APPLICATION OF ERGONOMIC PRINCIPLES IN COMPUTER WORKSTATIONS TO ALLEVIATE HEALTH RISKS FROM EXTENDED COMPUTER USE

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by

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Ergonomic design of computer workstations has fallen behind recent research findings in the field of ergonomics. The health of employees and other people who work in front of a computer for extended periods of time can be improved through the use of applying these new ergonomic practices. Through a careful study of recent ergonomic research findings, the purpose of the research is to design a workstation which improves the health and productivity of long term computer users.

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Chapter 1: Introduction

1.1 Overview

Ergonomics at work has become a rising concern in the modern workplace. A number of studies have been made to maximize the safety and comfort of employees who work on computers for long periods at a time, detailed in the background research for this design. The results of the background research set by Awbrey (2014) will be used in the design of a workstation that seeks to place every element needed for computer work in the optimal position for safety and ease. The purpose of this thesis is to create a working concept for a workstation which incorporates the latest research into ergonomics which can be developed into a product for production and sale to the general market.

Picture a person working at a computer all day. Generally what comes to mind is someone sitting, perhaps a little hunched over, typing away at a keyboard. They sit in front of a desk which has their monitor on it, perhaps even their keyboard and mouse which they are typing and clicking furiously at. This traditional desk and chair setup is actually contrary to the results of many modern ergonomic studies. The poor ergonomics of a modern workstation featuring upright posture, positioning of a computer screen on the flat desk with the keyboard and mouse, and many other small details can actually be taxing on the human body and can lead to injury according to the Canadian Centre for Occupational Health and Safety (2009). By redesigning the modern workstation with the latest ergonomic research in mind, the health, comfort, and productivity of employees can be increased and preserved.

Certain limitations on the design will help to ensure that the workstation will last for a long time and be cost effective to the customer. The idea of the fully ergonomic workstation is not new as there are other models on the market. Most of these workstations however cost well over one thousand dollars or even more according to a basic search for them on Amazon (2014). This makes safety and health unobtainable for many companies and people in their home offices, where they can spend as little as one-hundred fifty dollars on both a desk and chair. There are a great deal of considerations that must be taken into account through this design, and therefore the focus is entirely on low cost production and effective use of ergonomic research.

1.2 Limitations

It is the decision of the designer to limit the parts used in the design heavily. The first and perhaps the hardest limitation to overcome is not using springs. The second limitation is to avoid using tension as a method of holding something up against gravity. The third limitation is to refrain from including any hydraulics. These limitations offer a number of challenges to overcome, but by adhering to them, the design will gain a few significant advantages with relation to the key goals of the design.

Springs are extremely helpful when designing parts which can be adjusted by the consumer. Most modern chairs and adjustable desks have a number of them for different purposes. While springs themselves hold little danger when used correctly in a design, they do wear out over time. When the springs eventually wear out, they fail, and could potentially cause injury unless further fail-safes and expense is spent on the assembly. The main reason for preventing the use of springs in this design is that their use generally requires the design and fabrication of special purpose parts to house them. This would mean adding complication to both the design and the fabrication process, bringing cost up. Since the key goals of this design are customer safety and low cost, springs get in the way of both of these goals. It is more efficient then to spend more time considering configurations which do not involve springs and perhaps sacrifice a small portion of user adjustability in favor of keeping with the overall design goals.

Tension is a powerful tool and is also seen heavily in the field of user adjustments on an end product. Using the tension of an over-tightened screw, a user can lift, twist, and move the parts into a number of configurations if the design is made for it. A key merit of using tension in this way is the low cost of such an adjustment. Rather than use hydraulics to lift a part and hold it, which can be expensive even for small systems, having a support beam with a ring and a screw for the user to tighten can be used. While this seems very tempting, especially with trying to keep costs low, this can also be very unsafe. In respect to this particular design, the user will be seated in and amongst the entire assembly. Having a component held up purely by tension is too risky to the consumer. If the user fails to tighten the screw enough, or has made several adjustments causing the parts to smooth out and weaken, the connection will fail and could potentially cause injury to the user. This said, there might be some parts of the assembly where tension is acceptable, these parts however must be non-critical to the assembly and also not cause injury to the user in the event of failure.

Hydraulics are both a wonderful tool, and sometimes a pest to consumers. Most office chairs feature a hydraulic lift allowing the user to adjust the height to suit them. While it would seem natural for a design such as this to feature a hydraulic lift, the inherent design does not require one. The comfort of the workstation is built into the angles of each major joint in the human body. This means that height adjustment is not necessary for most users. The design is also a very large assembly all together and adding a height adjustment would become a very expensive and complicated venture as every component of the design would have to be mobile. Hydraulics could also be used for a number of other moving parts, especially considering the limitation on springs and tension screws, however hydraulics, much like the other two limited parts, eventually fail and can be expensive to the user to replace. Hydraulic failure does come with the advantage of very rarely causing injury to the user as it has a natural failsafe built into the system (minimum closing height), but the cost of a hydraulic lift alone is enough to remove it from the considered parts list.

This thesis will also not be covering every aspect of a product design. The product life cycle is not covered from start to finish. While manufacturability of parts is taken into consideration, specific machinery or production techniques are not discussed. Without building a prototype, certain tests are not possible and labor costs are too difficult to include. As there was no prototype built for the purpose of this research, these topics are not covered as well.

