000
ECCN	EAR99

Screw 4-40 x .75



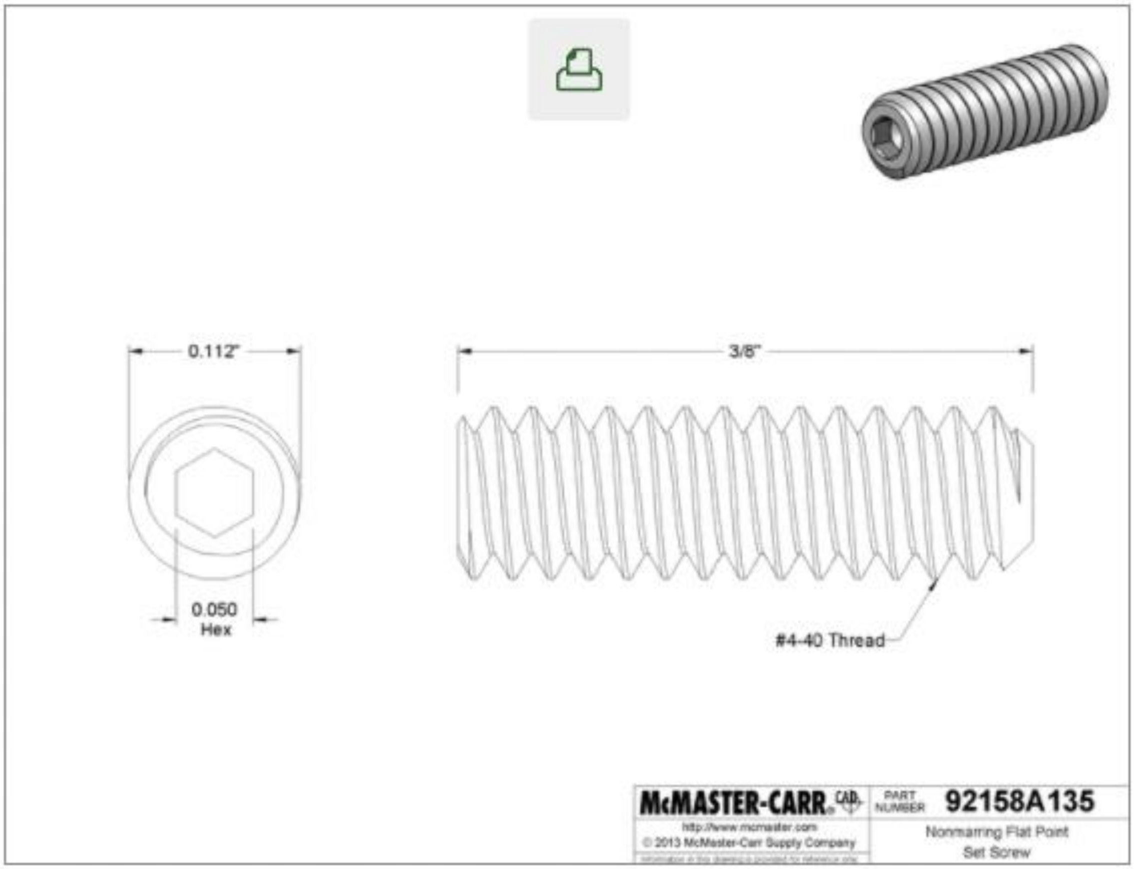
Thread Size	4-40
Length	3/4"
Threading	Fully Threaded
Head Diameter	0.219"
Head Height	0.080"
Drive Style	Phillips
Drive Size	No. 1
Material	Cadmium-Plated Steel
Hardness	Rockwell B69
Tensile Strength	60,000 psi
Screw Size Decimal Equivalent	0.112"
Thread Type	UNC
Thread Spacing	Coarse
Thread Fit	Class 2A
Thread Direction	Right Hand
Head Type	Rounded
Rounded Head Style	Pan
Rounded Head Profile	Standard
System of Measurement	Inch
Specifications Met	ASME B18.6.3, Fed. Spec. FF-S-92, Fed. Spec. QQ-P-416, MS35206-219, NASM35206
RoHS	RoHS 3 (2015/863/EU) Compliant
REACH	REACH (EC 1907/2006) (06/25/2020, 209 SVHC) Compliant
DFARS	Specialty Metals COTS-Exempt
Country of Origin	United States
USMCA Qualifying	No
Schedule B	731815.9000
ECCN	EAR99

Screw 4-40 x .5



Thread Size	4-40
Length	1/2"
Threading	Fully Threaded
Head Diameter	0.219"
Head Height	0.080"
Drive Style	Phillips
Drive Size	No. 1
Material	Cadmium-Plated Steel
Hardness	Rockwell B69
Tensile Strength	60,000 psi
Screw Size Decimal Equivalent	0.112"
Thread Type	UNC
Thread Spacing	Coarse
Thread Fit	Class 2A
Thread Direction	Right Hand
Head Type	Rounded
Rounded Head Style	Pan
Rounded Head Profile	Standard
System of Measurement	Inch
Specifications Met	ASME B18.6.3, Fed. Spec. FF-S-92, Fed. Spec. QQ-P-416, MS35206-217, NASM35206
RoHS	RoHS 3 (2015/863/EU) Compliant
REACH	REACH (EC 1907/2006) (06/25/2020, 209 SVHC) Compliant
DFARS	Specialty Metals COTS-Exempt
Country of Origin	United States
USMCA Qualifying	No
Schedule B	731815.9000
ECCN	EAR99

Cam set screw



Material	316 Stainless Steel
Thread Size	4-40
Length	3/8"
Drive Size	0.050"
Screw Size Decimal Equivalent	0.112"
Hardness	Rockwell B80
Specifications Met	ASME B18.3
Thread Type	UNC
Thread Spacing	Coarse
Thread Fit	Class 3A
Thread Direction	Right Hand
Drive Style	Hex
Tip Type	Flat
Head Type	Headless
System of Measurement	Inch
RoHS	RoHS 3 (2015/863/EU) Compliant
REACH	REACH (EC 1907/2006) (01/19/2021, 211 SVHC) Compliant
DFARS	Not Specialty Metals Compliant
Country of Origin	Taiwan
Schedule B	731815.9000
ECCN	EAR99

3M adhesive

Specifications

Dimensions

Core Diameter (in.)	1	Tape Length (ft.)	4.17
Tape Width (in.)	1	Thickness (mm)	0

Details

Color Family	Whites	Color/Finish	White
Dispenser Included	No	Maximum Weight Capacity (lb.)	2
Office Supply Type	Double-Sided Tape	Quantity	1
Storage Product Type	Office Supplies		

Scotch Indoor Mounting Tape is a double-coated foam tape that adheres and conforms to a variety of surfaces. This tape is designed for attaching items up to 5 lbs. Lose the screws, nails, and tools with Scotch Indoor Mounting Tape. It is perfect for discretely mounting items on glass, tile, or mirrors. This mounting tape is designed for attaching indoor items up to 5 lbs. Scotch Indoor Mounting Tape is available in various sizes and is not recommended for brick or concrete.

