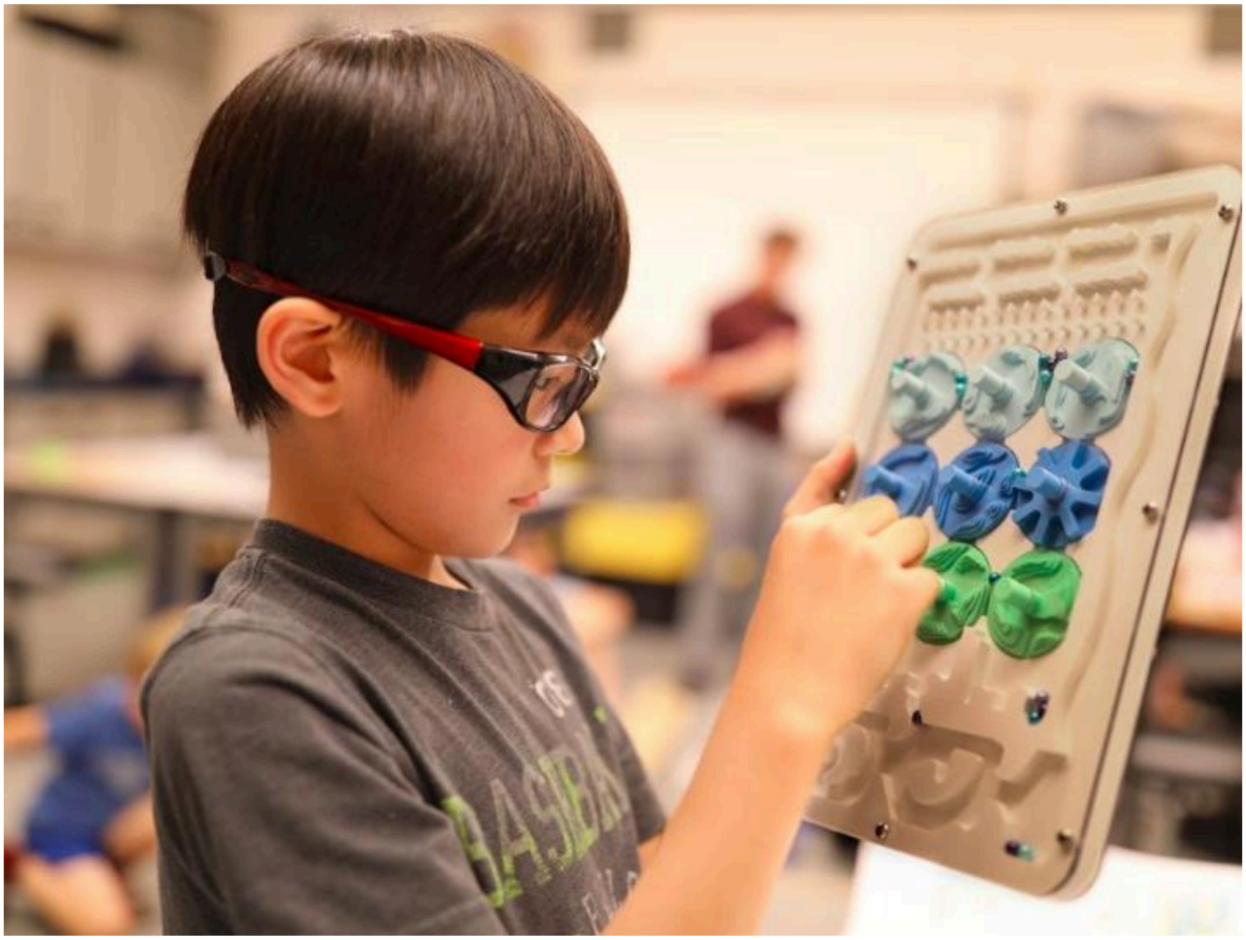
EcosySTEM ARTS
Comprehensive Design Review



Team #6
Tyler Edens
Eleanor Pearson
Fatin Nasser
Radhi Aziz
Brent Frieden
Madison Emmett

Department of Mechanical Engineering
University of Colorado Boulder
13 November 2018

Table of Contents

I. Background and Motivation

EcosySTEM ARTS is dedicated to providing STEAM education opportunities for children in Children's Hospital and involving other student in design-learning through empathy. EcosySTEM ARTS is a nonprofit that was founded by Brian Jernigan to help hospitalized children through empathy and engineering. Three years ago, Mr. Jernigan found that kids at Children's Hospital were not able to play with common toys due to the strict risk management standards and sterilization procedures. He approached Children's Hospital with his idea to make the kids a better toy to use during their stay.

Mr. Jernigan decided to collaborate with the CU Boulder Senior Design Program to design and fabricate the toy. The first product, developed from 2016-2017, ended up being too large and did not meet hospital standards. Based on these results, the EcosySTEM team determined that it is best to keep the product simple and feasible.

During the 2017-2018 school year, the new design team utilized feedback from local children to determine what kids were looking for in a STEAM toy. The result was that the kids who had experiences with illness, and also their family members, bonded very strongly and came up with the ideas that were the most impactful on the design process. From this, the idea of a therapeutic design session was created.

This year is the third year of collaboration between Design Center Colorado and EcosySTEM ARTS. This year's project has the specific aim of providing an engaging and STEAM oriented toy to Children's Hospital Colorado. Along with providing a fully functional, trade-level toy, the product will be capable of having a curriculum developed around it where students will be involved in the design process and make their own iterations and designs of the toy itself. The team also wants to take the project a step further and create a product that will support and aid EcosySTEM ARTS and children at Children's Hospital into the future, and create a platform from which future Senior Design teams, and students around the country can learn from and participate in. The final product will be impactful for the future of the nonprofit and will outline the company's path for helping sick kids around the world through creativity, STEM, and Arts.

II. Project Mission

The mission of this project is to create a toy that will help enhance the lives of kids who are hospitalized. Children who are hospitalized for an extended period of time often regress mentally due to the constant feeling of not being in control of anything in their lives. They are denied many things that children who live outside the hospital use to develop. For this reason, we are creating an educational toy that can be used by these kids while they are unsupervised. In order to be unique, this toy needs to be designed to teach scientific concepts to children of many different backgrounds. The toy will have a STEM and Arts focus and will be targeting children who have a mental age of 4-8 years old. To get these toys into the hospital they have to be durable and childproof so that they do not break while in use. The toy also has to conform to the Children's Hospital Risk Management standards so that the toy is as safe as possible.

The mission for the product and for EcosySTEM Arts further down the road is to create a curriculum that can be shared with students all over the world so that they can create their own toy and customize it using our design as a template. The nonprofit is looking to reach out to schools who have a hospitalized student and help them design a toy to give to that child while they are in the hospital. Building this toy can be used as an opportunity for high school students to get some manufacturing experience. We are hoping to document and share our entire process on the EcosySTEM Arts website so that they can learn from our experience.

III. Project Requirements

This section of the report will go in-depth into the project requirements. These requirements include ones imposed by EcosySTEM ARTS, Children's Hospital Risk Management, and also ones created by the team to create a better product. Specific design requirements are explained below.

A. Weight

One important factor for the toy is its weight. Our goal is to make a toy that in no way inconveniences hospital staff and is not cumbersome in any way. To be an easily useable toy, the toy will be less than 2 lbs fully assembled. Using SolidWorks material properties estimations, the full assembly weight is estimated to be under two pounds.

B. Size

Another factor playing into the toy's ease of use is its size. The toy was designed to be smaller in volume than a standard iPad size rectangular prism of 10x7x7 inches. The design has a size of 8x8x4 inches, which is smaller in volume than the volume limit.

It was also decided that the toy should have no more than two separate assemblies. This was to ensure that parts of the toy could not be lost, making the toy unusable, and so that the design was easier to keep track of. The toy delivered to the hospital will be one sealed assembly, meeting this requirement.

C. Safety

Due to the toy's use in Children's Hospital, there are many very specific safety requirements that must be met and followed precisely. After passing inspection by Hospital Staff and Risk Management, the toy will be left unsupervised with children at the hospital. For this reason, it is imperative that the toy not have sharp edges or choking hazards, or be able to come apart in the hands of a child. Some children in the hospital are on self-harm watch and ensuring that our toy can be in no way be manipulated to be used for self-harm is of the utmost importance. If our toy in any way harms a child in the hospital our project will have failed. The toy must be safe under even extreme use by the children.

D. Durability

As mentioned above, the toy will be left in the hands of children unsupervised. The toy will need to be ‘kid-proof’ and be able to withstand children’s use and abuse. Specifically, the entire assembly must be impact resistant and remain intact when it is dropped and handed roughly. Testing to ensure these characteristics will be described later in this report. The toy will also be sanitized after every use, so it is necessary that the device retain its transparency after repeated cleanings.

Table 1: Project Requirements

ID	Category	Description	Status	Notes	Source
1	Weight	The fully assembled toy shall weight no more than 2 lbs.	Preliminary	This way children can hold in in their lap without issue.	Client meeting #1
2.1	Size	The toy will be no larger than 10x7x7 inches.	Preliminary	iPad size with room for 3D expansion	Client meeting #1
2.2		The toy shall have no more than 2 separately sealed assemblies.	Firm	This gives us some options without limiting to one sealed assembly.	Team brainstorming session
3.1	Safety	The toy will have rounded and filed edges of 1/4 inch.	Preliminary	No sharp corners or edges. The purpose of this specification is to make sure nothing will harm the user. So we really only need to file down edges, as told by the hospital risk management staff.	Team brainstorming session
3.2		The toy will not have flashing lights.	Firm	For children with epilepsy and who are prone to seizures, this is very important.	Hospital standards
3.3		The toy shall conform to Children's Hospital Risk Management standards.	Firm	If we don't meet these standards, the project is a failure.	Hospital standards
3.4		The toy will not have any exposed components that can fit through a tube of 1.75 inch diameter.	Firm	Need to avoid choking hazards.	Hospital standards
4.1	Durability	The device shall still function after being dropped from 4 feet over 25 times.	Preliminary	If toy falls off bed or kid drops it, it needs to function still.	Client meeting #1
4.2		Opacity must be no more that 30% on all clear parts.	Preliminary	If you can't see inside the toy then it is a failure.	Team brainstorming session
5	User Friendly	The toy must go through iterations and testing with children to ensure they enjoy playing and learning from our product.	Firm	The goal of the toy is to be interesting, engaging, and educational for children. If kids do not like our product, then our efforts are all for naught.	Client meeting #1

IV. Design Overview

The EcosySTEM ARTS project is a very open-ended project. The biggest initial challenge was determining what the team would make that would be both an engaging toy for children and an engineering challenge for the team. The team was inspired by the previous teams’ projects and toys they researched online, but a unique idea specifically designed for EcosySTEM Arts’ goal was needed. Thus, the team was tasked with each member brainstorming three unique ideas for an educational STEAM toy. These eighteen ideas were then presented to the rest of the group, the client, and director. Each of the ideas were discussed at length for their overall pros and cons and engineering challenges. Eventually, the ideas were voted on and refined to three distinct toys: Foosball Coding game, Probability game, and 3D Maze.

The team then divided themselves into three groups and each produced an initial prototype for the toy ideas. The prototypes were aimed to answer important initial questions, including size considerations, complexity of human-toy interaction, and engineering feasibility. The prototypes were also presented to children at a local elementary school and given feedback for what the children liked or disliked about each prototype. By the end of this process, the team chose to create the 3D Maze with interlocking personalization abilities. This option was liked best by the elementary school children, offered the greatest potential engineering challenges, and showed potential for creativity and a multitude of teaching opportunities. The 3D Maze would also provide mental stimulation for children since it would require eye-hand coordination, spatial visualization, and various kinds of mazes and worlds within mazes to reach children with different interests and skills. The 3D Maze will be designed to be played in multiple ways so as to avoid frustration in children who might not be ready for such difficulty, and to continue challenging children who want to figure out every possible way to solve the maze.

The final design for the 3D Maze will include four cubes that attach to a central part made from aluminum. The central part will allow the cubes to be interlocking so users can personalize each cube and have the mazes be specific to their interests. This also means the team will have to face the challenge of creating an interlocking component that is not only strong but lightweight. This design enables each maze to be sealed off, so children will not have access to any components that might pose a choking hazard.

The 3D Maze design will allow the team to reuse ideas from the initial design process as well. Each cube is its own component and can have its own world and specific educational goal. Thus, the eighteen original ideas for educational toys can be brought back into the final toy design as maze concepts. This means that the entire design process will be more circular and also more efficient since the team can use their own previous ideas to create something wonderful for the final 3D Maze toy product.

