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Phototherapy Mounting System for Inpatient Rehabilitation

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Abstract

Through a feedback-driven iterative prototyping process, we developed a 2-mount system for the phototherapy treatment devices at St. Rita's Medical Center in Lima, Ohio. The primary issues we sought to mitigate were: reproducibility, full treatment dosage delivery, nurse time spent rearranging patient belongings, cord length issues, and safety hazards such as devices falling and people tripping over out-stretched cords. Secondary issues we ran into along the way included: mount stability, alternative mount uses, cleanliness of the mounts, a universal connection, minimizing tabletop space used, providing an additional outlet for patient use, cord storage, and safety hazards surrounding mount wiring.

Our complete table mount is a commercially-available computer monitor mount equipped with a standard VESA mounting plate. The bottom of the mount's base has a closed-cell padding which reduces sliding and repels fluids. The stem of the mount telescopes with a hand-operated collar, eliminating the need for tools for adjustment. We stabilized the mount with a pair of aluminum brackets which are attached to the top of the table mount and slide under the table face. Onto the larger of the two brackets, we attached a full outlet with two USB ports and a 15-ft grounded extension cord. This bracket also has two hooks for winding and storing the extension cord when not in use.

Attached to the table mount's VESA mounting plate is the female side of a connection piece made from 16-gauge folded aluminum. This piece is closed on 3 sides, with a springy metal piece on the 4th, and top, side to prevent the light device from being bumped out accidentally. The metal piece must be depressed to insert or remove the light or attachment. The male side of the connection is adhered to the light, or other attachment. Other attachments designed for the table mount include a book stand and a mirror.

The wall mount is a 5-ft, 5-jointed arm which folds in upon itself to a small surface area. The end of the wall mount is also equipped with a standard VESA mounting plate, making it compatible with the connection piece as well. The 5th joint, which is located between the VESA plate and the rest of the wall mount, has 360° rotation, which allows the nurses to easily position the light device. TapCon® 0.25-inch diameter screws hold the wall mount to the wall.

Medical staff who provide the treatment to patients have provided feedback along the way. Initially, these personnel reported spending as many as 3-6 minutes setting up the light device for any one-treatment session. After multiple generations of each mount, we have achieved a reduced time in light setup. Additionally, we have increased usage of the space to patient comfort by providing the outlet and USB ports on the table mount. Shortage of outlets was reported by personnel to be a common complaint by patients in the facility. Overall, we saw an 86% increase in satisfaction from initial reports of device usefulness.

Background

Phototherapy is a branch of medical treatment that uses parts of the light spectrum to influence the production of certain chemicals and hormones in the body. This stimulus is generally used to increase effectiveness of conventional treatments. Modern phototherapy is a fairly new idea. Applications for improving seasonal affective disorder (SAD) have only been in use since the late 1980's (Wehr & Rosenthal, 1989), and applications for treating infant jaundice have been used since the early 1990's (Tan, 1996). While new, the research done on this subject has exploded in the last three decades, making resources and perspectives plentiful.

When the benefits of light treatment were initially detected, the prescribed dosage was set as 2,500 lux for 6 hours a day administered three before dawn and three after dusk (Rosenthal et al., 1984). In Rosenthal et al.'s article, the team found that two hours a day at 2500 lux was sufficient to facilitate the results of the treatment. In a later experiment, another team determined that the intensity of the light could be increased to 10,000 lux and remain effective at a reduced time of 30 minutes (Wehr & Rosenthal, 1989). This dosing level has become the accepted treatment plan listed on many light devices and prescribed by doctors.

While the treatment application for mood improvements began as a method to combat seasonal affective disorder, several experiments have been done to determine broader applications. In 2004, scientists published an article concerning a study of the effects of bright light on symptoms of dementia. They showed results of decreased night time activity, and somewhat stabilized sleep periods (Skjerve, Bjorvatn, & Holsten, 2004). In 2011, a team working with non-seasonal major depressive disorder in elderly patients reported long-term improvements in ability to get up after sleeping, cortisol levels and 24-hour UFC excretions (Rutten, et al., 2012). They also reported non-major changes in other sleep measures, suggesting a more acute improvement to depression over sleeping disturbances.

All the applications of phototherapy filter into two main categories – UV exposure for skin effects (Tan, 1996) and light intensity for mood effects. Our project focuses on the light intensity application. At St. Rita's Medical Center in Lima, OH, the inpatient rehabilitation unit sees patients daily who struggle with depression. Part of the inpatient status means that patients in this ward rarely get to experience sunlight, a major factor in serotonin development. Because of this, seasonal affective disorder is prevalent and often transitions into more long-term forms of the disorder. To combat this, phototherapy is often prescribed as a free, alternative treatment.

Currently, St. Rita's uses Nature Bright's SunTouch Plus. The device was created as a mood and energy booster (Nature Bright, 2016). It emits 10,000-lux, 17,000-Kelvin, ultra-violetfree, white light and contains a negative ionizer. The device features built-in timers of 15, 30, 45 and 60-minute intervals. The device is approximately 13 inches tall, 9 inches wide and 6 inches deep. St. Rita's medical center has reported qualitatively noticeable benefits from the device on patient mood and activity level. The device is set up 18-24 inches away from the patient's face at a 45-degree angle. Anyone using the SunTouch Plus is advised not to look directly into the light for an extended period. During the device's use at St. Rita's, no negative side effects have been seen.

Problem Statement

In St. Rita's hospital in Lima, Ohio, doctors have seen remarkable success using phototherapy with patients in their extended-stay rehabilitation ward. Like many treatment forms, the success of this therapy lies heavily on delivering the correct dosage. For this treatment, the important parameters are: the distance to the patient and an unobstructed path of light to the patient.

Figure 1 – Light Box

Currently, bulky light boxes are used to deliver the bright light. These devices are placed on a busy tray table or nightstand that oftentimes is cluttered with personal belongings. Often, personnel must remove patient belongings to fit the light on the table, and create an unobstructed path between the light and patient for treatment delivery. Additionally, reaching an outlet is an issue because the medical center rooms are small with few vacant outlets and the current light devices have cords too short to reach from the bed to the available outlet. Nurses therefore spent precious minutes rearranging devices and furniture to reach an outlet. Furthermore, patients must receive this light dosage for 30 minutes, and patient cooperation to not move the light box when the nurse leaves is sometimes problematic.

Nurses need a design which eliminates these issues, and creates a streamlined process that will save them time with every touch of the device. Units must be around $200 per room, and must fit ergonomically in with already-existent equipment and furniture. However, the biggest cost to the medical center is in time wasted by trained personnel rearranging patients' belongings.

Definition of Success

Staff at St. Rita's Medical Center in Lima, Ohio., find phototherapy to be extremely effective in motivating patients to complete physical therapy and thereby allowing patients to heal more quickly. Because the success of the treatment was not in question, we consulted with St. Rita's to determine the ways in which to measure the success of the design. After we observed the inpatient ward, the medical staff presented us with several standards by which to judge success:

First, the device must fit into the hospital room without obstructing any important medical devices, and without being obstructed by anything else. The fulfillment of this criterion will be determined by survey feedback from medical personnel and patients concerning ease of storage and access.

Second, the device must be easily positioned by staff (nurses, occupational therapists, doctors, etc.) to ensure efficient application of the treatment. This measure will rely mainly on survey feedback from those personnel on how easily they can maneuver the device, and how quickly they can position it. Time trials of personnel setting up the equipment may also be a source of qualitative data.

Third, the device must deliver the treatment in such a way as to maximize patient comfort. The major way that this criterion will be quantified is through lux meter readings. Multiple volunteers will sit/lay in common positions, and the device will be oriented towards the patient with a lux reading taken at distances in 3-inch increments to compare the performance of the light with and without the mounts.

Fourth, the maintenance and cleaning staff must have no increased work demand to keep the device in useable condition. This standard will primarily be reliant on survey results from staff dealing with the housekeeping of the device. This standard will also be fulfilled by using medically-approved materials, such as stainless steel 304 and material coating techniques.

Fifth, the final device design must cost less than $200 per unit. If the device is adaptable to the majority of similar light models, the price of the light device will not be included in our unit cost. If we choose to move forward with a mechanism specific to a particular light model, that light's new unit price will be factored into our overall per unit device cost.

Sixth, the device must be useful as a viewing light for visiting medical personnel. This criterion also may be quantified as successful with survey feedback from those personnel using the device for this specific purpose.

Approaches

We initially considered designing a new phototherapy device, such as a wearable or TV-mounted unit; however, these options proved to be more limiting and costly to the medical center. Wearable devices also pose serious complications for patients with traumatic head injuries, or with mental or physical disability. For example, after suffering from a stroke, some patients experience hemi spatial neglect, where the individual is entirely unaware of half of their body. The device could be accidently repositioned without the patient's knowledge. We considered a TV-mounted unit to improve patient focus by allowing them to watch television while receiving treatment. However, a TV-mounted device would be dependent on the type and location of the television in the room, which may change over time. Additionally, because the intensity of light is dependent on its distance from the patient's face, the required dosage to reach the patient would be too strong to be in the patient's direct line of vision. A standing light is also a possibility, but there is already limited floor space and a stand has limited mobility. Also, the device could topple easily with such a high center of gravity.

Patients use the phototherapy device primarily at either the bed or the armchair. A design consisting of a small mount, attached either to hospital furniture or the wall, could therefore offer cord management possibilities and eliminate the need for floor space. Several locations for mounts were considered including: a wall mount located behind the chair, a wall mount located near the bed, a table mount set on top on the bedside table, and mount clamped to the major stem of the bedside table. Having a wall-mounted light around the bed would also allow the light to be used for examination purposes. Currently, the device is placed on the table, which allows for an extensive range of motion, as well as a stable base that does not require wall space. For these reason, we also considered a mount attached to the table.

Several types of arms were considered, including arms with telescoping capabilities, multiple joints, or a swivel base. A telescoping arm would allow basic extension along the length of any given support. A swiveling base would allow for rotation of the device. A multi-jointed arm system would provide a wide range of motion paired with long reach. To ensure flexibility, the mount design could incorporate a mag-base, gooseneck and/or ball and socket joints.

To address the issues of cord length and outlet location, we considered replacing the cord on the device, though this would hurt the integrity of the light and result in alterations to any new device purchased by the hospital. The team also considered extension cords, although safety requirements within a hospital can be strict. If a table mount is chosen, wiring the table is another option. Being able to attach an outlet with a USB port would help manage cords in the hospital rooms, including patient phone and computer chargers, which are currently a nuisance to hospital staff. Staff also suggested a battery-powered or rechargeable device. Although replacing the devices currently in use may cause budgetary conflicts, we are also exploring using a different phototherapy unit as an option for solving cord issues. All in all, we want to be sure that our design will work for any device the hospital chooses to purchase.

Selected Approach

Because we are fulfilling the needs of a client, we chose an iterative approach. This method allows the final design to be crafted to the specific wants of St. Rita's Medical Center. While simply presenting one final design to the hospital without having rounds of feedback might lead to a technically-successful design, there may be issues important to the staff which our selected approach would not consider, and we would therefore fail to fulfill our criteria for success.

A mounting system was chosen as the best general approach to solve the hospital's functionality issues. Out of the approaches considered, we moved forward with a system incorporating a mount for the wall next to the bed and a mount for the table. The wall mount allows patients to easily receive treatment while in bed, and allows the phototherapy light to be used as an examination light. The mount for the table allows movement throughout the room and would be particularly useful for patients receiving treatments at the chair. A wall mount by the chair, while considered, would be very difficult due to the many fixtures already mounted to the walls around the chair. We feel confident that using the table will also offer more stability than using a tall floor lamp.

When we considered the problem posed by the limited cord length and lack of accessible outlets, we designed an external outlet for the table mount that connects to a retractable extension cord on the base of the mount. Although the device itself does not have a grounded cord, we added a grounded extension cord. Based on hospital regulations, an extension cord is required to prevent electrical hazards such as power surges. We will store the cord by winding it on two hooks located on table brackets (discussed later) adjacent to the table mount.

We considered changing the cord on the device, but this would not allow the hospital to easily update the phototherapy device. By using the outlet and grounded extension cord, the hospital can then use any new phototherapy device without altering the existing cord. While staff will need to tie up the original cord to keep it out of the way, the overall profile of the mount will still be clean, the cord can stay in the tied position, and the increased available length from the device to the wall outlet will streamline setup. In addition to these benefits, the hospital will also gain an outlet on the table, available for patient use.

Methods

The highly iterative process we employed allowed us to adjust the design multiple times to hone the final deliverables in response to personnel feedback. The practicality and reproducibility of the design are also a large factor in the design process.

As mounting systems already exist for televisions, tablets and computer monitors, we initially investigated and purchased commercially-available mounts. From these commercially-available mounts, we adapted and designed specific pieces to add to existing mount parts to accurately fulfill our criteria of success. We took the initial commercial mounts to St. Rita's for staff to operate and then offer us feedback. From there, we could begin the design process of those unique pieces.

In the case of the table mount, we found a single, commercially available mount that fulfilled the medical center's needs, and simply affixed the phototherapy-device connection and the brackets and cord management system.

The wall mount was not as simple. While we could develop a usable prototype from two different commercially-available mounts, the reach of that wall mount was too short. Therefore, we designed and fabricated a third arm-piece and fourth joint to the design, as well as a connection piece at the end of the mount. We also added our own cord management system with a fused plug to this design.

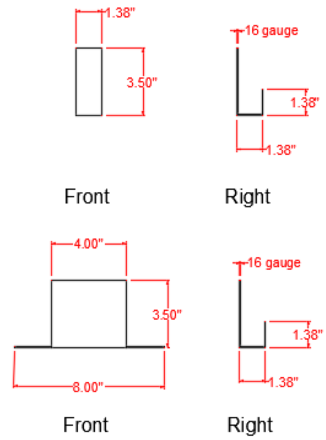


Figure 3 - Table Brackets

To consider ourselves successful, the patient must receive the same, if not a more consistent and complete, treatment dosage. To address this criterion, we obtained a lux meter to measure the lux output of the light without a mount, with the table mount, and with the wall mount. We took data from multiple individuals of various heights at eight established distances from the light. By comparing the lux readings without a mounting system to the lux readings with either mounting system, we determined success based on the current standard used at St. Rita's Hospital.

Final Design

For the hospital's purposes, we wanted a simple, clean design that would not overcomplicate the issue. We chose a two-mount system.


