Monkey Board

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Abstract

Over three million Americans are affected by glaucoma, yet only half of them know they actually have the disease (cite the glaucoma facts and stats). It is for this reason that research on the topic of glaucoma has the potential to benefit humanity. Researchers at the University of Wisconsin-Madison hospital are currently using fluorophotometry to help understand glaucoma. Their test subjects are Cynomolgus Monkeys. The testing consists of dropping fluids into the anesthetized monkey's eyes. In the previous design, the monkeys were simply placed on a metal board and the researcher would have to move the board manually in order to line it up with the stationary eyedropper. Since this is not the ideal design, three potential designs have been proposed. The client insisted on having movement of the board in the x and y direction with 90 degrees rotation. Three different designs were proposed: a gear mechanism, foosball design, and an X-Y table. After computing the pros and cons of all three designs, the team decided that the design with the compound table best solved our problem. However, due to a misinterpretation of the client about which axes were the x and y-axis, there is much future work to be done. Instead of the y-axis being in the flat plane with the x-axis and parallel with the floor, the y-axis is instead to be interpreted as the vertical axis rising out of the table perpendicular to the floor. For the remainder of the semester, the team plans to alter the design concepts in order to work according to the specifications. Next, we will fabricate our device, and if there is time, test the product.

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Motivation

Our client has requested a table that moves in the xy-plane to help improve the efficiency of his research on glaucoma. Galen currently has a monkey board that is simply a piece of steel that has a headpiece attached to it. A picture of the current board can be seen in Figure 1. The monkey board functions very well, however it is difficult for Galen to hold the monkey's eyelid open and line up the monkey with the flurophotometer. Our task is to design a device that connects to the monkey board to an underlying table that is able to move in the xy-plane, and swivel. This will allow Galen to lock the monkey board into the position that he needs. Currently Galen collects information on one monkey every half hour for six hours. A lot of time is wasted positioning the monkey, so our motivation is to increase the efficiency of his research. Galen and his team will be able to spend more time focusing on their research instead of positioning monkeys.

Figure 1: Current monkey board in use for glaucoma research at University of Wisconsin Hospital.

Client Information

The client is a graduate student, Galen Heyne, who studies glaucoma at the University of Wisconsin School of Public Health.

Problem Statement

Galen Heyne, the client, has requested a device to allow a monkey board to adjust in the XY plane (move in X direction, move in Y direction, and be able to rotate at a minimum of 90 degrees) in order to make his research on glaucoma more efficient.

Background Information

Glaucoma is an eye condition where the optic nerve is damaged due to a steady increase in the intraocular pressure. The optic nerve has more than one million neurons that carry visual information from the retina to the brain. The diagram of the eye is shown in Figure 2.

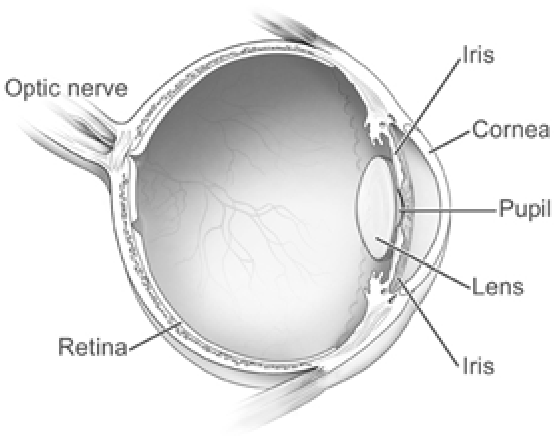

Figure 2: Diagram of eye showing optic nerve REF.

There are many different types of glaucoma, including open-angle glaucoma, angle closure glaucoma, and congenital glaucoma. Open angle glaucoma is the most common form of glaucoma and people generally have no symptoms until they begin to lose their vision (Glaucoma Resarch).