V. Subsystem Review

This section of the report will provide a detailed description of critical components of the design and the teams design considerations.

A. Cube

The first critical component of the maze is the cube that contains the mazes. The complete assembly will contain four cubes attached to the interlocking center. In order to pass inspection by hospital staff, the toy must be completely sealed, strong and durable, and safe enough to leave with a child unattended.

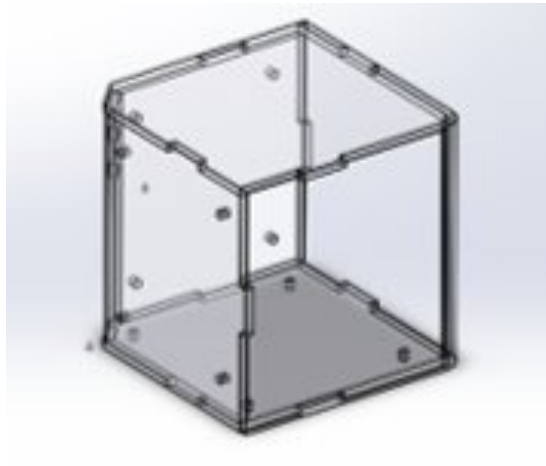


Figure 1: Fully assembled cube

After some quick materials research, polycarbonate was decided upon for the cube's material. The sides of the cube need to be transparent for ease of use. Also, the material needed to be very strong and impact resistant to withstand the prolonged use from children. With these factors in consideration, polycarbonate was a great fit as it is clear and incredibly impact resistant.

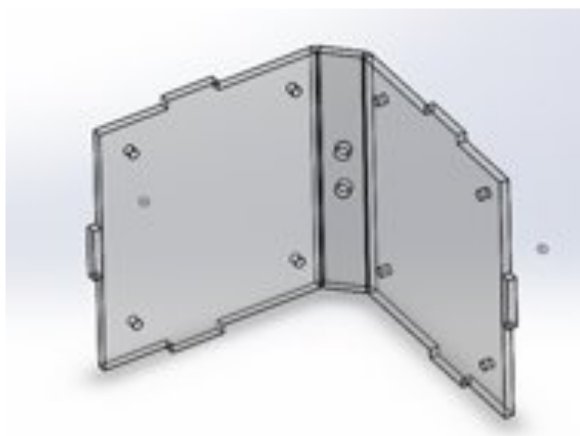


Figure 2: Polycarbonate walls of the cube with interlocking mounting holes

An initial problem with the design was figuring out how to fasten all of the faces of the cube together. The first idea was to have 7 separate planes but that was quickly deemed too complicated. After contacting some manufacturers, we settled on using bent polycarbonate for the walls and windows. This reduced the number of components and the number of interfacing parts. Another benefit of this design is the reduction of sharp edges and an easier interface with the interlocking center. These bent pieces can be seen in Figures 2 and 3.

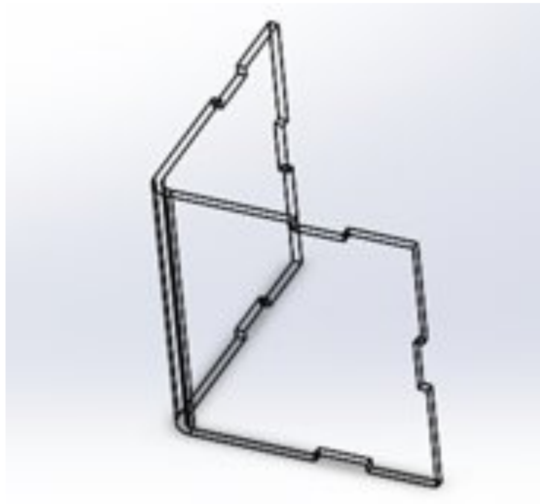


Figure 3: Bent polycarbonate cube window

The cube faces were designed with tabs and slots as locating features. This will ensure correct location when assembling the cube itself and allow for the cube to holds its shape before being fastened. The tabs will also provide additional support at the edges which will help with impact resistance and general strength of the cube assembly.

To minimize the number of fasteners and further lessen the number of components, Dichloromethane (DCM) will be used as a solvent to seal the cube faces together. The benefits of this fastening method are numerous: fewer parts, strong material properties at the edges, no material buildup through fastened edges, and aesthetic. Using a solvent, the junction will have near the original material strength as opposed to needing bolt holes and attaching dissimilar material. A well done sealant application will not allow any material to squeeze into the cube, as it will be sealed and not merely pressed or clamped together. Following the advice of the Machine Shop staff, the ceiling and floor of the cube will be inset to allow for a better sealed edge. The inset design with the tabs and slots will make a very strong attachment when the solvent has been applied. The walls of the cube will include holes for mounting the maze. The entire exploded assembly can be seen in the figure below.

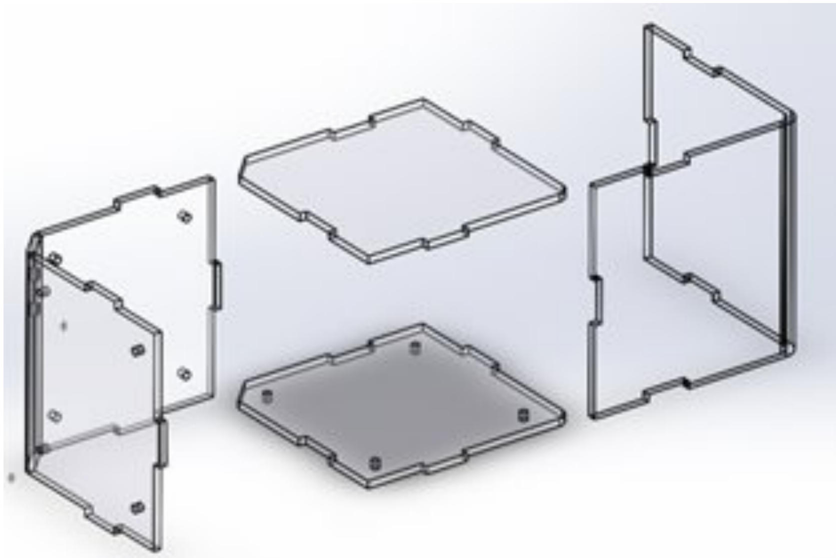


Figure 4: Exploded view of cube assembly

The polycarbonate will be laser cut and bent by Colorado Plastics, a local manufacturer. The polycarbonate cannot be laser cut at the university because polycarbonate releases chlorine gas, which cannot be handled with the university's current resources. Outsourcing the plastic will also cut down on manufacturing time and allow for large batch orders.

B. Interlocking Part

In order for the toy to be customizable, we decided to make the cubes detachable. The interlocking system that best fit in our design is as shown in Figure 5. The system consists of an aluminum T-slot, four slide-in T-nuts and two custom-made caps. This system will be the centerpiece of the toy and all the cubes will be attached around this interlocking system. As the project require us to make a toy that is safe for toddlers, this centerpiece can only be accessed by adults as it will be securely fastened with screws.

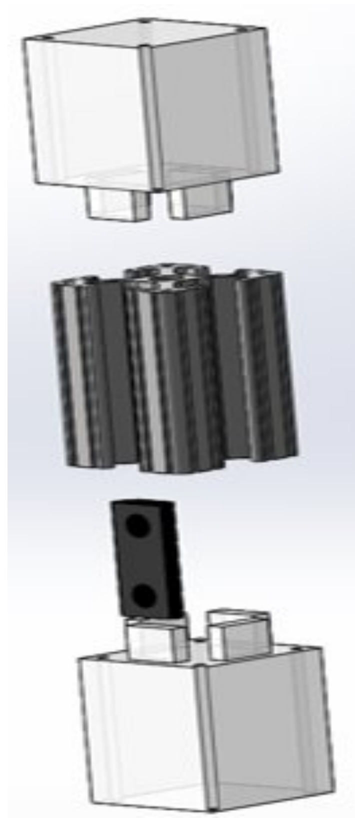


Figure 5: Interlocking system components

In the initial process of designing, we made our own T-slot design, but after a few design iterations, we decided to use readily available T-slotted aluminum. T-slotted aluminum is very common and easy to acquire and will also reduce our manufacturing time. We decided to use 80/20 aluminum T-slot of 1x1x1.5 inches dimension shown in Figure 6 because of the strength advantage that comes with it. We will customize the T-slot by making 8 threaded holes using milling machine.

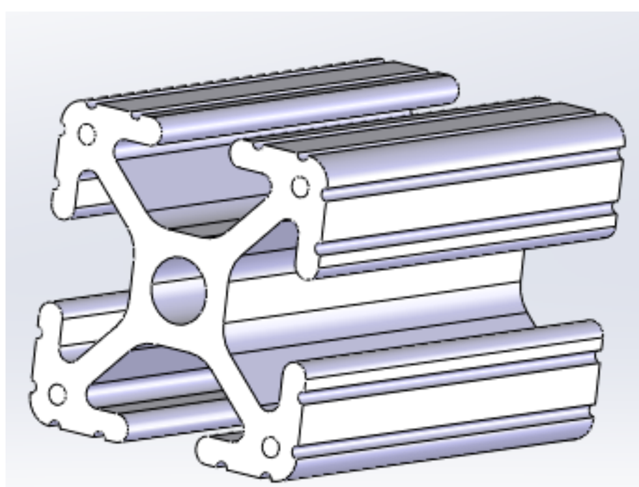


Figure 6: 8020 Aluminum T-slot

All of the cubes will be fastened to double slide-in T-nuts, so that the cubes are able to stay in place around the centerpiece. Initially, we wanted to use a one-hole T-nut to reduce the length of the aluminum T-slot, but one hole would leave the cube free to rotate. Therefore, we decided to use double slide-in T-nut so the cube would not rotate and also provide some extra strength and support. We will be using zinc alloy double slide-in T-nut of 0.936 inches long which is shown in Figure 7. This piece is a standard size and readily available for purchase as well.

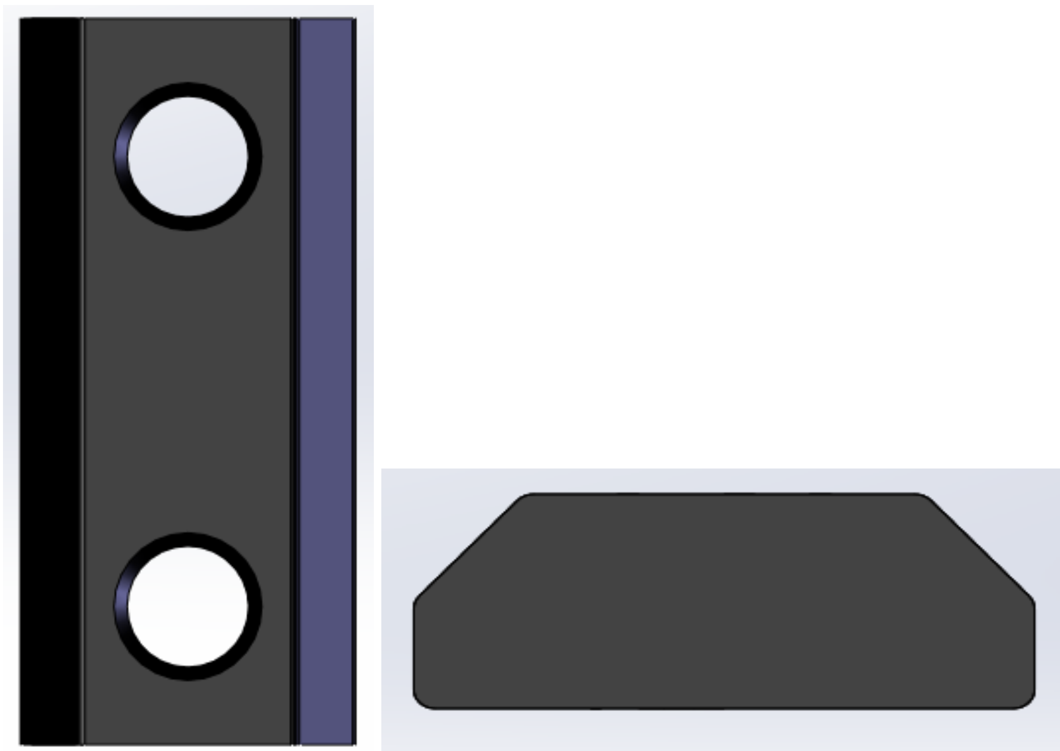


Figure 7. Front and bottom view of zinc alloy double slide-in T-nut.