- Ideal for: indoor surfaces that are clean, dry and smooth
- Very high adhesion level
- Holds up to 5 lbs.
- Color: white
- Use instead of nails or screws
- Available in various sizes
- Number of rolls included: 1
- Great for DIY
- Note: product may vary by store

PETG Filament

Roll over image to zoom in

Amazon Basics PETG 3D Printer Filament, 1.75mm, Black, 1 kg Spool

Visit the Amazon Basics Store

3,502 ratings | 10 answered questions

Amazon's Choice in 3D Printing Filament by Amazon Basics

Price: $21.99 ✓prime & FREE Returns

Save up to 5% with business pricing. Sign up for free Amazon Business account

Color: **Black**

Brand	Amazon Basics
Material	PETG
Color	Black
Item Weight	1 Kilograms

About this item

- 3D printer filament (1.75mm diameter, black; 1 kg spool); designed to fit most common 3D printers (check spool size for compatibility)
- Made of PETG plastic, known for its ease of use (like PLA) and durable strength (like ABS); no heating bed needed; offers easy bed adhesion, stiffness, and a glossy-type finish
- Engineered to reduce jamming
- Backed by an Amazon Basics 1-year limited warranty

Breadboards

4PCS Breadboards Kit Include 2PCS 830 Point 2PCS 400 Point Solderless Breadboards for Proto Shield Distribution Connecting Blocks

Visit the REXQualis Store

1,906 ratings | 8 answered questions

Amazon's Choice for "bread board"

Was: ~~$10.99~~ Details

Price: $9.99 ✓prime & FREE Returns

You Save: $1.00 (9%)

Save up to 16% with business pricing. Sign up for free Amazon Business account

- 400 point and 830 point breadboards are available to meet your various experimental needs.
- White ABS Plastic Body with Black Printed Legend. Color Legend on Distribution Strips.
- With Self-Adhesive Tape on the Back, Easy to Stick on the Arduino Prototype Shield.
- Inter Connect Any Components with 20-29 Awg (0.3-0.8mm) Wire.
- Good for Arduino Breadboard Jumper Wires kit Project and other Electrical DIY kits.

Jumper Wires

Roll over image to zoom in

IZOKEE 240pcs 10CM and 20CM Jumper Wire Solderless Breadboard Jumper Wires Male to Female, Male to Male, Female to Female for Arduino Project (3x10cm, 3x20cm)

Brand: IZOKEE

194 ratings

Was: ~~$8.99~~ Details

Price: $7.99 prime & FREE Returns

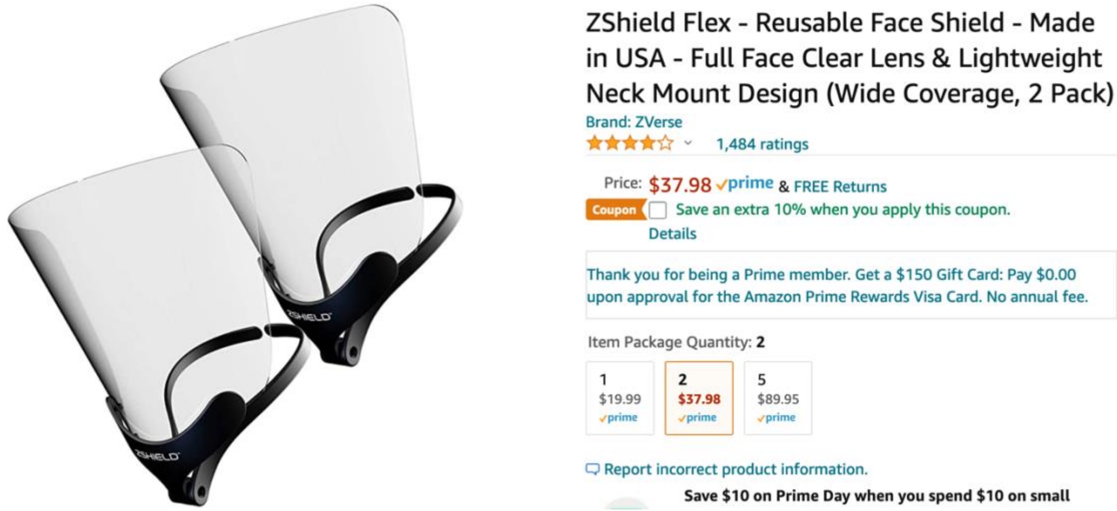
You Save: $1.00 (11%)

Thank you for being a Prime member. Get a $150 Gift Card: Pay $0.00 upon approval for the Amazon Prime Rewards Visa Card. No annual fee.

May be available at a lower price from other sellers, potentially without free Prime shipping.

- 【2 LENGTHS】: This kit includes two sizes jumper wires: 10cm and 20cm, which are the most commonly used lengths.
- 【3 TYPES】: There are three types of jumpers for each length: male to female, male to male, and female to female. Perfectly meet all your project needs.
- 【SUFFICIENT QUANTITY】: 6 sets of jumper wires, each set of jumper wires consisting of 40 separate wires, a total of 240 wires. Each wire can be used separately.
- 【COMPATIBILITY】: The pitch of jumper is 2.54mm, which is compatible with most breadboards on the market.
- 【WIDE APPLICATION】: Widely used in electronic projects for interconnections, such as Raspberry Pi, Breadboard, Arduino, etc.. Fast circuit testing without soldering. It can also be used to extend experiments and improve experimental performance projects.

Z-Shield


ZShield Flex - Reusable Face Shield - Made in USA - Full Face Clear Lens & Lightweight Neck Mount Design (Wide Coverage, 2 Pack)
Brand: ZVerse
1,484 ratings
Price: $37.98 prime & FREE Returns
Coupon
Save an extra 10% when you apply this coupon.
Details
Thank you for being a Prime member. Get a $150 Gift Card: Pay $0.00 upon approval for the Amazon Prime Rewards Visa Card. No annual fee.
Item Package Quantity: 2
1 $19.99 prime
2 $37.98 prime
5 $89.95 prime
Report incorrect product information.
Save $10 on Prime Day when you spend $10 on small

Zoweetek Portable Voice Amplifier

SHIDU S258 Portable PA System with Headset. S258 is a highly integrated system with many features. It is a public address system that amplifies your voice with HD sound quality. You can use a wired microphone to talk into it. It is a Music Player. You can play music from a TF card or USB flash disk.
Please read the instructions carefully before using it.

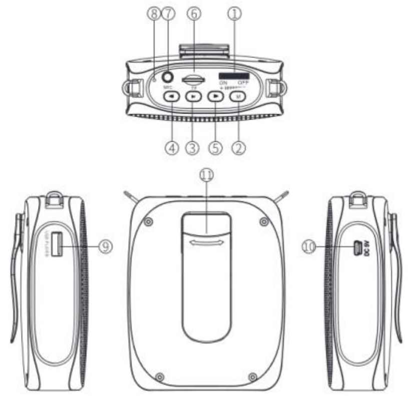
Features:

1. SHIDU patented appearance;
2. Stylish, ergonomic and comfortable design;
3. Power double magnetic trumpet --- more clear and penetrating;
4. 10W power output, sound coverage up to 800m^2;
5. Adopt SHIDU Acoustic amplification electroacoustic system;
6. Equipped with SHIDU special acoustic microphone --- Hi Fi original sound amplification;
7. Super MP3 audio encoding technology --- support TF card & U flash disk.