Angle-closure glaucoma is a form of glaucoma in which the fluid in the front of the eye cannot reach the angle and leave the eye. The angle is part of a chamber that allows fluid to exit the eye as seen in Figure 3. The angle is blocked by a portion of the iris causing most people with angle closure glaucoma have a sudden increase in eye pressure. Common symptoms include severe pain, nausea, cloudiness, and redness of the eye. Angle-closure glaucoma is a medical emergency and treatment usually involves laser surgery and/or medication to clear the blockage of the eye. The operation that the doctors perform is called an iridotomy. An iridotomy uses a laser to open new channels in the iris, which relieve pressure and prevent more attacks.

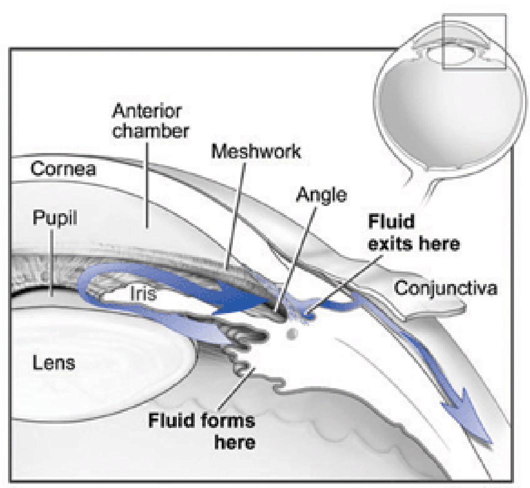

Figure 3: Diagram of eye showing the pathology of glaucoma REF.

Congenital glaucoma is a form that children are born with. Congenital glaucoma is due to a defect in the angle of the eye that slows the drainage of the fluid out of the eye. Eyeballs of children with congenital glaucoma are usually cloudy and very sensitive to light. Surgery is the typical treatment and is generally safe if done promptly. Typically, children that get surgery right away have a good chance of acquiring better vision.

Secondary glaucoma is caused by a complication of another medical condition including cataracts, eye injuries, eye tumors, and eye inflammation. Pigmentary glaucoma occurs when the pigment from the iris breaks off and blocks the meshwork in the eye, thus slowing fluid drainage. Glaucoma has also been linked to diabetes and can be triggered by some medications (Funding an innovated solution to glaucoma).

A person with glaucoma will slowly start to lose their vision. First, their vision will be cloudy on the periphery and then they will start to lose vision. A picture of what a person would see with normal vision and a picture of a person's vision with glaucoma would look like is compared in Figure 4.

Figure 4: Vision of person with no abnormalities (left) compared with vision of person with glaucoma (right) REF.

Various treatments are used for the different types of glaucoma. Open-angle glaucoma is treated quite successfully with eye drops. The eye drops are used to decrease the intraocular pressure. Laser treatment and surgery are also used to open new outflow channels in the eye. Some medications cause the eye to have less fluid, while others lower the pressure by enabling fluid to drain from the eye. Although there are drugs available for glaucoma, the exact cause of glaucoma is unknown. Many researchers are researching how glaucoma starts and how to prevent it.

Fluorophotometry measures the amount of fluorescein in the eye. Our client is interested in the level of fluorescein in the cornea and the anterior chamber segments of the monkey eye. Drops are given the evening before taking measurements with the device.

Glaucoma is highly correlated with high intraocular pressure (IOP), which may be due to many different things happening in the eye. This could include an increase in aqueous humor production, which is the fluid in the anterior chamber of the eye. By measuring the level of fluorescein in the eye over a period of time, he can observe how quickly the fluorescein is leaving the eye or being diluted by aqueous humor formation. By using a computer program, he can calculate the difference in outflow from the anterior chamber and cornea, compare the right and left eyes, and compare the baseline data to the data after administering a drug. Because there is such a low volume of eye fluid in the anterior chamber, the formation of aqueous humor must be very close, if not the same as aqueous flow. Therefore, he can assume that if a drug causes the fluorescein to be diluted more quickly, and then it increases aqueous humor formation.

