Portable Sensory Room

for the West Orange County Consortium
for Special Education

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STATEMENT OF DISCLAIMER

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EXECUTIVE SUMMARY

This report discusses the development of a Portable Sensory Room to be used at Newland Elementary School in Huntington Beach. Newland Elementary has an exceptional Special Needs program that teaches the children with the most severe cases of autism in its school district. People with autism typically also have sensory processing disorders, which can be extremely disruptive for a child's development and can make it difficult for a child to be able to concentrate long enough to gain necessary life skills. The idea behind a Sensory Rooms is to create a place to calm the students and to expose them to new stimuli to explore and learn in a calm and non-threatening environment. There are three different Special Needs classrooms that the Portable Sensory Room will be moved between in a single day. The teachers at Newland Elementary also desired a swing element and a pressure applying device. Both of these components are used regularly in Occupational Therapy with children with autism and have been proven to help children develop necessary skills in life.

The design of the Portable Sensory Room, which was composed of several brainstorming sessions and decision matrices, lasted several months from Fall 2015 to midway through the Winter 2016 quarter. The final design consists of seven different components - five of the components act as the structure of the room and can easily connect to one another to achieve a uniform enclosure and two are separate from the room structure. All of these components have interactions on their faces that either comfort or challenge the children and all contribute to a calming sea theme throughout. The components are all on locking casters which makes transportation of the assembly easy. The five components of the room structure are: the tactile wall, the bookshelf, the tactile station, the fabric panels, and the LED panels. The tactile wall focuses on helping the children gain fine motor skills by use of tracks that the children can move fish along, a moveable gear set, and a whiteboard. The bookshelf is filled with activities for fine motor skills as well, and provides extra storage for the teachers to arrange according to their desires. The tactile station is a dresser with calming light effects at the top. The drawers can be completely removed and put on the floor, where the children can play with tactile interactions in an enclosed space to avoid a mess. The fabric panels provide tactile sensations using several swatches of fabric that range from calming to challenging. The LED panels have a calming ocean mural and also allow children to observe the notion of cause-and-effect via a control box that changes the light display.

The other two components are the swing structure and the pressure applicator, which can either be used in the room or separately from the room depending on the teachers' preferences. The swing structure was purchased from Amazon and allows for a 360 degree rotation. The pressure applicator was built by the team and is comprised of two horizontal rollers that the child can slide in between. The addition of rubber bands allows the child/teacher to choose how much pressure will be exerted on the child.

The build phase of the project lasted from the end of Winter 2016 quarter to the end of Spring 2016 quarter. All of the components were made from lumber and sanded down in order to avoid any sharp edges. Testing was performed to verify that the teachers would not have to exert an enormous effort to move all of the components, as well as to determine the tipping loads for each of the components. The tipping loads were below the desired specification; in order to mitigate this, two adults will be required to move each component. When the room is assembled together, the entire structure is quite stable and does not pose a tipping hazard. The final product will be delivered to Newland Elementary School on June 17th, 2016.

CHAPTER 1: INTRODUCTION

Children with autism, especially moderate to severe cases, struggle to interact in environments in which typically-developing people can thrive. Individuals with autism are much more likely to have sensory processing disorders which can make standard sensations uncomfortable or even painful. These sensory processing disorders can be extremely disruptive for a child's development and make it difficult for a child to be able to concentrate long enough to gain necessary life skills. The idea behind Sensory Rooms is to create a place to expose these students to new stimuli which allows for exploration and learning in a calm and non-threatening environment. Many special education classrooms are currently experiencing a clear and present need for environments that are more closely catered to the sensory needs of their students, especially students that have more severe disorders. The Portable Sensory Room is a tool that special education classrooms can utilize to teach students with autism and other developmental disorders how to interact with their environment and cope with undesirable stimuli.

Many students with autism become overwhelmed with the noises and textures surrounding them as well as the sometimes unpredictable and abrasive nature of a day at school. The project goal is to assemble a space where students can remove themselves from their stressors in order to achieve balance and calmness, either individually or with an instructor. The Portable Sensory Room is intended to provide the students with sensory stimuli that interest, comfort, and even challenge students when they are attempting to integrate all of their sensory input. The Portable Sensory Room's main purpose is to soothe the students; any sensory exploration available in the system would be an added benefit.

The Sensory Room is being built for the West Orange County Consortium of Special Education, which is dedicated to the growth and success of every student affiliated with their schools. The main correspondent on the project is Lisa Colburn, an Occupational Therapist working with multiple special education programs at schools based in Orange County, California. The main school that the Portable Sensory Room is being designed for is Newland Elementary School, which supports children with the more severe cases of autism in the school district. The Portable Sensory Room will be used in classrooms with individuals who have moderate to severe autism from the kindergarten to fifth grade level.

The goal of the sensory room to be used for Newland Elementary School is to be as universal as possible. Although each child and their experiences with autism are unique, children with autism and other sensory processing disorders typically fluctuate between two levels of processing: hyposensitive and hypersensitive. Hyposensitive individuals are under-sensitive to sensory information they receive and thus are often "sensation-seeking" or looking for sensory stimuli. These individuals need a balance of activities that stimulate all of their senses. In juxtaposition, hypersensitive individuals are oversensitive to sensory stimulation and thus will try and avoid this stimulation. These individuals must learn to cope with sensory stimulation and learn how to avoid becoming overwhelmed with sensory input. Since the portable sensory room must accommodate all of the children, components that cater to each category are present. Ben-Sasson et al (2007/2009) found that toddlers with autism disorder were most likely to be under-responsive (hyposensitive) to sensory stimuli, while children with autism older than a toddler tended to be more hypersensitive. The sensory room will cater to children from three years of age to ten years old, therefore it should allow the user to dynamically control how much stimuli the child will be exposed to at one time. This will allow for under and over-responsive children, however the room will favor those who are hypersensitive.

CHAPTER 2: BACKGROUND/OBJECTIVE

Currently, Newland Elementary School has several tactile tables, examples of which are pictured below in Figure 1. The tables at Newland Elementary allow the children to play with textures such as shaving cream or water, as well as several different small toys or other tactile objects. They also have some weighted blankets and beanbags that can stimulate the children with pressure. This project is the first time that the idea of a sensory room has been explored in that school district but there are several occupational therapists and individuals that have been using sensory rooms as processing disorder therapy for years.

Figure 1. Examples of Tactile Interactions

One sensory room-related company that has gained popularity is called Snoezelen: Multi Sensory Environments (MSE). This company builds custom permanent sensory rooms (or Snoezelen Rooms) for their users and "incorporates a specialized selection of sensory equipment and materials that may help clients adapt their responses to sensory stimulation … The blend of sights, sounds, textures, aromas, and motion … may be modified to meet each participant's sensory needs" (Snoezelen). In a study conducted by Fava & Strauss (2009), the Snoezelen room was shown to decrease disruptive and aggressive behaviors in children with Autism (p. 167). The Snoezelen room in this study was, "9 m by 7.50 m, had white walls, a carpeted floor, as well as commercially purchased visual, tactile, auditory, olfactory, and vestibular sensory equipment. It included a rocking chair, vibrating pillow, kaleidoscope-like color wheel, rotating electric colored lights ball, magna light (lava lamp), color carousel ball with flashing lights, bubble column, bean bags, tactile panel with different texture tile, tactile books with textures, rotating projector (abstract shapes, planet, clouds, stars), rain stick, a fiber-optic, auditory melody disks, and aromatherapy oils" (p. 161). All of these items are typically suggested for use in sensory rooms and can be purchased through several different companies. The Snoezelen room is built into the customer houses, while the sensory room for Newland Elementary is portable.

Figure 2. Example Sensory Room

A similar product was patented in 2006 by Kathryn and Jeremy Smith. This unit acts as a traveling container for sensory equipment with several cabinets for storage, as well as a power supply for audio-visual stimulants. The patent is very broad in scope and solely discusses the container and portable aspects of the sensory apparatus. The Newland Elementary sensory room is designed as a blend of the Snoezelen room and the "Sensory Apparatus" discussed here - when the unit is expanded and in operation, it acts like a functioning room but is able to pack up and travel from classroom to classroom. Similar to the Snoezelen room, the "Sensory Apparatus" can be filled with items purchased specific to the customer's/ students' sensory preferences.

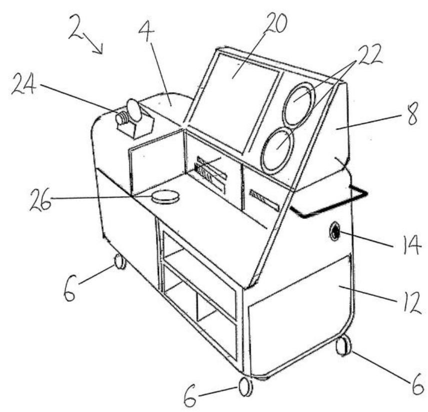

Figure 3. Patented Sensory Apparatus for the mobile transport of sensory items in hospitals

One such company which is committed to selling components to build the optimum sensory room is Southpaw. There are a vast amount of sensory room components including lights, swings, jungle-gyms, interactive panels, and vibratory objects. Although these companies offer several components, it is possible to build a sensory room on a stricter budget. Due to the abundance of creative sharing websites such as Pinterest, as well as forums for parents of children with autism, a large number of "Do-It-Yourself" sensory rooms and equipment ideas are available online. There are several various tactile objects that can be made easily and cheaply, such as weighted sensory blankets, simple ball pits, and countless others. The Newland

Elementary School sensory room is a mix of handmade items and purchased items in order to remain within the budget.

Two types of equipment that are included with the sensory room at Newland Elementary School are a pressure-applying device and a swing. According to Temple Grandin, a person with a doctorate and autism, deep touch pressure can help assuage nervousness, as well as "help overcome problems of oversensitivity"(Grandin, 1992). She built herself a "Squeeze Machine" that has two padded boards on either side of the user in a V-formation, shown in Figure 4. The user controls the actuation of the two boards via a lever, and commands the boards to squeeze the user and apply deep pressure all along the user's body. The relaxing effect of the Squeeze Machine was most apparent when the pressure was applied slowly and steadily, without any sudden movements. Other pressure-applying devices that are much simpler than the "Squeeze Machine" are weighted sensory blankets, with beads sewn in to give the blanket added density, or bean bags. There is also the option of using vests that tighten in order to "hug" an individual, providing deep-touch pressure. One piece of equipment that is already on the market is the "Single Squeezer", shown in Figure 5, which uses bungees and foam rollers to apply the desired pressure. All of these pressure-applying devices satisfy a proprioception craving that is prevalent in people with autism.

Figure 4. Temple Grandin's Squeeze Machine

Figure 5. Pressure Applicator "Single Squeezer"

A swing is also highly desired for the sensory room. In the article "Swings not just for Recess" by physical therapists, Jane Ruge and Ellen Hanso, the use of a therapy swing for children with autism was supported. "Therapy swings meet children's needs in a variety of ways. They offer opportunities for improving arm, leg, and trunk strength, increased body awareness, and sensory and proprioceptive integration. They also help children who have difficulty maintaining their equilibrium and tolerating stimulus. In addition, the swinging motion impacts the vestibular system, which can improve a child's balance and in turn their stair navigation and ambulation skills. Improvements in motor coordination, ability to put movements together, and sequencing skills have also been observed as a result of therapy swing" (p. 1). There are many swing attachments available for occupational therapy, such as the one shown in Figure 6. Newland Elementary School already had a few attachments, so only the swing stand was needed. The swing stands alone and can be separate from the sensory room.

Figure 6. Example Therapeutic Swing

Several design specifications have been researched in order to find the current code or standard to ensure the sensory room meets safety standards. The Consumer Product Safety Commission was used in order to determine various safety standards such as the minimum size for a component to be considered a choking hazard and the proper size of any gaps so that the child cannot get stuck. The OSHA regulations for a safe fire exit were used to help define the proper size of the exit of the sensory room. While the design of the sensory room should be able to meet the width standards without an issue, the height of the exit is required to be 7.5 feet which may be taller than the sensory room itself. However, the final design lacks a roof which renders this specification null. The last specification that was needed was the proper air flow of the room to be properly ventilated. This standard came from the ASHRAE Ventilation for Acceptable Air Quality manual. The sensory room was approximated as an art classroom with an exhaust rate required of 0.70 cfm/ft^2 exhaust rate so that there would not be any concern for the tactile objects or olfactory scents to not be able to off-gas appropriately. Again, without a roof the sensory room is wide open to the classroom air so no air flow specification is required. References to all of the stated standards organizations can be found in Appendix A: References.

OBJECTIVE:

The Portable Sensory Room is a partially enclosed area, with various foldable walls and storage capability. The walls do not close completely, giving the teacher full view of the student at all times to ensure proper safety. Inside the room, a calming environment is created using sensory elements. Additionally, these sensory elements can be used as a learning tool so that the child will become better accustomed to a variety of sensory inputs. The inputs utilize sight, hearing, touch, and body movement to give the students a range of experiences that can both calm and stimulate their minds and bodies.

Two different large mechanisms, a swing and a pressure applicator, are included in the sensory room to address the main needs of the students. The swing will fulfill the students' needs for vestibular motion; swings help the students become familiar with ordinary movement or allow the student to move around while learning. Lateral and rotational swinging both provide different types of vestibular sensory input, which is very beneficial for various parts of the brain. Occupational therapists will also use swings to help students multitask and interact with others, such as passing a ball back and forth. The pressure applicator is incorporated so that the students are able self soothe themselves by applying deep pressure evenly throughout the body. Deep pressure is highly beneficial to individuals with sensory integration disorders. It is known to lower heart rate, lower respiration rate, and decrease overall agitation and stress. Tactile tables are also included to provide opportunities for students to explore normally uncomfortable or anxiety-inducing textures, such as sand, shaving cream, beads, et cetera. These mechanisms, combined with a multitude of other sensory inputs, such as LED lights, music, and sounds create an environment that will evoke deeper learning and personal connections in both hypersensitive and hyposensitive children.

To develop the Design Specifications specific to this project, listed in Appendix B, a method called Quality Function Deployment (QFD) was implemented. The output of the QFD process is the "House of Quality," which is also located in Appendix B. The House of Quality diagram contains all the information relating customer requirements to engineering requirements. In addition, it uses data from competitors and evaluates their methods deployed to satisfy customers. The customer requirements for this project which were used in the Quality Function Deployment method can also be found in Appendix B.

CHAPTER 3: DESIGN DEVELOPMENT

ROOM STRUCTURE:

After a multitude of brainstorming sessions, a Pugh Matrix, located in Appendix C, was used to compare and analyze several concepts and ideas for the design of the room structure. After the completion of the Pugh Matrix, several important features of the room structure were determined, including how the structure would be portable, what the walls of the room structure would look like, and how the room structure would collapse during transport. During the re-design, several additional characteristics were determined, including where the components of the room would go during transport and how the room would be transported through doorways and around tight corners in the school.

Firstly, during the Pugh Matrix comparisons, the most maneuverable design was chosen using wheels, giving the teachers and classroom aides the most flexibility to move the room structure themselves. One wheel design that was investigated contained wheels that were able to fold underneath the structure while the room was in use so that the structure would be in full contact with the ground while in use. It used levers attached to the wheels so that when the room needs to be transported, the wheels could be easily pulled back into place. A similar wheel with attached levers can be seen below in Figure 7. However, it was decided that this wheel design would be too unfamiliar to the teachers and that it is less user-friendly. Other designs such as attaching the room to a dolly or a cart were too bulky and would have forced the room structure itself to be smaller to fit in the confines of the space provided. Therefore, lockable casters were chosen because they were the most compact and the easiest to use for the teachers.

Figure 7. Wheel Design Attached with Levers

Secondly, the designs with rigid walls were chosen over designs with more flexible walls, such as a tent structure. Rigid walls offered more stability for the structure itself, reducing the risk of the structure collapsing if it is bumped into or accidently struck. Another benefit of the rigid wall designs was that tactile boards and other sensory interactions could be placed on the walls. This increases the surface area that could be utilized to incorporate sensory interactions for the students, which is the top priority for this project. Another advantage of the rigid walls is that it provides more noise and light cancellation which will allow for more visual and auditory elements to be used without disrupting other students or lessons in the classroom. Initially, the structure was planned to be made out of acrylic and aluminum extrusion, however the structural integrity of acrylic was called into question. Instead, it was decided to use wood for its ease of manufacturability and low cost.

Thirdly, the flexibility of the foldable walls design offered the most advantages for the room structure than the other designs that were generated. A similar structure design can be seen in Figure 8 below. Rigid walls, while the most sturdy, were also the most difficult to compact into a space small enough to fit through the doorways in the classrooms. By separating the walls into several segments and attaching them with hinges so that they will fold on top of each other and disconnect into several different components, the room structure can be easily taken down in a relatively short amount of time, giving the teachers the ability to both move the portable sensory room to several different classrooms on a daily basis and quickly move the portable sensory room to a student in need of a calming environment in an emergency situation.

Figure 8. Similar Pre-Existing Structure Design with Foldable Walls

During the re-design, other key decisions about the room structure were made as well. Firstly, the increased storage provided by the incorporation of a bookshelf was determined to be critical to the reduction of time needed to take down and set up the room structure. This addressed the concern over where all of the sensory interactions in the room would go when the room needed to be moved. By providing easily accessible storage, the room and all of its components could be quickly collapsed when needed.

Secondly, it was decided that since the structure has to be able to turn around tight corners in hallways in between the classrooms, the structures should be no more than 3-4 feet in length so that they would be more manageable during transport. This also reduces the weight of each component, enabling teachers and classroom aides to be able to move the structure themselves rather than relying on the presence of other people. By making the maneuverability of the structure as independent as possible, there will be more flexibility to address emergency situations when the room is needed quickly.

PRESSURE APPLICATOR:

In the initial brainstorming process, several concepts were judged via Pugh matrix to determine the optimal characteristics to include in the final design. The Pugh matrix for the pressure applicator can be found in Appendix C. The pressure tunnel idea consisted of several subsequent walls each with two therapeutic rollers that could rotate about their own axes and a gap between the rollers. Each gap would be at different heights so the child would have to navigate through the walls to get to the other side. The walls would be quite close together to fully support the child and close to the ground so that there is no opportunity for the child to fall down. With multiple walls, this design would likely be cumbersome and difficult to transport.

The next idea was deemed the "Dinosaur Mouth" and is composed of a lower bed of therapeutic rollers that are allowed to spin and a top bed at a slope that gets increasingly closer to the lower bed. The concept of operation is that the child could slide into the space between the two levels. The more pressure that the child desires, the farther into the gap they can press. This design would also be somewhat cumbersome and take up a large amount of space. Moving away from using therapeutic rollers, another concept explores the use of a weighted blanket as an hammock. The child would be able to hang in the hammock and their own weight would push them into the blanket. There would be excess material at the sides of the hammock with extra weight in them that the children could wrap around themselves and add extra pressure. While this design would be easy to store, it would require two extremely sturdy supports to allow for the children to climb into the hammock and move around in it.

Another design option is slightly more complicated. The child would lie down on a bed with a plush covering, similar to a memory foam, which would allow them to sink in and feel surrounded. An elastic blanket that is fixed to a wall would be placed over the child and attached to a crank. The teacher would crank the blanket tighter in order to provide compression. The pressure achieved by this device is unknown, and would require significant testing. This design would also require a large amount of storage space. The last design explores a concept that is already on the market, the T. Jacket. The T. Jacket uses air pockets throughout the vest to achieve the optimal pressure to calm the wearer. The product on the market has the ability to be controlled via an app, and responds to the user's movements to keep the optimal pressure. One disadvantage of this product is that it must be perfectly sized to the wearer and therefore could not be universal to all of the students.

Temple Grandin's Squeeze Machine was chosen as the datum to judge the other concepts against. This machine is already proven to work and exert the proper pressure to calm those with autism. After completing the Pugh matrix, several conclusions were reached. The designs with the rollers are simple and sturdy, and would be feasible to design and build within the timeframe given. Both the "Weighted Hammock" and the "Stretchy Blanket" design involve various fabrics that would need to endure heavy stress. The durability of the product is a very important customer requirement so these concepts were eliminated from the final design. The machines using air pumps such as the "T. Jacket" and the "Squeeze Machine" were favorable in the pressure that they could provide but the noise that the pumps would produce is cause for concern.

After reevaluating the designs, two final concepts were reached to present in the Conceptual Design Review, one using rollers as the pressure applicator and another using air. This would provide two different methods of pressure and would allow the children to choose which device they prefer in order to cater to the widest audience. The first design, the "Squeeze Tunnel", can be viewed in Figure 9, and consists of two beds of rollers. The lower bed of rollers are able to rotate around their own axes, while the top rollers rotate about their own axes, while being able to rise up and down. The top rollers would be connected to the base via a spring. The top and bottom layer of rollers are encircled by a soft material, such as memory foam, much like the tread on the wheels of an army tank. This will prevent the child from being able to get their arms or legs stuck in between the rollers. At the spring's unstretched length, there would be a slight gap between the upper and lower levels so as to be inviting to the child. As the child moves through the machine, the springs will stretch and allow the child to pass under, while applying pressure to the child. The child will only have part of their body in the mechanism at any time, as seen in Figure 10. The "Squeeze Tunnel" will also have a handle and two wheels at the base so it can be easily moved around, such as a suitcase or a dolly. When not in use, the "Squeeze Tunnel" will be stored separately from the room. The open design of the "Squeeze Tunnel" allows for easy supervision of the child.

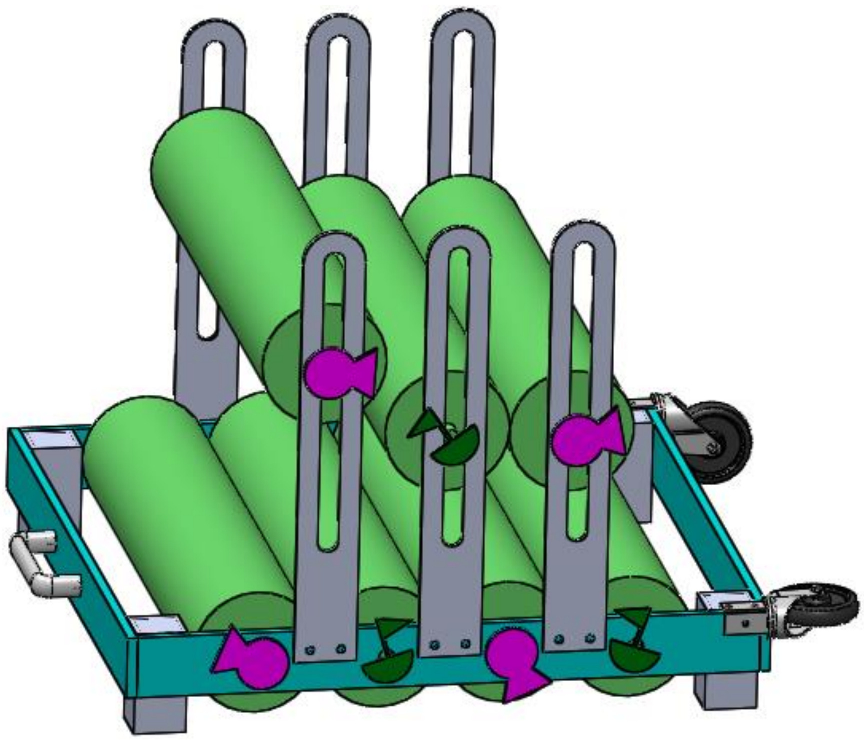

Figure 9. Pressure Applicator Concept: Squeeze Tunnel

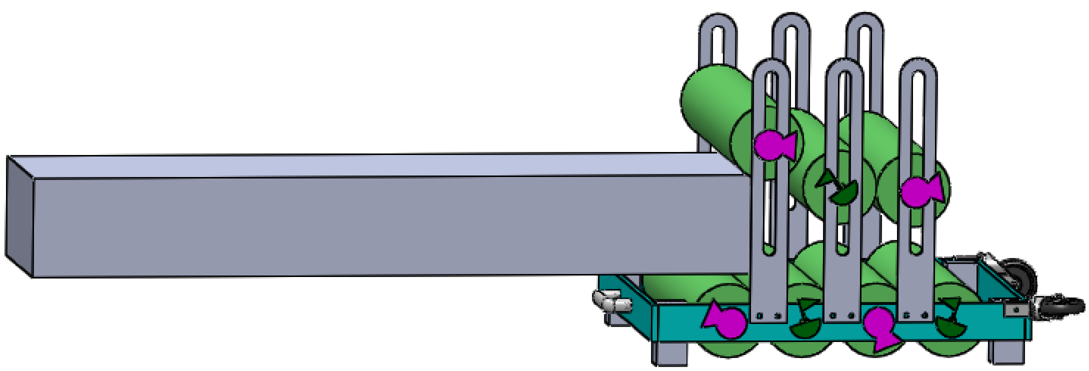

Figure 10. Squeeze Tunnel shown in scale. The prism shown is roughly the size of an eleven year old in the 90th percentile.

The second design concept for pressure application at the time of the Conceptual Design Review was the "Cozy Vest". The vest is inspired by the T. Jacket but aimed to make a much more universal fit that could be used with varying sizes of children. The vest will consist of a layer of either weighed or compression material. There would be another layer of air pockets, which would be pumped up via a hand pump, similar to those used to pressurize blood pressure cuffs. Velcro and buckles with tightening straps would be used to enclose the child in the vest and allow for the largest variance in wearer.