Specification:

Output power:	10W	Frequency response:	90Hz-18KHz
Output Impedance:	4Ω	Work temperature:	-10°C - 45°C
Charging voltage:	DC 5V 500mA+	Amplify time:(50%volume)	8-12 hours
Music-play time:	6-10 hours	Charging time:	3-5 hours

Function Illustration:



1. **Power switch & volume control:** Rotate the knob to "ON" to turn on the amplifier and the blue indicator light will on. Rotate to "+" continuously to increase the volume, rotate to "-" continuously to decrease the volume till turn off.
2. **Mode:Short Press:** You can short press this mode button to select a working mode (USB or TF). When TF card and USB flash drive are both inserted, use the "M" Key to select which storage you want to play.
3. **Play/Pause:** Short press it to pause, and press again to play the music under default mode. Long press " ⏯ " till the blue light blinks quickly to enter single music repeat mode. Long press the " ⏯ " till the blue light blinks normally to repeat all the music in storage.
4. **Previous:** Short press it to go to previous music; long press it to fast backward.
5. **Next:** Short press it to go to next music; long press it to fast forward.
6. **TF card:** Insert the TF card to play mp3. It is compatible with most brands, the max capacity is 32GB.
   Note: It may be unreadable when the file is large or complex.
7. **Ø3.5mm Microphone Jack:** Insert the wired microphone in any mode to amplify with current mode simultaneously. To avoid howling please do not point the microphone toward the speaker.
8. **Indicator:**
   Blue light: Will on all the time in the state of power-on;
   Red light: Will blinks when charging; and it will on all the time after fully charged.
   Notes: We suggest that you fully charge the amplifier before using it the first time.
9. **USB:** Insert the USB to play mp3. It is compatible with most brands, the max capacity is 32GB.
10. **Mini-USB Port (DC 5V):** Use the charger with DC 5V output connect with Mini-USB cable to charge the PA system.
   Note: Please connect the packed USB charging cable with the USB port of DC 5V (500mA ~ 1.5A) charger.
   Unplug the charger as soon as it is fully charged.
11. **Detachable clip**

Appendix G: Detailed supporting analysis

Motor Calculations

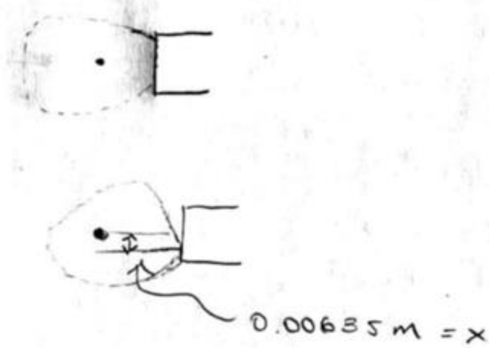
Motor Torque Calculations

FORCE REQUIRED FOR CAM

→ FROM TEST ON A GLASS CLEANER SPRAY

$F = 24.5\ N$

FOR A 0.25 IN (0.00635m) LEVER



$T = Fx$

$T = (24.5\ N)(0.00635\ m)$

$T = 0.156\ Nm$

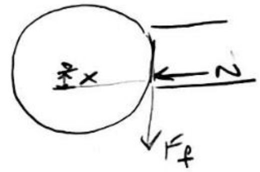
$T = 156\ mNm$

TORQUE REQUIRED

$T = 156\ mN \cdot m$
$T = 22.1\ Oz \cdot IN$
$T = 1.59\ kg \cdot cm$

MOTOR TORQUE IS COMMONLY RATED IN THESE THREE UNITS

FRICTION TORQUE ON CAM



$T = F_f x$

$F_f = \mu N$

FOR EXAMPLE, IF $\mu = 0.3$, $x = 0.022m$
$N = 25N$

$F_f = (0.3)(25N)$

$F_f = 7.5N$

$T = (7.5N)(0.022m)$

$T = 165\ mNm$

MORE EXTENSIVE ANALYSIS
CONDUCTED IN EXCEL

Excel Motor Torque, Speed, and Current Calculations

Friction Coefficients		
Type	Low	High
Plastic-Plastic	0.2	0.4
Plastic-Metal	0.1	0.3

Type	Normal Force [N]	Friction Force		Lever [m]	Torque [mN-m]	
		Low	High		Low	High
Plastic-Plastic	25	5	10	0.022	110	220
Plastic-Metal	25	2.5	7.5	0.022	55	165

Depress Torque [mN-m]	Total Torque [mN-m]		Total Torque [kg-mm]		
	Low	High	Low	High	Average
114	224	334	22.84	34.06	28.45
	169	279	17.23	28.45	22.84

Speed [RPM]		Current [A]		
Low Torque	High Torque	Low Torque	High Torque	Average
48.74	31.91	0.69	1.01	0.85
57.15	40.32	0.53	0.85	0.69

Automatic Disinfecting Spray Battery Lifespan

Component	Current [mA]	Time/Day [h]	Power [mAh]
Arduino	17	24	408
Motor	690	0.2	138
Sensor	15	24	360
Fan	180	0.4	72

Total Battery Draw For a 24-Hour Period [mAh]	Battery Capacity [mAh]	Battery Life [Hours]
978	3000	73.6

Assumptions:

- Workday for teachers and other staff extends beyond the hours students are in class
    - 12 hours of "active use", when the system may be actuated by a person interacting with a high touch surface
    - 12 hours of "passive use", hours when the school is empty, and system will not be actuated
- Timer and sensor will be in operation during active and passive hours
- Motor and fan will only operate during active hours
- Motor will run for 5 seconds every 5 minutes
- Fan will run for 10 seconds every 5 minutes

Timer Calculations

TIMER COMPONENTS

→ REQUIREMENT : 5 SECOND PULSE

$$t_{OUTPUT} = -\ln\left(\tfrac{1}{3}\right) R_A C$$

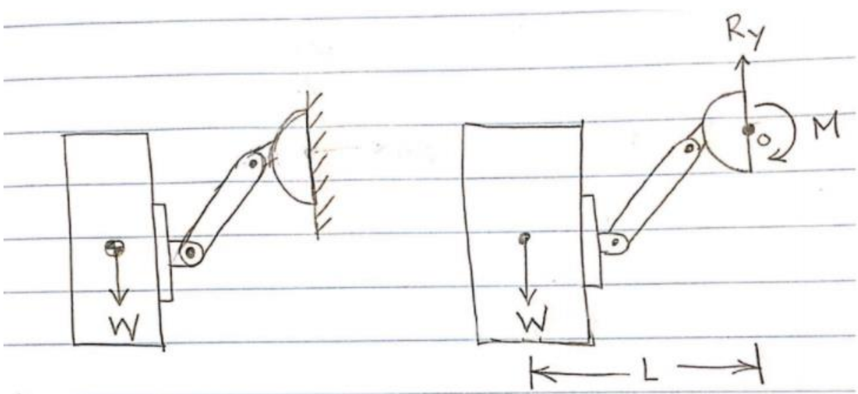
FOR : $R_A = 10 K\Omega$
$C = 470\ \mu F$