Competition

Since the client came to the team with an idea for a customized design, products that have the requirements do not currently exist. However, other monkey restraining devices have been examined. The current system the client uses is inefficient and inaccurate. The client must position the monkey manually. A past model used to restrain monkeys is used to study ovulation. This model is used on non-sedated monkeys and fabricated using metal, leather, and wood. However, this model does not meet the requirements given by the client. The restraint chair can move in the z-direction, but is unable to translate in the x- or y-direction. In addition, the apparatus appears inhumane (Balin & Israel, 1963).

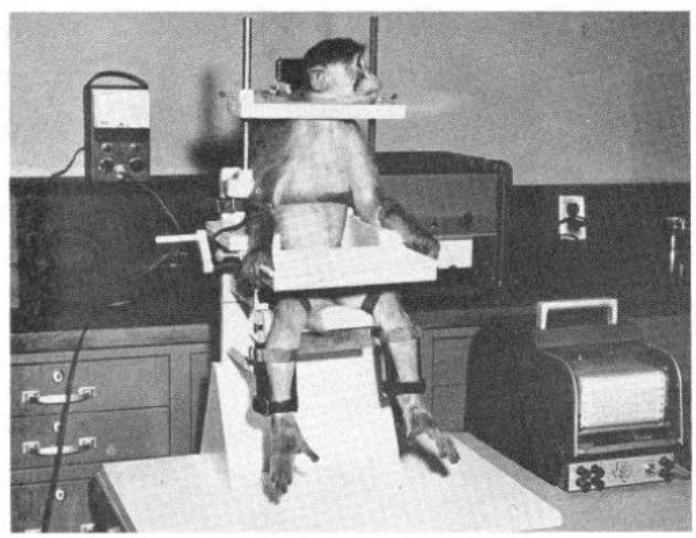

Figure 5: Past monkey restraining device used for studying ovulation (Balin & Israel, 1963).

Proposed Designs

Foosball Design

The foosball design implements rods that control a board. The user manually controls the rods by pushing and pulling the rods through carved holes in the base of the design.

The table will have holes that extend along the entire base of the board allowing the table to move in both the X and Y direction. There will be a clamping device that will allow the user to clamp the rods into position once the correct position is found. On the top of rods will be a board that the lazy susan attaches to. The pan with the monkey board will be located on top of the lazy susan allowing swiveling action. The pan will protect the foosball design from any bodily fluids from the monkey. Figure 6 shows the foosball design.

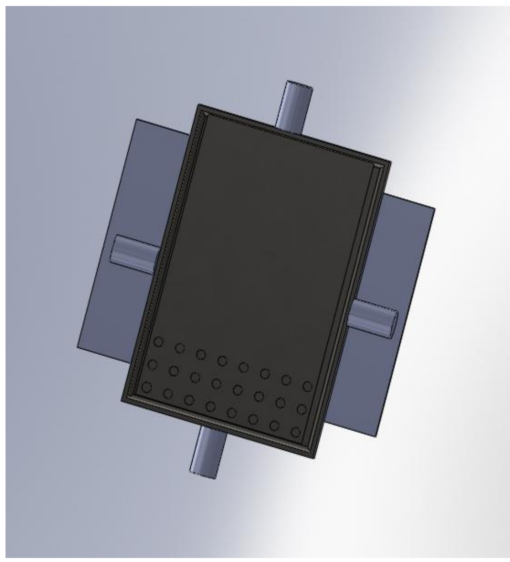

Figure 6: SolidWorks drawing of foosball design using preexisting monkey board.