1.3 Definition of Terms

The following is a list of terms specific to this text.

1.3.1 Ergonomics

Ergonomics is defined as a science of arranging things so that people can access them easily and safely (Merriam-Webster, 2014).

1.3.2 Average User

The definition of an average user for the purposes of this thesis are individuals with a functioning spine and full body control.

1.3.3 Target Consumer

The target consumer of the final product is a normal user who spends more than 4 hours per day at a computer.

1.3.4 Wheelchair User

A certain amount of the background research includes wheelchair users. This is defined by those who are unable to walk upright and must use a wheelchair for mobility due to any number of conditions. This type of user has a great deal of historical ergonomic research which proves useful for narrowing the target user group and understanding the basis of ergonomic research as a whole.

Chapter 2: Literature Review

2.1 Average Users

The first section of the literature review will be focusing on average users as defined in chapter 1 of this text. Average users are intended to be the primary customer for the workstation and the design will be built primarily around the findings listed in this section.

2.1.1 Wendling – "Forget About Sitting Up Straight…" (2007)

The white dots seen in the images below are water calibration tubes showing water decrease from poor posture. These were taken using a 0.6-Tesla whole body, positional MRI scanner as seen in figures 2.1 and 2.2. "The study included 22 healthy volunteers (mean age, 34 years; weight 67 kg; height 169 cm) with no history of back pain or surgery who underwent measurements of lumbar lordosis angles, inter vertebral disk heights, and translation of the nucleus pulposus using a 0.6-tesla whole-body, positional MRI scanner."

Dr. Waseem Amir Bashir – original study author "Overall, the worst position for the spine—as reflected in disk height—was the slouching position, followed closely by the upright 90-degree position, investigators at the University of Aberdeen (Scotland) reported." "The 135-degree position was very similar to a supine position". The supine position is the rest position used for 20 minutes to set the spine back to a natural position. "The 135-degree position has found its way into seat designs for the space industry and luxury auto makers."

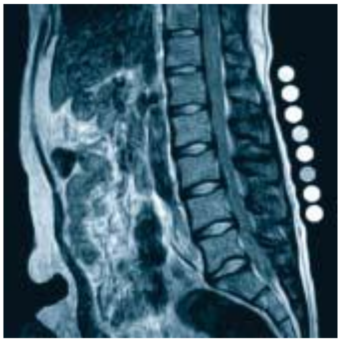

Figure 2.1 Upright, 90 degree seating angle. Small amount of pressure still forms along lower spine. (Wendling, 2007)

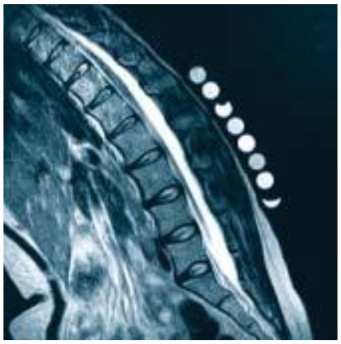

Figure 2.2 Bent over with elbows on side, shows stress forming along lower spine. (Wendling, 2007)

2.1.2 Hedge – "Ergonomic Seating?" (2013)

The following is a list of different requirements and facts collected and reported by Hedge (2013). This set of findings was used to help direct certain aspects of the dimensions of the workstation. One of the more important uses of this data however is to help show the faults of a traditional desk and chair style workstation.

Myths of Ergonomic Seating

1. Ergonomic seating always requires a single, 'cubist' (90° upright) postural orientation that is independent of the user's task (Dainoff, 1994).

2. You can judge how ergonomic a chair is by briefly sitting in it.

3. Users should be able to adjust everything.

4. Users don't need training on how to sit in a chair (Dainoff, 1994).

5. One chair design will provide the best fit for all users.

Ergonomic Chair Requirements are listed below:

(BSR/HFES 100, 2002)

Adjustable Seat Height

11.4 cm in range 38-56 cm

Seat Pan Angle Recline and/or decline

<= 6° total

Seat Pan-Backrest Angle

>=90°

Seat Pan-Backrest Recline

0-15°

Recommended range = 0-30° (if >

30° a head rest is needed)

Ergonomic Chair Recommendations

(BSR/HFES 100, 2002)

Seat Pan Depth

<=43cm

Seat Pan Width

>=45cm

Backrest Height and Width (top of backrest)

>= 45 cm above compressed seat height (CSH)

Backrest Lumbar Support

15-25 cm above CSH

Backrest width

>=36cm

Armrest height

17-27cm (fixed)

18-27cm above CSH (adjustable)

Armrest span

46cm

Chair casters

Appropriate for type of flooring at workstation.

2.1.3 NASA Skylab – “NASA-STD-3000” (1995)

This is a seemingly dated source, this is the most all-encompassing study on normal users to date. The standards used by NASA in the ergonomic design of products sent to the International Space Station were created by studying 12 individuals in the Skylab and comparing the data of the individuals in both microgravity and normal earth gravity. This data, shown in figures 2.3, 2.4, and 2.5 gives the most clear and well documented set of requirements for an average user to maintain the most natural and neutral body position while working.