Figure 2 - Table Mount

For the table mount, we selected a single vertical arm. The table itself is easily moved around the room. The arm on the table will sit on top of the table, which will increase the area patients can use without interfering with the optional filing cabinet located on the main stem of the table. The table mount has a pivoting head and a 360-degree rotating attachment. The height of the mount is adjusted with a telescoping vertical arm. We stabilize the mount using metal brackets that slide under the tabletop and over the mount's base. This ensures that the mount will not knocked off the table. Because the mount is not permanently attached to the tabletop, it can be easily removed to clean any potential spills.

The metal brackets hold the hooks for cord management and the wired outlet. The medical staff can easily deal with all electrical components and cords because they are contained on one small piece of metal. This setup means easy control for nurses when they move the light between mounts. The brackets are secured to the table mount base and slide onto the table in one easy motion.

The wall mount will use three foldable arms to achieve a reach of five feet. These arms are designed to fold flat to the wall on the side of the bed farthest from the door. This will keep the mount out of the way. A flexible connection piece at the end of the mount can be manipulated in every direction. The mount will be affixed to the wall in a location allowing application of treatment for a wide range of patient anatomies.

With this dual-mount system, the phototherapy device can be transferred from the table mount to the wall mount with ease and brevity. Although Velcro was first considered for this necessarily secure yet forgiving attachment, we dismissed it because its lifespan was too short, and it took too long to press the Velcro and achieve the proper hold. Velcro may also lead to patients with lower mental faculties unintentionally removing the device from the mount. Instead of Velcro, we designed a system of two mated metal plates. One plate will slip into the other, allowing the device to be installed quickly and securely on either mount.

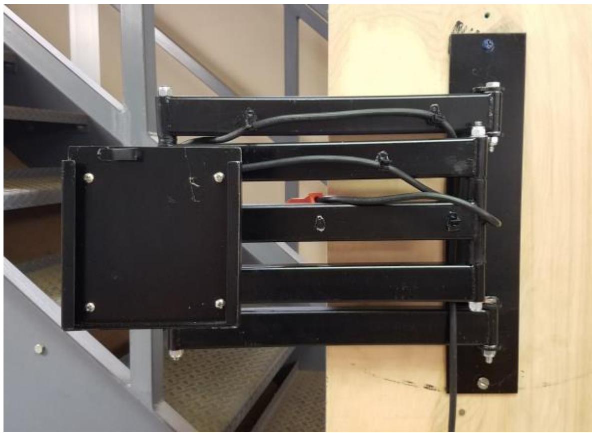


Figure 4 - Wall Mount

This connection piece needed to be durable, clean, simple, and easy to use. With these requirements in mind, we decided early on to use folded aluminum for its price and durability. We also determined that a two-part mount with the female half attaching to the VESA plate on the mount, and the male half adhered to the light box, would be the most effective. This set-up also fulfills a secondary request from our client that the table mount can hold other objects and devices in absence of the light to make patient and personnel life easier.

The female piece, seen in Figure 6, is closed on three sides, with the open top being where the male side is inserted. To keep the male half from accidentally sliding out when the light is tilted, we added another piece of aluminum, bent to curve just above the height of the three side walls. This metal piece rests at a right angle to the path of the male piece. It keeps the male side from accidently being unseated from the connection, but is easily depressed by anyone purposefully removing or placing the light or other implement.

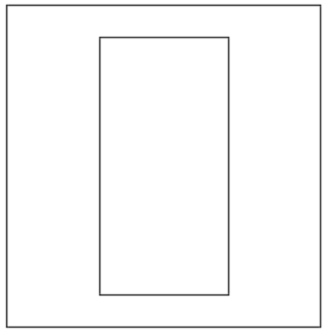


Figure 5 - Male Connection

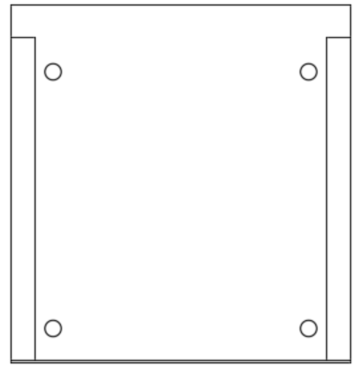


Figure 6 - Female Connection

The male side, seen in Figure 5, is folded to fit into the female half with minimal tolerances, to ensure stability of light placement. This piece is permanently adhered to the light box. We chose adhesive over hardware to allow future upgrades to other light options. Many of these newer models are tablet-thick, with no room to drill into the rear and add screws. So that the adhered area cleared the interference between male and female pieces, we added an extra fold of aluminum to the outside of the male piece. However, if the medical center decided to use hardware in the future, the area used for adherence can be easily drilled into during fabrication of the male connection.

The medical staff also requested alternative uses for the table mount, when the light is not in use. In response to this, we provided a mirror to be used for speech therapy and designed a book shelf for holding patient belongings such as a phone, tablet, or book.

Figure 7 – Book Shelf and Mirror Attachments

After the first generation of this connection was tested, we decided to expand the surface area of the adhered connection between the male side and the light. Additionally, a thicker gauge of metal sheet was chosen for the overall design. We made both improvements in response to a larger amount of flexion present in the first prototype than desired.

Analysis

Table Mount

With our table mount [See Figure 2], the staff brought up a few different safety concerns. These concerns included: a tipping hazard if the mount is hit or pulled; a tripping hazard if the cord comes off the ground; and a combined electrical and health hazard stemming from the possibility of a patient spilling their beverage onto the table. To eliminate the fear of tipping, we developed two brackets to stabilize the mount. These greatly increase the forces required to destabilize the mount. They also became a convenient location for our outlet and cord management solutions.

To combat the tripping hazard, we took a twofold approach. First, we added a 15-foot grounded cord to the table mount, doubling the cord length previously available. This immediately reduced the trip hazard as well as the tip hazard by ensuring that the cord is on the ground at all times. Additionally, by adding a cord management solution to the mount, staff can roll the extension cord up out of the way when not in use.

To solve the issues surrounding possible liquid spills on the table, we considered a few approaches. Initially, we hoped to create a watertight seal around the entire mount base so no liquids would pass under. After deciding that the process to provide this seal was more than necessary, we settled for a closed-cell foam beneath the mount that is water resistant, and easily cleaned. Because of our stabilizing brackets, permanent fixture of the mount became completely unnecessary to keep the patient and personnel safe.

To test the stability of the table mount with the light, we applied a load sensor to measure the force required to tip the system or compromise the brackets. Our baseline was a value of 20 lbs. applied to the mount in any point and direction. This is a value greater than that required to move the table on which the mount sits – this scenario was a concern among staff at the medical center. We performed the test at the highest point on the table mount, applying the force perpendicular to the back of the light device and parallel to each of the support legs on the mount base. All locations successfully withstood the testing point of 20 lbs. While we do not suggest using the table mount in this way, the mount is safe under these conditions.

Wall Mount

The wall mount [see Figure 4] also presented possible safety hazards. These hazards are: a bump hazard from a patient or other individual hitting their head on the mount when it is in use; and a falling hazard resulting from a patient using the mount to pull themselves up when attempting to stand or reposition. The bump hazard is addressed through recognition by staff to make the mount's presence known. We discussed options with staff for making the mount more obvious or padded, however they opted for a more neutral, discrete color to blend into the rooms.

A more minor concern brought to our attention was the cosmetic issues the wall mount's joints could cause to the hospital wall. We solved this problem by provided a thin plate that extends across the area on the wall where damage is likely to occur.

To address the possibility of an issue when a patient applying undue forces to the mount, loading scenarios with up to 300 lbs. of force were considered. After analyzing these diagrams, we determined that the mount can withstand that weight and more. Given that the walls of St. Rita's Medical Center are cinder block under plaster, a mounting mechanism known as TapCon® is used. This system is known to be very durable, easily overcoming our 300-lb. load, plus the light and mount's weight, with a factor of safety of at least 2.

We are using 0.25-inch diameter screws with an embedment depth of 1.75 inches. The ultimate shear loading of these screws is 1670 lbs., and the ultimate tensile strength is 2020 lbs. The static loading of the mount in normal loading scenarios should not exceed 25% of these values (factor of safety of 4). This translates to 417.5 and 505 lbs. for shear and tensile loads, respectively. The normal working load of our system, when the light is hung on the mount without assed weight, puts a tensile load of 75 lbs. with just over 2 lbs. of shear on each TapCon® screw. When a maximum load of 300 lbs. is applied at the end of the mount (worst-case scenario), the tensile load for each screw becomes 980 lbs. and the shear load becomes 100 lbs. Therefore, the factor of safety on the bolts is 2.

In deciding which material to use for the mounts, aluminum and steel were our main options. While aluminum would be the lighter and cheaper material, the deflection over the length of the beam is great enough to cause issues at our joints. Deflection in an equivalent beam of steel is almost 30 times less. Additionally, stainless steel is the preferred material of use in a hospital setting. Altogether, steel provided greater rigidity and cleanliness than aluminum, and so we chose steel for our construction.

Results

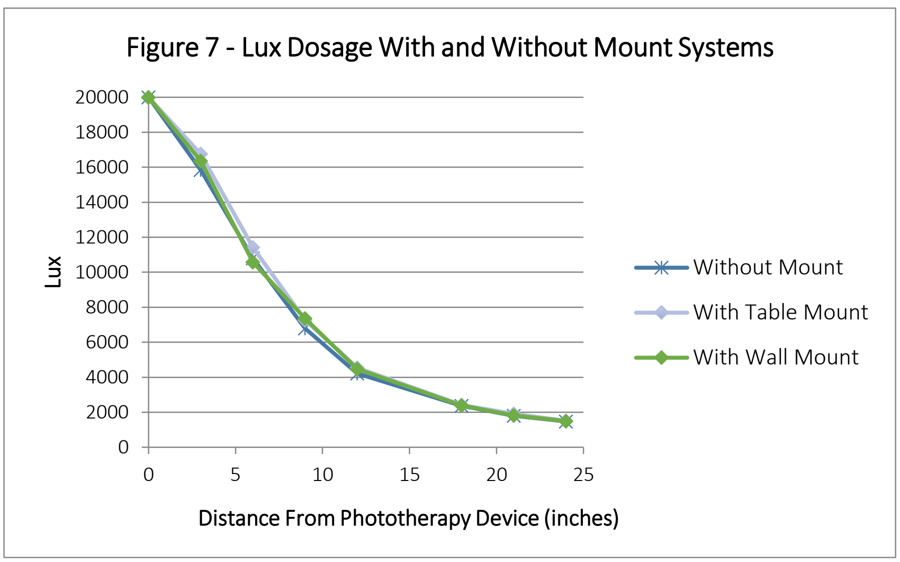
Design Feedback

After we presented the first generation of mounting system to St. Rita's, the hospital staff provided us with feedback. When asked to rate the design, staff gave it a 7.5 out of 10, and over half said that it reduced the time it took to use the device by two or more minutes. More importantly, our survey allowed personnel to conveniently provide input on problems and possible improvements. Some of the comments they provided included large issues with the cord reaching the outlet, and a desire to have a multi-functional aspect to the table mount. These suggestions guided our design of the second generation.

With our second generation, we chose a table mount with a smaller surface area, per staff feedback, and a wall mount with an extra section of length to increase reach. The staff liked aspects of the new table mount such as the adaptability with the collar where the light would be mounted, however were concerned with the thickness of the new mount's base. Concerns were that the thickness would increase chances of a spill, and be a point of irritation for the patients. Comments recorded also included a desire to remove the cord altogether and provide a battery-powered light. Overall, ratings went up to 9.3 out of 10.

After surveying the staff on the second generation of our designs, we could provide the medical center with a final design that effectively fulfilled all their desired properties. The table mount base was now both small enough and thin enough to not be a nuisance. While we did not provide a different light that was battery-powered, we did attach the new cord management system and outlet, which several staff members saw as a valuable contribution to patient comfort. We also purchased a large, hand-held mirror to attach to a male connection for presentation with the table mount. They were very excited to see the mirror, and mentioned more alternative uses for the table mount. The medical staff were thrilled by the wall mount's reach and location, mentioning that it reached just close enough to the patient, and was very maneuverable. We received initial feedback from them concerning this final design, and found a satisfaction rate of 9.3 out of 10. The average reported time savings are 2-4 minutes, and some of the most distinctive comments on the designs were that it was "really perfect," the light "hooks on easily," and the table mount "frees up space on the tray table."

Lux Analysis



We analyzed the lux emitted from the phototherapy device with and without both mounting systems. First, we set the light up as it would normally be used in St. Rita's without any mounting systems. The set-up was ideal, directly on the table at a 45° angle. Four volunteers then measured lux using a lux meter at distances ranging from 0 inches to 24 inches from the light. From these samples, we plotted an average value and set a baseline expectation for lux delivery while using our designs.

According to our analysis, our success depends on achieving a lux measurement of 1400-2500 lux at 18-24 inches from the light, at a 45° angle. We then repeated the analysis using the light on the wall mount and on the table mount. Both mounts produced the required lux.

Finally, we plotted the results for all three scenarios together. As can be seen in [Figure 7] above, our design is successful according to our lux delivery criterion. Based on the nurses' reports of difficulty setting up the device at the proper angle and distance without a mount, our designs also provide a more regular dose to patients.

Conclusion

Our first criterion for success was that the light device fit into the hospital room without obstructing, or being obstructed by, any important medical equipment or other objects. By having both the wall mount and the table mount, we maximized the possibilities for light placement and treatment. The wall mount's location on the far side of the bed is away from the bulk of medical supplies, which makes it unobstructed. The table mount lifts the light off the table surface, thus eliminating possible obstructions and providing the patient with more space to place personal belongings.

Our second criterion was easy positioning for staff. The table mount keeps personnel from needing to rearrange patient belongings to place the light device. The universal connection allows quick installation and removal of the light from either mount, and highly flexible joints allow a wide range of rotations and manipulations to help nurses get light positioning just right.

The third criterion was to deliver the full treatment, and in a way maximizing patient comfort. By having both a wall mount and a table mount, staff can easily position the light to reach a patient, whether that individual prefers to sit in the chair, lean forward in the bed, or lay down in the bed. Also, our lux testing showed equal treatment delivery with our mounts compared to ideal placement of the light, currently typical of the medical center.

Fourth, we wanted to make sure that maintenance and cleaning staff did not have increased work demand with our new mounts. To ensure this, non-porous materials were used and Velcro was avoided. Also, the table mount is not permanently affixed to the table, ensuring that staff can easily remove it to clean underneath.