$$t_{OUTPUT} = \left[-\ln\left(\tfrac{1}{3}\right)\right](10 K\Omega)(470\ \mu F)$$

$$\boxed{t_{OUTPUT} = 5.16 \text{ SECONDS} \approx 5 \text{ SECONDS}}$$

System Mounting Calculations

Full system



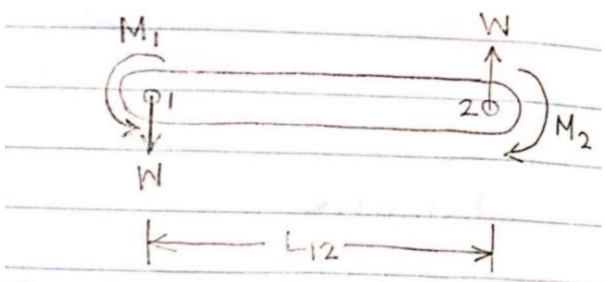
$$+\uparrow \Sigma F_y = 0$$
$$R_y - W = 0$$
$$R_y = W$$
$$\approx 3.2 \text{ lb}$$

$$\circlearrowleft + \Sigma M_o = 0$$
$$WL - M = 0$$
$$M = WL$$

Adjustable arm

Fully extended

FBD (Fully extended)

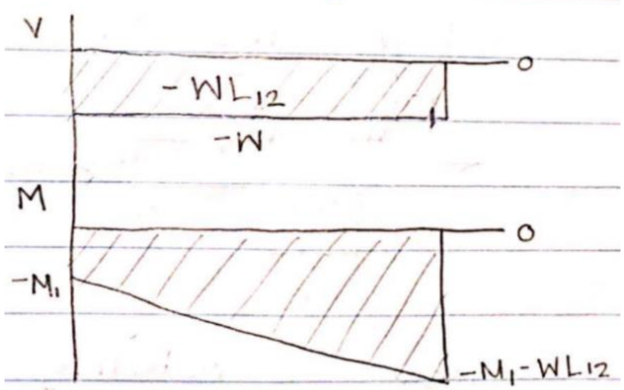


$$\circlearrowleft + \Sigma M_1 = M_1 + WL_{12} - M_2 = 0$$

$$M_2 = M_1 + WL_{12}$$

Shear-moment diagrams

shear-moment



Shear stress

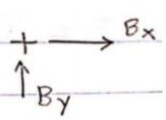
$$\tau_{max} = \frac{3V}{2A} \text{ rectangle}$$

Bending stress

$$\sigma_{xx} = E\varepsilon_{xx} = \frac{-My}{I}$$

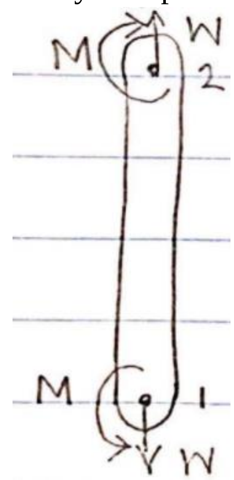
Bearing stress

$$\sigma_{BR} = \frac{\text{Bolt load}}{t_B d}$$



$$\text{Bolt load} = \sqrt{B_y^2 + B_x^2}$$

Fully collapsed



Axial stress

$$\sigma_{xx} = E(\varepsilon_{xx} - \alpha\Delta T) = \frac{P}{A}$$

Buckling

$$k = \sqrt{I/A}$$

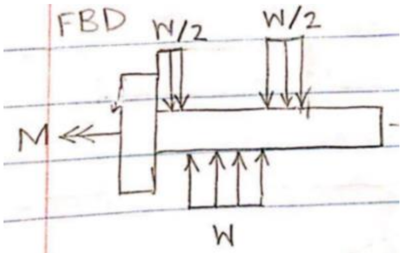
$$\left(\frac{L}{k}\right)_1 = \sqrt{\frac{2\pi^2 c I}{S_y}}$$

$$P_{cr} = \frac{\pi^2 E I c}{L^2}$$

Johnson	Euler
$\frac{L}{k} < \left(\frac{L}{k}\right)_1$	$\frac{L}{k} > \left(\frac{L}{k}\right)_1$

c = 1 (pin-pin)

Bolt / pin



Shear stress

$$\tau = \frac{F}{A}$$

Tensile stress

$$\sigma_b = \frac{F_i}{A_t}$$ A_t from Tables 8-1 & 8-2 p.404-405

$n = S_p/\sigma_b$, S_p = proof strength p.425

Torque & normal force

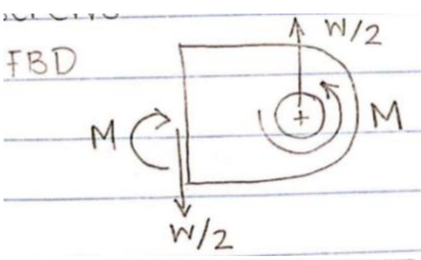
Recommended F_i

$F_i = 0.75 F_p$, $F_p = A_t S_p$

$T = K F_i d$ From Shigs p.430

$$F_i = \frac{T}{Kd}$$, $K \approx 0.20$

Mounting tab



Shear $\tau = \frac{F}{A}$

Bending $\sigma = \frac{My}{I}$

<u>Excel calculations</u>

Arm

PETG	http://www	Pin method to prevent rotation	
PARAMETERS			
Name	Value	Units	Description
L12	6	in	Arm length
a	0.625	in	Arm width
t	0.95	in	Arm thickness
Material	PETG		
Sy	4100	psi	Yield stress, 4100-8500
Su	3480	psi	Ultimate stress, 3480-10000
E	160000	psi	Elastic modulus, 160-2940 ksi
W	3.2	lb	System weight
Lcg_1	2.5	in	Length from housing cg to pin 1
Fully extended			
FBD			
M1	8	lb-in	Moment at pin 1
M2	27.2	lb-in	Moment at pin 2
d	0.5	in	Distance between pins
F	54.4	lb	Force on each pin
SHEAR-MOMENT DIAGRAMS			
V	3.2	lb	Maximum shear
M	27.2	lb-in	Maximum moment
SHEAR			
A	0.59375	in2	Cross-sectional area
τ	8.084211	psi	Shear stress
FS	253.5807	-	Safety factor, max shear theory
BENDING			
y	0.3125	in	Distance to principle axis
I	0.019328	in4	Moment of inertia
σ	439.7811	psi	Normal stress
FS	9.322821	-	Safety factor
BEARING			
BL	3.2	lb	Bolt load
t_b	0.95	in	Thickness of material
d	0.25	in	Bolt diameter
σ_br	13.47368	psi	Bearing stress
FS	304.2969	-	Safety factor

Fully collapsed

FBD

M	8	lb-in	Moment throughout arm

AXIAL

P	3.2	lb	Axial load
A	0.59375	in2	Cross-sectional area
σ	5.389474	psi	Axial stress
FS	760.7422	-	Safety factor

BUCKLING

I	0.019328	in4	Moment of inertia
k	0.180422	in	Radius of gyration
c	1	-	pin-pin
L/k_1	0.009646	-	Euler-Johnson crossover pt
L/k	33.25538	-	Actual k
Pcr	847.8122	lb	Critical axial load, Euler
FS	264.9413	-	Safety factor