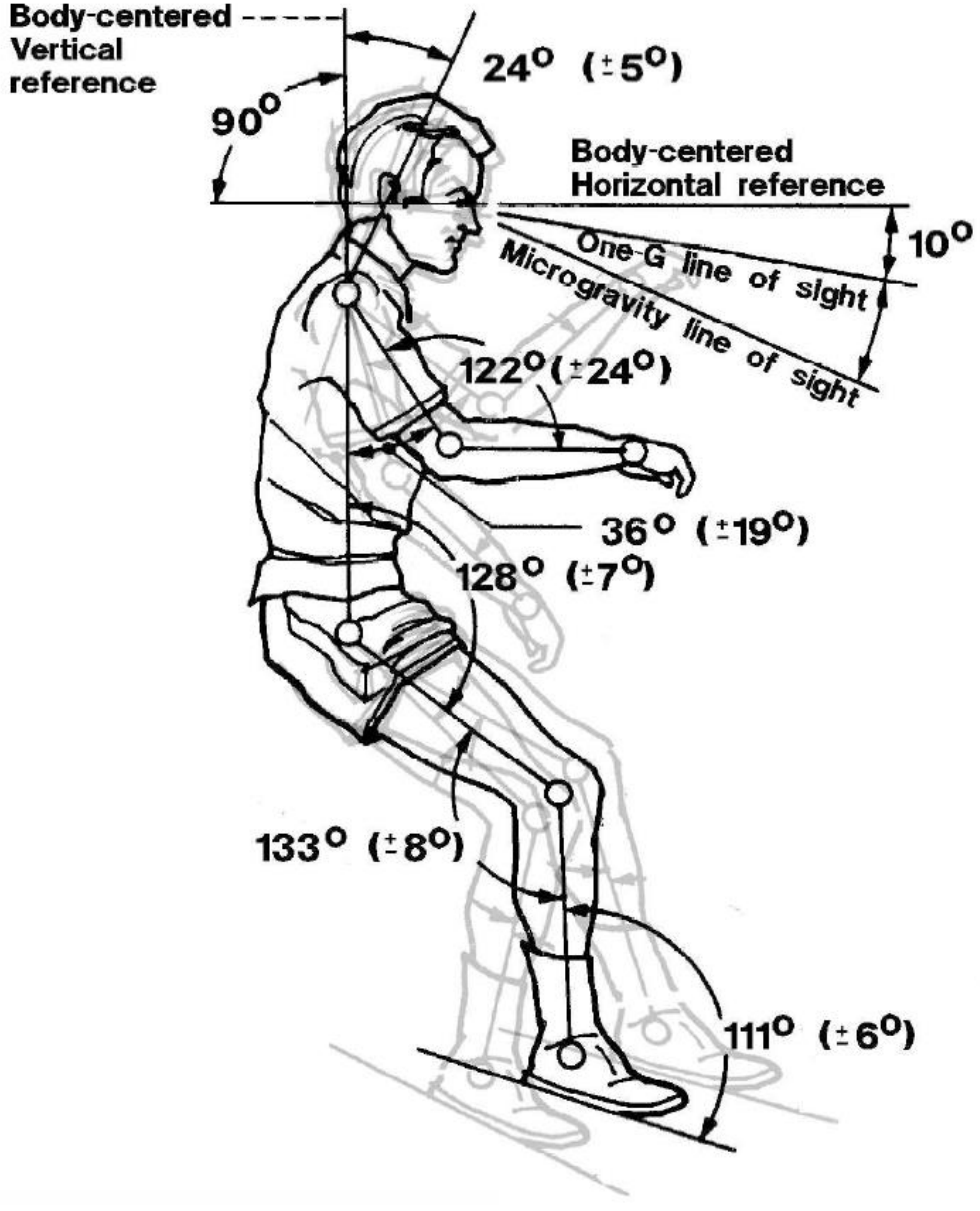

Figure 2.3 Shows the deviation of the median angle from the neutral body posture measured on Skylab. (NASA-STD-3000, deviations in grey added by Vogler (2005))