After the Conceptual Design Review, the Multiple Roller design was re-evaluated, when the question of how kid-friendly and safe the design would be surfaced. The process to design the pressure applicator was reiterated and resulted in three competing concepts to choose as the final design.

One of these designs is the original conceptual final design, the Multiple Roller design. One of the main issues of this design is that there would be several pinch points and openings that the children could be harmed. Other undesirable aspects of this design is that it is bulky and expensive to manufacture with several different components, and it is unknown if the children would be receptive to interacting with such a unique machine.

Another design evolved from a product currently on the market and is deemed the Single Squeezer, shown in Figure 11, which is for sale from several different companies for around $470. This concept uses only one roller each on the top and bottom and uses a bungee on each side to apply the desired pressure. The team would build their own "Single Squeezer," rather than purchasing one and modifying it, in order to keep the cost low. The Solidworks model, based on the Single Squeezer design, that the team used to build their own machine can be viewed in Figure 12. The simplicity of the design is ideal for manufacturing and durability, as well as for interacting with the children. There are limited pinch points or areas for the children to get any body parts stuck. The reviews of the current products on the market are encouraging and lead the team to believe that this design would be well received by the children.

Figure 11. Pressure Applicator Concept - Single Squeezer

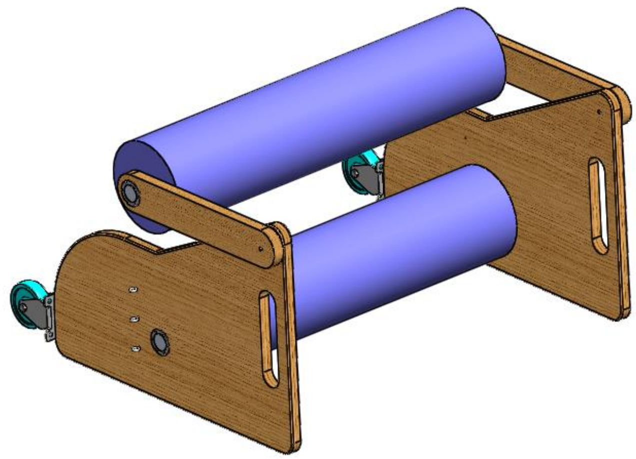

Figure 12. Pressure Applicator Concept - Single Squeezer Built by Team

The third pressure applicator concept, Loose Bungee concept, has roughly the same idea as the Single Squeezer concept. Rather than using straight shafts with bungees at either end to apply pressure, the Loose Bungee concept threads a bungee through both rollers and attaches the ends to sides of wood. At rest, the rollers would be almost touching one another but the bungees would stretch in order to allow a child to pass through. A sketch of the proposed Loose Bungee concept is shown in Figure 13. One worrisome aspect of this design is the potential pinch points and entanglement points that the loose roller creates.

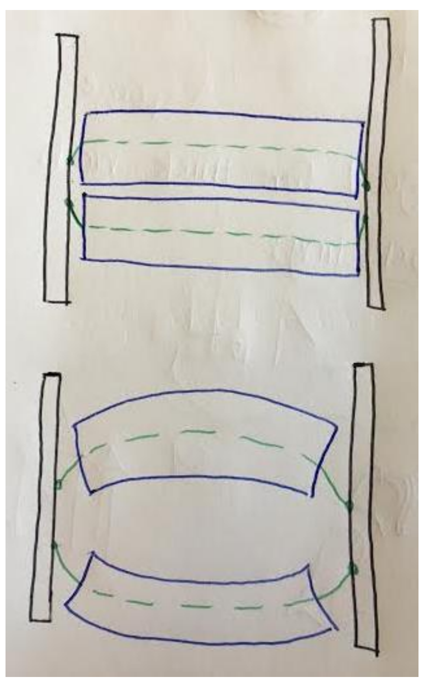

Figure 13. Pressure Applicator Concept - Loose Bungee

In order to determine the final design to manufacture and use in the Portable Sensory room, each of the three above concepts was analyzed to determine the ability to meet our desired specifications. It was assumed that each of these concepts would be designed with the proper springs/bungees to apply the desired pressure. The three criteria that each concept was judged by was the cost, kid-friendliness, and safety concerns. Both the Multiple Roller and Loose Bungee would need to be manufactured by the team, however the Single Squeezer could either be bought and adapted, or entirely manufactured by the team. All of the concepts use the same basic elements of rollers, bungees/springs, and a wooden frame so the comparison of cost is ultimately based in how many components each concept requires for the concepts the team would build. Using this ranking, the concepts would be ranked, in order from cheapest to most expensive: Loose Bungee, Single Squeezer (built), Multiple Rollers, Single Squeezer (bought and adapted).

In terms of kid-friendliness, the Single Squeezer design is the only concept with any previous knowledge of how children might interact with it. One of the concerns with all of these designs is that children may not be comfortable crawling in between the two rollers. There were some reviews for the Single Squeezer currently on the market that addressed this, that stated that their child was not comfortable with moving between the two rollers but would instead push and roll against the top roller which was able to satisfy the deep pressure desire. Although the Loose Bungee has a similar design to the Single Squeezer, the bungees would likely not be able to provide the same pressure that a firm support shaft can, and would likely not be able to satisfy the children without them passing through it. There is some apprehension that with the Multiple Roller concept, a child may get through the first set of rollers and not want to proceed and could get twisted in the machine and cause themselves injury. Based on this, the concepts are ranked from most kid-friendly to least: Single Squeezer, Loose Bungee, and Multiple Rollers.

The safety of the pressure applicator is the most vital criteria. If the mechanism is unsafe in any way, then its ability to apply pressure is rendered moot. The Multiple Roller concept has several potential pinch points, as well as areas that could trap a child’s arm and leg, which places it as the lowest safety concept. The Loose Bungee does not have any stiff moving parts which is less of a concern, however with the looser rollers, there is concern of a tripping hazard or that the child could be caught and twisted in the bungee. The Single Squeezer has the least amount of hazards associated with it with a limited number of moving parts and pinch points. The concepts ranked from the most safe to the least safe are the Single Squeezer, Loose Bungee, and Multiple Rollers.

Based on these three criteria and the rankings, the Single Squeezer was chosen as the final design that the team manufactured for the Portable Sensory Room.

More research was performed after the Conceptual Design Review in the effectiveness of using pressure vests to help children calm down. The Journal of Autism and Developmental Disorders published an article in 2009 on the effectiveness of weighted vests in treating inattentiveness, hyperactivity, aggression and self-injurious behaviors in children with Autism Spectrum Disorder. The researchers reviewed seven previous studies examining weighted vests,in which all studies included participants with varying degrees of Autism, children with pervasive developmental disorders, children with developmental delays, and typically-developing children. It was found across all studies that the consistent use of a weighted vest, even with the assistance of an occupational therapist, had very little to no effect on challenging behavior, and concluded that weighted vests are in ineffective approach to intervention. The researchers involved suggest that continued research be conducted, but ultimately that weighted vests cannot be recommended for clinical application at this point (Stephenson and Carter, 2009). This information is consistent with more recent studies. Based on this research, the original concept of the cozy vest will be removed entirely from the design due to the lack of knowledge of what its effect might be.

SWING:

A Pugh Matrix, located in Appendix G, was generated after several brainstorming sessions. The Pugh Matrix was utilized in analyzing and narrowing down design ideas,

The design ideas included both a standard swing set structure and a modified standard swing set that was slightly smaller. It was determined that these structures lacked stability and would take up too much space for our design, The rounded and straight supports with tripod base would take up less space, but they did not provide additional support. The “fold out from wall” and “track on ceiling” designs were less feasible than the standard swing. It was determined that the tripod swing structure would provide more support and take up less space than the standard swing structure. It was determined that all structures other than the modified standard would have the potential to provide a better range of motion. The tripod swing structure was selected as the option to move forward with. Rather than build the swing, the team decided to purchase it and a product currently on the market was found that satisfies the project requirements.

VISUAL AND TACTILE INTERACTIONS:

In designing the room’s tactile and sensory elements, it was desirable for each individual element to have a limited scope of sensory input, meaning that it will only stimulate one sense at a time. The goal is to have many different elements that, taken as a whole, could account for all aspects of sensory stimulation. This organization will help students learn about each sense individually as well as make connections between two different senses, while preventing the student from being overwhelmed.

Several ideas that were brainstormed for tactile and visual stimulation are listed below.

- Tactile Wall
- Button Control Box
- Floating Sand in Bell Jar
- Touch Active Paint
- Tactile Table
- Tactile Sensors
- Haptic Vibrational Motors
- Conductive Yarn

One of the main ideas that was agreed upon by the team was an interactive tactile mural/board. This included mechanical moving parts and multiple textures as well as a narrative that adds to the "Under the Sea" theme of the room. The idea of a tactile table was changed to instead create a tactile station which is further discussed in Chapter 4. For visual interactions, the finalized design is to have LEDs integrated into two of the panels that create sea themed pictures. This is thoroughly discussed in Chapters 4 and 5. One sensory input from a sensor is tied to another sensory output to aid in the developmental learning of the students and to help the students gain an understanding of cause-and-effect relationships through sensory stimulation.

CHAPTER 4: DESCRIPTION OF THE FINAL DESIGN

ROOM STRUCTURE:

Overall Layout

The room structure is composed of five separate modules: the tactile wall, the bookshelf, the tactile station, the LED panels, and the fabric panels. These modules attach together while the room is in use and then detach for transport. Tactile and visual interactions are built into each of these modules to create a calming space where students can both relax and learn to cope with different stimuli. A labeled layout of the room structure can be seen below in Figure 14.The fabric panels will have several different swatches of fabric, the continuous pattern shown in Figure 14 is only a representation.

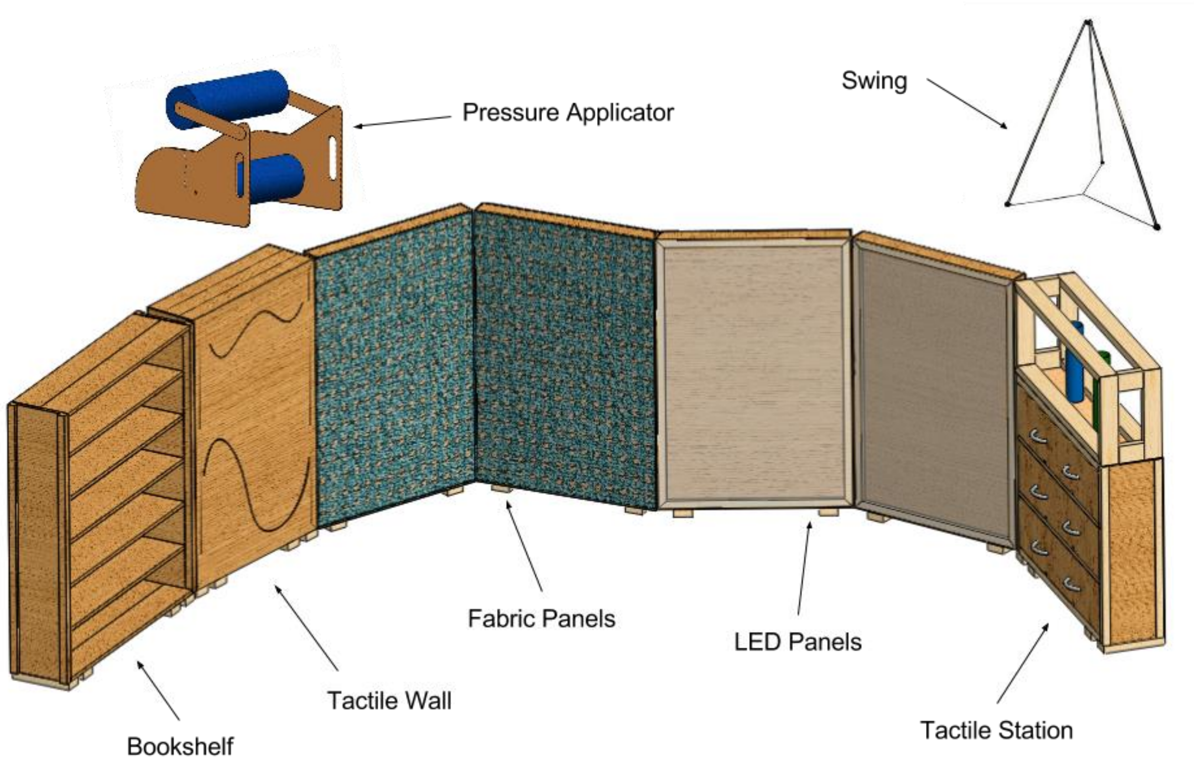

Figure 14. Labeled Room Components

The tactile wall allows the students to practice their fine motor skills with an abacus, sensory bands, and moveable gears. Students are also able to use a track to enable guided movement of objects. Tactile walls are an extremely important learning tool that have been utilized in a variety of different sensory rooms.

Another activity that was emulated in the design was the use of tactile tables, which was incorporated into the tactile station. Tactile tables, which are addressed in greater detail above, allow students to interact with a variety of different textures in a designated space. In this design, the tactile station is a portable dresser that was built with removable drawers. This way, the teachers can remove the drawers, place a desired texture inside of them, and then put the drawer on the floor of the room structure for the student to interact with. Adjustable dividers are also inside the drawers so that the teachers can choose to place more than one interaction in a drawer at a time. In addition, a variation of bubble tubes are placed on the top of tactile station to provide an added visual interaction for the students.

The bookshelf is used as a designated storage area for the teachers. Fine motor exercises, textures, and other sensory activities from the room are stored on the shelves so that the teachers can both readily access them or swiftly store them before transport. Lips on the edges of the shelves prevent items stored in the bookshelf from falling out while the room is moved to another classroom.

There are two sets of panels connected via a hinge which can open to whatever angle suits the room shape. Two of the connected panels are designated as “Fabric Panels” and are covered in swatches of various fabrics to allow students to pick and choose which ones they prefer. Each fabric panel incorporates calming textures towards the bottom to relax the students while the more challenging textures are towards the top to stimulate the students. The LED panels are designed for visual effects. Painted images on acrylic are backlit by LED strips with red green and blue LEDs that are powered by a rechargeable battery. The LEDs can be controlled via a control box that is to be plugged into one of the panels for interactive use. There is also a painted scene behind the acrylic so that even when the LEDs are not on, a calming ocean scene welcomes the children into the room.

Figure 15. First iteration of the LED panel walls providing visual interactions for the students.

Design Description

There are three different types of connection mechanisms used in the portable sensory room. Firstly, standard door hinges connect the two LED and fabric panels described previously. To avoid the panels opening during transport and to make it easier to fit through a doorway, either side of the panels are held shut using the hook mechanism shown in Figure 17 below. When setting up the room, the teachers can place the panel walls in their desired orientation and then lock the casters into their appropriate places.

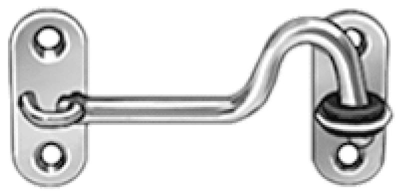

Figure 16. Hook mechanism used to connect panels together.

Figure 17. Locking mechanism used to keep each room component connected when the room is in use.

While the room is in use, the components are attached together with the locking mechanism shown in Figure 18. The three larger components (the bookshelf, the tactile wall, and the tactile station) are all mounted on four casters, which can be viewed in Figure 19 below. Each side of the connected panels, on the other hand, have two casters that are mounted on caster extensions that extend 3.5 inches off the edge of the panel. This extension was designed to improve the balance of the panels when they were opened. The casters rotate in all directions to allow for the maximum range of motion when the sensory room components are in transit. Once the structures are in the desired position, the teachers can activate a locking mechanism via a foot pedal, which prevents both the wheel from spinning and the caster from rotating. Yellow reflective safety strips were used on both the caster brake mechanisms on all of the room components and the caster extensions on the panels. This ensures that all tripping hazards are visible at all times and do not pose a safety risk. An example of these safety strips on the panel walls can be seen in Figure 18.

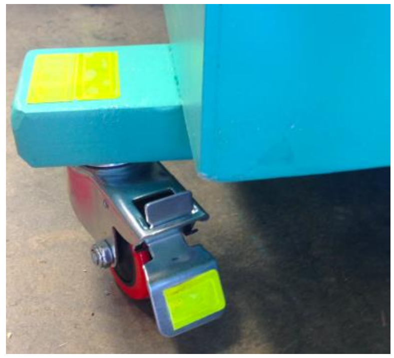
Figure 18. Lockable casters on panel walls with reflective yellow safety strips.

The bookshelf and the tactile station do not have the locking mechanism to prevent the room from being completely closed. Instead when the Portable Sensory Room is installed in a classroom, a gap will remain open which serves as an entrance and exit for the students and teachers. California State Law mandates an easy exit for the students that cannot be locked or permanently closed in any way and the gap meets this specification.

Analysis and Results

The amount of force required to tip the structure over was a major concern with the chosen design. Calculations were initially made using the worst case scenario, which was a single free-standing panel wall out of plexiglass and aluminum extrusions. It was found that a force of 17.9 pounds would be required to tip a single panel over, which can be seen in Appendix F. The panels will always be attached to each other during transit and will never stand alone so it would take a much larger tipping force to actually tip the pair of panels or any of the other panels. The material was changed to wood and the location of where the supports were was changed during the manufacturing phase which renders those previous calculations null. Instead, the panels were tested using a spring gauge to verify that it would not tip under too small of a load. These results can be viewed in Appendix J.

The weight capacity of the structure was another point of concern with the chosen design. The entire weight of the structure is 643 pounds, the breakdown for each component can be seen in Appendix J. Each caster has a load capacity of 300 pounds according to the manufacturer's specifications. The heaviest component was the tactile station which weighed 643 pounds. Since each component has 4 casters, there is a factor of safety of 1.87 for each caster. Since all other components are lighter and will therefore have a higher safety factor, this was deemed more than sufficient for this application. The shelves of the bookshelf were another concern because they would need to sustain the largest load of the whole structure due to the weight of the interactions. Therefore, it was decided that a pair of brackets would be used for each shelf that were rated for a load of 150 pounds each.

Cost Breakdown

The total cost for the room structure, with all components, was $2984.66. The wood and hardware for the structure was purchased from Home Depot so it could be picked up locally with no additional shipping costs. A more detailed breakdown of the costs of the room structure can be found in Appendix E.

Material and Component Selection

Wood was selected as the material to be used for the majority of the room components because of its durability and design flexibility. The components were made of 2x4's, 1x2's, .75" thick white oak, and 3/32" thick hardwood veneer, (detailed manufacturing is discussed in Chapter 5: Product Realization). Plexiglass sheets were also used on the outside front surface of the LED panels. Plexiglass was investigated as a material for the entire room but it was decided that it did not provide the appropriate stability necessary for the room structure. Metal sheets were also investigated but it was decided that they were too heavy for the teachers and classroom aides to manage on their own. Wood was chosen as the strongest and most inexpensive available option.

Next, several factors were considered when selecting the appropriate casters. First, there are two main caster wheel materials that are used when application requires multiple types of flooring: rubber and polyurethane. Since the room structure will travel across cement, asphalt, linoleum, and carpet; polyurethane wheels were chosen over rubber wheels with the aid of Figure 23 below, provided by CasterCity. Additionally, a weight capacity of 200-300 lbs was chosen over less than 200 lbs because it provides a higher factor of safety as well as more flexibility to the teachers who may heavily utilize the storage that will be provided.

Table 1. Caster Wheel Selection Chart from CasterCity.

Match the colored boxes to the different casters as you scroll down this page.

1 = 2" Soft Rubber Wheels
2 = 2" Polyurethane Wheels
3 = 3" Soft Rubber Wheels
4 = 3" Polyurethane Wheels
5 = Twin Polyurethane Wheels
6 = 2 3/8" Twin Rubber Wheels

Floor Surface	Your Weight is LESS than 200 lbs	Your Weight is MORE than 200 lbs	Easy Rolling for LESS than 200 lbs	Easy Rolling for 200 lbs to 300 lbs
Hardwood	1 2 3 4 5 6	2 3 4	1 2 3 4 5 6	3 4
Softwood	1 3	3	3	None
Ceramic Tile	1 2 3 4 5 6	2 3 4	1 2 3 4 5 6	3 4
Marble	1 2 3 4 5 6	2 3 4	1 2 3 4 5 6	3 4
Cement	1 2 3 4 5 6	2 3 4	1 2 3 4 5 6	3 4
Travertine	1 3	3	1 3	3
Linoleum	1 3 6	3	1 3 6	3
Vinyl	1 3 6	3	1 3 6	3
Carpet	4 5	4	4 5	4

Additionally, a large top pedal brake was chosen over floor and side lock options because of its ease of use and its similarity to other lockable casters currently in use at Newland Elementary School. It was decided that the teacher's familiarity with the caster locking mechanism was crucial for a smooth transition when the room is first delivered and used within the school.

Figure 19. Floor lock, side lock, and foot lock examples respectively.

Swivel wheels were also chosen on the casters to provide the greatest range of motion for the room structure when it is in transit. The structure will have to navigate tight corners and narrow hallways to move from one classroom to the next, so it was imperative that the casters provide good maneuverability. Another component that was chosen was the top plate mounting mechanism instead of a friction grip stem or a threaded stem, which can all be seen below in Figure 25. The top plate mounting mechanism offered an easier alternative to manufacturing the components. Since the casters will attach to a flat surface, the top plate will simply be screwed into the specified locations.

Figure 20. Friction stem, threaded stem, and top plate mounting caster mechanisms respectively.

Another consideration that was made was using marking versus non-marking wheels. Rubber wheels tend to be more likely to create black marks on the floor when they are used. By using polyurethane wheels, it will ensure that the room structure will not be making any marks on the floors of the school as it is transported from one classroom to the next. This will ensure that the teachers and classroom aides are as pleased with the room structure as possible.

Meeting Specifications

This final design both meets and exceeds the specifications provided, located in Appendix A. For instance, the final design is aesthetically pleasing, portable, and easily transportable between three classrooms daily. This was achieved with the attached wheels providing the portability, the foldable walls and separate structures allowing 1-2 people to move the collapsed room that will fit through standard doorways and around tight spaces, and the storage space which reduces the amount of time needed to collapse and set up the structure. In addition, the exterior walls will expand the room to fit within the provided 10 ft. by 15 ft. space. Also, the structure is large enough and stable enough to fit one student and one teacher. Furthermore, it provides a student with a permanent, easy exit that cannot be locked or closed and through which the teacher and classroom aides will be able to observe the student at all times.

Risk Analysis

One issue is that fact that the structure does not have a ceiling covering, which may affect the functionality of any lighting effects that are incorporated into the sensory room through the LED panels and the bubble tubes in the tactile station. The lighting of the classroom will need to be turned off during the use of these particular sensory elements. Another possible concern is that the structure will not be stable enough when it is in use. Lockable wheels, u-bolts, and hook mechanisms are all in place so that the room structure is as stable as possible.

Hazard Analysis

The provided Hazards Checklist is located in Appendix H and it identifies all potential hazards that this design might expose the user to. For example, the hinges and room connection hooks create pinching points that might harm the user if he or she places his or her fingers between the wall connections as it is moving. Door stops were placed in between the hinges on the fabric and LED panels to prevent these pinch points. Also, since the structures will be moving from classroom to classroom, there is a risk that the structures could hit a student or a teacher while in transport. Therefore, at least two adults will be needed on either side of each structure to move the sensory room so that if a student does cross in front of the structure, an adult will ensure that the student is not injured.

Figure 21. Rubber door stops used between hinges.

Additionally, there is a possible hazard that the structure will fall and possibly harm the user. The tipping loads of each of the panels were tested and are listed in Appendix J. These tipping loads are of the individual components with casters locked in their transport configurations, i.e. the panels are closed with the faces touching each other. The tipping loads failed to meet the specification; in order to avoid an issue, two adults will be required to move each of the components. When the room is in use, the panels are connected with u-bolts to the adjoining, larger structures which provides enough support from the surrounding components to ensure that the structure is stable. For the hanging objects on the tactile wall, industrial strength velcro with a rated load of ten pounds was used to ensure that there was a minimum risk of any objects falling.

There is another potential hazard risk that a student could be trapped inside the structure and unable to escape in an emergency situation. Lockable wheels will prevent the students from closing the structure and trapping themselves inside it. Once the teacher has set up the room structure to the orientations and locations he or she deems fit, there are no possible alterations to the structure while the wheels are locked. Lastly, there is a risk that a student could be injured inside the structure without the teacher's knowledge. The opening in the room structure is not covered to provide the teachers a way to observe their students at all times.

TACTILE WALL:

Design Description

This portion of the portable sensory room features many stimulating activities for students to explore. The highlighted feature of this wall are two tracks on which fish-shaped handles are mounted, creating a simple activity that allows students to move the fishes in a soothing wave-like motion. There are also sensory bands, a large white board, an abacus, and a gear set attached to the wall that the students can explore.