The last component for the interlocking system is the cap. In order to have the aluminum T-slot mount in the middle of the toy, we designed two identical caps to pinch the T-slot as shown in Figure 8. The extruded shapes on the cap are meant to hold the T-nuts in the T-slot and as a locating feature for the system. We decided to use Acrylonitrile Butadiene Styrene (ABS) plastic as it has a high tensile strength, strong impact resistance, and is shock absorbent. It is also lightweight and comes in variety colors. Therefore, it is very suitable for this project. We will machine plastic ABS stock into the shape using a milling machine.

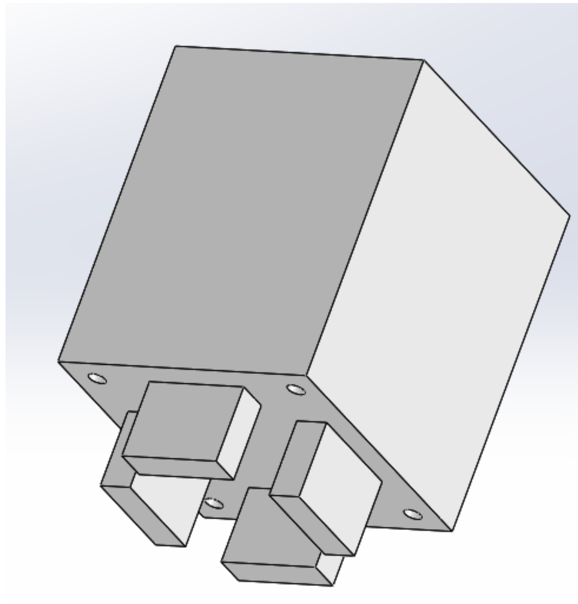


Figure 8: The ABS plastic cap

C. Mazes

The next critical subsystem in the toy is the actual game itself. This will be made up of four individual games that are put into the cubes which then create one unique toy that will teach kids scientific concepts in a fun way. Each maze will be made up of two planes with the goal being to get through the cube to the next cube to continue the game. Following along with our motto, “No Wrong Way to Play”, each game will be designed to be played both backwards and forwards. The purpose is to teach scientific concepts to young children while making the toy fun and engaging at the same time. There are many different languages and cultures in and around the hospital in Aurora, so the educational aspects need to be as universal as possible

In order to decide which four games to develop for the comprehensive design review, each team member created two drawings of potential games for the cubes based off of ideas the team had accumulated during our time interacting with children. From these twelve ideas shown in Figure 9, there are four concepts that have been developed further to complete an idea of one full product. One of these games has been finalized using SolidWorks and the team will have a full product with four completed games by our manufacturing review.

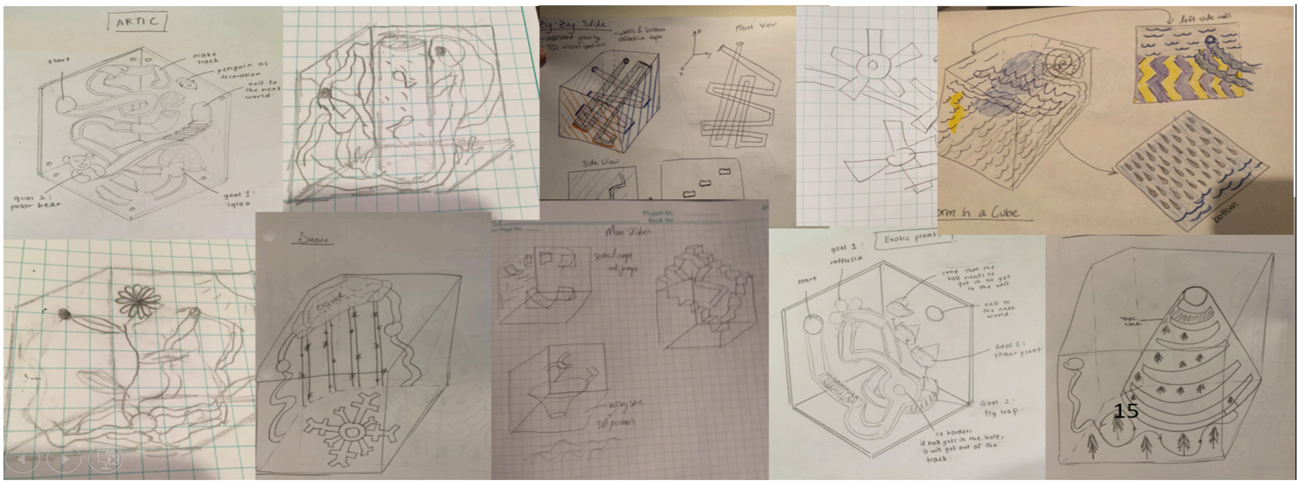


Figure 9: Original 12 game concepts.

The first game teaches kids about our solar system. It incorporates the original maze element on both the right and left hand the planes and there is a spiral track going through the center that represents the solar system. If one enters from the left side, the goal is to solve the maze and get to the solar system track, then go through the track starting at Pluto and falling off once your reach Earth. Originally, as shown in Figure 10, the maze was designed to have a bottom plane with many pegs representing an asteroid field. After falling off the spiral track at Earth, the game then continues onto the right-side maze which leads to the next cube. This can also be played in reverse, but the spiral maze is not necessary from this direction.

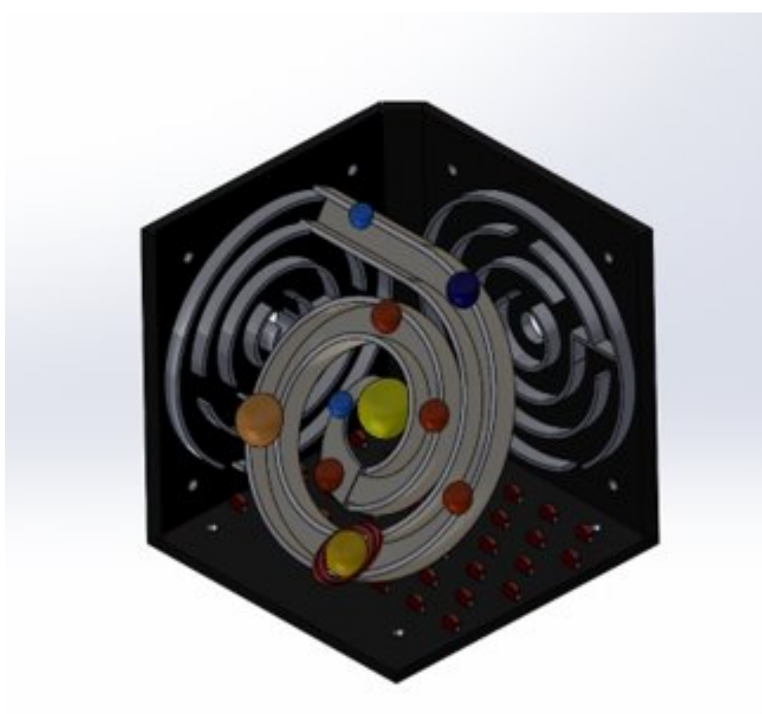
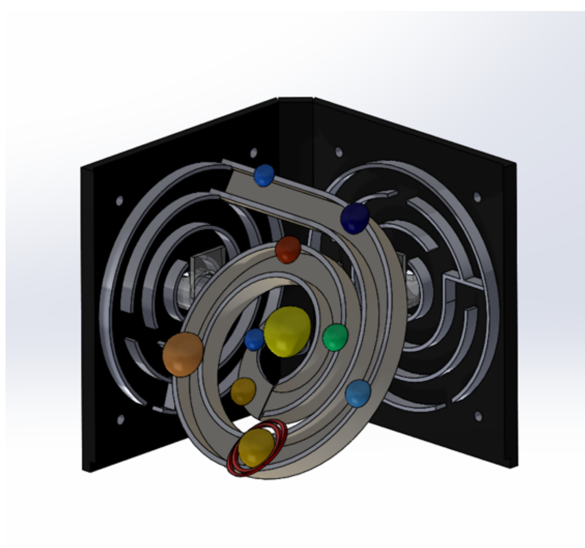


Figure 10: Original finished CAD for the space maze cube. Isometric view (top), view from right side (bottom left), and view from left side (bottom right).

Also seen in Figure 10 above is that there is nothing to stop the ball from flying into the center of the cube from previous cubes. To make it easier for children to drop the ball from the games in the adjacent cubes into the mazes on the faces of the space cube there is now a cap on both the right- and left-hand mazes. The assembled game with the new caps is shown in Figure 11.

The final design shown in Figure 11 also no longer includes the bottom plane. This decision was made to both decrease the weight of the final product and increase the visibility from the top and bottom so that the toy is able to be used upside down and right side up with ease.



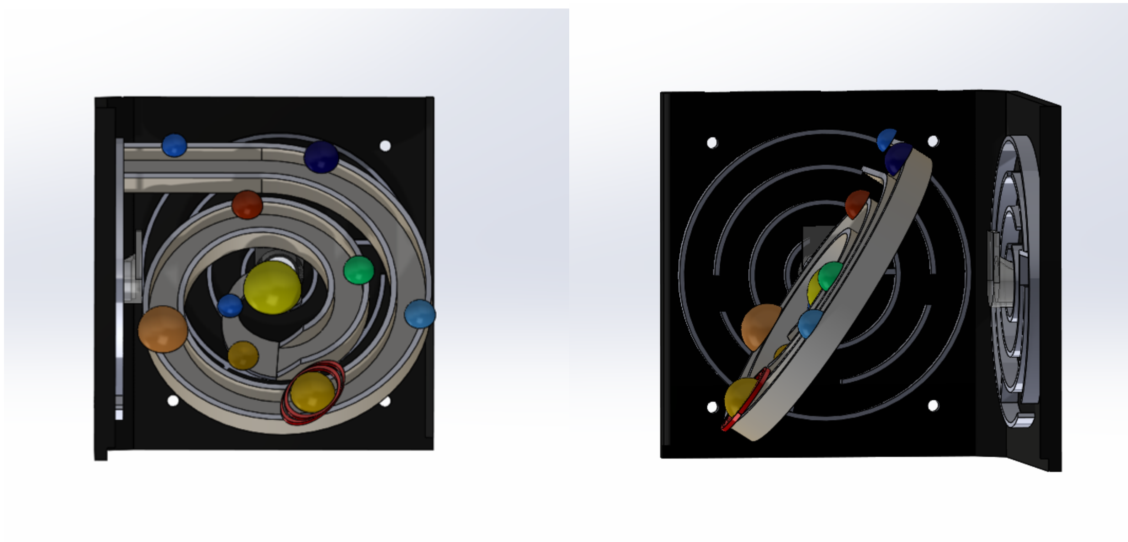


Figure 11: CAD for the space maze cube including the caps on the entrances. Isometric view (top), view from right side (bottom left), and view from left side (bottom right).

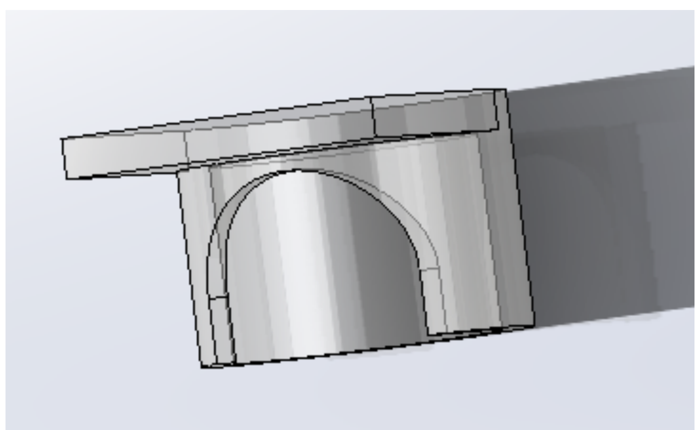


Figure 12: Initial concept for the caps on the entrances.

The second concept is a mountain climb. In order to not repeat too many concepts, this game does not include a maze component but instead, as shown in Figure 13, the left-hand plane is attached to a small track that will go around the cube. This track represents a ridge on the top of a mountain. The path will go to the base of the mountain on the right-hand side and then to get to the next cube you have to 'climb' the mountain. This game can also easily be played in reverse. The ridge is designed to be challenging and there is no punishment for falling off as it is easy to get through the cube without following this path. Originally the game was designed to have the bottom plane representing a lake that you would fall into if you fell off of the track as shown in the figure below, but that feature has been removed due to visibility and weight as stated above.