The fifth criterion for success was to keep the price per unit beneath $200. This value includes the wiring, brackets, table mount, and wall mount. Price varies greatly depending on the level of production the medical center chooses. Because price depends so greatly on the medical center's choices, our primary goal is to ensure that they have full, clear production instructions including detailed CAD drawings, materials lists, and parts numbers.

Our sixth, and final, criterion is for the light to be available to visiting medical personnel as a viewing light on the patient. This is the main reason the wall mount was a priority to our team. While the table mount fulfills all treatment expectations, as well as providing a location for other attachments useful to the patient and other staff, it cannot telescope to a height sufficient, or be oriented close enough to the patient to be useful as a viewing light. The wall mount is perfect for use on a patient in bed with its height and joint maneuverability.

From our criteria of success, we know that we completed all initial requirements. By being aware of our client's needs, we could provide solutions for all their issues. Through testing, we determined that our mounts enable full-dosage delivery of the treatment. From staff feedback and our own testing, we reduced set-up time by minutes. Both qualitatively and quantitatively, our mounting design is a complete success.

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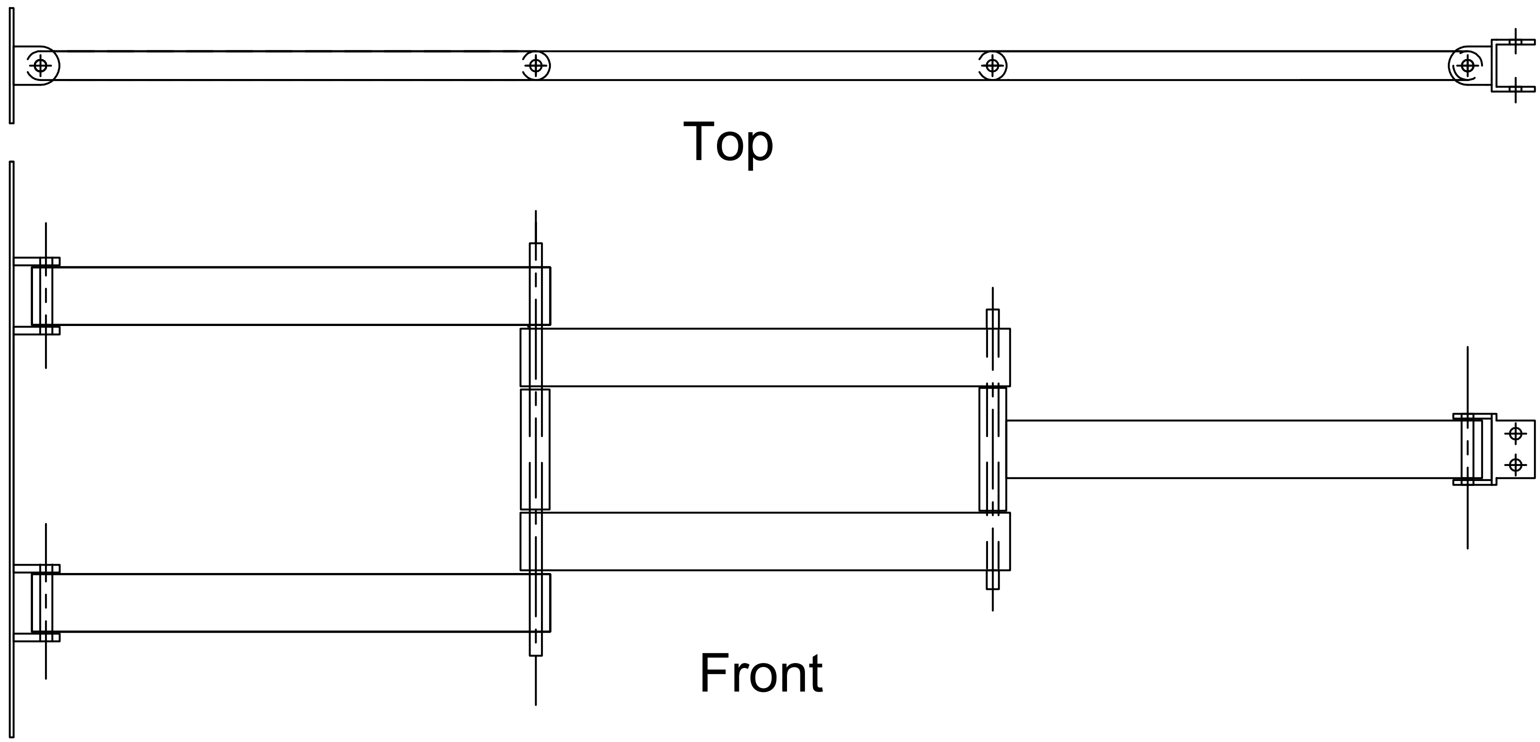
Appendix

##	Document		
1	CAD dwg – Assembled Design	13	CAD dwg – Swivel Connection Assembly
2	CAD dwg – General Arm Segment 1 Assembly	14	CAD dwg – Swivel Connection Pieces
3	CAD dwg – New Arm Segment 1	15	CAD dwg – Connector Rod 1
4	CAD dwg – Arm Bushing	16	CAD dwg – Male Connection, Pt 1
5	CAD dwg – General Arm Segment 2 Assembly	17	CAD dwg – Male Connection, Pt 2
6	CAD dwg – New Arm Segment 2	18	CAD dwg – Female Connection
7	CAD dwg – Last Arm Segment Assembly	19	CAD dwg – Table Brackets
8	CAD dwg – New Arm Segment 3	20	Unit Floor Layout
9	CAD dwg – Connector Rod & Sleeve 2	21	To-Scale Room Layout
10	CAD dwg – Wall Plate Assembly	22	Economic Analysis
11	CAD dwg – Wall Plate	23	Lux Data
12	CAD dwg – Wall Plate Tabs		



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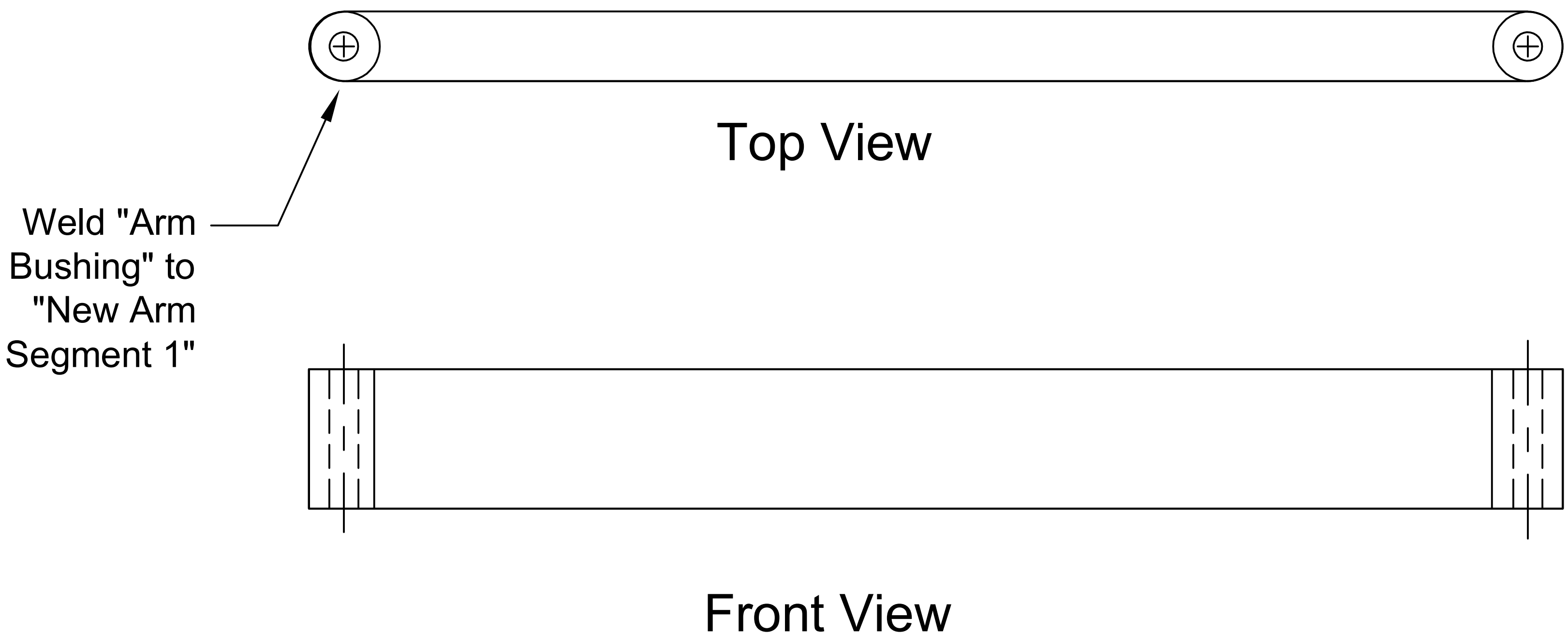
			Amount: 1	Units: inches	
Sheet 1		FILE	therapy2.dwg	Material: Steel	



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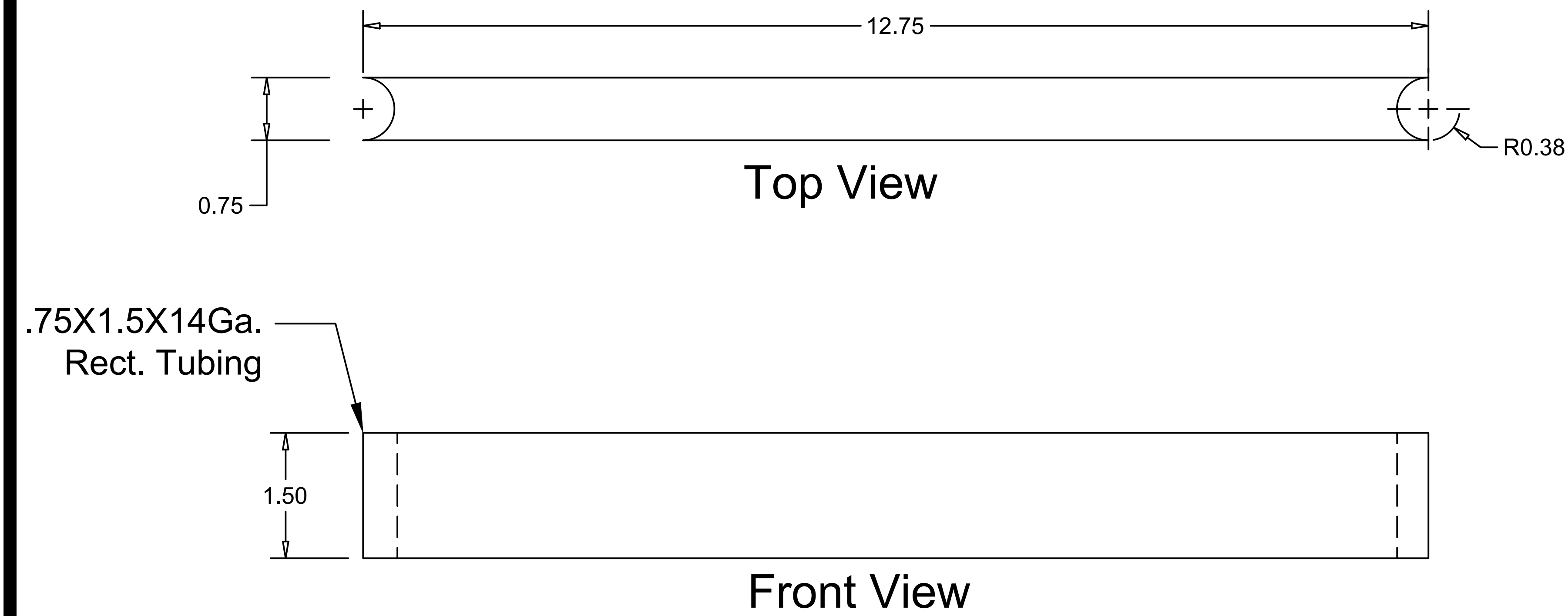
Revised by:	Drawn By: Jake Dixon	Scale 1:2
Sheet 2	FILE therapy2.dwg	Amount: 2 / Units: inches
		Material: Steel