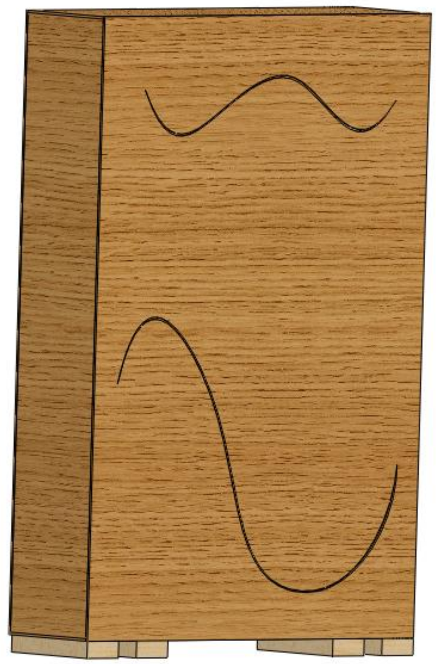

Figure 22. Solidworks Model for Tactile Wall (casters not shown)

Figure 23. Sensory band "Squiglets"

Cost Breakdown

The wall had a total cost of $66.15. By far the most expensive component of this wall is the fine motor gear set, which was about $20.

Meeting Specifications

This wall meets specifications as a part of the sensory room in which the children can actively interact and test new objects and ideas. These moveable activities will allow students to interact with their environment in a safe, predictable way. The soothing motion of the fish partnered with the more complex sensory bands and gears make for an interesting area of the portable sensory room, while avoiding being overwhelming. The tactile wall contributes to the number of tactile interactions in the room by adding four unique activities in the form of the abacus, the gears, the sensory bands, and the guided fish. This fulfills 40% of the required number of tactile interactions. The chosen objects are also large enough to prevent any possible choking hazards.

FABRIC PANELS:

Design Description:

Two of the panels are designated as fabric panels and include a variety of calming and challenging fabrics that maintain the room's ocean theme. Since the sensory room functions as both a space for calming children and a space for exploration and learning, it is important to provide both types of fabrics as an option. With the hope being that once an individual feels comfortable with the fabrics on the comforting sections, they can slowly transition towards trying out more stimulating and less pleasing to the touch fabrics that are located at the top of the panel. The different fabrics are cut and sized to be the length of a child's hand, about six inches. The reasoning behind this being that it allows for the child to be in the most control over what they are touching, leading to less likelihood of overstimulation. All of the fabrics are attached to the walls with velcro to allow for the fabrics to be removed and washed or replaced when needed. A model of the structure of the fabric panels can be seen in Figure XX below. The velcro is attached directly to the front of the panel.

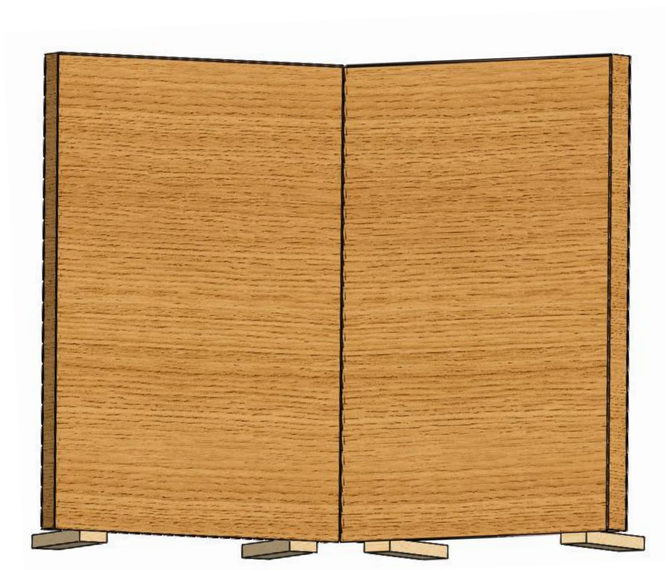

Figure 24. Solidworks Model of Fabric Panels (casters not shown)

Cost Breakdown:

The two fabric panels have a total cost of $172.24. The most expensive components of the panels being the velcro at $40. Majority of these fabrics were purchased in store from WalMart, some fabric was also donated by Betty's Fabric in San Luis Obispo. A more detailed cost breakdown can be found in Appendix E.

Meeting Specifications:

The fabric panels meet the specifications for the sensory room by providing an opportunity for tactile sensory interactions as well as providing a calming therapeutic environment. These fabric panels help the portable sensory room meet the criteria for a minimum of ten tactile interactions.

LED PANELS:

Design Description:

As seen in Figure XX, the LED panels consist of a similar frame to the fabric panels. Instead of having two sides of veneer, however, the LED panels have one side of acrylic which is backed by strings of red, green, and blue LED lights. The acrylic and the wooden background veneer has sea life painted on it to create a calming visual effect with or without the lights turned on. The lights are controlled via a control box with buttons and knobs that will change the lights and brightness.

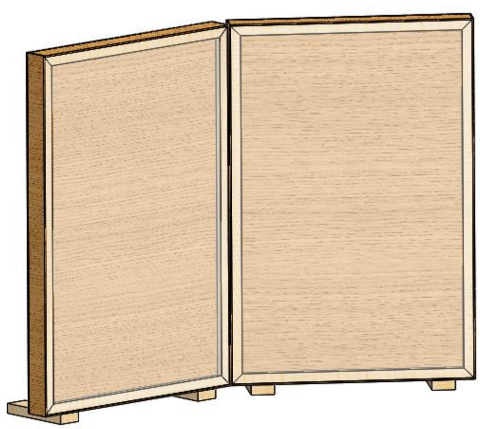

Figure 25. Solidworks model of the LED panels (casters not shown)

The interactive nature of the silhouette panels was designed to build a cause and effect relationship between the control box and the LED lights. The interaction with the control box was designed to be simple so that the students could easily use it on their own without the teacher's help. When the control box is not being used, the lights can remain on to serve as a simpler, non-fluctuating display. This duality allows the children and the occupational therapists the flexibility and maneuverability for choosing how to exactly use the LEDs on a child per child basis.

Cost Breakdown

The LED panels cost a total of $478.41. The most expensive component of the LED apparatus was the acrylic sheet at $108.99. The cost breakdown of the LED Panels is included in Appendix E.

Meeting Specifications

Two of the specifications defined in this project are the requirement for at least five visual interactions and three explorative programs. The LED Panels fulfill two visual interactions and one explorative program, in that it helps the children explore a cause and effect relationship. In terms of the hardware, the specifications that are specific to the LED Panel are in terms of the power, battery life, and lighting effects. All of these specifications are met by our hardware and will be discussed later in the report.

FINE MOTOR ACTIVITIES/ BOOKSHELF:

Overall Layout

Figure 26. Solidworks Model for the Bookshelf (casters not shown)

There are a multitude of activities that are available for use in the bookshelf, whose Solidworks model is available in Figure XX. The teacher or the student can then pull out any of the desired activities for the children to use on the floor of the sensory room, which allows for more room to strengthen their fine motor skills. The activities that are included are; a gel maze, fidgets, peg boards, an activity with bead lacing, connecting rubber bands on pegs, and a clothing doll with zippers, buttons and clasps. These fine motor activities focus on increasing finger and hand dexterity, strength, and flexibility. They are critical for children's development, augmenting their ability to harness the control and strength necessary to independently complete the instrumental activities of daily living such as: tying shoelaces, holding a fork to eat food, and holding a pencil correctly in order to improve handwriting skills.

Design Description

Many discussions were held during the brainstorming stage of this project regarding how to best incorporate a multitude of fine motor activities within the sensory room. The original idea was to integrate the fine motor station within a tactile table that would fold out from the wall. The tactile table would include activities that provided tactile sensations and worked on increasing fine motor control, strength, and dexterity of the hands and fingers. However, due to the high number of different fine motor activities that were to be included, it was decided that it would be unfeasible to include them all within the tactile station. The more variety that could be provided, the better. The decision of including a bookshelf was to create a space for the teachers to provide their own sensory elements, creating a more personalized and familiar space for the students. The bookshelf is also a great space to be utilized for storage of the fine motor activities. The shelves have ledges in order to secure the objects during transport and two of the shelves hold containers for loose objects or storage for the teachers.

Figure 27. Gel Maze

The gel maze pictured above is designed so that objects can be traced around a designated path to facilitate learning and to emphasize fine motor control. The gel maze was purchased from Amazon, see cost breakdown in Appendix E for further details.

Figure 28. Peg Board

The peg board utilizes fine motor control by having the child carefully pick up the peg and place it in the desired hole. This can be made more challenging by arranging the pegs in certain patterns or requesting that only a certain color peg be utilized. The pegs can also be stacked on top of each other, requiring even more precision. Peg boards were purchased from Amazon, see cost breakdown in Appendix E for further details.

Figure 29. Bead Lacing

The activity displayed above works on developing fine motor skills through improving finger dexterity and hand eye coordination by stringing beads. These items were purchased from Amazon, see cost breakdown in Appendix E for further details.

Figure 30. Geo Board

Geo boards are another type of peg board to increase fine motor control and dexterity is an activity that involves connecting rubber bands onto pegs. Once again, the instruction can be to create different designs or shapes to also help the child learn. These geo boards were purchased from Amazon, see cost breakdown in Appendix E for further details.

Figure 31. Fastener Tools

These fastener tools provide activities such as zippers and buttons, allowing the students to practice fine motor control and dexterity in direct relation to everyday activities, such as buttoning a shirt or zipping up a jacket. It is common for children to experience frustration when they are unable to fasten their clothing on their own. Two types of fastener items were purchased for clothing fasteners practice: one item includes a monkey with overalls with three different types of fasteners and shoes to practice lacing tennis shoes, the other item was a whale with five separate types of buckles and a zipper.

Cost Breakdown

The fine motor station cost a total of $231.07. Most of the items were purchased through Amazon. A more detailed Bill of Materials can be found in Appendix E.

Meeting Specifications

The variety of fine motor activities meet the specifications and will aid in improving fine motor control as well as strength and dexterity in the hands and fingers. By storing all of the activities in the bookshelf, it contributes to the overall portability of the room.

TACTILE STATION:

Design Description

The tactile station, the model which is shown in Figure XX, is comprised of two components: a lower section of drawers for storage for tactile activities and an upper section that houses bubble tubes which create a visual interaction for the user.

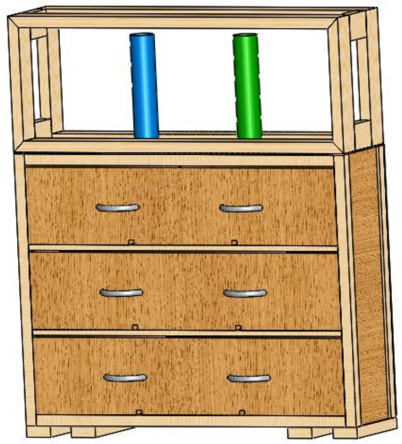

Figure 32. Tactile Station Solidworks Model

The tactile drawers have customizable interior layouts intended to house tactile interactions of the teachers choosing. The layouts are comprised of slots in sides of the drawers, so the teachers can orient the partitions to create any sized space they desire.

Figure 33. Drawer partitions to organize the tactile station

The bubble tubes are intended to add an element of light that is non-abrasive for the children. The purpose of this is to be able to incorporate visually stimulating elements that will not deter from the function of the room as a calming space. The initial concept was to construct the bubble tubes using water and a pump, but it was decided that this would be too noisy and heavy to benefit the room. Instead of this, the final design includes fluctuating LED lights placed within opaque cylinders that distort the light enough to make it soft without blocking it completely. The

LED lights are controlled by a remote mounted to the tactile station which has only two buttons for simplicity: one for power and one for toggling the various light effects. The housing for the bubble tubes is enclosed on all three sides which are painted with a reflective coating to add to the soft light. The bubble tubes are out of reach to most of the children, but there is a possibility that older or taller children will be able to reach them. This is not a concern since everything is loosely mounted so it will not damage the display to remove it and all of the components are safe for the children to interact with closely.

Cost Breakdown

The cost breakdown for the tactile station can be seen in Appendix E. The cost totalled $271.44.

Meeting Specifications

Although the tactile station does not directly meet any stated specifications, it provides space for storage for the tactile interactions which are a requirement. This storage space is also extremely customizable to the teachers' preferences which is a desirable customer requirement. The bubble tubes support and add to the function of the room as a calming sensory space. The final design meets specifications because it contributes to the goal of at least five visual interactions, as well as the ability to turn stimuli on or off.

PRESSURE APPLICATOR:

Design Description

The chosen concept for the pressure applicator is the “Single Squeezer,” shown in Figure 37, a modified design of a product currently on the market. The “Single Squeezer” is a stand-alone object and can travel and operate independently of the sensory room. It is up to the customer to determine whether they would like to place it inside the sensory room or not while in operation. The “Single Squeezer” operates by using two rollers. The bottom roller is fixed and can only rotate about its own axis, while the top roller is attached to two arms at either end and can move up down. The top roller also has a rubber band at either end that is connected to the larger section of wood via an eye hook that creates a downward force and exerts pressure when extended. Additionally, a solid aluminum shaft was chosen as the shaft to be able to properly support the children and make the top roller heavier for the child.

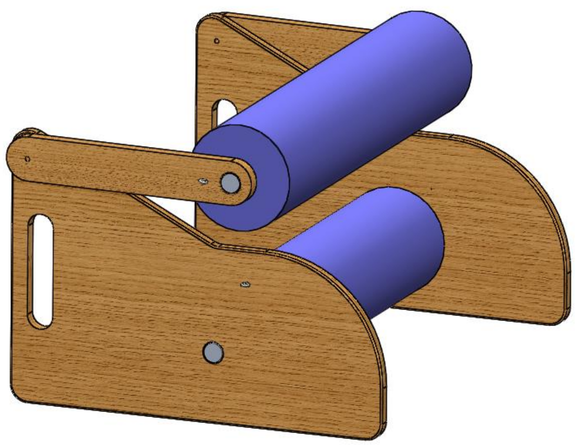

Figure 34. Final Pressure Applicator Design

Component Selection

The “Single Squeezer” mechanism is relatively simple and therefore has a limited number of components. The rollers were chosen to be made out of an aluminum core shaft, with therapeutic foam rollers surrounding them for comfort. 6061 Aluminum was chosen, because, although it is much weaker than steel, it is also much lighter which was an important aspect to consider given that this mechanism can be moved by the teachers at least three times a day if not more. The lighter rollers means that the entire unit is much lighter and easier to transport. The fact that aluminum is weaker than steel means that the shaft must be larger to support the same load, however it is desirable for the rollers to be as large as possible to increase the contact area with the student so the added volume is not a concern. Both 6061 Aluminum and 2024 Aluminum were considered, but the difference in shaft size was not significant and the 6061 is much more readily available. The therapeutic foam rollers were chosen because their firmness is able to exert a good amount of pressure and the material is easy to cut which simplified changing the lengths and boring the center.

The shape of the sides of the pressure applicator were mostly based off of the on-the-market product because its smooth edges and geometry met the needs of this project exactly. In order to determine which type of wood should be used, the hardness of various types of woods were researched. This research yielded the chart shown in Figure 38. The harder of the woods were investigated to determine the most available, as well as better priced options. After this comparison, the final choice of wood was White Oak. It is one of the hardest woods, which means that it is the hardest to mar, which is an important aspect since the pressure applicator will be used by children.

Table 2. Varying hardnesses of different hardwoods

Species	Pressure To Mar
(Kiln-dried)	(in pounds)
Hickory, Pecan	1,820
Hard Maple	1,450
White Oak	1,360
Beech	1,300
Red Oak	1,290
Yellow Birch	1,260
Green Ash	1,200
Black Walnut	1,010
Soft Maple	950
Cherry	950
Hackberry	880
Gum	850
Elm	830
Sycamore	770
Alder	590
Yellow Poplar	540
Cottonwood	430
Basswood	410
Aspen	350

Source: Wood Handbook: Wood as an Engineering Material, USDA, Washington, D.C.

Originally, bushings were chosen for the wood to metal shaft interface, however after manufacturing it was determined that metal shaft spun easily against the wood and the bushings were not needed. In order to keep the wood appropriately located on the shaft and remove the sharp edge of the shaft, rubber feet were added to the ends of the shafts.

The detailed drawings of the components being manufactured, as well as the assembly drawing of the Single Squeezer are included in Appendix D.

Detailed Analysis

Analysis was performed in order to determine the required sizing of the core shafts. The analysis was performed assuming infinite life and a distributed load of 150 pounds applied cyclically to the bottom shaft. Both the bottom shaft and top shaft were designed identically; the bottom shaft is expected to see the most use so that is the shaft that the analysis was performed on. The bottom shaft is slightly shorter than the top shaft due to the geometry of the design, since the pivoting arms are farther apart than the side supports. This difference in length is small (about 1.25 inches) and is considered negligible since the required safety factor is so large. The rotation of the shafts were ignored since the angular velocity would be extremely slow as the child moved across them. The load of 150 pounds is quite large and assumes that the child is placing all of their weight on the shaft, while in actuality the children will only be able to put a portion of their bodies' on the shaft at once, which makes this analysis conservative, which is desirable when dealing with human factors. Since this load force was so large, the weight of the shaft itself was neglected in calculations. The hand calculations for this analysis can be viewed in Appendix G. The Soderberg method was used to determine the safety factor from a variety of diameters, the result of which is shown in Table 41. A minimum acceptable safety factor of 3 was chosen, since this project is dealing with humans; the first nominal shaft diameter that occurs is at 1 ⅛" with a safety factor of 3.34.

Table 3. Results from Soderberg Method Given Diameter

D (in)	σ (psi)	n
0.5	34062	0.29
0.55	25591	0.39
0.6	19712	0.51
0.65	15504	0.65
0.7	12413	0.81
0.75	10092	0.99
0.8	8316	1.20
0.85	6933	1.44
0.9	5840	1.71
0.95	4966	2.01
1	4258	2.35
1.05	3678	2.72
1.06	3575	2.80
1.07	3476	2.88
1.08	3380	2.96
1.09	3288	3.04
1.1	3199	3.13
1.125	2990	3.34
1.15	2800	3.57
1.2	2464	4.06
1.25	2180	4.59
1.3	1938	5.16
1.35	1731	5.78
1.4	1552	6.44

Prior to manufacturing the Single Squeezer, analysis was performed to determine the necessary spring rate of the rubber bands. The roller must be able to supply a pressure between 15- 30 PSI to the child according to the specifications. The calculations were performed assuming that the child is in contact with a one inch by twelve inch contact area and also assumes that the bungee cords respond linearly. This assumption could be incorrect so testing will be performed to verify that the bungee cord will be able to supply the necessary force to obtain a pressure within the 15-30 PSI specification range. The value of 30 PSI is a maximum so the spring rate was necessary spring rate was calculated using a desired pressure of 25 PSI. The hand calculations are available in Appendix G. The required spring rate of the rubber bands based on these assumptions is 16.6 lbs/in. At this point in the design, springs that could be used as a backup were researched and are also included in the Appendix G with the hand calculations. During manufacturing however, it was decided that it would be better to use rubber bands instead. In order to achieve a higher pressure, the teacher simply installs additional rubber bands. Thus the exact spring rate is unnecessary to find, since the teacher can adjust the applied pressure by adding or removing rubber bands to meet the child's exact desires whether that is less than 15 PSI or within the 15-30 PSI range. It would take more rubber bands than could fit in the eye hooks to exceed the maximum specification of 30 PSI, so that specification is met.

Cost Breakdown

The cost of each of the components of the Single Squeezer is listed in Appendix E. The total of the pressure applicator came out to $143.68, which is dramatically cheaper than the option of purchasing the on-the-market Single Squeezer for $470.

Risk Analysis

This design is relatively simple so there are a minimum amount of risks involved that would cause it to fail to meet the specifications. The major specification that the pressure applicator must meet is the ability to provide a pressure between 15 PSI and 30 PSI. Whether the bungees will be able to meet this specification will be determined through testing. However, even if the bungees fail, the team has specified springs that could operate as backups, which makes this a low risk.

Hazard Analysis

A hazards analysis checklist for the Single Squeezer has been completed and is attached in Appendix I. There were a few items that cause additional discussion. The first statement inquires whether there are potential pinch points in the system. The only known pinch point occurs between the arm and the top of the side support of the pressure applicator, see Figure 41. This arm can move up and down; if the child were to place their hand on the side while the arm was raised and manage to release the roller at that time, there is potential for the fingers to get caught in between. However, this would be a difficult maneuver for the child to complete since they would be required to reach behind them and upward as they travel through the pressure applicator so it is unlikely they would ever find themselves in that position. If they were able to get into that position, the bungee would be close to its resting position and would be exerting very little, if any, force which means that the force on the hand would be very low and unlikely to cause any damage. If there were two children and one child's hand was in the pinch point and another child jumped on top of the top roller, then some damage could occur, however this item will only be used with one child at a time and under constant adult supervision which greatly limits the chances of that occurring.

Figure 35. Potential Pinch Point of Pressure Applicator

There is stored energy in the system in the form of the rubber bands. The rubber bands will be at - or close to- their unstretched length when the system is at rest so there will not be any stored energy when the system is untouched. The stored energy occurs when the child stretches the top roller away from the bottom roller and the rubber band applies a force. The rubber band will not be required to stretch far to exert the desired pressure so it is unlikely that the rubber band will be so tense that it will "snap" back into place. If the pressure applicator is being used appropriately, the rubber band will gradually return to its unstretched length as that child travels through the rollers. In order to get some kind of "snap" the top roller would have to be pulled up without a user in between the rollers. The children will only be using the pressure applicator under adult supervision and will not be allowed to use the machine in this way.

Maintenance/ Repair

The Single Squeezer is being designed with durability in mind so ideally none of the major components will wear out or break over the course of ten years. One item that will require attention is the rubber band. The rubber band is expected to wear out with continuous use, so to alleviate that, several rubber bands were given to the school so that they can be replaced periodically . The system will need to be continually cleaned, as is the case with most items in a classroom. The vinyl rollers and wood sides can simply be sprayed with a disinfectant and wiped down.

Meeting Specifications

The specifications specific to the pressure applicator are its ability to apply between 15 to 30 PSI to a child and its ability to support a load of 150 pounds. The flexibility to add as many rubber bands to achieve whatever pressure the child desires meets the pressure specification. The analysis shows that the system will be able to withstand a force of 150 pounds, and testing was performed to verify that claim is accurate.

SWING:

Description

The swing support is a portable tripod support with telescoping legs that have three different height settings.

Cost Analysis

The swing support was purchased from Amazon for $105.60.

Meeting Specifications

The swing structure and the attachments purchased for it all meet and exceed the weight specification of 150 pounds. The swing structure will also be stable and portable as specified. A rotational attachment was purchased to ensure that the swing supported a wider range of motion necessary for occupational use.

Figure 36. Rotational swing attachment and carribbeaner

Figure 37. Swing Support

CHAPTER 5: PRODUCT REALIZATION

ROOM STRUCTURE:

Figure 38. Completed Room Structure at Senior Expo

Figure 39. More detailed view of the room at the Senior Expo

There were several different manufacturing processes used to create the room structure. Each of the LED panels and fabric panels are composed of an internal frame of 2x4s joined together to form a rectangular frame by miter joints. The tactile wall is comprised of 3 more of these internal frames fixed together to create a sturdier structure of 12” x 48” x 36”. Douglas Fir 2x4s were also used for the framing of the bubble tube enclosure and the back supports of the dresser section of the tactile station. Pine 1x2s were utilized to support the veneer in the LED panels, the fabric panels, and tactile wall, as well as for the drawer keys and the trim of the tactile station, and the tactile wall. Pine 2x2’s were implemented as supports of the dresser of the tactile station and as the posts for the bookshelf. All of the lumber used in this project was cut using a compound miter saw, table saw, or hand saw. The frames of each of these components was then covered in a thin plywood veneer skin 7/32” thick to create a uniform look for all of the room components.

The bookshelf and the pressure applicator was constructed out of ¾” white oak. The bookshelf components were cut on the table saw and then biscuit-joined together. The sides of the drawer portion of the tactile station was also constructed using the same biscuit-joining method. The pressure applicator pieces were cut using a laser cutter and then sanded to achieve a smooth edge. The 0.125” thick plexiglass used to create the faces of the LED murals was cut using a table saw.

Each edge of all of the components was sanded to create a uniform finish and eliminate sharp edges for safety using a combination of an orbital sander, belt sander, and spindle sander.

Door hinges, shown in Figure XX below, were mounted between the LED panels and between the fabric panels using 0.125” screws in pre-drilled pilot holes. The hinges were placed eighteen and thirty-six inches from the bottom of the panels, making them equidistant from the edges.

Two hooking mechanisms, seen in Figure XX below, keep the two-panel components (the LED panels and the fabric panels) closed and secure while in transit. Four 0.125” inch screws were used to mount the hooking mechanisms 40 inches from the bottom of the panels and ⅜” inches from the edge.

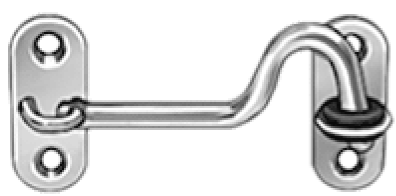

Figure 40. Hook mechanism used to connect panels together.

Figure 41. Locking mechanism used to connect room components while the room is in use

The sliding door locks shown above in Figure XX are used to connect the room components together when the room is in use. These bolts were selected because they provide a small enough clearance between the room components to create a uniform space when the room is set up. They also provide a secure enough connection to allow the room to stay attached if the room is jostled or moved. 0.125” inch screws were used to mount the sliding door lock mechanisms 45 inches from the bottom and ⅜” inches from the edge.