Pin

PETG http://www.matweb.com/search/datasheet_print.a:

PARAMETERS

Name	Value	Units	Description
Pin			
d_pin	0.15625	in	Pin diameter
d_p_b	0.5	in	Distance between pin & bolt

Material	SS	http://www.matweb.com/search/Data	
Sy	34800	psi	Yield stress
Su	79800	psi	Ultimate stress
E	28000000	ksi	Elastic modulus, 28000 ksi

PIN

Load on pin

F	57.6	in	Load on pin & bolt

Shear

A	0.019175	in2	Pin cross-sectional area
τ	3003.949	psi	Shear stress
FS	5.792375	-	Safety factor

Mounting tab

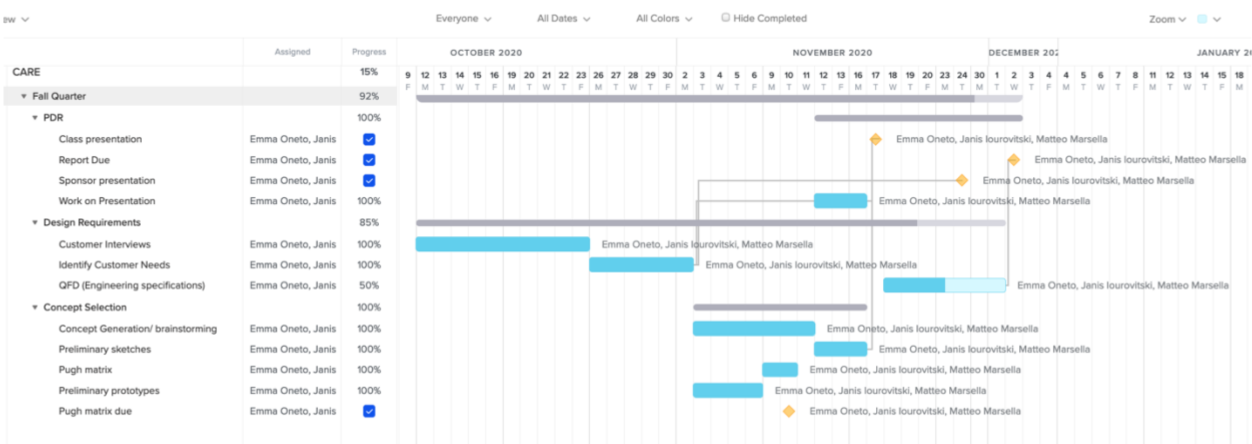
Mounting Tab			
a	0.625	in	Diameter
t	0.15	in	Thickness

Material	PETG	http://www.matweb.com/search/datashe	
Sy	4100	psi	Yield stress, 4100-8500
Su	3480	psi	Ultimate stress, 3480-10000
E	160000	psi	Elastic modulus, 160-2940 ksi

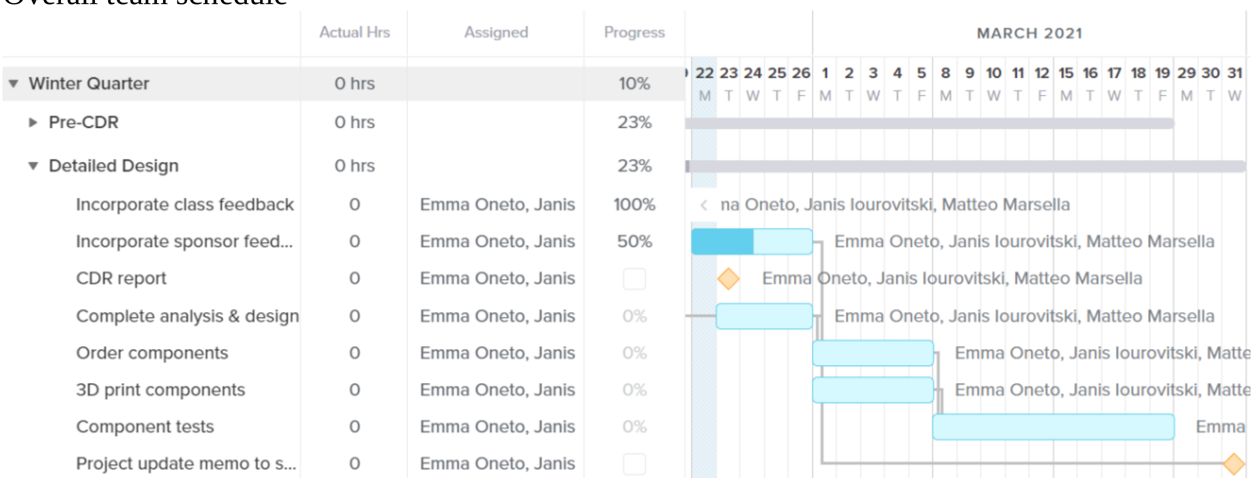
MOUNTING TAB			
F	28.8	lb	Load on each tab
Bearing			
BL	28.8	lb	Bolt load
t_b	0.15	in	Thickness of material contacting bolt
d	0.15625	in	Bolt diameter
σ_br	1228.8	psi	Bearing stress
FS	3.336589	-	Safety factor