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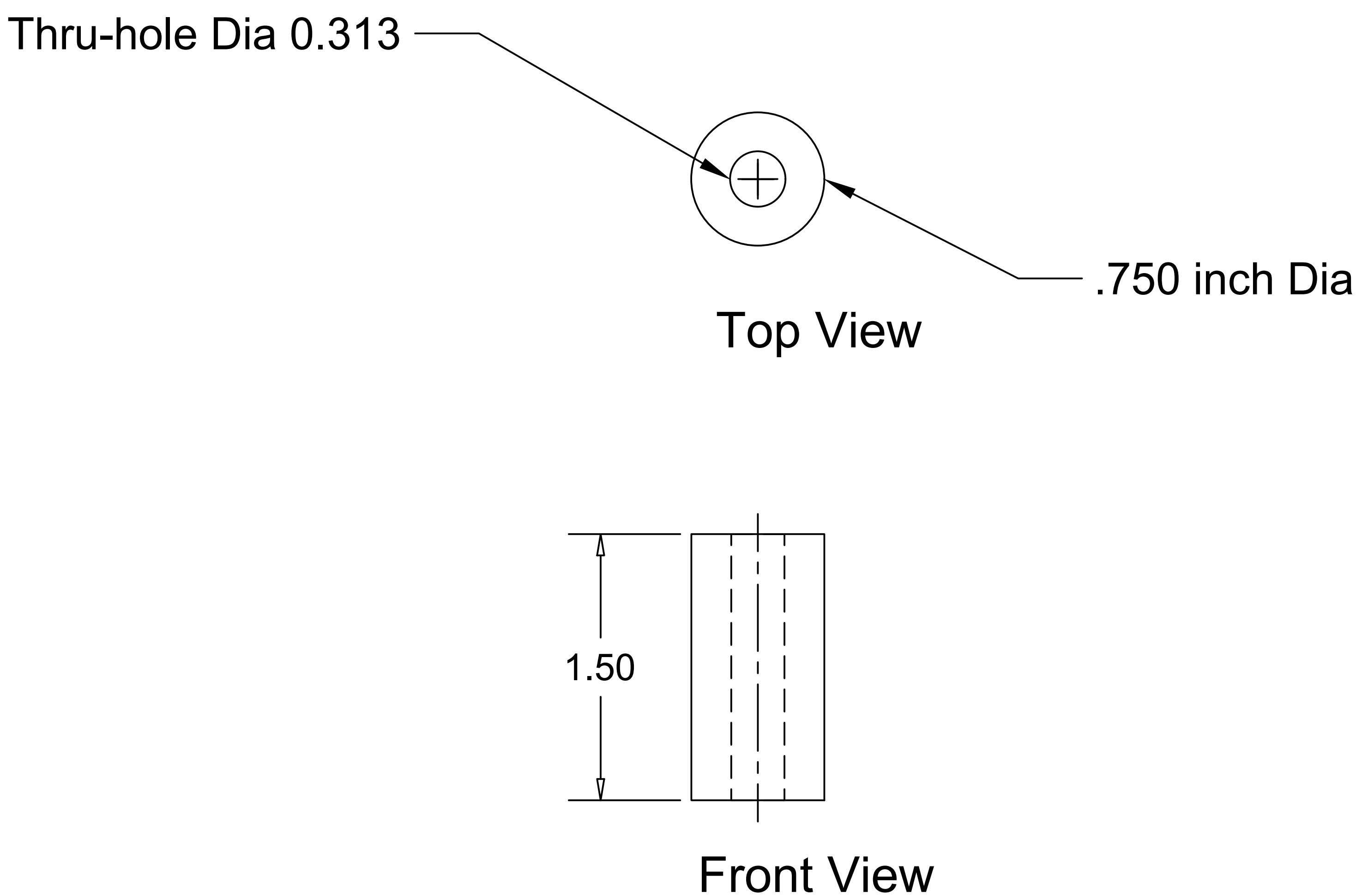
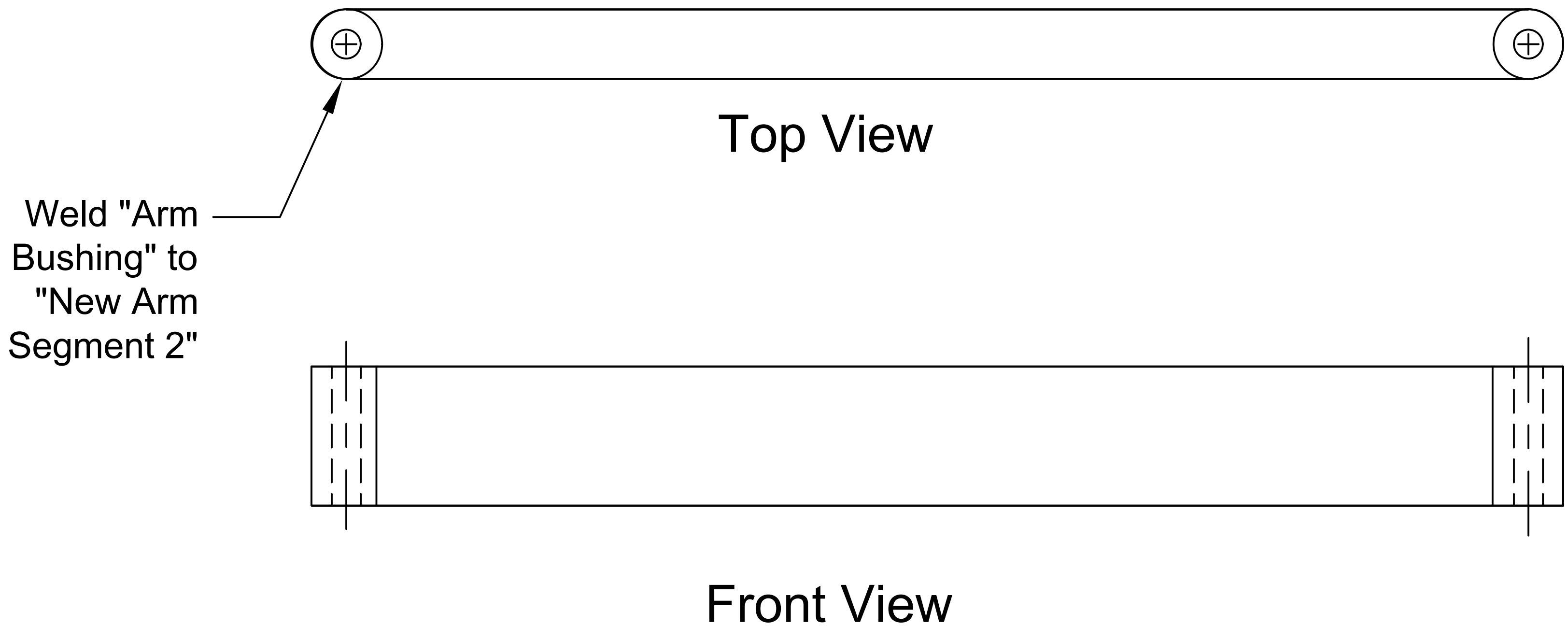
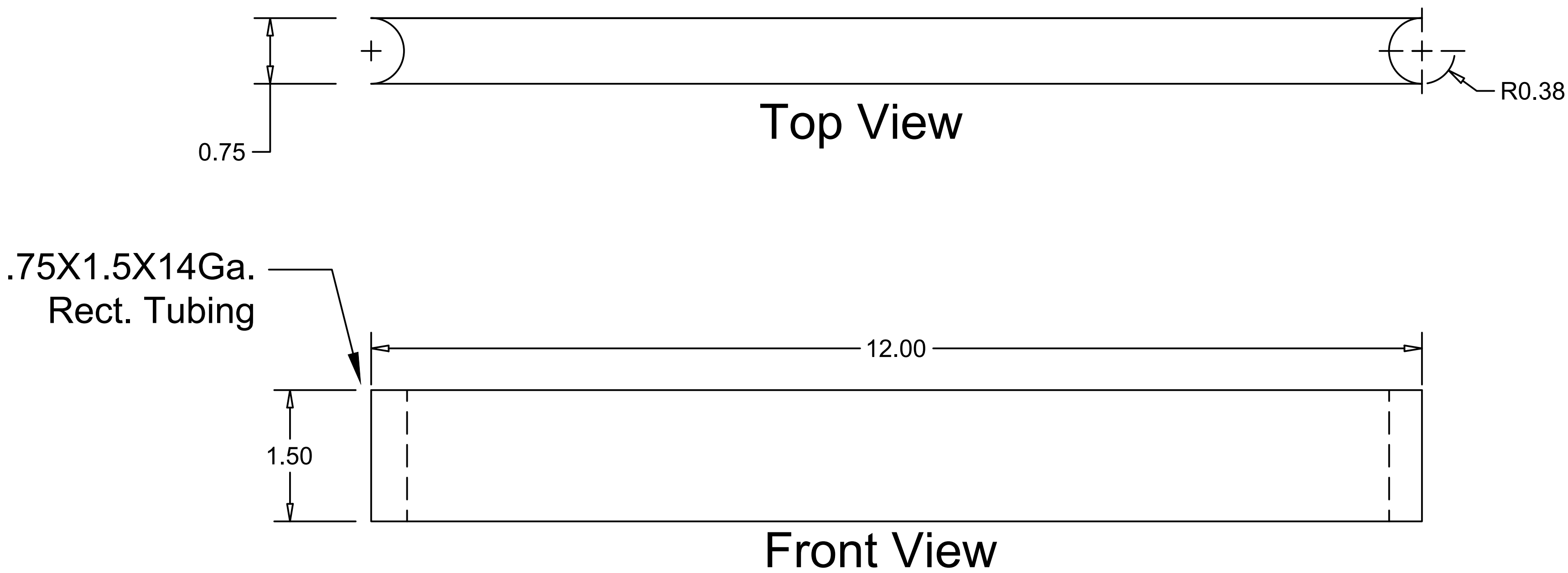
Revised by:		Drawn By: Jake Dixon		Scale 1:2	Units: inches
				Amount: 2	Tolerance: +,- .01
Sheet 3		FILE	therapy2.dwg	Material: Steel	



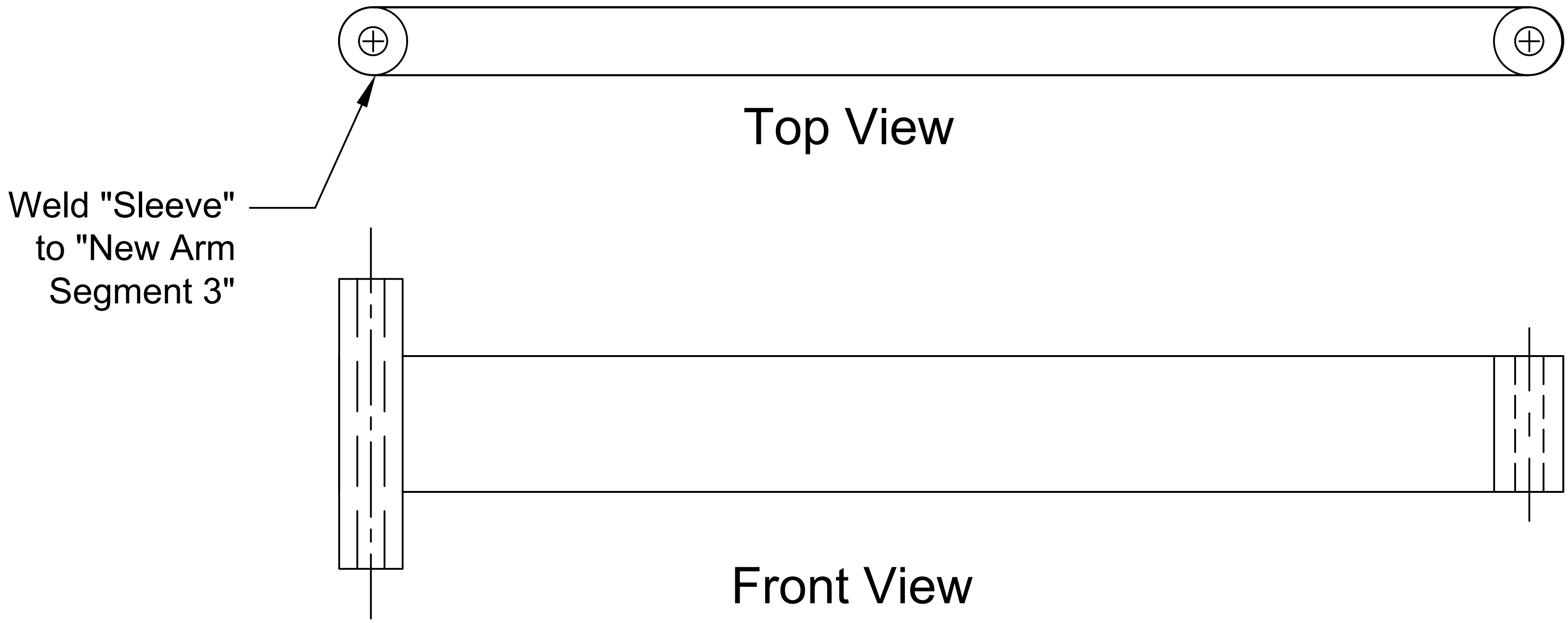
Dates: Drawn:12/3/16	Mount Designs	Sheet Title: Arm Bushing
Revised by:	Drawn By: Jake Dixon	Scale 1:1 / Tolerance:+,-.01
Sheet 4	FILE: therapy2.dwg	Amount: 9 / Units:inches / Material: Steel



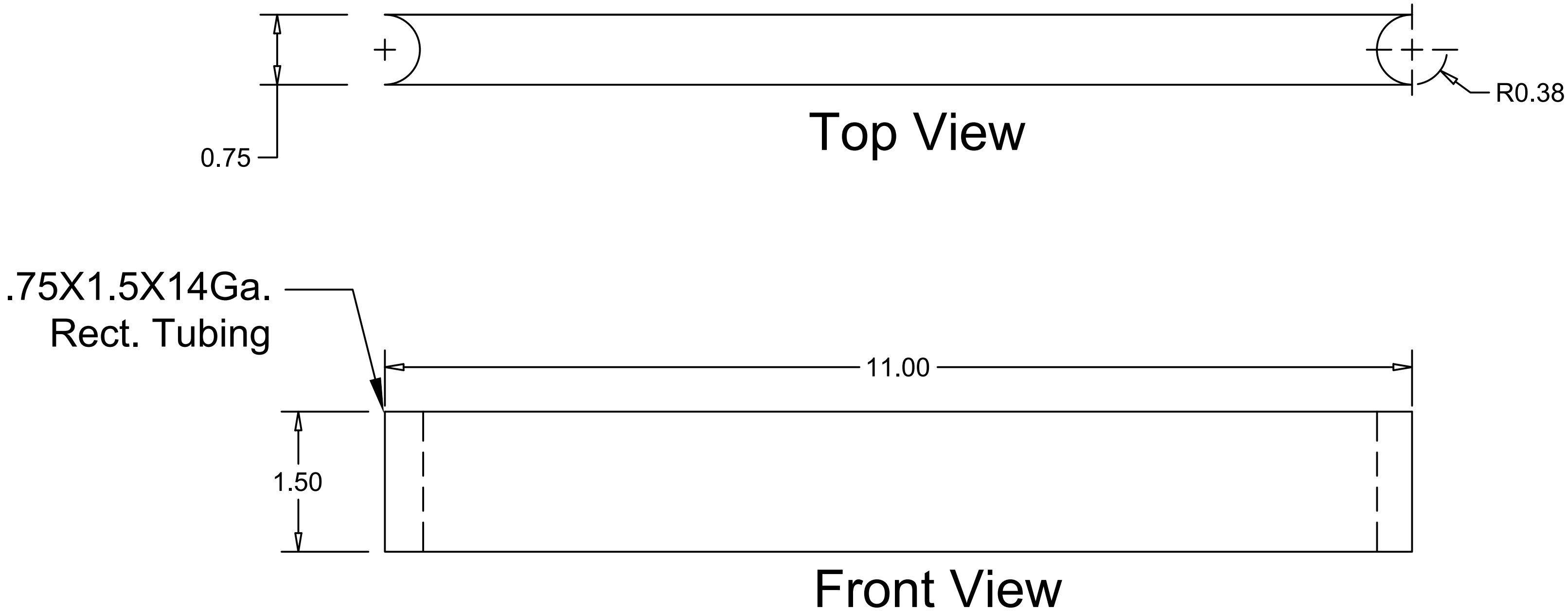
Dates: Drawn:12/3/16	Mount Designs	Sheet Title: General Arm Segment 2 Assembly
Revised by:	Drawn By: Jake Dixon	Scale 1:2
		Amount: 2 / Units: inches
Sheet 5	FILE therapy2.dwg	Material: Steel