The selected casters are equipped with a top plate mounting mechanism with four holes each, as seen in Figure 49 below. The casters were mounted to 2x4 blocks that will attach to each room component. 0.25” washers were used to hold the screws in place. ⅜” screws that are 2.5 inches long were used to attach the 2x4s to the bottom of each of the components.

Figure 42. Selected casters with visible top plate mounting mechanism complete with six different holes

The only custom components that were manufactured by the team were the components of the pressure applicator whose drawings can be viewed in Appendix XX. Stock parts were purchased at different locations which can be seen in greater detail in our final Bill of Materials in Appendix E. Throughout all of the manufacturing processes mentioned above, proper safety protocols were followed.

The room structure was finished using a double layer of primer and a double layer of high-gloss paint. The selected primer was a white water-based latex paint that served as a sealer and stain-blocker. It also was used for both interior and exterior applications, which was necessary since the room will be traveling outside while it is in between classrooms. The final coat was a high-gloss paint that was also designed for either interior or exterior use. It also was a low VOC paint (low level toxic emissions) which was ideal for a classroom application. The high-gloss created a more aesthetically pleasing look and also makes it easier for the teachers to clean the surfaces of the room. The color that was chosen was a light teal color that corresponded to the ocean theme and provided a calming effect for the students.

TACTILE WALL:

For the tactile wall, a jigsaw and a router was used to create the two tracks on the front layer of veneer for the fixed motion tracks, which can be seen below in Figure XX. The fish pieces were mounted to a bolt which had a large washer on the back, keeping the fish attached to the board. 200 grit sandpaper was used to smooth the rough edges of the tracks. 3/16” thick white board material was purchased in 2 foot by 4 foot segments and cut using a bandsaw into a 15 inch by 36 inch section. The white board, abacus, gear set, and sensory bands were all mounted on the front of the tactile wall using adhesive velcro. The remaining whiteboard was cut up in square segments to be stored in the bookshelf to be used as personal whiteboards either inside or outside of the sensory room.

Figure 43. Tactile Wall

FABRIC PANELS:

Figure 44. Fabric Panels

The final fabric panels are pictured in Figure XX. Wooden veneer panels were attached to the sides and top of the two fabric panels. Fabric was cut in appropriately sized strips using fabric scissors.

The main sections of fabric were created using a quilting type of technique using a sewing machine (Figure XX). A large piece of donated fabric was used as the backing, strips of fabric were sewn together, and the two were sewn together and filled with batting. Various ribbons were sewn between each strip to reinforce the seams and provide additional textures.

Figure 45. Backing of quilt-style fabric sheet being sewn

Burlap strips were created for each panel as well, with different colors of fabric used for backing and strips of other fabric used to differentiate the strips and provide additional textures and aesthetics. Velcro was attached to the back of the fabric sections/strip and to the front veneer on each panel to attach the fabric to the panel.

Figure 46. Burlap fabric layers

LED PANELS:

Figure 47. LED Panels to fulfill visual interactions

Two LED Panels were built as shown in Figure 28, both of which consist of silhouettes of different sea creatures painted onto the acrylic panels. A background seascape was painted on wooden veneer sheets and mounted an inch behind the acrylic panels. The painted items on the acrylic are backlit by RGB LED strips that have been mounted to the back side of the acrylic and behind the paint. Each panel with LED strips is powered by a rechargeable lithium-ion battery that can be removed by the teacher to allow for recharging of the battery away from the Portable Sensory Room, the batteries are also able to power the LED strips and recharge from a wall outlet simultaneously at the teacher's' discretion. A wooden box with a mix of buttons and turning knobs will control the LED lights when the box's cable is connected to the that specific panel. The panel not connected to the control box is able to keep the LED lights on but any modification of the RGB settings of that panel is not possible (the control box is required for visual control).

A wooden veneer panel was placed one inch inside the LED panels. Sketched sea-themed drawings were projected onto the wooden veneer murals using a document camera. These images were then traced using a pencil before acrylic paint was used to create the desired images, which can be see in Figure XX. Finishing nails were used to attach the inner veneer layer to the internal 2x4 and 1x2 supports inside the panels. A slot was cut using a hand saw that was eight inches by three inches so that enough clearance was made for the battery to easily slide in and out.

Acrylic was placed on the outside of the LED panel, directly in front of the the wooden veneer. A 0.125” acrylic drill bit was used to drill pilot holes into the plexiglass. A countersink tool was attached to a hand drill to create a sink for the heads of the screws to fit into when the acrylic was screwed into place. An access panel was needed so that the teachers would be able to easily reach the battery to remove it for charging. A six inch by thirty-six inch piece of acrylic was attached to the bottom of the larger four feet by three feet piece of acrylic using self-closing overlay hinges from Home Depot, which can be seen below in Figure XX. The same 0.125" acrylic drill bit was used to create five holes for each hinge. Bolts were used to secure the hinge to both sides of the acrylic. Two hinges were placed at twelve inches from either end of the LED panels.

Figure 48. Self-closing overlay hinge

The silhouettes on the LED panels were painted on free-hand with acrylic paint and a clear gloss polyurethane coating was sprayed over the finished paintings for protection against the elements. Acrylic paint was chosen for both murals because oil-based paints can melt or damage the acrylic sheets. A high-gloss polyurethane sealant was also used on both the acrylic murals and the wooden veneer murals to ensure that the murals will experience less cracking and fading over time.

The panel design can be split into three electronic components, two sets of 3528 RGB LED strips with one accompanying 12v DC 8300 mAhr battery per panel and one stm32L476RG-nucleo microcontroller (mcu) with four accompanying AA batteries to power it. The mcu and it's housing can connect to either of the panels via four pin male-female cable connectors which have clips to prevent disconnection while in use. The 4 wire cable has been securely mounted on both the panels as well as the control box so that any tug or yank will not disconnect any of the circuitry.

The LED strips when using the control box, are driven by three pulse width modulated signals (pwm), one for each color. The driving circuitry for the LED strips is shown in first schematic found in Appendix D. Three Fairchild N-channel MOSFET power transistors are controlled by the pwm signals sent out by the mcu. The transistors in turn control the ground for each color on the LED strip. When a transistor's gate voltage is driven high, the transistor allows for current to drain through to the source or common ground. This pulls the ground for that color of the LED strip down to the common ground, thus turning on the LED by allowing current flow through the series of LED lights as well. When a transistor is turned off by a low signal to its gate, the ground for that color LED becomes 12v, this creates a zero voltage drop across the LEDs on the strip and with no voltage drop there is no current and thus the LED lights go off. A 10 kΩ pull up resistor was placed on the gate of each transistor to remove any floating signals to the transistor when the mcu is not driving the transistor. A pull up resistor was chosen so as to pull the LEDs up to an on state when the the control box is not in use. A pull down resistor would pull the transistor's gate voltage down to ground and turn off the lights, meaning that the lights would be useless without the box plugged in.

The final box design is shown in Figure XX. There are a total of six buttons and three rotational potentiometers (knobs). Two buttons will turn the micro controller on and off, white and black, three buttons will isolate each of the red, green, and blue LEDs and the final button (yellow) will create a gentle blinking effect on the LED strips. The three knobs will drive the red, green, and blue pwm signals proportionately from the values read from each respective potentiometer. The knobs allow for mixing and matching the colors on the panel.

Figure 49. Control Box

TACTILE STATION:

Figure 50. Tactile Station with Bubble Tubes

Figure 51. Close up of Bubble Tube Enclosure

The tactile station was manufactured in two separate components: the dresser and the bubble tube enclosure. The dresser was manufactured by making the frame out of 2x4s, 2x2s, and 2x1s. The drawers were built out of white oak and were assembled via biscuit joining. Dividing panels were cut out of veneer and adhesive slots were installed in the drawers to allow for the teachers to arrange a configuration that they think would be best.

The bubble tube enclosure was created out of a frame of miter-joined 2x4s. Veneer was placed over this frame on three sides and spray-painted with a metallic reflective coating in order to allow the light to reflect softly off all sides. The tubes were created out of flexible cutting board material; thick gauge wire was wrapped around the inside of the tubes and the LED string lights were wrapped around this wire in order to achieve a stable column of lights. Structures similar to free-standing paper towel holders were built to provide additional stability for the bubble tubes. The LED string lights were purchased from Amazon and came with a variety of different lighting patterns such as steady-on, slow glow and fade, and flash. The desired mode can easily be selected by pressing the “Function” button on the remote that was attached by adhesive to the front of the tactile station.

PRESSURE APPLICATOR:

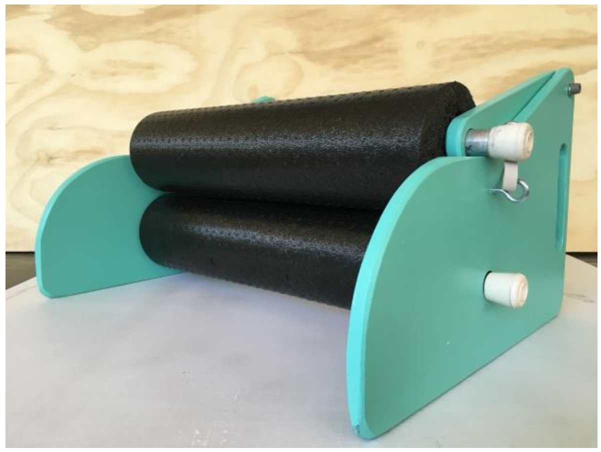

Figure 52. Fully built pressure applicator

The outline of the sides and arms of the pressure applicator were laser cut from a sheet of plywood of white oak to match the drawings found in Appendix D. Once the outline was deep enough for a saw to easily follow the path, a bandsaw was used to remove the excess material. Every piece was then sanded in order to obtain smooth edges.

The shafts were cut to length by the manufacturer (Metals Depot) so they were shipped ready to install on the machine. The two foam rollers were purchased from Amazon. The center bore was started using a 1" drill bit, after that a PVC pipe with a sharpened edge (similar to a hole saw) was used to bore all the way through the roller. The rollers were slid onto the shafts and through the wood pieces, then rubber caps were installed to hold the rollers in compression and to cover the sharp ends of the metal shafts. The clearance bolts for the connection between the sides and the arms was tightened, but remains loose enough for the arm and side to easily slide past each other. An eye hook was screwed into both sides of the pressure applicator and the lever arm which is where the rubber band is installed to exert pressure.

SOFTWARE DEVELOPMENT:

The software for LED control was written in C and used the ARM mBed online development platform to write and compile the code into a .bin file to be uploaded onto the STM32-L476RG microcontroller. The software reads in the analog voltage values from the three potentiometers and if there is any change from the last reading a proportional duty cycle is written to the pwm signal output. The frequency of the pwm signals remains at a constant 1 kHz. When one of the corresponding RGB buttons is pressed, that color is turned fully on and the other two colors are turned off. The function button (yellow) will slowly blink all three colors on and off at a one hertz frequency. Keeping overstimulation and epileptic response in mind, the blinking lights were tested with a dark room and a frequency of five hertz. The LEDs are low power and thus have low brightness even at full power, this means that even at frequencies in the 5 to 30 Hz danger zone for epilepsy, overstimulation will not be a concern for the students. The two remaining black and white buttons are separate on and off buttons. Using the deep sleep capabilities of the microcontroller, the buttons will either wake up or put to sleep the micro controller. With the pull up resistors on the MOSFET's gate, the off button may not seem to work but the button does not intend to turn the LED lights off but simply turn off the microcontroller. Along with the buttons to put the mcu to sleep, a software timer was implemented so that after five minutes of no use, the mcu will enter deep sleep mode for power saving purposes.

CHAPTER 6: DESIGN VERIFICATION

The specification verification checklist is available in Appendix J . The summaries for the main structures' testing are given below.

ROOM STRUCTURE:

The following testing procedures were conducted for each component of the room structure. Each component was placed on four scales (one caster on each scale) in order to evaluate the weight of each component to ensure that it met our specifications of below 100 pounds. A table of the various weights of the components can be viewed in Appendix J with the Specification Verification Checklist. As can be seen in the table, none of the components met this specification besides the pressure applicator. However, this is still an acceptable product. The 100 pound specification was developed before the final design was achieved, so the team was unsure if the teachers would be lifting or carrying the items at any point in transport. The only item that will actually be carried will be the pressure applicator, which is well within the 100 pounds specification. The other components are all on casters and take less than a 100 pound force to move. The original goal of this specification was to limit the amount of force necessary to transport the room and all of the components are able to meet this desire.

A standard tape measure was used to verify that the room structure falls within the required space parameters of 8ft x 10ft x 15ft. The room structure is obviously quite fluid and can be changed to meet the teachers' desires, however the team was able to fit the connected room into an area of 4 ft 9" x 8ft x 10ft when pressed for space at the Cal Poly Senior Expo so the team is confident that the room meets this specification. Each of the components was also measured to verify that all items would be able to fit through a standard doorway as well as transported through several different doorways to validate those measurements. The measurements can be found in Appendix J as well. The room was also transported, connected, and unconnected several times to verify that the desired time for "installation" and "take-down" was within the 10 minute time period and the team was able to meet and exceed this expectation. Another specification called for the exit to be more than 28" wide. This specification will be up to the teachers to maintain every time they install the room, however the team has found that the room fits comfortably in the desired 10ft x 15 ft space with an exit larger than 28 inches so it should not be difficult for the teachers to meet this specification. A spring gauge was used to test the tipping loads of all of the individual components, the results of which can be seen in Appendix J. None of the components met the original tipping load specification of 50 pounds. In order to prevent this from becoming an issue, two people will be required to move each of the components. When the room is completely connected together, the entire structure is much more stable than any component by itself and does not present a tipping concern.

LED PANELS:

The specifications of interest that were analyzed were the power and lighting effects. The power specifications are 120 Volt maximum and 60 Hz maximum coming from any wall outlet that will charge the 12v battery pack. The LED strip will run at 12 volts DC and up to 2 amps, the max power consumption will be 24 watts. The button box will run at 3 volts DC and up to 2.78 milliamps, the max power consumption will be 8.35 milliwatts. The battery life requirement is that the non-rechargeable battery will last for 3 months (1400mAh) before needing to be replaced. The standard alkaline AA battery has a life of 2500mAh so the button box will be able to run for over six months before the batteries will need to be replaced. The battery life requirement for the rechargeable battery pack will be to last for a minimum of one eight hour day of school (16 Ah). The battery pack that will be used for the LED has a capacity of twenty amp hours (20Ah) and will be able to power the panel for a full ten hours per charge.

One lighting effect specification is that the LED strips will give off less than 1000 LUX. The LUX is a function of the lumens the light source outputs as well as the area that the light will be shined on. Assuming that the LED strip casts light over a 2 ft radius, the corresponding lumens for 1000 LUX is about 4669 lumens. The LED strip is stated to output 60 lumens per watt; the LED strip will receive a maximum of 24 Watts which creates 1440 lumens, well within our specification. One other specification that the LED Panels must meet is that they do not flicker at any rate that could induce epilepsy. The microcontroller will take these values into account and prevent the system from pulsing at those specific frequencies. Another specification that the LED Panels fulfill is the ability for the interaction to be turned on or off. There will be a power switch for the entire panel for the teachers to use when closing up the room, as well as the buttons that the child will be able to use.

PRESSURE APPLICATOR:

The pressure applicator specifications are the ability to apply between 15 and 30 PSI to the user and to support a load of 150 pounds. For the pressure, hand calculations were performed to determine the necessary spring rate for the rubber bands using the weight of the shaft and the roller. The necessary spring rate found is 16.6 lbs/in. This calculation was performed when the design was to use one bungee cord, however since the design was changed to using rubber bands this calculation is rendered null. The teachers can add as many rubber bands as needed to meet each child's desired pressure application so finding an exact spring that meets this requirement was rendered unnecessary. Those calculations can be found in Appendix G, which For the load test, each shaft was subjected to a load of 150 lbs. Both shafts easily supported the 150 pound load and therefore meet this specification.

SWING:

The manufacturer rated loads meet and exceed the required loading specifications. The swing structure is rated to support up to 350 pounds, exceeding the requirement of supporting 150 pounds. This rotational swing attachment is rated for 1,000 pounds. A caribeeaner was also purchased to connect the swing to the rotational attachment which was rated for 5,000 pounds. Both of these far exceed the 150 pound weight requirement and are therefore deemed as safe.

CHAPTER 7: PROJECT MANAGEMENT PLAN

The team operated with the following roles:

1. Team Lead: Sarah
    a. Ensures all design and manufacturing decisions are cohesive
    b. Ensures design decisions correspond to requirements
    c. Oversees the design and manufacturing of the room structure
2. Communications Officer/Secretary: Lindsey
    a. Main point of communication with Sponsor
    b. Facilitate meetings with Sponsor
    c. Maintains Google Docs
    d. Oversees the design and manufacturing of the pressure applicator
3. Systems Engineer: Kaylee
    a. Maintains Google Calendar
    b. Oversees the design and manufacturing of the fabric panels
    c. Maintains budget
4. Director of Research: Emma
    a. Provide empirical research for therapeutic applications and functions
    b. Ensures all components of the room are therapeutically sound and child safe
5. Chief Technology Officer: Nate
    a. Ensures all electrical components are practical, safe and effective
    b. Leads and facilitates the design and debugging of all code
6. Associate Director of Research: Claire
    a. Keeps meetings on track and ensures meeting goals are achieved
    b. Acts as mediator to ensure all conflict is positively addressed in the team
7. Child Development Representative: Alex
    a. Research socialization and funding of schools, specifically special education classes
    b. Provide empirical research for therapeutic elements

Though these are the main assigned roles for each team member, all team members participated in all parts of the design process. all members were involved in design decisions, prototyping/building, and testing. The group met weekly for discussions and deliverable assignments to maintain the project's progress with the key milestone deliverables following in Table C.

The amount of hours that each individual enrolled in the Interdisciplinary class was expected to contribute per quarter is shown in Table B. Claire Francis worked with several different projects in the Interdisciplinary class so her involvement fluctuated on a week-by-week basis. Alex Fox joined the team in the Winter Quarter of the project. It was expected that each of the five main team members would spend a minimum of 330 total hours on the project, which results in 1,650 hours for the entire team.

Table 4. Individual main team member's expected time commitment per quarter

Quarter	Project Phase	Minimum Time Spent
Fall	Research and Define	9 hours/week
Winter	Design and Build	12 hours/week
Spring	Build	12 hours/week

The entire project schedule in the form of a Gantt chart can be viewed in Appendix H.

CHAPTER 8: CONCLUSIONS AND RECOMMENDATIONS

Overall, the chosen design exceeds the needs and specifications of the project. A space has been created that functions as both a calming environment and a learning tool to allow students at Newland Elementary School to explore sensory stimuli in a controlled environment. The room structure fits within the provided 10 ft by 15 ft floor space. Each component of the room: the bookshelf, the tactile wall, the tactile station, the LED panels, and the fabric panels, are modular and roll on locking casters. Each of these modules fit easily through a doorway and across a variety of both indoor and outdoor flooring types. The pressure applicator provides a deep pressure stimulation that will help calm the children. The swing promotes vestibular motion which creates a calming effect on the students with autism.

It is recommended that when transporting the room structure, a minimum of two people should move each of the room components. The users should stand on either side of the room component to ensure that it is moved safely with little risk of damaging the room or any possible students or teachers walking nearby. It is also advised that the teachers or teacher aides lock all wheels before allowing the students to enter or use the portable sensory room. Additionally, it is recommended that a teacher or a teacher aide remains with the student at all times to monitor their exposure to sensory stimuli at a pace that is most comfortable for each individual child. These safety measures will ensure that the students will utilize the room in a safe and secure way.

APPENDICES:

APPENDIX A: REFERENCES

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APPENDIX B: QFD TABLE, CUSTOMER REQUIREMENTS, AND ENGINEERING SPECIFICATIONS

CUSTOMER REQUIREMENTS:

- Portable cubicle that could be easily transported between 3 classrooms throughout the day.
- 10 ft x 15 ft enclosed area when set up.
- Must be able to be transported using 1-2 people
- Must be able to fit through standard door frame (2'11" x 6'11")
- Capacity: 1 student and 1 teacher
- Primary application: calming children with moderate to severe autism
- Contains a swing
- Contains a pressure applying machine
- Allows student to be fully enclosed (ie hammock, cocoon, teepee)
- Several different tactile interactions available
- Calming visual effects (ie lava lamps and bubble tubes)
- Child safe- no choking hazards, sharp edges, etc.
- Stable, sturdy
- Light controlled to prevent triggering any seizures
- Suitable for children testing mentally at 6-18 months
- Room could be operated by child independently
- Somewhat temperature regulated to prevent overheating
- 1 permanent, easy access exit
- A minimum of 1 view port
- Lifetime as long as possible
- Used multiple times each day
- User-friendly
- Aesthetically pleasing

ENGINEERING SPECIFICATIONS:

Spec No	Parameter Description	Target (units)	Tolerance	Risk	Compliance
1	Length	10 ft	Max	L	T, I
2	Width	15ft	Max	H	A,T,I
3	Height	8 ft	Max	L	T, I
4	Weight	100 lbs	Max	H	A,T,I
5	Room Structure Tipping Load	50 lbs	Max	H	A,T,I
6	Swing Tipping Load	50 lbs	Max	H	A,T,I
7	Swing Support Load	150 lbs	Max	H	A,T,I
8	Pressure Applicator Support Load	150 lbs	Max	M	A,T,S,I
9	Load	450 lbs	Max	H	A,T,I
10	Lifetime	10 years	Max	M	A,T,S,I
11	Power	60 Hz	Max	M	A,T,S,I
12	Power	13 Volts	Max	M	A,T,S,I
13	Power	6 A	Max	L	A,T,S,I
14	Power	72 W	Max	L	A,T,S,I
15	Battery Life	3 months	Min	H	A,T,S,I
16	Sound	No irritating noises	Max	M	A,T,S,I
17	Light	1000 LUX	Max	M	A,T,S,I
18	Choking Hazards	None	Max	L	A,T,S,I
19	Reliability	99.00%	±.05	H	A,T,S,I
20	Ease of Cleaning	1 cleaning/day	Min	L	T, I
21	Cost to Manufacture	$5,000	Max	H	A,T,S
22	Hazardous Materials	None	Max	L	I
23	Ease of Assembly	5 minutes/unit	Max	H	A,T,I
24	Size of Gaps	< 3in, > 9 in	Max	L	A,T,I
25	Lighting Effects Causing Epilepsy	None	Min	L	A,T,S,I
26	Ability to Turn Stimuli On/Off	1 button	Min	M	A,T,S,I
27	Tactile Interactions	10	Min	M	A,T,S,I
28	Visual Interactions	5	Min	M	A,T,S,I
29	Explorative Programs	3	Min	M	A,T,S,I
30	Fine Motor Skills Interaction	2	Min	M	A,T,S,I
31	Swing Load	150 lbs	Max	H	A,T,S,I
32	Adjustable Pressure	15/30 PSI	Min/Max	H	A,T,S,I
33	Exit Width	28 in	Min	L	A,T,S,I

34	Travel Configuration	100 lbs	Max	H	A,T,I
35	Travel Configuration Width	2 ft 11 in	Max	H	A,T,I
36	Travel Configuration Height	6 ft 11 in	Max	H	A,T,I
37	Durability	50 lb	Min	M	A,T,I