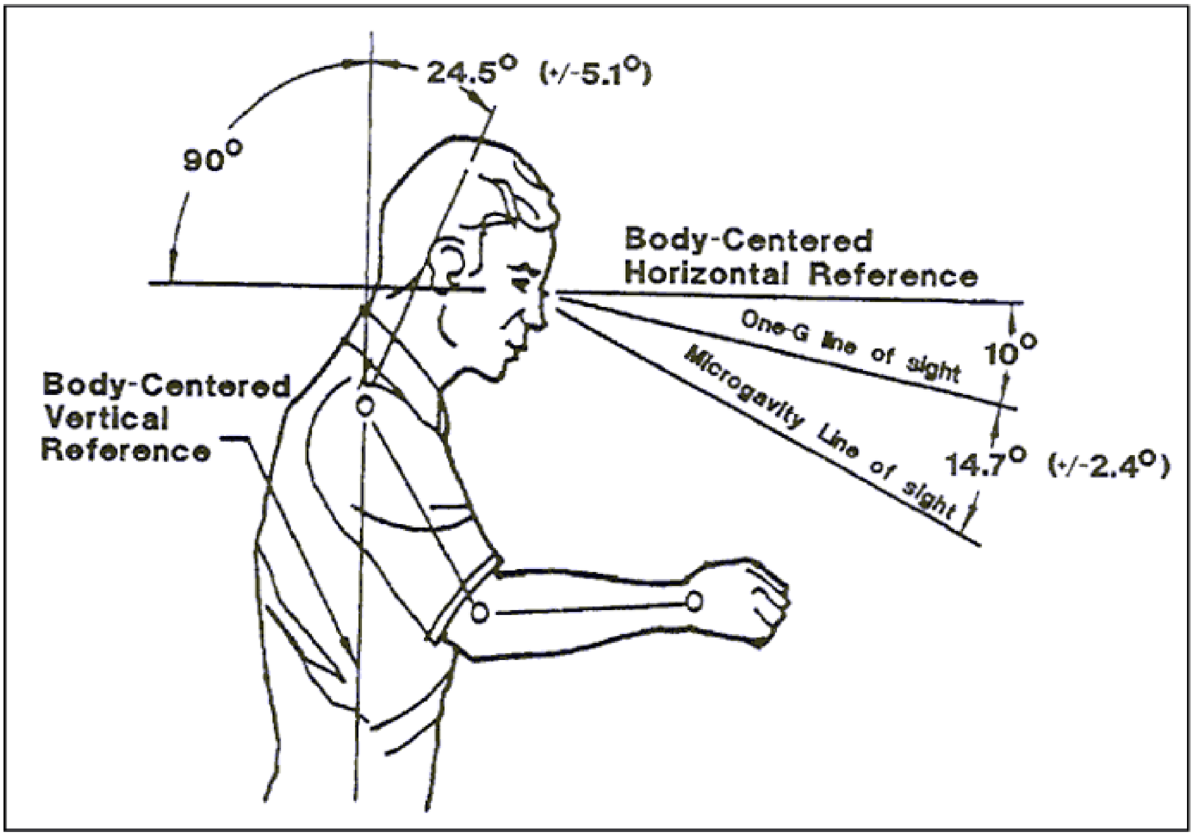

Figure 2.4 Line-of-sight for One-G and Microgravity (NASA-STD-3000, 1995)

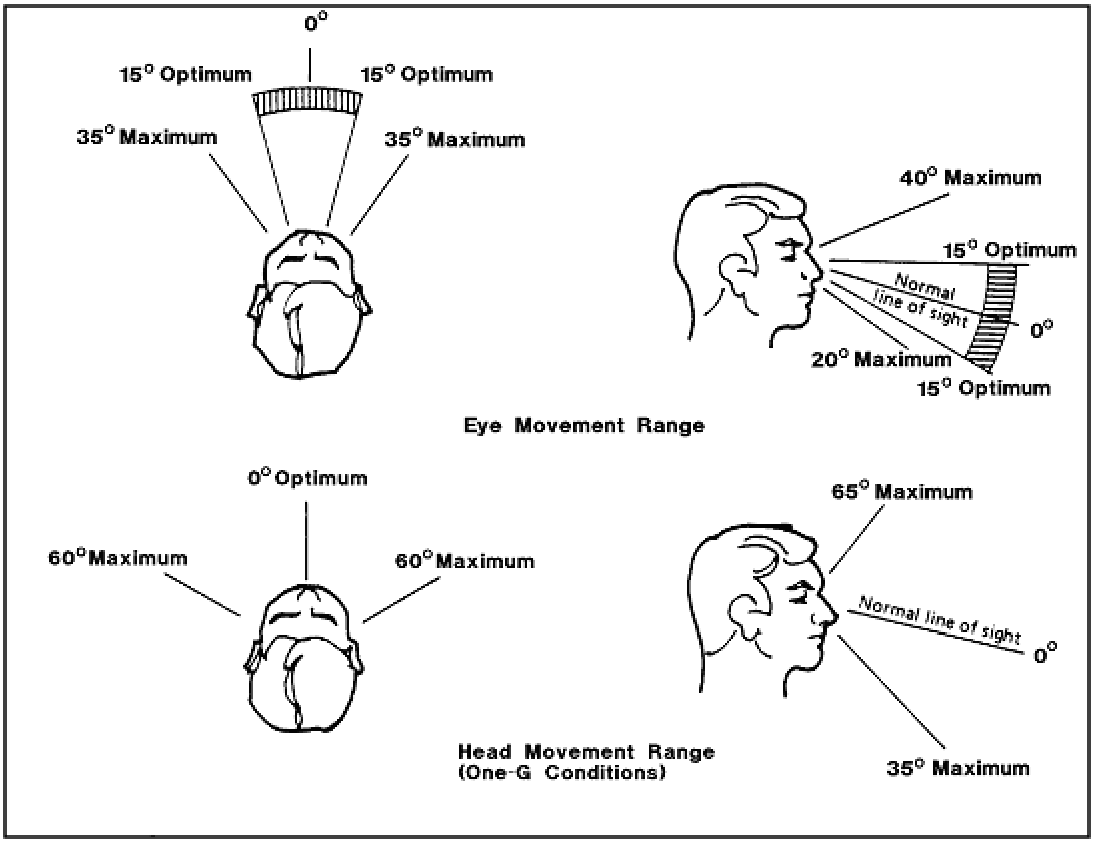

Figure 2.5 Eye and Head Movement Ranges (Line-of-sight Depends on G-Level) (NASA-STD-3000, 1995)

2.2 Wheelchair Users

While the target consumer of the workstation is primarily average users, there are two key reasons for looking at wheelchair users. The first is that they are still a potential consumer, as the workstation does not require the use of legs to function properly. The second reason is that a great deal of studies have been performed on the ergonomic positioning of wheelchairs as the individuals who require their use for mobility must spend a great deal of time in a seated position. This research offers further insight into the preferred and healthy positioning of the spine over long periods of seated time, as well as information into another potential client base.