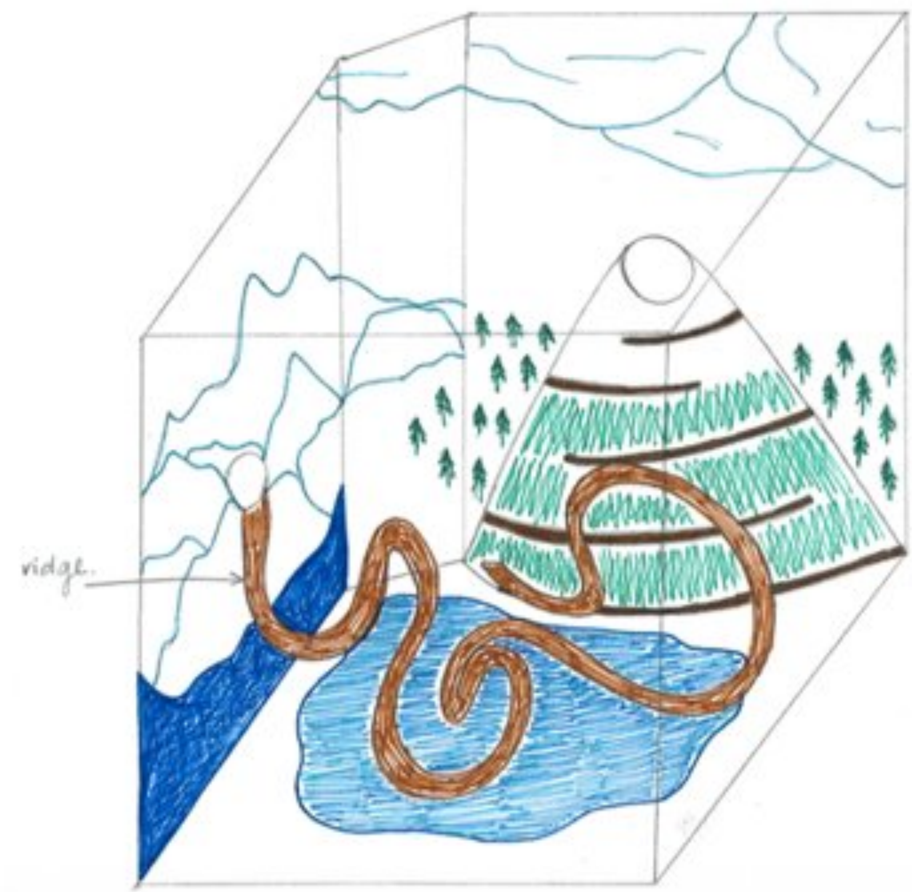


Figure 13: Original drawing of the mountain climb game before the CDR presentation.

The third concept is about the ocean. The left plane will be a sunken pirate ship and the right-hand plane will be covered in aquatic animals as shown in Figure 15. This has changed from the original design shown in Figure 14 because all of the bottoms planes of the games have been removed as explained above. There will also be a tube in the center that is filled with glitter and covered in fish stickers to represent that the game is played under water.

After interacting with children at multiple schools, we saw that they enjoyed a toy similar to the glitter tube that is filled with water. In order to keep the weight to a minimum, we will not fill the tube with water but will still get a similar effect. In order to make the sunken ship, we will be making it out of modeling clay and then using the 3D scanner. This will allow us to create a more organic shape for the 3D print.

Figure 14: Original drawing of the ocean game for the CDR presentation.

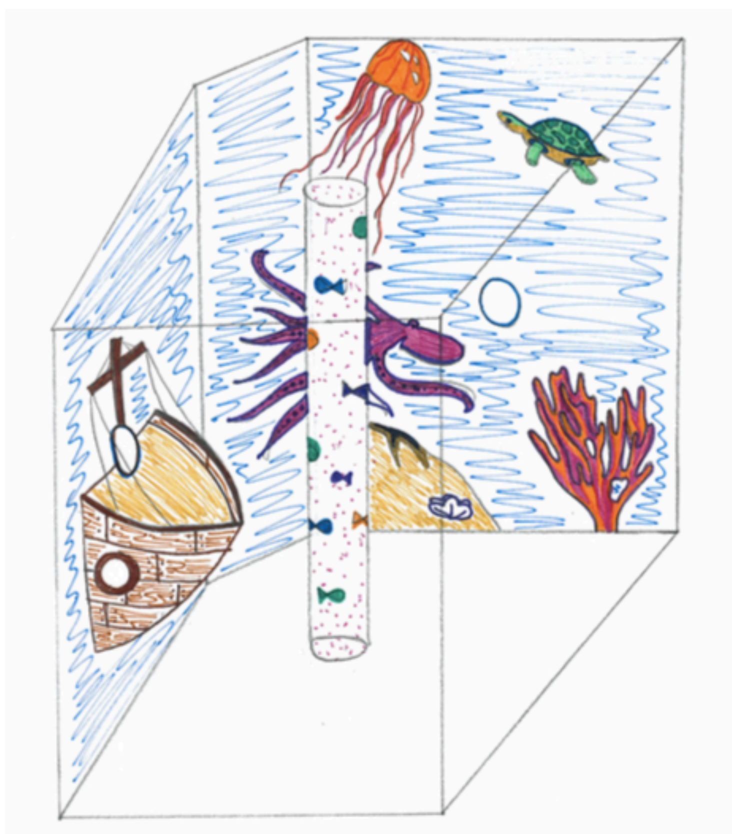


Figure 15: New drawing of the ocean game with the bottom removed and the animals moved to the right-hand plane.

The final concept developed was originally a zig-zag maze that is designed to teach the concept of gravity shown in Figure 16. In order to play this game one would enter from either side and tilt the maze from one side to the other in order to get through to the next side.

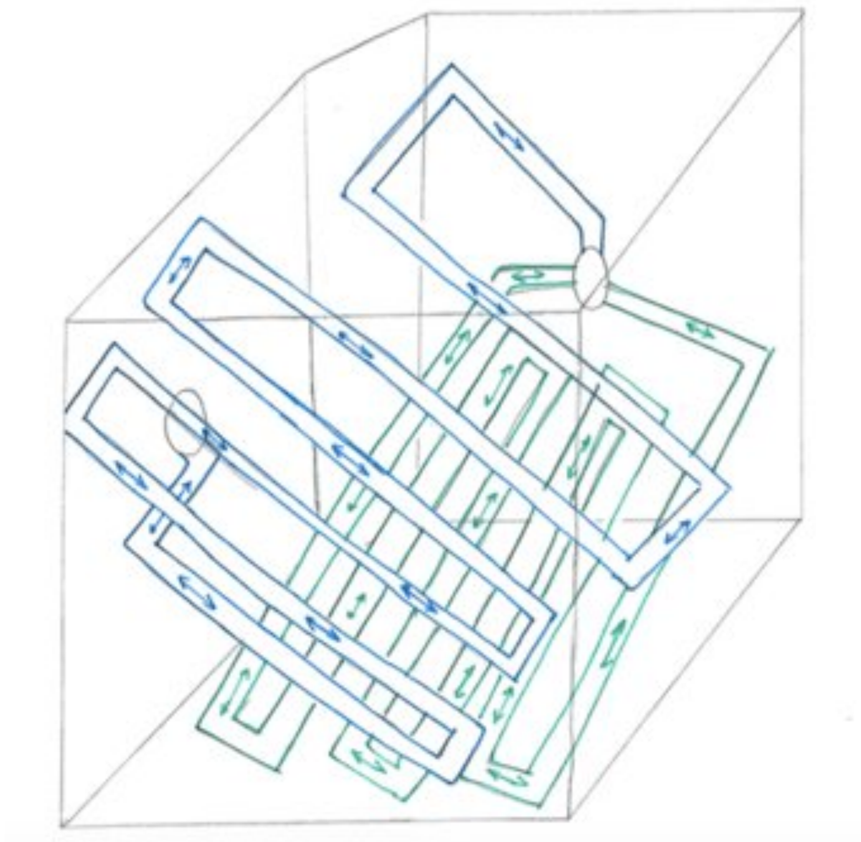


Figure 16: Original zig-zag maze concept.

However, this game has been changed and is now a ‘skatepark’, shown in Figure 17, with many slides and ramps in the cube. This change was made in order to avoid repetition with too many mazes and to give each cube a unique feature.

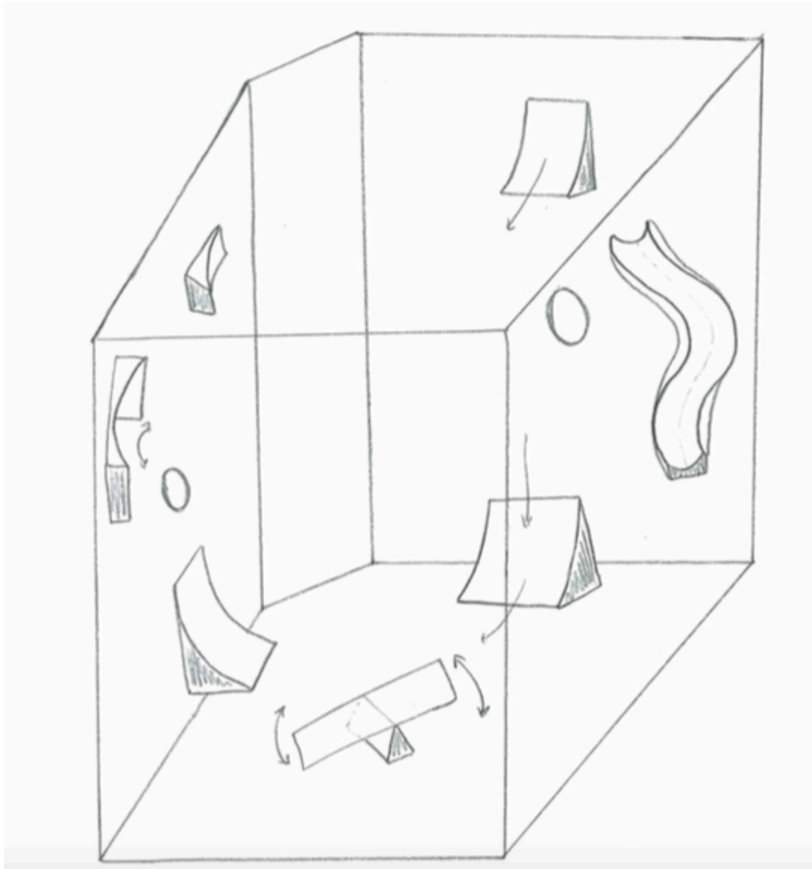


Figure 17: Initial ‘skatepark’ maze designs.

In order to make these games artistically pleasing, we will be using different colored 3D printing material. We are also looking into the possibility of painting some of the features such as the planets in the space game or the animals in the ocean game. This could be difficult because the paint may begin to chip away as the ball goes through the game multiple times. Also, if we need multiple layers of the paint it could add too much weight to the final design.

VI. Assembly Review

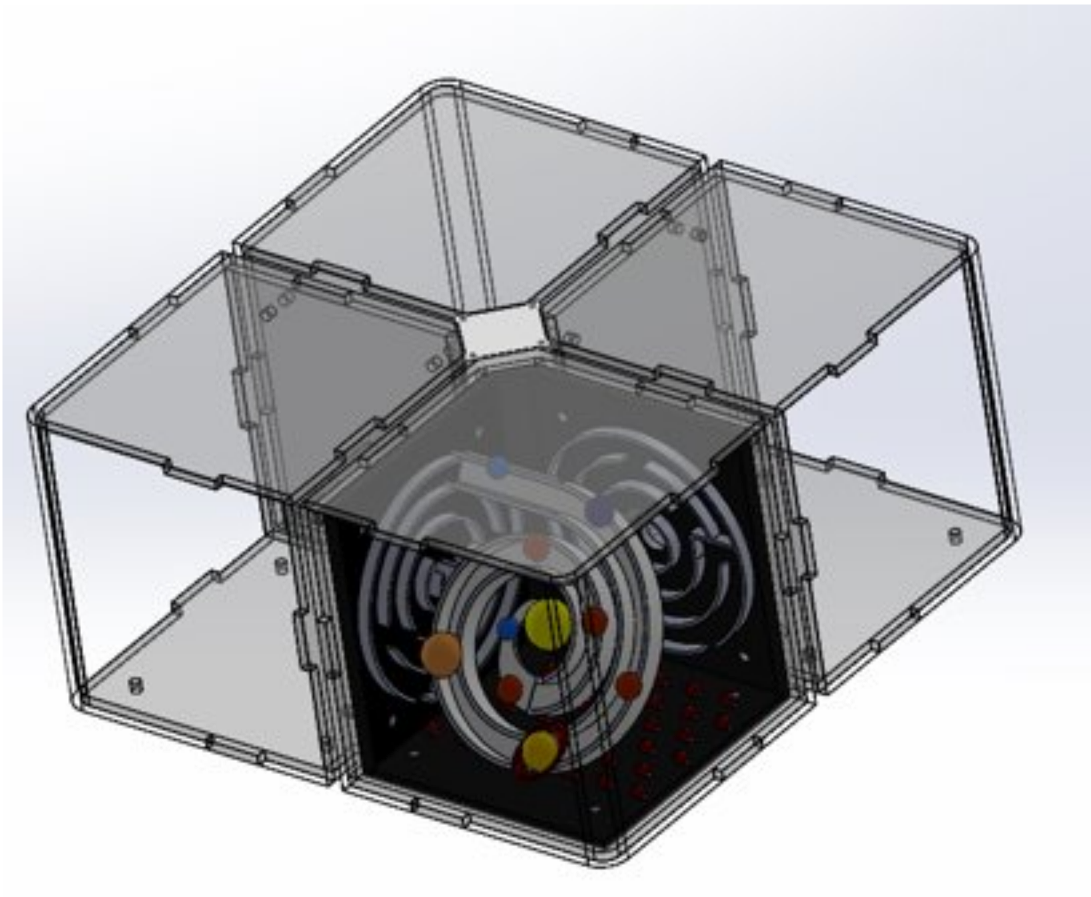


Figure 18: Assembly of the design.