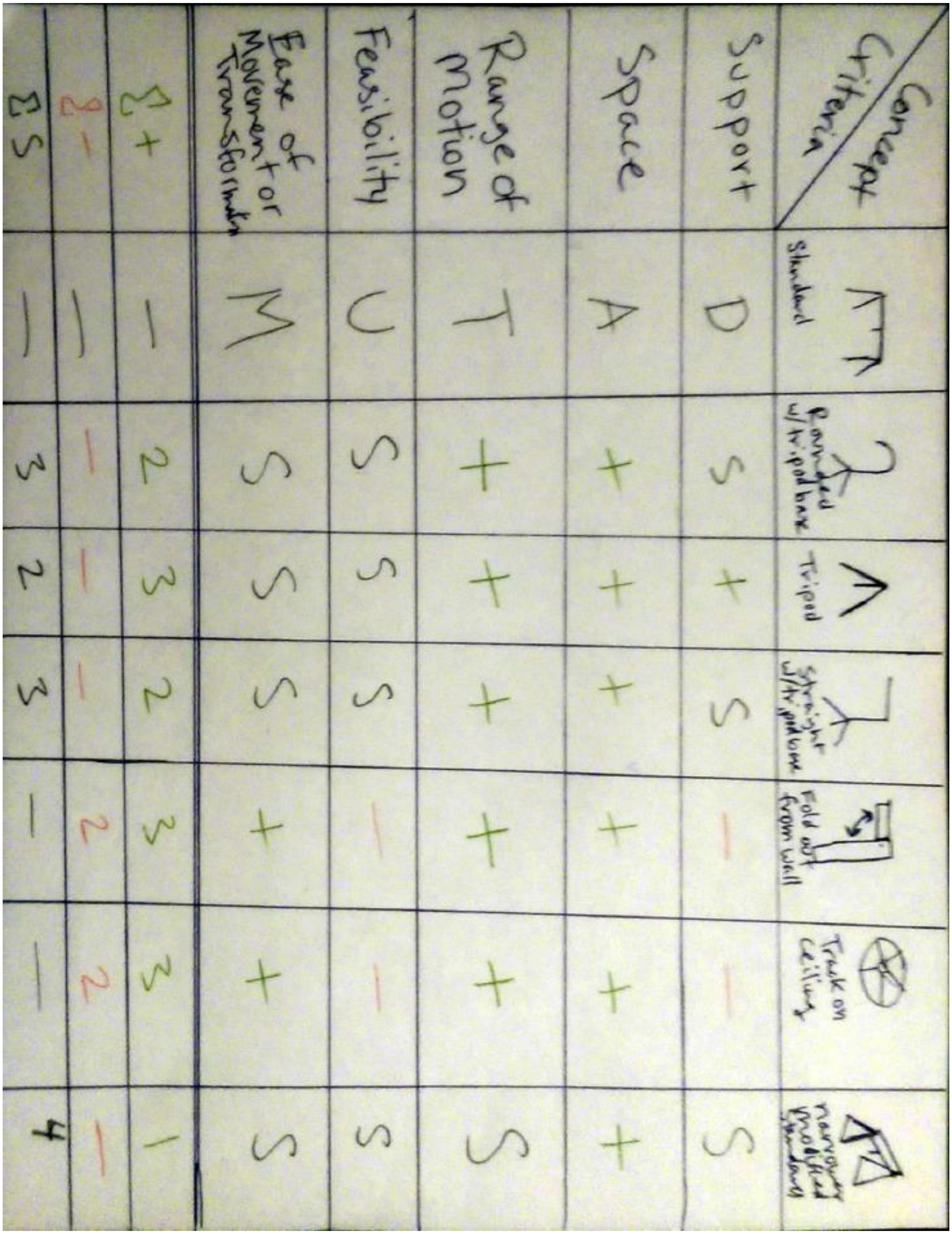
eighting	Size 10	Travel Configu	Travel Cor < 211"	All objects/structur forc	All wiring inaccessib par	No poisonous/ haz	All small parts large X 1	All gaps < 3", >9" s stu	Weight C 450	Lifes 10 y	Standard Wall Pow Battery that takes le cha	Lowest Li 0.1 L	Brightes 1000	No lighting effects eple	Ability to turn ea	Maximum 60	10 or more tact	5 or more visu	3 or more explor	2 or more fine	Swing attachment	View at a minimu	Adjustable	Exhau >0.70 d	Maximum 40 p	Ex 28" x
12.03				3	9	9	9	9	3			9		9	3	3						3	9	3	9	3
11.28	1																									9
10.53												3	9	9	9	9	9				3					
9.77	3	3	3	9					3																	
8.27				9	3				3	9	3															
8.27	9										3								1							
7.52	1									3											9					
6.77	1	3	3				3		3	3	9				1	3							9		9	
5.26	9								9																	
5.26								1				1						1				9				
3.76	9	9	9		1		1		1								1	1	3							
3.76				3		3	3								1		9		1	3						
3.01											3	3	3	3	1			9	1		1	1				
2.26							1										1		1	9						
1.5							1				3		1	1	1	3	3	3	9		1					
0.75	1							3		1	1					1								9		3
	211.24	83.46	83.46	209.73	136.84	119.55	147.38	115.78	161.62	118.05	124.83	154.15	105.30	213.57	145.90	156.42	139.13	40.61	42.08	31.62	103.78	86.44	169.20	42.84	169.20	139.86
	98.91	39.08	39.08	98.20	64.07	55.98	69.01	54.21	75.68	55.27	58.45	72.18	49.30	100.00	68.31	73.24	65.14	19.01	19.70	14.81	48.59	40.47	79.22	20.06	79.22	65.49

APPENDIX C: DECISION MATRICES

Figure C-1 Pressure Applicator Decision Matrix

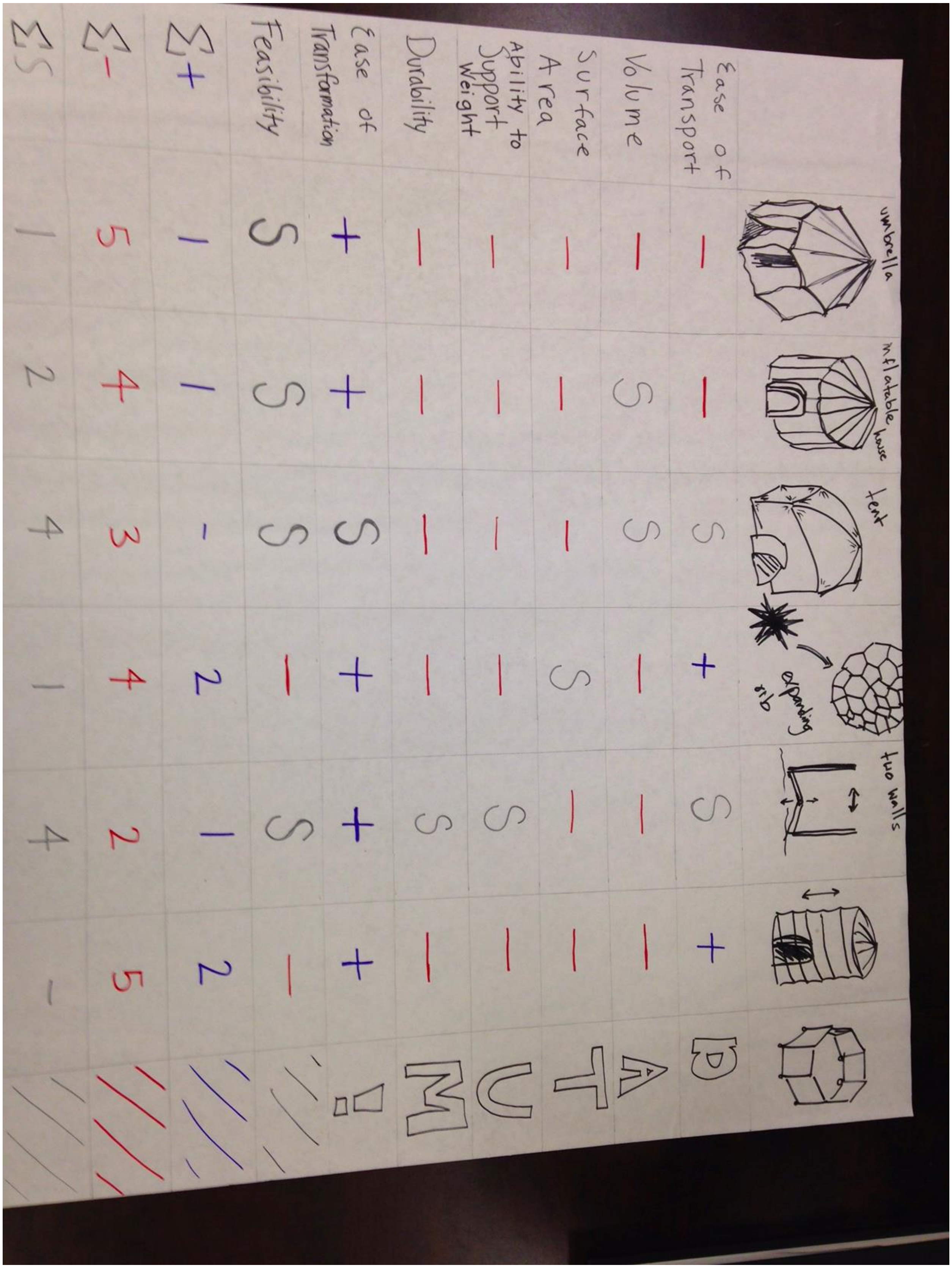
Criteria \ Design Concepts	#1 Pressure Tunnel!	#2 Dinosaur Mouth!	#3 Grandin's Squeeze Machine	#4 Weighted Hammock Cacoon	#5 Stretchy Blanket	#6 "T Jacket" Air Pump
Pressure Applying Ability	-	-	D	-	-	S
Feasibility of Design	+	+		+	+	S
Transportability	S	S	A	+	S	+
Expense	+	+		+	+	S
Safety	+	+	T	+	+	S
Feasibility to Build in Timeframe	+	+		+	+	+
Durability	+	+	U	-	-	S
Σ+	5	5		5	4	2
Σ-	1	1	M	2	2	Ø
ΣS	1	1		Ø	1	5

Figure C-2. Swing Pugh Matrix



Criteria / Concept	Standard	Rounded w/ tripod base	Tripod	Straight w/ tripod base	Fold out from wall	Track on ceiling	narrower modified standard
Support	D	S	+	S	−	−	S
Space	A	+	+	+	+	+	+
Range of Motion	T	+	+	+	+	+	S
Feasibility	U	S	S	S	−	−	S
Ease of Movement or Transformation	M	S	S	S	+	+	S
Σ+	—	2	3	2	3	3	1
Σ−	—	—	—	—	2	2	—
ΣS	—	3	2	3	—	—	4

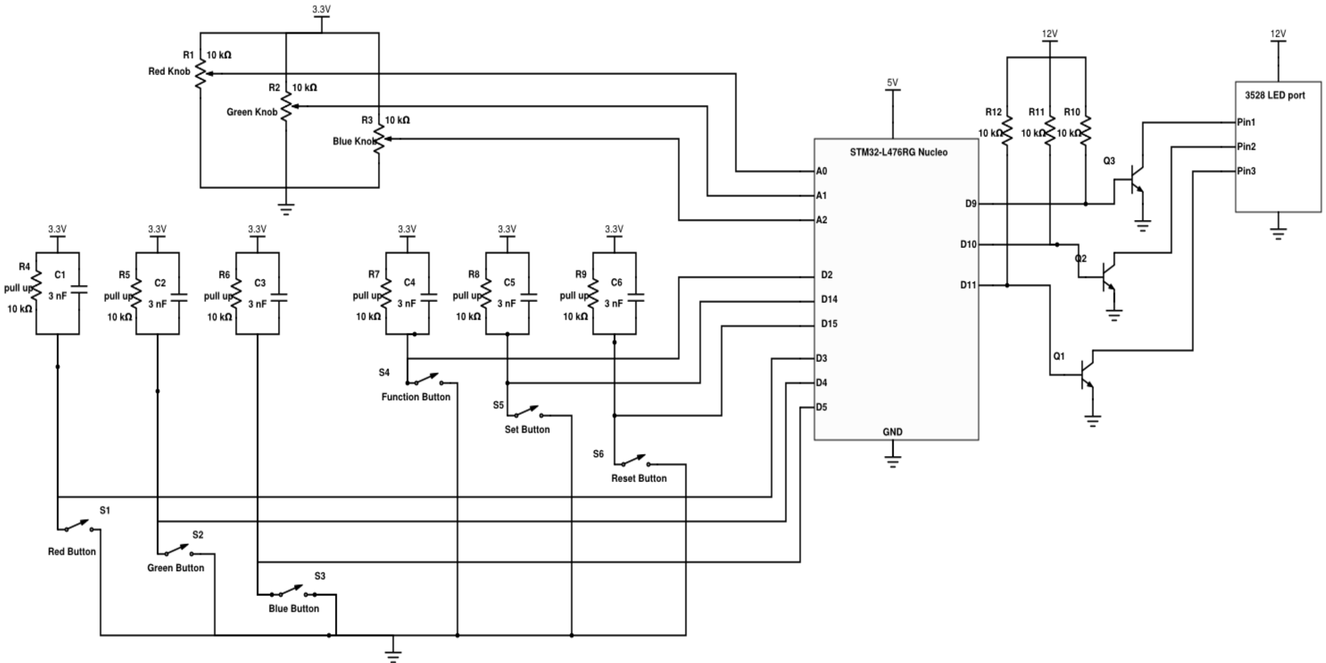
Figure C-3. Room Structure Pugh Matrix



	umbrella	inflatable house	tent	expanding orb	two walls		DATUM
Ease of Transport	−	−	S	+	S	+	
Volume	−	S	S	−	−	−	
Surface Area	−	−	−	S	−	−	
Ability to Support Weight	−	−	−	−	S	−	
Durability	−	−	−	−	S	−	
Ease of Transformation	+	+	S	+	+	+	
Feasibility	S	S	S	−	S	−	
Σ+	1	1	-	2	1	2	
Σ-	5	4	3	4	2	5	
ΣS	1	2	4	1	4	-	

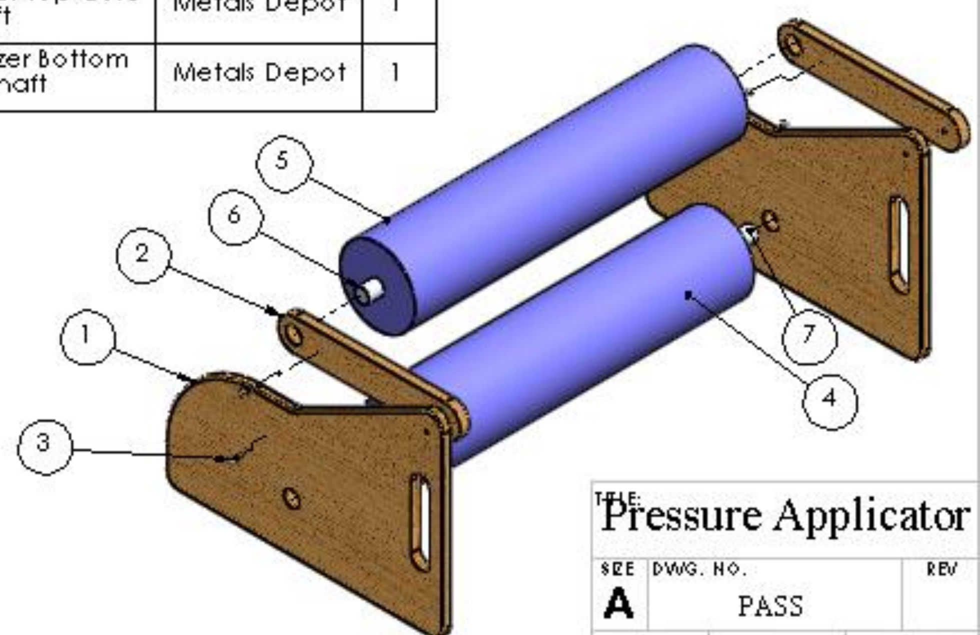
APPENDIX D: FINAL DESIGN DRAWINGS & SCHEMATICS

3528 LED Controller Schematic



Pressure Applicator:

ITEM NO.	P/N	DESCRIPTION	VENDOR	QTY.
1	PASS - 01	Single Squeezer Side Support	In-House	2
2	PASS - 02	Single Squeezer Pivot Arm	In-House	2
3	30425T26	Screw-Eye	McMaster-Carr	4
4	PASS - 05	Single Squeezer Bottom Padding	Amazon	1
5	PASS - 06	Single Squeezer Top Padding	Amazon	1
6	PASS-04	Single Squeezer Top Core Shaft	Metals Depot	1
7	PASS-03	Single Squeezer Bottom Core Shaft	Metals Depot	1



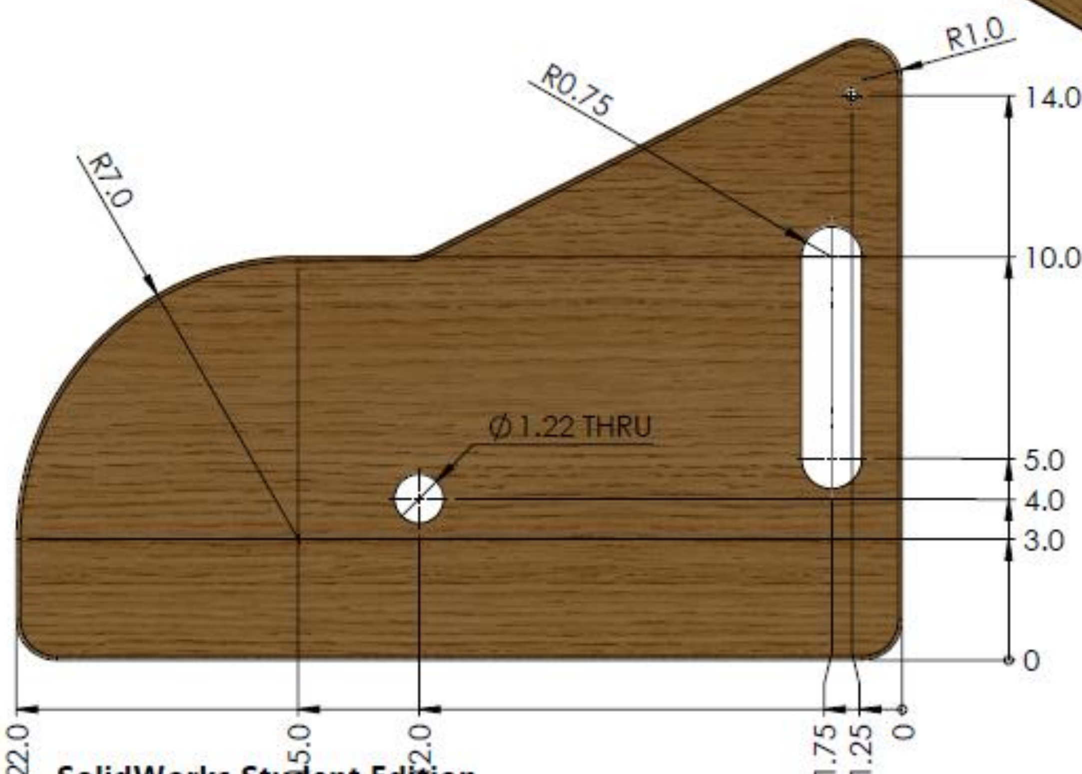
TITLE: Pressure Applicator

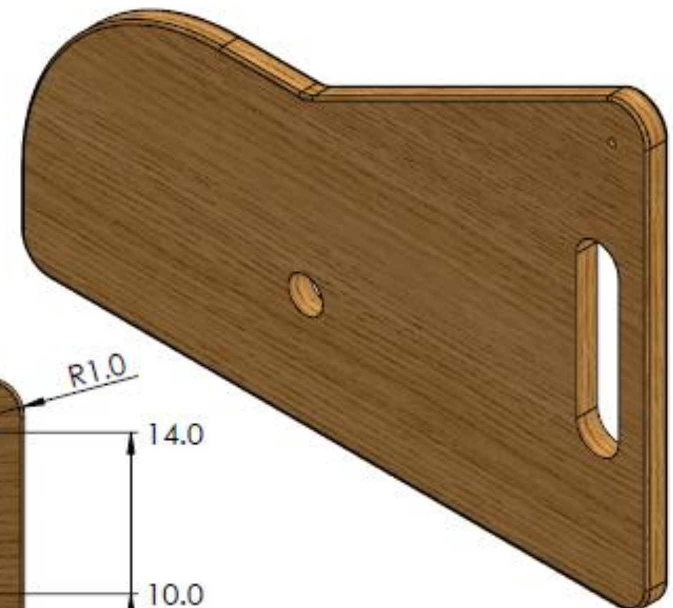
SIZE: A | DWG. NO.: PASS | REV

SCALE: 1:8 | WEIGHT: | SHEET 1 OF 1

NOTES:

1. WOOD VENDOR: HOME DEPOT
2. STOCK THICKNESS: 3/4 "
3. MATERIAL: WHITE OAK
4. REMOVE ALL BURRS. ROUND ALL EDGES.
5. ALL TOLERANCES ± 0.1 UNLESS OTHERWISE SPECIFIED.



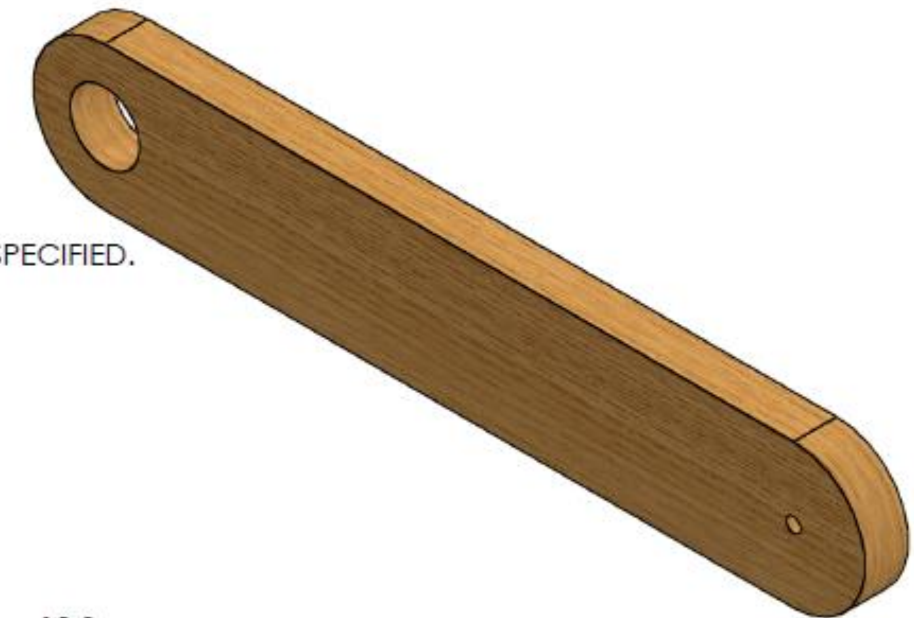


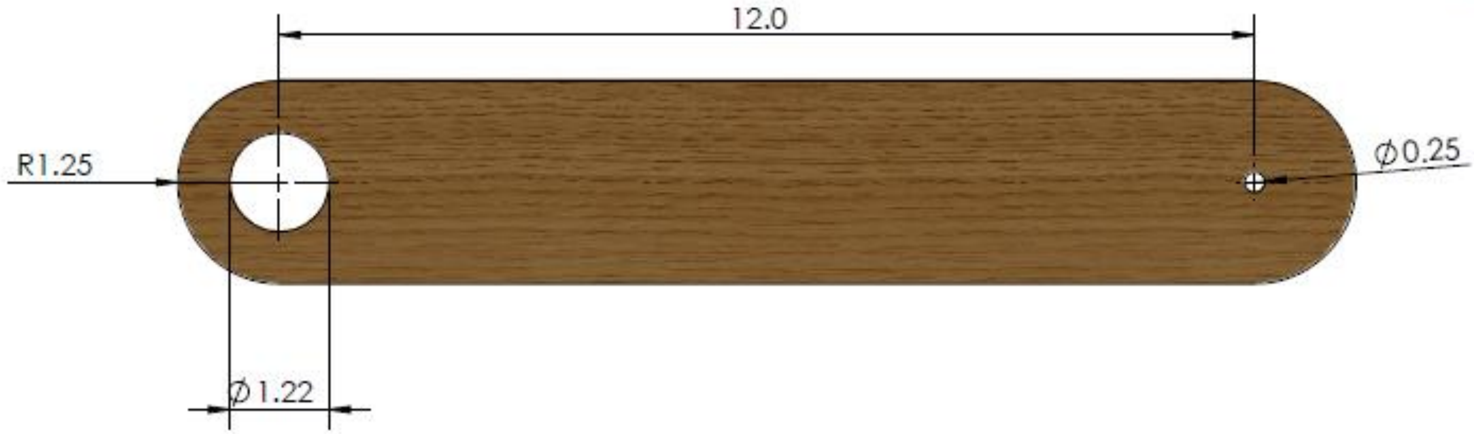
SolidWorks Student Edition.
For Academic Use Only.

TITLE: Single Squeezer Side Support		
SIZE A	DWG. NO. PASS - 01	REV A
SCALE: 1: 4	WEIGHT:	SHEET 1 OF 1

NOTES:

1. WOOD VENDOR: HOME DEPOT
2. STOCK THICKNESS: 3/4 "
3. MATERIAL: WHITE OAK
4. REMOVE ALL BURRS. ROUND ALL EDGES.
5. ALL TOLERANCES ± 0.1 UNLESS OTHERWISE SPECIFIED.





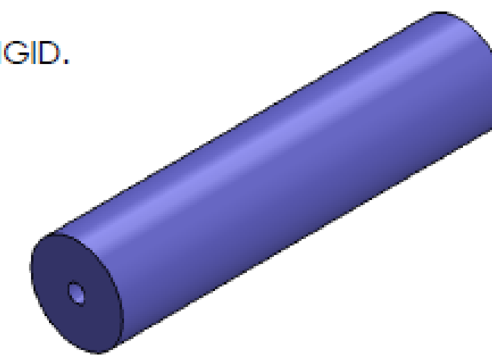
SolidWorks Student Edition.
For Academic Use Only.

TITLE: Single Squeezer Pivot Arm		
SIZE A	DWG. NO. PASS-02	REV A
SCALE: 1:2	WEIGHT:	SHEET 1 OF 1

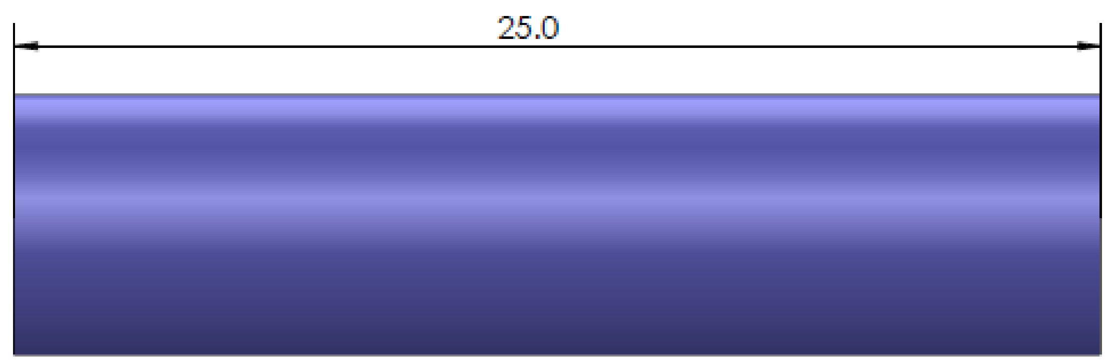
5 4 3 2 1

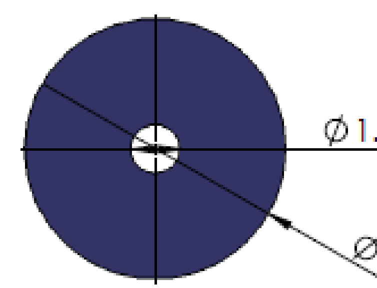
NOTES:

1. THE OUTER DIAMETER IS PURELY AN ESTIMATE SINCE THE PADDING IS NOT RIGID.
2. ALL TOLERANCES ±0.1 UNLESS OTHERWISE SPECIFIED.