Gear Mechanism

The gear mechanism work as its name suggest, with gears. The top portion of the gear mechanism consists of a sheet of non-rusting metal, such as aluminum. The top sheet that moves in the X direction will have the dimensions of 16 by 12 inches and 0.75 inches thick. Underneath this sheet, there exists a 16 inch rack gear that will be centered between the sheets. The linear rack will be connected to two linear rods that have a diameter of 1 inch with 8-inch separations between the two via hollow cylinders filled with ball bearings and welding. The rods will go inside the cylinders so that the table could move in a back forth motion. The distance between the sheet and the linear rods will be 5 inches. The rods will have their ends attached to a base that will be located below the 2 rods. This base will provide the structural support for this portion and allow it to move back and forth. In between the rods and the sheet will be a circular gear (A) that will bind with the rack gear. The circular gear (A) will be pinned on both sides and attached to the base. Another gear of similar size (B) will be meshed with gear (A). Gear (B) will also be secured to the base, but will have a long handle of 12 inches through its center. This will provide the coarse adjustment of the back and forth movement. Another gear (C) will be meshed with gear (A) and will be of smaller size. This too will have a handle going through it of 12 inches in length and will be secured to the base. Gear (C) will provide the fine adjustment. Another frame 2 will be replicated as frame 1 and will be rotated 90 degrees and welded bottom to the base. This now will move in the xy-plane. On top of the sheet on frame 1 will have latches to attach the monkey board/pan piece. This will provide a mechanism to detach the money board/pan piece so that it can be sterilized. A lazy susan with the locking mechanism as explained previously will be attached below frame 2 to provide 360 degrees of rotation.

XY-Table

The xy-table includes a lazy susan to allow the monkey board to rotate a minimum of 90 degrees. The xy-table design includes a xy-table that will be attached to a pan that the monkey board sits on top. This will allow the device to move the monkey board in the x and y directions as well as swivel. A xy-compound table is shown in Figure 7.

Figure 7: An example of a xy-compound table to be used in design (http://cdn6.grizzly.com/pics/jpeg288/g/g8750.jpg).

Design Matrix

In order to compare the advantages and disadvantages of the three design ideas, the team developed a design matrix. The design matrix evaluates three different types of designs: the xy-table, the foosball idea, and the gear mechanism idea. The categories that the team used to evaluate the materials were determined from our client's specifications.

	Weight	X-Y Table	Foosball	Gear Mechanism
Feasibility	1	4	2	2
Cost	1	2	2	1
Durability	0.7	4	3	4
Safety	0.75	3	3	3
Ergonomics	0.9	3	1	2
Accuracy	0.8	4	1	3
TOTAL		**16.95**	**10.05**	**12.25**

Table 1: Design Matrix.

The design matrix is shown in Table 1. The categories chosen to evaluate the materials include feasibility, cost, durability, safety, ergonomics, and accuracy. The team weighted these categories by ranking them on a scale from 0 to 1, with 1 being the most important. Each design was given a score from 1 to 4 relative to each other, with 0 being the worst and 4 being the best.

Some categories were considered more important than others were. The feasibility category was weighted 1 out of 1 because the more difficult the product is to make, the more room there will be for making errors. Given the task at hand, the most important aspect of the final product is that it has to work. The cost category was also weighted 1 out of 1 because at a budget of $200, the team is limited in the resources that it can acquire. The durability category was weighed 0.7 out of 1. Even though our intentions are to create a long lasting piece of equipment, the main reason for this project to assist the client in his research. Consequently, the final product has to last as long as the research does, which is not forever. The safety category was weighted at 0.75 out of 1. The team is not at all dismissing the importance of safety; however, given the mechanical nature of the project, a life-threatening malfunction such as electrical shock or overdose of radiation is not likely to occur. The ergonomics category was weighted at 0.9 out of 1 because, once again, due to the nature of the task at hand, the whole purpose of the project is to make the client's job easier and having a difficult machine to use defeats this purpose. This is why ergonomics was given a high weight. The accuracy category was weighted 0.8 out of 1. Since the required accuracy needed to be 0.5 mm, the team determined that a weight for the accuracy should be relatively high.