The overall assembly is as shown in the Figure 18. The total dimensions are 8x8x4 inches with total weight of 2.0 lbs. Everything will be securely fasten and fully sealed.

The assembly process is as follows:

1. Attach two screws from the polycarbonate back wall to the T-nuts.
2. Attach the maze on the polycarbonate back wall and fastened it securely.
3. Attach the transparent polycarbonate windows.
    a. Front wall
    b. Top and bottom walls
4. Fasten bottom cap onto the T-slot.
5. Slide in completed cubes assembly into the T-slot.
6. Fasten top cap onto the T-slot.

VII. Structural Analysis

In order to establish confidence in our design's ability to withstand the abuses of children, we have applied structural analysis methods to the locations we feel are most likely to fail during play. The three most critical failure locations are the joint connections, the back face, and any locations where screws will be threaded into the polycarbonate (see Figure 19).

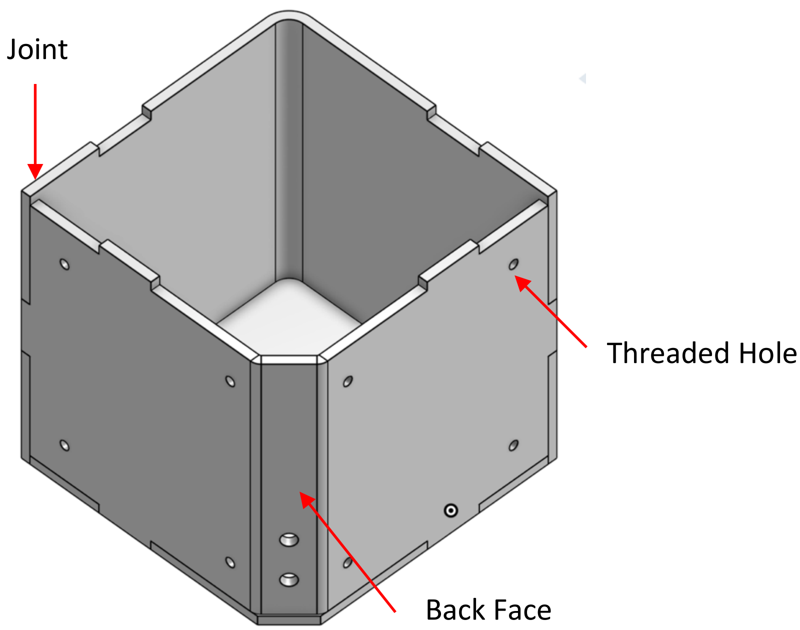


Figure 19: Visual representation of critical locations

We chose to analyze these locations as they are the most exposed during user interface, and they are made of polycarbonate which is more susceptible to fracture than aluminum or steel.

The back face is a critical location for analysis as it is subject to bending if a child were to try to pull the toy apart or step on it on its side. In order to analyze the back face, we modeled it as a simple beam with two applied loads and two stress concentrations at the holes. (Figure 20 and 21).

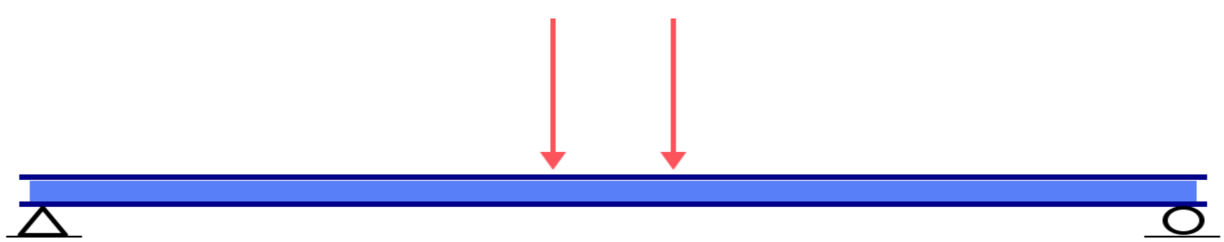


Figure 20: Simplified Beam with 2 equivalent applied loads

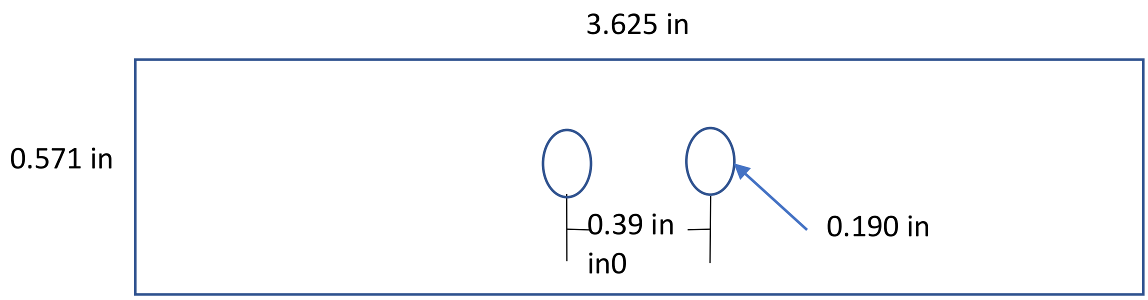


Figure 21: Dimensions of back face

Using the flexural strength of polycarbonate ($\sigma_{flexPC} = 135$ ksi [reference]) we were able to determine that the maximum force that can be applied to each hole in the back face before fracture is approximately 40.1 lbs. for a total applied load of 80.2 lbs. Given the strength required to apply a load of 80.2 lbs. in a pull-apart motion (similar to Figure 22), it is highly unlikely that a child will be able to pull this toy apart.

Figure 22: Pull-apart motion

Perhaps the most critical location to analyze is the joint connections. The joint connections are the most critical because they are where we expect the structure to fail upon impact. To analyze shearing at the joints, we treated the joint connections as two simple beams joined together by an adhesive of strength $\tau_s = 2400$ psi (shear strength of 4SC Low VOC Acrylic Plastic Cement) with an applied load at the joint (See Figure 23).

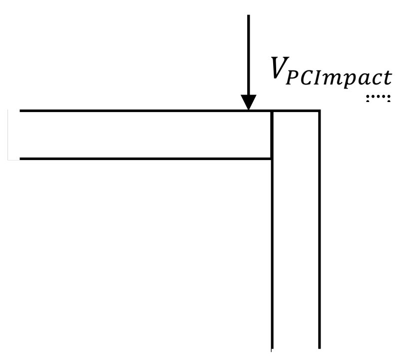


Figure 23: Simple beam representation of corner joint

With these assumptions, we found the maximum shear force that can be experienced by the adhesive is $V_{max-solvent} = 25$ lbs. This result was alarming at first, but we soon realized that the locating tabs (Figure 24) would add structural support to the design. Using the shear strength of polycarbonate ($\tau_{PC} = 9200$ psi) we found that the force required to shear the polycarbonate tabs would be $V_{max-PC} = 863$ lbs.

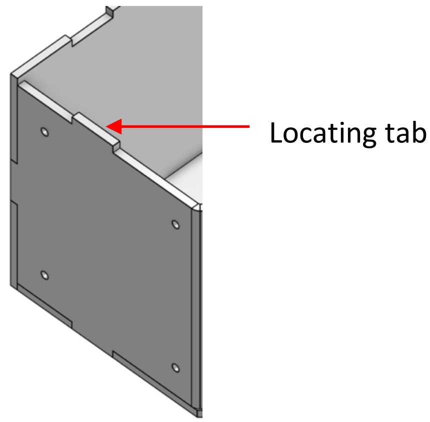


Figure 24: Locating tab

To determine the force of impact, we used a force of impact calculator from hyperphysics.com [reference] and the following assumptions: simple beam, neglect air resistance, deformation of 0.25 inches upon impact, dropped from rest, mass of 2 lbs., height of 4 feet. From the calculator we determined that the force of impact experienced by the toy would be about 384 lbs. Assuming that the worst location to drop the toy would be directly on the corner, we utilized trigonometry to determine the shearing force experienced in the corner joint. The shearing force experienced in the joint when dropped from 4 ft. would be $V_{PCimpact} = 272$ lbs. Because 272 lbs is much less than 863 lbs., we are confident that the toy will survive a fall of 4 ft.

After determining that 4 ft. would prove to be a safe drop height, we varied the height on the force of impact calculator to determine the max height that would produce an impact force capable of shearing the polycarbonate. The maximum height that the toy can be dropped from before shearing the joints is about 12.75 ft. Given this number is so high, we will conduct extensive drop tests to ensure that these numbers are accurate.

The final locations we have analyzed are the threaded holes. Even if the structure of the toy itself is strong, it is still possible that the toy will fail due to bolt pullout. Pullout is when the threads of the female component break when a high shearing force is applied (Figure 25). We know that the female component will fail before the male component because the female component is made of polycarbonate whereas the male component is made of steel and the shear strength of polycarbonate is much less than that of steel. It was determined that a pulling force of 686 lbs. is required to pull a bolt of 0.190-inch diameter out of a sheet of 1/8th-inch thick polycarbonate. Given that the toy will be played with by small children, we are confident that the bolts will not experience a force high enough to pull them out.

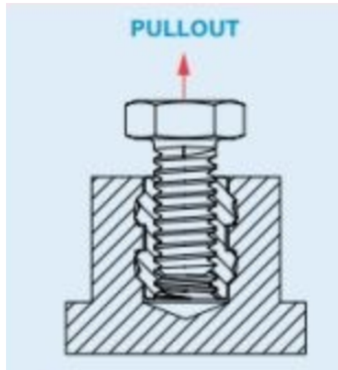


Figure 25: Visual representation of bolt pullout

The numbers we have found through our calculations give us confidence in the integrity of our design as we prepare to prototype and manufacture. It is likely, however, that there are factors we have not accounted for in our calculations and physical testing of the product and its materials will need to be conducted before we can trust the safety of our design with children. Our test plan is described in detail in the following section. To review the details of the calculations described in this section, please refer to Appendix A.

VIII. Integration and Testing

The final product we have designed will include many components. Luckily, none of them will need to be moving to create a successful toy, except for the small metal ball that will be used inside the cubes to interact with the mazes. This means that the integration of our components will be done on a rolling basis. When we finish a part, we will check its production quality and tolerances, and test whether it fits into its designated location within the full toy assembly. This way we can be sure all parts work separately, and then within their smaller sub-assembly, before forcing every part together in the final assembly and discovering none of the parts fit together. This also means the testing process can be an ongoing process. We can test materials and components before the final assembly is created so we can be sure the products we have chosen for our design are of high quality and fit within our specifications. The testing will be done for each specification section and can be found below.

A. Weight

1. The toy shall weigh less than or equal to 2 lbs. This specification is technically a preliminary design target, but we want to stay firm to this goal so as to make a toy that is easy for children to hold in their lap without issue.

- **Testing Procedure**
    1. Weigh all components of the toy separately on an imperial scale. This will include each individual cube assembly, all fasteners, the interlocking component, each 3D printed maze, all ball bearings, and any other feature that may be included. This will give us a better understanding of which part of the toy will be the area to reduce weight in if the toy does not meet the 2 lbs requirement. Weigh the completed assembly of the entire toy, all parts included, on an imperial scale.