SCALE: 1:8

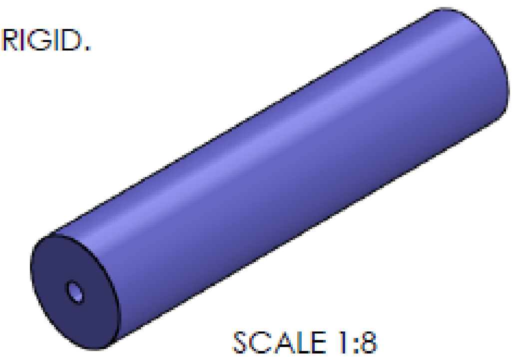




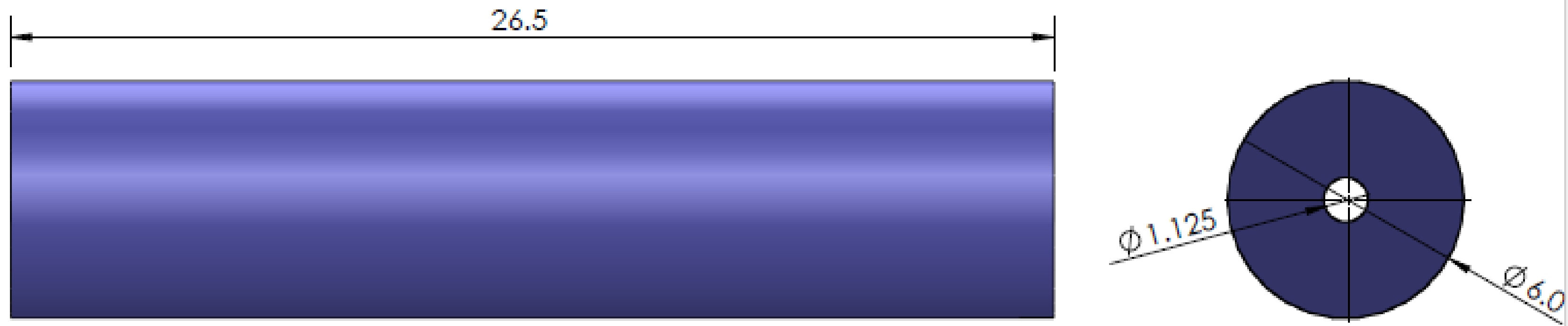
TITLE:	Single Squeezer Bottom Padding
SIZE A	DWG. NO. PASS-05

NOTES:

1. THE OUTER DIAMETER IS PURELY AN ESTIMATE SINCE THE PADDING IS NOT RIGID.
2. ALL TOLERANCES ±0.1 UNLESS OTHERWISE SPECIFIED.



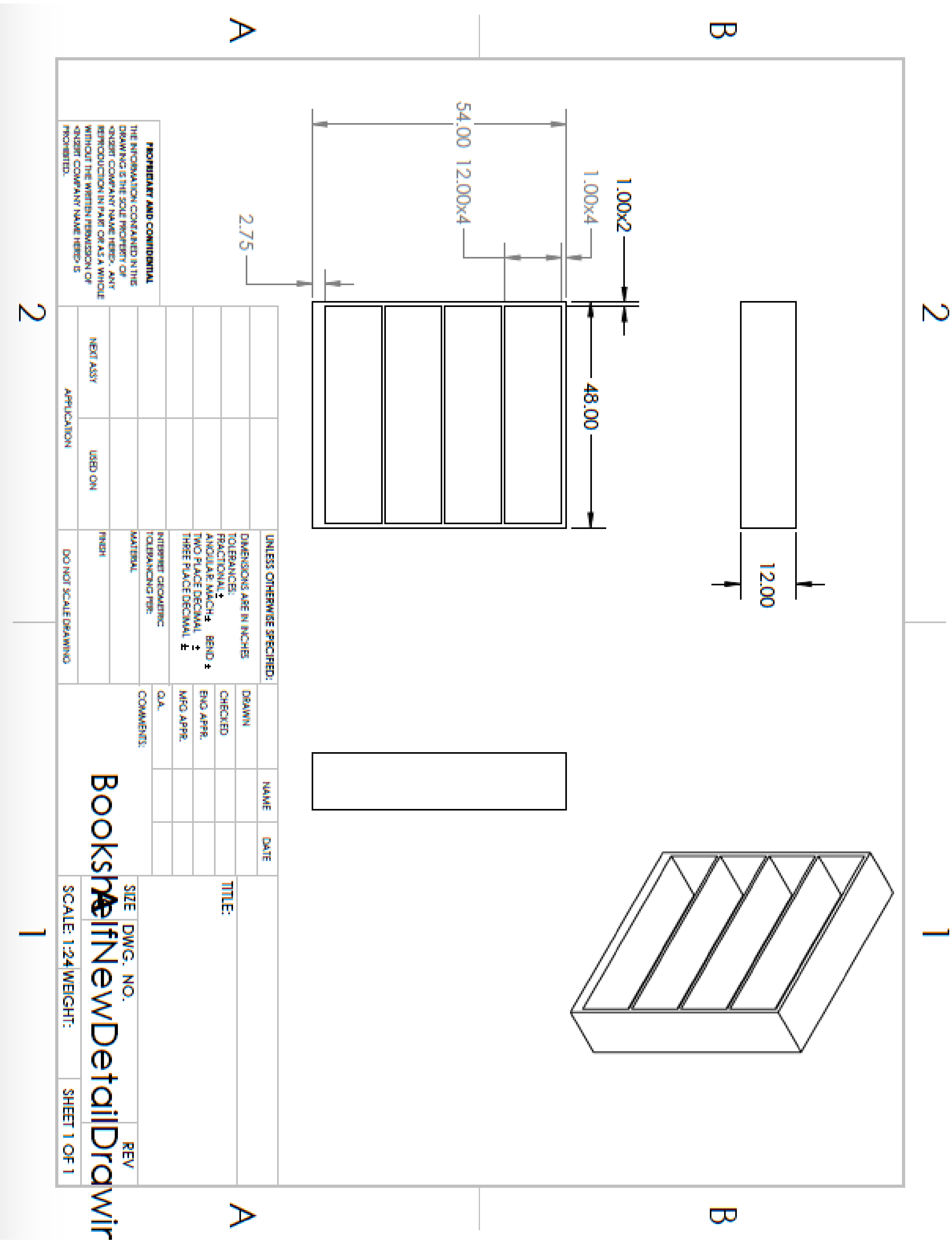
SCALE 1:8

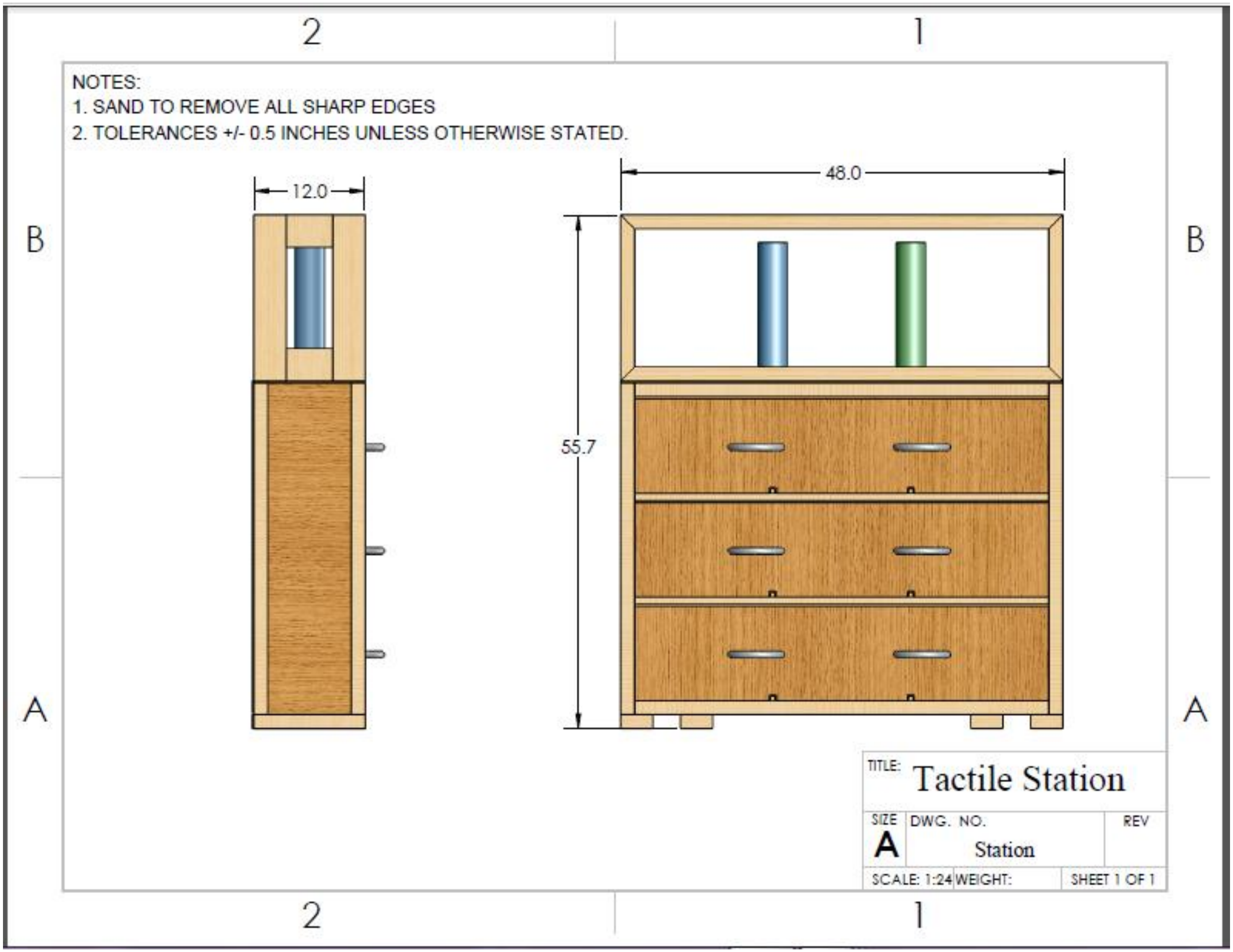


TITLE: Single Squeezer Top Padding		
SIZE A	DWG. NO. PASS-06	REV A
SCALE: 1:4	WEIGHT:	SHEET 1 OF 1

5 4 3 2 1

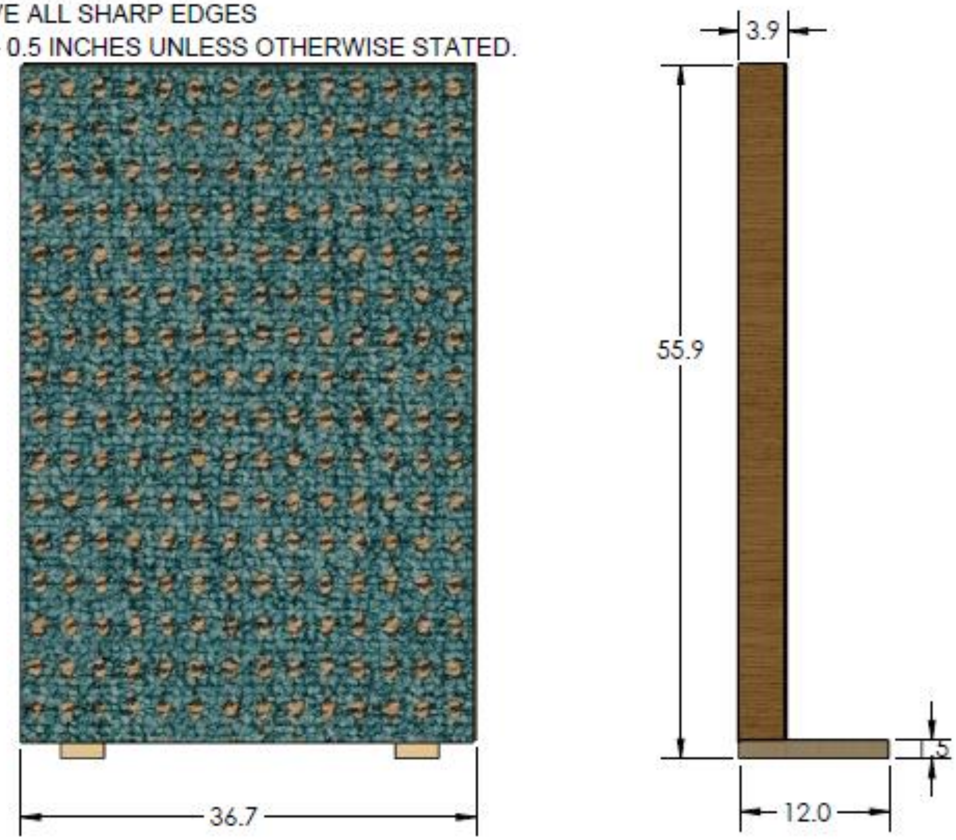
Room Structure


A
B
2
1
54.00
12.00x4
1.00x4
1.00x2
2.75
48.00
12.00
PROPRIETARY AND CONFIDENTIAL
NEXT ASSY
USED ON
APPLICATION
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
DRAWN
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
NAME
DATE
TITLE:
SIZE
A
DWG. NO.
BookshelfNewDetailDrawir
REV
SCALE: 1:24
WEIGHT:
SHEET 1 OF 1

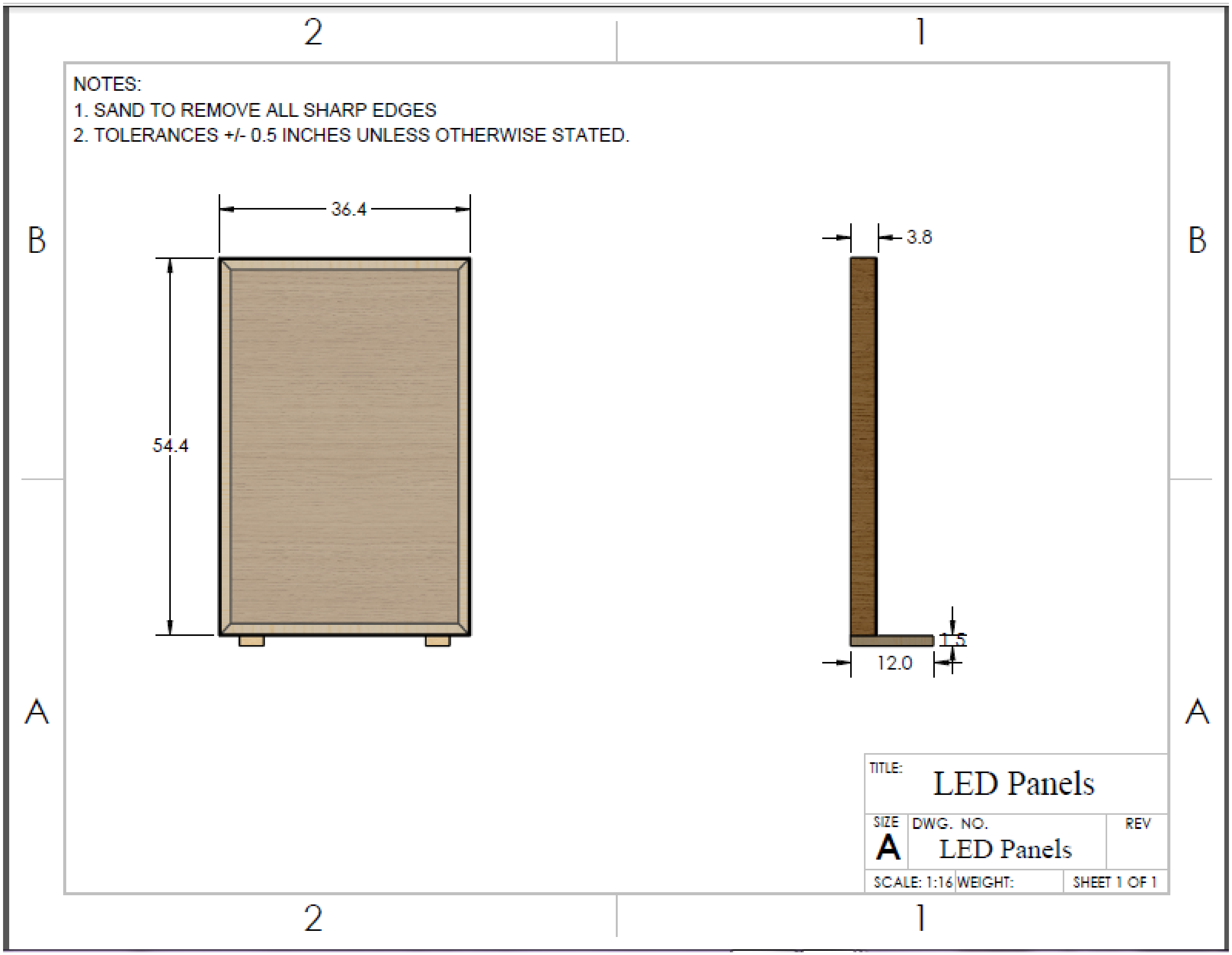

2
1
B
A
NOTES:
1. SAND TO REMOVE ALL SHARP EDGES
2. TOLERANCES +/- 0.5 INCHES UNLESS OTHERWISE STATED.
12.0
48.0
55.7
TITLE: Tactile Station
SIZE A
DWG. NO. Station
REV
SCALE: 1:24
WEIGHT:
SHEET 1 OF 1

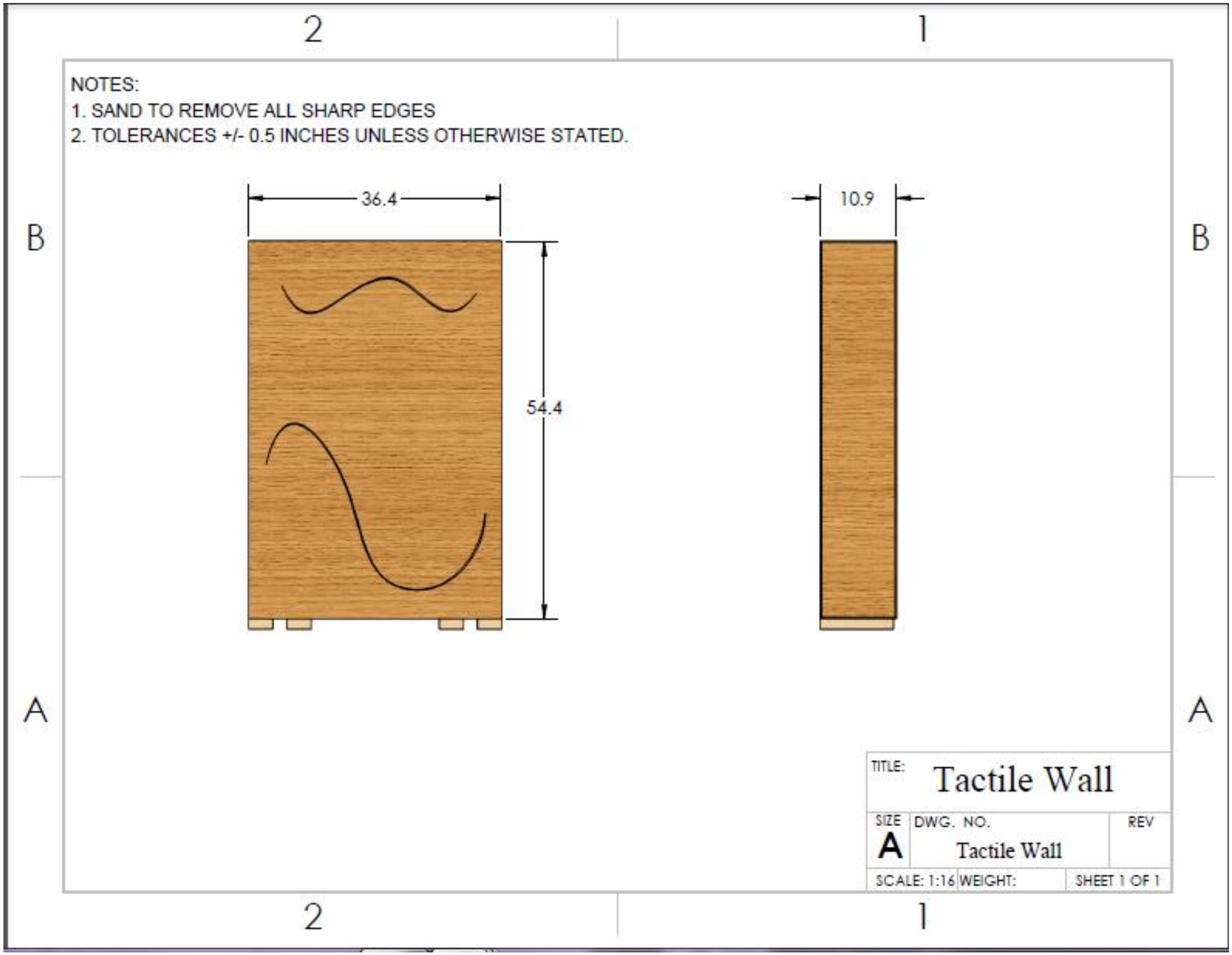
NOTES:

1. SAND TO REMOVE ALL SHARP EDGES
2. TOLERANCES +/- 0.5 INCHES UNLESS OTHERWISE STATED.



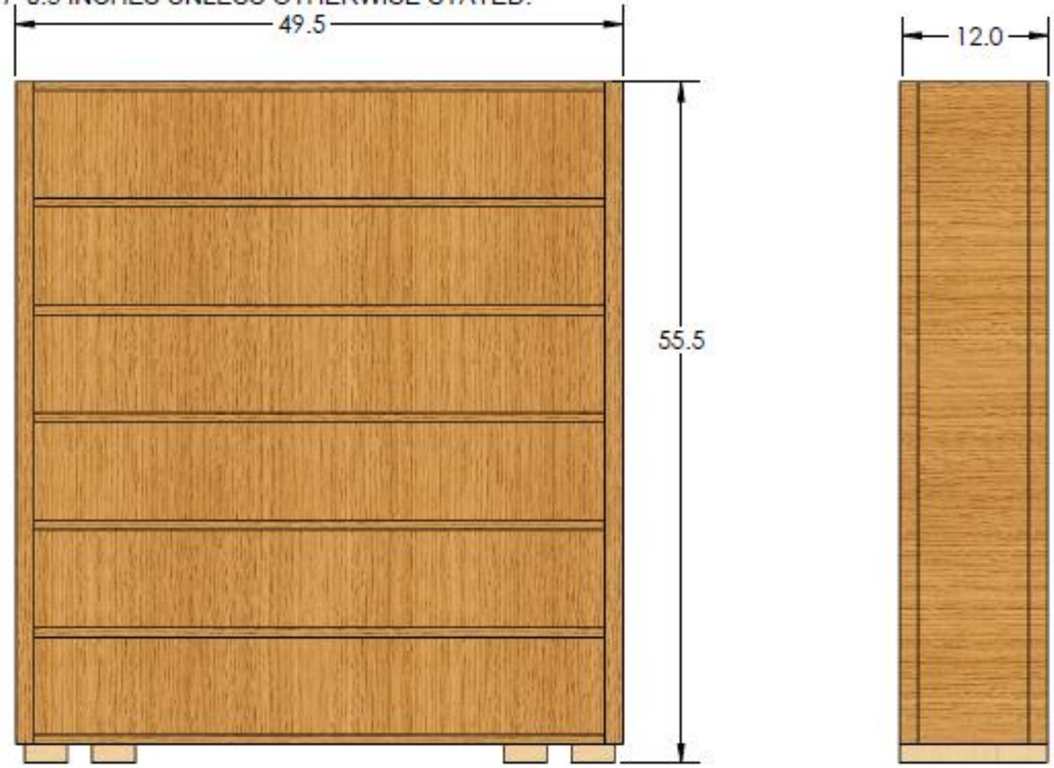
TITLE:	Fabric Panel		
SIZE A	DWG. NO. Fabric Panel		REV
SCALE: 1:16	WEIGHT:		SHEET 1 OF 1


NOTES:
1. SAND TO REMOVE ALL SHARP EDGES
2. TOLERANCES +/- 0.5 INCHES UNLESS OTHERWISE STATED.
36.4
54.4
3.8
1.5
12.0
TITLE:
LED Panels
SIZE
A
DWG. NO.
LED Panels
REV
SCALE: 1:16
WEIGHT:
SHEET 1 OF 1



2
1
B
A
NOTES:
1. SAND TO REMOVE ALL SHARP EDGES
2. TOLERANCES +/- 0.5 INCHES UNLESS OTHERWISE STATED.
36.4
54.4
10.9
TITLE: Tactile Wall
SIZE A
DWG. NO. Tactile Wall
REV
SCALE: 1:16
WEIGHT:
SHEET 1 OF 1

NOTES:
1. SAND TO REMOVE ALL SHARP EDGES
2. TOLERANCES +/- 0.5 INCHES UNLESS OTHERWISE STATED.