2.2.1 Ding – "Usage of Tilt-in-space, Recline, and Elevation... Wheelchair Users" (2008)

The research presenting by Ding focuses on several aspects of tilt and recline with respect to wheelchair users. The most important aspect of this research is the recline and tilt which will be used in a later analysis of the different user types. "Researchers found that tilt-in-space significantly reduced static seating pressure, a key component in pressure ulcer development, and combining tilt-in-space with backrest recline reduced pressure more than tilt-in-space alone" - (Sprigle and Sposato 1997)

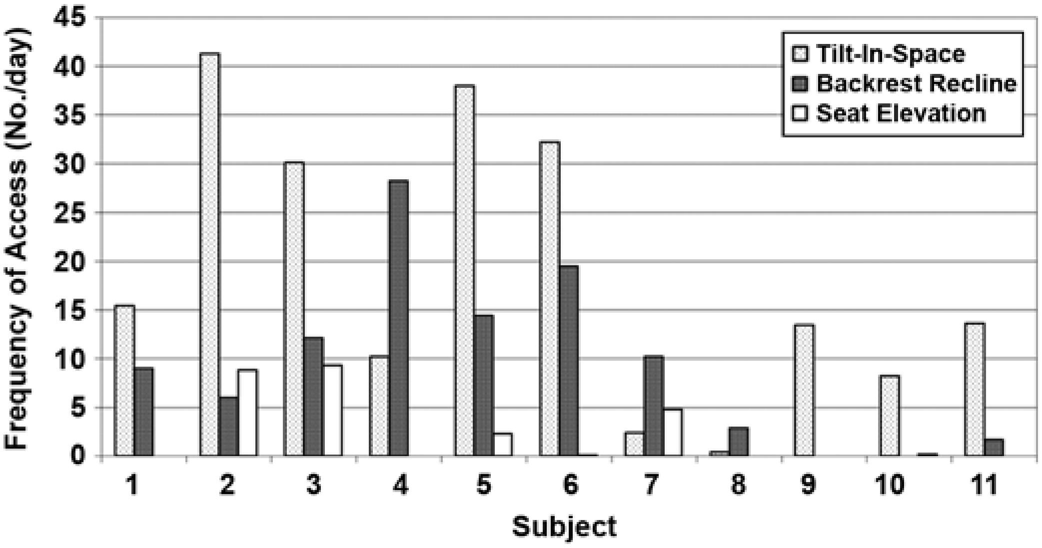

Figure 2.6 Frequency of access each day to individual seating functions of 11 wheelchair users. (Sprigle and Sposato 1997)

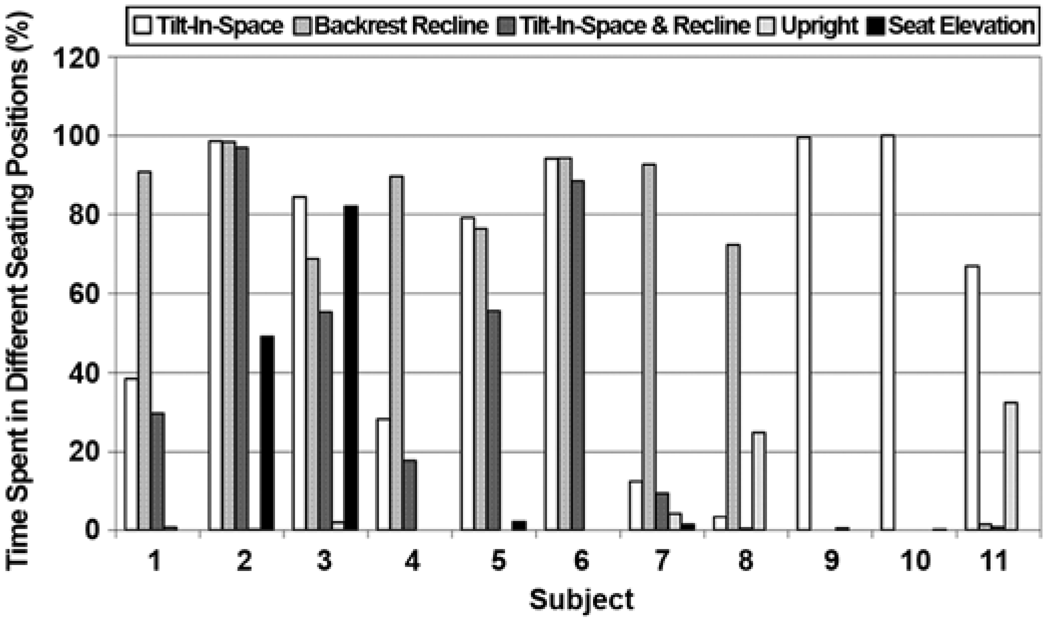

Figure 2.7 Duration of access each day to different seating positions of 11 wheel-chair users. (Sprigle and Sposato 1997)

Table 2.1 Tilt-in-space frequency and duration of access (in mean ± standard deviation) for different ranges of angles of 11 wheelchair users.

Angle (Degrees)	Frequency (No./Day)	Duration (Min/Day)
2.5-10.0	6.6 ± 4.9	272.7 ± 228.7
10-20	7.3 ± 6.6	157.3 ± 171.8
20-30	2.2 ± 2.5	24.6 ± 37.8
30-40	0.9 ± 1.2	11.6 ± 21.5
>40	1.6 ± 4.1	14.8 ± 28.6

Table 2.2 Backrest recline frequency and duration of access (in mean ± standard deviation) for different ranges of angles of 11 wheelchair users.