With the weights determined, the three designs were given scores. In the feasibility category, the XY compound design was given a 4, the foosball was given a 2, and the gear mechanism was given a 2. Since the XY compound required no further labor, it was given 4. Both the foosball and the gear mechanism would require more intensive labor, they received a 2. In the cost category, the XY compound design was given a 2, the foosball design was given a 2, and the gear mechanism was given a 1. Because all three designs would require a huge chunk of the budget, they all received low marks with gear mechanism receiving the lowest because it would cost the most to make due to the high price of gears.

In the durability category, both the XY compound and the gear mechanism received perfect scores of 4, while the foosball received a 3. All three designs are durable, but since the foosball mechanism would have more moveable parts, the team determined that the design had a greater chance of breaking so it got a lower score. In the safety category, all three designs tied with the score of 3 because none of the designs stood out as being more dangerous than one another. None received a perfect score because each design could still cause injury if mishandled. In the ergonomics category, the XY compound received a 3, the foosball mechanism received a 1, and the gear mechanism received a 2. This score was based mostly on how much the final project would weigh, which would influence how easily it would be transportable. The XY compound was the lightest, followed by the gear mechanism and lastly the foosball mechanism being the heaviest.

In the accuracy category, the XY compound received a 4, the foosball mechanism received a 1, and the gear mechanism received a 3. The foosball received the lowest score because locking and position would be a huge problem for this design. The gear mechanism received the second best because there was the possibility of backlash occurring if the team had to construct the mechanism .The XY compound was given a perfect score because it would be shipped from a factory who had done testing on it and solved any problems with regards to backlash. Totaling up the weighted scores, the clear winner was the XY compound with a score of 16.95, followed by the gear mechanism with 12.25 points, and followed by the foosball idea with a total of 10.05 points.

Final Design:

The major concern of the client is to position the monkeys more efficiently. A xy-compound stage will be utilized to move the board in the x-y plane. The team has chosen the Grizzly X-Y table as shown in Figure 7. A lazy susan will be used to rotate the monkey board 180 degrees to make the positioning easier for the client.

To lock the position of the monkey board during the procedure, a small rod will be placed in a circular metal plate, shown in Figure 8. The bar will also go through another piece of sheet metal, which will prevent further rotation. Holes will be made at 90 degree increments, allowing the client maximum versatility in positioning the monkey. Above the lazy susan, there will be a stainless steel pan, Figure 9. This enables the researchers to keep the mechanism sanitary for the monkeys, as bodily fluids will be caught in pan, and not in the xy-compound stage. The pan will be removable to keep it as clean as possible. The existing monkey board, Figure 10, will be utilized as well. This will be placed in the pan, as it will be removable to maintain a sanitary environment for the monkeys. The headgear and current hardware will remain, as the client still finds this helpful. The full assembly is shown in Figure 11.

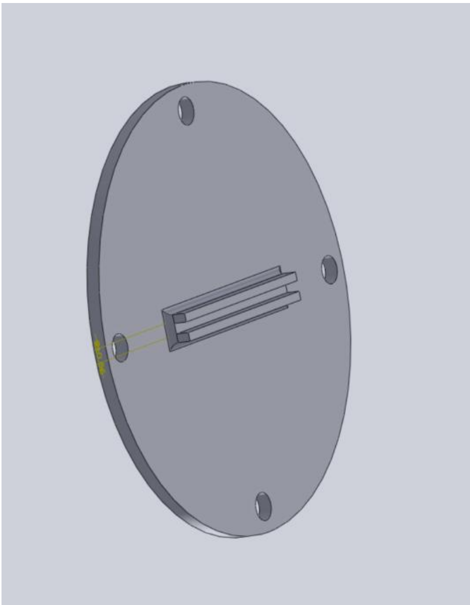

Figure 8: SolidWorks drawing of circular plate to be welded onto xy-compound table and lazy susan.