TITLE:	Bookshelf	
SIZE A	DWG. NO. Bookshelf	REV
SCALE 1:12	WEIGHT:	SHEET 1 OF 1

APPENDIX E: BILLS OF MATERIALS

Table E-1. Pressure Applicator Single Squeezer BOM

Item	Quantity	Price Per Item ($)	Shipping	Total Price ($)
Wood	3/4inx2ftx4ft	25	0	25
Shafts 29"	2	22.07	11.82	55.96
Bearing	2	5.48	6.00	16.96
Rubberbands	2	15	0	15
Screw Eyes	1	7.77	0	7.77
Bolts	2	4	0	4
Foam Rollers	2	18.99	0	18.99
				143.68

Table E-2. Room Structure BOM

Item	Quantity	Price Per Item ($)	Shipping	Total Price ($)
Plywood big	4	49.98	0	199.92
Plywood sheets for panels	18	11.97	0	215.46
Fir 2x4	20	3.58	0	71.6
1x2x8	12	2.45	0	29.4
Door Hinges (3Per)	1	7.98	0	7.98
Locking Hinges	6	14.5	0	87

Polyurethane 3" Caster w/ break	20	7.97	0	159.4
2" swivel break caster	8	5.18	0	41.44
Sliding Loop Lock	4	4.98	0	19.92
Screws- Phillips flat heads (1lb)	1	8.47	0	8.47
Washers	1	8.98	0	8.98
Screws- Phillips flat heads (5lb)	1	27.48	0	27.48
Wood screws	2	1.18	0	2.36
Finishing Nails(80pack)	1	1.3	0	1.3
Finishing Nails(250pack)	2	2.48	0	4.96
Gorilla Wood Glue	1	4.44	0	4.44
Interior/Exterior Paint	2	29.98	0	59.96
Exterior Primer	1	22.98	0	22.98
Masking Tape	1	2.97	0	2.97
Paint Brush Set	1	7.97	0	7.97
Tarps	4	6.48	0	25.92
Variety Ocean Wall Decals	-	200	0	200
Rollers	3	5.98	0	17.94
Roller Frames	3	4.68	0	14.04
Roller Tray	2	3.97	0	7.94

Wood Putty	2	8.36	0	16.72
Door Stops	2	3.78	0	7.56
Misc.	-	56.38	0	56.38
				1330.49

Table E-3. LED Panels BOM

Item	Quantity	Price Per Item ($)	Shipping	Total Price ($)
STM32 Board	2	14	5	33
Misc. Hardware	-	-	9.21	66.04
AA Battery Pack	1	5	0	5
Development Boards	-	-	9.21	20.11
Lithium Battery Pack	2	48.99	0	97.98
LED Strip	1	15.98	0	15.98
Rubber leg Tips	1	2.58	0	2.58
Power Jacks	2	8.62	0	8.62
Control buttons	1	36.54	0	36.54
Acrylic Paint	1	48.97	0	48.97
Arcylic Sealant	2	17.3	0	34.6
Acrylic Sheet	1	108.99	0	108.99
				478.41

Table E-4. Fabric Wall BOM

Item	Quantity	Price Per Item ($)	Shipping	Total Price ($)
Feather Boa	1	6.44	0	6.44
Glitter Ribbon	1	2.44	0	2.44
Ribbon	3	2.97	0	8.91
Wavy ribbon	1	4.44	0	4.44
Ribbon	3	1	0	3
Ribbon	2	1.97	0	3.94
Trim	2	2.97	0	5.94
Dark blue thread	1	2.27	0	2.27
Light blue thread	1	2.27	0	2.27
White thread	1	2.27	0	2.27
Mesh	2	5.77	0	11.54
Felt dolphin, 0.5yd	2	1.97	0	3.94
Light blue rose plush, 0.5yd	1	3.92	0	3.92
Pom pom trim	1	2.97	0	2.97
Whales fleece	1	2.49	0	2.49
Shell cotton	1	2.43	0	2.43
Ocean cotton	1	1.99	0	1.99
Blue flannel	1	2.63	0	2.63
Batting	2	3.97	0	7.94
Tulle	1	0.73	0	0.73
Cork tape	1	4.97	0	4.97

Velcro	2	19.97	0	39.94
Scotch Guard	1	11.88	0	11.88
Fabric Adhesive	1	4.47	0	4.47
Miscellaneous and tax	-	-	0	28.48
				172.24

Table E-5. Tactile Station BOM

Item	Quantity	Price Per Item ($)	Shipping	Total Price ($)
Drawer Dividers	1	17.99	0	17.99
Drawer Slides	3	7.99	0	23.97
Pine Board	4	37.69	0	150.76
Drawer Handles (10 Count)	1	8.00	0	8.00
Sea Animals (90)	1	13.08	0	13.08
Metallic Spray Paint	1	22.56	0	22.56
Cutting Mats	2	7.55	0	15.10
Lights	2	9.99	0	19.98
				271.44

Table E-6. Tactile Wall BOM

Item	Quantity	Price Per Item ($)	Shipping	Total Price ($)
Gears	**1**	**5.49**	**0**	**5.49**
Squigglets, Assorted colors	**1**	**6.52**	**0**	**6.52**
Marker Board	**1**	**9.97**	**0**	**9.97**
Wooden Fish	**3**	**2.73**	**0**	**8.19**
Fine Motor Gear Set	**1**	**19.99**	**0**	**19.99**
Misc	**-**	**-**	**0**	**10**
Crayola Dry Erase Crayons	**1**	**5.99**	**0**	**5.99**
				66.15

Table E-7. Fine Motor Station BOM

Item	Quantity	Price Per Item ($)	Shipping	Total Price ($)
Oak 4x8x3/4in	4	49.98	0	199.92
Marine Animal Themed Bead Maze	1	20.99	0	20.99
Foam Gears	1	13.36	0	13.36
Wikki Stix Book of Wiggles	1	7.99	0	7.99
Fidget Toy. set of 3	1	12.89	0	12.89
Lacing and Stringing Beads	1	15.77	0	15.77
Magnetic Stick N Stack Mags	1	19.99	0	19.99
Montessori pegboard	1	19.99	0	19.99
Monkey Peg Set	1	14.21	0	14.21
Big Buttons	1	6.44	0	6.44
Lava Lamp Timer	3	7.99	0	23.97
Buckle Whale	1	19.99	0	19.99
Little hands learn to dress monkey	1	21.99	0	21.99
Sound Machine	1	21.97	0	21.97
Gel Maze	1	32.51	0	32.51
				231.07

Table E-8. Swing BOM

Item	Vendor	Quantity	Price Per Item ($)	Shipping	Total Price ($)
Swing	**Amazon**	**1**	**105.6**	**0**	**105.6**

Table E-9. Miscellaneous Manufacturing Supplies BOM

Item	Quantity	Price Per Item ($)	Shipping	Total Price ($)
Biscuits(100)	1	8.12	0	8.12

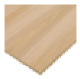
Biscuit Joiner	1	68	0	68
Sanding Disc	2	7.97	0	15.94
Sanding Sheets	1	3.97	0	3.97
Drill Bit	1	2.97	0	2.97
Staples	1	3.22	0	3.22
Misc.	-	-	0	83.36
				185.58

Table E-10. Total Bill of Materials

Room Structure	1330.49
Pressure Applicator	$144
LED Wall	478.41
Fabric Wall	172.24
Tactile Station	271.44
Tactile Wall	66.15
Fine Motor Station	231.07
Swing	105.6
Misc. Manuf.	185.58
Total	**2984.66**

***Note* Bill of materials includes both prototyping and final product. Some materials may not be included in the final product.**

APPENDIX F: VENDOR SUPPLIED COMPONENT SPECIFICATIONS



Columbia Forest Products | Model # 2076 | ★★★★★ (23)

3/4 in. x 2 ft. x 4 ft. PureBond White Oak P...

$24.99 /each

RELATED ITEMS | PRODUCT OVERVIEW | SPECIFICATIONS | RECOMMENDED ITEMS | QUESTIONS & ANSWERS | CUSTOMER

SPECIFICATIONS

DIMENSIONS

Actual product thickness (in.)	.703	Product Length (ft.)	4 ft
Actual product width (in.)	24	Product Thickness (in.)	3/4 in
Product Depth (in.)	48	Product Width (ft.)	2 ft
Product Height (in.)	0.703	Product Width (in.)	24

DETAILS

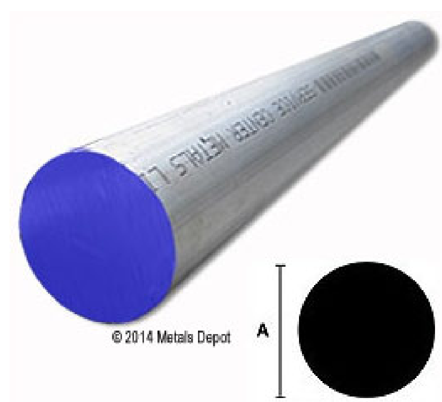
Plywood Type	Hardwood Plywood	Returnable	90-Day
Pressure Treated	No	Stainable/Paintable	Stainable & Paintable
Product Thickness x Width x Length	3/4 in. x 2 ft. x 4 ft.	Tounge and Groove	No

6061 Aluminum Round

6061 Aluminum Round, is an extruded aluminum product that is very versatile and has a wide range of applications. 6061 Aluminum Round is widely used for all types of fabrication projects where lightweight and corrosion resistance is a concern.

- Specifications: ASTM B221, QQA-200/8, 6061-T6511
- AKA: aluminum round bar, aluminum rod
- Applications: braces, supports, trim, shafts, ornamental, pins, dowels
- Workability: Easy to Weld, Cut, and Machine.
- Mechanical Properties:Brinell = 95, Tensile = 45K +/-, Yield = 40K +/-
- How is it Measured?Diameter (A) X Length
- Available Stock Sizes: 2ft, 4ft, 6ft, 8ft, 12ft or Cut to Size

Stock lengths may vary +/- 1/4"
Please call if you need specific lengths.



		Stock Number	Item Description	Size	Status	Price Each	Totals
	1	R3118	1-1/8 inch Dia. 6061-T6 Aluminum Round	2' 5" Custom Size	✓ In Stock	$22.07	**$22.07**
	1	R3118	1-1/8 inch Dia. 6061-T6 Aluminum Round	2' 3 1/2" Custom Size	✓ In Stock	$21.41	**$21.41**
						Sub-Total:	$43.48

93405 | United States | University / School

Select a shipping option	
UPS Ground (93405)	$15.98
UPS 3-Day Select (93405)	$27.48
UPS 2nd Day Air (93405)	$42.35
UPS Next Day Air (93405)	$62.53

Shipping: Pending

Total: * $43.48

LED Panel

3528 SMD LED Strip Electronic Characteristics

Characteristics

Absolute Maximum Rating at TA=25℃

Parameter	Symbol	Absolute Maximum Rating	Unit
Forward Current	IF	200	mA
Power Dissipation	PD	2.4	W
Electrostatic discharge	ESD	400	V
Operating Temperature	Topr	-25∽+60	℃
Storage Temperature	Tstg	-40∽+80	℃

Electrical / Optical Characteristics at TA=25℃

Part No.	Color	Wavelength	Brightness(lm)	Forward Voltage	Forward Current
PF8W-WW-30	Warm White	3000k-4000k	95	DC 12V	200 mA
PF8W-W-30	White	5000k-6000k	115	DC 12V	200 mA
PF8W-R-30	Red	620-630nm	102	DC 12V	200 mA
PF8W-B-30	Blue	455-470nm	52	DC 12V	200 mA

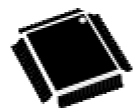
STM32L063C8 STM32L063R8

Ultra-low-power 32-bit MCU ARM®-based Cortex®-M0+, 64KB Flash, 8KB SRAM, 2KB EEPROM, LCD, USB, ADC, DAC, AES

Datasheet - production data

Features

- Ultra-low-power platform
  - 1.65 V to 3.6 V power supply
  - -40 to 125 °C temperature range
  - 0.27 µA Standby mode (2 wakeup pins)
  - 0.4 µA Stop mode (16 wakeup lines)
  - 0.8 µA Stop mode + RTC + 8 KB RAM retention
  - 139 µA/MHz Run mode at 32 MHz
  - 3.5 µs wakeup time (from RAM)
  - 5 µs wakeup time (from Flash)
- Core: ARM® 32-bit Cortex®-M0+ with MPU
  - From 32 kHz up to 32 MHz max.
  - 0.95 DMIPS/MHz
- Reset and supply management
  - Ultra-safe, low-power BOR (brownout reset) with 5 selectable thresholds
  - Ultralow power POR/PDR
  - Programmable voltage detector (PVD)
- Clock sources
  - 1 to 25 MHz crystal oscillator
  - 32 kHz oscillator for RTC with calibration
  - High speed internal 16 MHz factory-trimmed RC (+/- 1%)
  - Internal low-power 37 kHz RC
  - Internal multispeed low-power 65 kHz to 4.2 MHz RC
  - Internal self calibration of 48 MHz RC for USB
  - PLL for CPU clock
- Pre-programmed bootloader
  - USART, SPI supported
- Development support
  - Serial wire debug supported
- Up to 51 fast I/Os (45 I/Os 5V tolerant)
- Memories
  - 64 KB Flash with ECC
  - 8KB RAM
  - 2 KB of data EEPROM with ECC
  - 20-byte backup register
  - Sector protection against R/W operation
- LCD driver for up to 8×28segments
  - Support contrast adjustment
  - Support blinking mode



LQFP64 10x10 mm
LQFP48 7x7 mm

  - Step-up converted on board
- Rich Analog peripherals
  - 12-bit ADC 1.14 Msps up to 16 channels (down to 1.65 V)
  - 12-bit 1 channel DAC with output buffers (down to 1.8 V)
  - 2x ultra-low-power comparators (window mode and wake up capability, down to 1.8 V)
- Up to 24 capacitive sensing channels supporting touchkey, linear and rotary touch sensors
- 7-channel DMA controller, supporting ADC, SPI, I2C, USART, DAC, Timers, AES
- 8x peripherals communication interface
- 1x USB 2.0 crystal-less, battery charging detection and LPM
- 2x USART (ISO 7816, IrDA), 1x UART (low power)
- 2x SPI 16 Mbits/s
- 2x I2C (SMBus/PMBus)
- 9x timers: 1x 16-bit with up to 4 channels, 2x 16-bit with up to 2 channels, 1x 16-bit ultra-low-power timer, 1x SysTick, 1x RTC, 1x 16-bit basic for DAC, and 2x watchdogs (independent/window)
- CRC calculation unit, 96-bit unique ID
- True RNG and firewall protection
- Hardware Encryption Engine AES 128-bit
- All packages are ECOPACK®2

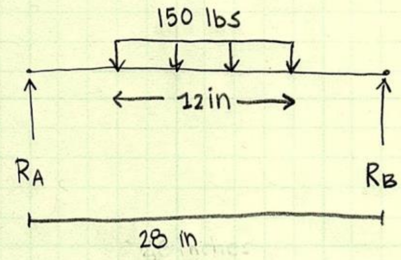
APPENDIX G: DETAILED SUPPORTING ANALYSIS

PRESSURE APPLICATOR: BOTTOM SHAFT ANALYSIS

GIVEN: LOAD OF 150 LBS

ASSUME: CHILD WIDTH = 1 FOOT
WEIGHT OF SHAFT IS NEGLIGIBLE.

FBD:



* treat 150 lb force as point load in the middle.

* assume that reaction acts at ½" from the end of the shaft on either side.

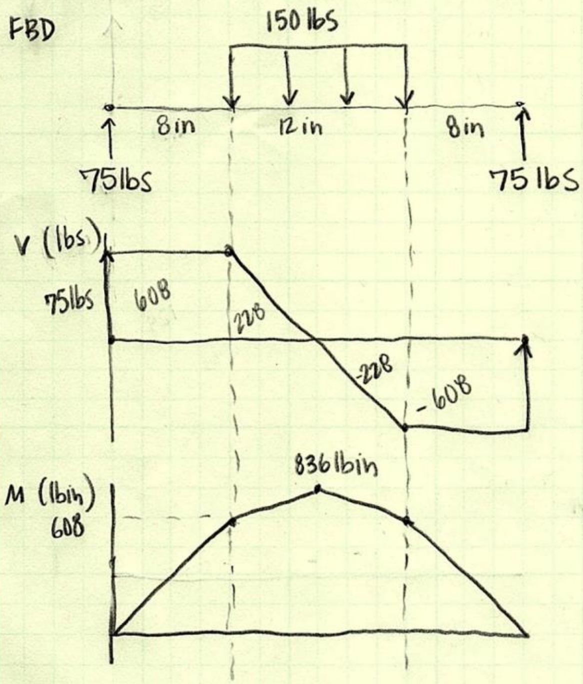
$$\Sigma F_y = -150 \text{ lbs} + R_A + R_B = \emptyset$$

$$\Sigma M_A = -(14 \text{ in})(150 \text{ lb}) + (28 \text{ in})(R_B) = \emptyset$$

$$R_B = 75 \text{ lbs}$$

$$R_A = 75 \text{ lbs}$$

SHEAR AND MOMENT DIAGRAMS

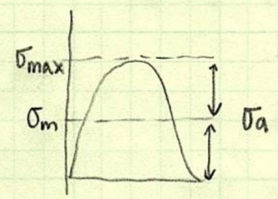


$$M_{max} = 836 \text{ lb·in}$$

USING $M = 836$ lb·in, ANALYZE FOR VARIABLE LOADING USING THE STRESS LIFE METHOD.

EXPECT ABOUT 10^5 CYCLES OVER 10 YEARS BUT WILL DESIGN FOR INFINITE LIFE JUST IN CASE.

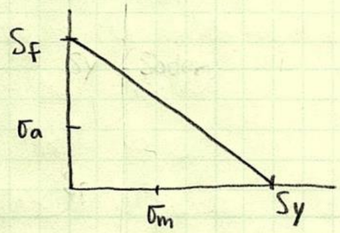
CYCLIC LOADING:



$$\sigma_{max} = \frac{32\, M_{max}}{\pi d^3}$$

$$\therefore \quad \sigma_a = \sigma_m = \frac{16\, M_{max}}{\pi d^3}$$

USE SODERBERG METHOD:



$$\frac{\sigma_a}{S_e} + \frac{\sigma_m}{S_y} = \frac{1}{n}$$

* ALUMINUM IS DUCTILE → REPLACE S_e WITH S_F.

$$\boxed{n = \frac{1}{\dfrac{\left(\frac{16 M_{max}}{\pi d^3}\right)}{S_F} + \dfrac{\left(\frac{16 M_{max}}{\pi d^3}\right)}{S_y}}}$$

CREATE EXCEL FILE AND SOLVE FOR "n" FOR VARIOUS DIAMETERS.

CALCULATIONS FOR BOTH 2024 ALUMINUM AND 6061 ALUMINUM ARE GIVEN.

S_F, S_y FOR THE MATERIALS WERE FOUND ON MATWEB.

PRESSURE APPLICATOR: BOTTOM SHAFT ANALYSIS

3/4

2024 Aluminum

M_{max}	836	lbin
S_f	20000	psi
S_y	45000	psi

D (in)	σ (psi)	n
0.5	34062	0.41
0.55	25591	0.54
0.6	19712	0.70
0.65	15504	0.89
0.7	12413	1.12
0.75	10092	1.37
0.8	8316	1.67
0.85	6933	2.00
0.9	5840	2.37
0.95	4966	2.79
0.96	4812	2.88
0.97	4665	2.97
0.98	4524	3.06
0.99	4388	3.16
1	4258	3.25
1.05	3678	3.76
1.1	3199	4.33
1.15	2800	4.95
1.2	2464	5.62
1.25	2180	6.35
1.3	1938	7.14
1.35	1731	8.00
1.4	1552	8.92

6061 Aluminum

M_{max}	836	lbin
S_f	14000	psi
S_y	35000	psi

D (in)	σ(psi)	n
0.5	34062	0.29
0.55	25591	0.39
0.6	19712	0.51
0.65	15504	0.65
0.7	12413	0.81
0.75	10092	0.99
0.8	8316	1.20
0.85	6933	1.44
0.9	5840	1.71
0.95	4966	2.01
1	4258	2.35
1.05	3678	2.72
1.06	3575	2.80
1.07	3476	2.88
1.08	3380	2.96
1.09	3288	3.04
1.1	3199	3.13
1.125	2990	3.34
1.15	2800	3.57
1.2	2464	4.06
1.25	2180	4.59
1.3	1938	5.16
1.35	1731	5.78
1.4	1552	6.44

WANT: $n > 3$

YELLOW = 1^{ST} VALUE WHERE $n > 3$

GREEN = 1^{ST} NOMINAL VALUE WHEN $n > 3$

CHECK STATIC LOADING:

FOR 2024 ALUMINUM:

$$\sigma = \frac{4M}{\pi r^3}$$

$$= \frac{4\,(836\text{ lb·in})}{\pi\,(.5)^3}$$

$$\sigma = 8515\text{ psi}$$

$$n = \frac{\sigma_{all}}{\sigma_{act}} = \frac{45\text{ ksi}}{8515\text{ psi}}$$

$$n = 5.28\ \checkmark$$

FOR 6061 ALUMINUM:

$$\sigma = \frac{4M}{\pi r^3}$$

$$= \frac{4\,(836\text{ lb·in})}{\pi\,(0.5625\text{ in})^3}$$

$$\sigma = 5980.7\text{ psi}$$

$$n = \frac{\sigma_{all}}{\sigma_{act}} = \frac{35\text{ ksi}}{5981\text{ psi}}$$

$$n = 5.85\ \checkmark$$

PRESSURE APPLICATOR: BOTTOM SHAFT ANALYSIS

BOTH 2024 ALUMINUM AND 6061 ALUMINUM HAVE SUFFICIENT SAFETY FACTORS FOR THE DESIRED LOADING.

COST ANALYSIS

NEED 2 29" LONG Ø 1.1/8" SHAFTS (6061) OR 1" (2024)

2024 ALUMINUM:

MCMASTER CARR 6 ft $83.33 (W/O SHIPPING)

6061 ALUMINUM:

METALS DEPOT

29" $22.07 ea = $44.14

+ $20 SHIPPING

$64.14

OR

5 ft $42.45 + $ 20 SHIPPING

= $ 62.45

6061 ALUMINUM MUCH CHEAPER THAN 2024 ALUMINUM.

GETTING THE ALREADY CUT PIECES BARELY COSTS MORE AND WILL BE MUCH FASTER FOR MANUFACTURING.

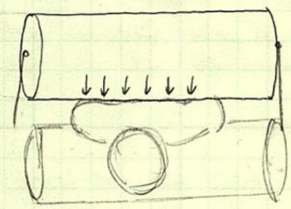
FINAL DECISION:

6061 ALUMINUM

2 29" SHAFTS Ø 1 1/8"

$ 64.14

PRESSURE APPLICATOR: BUNGEE SPRING RATE ANALYSIS



WANT: 15 - 30 PSI PRESSURE ON USER.

CALCULATE SPRING RATE FOR 25 PSI SO THE MAXIMUM IS NOT EXCEEDED.

ASSUME: CHILD WIDTH IS 1 FOOT
CHILD IS IN CONTACT WITH A 1 inch SECTION OF THE ROLLER.

$P = \frac{F}{A}$ $\quad F = PA$

$F = (25 \frac{lb}{in^2})(12 in \times 1 in)$

$F = 300 lbf$

$W_{SHAFT} = 1.17 \frac{lb}{Ft} \times 29 in \times \frac{1 ft}{12 in} = 2.83 lbs$ (1.17 lb/ft STATED BY MANUFACTURER)

USE HIGH DENSITY RUBBER SPECS TO ESTIMATE PADDING WEIGHT

$\rho = 0.0167 \frac{lb}{in^3}$

ASSUME 3 inches THICK, 28 inches LONG, 4 inches WIDE ($\sim \pi D_{SHAFT}$ CIRCUMFERENCE)

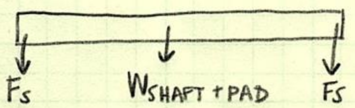
$W = \rho V$

$= 0.0167 \frac{lb}{in^3} \times (3 in \times 28 in \times 4 in)$

$W_{PADDING} = 5.61 lb$

PRESSURE APPLICATOR: SPRING RATE ANALYSIS

FBD:



$\Sigma F_Y = -300$ lbs

$-F_S - F_S - W_{SHAFT+PAD} = -300$ lbs

$2F_s = 292$ lb

$F_s = 146$ lbs

ASSUME BUNGEE IS LINEAR, ∴ $F_s = K\Delta X$.