Dates: Drawn:1/26/17	Mount Designs	Sheet Title: New Arm Segment 2
Revised by:	Drawn By: Jake Dixon	Scale 1:2 / Units: inches
Sheet 6	FILE: therapy2.dwg	Amount: 2 / Tolerance: +,- .01
		Material: Steel



Dates:	Drawn:12/3/16	Mount Designs	Sheet Title	Last Arm Segment Assembly
Revised by:		Drawn By: Jake Dixon	Scale 1:2	
			Amount: 1	Units: inches
Sheet 7		FILE therapy2.dwg	Material: Steel	



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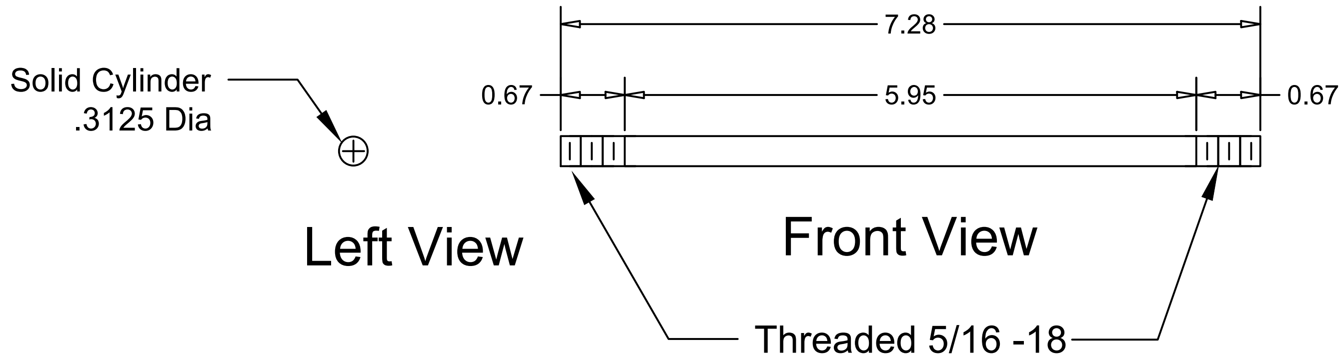
Revised by:	Drawn By: Jake Dixon	Scale 1:2	Units: inches
Sheet 8	FILE therapy2.dwg	Amount: 1	Tolerance: +,- .0
		Material: Steel	

Connector Rod 2

Scale:1:2



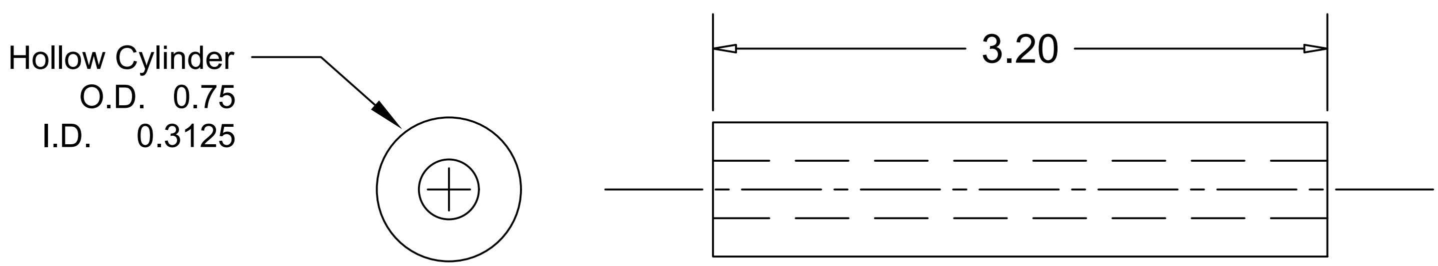
Left View

Front View

Amount: 1

Sleeve

Scale:1:1

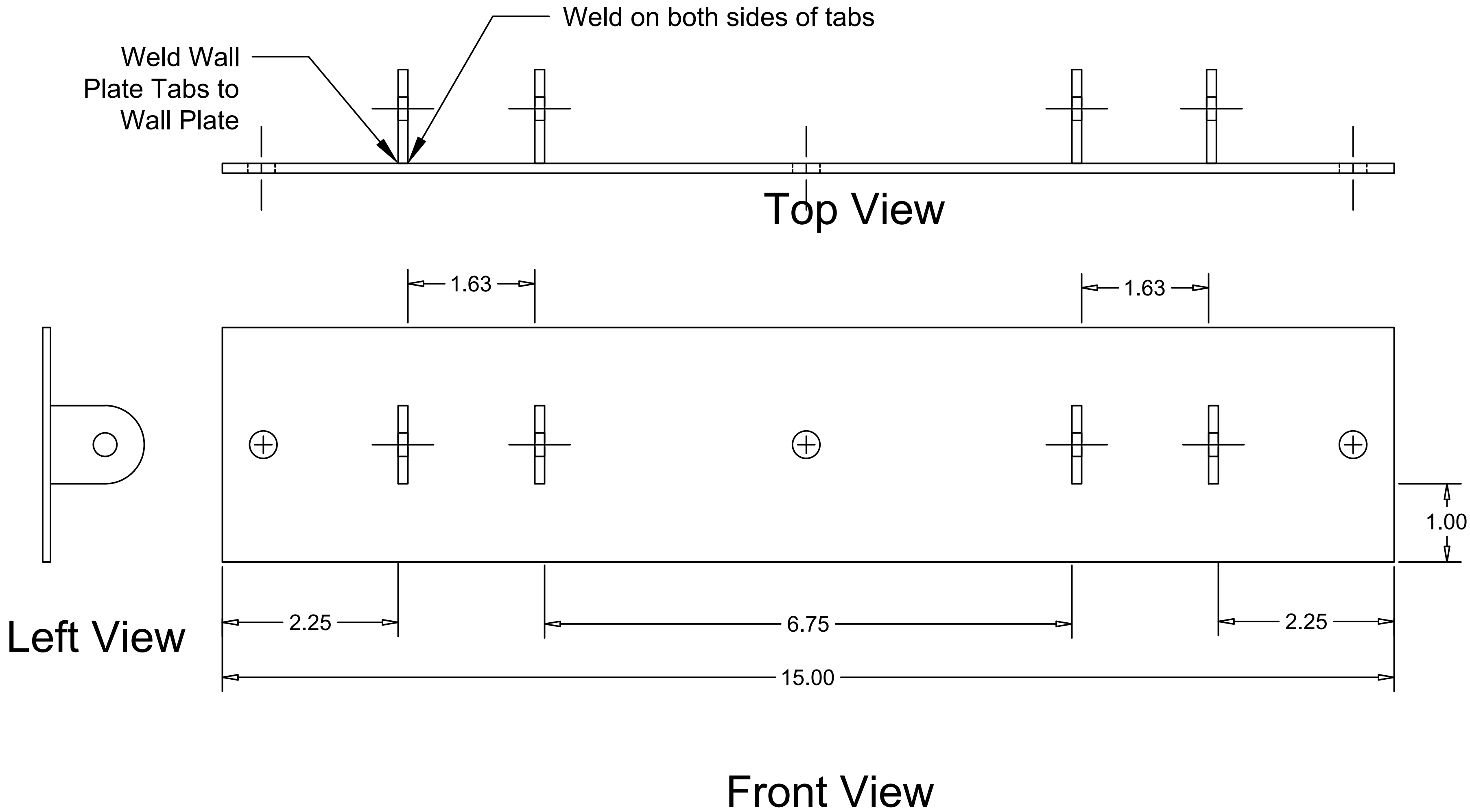


Left View

Front View

Amount: 2

Dates:	Drawn:1/27/17	Mount Designs	Sheet Title: Connector Rod and Sleeve 2
Revised by:		Drawn By: Jake Dixon	Tolerance:+,- .0
Sheet 9		FILE: therapy2.dwg	Units: inches
			Material: Steel



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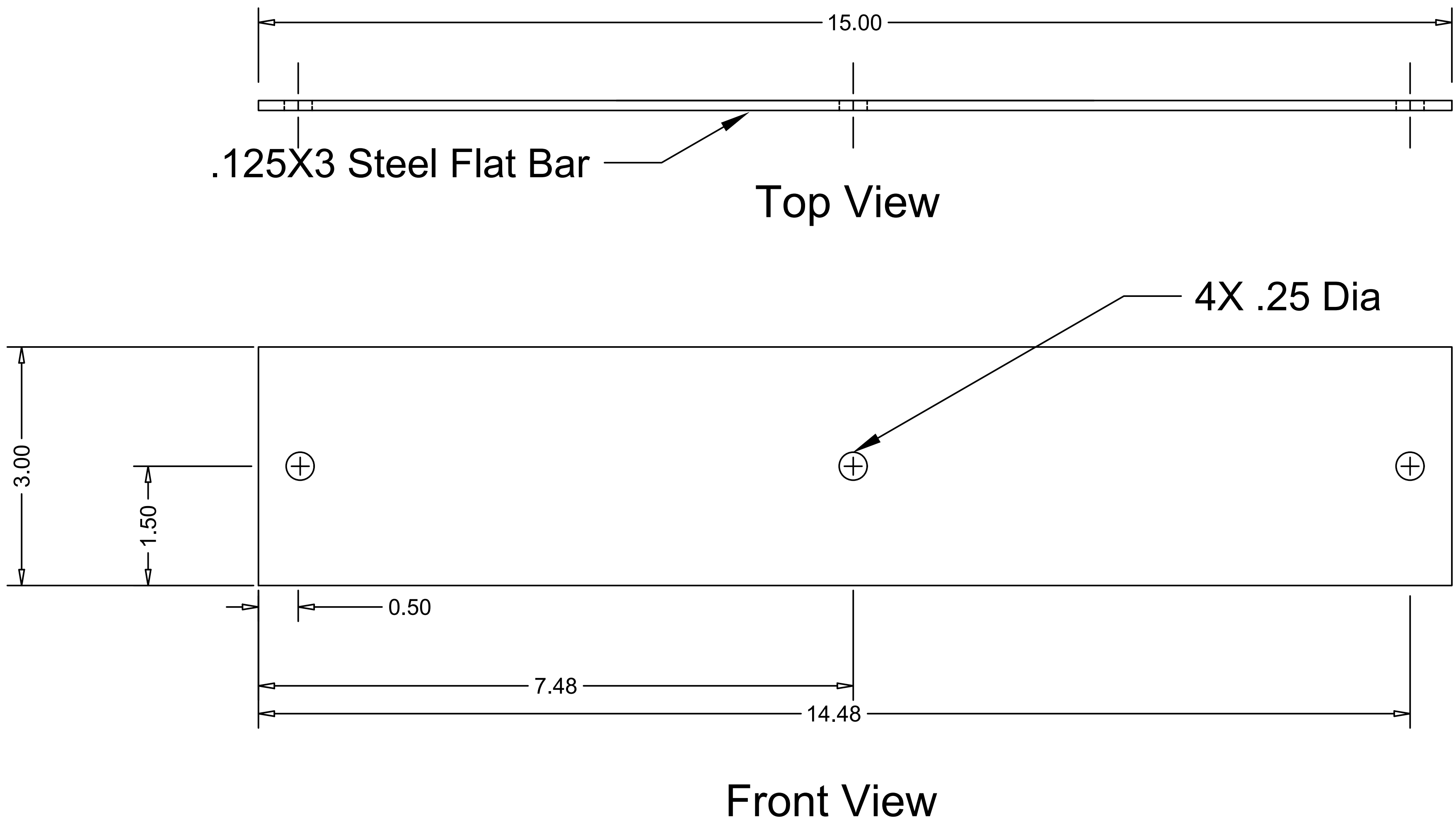
Revised by:	Drawn By: Jake Dixon	Scale 1:2 / Tolerance:+,-.01
Sheet 10	FILE therapy2.dwg	Amount:1 / Units: inches
		Material:Steel