- **If Meets Specification**
    1. No adjustments need to be made to the completed assembly in regards to weight.
- **If Fails Testing**
    1. Need to evaluate where the most of the weight is coming from within the assembly. Then we need to remove material or design a smaller assembly that will reduce overall weight. This could include adjusting cube sizes, changing the amount of aluminum used for the interlocking component, and changing the thickness of cube walls.

B. Size

1. The toy will be no larger than 10x7x7 inches in volume. This is a preliminary specification that will help dictate the scale of the toy.
2. The toy shall have no more than two separately sealed assemblies. This is so that children do not need more than two hands to handle and play with the toy. This is also a safety concern so that nothing on the toy can be ripped off during play.

- **Testing Procedure**
    1. We will measure our toy using an imperial measuring tape. The length, width, and height need to be measured to find the volume and size.
    2. When the toy is fully assembled, no parts will be able to be torn off and turned into a random assembly that we did not design for. We will test this through rough manhandling of the product, including impact testing (throwing the toy on the ground at a high velocity), and strain testing (through pulling opposite ends of the product apart at high loads).
- **If Meets Specification**
    1. Then no changes need to be made to the size of the toy.
    2. The toy is tough and cannot be taken apart and made into something we did not design for.
- **If Fails Testing**
    1. We would need to reevaluate either our specification or the size of the toy. We could take a poll of children and see if they think the toy is too large. If so, then we would need to redesign our product.
    2. We will need to re-evaluate the strength of our materials. The weak points could be at milled components of polycarbonate, at the interlocking interface between the cubes and the aluminum, and at corners where an impact could be the most detrimental. If changing the materials cannot be done, then we will add bumpers to reduce the impact of the toy components and will add reinforcements to any connection points that might break.

C. Safety

1. The toy will have rounded and filed edges of ¼ inch. The purpose of this is to make sure nothing will harm the user. We really only need to file down edges, as told by the hospital risk management staff, but we will use ¼ inch as our standard.
2. The toy will not have flashing lights. For children with epilepsy and who are prone to seizures, it is very important we avoid flashing lights.

3. The toy shall conform to Children's Hospital Risk Management standards. If we don't meet these standards, the project is a failure and cannot be given to children in the hospital.
4. The toy will not have any exposed components that can fit through a tube of 1.75-inch diameter. This will eliminate any choking hazards.

- **Testing Procedure**
    1. We will file down all edges of the exterior of our toy, including but not limited to, polycarbonate edges and corners, and aluminum edges. These will be compared to a known object with 1/4" radius edges to determine the validity of the rounded edges of our final product.
    2. We will not include flashing lights at all in our toy so this will not be an issue.
    3. We will make a check list of all hospital standards our product must conform to. Most of these standards have already been listed. The final assembly will go through a thorough quality control check by our team to ensure all safety measures have been met.
    4. We will use a toilet paper role (which has the diameter of 1.75 inches) and compare all exposed components of the assembly, that can be actively used and accessed by children. This does not include any internal parts which will be entirely enclosed.
- **If Meets Specification**
    1. No adjustments need to be made, and we can continue with testing procedures.
    2. This has to pass since we are not including flashing lights in the toy.
    3. Our product meets all hospital safety measures and is ready to be introduced to a hospital environment.
    4. The toy meets this standard and no choking hazards are being given to children.
- **If Fails Testing**
    1. Keep filing edges until the specification is met or add bumpers onto the sides and corners of the exposed edges to reduce the sharpness.
    2. This test will not fail based on essence of our design.
    3. We clearly need to review what aspect of the product does not meet the safety standards and change this so that it can be used in a hospital. This could mean changing designs, materials, and any and all else to meet these specifications.
    4. The components that are too small HAVE to be changed to meet specification. This could mean changing designs and finding new materials.

D. Durability

1. The device shall still function after being dropped from 4 feet over 25 times. The device shall be tested until it fails so we know at what point it will fail if a child abuses it. This will actually we a much rougher test since we need to ensure destruction of the toy happens at a point that is impossible for children to reach.
2. Opacity must be no more that 30% on all clear parts. If you cannot see inside the toy, then it cannot be used and thus is a failure.

- **Testing Procedure**
    1. We will drop each prototype and final product from a height of 4 feet. We will record the damage incurred after each drop until we reach 25 iterations. This includes external and internal damage. After this, we will proceed to test the toy under worse situations, include slamming it in doors, stomping on it, and banging it on the ground. We want to be sure the toy cannot break when a child uses it, and potentially abuses it. We do not want to give any child the opportunity to harm themselves due to our product breaking.
    2. Visual test that will include comparing the clarity of the toy's windows and walls after sanitation to that of an object with 30% opacity. This visual inspection will be performed after multiple sanitations (over 50).
- **If Meets Specification**
    1. We do not need to change anything since the toy survived the impact testing. This means it is child proof and can be thrown around a ton.
    2. Then no changes need to be made.
- **If Fails Testing**
    1. We will need to check our attachments on every aspect of the toy. The impact failure is likely to fail at corners or at the interface between the interlocking component and the cubes. If we cannot strengthen these parts, then we can add bumpers to the corners and edges where the toy might break. After adding these changes, the drop tests need to be done again. If the failure happened to the internal maze, then we need to consider better ways to attach the maze and how we can make it more impact resistant.
    2. We would need to consider the material properties of our product and find out why the chemicals are causing clouding over the clear aspects of the toy. We could consider a super thin vacuum sealed cover over the whole toy that would be disposable and not need the sanitation.

E. User Friendly

1. The toy must go through iterations and testing with children to ensure they enjoy playing and learning from our product. The goal of the toy is to be interesting, engaging, and educational for children. If kids do not like our product, then our efforts are all for naught.

- **Testing Procedure**
    1. We will take our toy to Horizons K-8 and have children ages 4-8 play with the toy and give feedback. We will give them a survey to fill out answering the following questions: 1. Is the toy too heavy? 2. Is the toy easy to play with? 3. Do the concepts in each maze make sense? 4. What can we add or improve on each maze? 5. What do you like about this toy? 6. What do you dislike about this toy? The feedback from the children will help us have hard concepts to adjust and iterate so our final product will be as kid friendly as possible.
- **If Meets Specification**
    1. Passing will mean that the children overall enjoy the toy and do not have any concrete changes for us to make (i.e. weight, color, maze design, etc.).

This will mean we can finish iterating and focus on manufacturing a final product.

- **If Fails Testing**
  1. Failing testing will mean more that there are clear design features the children gave us feedback on to change. This means we will have to iterate multiple times to make a product the children love to use. This will also mean repeat visits with children to gather feedback after each stage of iteration.

All of these tests will be performed on the final assembly. Some of these tests will also be performed on individual components and sub-assemblies. Table 2 illustrates all the components of our design and which parts will be tested according to specification category. The testing will follow the procedures outlined in the above sections.

Table 2: Assembly components and tests they will undergo.

Assembly Component			Testing Type								
Part ID	Component	Material	Impact	Sanitation	Weight	Size	Edge Safety	CHRM Standards	Opacity	Choking Hazard	Userability
1 - Cube	Walls	Polycarbonate	x	x	x	x	x	x	x		x
	Windows	Polycarbonate	x	x	x	x	x	x	x		x
	Top	Polycarbonate	x	x	x	x	x	x	x		x
	Bottom	Polycarbonate	x	x	x	x	x	x	x		x
	Solvant	Dimethyl Carbonate solvent	x	x	x	x		x	x		x
	Corner Protectors	PVC	x	x	x	x	x	x	x	x	x
2 - Interlocking	Slotted Center	1010 - 80/20 Aluminum		x	x	x	x	x		x	x
	Double Slide-in T-nut	1215 Steel, Zinc finish		x	x			x		x	x
	3/4" Screws	Stainless Steel	x	x	x		x	x		x	x
	3/16" Screws	Stainless Steel		x	x		x	x		x	x
	Caps	ABS	x	x	x		x	x		x	x
3 - Maze	Prototype Print	PLA	x		x			x			x
	Final Print	VeroWhitePlus	x		x			x			x
	Paint	Tamiya Primer and Color			x			x			x
4 - Bearing Balls	Balls	Chrome Steel			x			x		x	x

IX. Finances

CU Boulder provides our team a total fund of $ 2,000 but as for now, we only have $ 200 (this amount is included in the total fund) until Mr. Brian Jernigan officially signs off our final bill of material. The expense summary of the updated budget and the project breakdown assists in determination of project attainability. Below are the details of the updated budget that we plan to spend for the rest of the year.

Table 3: Expense summary of the updated budget.

Expense Summary		
Outer component	$	480.39
Inner component	$	536.60
Prototype	$	623.38
Documentation	$	101.49
Contingency 7%	$	121.93
Unallocated	$	136.21
Total Project Estimate	$	1,863.79

To display the percentage of each aspect, we also created a project breakdown as follows.

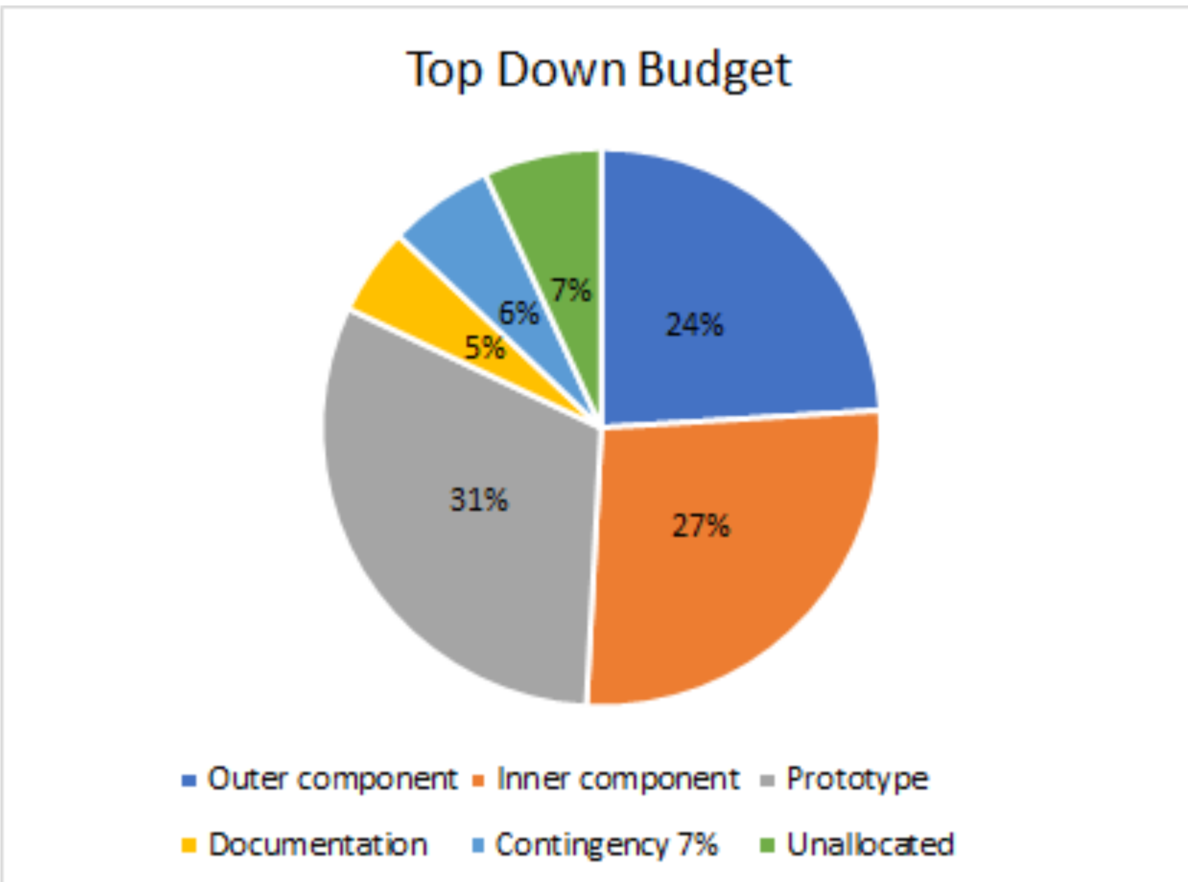


Figure 26: The breakdown of the updated budget.

Below are the details of the updated budget that we are going to utilize.

Table 4: Detail of the updated budget.