Appendix G: Gantt chart

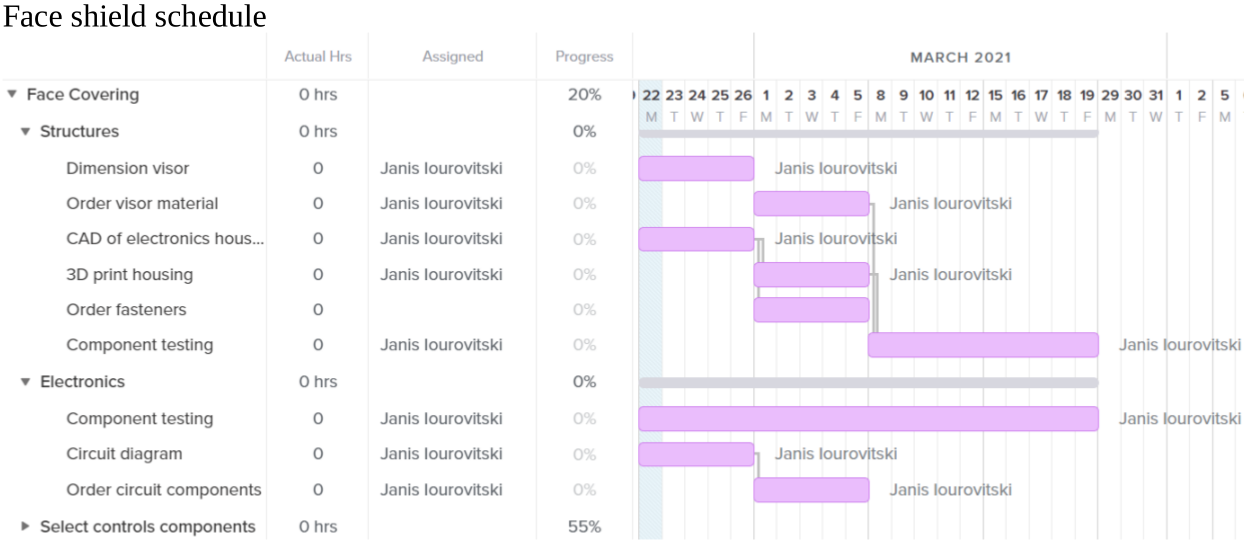
Fall Quarter



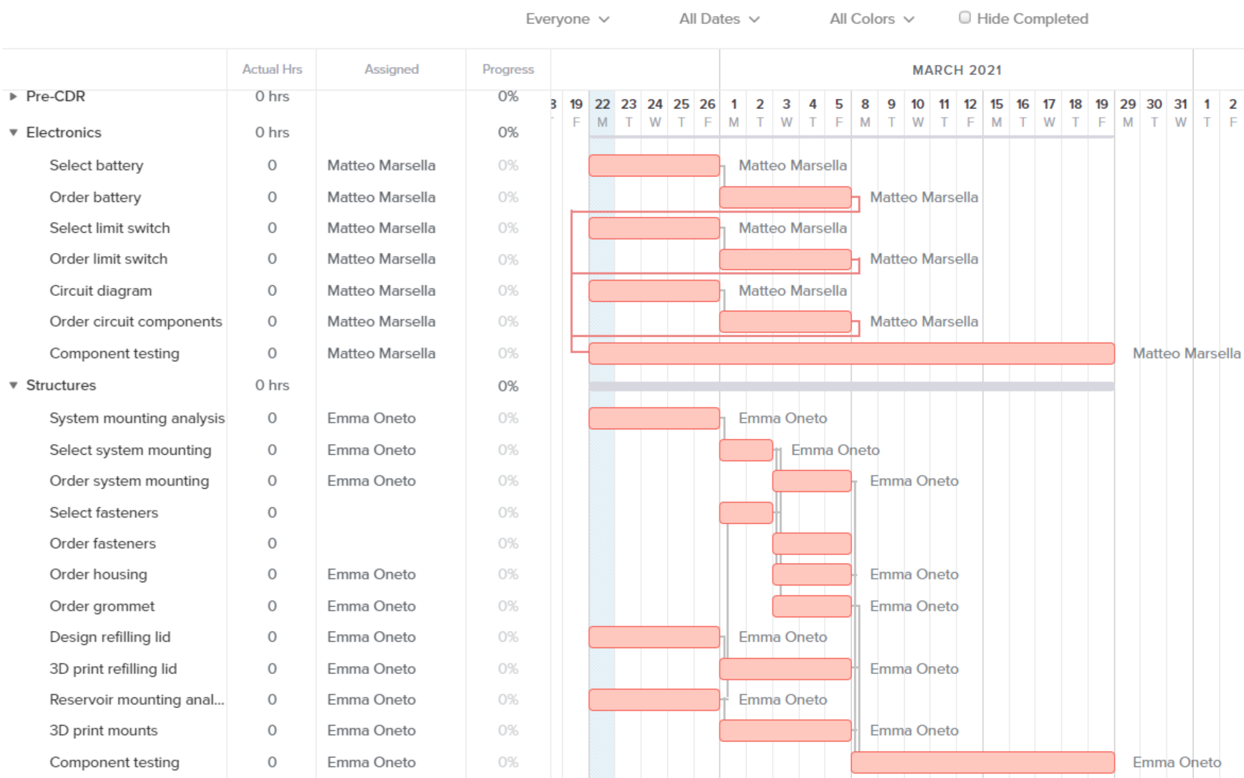
Winter Quarter
Overall team schedule



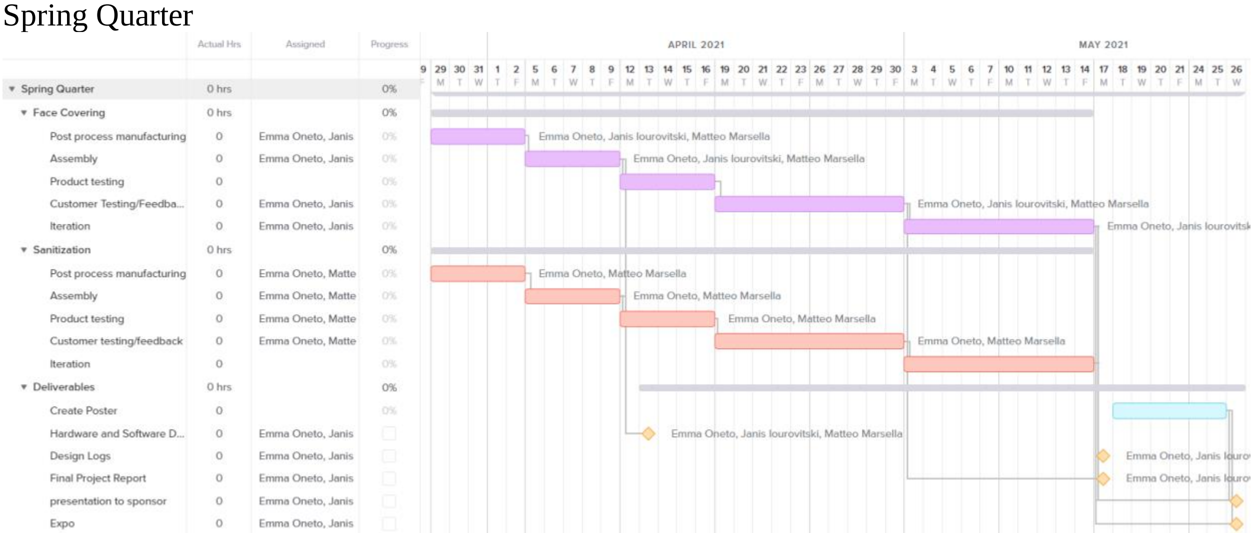
Face shield schedule



Disinfecting schedule



Spring Quarter



Appendix H: Safety Check List

SENIOR PROJECT CONCEPTUAL DESIGN REVIEW HAZARD IDENTIFICATION CHECKLIST
AUTOMATIC DISINFECTING SPRAY

Y	N	
■	□	Will any part of the design create hazardous revolving, reciprocating, running, shearing, punching, pressing, squeezing, drawing, cutting, rolling, mixing or similar action, including pinch points and sheer points?
□	■	Can any part of the design undergo high accelerations/decelerations?
□	■	Will the system have any large moving masses or large forces?
■	□	Will the system produce a projectile?
■	□	Would it be possible for the system to fall under gravity creating injury?
■	□	Will a user be exposed to overhanging weights as part of the design?
■	□	Will the system have any sharp edges?
□	■	Will all the electrical systems properly grounded?
□	■	Will there be any large batteries or electrical voltage in the system above 40 V either AC or DC?
■	□	Will there be any stored energy in the system such as batteries, flywheels, hanging weights or pressurized fluids?
□	■	Will there be any explosive or flammable liquids, gases, dust fuel part of the system?
□	■	Will the user of the design be required to exert any abnormal effort or physical posture during the use of the design?
■	□	Will there be any materials known to be hazardous to humans involved in either the design or the manufacturing of the design?
□	■	Can the system generate high levels of noise?
□	■	Will the device/system be exposed to extreme environmental conditions such as fog, humidity, cold, high temperatures ,etc…?
□	■	Will the system easier to use safely than unsafely?
□	■	Will there be any other potential hazards not listed above? If yes, please explain below?