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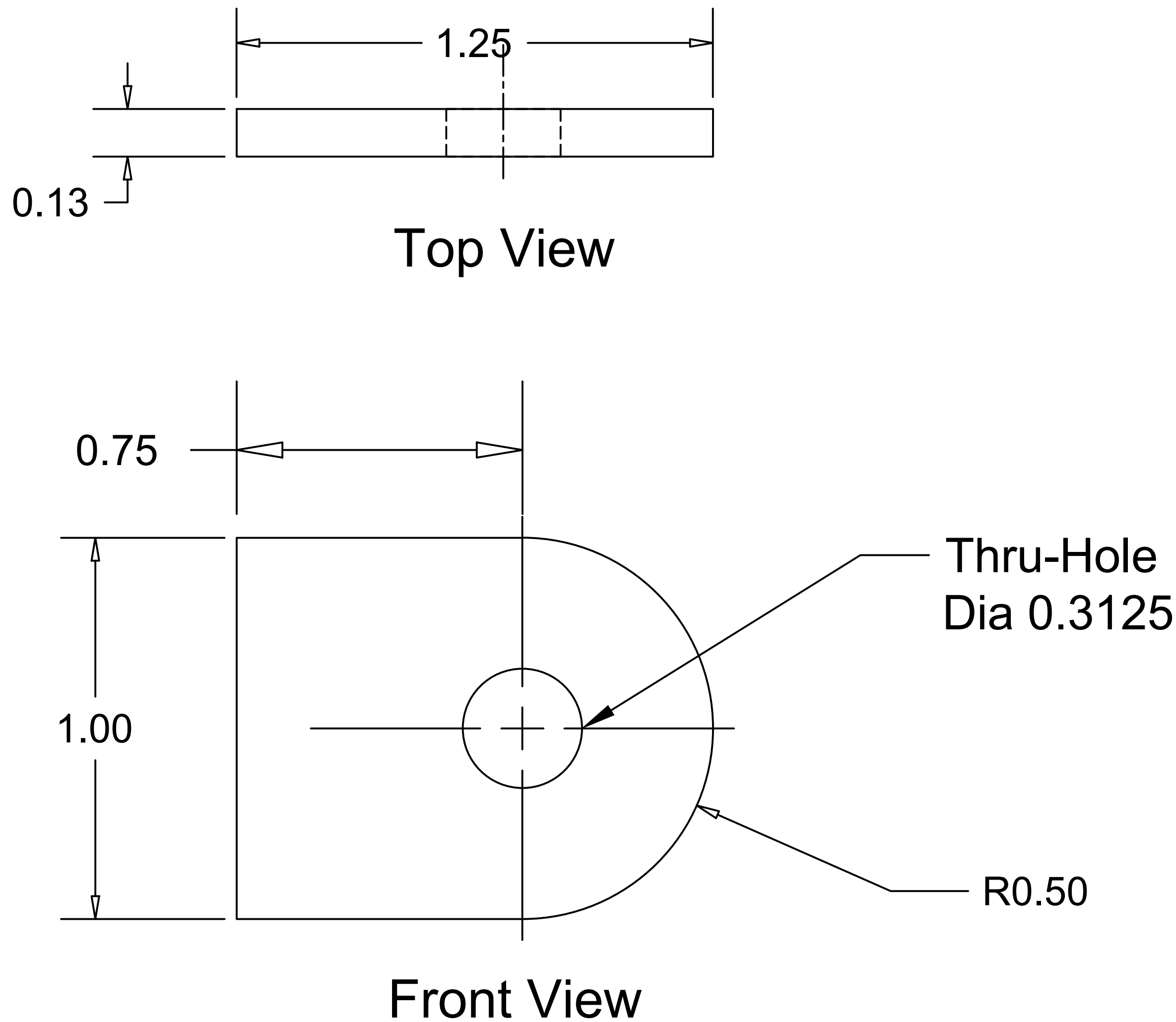
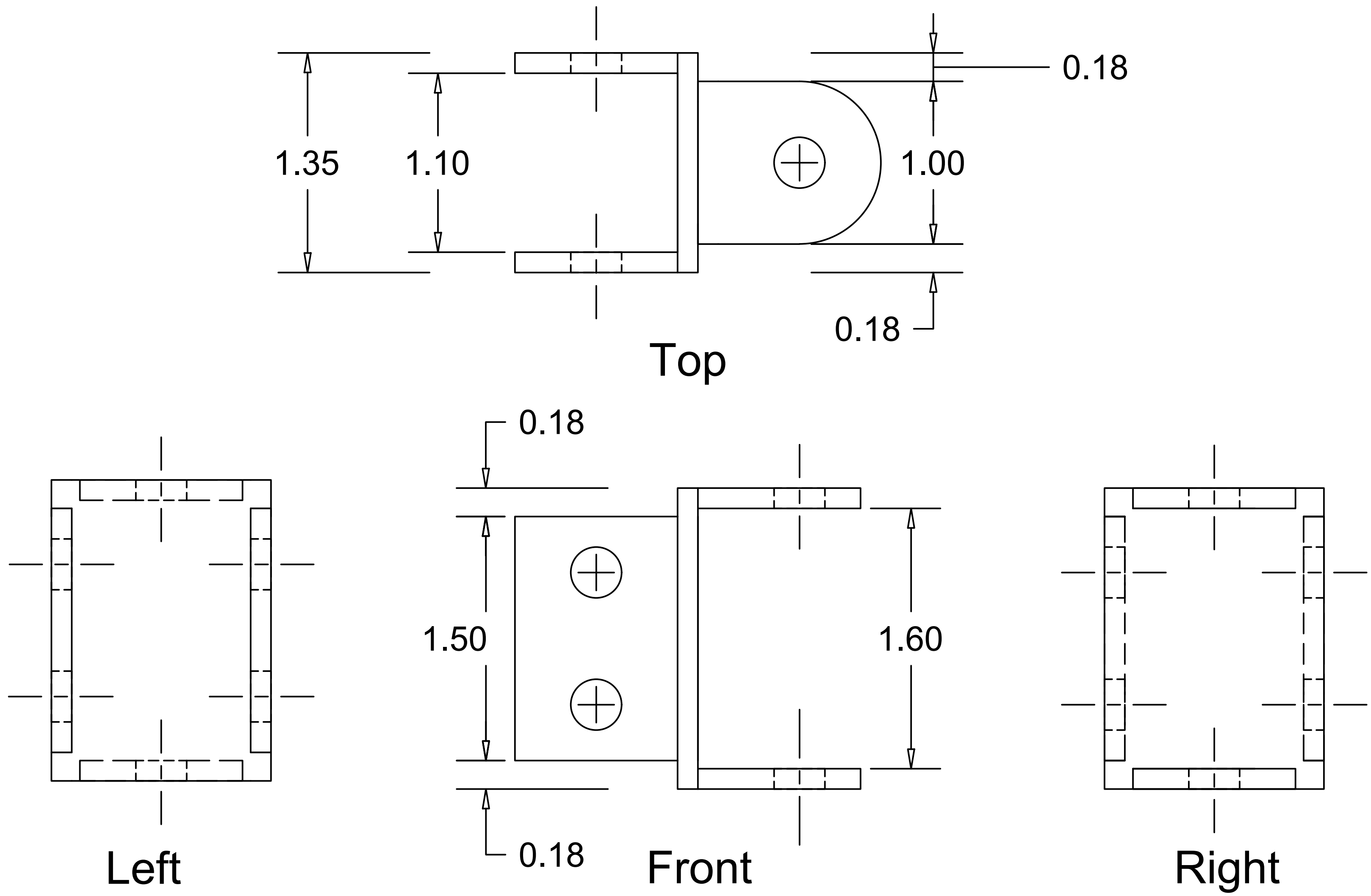
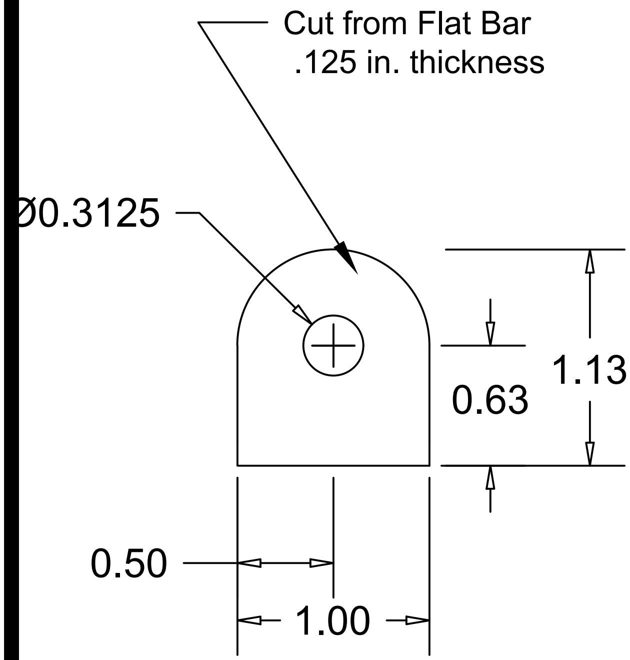
Revised by:	Drawn By: Jake Dixon	Scale 1:4	Tolerance:+,-.1
		Amount:1	Units: inches
Sheet 11	FILE therapy2.dwg	Material: Steel	



Dates:	Drawn:1/27/17	Mount Designs	Sheet Title	Wall Plate Tabs
Revised by:		Drawn By: Jake Dixon	Scale 2:1	Tolerance:+,-.01
Sheet 12		FILE therapy2.dwg	Amount: 4	Units: inches
			Material: Steel	

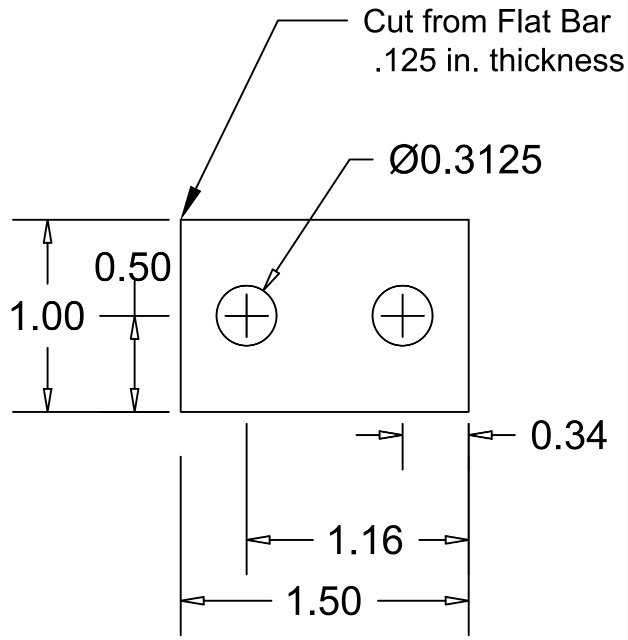


Dates:	Drawn:1/27/17	Mount Designs	Sheet Title: Swivel Connection Assembly
Revised by:		Drawn By: Jake Dixon	Scale 1:1 / Tolerance:+,-.01
Sheet 13		FILE therapy2.dwg	Amount:1 / Units: inches
			Material:Steel



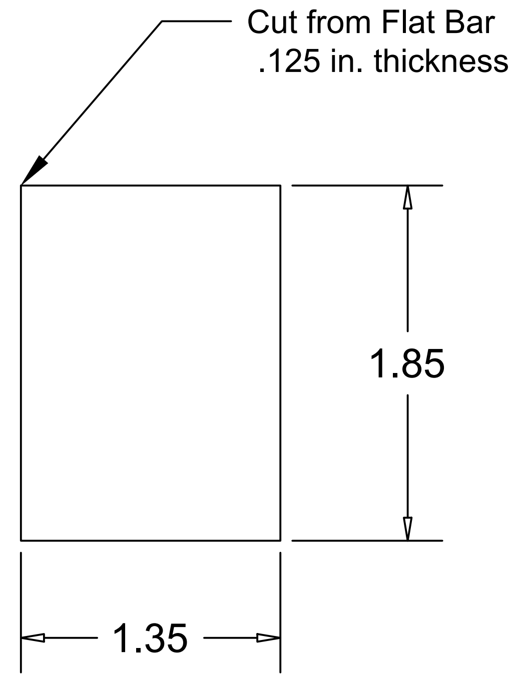
Piece A

Amount: 2



Piece B

Amount: 2



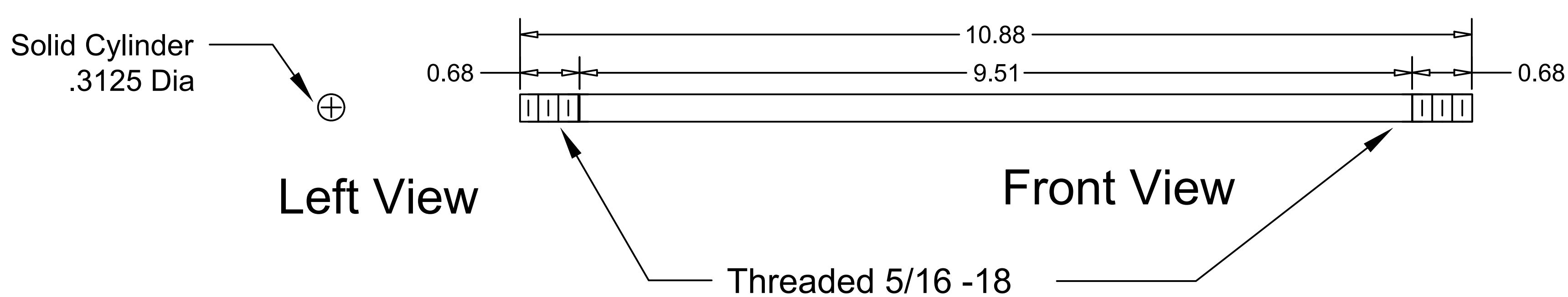
Piece C

Amount: 1

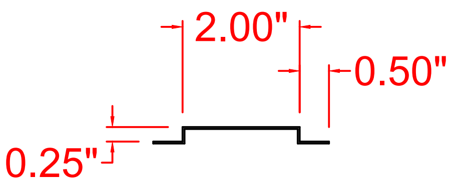
Dates: Drawn:4/17/17	Mount Designs	Sheet Title: Swivel Connection Pieces
Revised by:	Drawn By: Jake Dixon	Scale 1:1 / Tolerance:+,-.01
		Units: inches
Sheet 14	FILE therapy2.dwg	Material: Steel

Connector Rod 1

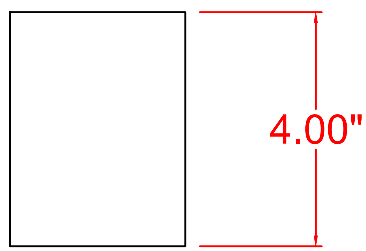
Scale:1:2



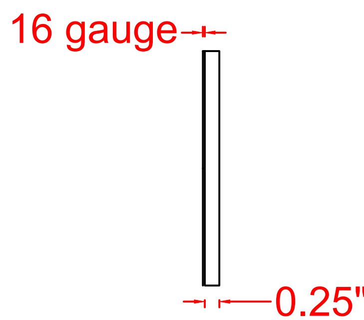
Dates:	Drawn:1/27/17	Mount Designs	Sheet Title: Connector Rod 1
Revised by:		Drawn By: Jake Dixon	Tolerance:+,- .01
Sheet 15		FILE: therapy2.dwg	Amount: 1
			Units: inches
			Material: Steel



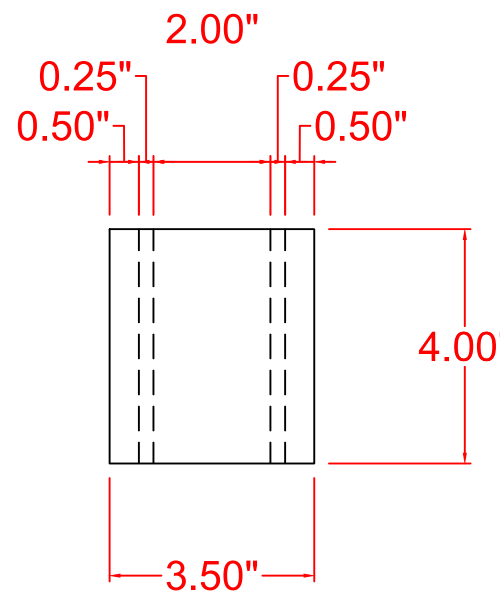
Top



Front



Right



Unbent Piece

Dates: Drawn:1/27/17

Revised by:

Sheet 16

Mount Designs

Drawn By: Kelsey Henderson

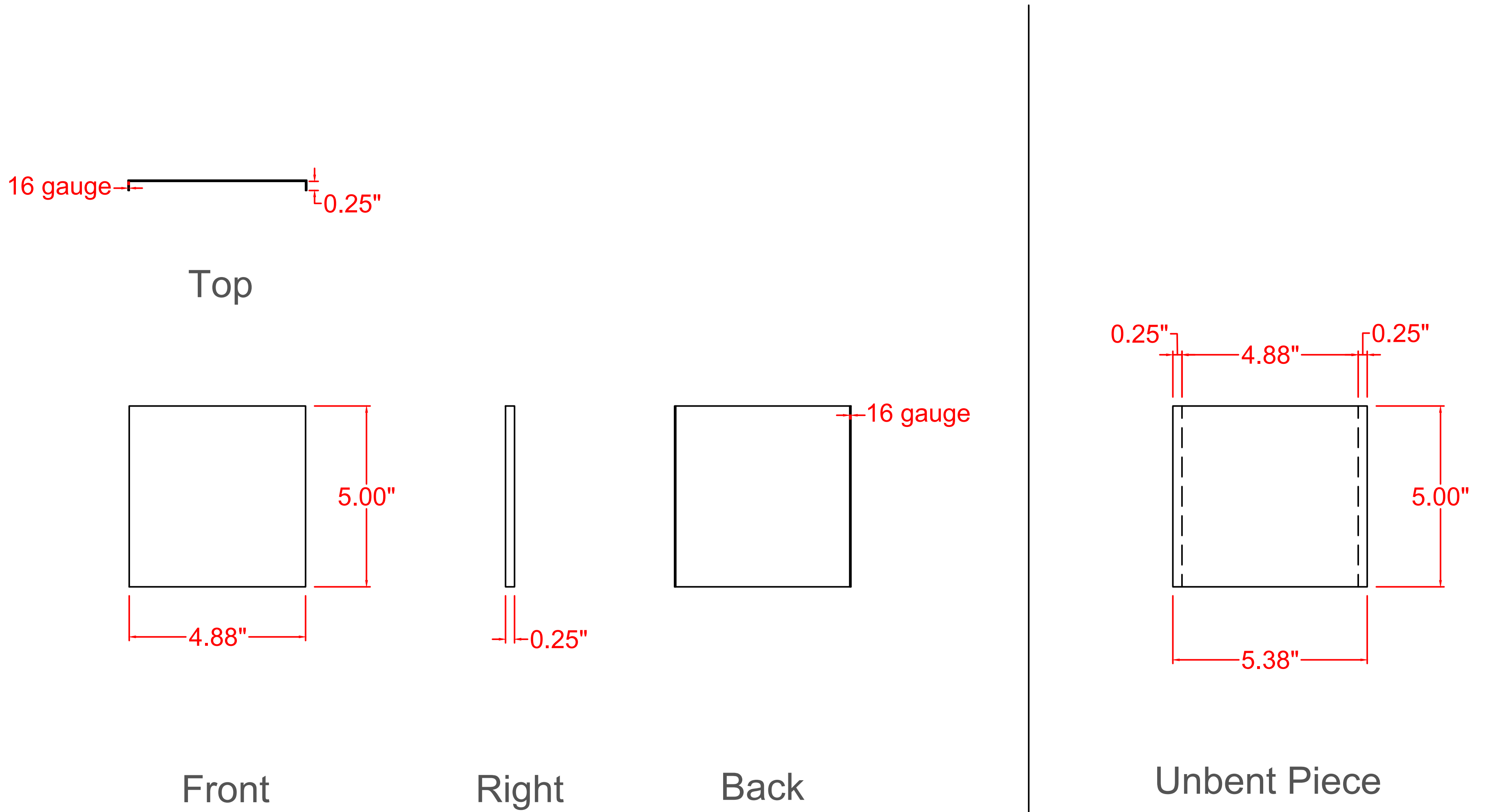
FILE connections.dwg

Sheet Title: Male Side, Part 1

Tolerance:+,- .0

Units: inches

Material: Aluminum



Dates:	Drawn:1/27/17	
Revised by:		
Sheet 17		

Mount Designs

Drawn By: Kelsey Henderson

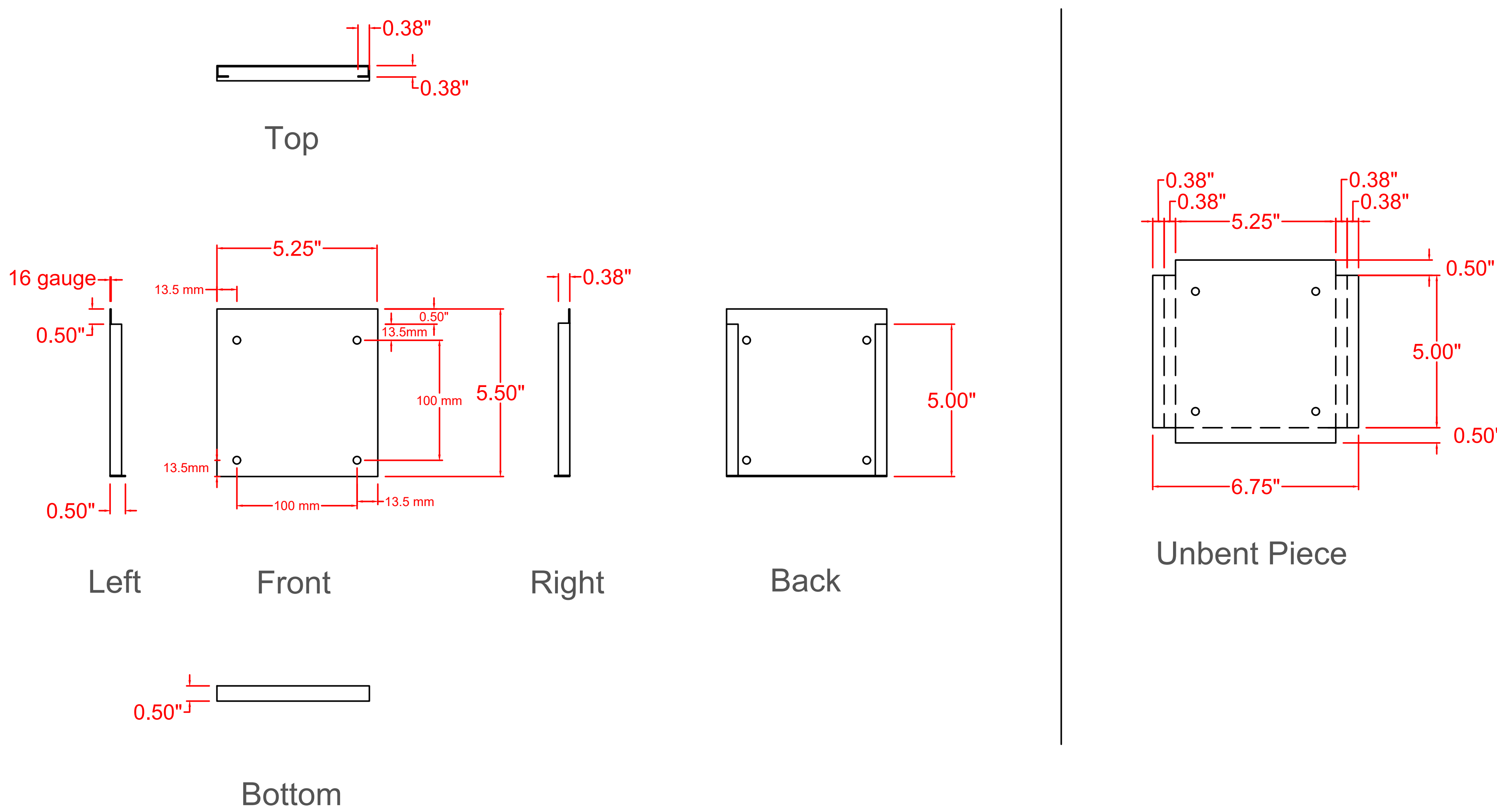
FILE connections.dwg

Sheet Title: Male Side, Part 2

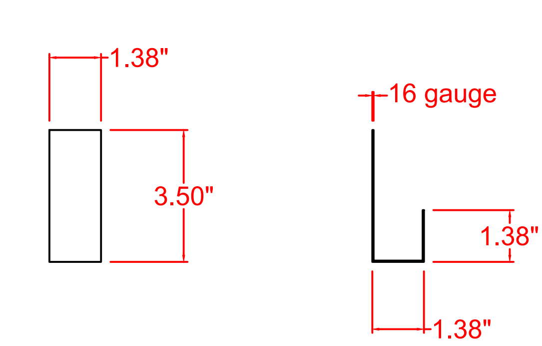
Tolerance:+,- .0

Units: inches

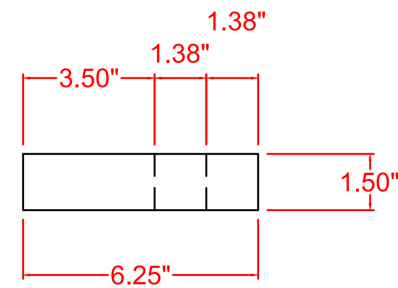
Material: Aluminum



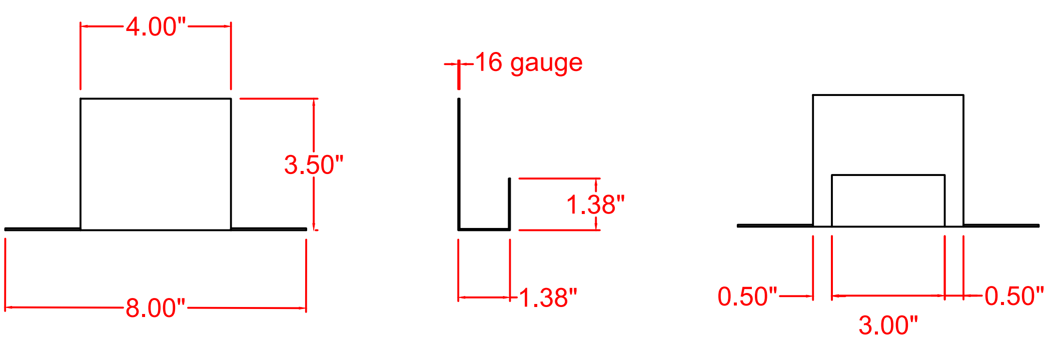
Dates:	Drawn:1/27/17	Mount Designs	Sheet Title: Female Side
Revised by:		Drawn By: Kelsey Henderson	Tolerance:+,- .0
Sheet 18		FILE connections.dwg	Units: inches
			Material: Aluminum