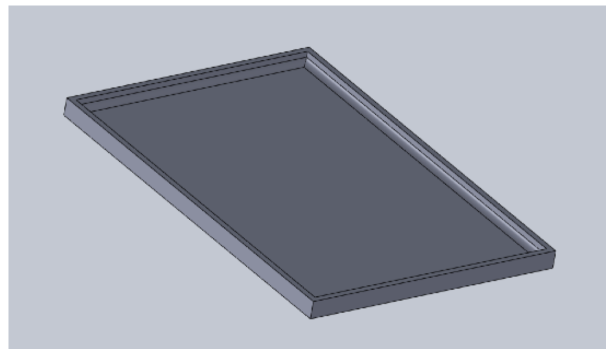

Figure 9: SolidWorks drawing of stainless steel pan that will hold preexisting monkey board.

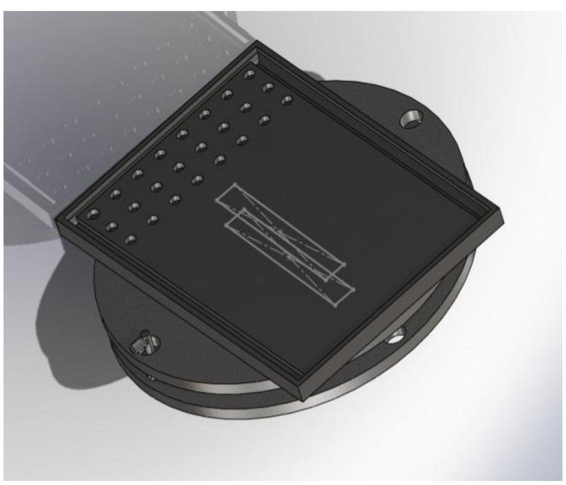

Figure 11: SolidWorks drawing of assembly of final design.

Figure 10: SolidWorks drawing of monkey board used currently by researchers.

Ergonomics

This device will be able to be used by any researcher familiar with the procedure carried out by those at the University of Wisconsin-Madison Hospital. The device will rotate and lock in 90-degree increments, yet have the ability to rotate with a full range of 360 degrees if needed. The movement in the x and y directions is also easily carried out by the researcher to create minimum effort, yet maximum efficiency. The stainless steel pan will also make it easier for the client to sterilize and clean after experiments since all bodily fluids and other insanitary materials will be contained inside the pan. The monkey board will also be designed with the monkey's comfort in mind. Since a comfortable headrest is already provided, a padded bed will be implemented in the pan so the monkey can remain at ease during the procedure and to keep it from getting too cold while anesthetized.

Ethical Considerations

The main ethical consideration related to this project is the issue of animal safety. Just because the device is built for monkeys, does not mean they should receive any less respect than a human should. The design must be humane towards the monkey and make sure they are in as comfortable of an environment as possible. The lack of physical constraints should help put the monkey in a less stressful environment. The device was made 100% mechanical in order to avoid any electrical malfunction that could harm the animal. In addition, the pan on which the monkey is placed is to ensure that the monkey could not get pinched by any of the hardware beneath them and to make sure that the monkey's bodily fluids do not spread to and defect the XY-compound or the lazy susan.

Future Work

Due to a miscommunication with our client, there was confusion about which directions the x and y-axes are pointing. Our team interpreted the x and y directions to be in the standard Cartesian coordinate system, as seen in Figure 12. However, our client uses a y-axis that points vertically into the sky creating an x -y plane that is perpendicular to the floor (Figure 13). For the

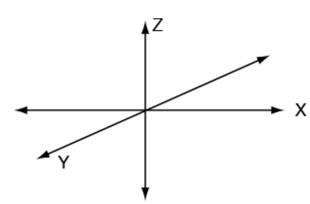

Figure 12: Coordinate system used by team.