Appendix I: Product Guide for User

Face Shield User Manual

Step 1: Insert the speaker into the case

Step 2: Close the latch

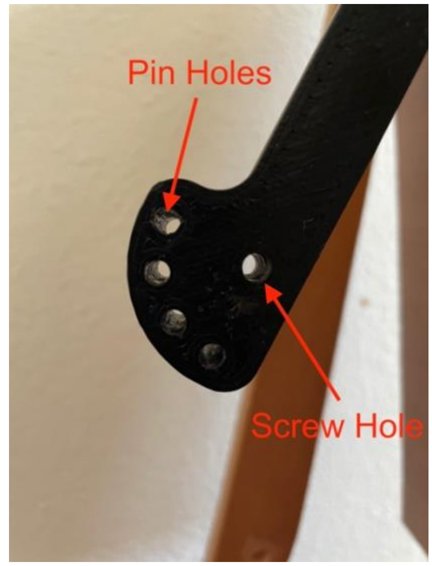
Step 3: Spin the wheel towards “ON” to increase the volume, plug in the microphone into the audio jack

Step 4: Put on the face shield with the support resting on your collar bones, adjust angle for comfort; rest microphone over ears or neck

Speaker Charging

Step 1: Attach adhesive tape to the back of the wall mount

Step 2: Peel adhesive tape cover and press onto surface to attach

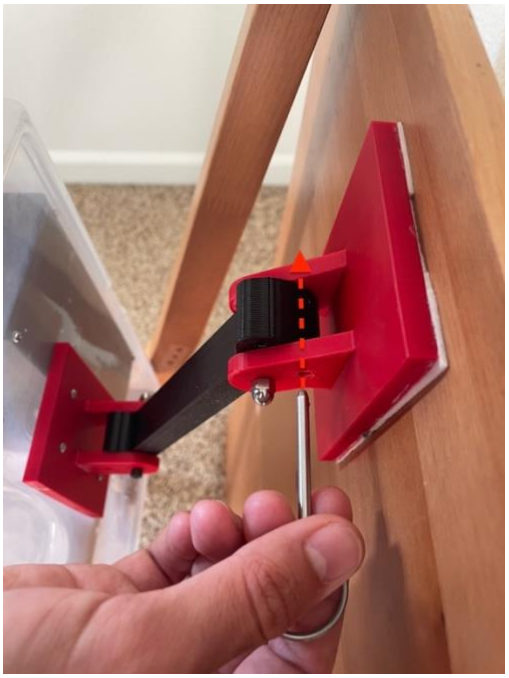


Arm hole layout

Step 3a: Line up the arm screw hole with the corresponding hole on the wall mount and insert the screw

Step 3b: Screw on the nut to the protruding threads of the screw

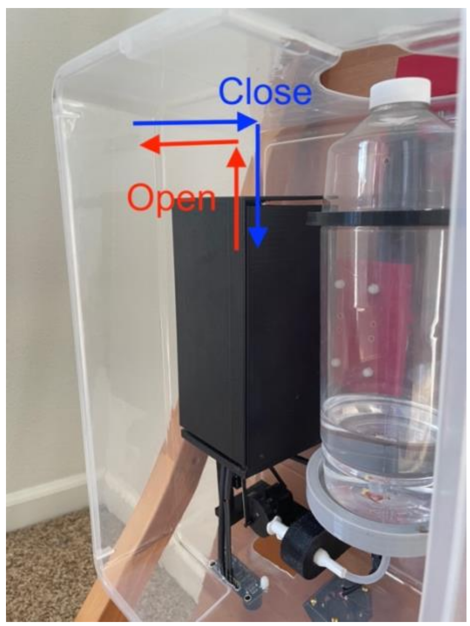
Mount appearance when screw is properly located in the mount



Step 4: Line up the pin with the pin hole for your desired position

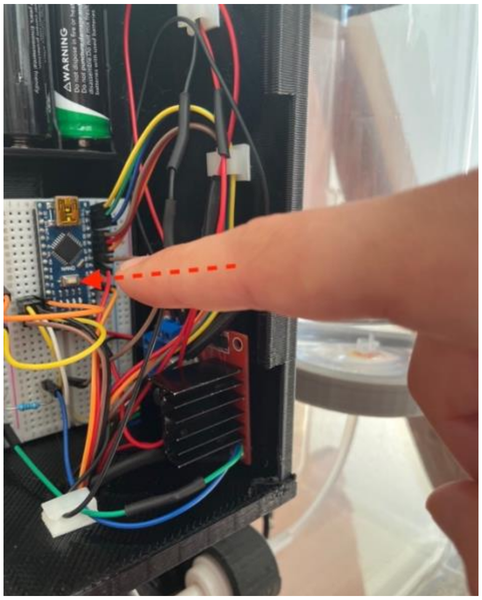
Mount appearance with screws and pins properly located in the mount

Step 5: Unscrew the cap of the reservoir and fill using sanitizer, screw cap back on when reservoir is at desired level



Step 6: Open the electronics housing

Step 7: Add batteries to battery pack



Step 8: Press reset button on Arduino Nano to calibrate, system is now ready to operate