Angle (Degrees)	Frequency (No./Day)	Duration (Min/Day)
95-100	2.1 ± 2.6	135.0 ± 203.4
100-110	5.0 ± 4.3	227.2 ± 231.2
110-120	2.0 ± 2.0	29.5 ± 35.4
120-130	0.8 ± 0.9	6.2 ± 9.8
>130	0.4 ± 0.7	4.8 ± 11.2

Subjects in this study spent considerable time, i.e., 11.8 ± 3.4 hours a day, in their wheelchairs and performed only a limited number of transfers in and out of their wheelchair. This is shown in figures 2.6 and 2.7. According to Ding, they accessed tilt-in-space for an average of 19 ± 14 times and spent 64.1 percent of their time each day in tilted seating positions. The access to backrest recline was found less frequently but slightly longer compared with tilt-in-space, i.e., 12 ± 8 times and 76.0 percent of their time each day in reclined seating positions.

In previous studies, researchers found that a tilt-in-space angle of ≤ 15° can be used to change back pressure distribution, but an angle >15° is necessary to achieve an effective weight shift. In addition, maximum reductions in peak seating pressures occur when tilt-in-space angles are ≥ 45°, Ding wrote, reproduced in tables 2.1 and 2.2 above. The most common recline angles on the basis of duration and frequency of accesses were generally between 100° and 110°.

2.2.2 Leister – "Effectiveness and Use of Tilt-in-space and Recline Wheelchairs" (2005)

Leister's research was similar to that provided by Ding. This enabled a cross reference to be used in the analysis to follow in the next section. The raw data is shown below in table 2.3.

Table 2.3 Summary of Tilt and Recline usage of one test subject using a wheelchair 9.4 hours ± 2 hours each day for a total of 10 days (Liester, 2005).

	Average Results	**Ranges**
Tilt Access per Hour	6.5	2 – 11
Average Time Tilt was Accessed (min)	9	4.7 – 16.5
Most Common Tilt Angle	0º to 5º	-5º – 53º
% of the Time Spent in Most Common Tilt Angle	47%	32% – 63%
2nd Most Common Tilt Angle	5º to 10º	-5º – 53º
% of the Time Spent in 2nd Most Common Tilt Angle	31%	3% – 62%
Recline Access per Hour	18	8 – 24
Average Time Recline was Accessed (min)	3.5	2 – 6.7
Most Common Recline Angle	Below 90º	85º – 136º
% of the Time Spent in Most Common Recline Angle	56.5%	33% – 91%
2nd Most Common Recline Angle	90º to 95º	85º – 136º
% of the Time Spent in 2nd Most Common Recline Angle	31.5%	9% – 60%

2.3 Historical Data Analysis

After exploring each of these studies in some detail, the results from them will be compared in an objective, statistic manner. This will confirm or deny their relation and relevance to each other and provide a basis for continuing study into modern ergonomics. The hypothesis to be tested is that each of the studies will have similar results when compared to one another within a confidence interval of at least 90%. Conclusions will be drawn based on the results of the tests used to confirm or deny the hypothesis.

The bulk of the data collected ended up with a range of results; therefore the data is to be analyzed as a set of ranges. The collected data is summarized in table 2.4.

Table 2.4 Combination of minimum and maximum angles found in historical research

Source	Minimum Angle (Degrees)	Maximum Angle (Degrees)
Wheelchair		
Ding	110	130
Leister	134	139
Normal		
Bashir	135	135
Hedge	90	135
Microgravity		
Skylab	121	135

There is a larger variety of minimum angle measurement than there are maximum, with the minimum having a range of 44 degrees and the maximum having a range of only 9. Using this data, find the average and the standard deviation of the measurements, shown in table 5.2, to get a better overview of the research and it's relation to our conclusion and to setup our hypothesis test.

Table 2.5 Average and standard deviation of findings in historical research

	Minimum Angle (Degrees)	Maximum Angle (Degrees)
Average	118	134.8
Standard Dev	18.72	3.19

The minimum angle from Hedge is well outside of our average minus standard deviation. The results with the outlier removed are in table 2.5.

Table 2.6 Average and standard deviation of findings in historical research with outliers removed

	Minimum Angle (Degrees)	Maximum Angle (Degrees)
Average	125	134.8
Standard Dev	11.86	3.19
Range	25	9

The new range for optimal comfort and natural position is between 125 and 134.8 degrees as shown in table 2.6. The next step is hypothesis testing. The hypothesis was that each of the studies yielded similar results within a 90% degree of confidence. In order for this to remain true, all of the data would need to fall within the range of 112.5 – 137.5 degrees for the minimum and 121.32 – 148.28 degrees for the maximum. There are two data points which do not fit this range, meaning they are outside of our expected value by greater than 10%. Those two data points are Hedge's minimum, which we already disregarded as an outlier, and Ding's minimum. Since a value which was expected to be within our confidence interval is not, we must reject our hypothesis and accept the null hypothesis. The null hypothesis is that the results of the studies are not similar within a 90% confidence interval.

Using the data collected from several sources and studies in recent times, it is concluded that they do not all report similar findings within a 90% confidence interval. This is however not necessarily a problem, as Hedge (2013) stated that it is a myth that one chair design will provide the best fit for all users. Each person and each situation is unique, and that must be taken into account when trying to make a design more ergonomic.