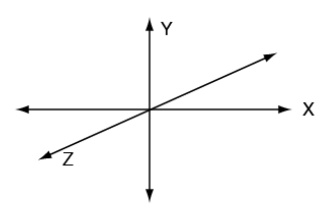

Figure 13: Coordinate system used by client.

remainder of the semester, the team plans to reconstruct our design concepts according to our newfound understanding of the client's needs. Potential areas of design development include the research of different types of jacks and ways to incorporate both vertical and lateral movement into our design concept. Once the team has the new design finalized, the team will order the necessary parts. Assembly is hard to plan before the parts are ordered, so a better idea of how we will put together our device will be achieved with all of the parts in our hands. If there is time before the end of the semester, testing will be performed on the device to make sure it is up to code with animal safety regulations and improve the efficiency of the research.

Conclusion

Galen and his team at the University of Wisconsin-Madison need a more convenient way to situate their test subjects in a position where they can be analyzed. Three initial designs were proposed: a model implementing gears, one using a foosball model with rods attached to the board, and finally an x-y compound table. The compound table design was deemed the best solution to the problem. However, due to miscommunication with the client about where the y-axis is pointing, new design concepts must be researched. For the remainder of the semester, new ideas about how to solve the problem will be sought after. When the team has the design narrowed down to the best solution, and then will order parts and fabricate the device. If there is time, the team would like to test the product to make sure it is safe for use. The team will continue to work with the client to make sure that the design stays within the constraints of what is desired.

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Appendix

I. Project Design Specifications

Board for Glaucoma Research (PDS)

10/15/10

Laura Platner, Baljit Kler, Taylor Powers, Danny Tighe

Function: Galen Heyne, the client, has requested a device to allow a monkey board to adjust in the XY plane (move in X direction, move in Y direction, and be able to rotate at a minimum of 90 degrees) in order to make his research on glaucoma more efficient.

Client requirements:

- Must be able to move in the X direction (rough and fine adjustments)
- Must be able to move in the Y direction
- Rotate at least 90 degrees
- All rotations must be mechanical (no electronics for Animal safety)
- Has to be easily cleaned
- Preferably have a pad to keep monkeys warm

Design requirements:

1. **Physical and Operational Characteristics**
    a. *Performance requirements:*
        i. Must move in XY plane
        ii. Must be able to rotate 90 degrees
        iii. Must have a locking mechanism
    b. *Safety:*
        i. Must be mechanical
        ii. Must have a heating pad to keep monkeys warm
    c. *Accuracy and Reliability*
        i. Needs to have a mechanically controlled amount of precision
        ii. Needs to have consistency with positioning
        iii. Consistent initial securement for each monkey
    d. *Life in Service:*
        i. We want to design this board so that it will last for 10 years
    e. *Shelf Life:*
        i. Sterile before use
        ii. Easily storable
    f. *Operating Environment:*
        i. Laboratory research
        ii. Room Temperature- 15-30 degrees Celsius
    g. *Ergonomics:*

i. Comfortable for the cynomolgus monkey
ii. Increase efficiency of the research
iii. Easy to use for the research

h. *Size:*
    i. Monkeys are 38 to 55 cm long
    ii. *Weight*
        1. Females are 7 - 13 lbs
        2. Males are 11-20 lbs

i. Weight:
    i. Females are 7 - 13 lbs
    ii. Males are 11-20 lbs
    iii. Weight of Board: (find later)

j. *Materials:*
    i. Metal
    ii. Plastic

k. *Aesthetics, appearance, and finish:*
    i. Function over aesthetics

2. Production Characteristics

a. *Quantity:*
    i. Only need to make one

b. *Target Product Cost:*
    i. $200.00

3. Miscellaneous

a. *Standards and Specifications:*
    i. Follow monkey handling ethical specifications
    ii. Must be safe and comfortable for monkeys
    iii. Must decrease stress of monkey

b. *Customer:*
    i. Customer m*ust be* able to move to the table

c. Patient-related concerns:
    i. Don't want the researcher or monkey to get pinched
    ii. Whole machine must be sterile

d. *Competition:*
    i. The competition is the preexisting board