WANT EXTENSION TO BE LARGER THAN THE LARGEST EXPECTED CHILD,

CHOOSE $\Delta X_{max} = 9$ inches.

$$K = \frac{F_S}{\Delta X}$$

$$K = \frac{146 \text{ lbs}}{9 \text{ in}}$$

$= $ **16 lb/in SPRING RATE DESIRED**

BUNGEES WILL BE TESTED TO VERIFY THEY CAN MEET THIS SPRING RATE. IF THEY FAIL, ONE OF THE BACKUP SPRINGS HIGHLIGHTED ON THE FOLLOWING PAGE WILL BE USED INSTEAD.

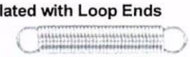
McMASTER-CARR. OVER 555,000 PRODUCTS
(562) 692-5911
(562) 695-2323 (fax)
la.sales@mcmaster.com
Text 75930

Steel Music Wire Extension Springs


With Loop Ends


With Hook Ends

Unplated with Loop Ends


With Loop Ends

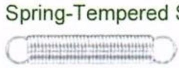
Spring OD	Wire Dia.	Extended Lg.	Load, lbs. Min.	Load, lbs. Max.	Rate, lbs./inch	Pkg. Qty.		Pkg.
5.812" Overall Length								
0.547"	0.080"	7.785"	4.00	24.00	10.00	3	9654K305	$7.50

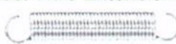
Unplated with Hook Ends


With Hook Ends

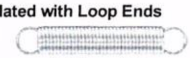
Spring OD	Wire Dia.	Extended Lg.	Load, lbs. Min.	Load, lbs. Max.	Rate, lbs./inch	Pkg. Qty.		Pkg.
6.25" Overall Length								
0.875"	0.120"	7.24"	17.24	35.00	17.76	3	9654K334	$12.92
8" Overall Length								
1.25"	0.207"	9.04"	75.04	162.70	87.66	1	9654K391	9.18
8.25" Overall Length								
1.063"	0.135"	9.27"	17.80	30.00	12.20	1	9654K338	7.09

Spring-Tempered Steel Wire Extension Springs


With Loop Ends

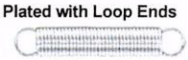

With Hook Ends

Unplated with Loop Ends


With Loop Ends

Spring OD	Wire Dia.	Extended Lg.	Load, lbs. Min.	Load, lbs. Max.	Rate, lbs./inch	Pkg. Qty.		Pkg.
5" Overall Length								
0.5"	0.072"	7.82"	6.15	31.37	8.95	6	9654K326	$11.30
5.25" Overall Length								
0.625"	0.080"	9.12"	6.04	34.17	7.27	6	9654K327	12.70
5.375" Overall Length								
0.688"	0.091"	8.705"	8.35	44.60	10.88	6	9654K331	12.70
6.5" Overall Length								
0.75"	0.120"	8.8"	20.80	87.75	29.07	3	9654K336	6.84

Zinc Plated with Loop Ends


With Loop Ends

Spring OD	Wire Dia.	Extended Lg.	Load, lbs. Min.	Load, lbs. Max.	Rate, lbs./inch	Pkg. Qty.		Pkg.
5.5" Overall Length								
0.438"	0.063"	8"	4.70	18.00	5.29	3	9654K535	$8.22
0.688"	0.080"	7.67"	5.36	15.72	4.78	6	9654K922	14.61
6" Overall Length								
0.5"	0.063"	9.59"	3.84	15.58	3.27	3	9654K181	6.82
0.578"	0.072"	9.42"	5.05	20.08	4.40	3	9654K179	7.96
0.875"	0.091"	9.05"	5.54	17.90	4.05	1	9654K247	3.28
6.5" Overall Length								
0.625"	0.080"	8.52"	6.45	17.18	5.31	1	9654K248	2.64
0.75"	0.091"	8.72"	7.54	20.68	5.93	1	9654K249	3.06

PRESSURE APPLICATOR: SPRING RATE ANALYSIS

Zinc Plated with Hook Ends


With Hook Ends

Spring OD	Wire Dia.	Extended Lg.	Load, lbs. Min.	Max.	Rate, lbs./inch	Pkg. Qty.		Pkg.
6" Overall Length								
0.641"	0.080"	9.28"	6.29	24.45	5.54	3	9654K427	$9.39
0.734"	0.092"	8.98"	8.72	31.09	7.52	3	9654K426	10.81
0.844"	0.106"	8.75"	11.62	40.69	10.57	3	9654K176	11.42
0.969"	0.121"	8.53"	15.14	51.57	14.43	1	9654K424	4.75
7" Overall Length								
1.375"	0.207"	8.61"	60.00	178.44	73.56	1	9654K476	15.04

Type 302 Stainless Steel Extension Springs

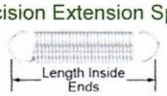

With Hook Ends

With Hook Ends


With Hook Ends

Spring OD	Wire Dia.	Extended Lg.	Load, lbs. Min.	Max.	Rate, lbs./inch	Pkg. Qty.		Pkg.
6" Overall Length								
0.73"	0.092"	9.44"	8.72	33.97	6.47	1	94135K39	$8.24
0.84"	0.106"	9.49"	11.62	43.69	9.05	1	94135K87	9.00
0.96"	0.121"	9.19"	15.14	55.23	12.37	1	94135K42	9.51
6.5" Overall Length								
0.75"	0.120"	8.695"	20.8	76.3	25.28	1	94135K62	12.14
8" Overall Length								
1.063"	0.135"	9.877"	11.04	33.04	11.72	1	94135K85	20.16

Precision Extension Springs with Hook Ends



Specification	Tolerance
OD 0.094" to 0.188"	+0.003"/−0.005"
OD 0.25" to 0.5"	±0.008"
OD 0.625" to 0.75"	±0.015"
Minimum Load	±15%
Rate, lbs./inch	±10%

Springs are manufactured to specific OD, extended length, minimum load, and rate tolerances.

Zinc-Plated Steel Music Wire Springs—Meet ASTM B633 and offer some corrosion resistance.

Black-Oxide Steel Music Wire Springs—Are treated for durability and rust resistance.

Type 302 Stainless Steel Springs—Meet ASTM A313 and offer excellent corrosion resistance.

Also Available: Springs with a certificate of compliance. Select 9432K999 for steel music wire springs or 9433K999 for Type 302 stainless steel springs and specify the spring part number.

Zinc-Plated Steel Music Wire

Spring OD	Wire Dia.	Extended Lg.	Load, lbs. Min.	Max.	Rate, lbs./inch	Pkg. Qty.		Pkg.
3" Length Inside Ends								
0.625"	0.063"	7.27"	1.50	19.86	4.30	3	9432K119	$6.03
4.5" Length Inside Ends								
0.375"	0.055"	8.13"	2.00	21.90	5.90	6	9432K64	11.08

Black-Oxide Steel Music Wire

Spring OD	Wire Dia.	Extended Lg.	Load, lbs. Min.	Max.	Rate, lbs./inch	Pkg. Qty.		Pkg.
4.5" Length Inside Ends								
0.625"	0.069"	9"	2.80	21.91	3.79	3	3114T112	$9.23
5" Length Inside Ends								
0.5"	0.063"	9"	3.00	21.36	4.08	6	3114T92	14.36

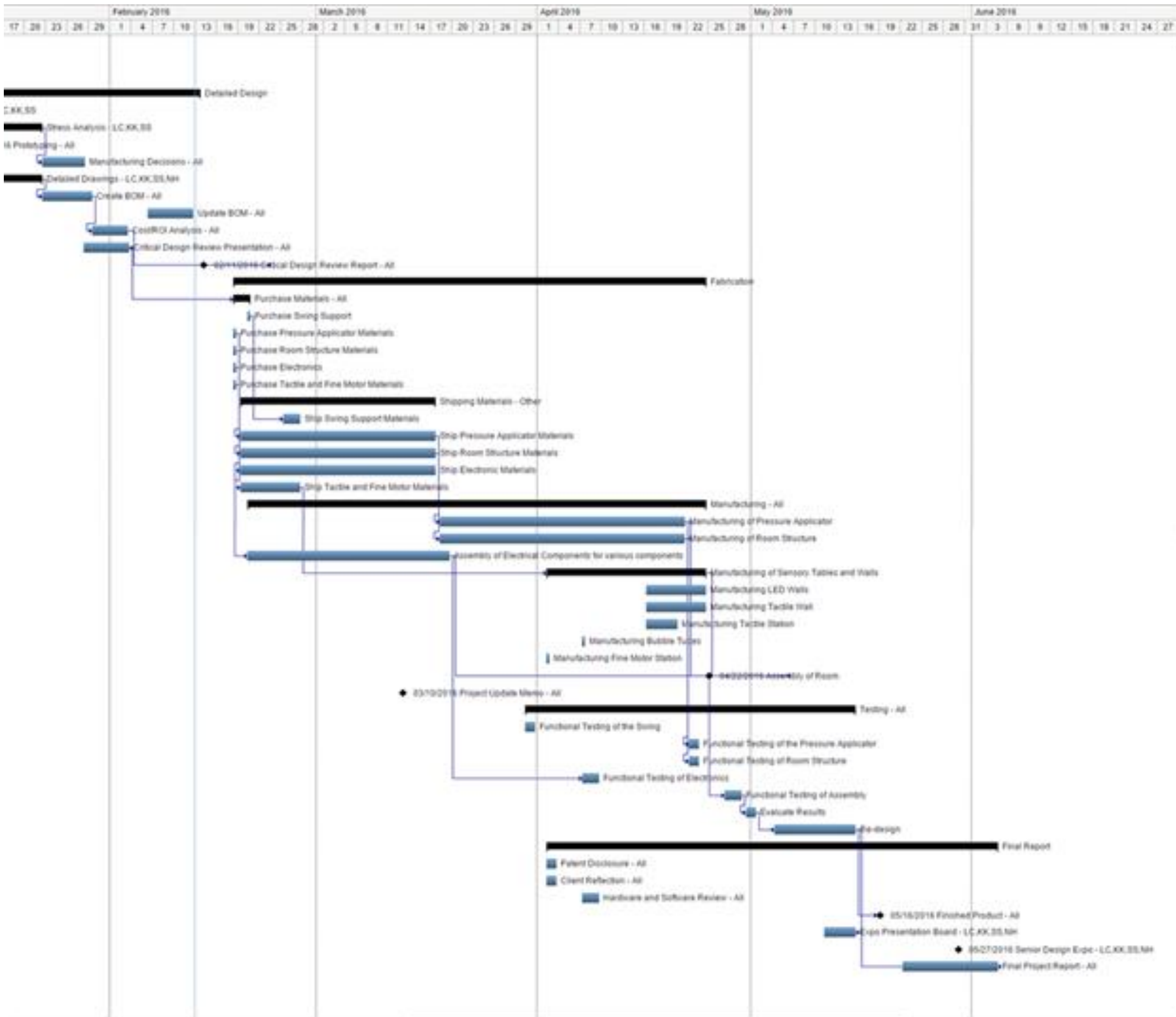
Type 302 Stainless Steel

Pressure Applicator Weight Calculation:

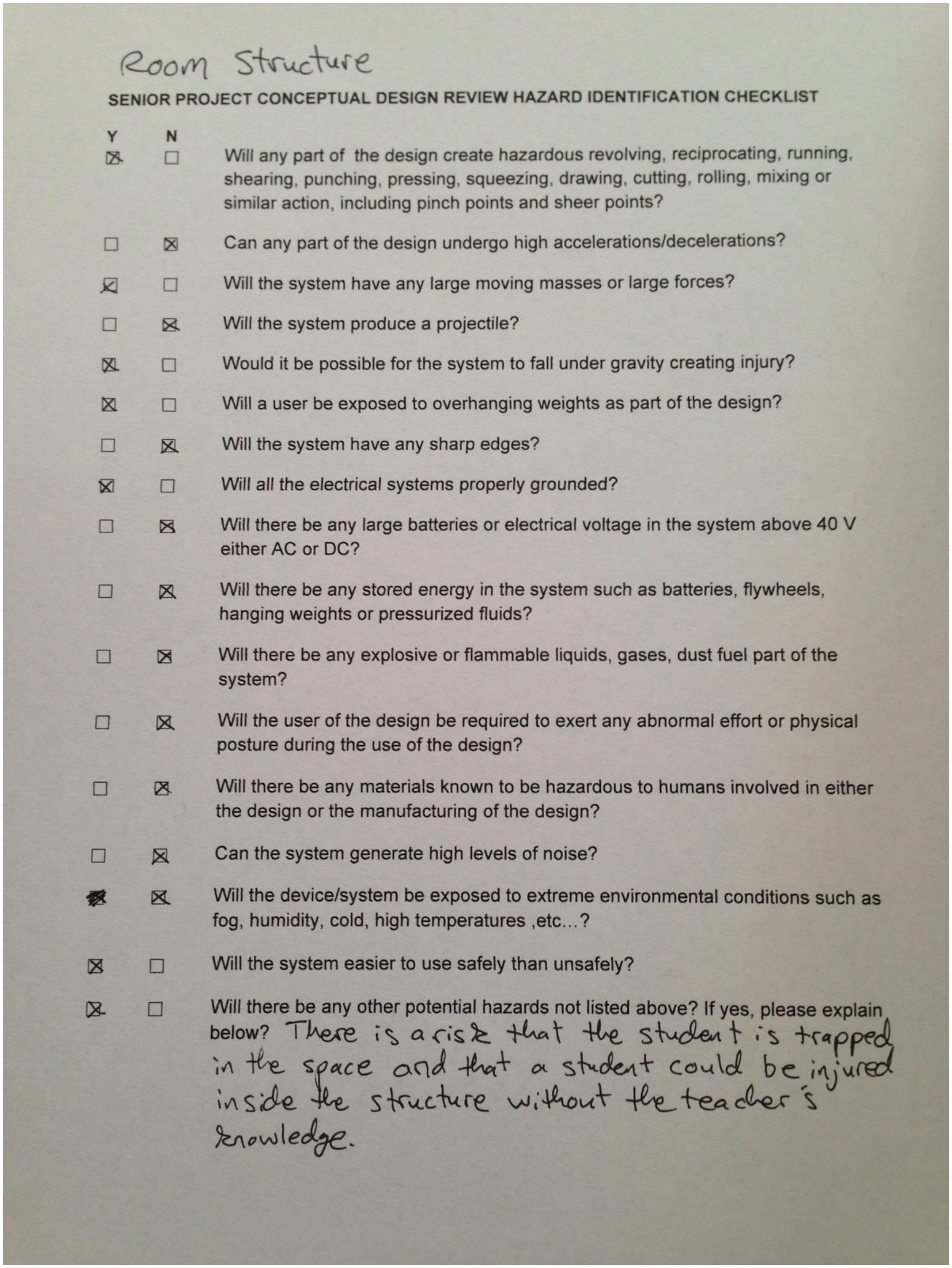
Component	Quantity	Weight (lbs)	Total Weight (lbm)
Shafts	2	2.83	5.7
Bushings	6	.10	.6
Wood	1	18	18
Foam	2	5.5	11
Total	**-**	**-**	**35.3 lbs**

APPENDIX H: GANTT CHART

		Name	Duration	Start	Finish	Predecessors	Resources
1		**⊞Project Assigned**	2d	**10/06/2015**	**10/07/2015**		
4		**⊞Project Definition**	5d	**10/06/2015**	**10/12/2015**		
8		**⊞Concept Design**	34d	**10/13/2015**	**12/02/2015**		
15		**⊟Detailed Design**	30.5d	**01/04/2016**	**02/11/2016**		
16		**⊞CAD Models**	2d	**01/04/2016**	**01/05/2016**		**LC,KK,SS**
20		**⊞Stress Analysis**	12d	**01/06/2016**	**01/20/2016**		**LC,KK,SS**
23		Prototyping	5d	01/04/2016	01/08/2016	14	All
24		Manufacturing Decisions	4d	01/20/2016	01/26/2016	20	All
25		**⊞Detailed Drawings**	14d	**01/04/2016**	**01/20/2016**		**LC,KK,SS,NH**
30		Create BOM	5d	01/20/2016	01/27/2016	25	All
31		Update BOM	5d	02/04/2016	02/10/2016		All
32		Cost/ROI Analysis	3d	01/27/2016	02/01/2016	30	All
33		Critical Design Review Presentation	5d	01/26/2016	02/01/2016	32FF	All
34		Critical Design Review Report	8d	02/02/2016	02/11/2016	32FF	All
35		**⊟Fabrication**	44d	**02/16/2016**	**04/22/2016**		
36		**⊟Purchase Materials**	3d	**02/16/2016**	**02/18/2016**	**33**	**All**
37		Purchase Swing Support	1d	02/18/2016	02/18/2016		
38		Purchase Pressure Applicator Materials	1d	02/16/2016	02/16/2016		
39		Purchase Room Structure Materials	1d	02/16/2016	02/16/2016		
40		Purchase Electronics	1d	02/16/2016	02/16/2016		
41		Purchase Tactile and Fine Motor Materials	1d	02/16/2016	02/16/2016		
42		**⊟Shipping Materials**	20d	**02/17/2016**	**03/15/2016**		**Other**
43		Ship Swing Support Materials	3d	02/23/2016	02/25/2016	37	
44		Ship Pressure Applicator Materials	20d	02/17/2016	03/15/2016	38	
45		Ship Room Structure Materials	20d	02/17/2016	03/15/2016	39	
46		Ship Electronic Materials	20d	02/17/2016	03/15/2016	40	
47		Ship Tactile and Fine Motor Materials	7d	02/17/2016	02/25/2016	41	
48		**⊟Manufacturing**	42d	**02/18/2016**	**04/22/2016**		**All**
49		Manufacturing of Pressure Applicator	20d	03/16/2016	04/19/2016	44	
50		Manufacturing of Room Structure	20d	03/16/2016	04/19/2016	45	
51		Assembly of Electrical Components for various component	21d	02/18/2016	03/17/2016	46SS	
52		**⊟Manufacturing of Sensory Tables and Walls**	17d	**03/31/2016**	**04/22/2016**	**47**	
53		Manufacturing LED Walls	7d	04/14/2016	04/22/2016		
54		Manufacturing Tactile Wall	7d	04/14/2016	04/22/2016		
55		Manufacturing Tactile Station	3d	04/14/2016	04/18/2016		
56		Manufacturing Bubble Tubes	1d	04/05/2016	04/05/2016		
57		Manufacturing Fine Motor Station	1d	03/31/2016	03/31/2016		
58		Assembly of Room	10d	04/11/2016	04/22/2016	49FF,50FF,51FF	
59		Project Update Memo	3d	03/08/2016	03/10/2016		All
60		**⊟Testing**	35d	**03/28/2016**	**05/13/2016**		**All**
61		Functional Testing of the Swing	2d	03/28/2016	03/29/2016		
62		Functional Testing of the Pressure Applicator	2d	04/20/2016	04/21/2016	49	
63		Functional Testing of Room Structure	2d	04/20/2016	04/21/2016	50	
64		Functional Testing of Electronics	3d	04/05/2016	04/07/2016	51	
65		Functional Testing of Assembly	3d	04/25/2016	04/27/2016	58	
66		Evaluate Results	2d	04/28/2016	04/29/2016	65	
67		Re-design	10d	05/02/2016	05/13/2016	66	
68		**⊟Final Report**	46d	**03/31/2016**	**06/02/2016**		
69		Patent Disclosure	2d	03/31/2016	04/01/2016		All
70		Client Reflection	2d	03/31/2016	04/01/2016		All
71		Hardware and Software Review	3d	04/05/2016	04/07/2016		All
72		Finished Product	1d	05/16/2016	05/16/2016	67	All
73		Expo Presentation Board	5d	05/09/2016	05/13/2016	67FF	LC,KK,SS,NH
74		Senior Design Expo	1d	05/27/2016	05/27/2016		LC,KK,SS,NH
75		Final Project Report	10d	05/20/2016	06/02/2016	67FF	All


February 2016
March 2016
April 2016
May 2016
June 2016
Detailed Design
Stress Analysis - LC,KK,SS
Manufacturing Decisions - All
Detailed Drawings - LC,KK,SS,NH
Create BOM - All
Update BOM - All
Cost/ROI Analysis - All
Critical Design Review Presentation - All
Critical Design Review Report - All
Fabrication
Purchase Materials - All
Purchase Swing Support
Purchase Pressure Applicator Materials
Purchase Room Structure Materials
Purchase Electronics
Purchase Tactile and Fine Motor Materials
Shipping Materials - Other
Ship Swing Support Materials
Ship Pressure Applicator Materials
Ship Room Structure Materials
Ship Electronic Materials
Ship Tactile and Fine Motor Materials
Manufacturing - All
Manufacturing of Pressure Applicator
Manufacturing of Room Structure
Assembly of Electrical Components for various components
Manufacturing of Sensory Tables and Walls
Manufacturing LED Walls
Manufacturing Tactile Wall
Manufacturing Tactile Station
Manufacturing Bubble Tubes
Manufacturing Fine Motor Station
Assembly of Room
03/10/2016 Project Update Memo - All
Testing - All
Functional Testing of the Swing
Functional Testing of the Pressure Applicator
Functional Testing of Room Structure
Functional Testing of Electronics
Functional Testing of Assembly
Evaluate Results
Re-design
Final Report
Patent Disclosure - All
Client Reflection - All
Hardware and Software Review - All
05/16/2016 Finished Product - All
Expo Presentation Board - LC,KK,SS,NH
05/27/2016 Senior Design Expo - LC,KK,SS,NH
Final Project Report - All

APPENDIX I: HAZARD IDENTIFICATION CHECKLISTS



Room Structure

SENIOR PROJECT CONCEPTUAL DESIGN REVIEW HAZARD IDENTIFICATION CHECKLIST

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? There is a risk that the student is trapped in the space and that a student could be injured inside the structure without the teacher's knowledge.

SWING STRUCTURE SUPPORT CONCEPT HAZARD IDENTIFICATION CHECKLIST:

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

Fall from swing, Impact injury from being hit by swing, The system should allow for constant supervision of the children by the teacher.

SINGLE SQUEEZER CONCEPT HAZARD IDENTIFICATION CHECKLIST:

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

The system should allow for constant supervision of the children by the teacher.

APPENDIX J: SPECIFICATION VERIFICATION CHECKLIST

Table J-1. Component Final Weights

Component	Height	Length	Width	Weight (lbs)
LED Panels	4’ 6”	3’	3.75”	112
Fabric Panels	4’6”	3’	4”	110
Tactile Station	4’ 9”	4’	1’	163
Bookshelf	4’7”	4’1.5”	1’	145
Tactile Wall	4’6.5”	3’	10.5”	113
Pressure Applicator	26.75”	21.5”	15.25”	17

Table J-2. Component Tipping Loads

Component	Tipping Load (lbs)	Pass/Fail
LED Panels	15	F
Fabric Panels	17	F
Tactile Station	23	F
Bookshelf	20	F
Tactile Wall	12	F

DVP&R

Report Date		Sponsor	Lisa Colburn, WOCCSE					

TEST PLAN

Item No	Specification or Clause Reference	Test Description	Acceptance Criteria	Test Responsibility	Test Stage	SAMPLES		TIMING	
						Quantity	Type	Start date	Finish da
1	Expanded Length	Measuring Expanded Room Dimensions	< 10 ft	Emma	PV	1	C	4/25/2016	4/27/201
2	Expanded Width	Measuring Expanded Room Dimensions	<15 ft	Emma	PV	1	C	4/25/2016	4/27/201
3	Expanded Height	Measuring Expanded Room Dimensions	< 8 ft	Emma	PV	1	C	4/25/2016	4/27/201
6	Fire Exit	Fire Exit	>28 inches wide	Emma	PV	1	C	4/25/2016	4/27/201
4	Weight	Structure Weight	<100 lbs	Sarah	DV	6	C	3/16/2016	4/19/201
5	Traveling Size	Travelling Room Dimensions	< 6'11" tall, <2.5' wide	Sarah	DV	6	C	3/16/2016	4/19/201
7	Withstanding Loads	Room Structure Tipping Load	>50 lbs	Sarah	DV	6	B	3/16/2016	4/19/201
8		Swing Tipping Load	> 50 lbs	Kaylee	PV	3	C	3/28/2016	3/29/201
9		Swing Support Load	> 150 lbs	Kaylee	PV	1	C	3/28/2016	3/29/201
10		Pressure Applicator Load	>150 lbs	Lindsey	PV	1	C	4/20/2016	4/21/201
11	Power	Voltage	<13V	Nate	DV	3	B	4/5/2016	4/7/201
12		Amperage	<10 mA	Nate	DV	3	B	4/5/2016	4/7/201
13		Battery Life	3 months = 2000 mAh	Nate	DV	3	B	4/5/2016	4/7/201
14		Power component access	All power components require a tool to access.	Nate	PV	3	C	4/25/2016	4/27/201
15	Choking Hazards	Choking Hazards	No choking hazards exist.	Claire	PV	6	C	4/25/2016	4/27/201
16	Gaps to Get Stuck In	Gaps to Get Stuck In	All gaps are outside of the range of 3-9in	Claire	PV	6	C	4/25/2016	4/27/201
17	Sound	Irritating Noises	No squeaking or irritating noises during set up and operation.	Claire	PV	8	C	4/25/2016	4/27/201
18	Brightness	Brightness	<1000 LUX	Nate	DV	3	B	4/25/2016	4/27/201
19	Epilepsy	Light Frequencies	Does not induce epilepsy	Nate	DV	3	B	4/5/2016	4/7/2016