That said some interesting parallels and secondary conclusions can be drawn. Wheelchair users seem to have a much stronger preference for the upright posture than a reclined one. This could be because in a normal day, many people will spend a great deal of time standing or walking which requires us to have a more upright posture, so those bound to a wheelchair use that seated position for the same uses a healthy person would normally be standing. Another possible variable that could skew the data is culture. It is considered proper posture and good practice to sit upright in many cultures. This could develop a bias in an individual causing them to mentally feel more comfortable in an unnatural position even though anatomically they would be more comfortable a different one. This variable can be observed in the studies which were performed outside of a laboratory setting, where there are many more variables such as this introduced into their study that are difficult to account for.

Chapter 3: Ideation

3.1 Process of Design

This chapter follows the creation of the design from the initial hand sketches through the final configuration combination of the key elements. Each key component with respect to the ergonomic considerations of the user is first examined and considered in a variety of possible configurations. These configurations were then picked and chosen based on practicality, cost, and compatibility with other potential configurations.

3.2 Keyboard and Mouse Configuration Considerations

The keyboard and mouse tray is one of the more difficult components of the design. Users require a comfortable place to rest their peripherals, which generally consists of only a keyboard and mouse, but extra room should be available for other tools. The position is not as critical, as according to NASA (1995) the elbow and shoulders have a large working range of 78 degrees total. The difficult consideration for this component however is the ability of the user to get into and out of the workstation. The keyboard and mouse should be placed directly over the lap of the user, and remain secured during use.

Many common workplace desks overcome this difficulty by having the tray on a slide which comes out from underneath the work surface of the desk. That design allows the user to move the tray in and out as they wish to make it easy to access the desk. Another common design simply uses the fact that desk chairs are separate from the desk, so the user is able to easily position themselves however they see fit. One key limitation to most keyboard and mouse tray designs is that they are generally not movable in the vertical direction, they are at a fixed height.

This is a cause for frustration to many users and a particularly tall or short user could have difficulty using the tray.

This design has a number of difficulties which are not solvable using conventional means and seeks to allow users vertical adjustment. Since there is no desk surface for a tray to extend from, this is not a plausible solution to allow the user access to their seat. The chair is also a part of the design, relying on the users' ability to position themselves is also not viable. Therefore, a solution must be created which will allow each user to enter and exit the chair, as well as adjust the tray for their preferred height.

3.2.1 Keyboard and Mouse Configuration A

In this configuration (see appendix 1-A: Keyboard and Mouse Configuration Design Hand Sketches), the keyboard and mouse tray is removable completely by the user to allow access into the seat. The tray rests on two bars which fit around the armrests and are held in place by a pin. If the armrests are designed with circular supports, this would also allow one side to be unhooked from the armrest and leaving the other hooked to let the armrest swivel out to one side.

The first and biggest advantage of this configuration is that the tray would always be in a height relation to the armrests. If the user were to adjust the armrest higher, the tray would move with them. This design would also help the user ensure that the armrests are at equal height, as failure to have the armrests at the same height would not allow the tray to be locked into position. This is a very sturdy design as any downward force put on the tray would be transferred onto the armrest rather than stressing the arms holding the tray.

The disadvantages of this configuration however are many. The first and largest disadvantage is the complication of the design. In order for this to work, the armrests and the linking part of the tray would have to have extremely low tolerance. This would greatly increase cost of producing the component. Another major disadvantage is the difficulty the user would have when using the feature to remove or attach the tray. Trying to add or remove it requires a decent degree of precision as well as accessing pins which would be located behind the armrest. This puts the user in an awkward position physically to manipulate the mechanisms. The final disadvantage is a minor safety issue. The locked tray would make it difficult for the user to leave the chair in the event of an emergency. This configuration would physically lock the user into the chair.

3.2.2 Keyboard and Mouse Configuration B

This configuration (see appendix 1-A: Keyboard and Mouse Configuration Design Hand Sketches), seeks to alleviate the key issue of the user being able to enter the workstation. The try is attaches to a round tube using two arms for support. The top of the tube is covered by a ring which keeps the tray from falling, and both supports are attached to rings which allow it to swivel from side to side. The idea is that the user can turn the tray away from the seat easily, sit down, and turn the tray back into their lap. The tube which holds the tray up will be attached to the frame of the assembly, rather than the armrests as the previous configuration.

The main advantage of this configuration is the ease of movement by the user both into and out of the chair. The tray itself can be of a very large size and still be easily manipulated. Unfortunately, this design does not solve the issue of vertical placement. Since the top of the tube is what is used to prevent the tray from falling due to gravity, the component must rest at this height only. A telescoping tube would allow for vertical adjustment, however it would also break many of the limitations set on this design; increasing cost and relying on one of the three limited parts, springs, hydraulics, or tension. Another disadvantage would be that there is no limiting factor to the swiveling. This could result in the user swinging the component to far out and damaging a nearby object or person, as well as the inconvenience of the tray potentially swinging when trying to move the mouse.

3.2.3 Keyboard and Mouse Configuration C

In this configuration (see appendix 1-A: Keyboard and Mouse Configuration Design Hand Sketches), the keyboard and mouse tray is hanging from the monitor assembly above the workstation. Two bars with holes in them extend down from monitor holding frame and the keyboard and mouse tray is held in place by pins going through those bars. This concept was made from trying to think “outside the box” leading to an interesting idea with a large number of flaws.