Battery Charging

Appendix J: DVP&R

			DVP&R Sanitizer											
Report Date				Sponsor									REPORTING ENGINEER:	
			TEST PLAN								TEST REPORT			
Item No	Specification or Clause Reference	Test Description	Equipment	Acceptance Criteria	Test Responsibility	Test Stage	SAMPLES Quantity	SAMPLES Type	TIMING Start date	TIMING Finish date	TEST RESULTS Test Result	TEST RESULTS Quantity Pass	TEST RESULTS Quantity Fail	NOTES
1	Battery Life	Run system from battery fully charged to battery drained	Battery Charger, Complete electronics system	72 Hours	Matteo	PV	1	C	5/28/21	5/31/21	Pass	1	0	Battery exceeded expectations, system was not actuated as often as expected in assumptions
2	Spray Distance	Measure distance between spray bottle & sprayed surface	Ruler	3" min	Emma	CV	3	A	4/12/21	4/12/21	4.5"	3	0	
3	Motor Torque	Check motor has sufficient torque by testing if it can depress the nozzle	Motor Driver, Motor, Arduino Nano, Nozzle	Can Depress Nozzle	Matteo	DV	3	B	4/24/21	4/26/21	Pass	3	0	
4	Sharp edges inspection	Visual and physical inspection to ensure no sharp edges or physical components that can cut the user	N/A	No sharp edges	Emma	DV	1	B	5/31/21	5/31/21	Pass	1	0	
5	Verify Motor voltage	Measure voltage drop across motor using voltmeter	Voltmeter	> 6 V	Matteo	DV	1	B	4/26/21	4/27/21	6.6 V	1	0	Sufficient voltage for the motor
6	Verify Motor Current	Measure current through motor using ammeter	Ampmeter	< 0.69 A	Matteo	DV	2	B	4/26/21	4/27/21	0.1-0.25 A	2	0	Range depending on whether the cam is actively depressing or not
7	verify sensor voltage	Measure voltage drop across sensor using voltmeter	Voltmeter	5 V	Matteo	DV	2	B	4/10/21	4/10/21	5 V	2	0	Arduino 5V pin appears to work well
8	verify sensor current	Measure current through sensor using ammeter	Ampmeter	Check vs 15 mA	Matteo	DV	3	B	4/9/21	4/10/21	14-16 mA	3	0	Current varies lightly but is very close to expected
9	verify cam displacement	Measure difference between min. & max. radius of cam	Calipers	0.375	Emma	DV	3	B	4/13/21	4/13/21	0.375	3	0	
10	verify motor + cam can depress spray	Rotate motor & cam together & visually verify that nozzle gets fully depressed	Spray Nozzle, Motor, Cam, Arduino Nano, Motor Driver	Visual pass	Matteo	CV	5	A	4/26/21	4/26/21	**Pass**	5	0	Rotated cam to depress the nozzle multiple times
11	verify volume of sanitizer dispensed per spray	Measure volume of N sprays & divide by N to get volume of one spray	Measuring cup	.04 oz max	Emma	DV	3	B	4/12/21	4/12/21	0.02 oz	3	0	
12	Spray area	Measure max. surface area fully coated by one spray - spray on paper to visualize coated area	Ruler, paper towel	4" x 2" min. area	Emma	DV	3	B	4/12/21	4/12/21	4" x 3.5"	3	0	
13	Mounting force capacity	Measure force supported by mounting	Complete housing & mounting	4.5 lb	Emma	CV	1	A	5/11/21	5/29/21	4.5 lb	1	2	Suction cup failed. Replaced with 3M adhesive
14	Battery output voltage	Measure voltage drop across battery using voltmeter	Voltmeter	> 6V	Matteo	DV	2	B	4/5/21	4/5/21	8.2 V	2	0	Voltmeter across batteries
15	Seal leak testing	Make sure liquid does not leak out of reservoir connection	N/A	No leakage (visual pass)	Emma	CV	1	A	5/29/21	5/29/21	**Pass**	1	0	
16	Ultrasonic Sensor Code	Place objects at known distances and measure the distance with the ultrasonic sensor	Ultrasonic Sensor, Arduino Nano	Serial moniter reports accurate distance measurements	Matteo	DV	4	B	4/6/21	4/7/21	**Pass**	4	0	Correctly measured the distances to objects at 1in, 3in, 6in, 12 in

			DVP&R Sanitizer											
Report Date				Sponsor									REPORTING ENGINEER:	
			TEST PLAN								TEST REPORT			
Item No	Specification or Clause Reference	Test Description	Equipment	Acceptance Criteria	Test Responsibility	Test Stage	SAMPLES Quantity	SAMPLES Type	TIMING Start date	TIMING Finish date	TEST RESULTS Test Result	TEST RESULTS Quantity Pass	TEST RESULTS Quantity Fail	NOTES
17	Ultrasonic Sensor Calibration Code	Place and object at a known distance and have the sensor run its calibration cycle	Ultrasonic Sensor, Arduino Nano	Serial monitor reports accurate calibration distance	Matteo	DV	6	B	4/12/21	4/14/21	**Pass**	4	2	Failures were due to issues in the code, once they were resolved the test proceeded as excepted
18	Ultrasonic Detection Code	Place hand close to sensor after it is calibrated	Ultrasonic Sensor, Arduino Nano	Serial monitor reports detection	Matteo	DV	7	B	4/12/21	4/14/21	**Pass**	4	3	If ultrasonic sensor is resting on a flat surface it can erroneously detect the surface it is resting on. Problem is resolved when sensor emitter and reciever are free floating. In practice the sensor will not be resting on a surface so this issue should not be a problem in system operation. 50% measurement change is an acceptable change for the determining detection
19	Limit Switch Code	Depress limit switch	Limit Switch, Arduino Nano	Serial monitor reports limit switch open or closed	Matteo	DV	3	B	5/1/21	5/2/21	**Pass**	3	0	Arduino receives information from the limit switch as expected. Successfully printed lines for open and closed
20	Motor Code	Turn motor on and off at speed	Motor Driver, Motor, Arduino Nano	Motor runs at speed	Matteo	DV	3	B	4/17/21	4/18/21	**Pass**	3	0	Motor was able to be controlled to run at 0%, 50%, and 100% of max speed
21	Fan Code	Turn fan on and off at speed	Fan, Motor Driver, Arduino Nano	Fan runs at speed	Matteo	DV	3	B	4/20/21	4/21/21	**Pass**	3	0	Fan was able to be controlled to run at 0%, 50%, and 100% of max speed
22	Ultrasonic Sensor and Motor Code	Trigger sensor detection to run motor	Ultrasonic Sensor, Motor Driver, Motor, Arduino Nano	Serial monitor reports detection and motor runs	Matteo	DV	4	B	4/19/21	4/22/21	**Pass**	3	1	Had to reset the arduino during the first test, worked as expected after that
23	Limit Switch and Motor Code	Turn motor on and off by closing the limit switch	Limit Switch, Motor Driver, Motor, Arduino Nano	Motor turns on when limit switch is closed and is off when the limit switch is open	Matteo	DV	3	B	5/3/21	5/6/21	**Pass**	3	0	Motor successfully turns on and off when closing the limit switch, suggests the code can be integrated successfully
24	Motor Calibration Code	Motor rotates cam into contact with limit switch and then backs off the limit switch	Motor Driver, Motor, Limit Switch, Arduino Nano	Motor sucessfully roates cam into contact with limit switch and then backs	Matteo	DV	8	B	5/7/21	5/20/21	**Pass**	3	5	Took several attempts to dial in the correct time for the cam to back off of the limit switch, worked well and consistently once the delay was dialed in

			DVP&R Sanitizer											
Report Date				Sponsor									REPORTING ENGINEER:	
			TEST PLAN								TEST REPORT			
Item No	Specification or Clause Reference	Test Description	Equipment	Acceptance Criteria	Test Responsibility	Test Stage	SAMPLES Quantity	SAMPLES Type	TIMING Start date	TIMING Finish date	TEST RESULTS Test Result	TEST RESULTS Quantity Pass	TEST RESULTS Quantity Fail	NOTES
24	Motor Calibration Code	Motor rotates cam into contact with limit switch and then backs off the limit switch	Motor Driver, Motor, Limit Switch, Arduino Nano	Motor sucessfully roates cam into contact with limit switch and then backs	Matteo	DV	8	B	5/7/21	5/20/21	**Pass**	3	5	Took several attempts to dial in the correct time for the cam to back off of the limit switch, worked well and consistently once the delay was dialed in
25	Complete Code	Trigger sensor detection run motor and fan	Ultrasonic Sensor, Motor Driver, Motor, Limit Switch, Fan, Arudino Nano	Sensor calibrates, motor calibrates, motor runs after detection, fans runs (i.e. code works with the entire hardware system)	Matteo	DV	4	B	5/23/01	5/30/21	**Pass**	4	0	System works, motor and sensor calibrate, and the system holds off actuating in the event a hand is still present when it should actuate, howver, there is some leading out of the nozzle mount, not quite sure where it is from