Outer components

Item #	Description	Vendor	Part No.	Quantity	Price Per Unit	Shipping (Est)	Total (Est)
Aluminum 1010-80-20	T-slotted profile (24"Lx1" Wx1"T) for middle interlocking part	Servocity	1010	1	$ 14.99	$ 6.99	$ 21.98
Customized straight Lexan Polycarbonate sheet	Cube wall for top and bottom (1/8"x4"x4")	Colorado Plastic	NA	16	$ 10.00	$ -	$ 160.00
Customized 90˚ bent Polycarbonate sheet	Cube wall for attaching with the middle interlocking part	Colorado Plastic	NA	8	$ 11.31	$ -	$ 90.48
Customized 45˚ bent Polycarbonate sheet	Cube wall for front display	Colorado Plastic	NA	8	$ 11.31	$ -	$ 90.48
10-series 10-32 double anchor slide in T-nut	To attach the middle interlocking part with the cube	80/20 Inc	3085	8	$ 1.30	$ 13.90	$ 24.30
ABS plastic block (2"x4"x6")	To cover top and bottom of the middle interlocking part (3 pieces)	Amazon	ABSB-246-BIS	1	$ 70.00	$ -	$ 70.00
Corner rubber protector	To cover the sharp corner of the cube (20 pieces)	Amazon	B07H8WXLPB	1	$ 9.74	$ -	$ 9.74
316 Stainless Steel Phillips Flat Head Screws, 10-32 Thread Size, 3/4" Long	To attach the maze, cube, slide in T-nut to the middle interlocking part (25 pieces)	Mc-Master Carr	91500A831	2	$ 5.28	$ -	$ 10.56
316 Stainless Steel Phillips Flat Head Screws, 0-80 Thread Size, 3/16" Long	To attach the maze and the cube (50 pieces)	Mc-Master Carr	91500A301	1	$ 7.83	$ -	$ 7.83
						Subtotal	$ 485.37

Inner components

Item #	Description	Vendor	Part No.	Quantity	Price Per Unit	Shipping (Est)	Total (Est)
Tamiya Primer 180 mL	First coat for painting maze	Amazon	87042-000	1	$ 12.08	$ -	$ 12.08
VeroWhitePlus 3D filament model	Cube maze. 3D print with Object30	ITLL	RGD835	600 gram	$ 0.60	$ -	$ 360.00
VeroWhitePlus 3D filament support	Spport material for hanging pieces in the cube maze. 3D print with Object30	ITLL	RGD835	360 gram	$ 0.30	$ -	$ 108.00
Tamiya color spray paint	To beautify the maze	MegaHobby	TAM85000	6	$ 6.65	$ 8.95	$ 48.85
5 mm mini ball (100 pieces)	Ball for playing the maze	Bearing Ball Store	NA	1	$ 5.00	$ 2.67	$ 7.67
						Subtotal	$ 536.60

Prototype

Item #	Description	Vendor	Part No.	Quantity	Price Per Unit	Shipping (Est)	Total (Est)
Customized straight Lexan Polycarbonate sheet	Cube wall for top and bottom (1/8"x4"x4")	Colorado Plastic	NA	24	$ 10.00	$ -	240
Customized 90˚ bent Polycarbonate sheet	Cube wall for attaching with the middle interlocking part	Colorado Plastic	NA	12	$ 11.31	$ -	$ 135.72
Customized 45˚ bent Polycarbonate sheet	Cube wall for front display	Colorado Plastic	NA	12	$ 11.31	$ -	$ 135.72
10-series 10-32 double anchor slide in T-nut	To attach the middle interlocking part with the cube	80/20 Inc	3085	12	$ 1.30	$ 13.90	$ 29.50
Lexan polycarbonate sheet	To assemble as a cube (12"x24"x0.118")	Zoro	1ETL8	4	$ 11.86	$ 5.00	$ 52.44
PLA Filament 3mm thickness	Cube maze	ITLL	PLA30NAT010A	1	$ 30.00	$ -	$ 30.00
						Subtotal	$ 623.38

Documentation

Item #	Description	Vendor	Part No.	Quantity	Price Per Unit	Shipping (Est)	Total (Est)
Expo poster	To display at Expo (Standard Heavyweight 24" x 36" with mount and laminate)	Staples	NA	1	$ 71.99	$ -	$ 71.99
Printing (B&W)	To print out reports	CU	NA	200	0.08	$ -	$ 16.00
Printing (Color)	To print out diagrams in the reports	CU	NA	30	0.45	$ -	$ 13.50
						Subtotal	$ 101.49

As we refer from Table 2, the updated project budget now stands only $ 1,863.79 which leaves 7% unallocated amount from the total funding. There is 7% contingency for every aspect as we want to be safe with our estimate. The team is going to make 1 prototype of a cube, 3 full assembly prototypes, and 2 final 3-D maze toys. We plan to create 1 final product for Children's Hospital and another one for Expo. We are going to spend the initial amount of money of some materials to make at least one prototype before our Manufacturing Review at the end of the semester.

From Table 4, we analyze that the Aluminum 1010-80-20 of the Outer Components section has longer dimension that what we need. For 5 3-D mazes, the total required length that we need is only 6 inches. We will need to reduce the cost and the length by asking for scrap material from the machine shop or getting a promotional discount from the vendor. Additionally, the specific price for the customized straight and 45° bent polycarbonate sheets from Colorado Plastics vendor are just an estimation price from the quote that they give based on the 90° bent polycarbonate sheets. The quote given is $ 364 for 32 pieces, however, this price will change because we need to specify the tolerance and the dimensions on the drawings of the customized polycarbonate sheets. Specific quotes from Colorado Plastics are to be expected before the Manufacturing Review which is on Dec 17, 2018.

We also target to produce more prototypes and final products to enhance the feasibility of the design. With our current funding, it is not enough to produce more than we plan, hence, we shortlist several extra funding sources and we find that we could apply for the Outreach Micro Grant to get an additional funding of $ 1,000. We estimate that the total potential funding would be $ 3,000. We also plan to raise crowdfunding from the CU Boulder Crowdfunding website to get an extra of $ 5,000 in order to produce high quality toy with the help of KODO Kids manufacturer. We plan to collaborate with Leeds School of Business students to help us advertise our project and find donors that are willing to support us. The table below shows the additional sources of funding that we could and could not apply for. The red column shows that the project does not fit the requirement of the grants, the yellow column means that we could still apply for the grant but there is low chance of getting it because the faculty member of CU, Prof. Daniel Knight has helped the previous teams, and the green one means there is high chance of getting the grant if we apply for it before the deadline which is on Jan 25, 2019.

Table 5: The additional funding sources with their respective amount of money and the outlook.

Grants and Donation Strategy

Funding Source	Amount	Outlook
Engineering Excellent Fund (EEF)	$ 1,500	Not applicable
Research & Innovation Office (RIO)	$ 50,000	Not applicable
Undergraduate Research Opportunity Program (UROP)	$ 1,500	Closed
Outreach Community Impact (OCI)	$ 1,500	Applicable
Outreach Micro Grant (OMG)	$ 1,000	Applicable & very promising

Total future funding: $ 3,000

35

X. Project Schedule

With roughly 5 months, the team is able to keep on track and manage to meet the milestones and deadlines. We have approximately 3 weeks after Fall Break to prepare for the Manufacturing Review. The Work Breakdown Schedule is shown as follows.

EcosySTEM Arts Design Scope			
START DATE	END DATE	DESCRIPTION	DURATION (days)
9/18/18	10/2/18	Specification and Planning	14
10/2/18	10/23/18	Preliminary Design Review	21
10/23/18	11/13/18	Comprehensive Design Review	20
11/13/18	12/14/18	Manufacturing Review	31

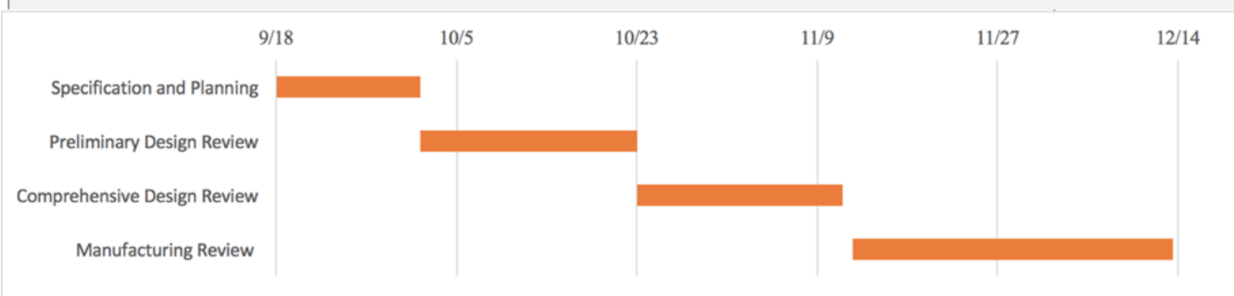


Figure 27: Schedule of the rest of the semester in two forms.

XI. References

Curbell Plastics. (2018). Polycarbonate. Retrieved from https://www.curbellplastics.com/Research-Solutions/Materials/Polycarbonate

Engineering ToolBox, (2003). Young's Modulus - Tensile and Yield Strength for common Materials. Retrieved From https://www.engineeringtoolbox.com/young-modulus-d_417.html

Nave, R. (2000). Impact Force from Falling Object. Retrieved from http://hyperphysics.phy-astr.gsu.edu/hbase/flobi.html

Norton, R. L. (2006). *Machine design: An integrated approach*. Upper Saddle River, NJ: Pearson Prentice Hall.

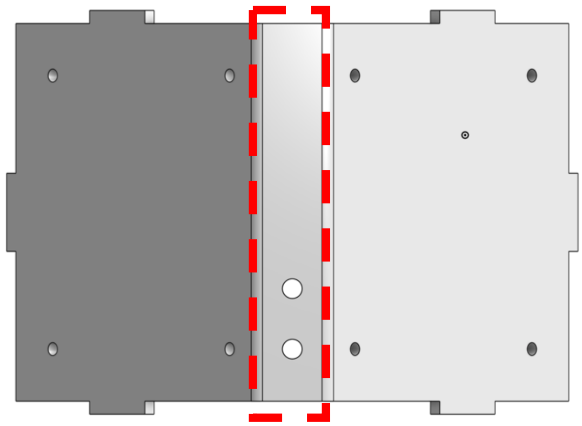
Rogers, T. (2015). Everything You Need To Know About Polycarbonate (PC). Retrieved from https://www.creativemechanisms.com/blog/everything-you-need-to-know-about-polycarbonate-pc

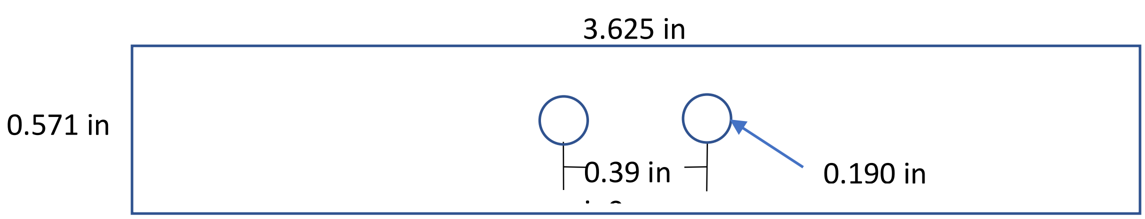
SCIGRIP Americas. (2014). *4SC Low VOC Acrylic Plastic Cement*. Retrieved from http://gluewarehouse.com/www/files/pdfs/product_tabs_pdf/4SC_TDS.0814.pdf

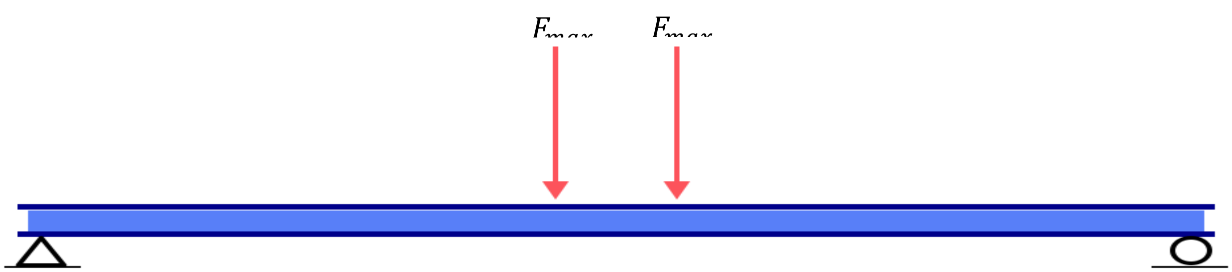
XII. Appendices

Appendix A: Structural Analysis

Back Face Integrity:







Assume: Beam, infinite plate

$$Flexural\ Modulus\ PC = \ \sigma_{flexPC} = 135\ ksi$$

$$\frac{d}{h} = \frac{0.190}{0.125} = 1.52$$

$$K_T \approx Ae^{b\left(\frac{d}{w}\right)} \approx 2.0243e^{-0.80821*\left(\frac{0.91}{0.571}\right)} = 1.5470 * 2\ (because\ 2\ holes)$$

$$I = \frac{1}{12} * b * h^3 = \frac{1}{12} * 0.571 * 0.125^3 = 9.29 * 10^{-5}\ in^4$$

$$M = F * d = 30 * 1.6175 = 48.53\ lb * in$$

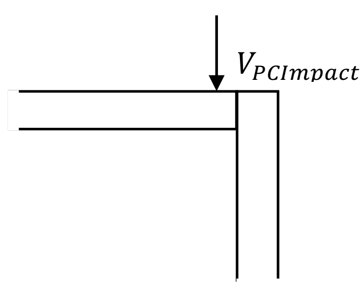
$$\sigma_b = \frac{My}{I} = \frac{48.53 * 0.0625}{9.29 * 10^{-5}} = 32.63\ ksi$$

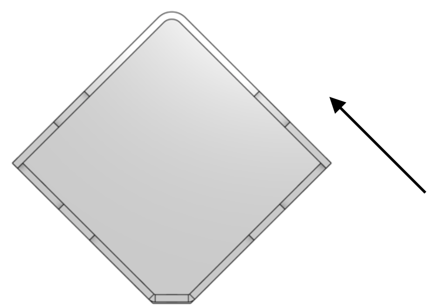
$$\sigma = \sigma_b * 2 * K_t = 100.97\ ksi$$

$$F_{max} = \frac{\sigma_{flexPC} * I}{l * y * 2 * K_t} = 40.1\ lbs$$

$$F_{max-total} = 2 * F_{max} = \mathbf{80.2\ lbs}$$

Shear at Joints:



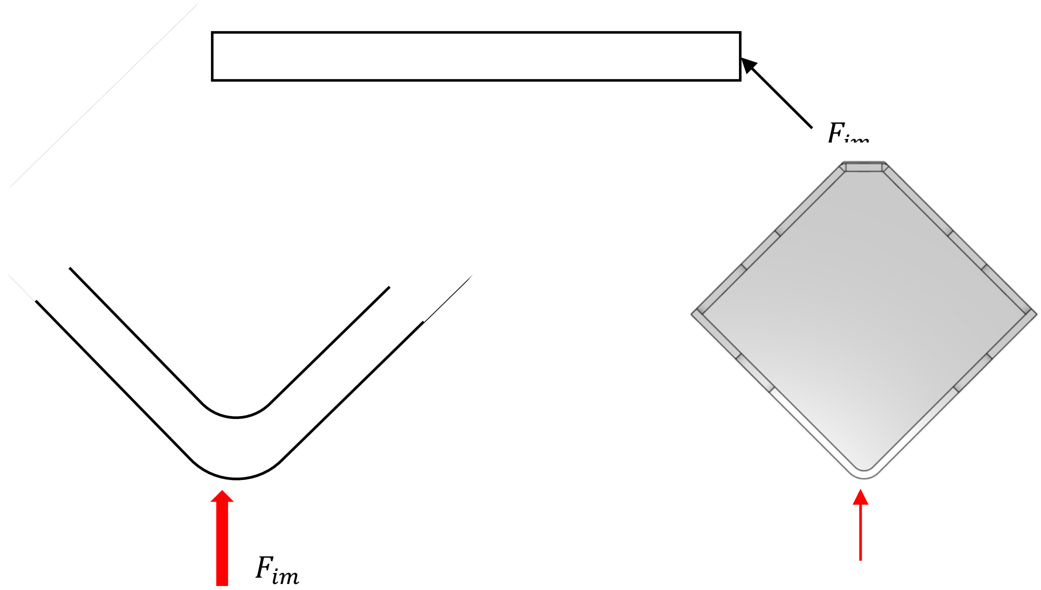


Assume: Beam

$$Bond\ Strength\ of\ General\ Solvent = \tau_s = 2400\ psi$$
$$I = 0.0203\ in^4$$
$$Q = 2.44 * 10^{-4}\ in^3$$
$$t = 0.125\ in$$
$$V_{max-solvent} = \frac{\tau_s It}{Q} = \mathbf{25\ lbs}$$

$$\tau_{PC} = 9200\ psi$$
$$A = 0.09375\ in^2$$
$$V_{max-PC} = \tau_{PC} * A = \mathbf{863\ lbs}$$

Impact Force:

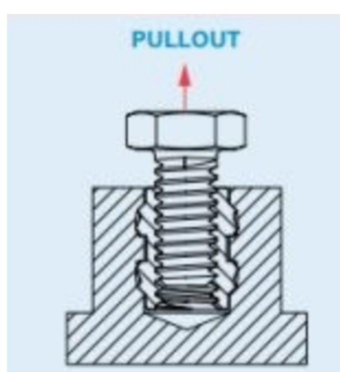


Assume: Beam, neglect air resistance, deformation of 0.25 inches upon impact, dropped from rest, mass of 2 lbs., height of 4 feet.

$$F_{impact} = 384\ lbs\ (from\ hyperphysics\ calculator)$$
$$V_{PCimpact} = F_{impact} * \cos(45°) = 272 \text{ lbs}$$
$$272\ lbs < 863\ lbs$$
$$\boldsymbol{V_{PCimpact} < V_{max-PC}}$$

When dropped from about **12.75 feet**, the impact force becomes about 1221 lbs. which is the maximum impact force that can be experienced before shearing the polycarbonate (from playing around with the impact calculator)

Pullout:



$$A_{shear} = \pi * d_{shear} * length\ of\ engagement = \pi * 0.190 * 0.125 = 0.0746\ in^2$$
$$F_{pullout} = \tau_{PC} * A_{shear} = \boldsymbol{686\ lbs}$$

Appendix B: Full Specification and Testing Procedure Table

ID	Category	Description	Status	Notes	Source	Testing Procedure	If Passes Testing	If Fails Testing
1	Weight	The fully assembled toy shall weight no more than 2 lbs.	Preliminary	This way children can hold in in their lap without issue.	Client meeting #1	Weigh all components of the toy separately on an imperial scale. This will include each individual cube assembly, all fasteners, the interlocking component, each 3D printed maze, all ball bearings, and any other feature that may be included. This will give us a better understanding of which part of the toy will be the area to reduce weight in if the toy does not meet the 2 lbs requirement. Weigh the completed assembly of the entire toy, all parts included, on an imperial scale.	No adjustments need to be made to the completed assembly in regards to weight.	Need to evaluate where the most of the weight is coming from within the assembly. Then we need to remove material or design a smaller assembly that will reduce overall weight. This could include adjusting cube sizes, changing the amount of aluminum used for the interlocking component, and changing the thickness of cube walls.
2.1	Size	The toy will be no larger than 10x7x7 inches.	Preliminary	iPad size with room for 3D expansion	Client meeting #1	We will measure our toy using an imperial measuring tape. The length, width, and height need to be measured to find the volume and size.	Then no changes need to be made to the size of the toy.	We would need to reevaluate either our specification or the size of the toy. We could take a poll of children and see if they think the toy is too large. If so, then we would need to redesign our product.
2.2		The toy shall have no more than 2 separately sealed assemblies.	Firm	This gives us some options without limiting to one sealed assembly.	Team brainstorming session	When the toy is fully assembled, no parts will be able to be torn off and turned into a random assembly that we did not design for. We will test this through rough manhandling of the product, including impact testing (throwing the toy on the ground at a high velocity), and strain testing (through pulling opposite ends of the product apart at high loads).	The toy is tough and cannot be taken apart and made into something we did not design for.	We will need to re-evaluate the strength of our materials. The weak points could be at milled components of polycarbonate, at the interlocking interface between the cubes and the aluminum, and at corners where an impact could be the most detrimental. If changing the materials cannot be done, then we will add bumpers to reduce the impact of the toy components and will add reinforcements to any connection points that might break.
3.1	Safety	The toy will have rounded and filed edges of 1/4 inch.	Preliminary	No sharp corners or edges. The purpose of this specification is to make sure nothing will harm the user. So we really only need to file down edges, as told by the hospital risk management staff.	Team brainstorming session	We will file down all edges of the exterior of our toy, including but not limited to, polycarbonate edges and corners, and aluminum edges. These will be compared to a known object with 1/4" radius edges to determine the validity of the rounded edges of our final product.	No adjustments need to be made, and we can continue with testing procedures.	Keep filing edges until the specification is met, or add bumpers onto the sides and corners of the exposed edges to reduce the sharpness.
3.2		The toy will not have flashing lights.	Firm	For children with epilepsy and who are prone to seizures, this is very important.	Hospital standards	We will not include flashing lights at all in our toy so this will not be an issue.	This has to pass since we are not including these in the toy.	This test will not fail based on essence of our design.
3.3		The toy shall conform to Children's Hospital Risk Management standards.	Firm	If we don't meet these standards, the project is a failure.	Hospital standards	We will make a check list of all hospital standards our product must conform to. Most of these standards have already been listed. The final assembly will go through a thorough quality control check by our team to ensure all safety measures have been met.	Our product meets all safety measures and is ready to be introduced to a hospital environment.	We clearly need to review what aspect of the product does not meet the safety standards and change this so that it can be used in a hospital. This could mean changing designs, materials, and any and all else to meet these specifications.
3.4		The toy will not have any exposed components that can fit through a tube of 1.75 inch diameter.	Firm	Need to avoid choking hazards.	Hospital standards	We will use a toilet paper role (which has the diameter of 1.75 inches) and compare all exposed components of the assembly, that can be actively used and accessed by children. This does not include any internal parts which will be entirely enclosed.	The toy meets this standard and no choking hazards are being given to children.	The components that are too small HAVE to be changed to meet specification. This could mean changing designs and finding new materials.
4.1	Durability	The device shall still function after being dropped from 4 feet over 25 times. The device shall be tested until it fails so we know at what point it will fail if a child abuses it.	Preliminary	If toy falls off bed or kid drops it, it needs to function still. No child shall be injured by our toy if it breaks.	Client meeting #1	We will drop each prototype and final product from a height of 4 feet. We will record the damage incurred after each drop until we reach 25 iterations. This includes external and internal damage. After this, we will proceed to test the toy under worse situations, include slamming it in doors, stomping on it, and banging it on the ground. We want to be sure the toy cannot break when a child uses it, and potentially abuses it. We do not want to give any child the opportunity to harm themselves due to our product breaking.	We do not need to change anything since the toy survived the impact testing. This means it is child proof and can be thrown around a ton.	We will need to check our attachments on every aspect of the toy. The impact failure is likely to fail at corners or at the interface between the interlocking component and the cubes. If we cannot strengthen these parts, then we can add bumpers to the corners and edges where the toy might break. After adding these changes, the drop tests need to be done again. If the failure happened to the internal maze, then we need to consider better ways to attach the maze and how we can make it more impact resistant.
4.2		Opacity must be no more that 30% on all clear parts.	Preliminary	If you can't see inside the toy then it is a failure.	Team brainstorming session	Visual test that will include comparing the clarity of the toy's windows and walls after sanitation to that of an object with 30% opacity. This visual inspection will be performed after multiple sanitations (over 50).	Then no changes need to be made.	We would need to consider the material properties of our product and find out why the chemicals are causing clouding over the clear aspects of the toy. We could consider a super thin vacuum sealed cover over the whole toy that would be disposable and not need the sanitation.
5	User Friendly	The toy must go through iterations and testing with children to ensure they enjoy playing and learning from our product.	Firm	The goal of the toy is to be interesting, engaging, and educational for children. If kids do not like our product, then our efforts are all for naught.	Client meeting #1	We will take our toy to Horizons K-8 and have children ages 4-8 play with the toy and give feedback. We will give them a survey to fill out answering the following questions: 1. Is the toy too heavy? 2. Is the toy easy to play with? 3. Do the concepts in each maze make sense? 4. What can we add or improve on each maze? 5. What do you like about this toy? 6. What do you dislike about this toy? The feedback from the children will help us have hard concepts to adjust and iterate so our final product will be as kid friendly as possible.	Passing will mean that the children overall enjoy the toy and do not have any concrete changes for us to make (i.e. weight, color, maze design, etc.). This will mean we can finish iterating and focus on manufacturing a final product.	Failing testing will mean more that there are clear design features the children gave us feedback on to change. This means we will have to iterate multiple times to make a product the children love to use. This will also mean repeat visits with children to gather feedback after each stage of iteration.