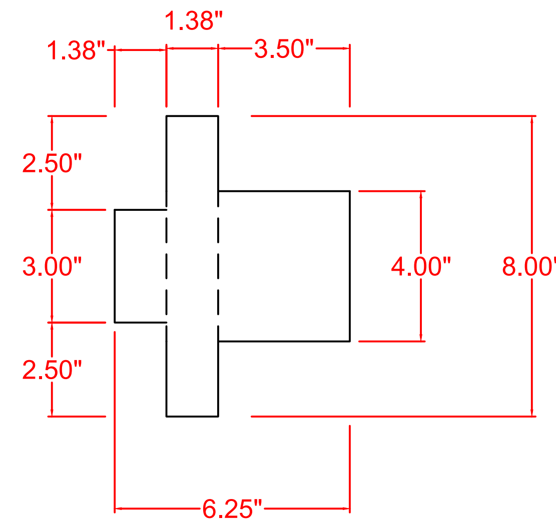
Front Right



Unbent Piece

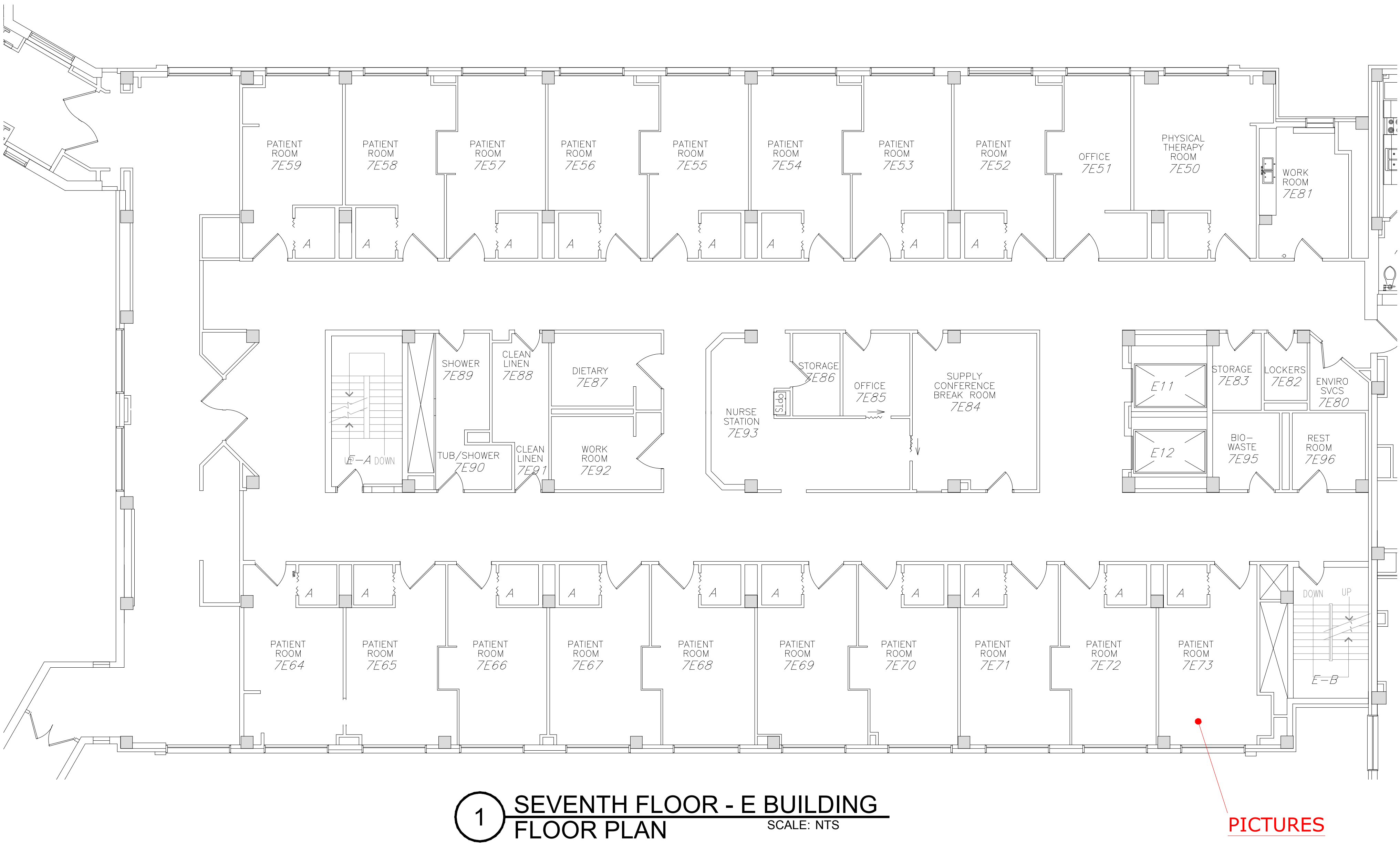


Front Right Back



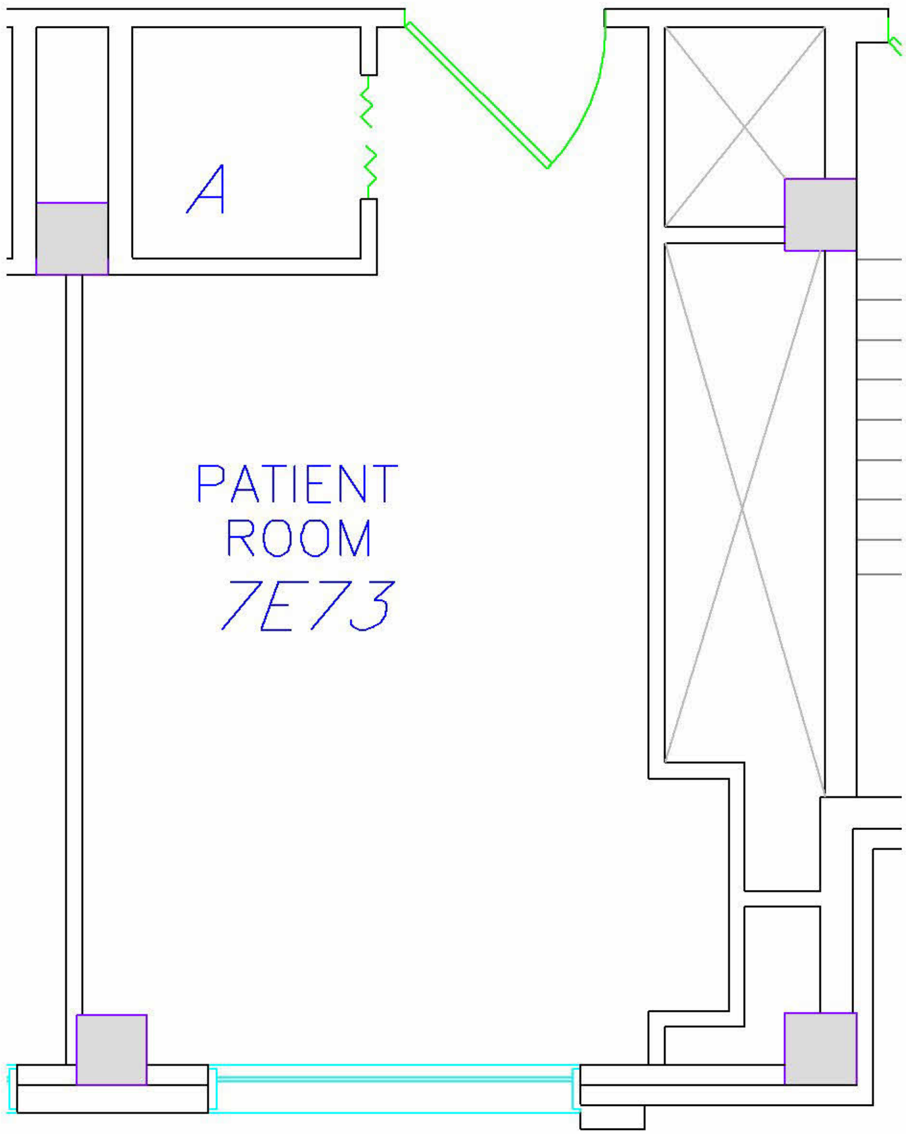
Unbent Piece

Dates:	Drawn:1/27/17	Mount Designs	Sheet Title: Table Mount Brackets
Revised by:		Drawn By: Kelsey Henderson	Tolerance:+,- .0
Sheet 19		FILE: connections.dwg	Units: inches
			Material: Aluminum



1 SEVENTH FLOOR - E BUILDING FLOOR PLAN

SCALE: NTS



1 SEVENTH FLOOR - ROOM 7E73
FLOOR PLAN
SCALE: 1/4" = 1'-0"

St.Rita's
Medical Center
730 West Market Street
Lima, Ohio 45801-4667

Project Name and Address
EXISTING CONDITIONS
E SEVENTH FLOOR
730 W. MARKET

Project	Sheet
FLOOR PLAN	A-7E73
Date 08/01/2016	
Scale 1/4" = 1'-0"	

Phototherapy Team

Jake Dixon, Libby Fortunato, & Kelsey Henderson

BSE 404

11/03/2016

Economic Analysis Report

Intro

Our team is working together with a hospital in Lima, Ohio, in hopes to improve the frequently used light therapy. The current method of treatment involves using a bulky light therapy device that needs substantial table/counter space to be set up properly, and must be placed close enough to both patients and wall outlets. Space in a hospital room can often be hard to come by, and moving a patient's personal items can be a tricky obstacle to overcome, especially if this patient is not cognitively stable. The solution revolves around creating a mount for both a rolling tray table (already existent in hospital rooms) as well as a wall mount located behind the patient bed. The product we create must also be 200$ or less per unit.

Calculation Assumptions

For our analysis, we focused on comparing the current light therapy set up to our projected design's capabilities. To do this, we first assumed that we would be saving the nurses 3 minutes of valuable time per unit. We then concluded that a nurse must make two adjustments daily, and that therapy occurred every day throughout the year. We assumed that the nurses are paid an average $31.71 per hour. For costs to the design, we assumed that the total budget of $5000 be used and that the only operating costs were the cost of electricity to power the device $0.12 per kW-hr. Finally, we also assumed that the life of our design would be aimed at 10 years.

Cash Flow Diagrams

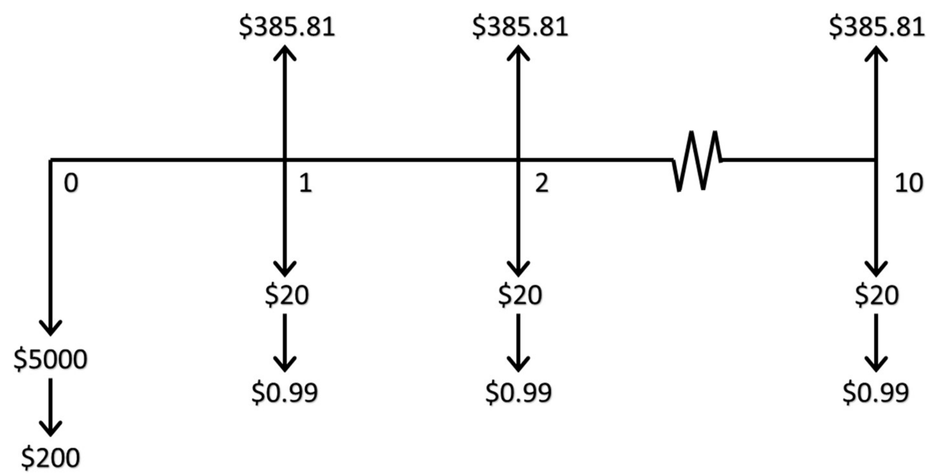
Worst-Case Scenario: 10 years of life; 1 minute of time saved

B/C Ratio: 0.5827

$$PW(B\&\$): \left(\frac{P}{A}, 4\%, 10\right) * 385.81 = 8.1109 * 385.81 = \$3129.27$$

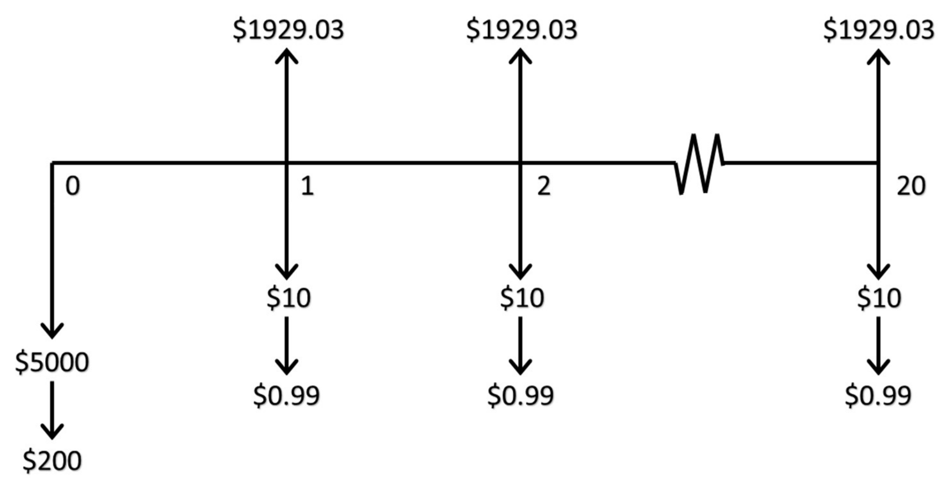
$$I: 5000 + 200 = \$5200$$

$$PW(O\&M): \left(\frac{P}{A}, 4\%, 10\right) * (20 + 0.99) = 8.1109 * 20.99 = \$170.25$$



Expected Scenario: 20 years of life; 5 minutes of time saved

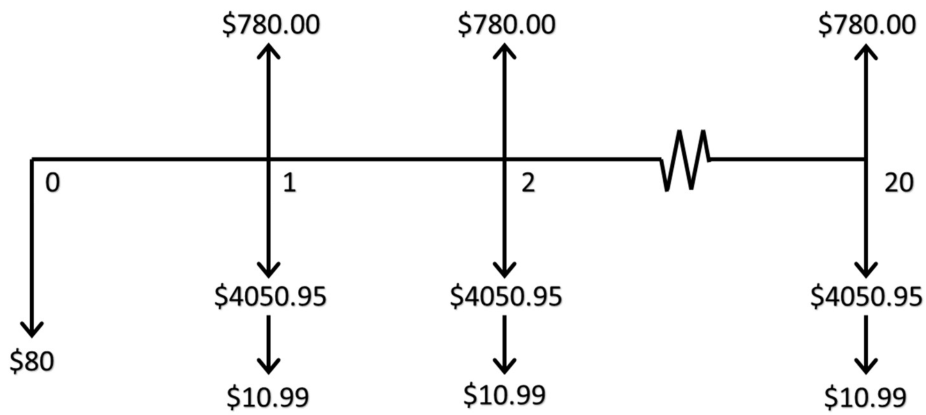
B/C Ratio: 4.9



Cost Comparison of Analysis

Scenario: No arm/mount on the light device (Current scenario)

B/C Ratio: 0.19



*Currently no actual monetary benefit – The nominal $15/wk fee was chosen as a placeholder for improvement of life, decreased time in hospital, etc.

Uncertainties

Human interaction is central to the success of this design, and with human interaction, uncertainties are to be expected in almost all areas. As has been described, many assumptions were made. The lifetime of the device was unknown, as well as the exact expense for research. For each issue, research was done on current values and an assumption of cost or benefit was reasonably assigned. From the time saved by nurses to the frequency of use, all assumptions were made conservatively.

By far, the greatest uncertainty is continued use of phototherapy within St. Rita's Medical Center. While the hospital is currently using the unit, there is little medical research to back up the device's effectiveness. It is hoped that this design will encourage the further use of phototherapy, but if the device is not used, there is no economic benefit.

Generally, even with the most powerful uncertainties under consideration, the analysis created a plan for the worst, which only showcases how lucrative the design project can be for the hospital.

Conclusion

Taking the assumptions, calculations, and possibly uncertainties into consideration, there is very little doubt that this design is worth the investment. All assumptions were made reasonably, but took the most conservative values. This should ensure an economic benefit higher than calculated. The only uncertainty that would drastically affect this analysis is the continued use of phototherapy. Based on accounts of the effectiveness of the treatment, it is unlikely, and by adding allowing the device to work more efficiently within the hospital, it is hoped that the mounting system being created will only lead to further use, thus adding to its own economic value. In conclusion, with a conservative benefit-cost ratio of nearly 5 at a MARR of 4.0%, this project is a good investment and has the potential to pay back more than the modest estimate found in this report.

Lux Data

Measured Lux

Without Mount in Chair

Distance (in)	0	3	6	9	12	18	21	24
Sample 1	20000	16100	10390	7970	3400	2200	1780	1400
Sample 2	20000	15300	10700	6300	4730	2550	2020	1560
Sample 3	20000	15000	8600	5900	4200	2260	1710	1440
Sample 4	20000	17000	13500	7000	4500	2430	1700	1500
Average	20000	15850	10797.5	6792.5	4207.5	2360	1802.5	1475

Without Mount in Bed

Distance (in)	0	3	6	9	12	18	21	24
Sample 1								
Sample 2								
Sample 3								
Sample 4								
Average								

With Mount in Chair

Distance (in)	0	3	6	9	12	18	21	24
Sample 1	20000	17800	10500	8000	4700	2500	1890	1500
Sample 2	20000	16400	11100	7200	4300	2440	1790	1490
Sample 3	20000	16800	10100	7000	4900	2150	2200	1590
Sample 4	20000	16000	14000	6900	4300	2600	1740	1470
Average	20000	16750	11425	7275	4550	2422.5	1905	1512.5

With Mount in Bed

Distance (in)	0	3	6	9	12	18	21	24
Sample 1	20000	16600	10400	7600	4400	2350	1840	1520
Sample 2	20000	16700	10700	7400	4200	2540	1780	1470
Sample 3	20000	15900	10200	7100	4600	2200	1900	1510
Sample 4	20000	16200	11000	7300	4700	2450	1770	1480
Average	20000	16350	10575	7350	4475	2385	1822.5	1495