The one advantage of this design is the ability to adjust the tray vertically with a strong connection on both sides. Unfortunately, the downsides are many and prevent much further investigation into this configuration. The arms coming down from the monitor frame would hinder the users’ ability to enter the workstation without much ability to change them. The bars must extend almost entirely to the users’ lap, and any ideas to move them would result in a weaker connection or more complications. The pin to hold the tray in the correct height would be difficult to adjust by the user, although not impossible. Perhaps the worst part of this design is its reliance on the monitors to be in a position which is convenient for the tray to rest. As monitor positioning is pivotal to the overall design, constraining it further by needing to consider the position of the keyboard and mouse tray would be potentially devastating to the whole workstation design.

3.3 Chair Configuration Considerations

The beginning of the idea for a workstation of this design started from a chair design. The initial research suggested that modern desk chairs were not optimal for the health of their users over long periods of time. The spine is supported by the chair, therefore this component must have the strictest of considerations regarding the ergonomics of the spine. Fortunately, there has been extensive research in the field, and a fairly well agreed upon angle for extended sitting is to have the back reclined at 120 degrees in relation to the seat of the chair. By simply moving the chair into this position, a great deal of the issues that modern desk chairs try to overcome by adding more complicated mechanics for adjustment are not necessary.

Consumers of desk chairs and workstations have certain expectations which need to be considered with the design. The first expectation is that desk chairs are upright, which has been shown to be unhealthy and by design is being changed. In order to help add appeal to the customer, possible designs should include an upright position, even if this isn’t meant to be the functioning configuration. By giving the workstation the ability to be upright, it should help the product to be more appealing to a potential customer. This however is not the goal of the design, and is likely to add unnecessary cost to the product.

In order for this component to be successful, it must accomplish several tasks. Most importantly, the chair must be able to recline back at 120 degrees and remain sturdy and stable. This will be the angle in which the user will rest and use the workstation, so this is the most important consideration. The chair must also be easily accessible to the user and not be impeded by the frame. Finally, if the chair does include the ability to raise upright, it must remain cost effective.

3.3.1 Chair Configuration A

The back of the chair is attached to the seat through a large hinge (see appendix 1-B: Chair Configuration Design Hand Sketches). The bottom of the seat is on a set of rails which allow limited motion forward and back. A single rod is placed in a precise location up from the back of the chair, which is otherwise only fixed through the hinge on the seat. This allows the user to sit down in the chair while it remains upright, then by sliding forward, the back of the chair will recline as it moves. At the end of the rail, the back of the chair will be resting at the proper 120 degree recline.

The key advantage of this design is the aesthetics. When not in use, the chair itself resembles a normal office chair with its upright positioning. The rails coming out in from give it a little "wow" factor for the customer as they notice the geometry changes when the seat slides forward. This design offers a cost effective way to enable the user to have some familiar sensation of a normal office chair without using any of the self-imposed limitations on parts.

This design is not without its problems though. A mechanism would need to be designed which allows the chair to 'lock' in both the upright and reclined position. Gravity would likely be sufficient for ensuring the chair stays reclined, however without a mechanism locking it upright the user might slip when first sitting down. The rails themselves may pose a safety hazard as the user might pinch their fingers or legs on the seat as it moves forward.

3.3.2 Chair Configuration B

Car seats have become a popular product used in ergonomic office seating in recent years. DX Racer, a company which makes very popular gaming chairs, bases every one of their designs off of car seats. The adjustability of the back and bucket seat give them a good ergonomic sense as well as appeal to the users as they are already familiar with the comfort of a car seat. This configuration is more for discussion about following other forward thinking companies which seek to have ergonomic design.

This configuration (see appendix 1-B: Chair Configuration Design Hand Sketches) has a number of very nice features and solves several problems that this component needs to address. The biggest issue is the ease of getting into and out of the chair. Since a car seat locks in a large number of positions both with back tilt and with lateral motion, it is very easy for the user to adjust it to fit their needs. Unfortunately, although this is a major advantage to the configuration, there are far too many problems for this to fully work.

Having the user in complete control is a common myth about ergonomic seating according to Hedge (2013). One of the key points of the overall design is to have the user reclined at the healthiest position according to modern research, and giving user control over this angle would defeat the purpose. The car seat would encourage the user to raise and lower the recline of the seat to what is “comfortable” o them without taking into account monitor positions, keyboard and mouse tray positions, or correct recline angle. Another issue with the car seat is balance. DX Racer boasts clever engineering to allow the user to recline their seats back to a startling 160 degrees using only a traditional single piston under the seat for support. After some testing of their products at home (the author purchased one) this is found to be true. The chairs developed by DX Racer which are simply car seats with a clever tilting and reclining mechanism cost over $300. A similar design would need to be used for the workstation, and this would raise the cost of the product significantly. Car seats also rely on springs, which is a self-imposed limitation to the design.

3.3.3 Chair Configuration C

Fixing the reclined angle of the chair is another possibility to be explored. In this configuration (see appendix 1-B: Chair Configuration Design Hand Sketches), the chair is held in place by the frame. The alternate version of the configuration has the frame placed on rails similar to chair configuration A. This will allow the user to slide into the work area since monitors will be suspended above the chair and may make it difficult for the user to enter.

Simple and cost effective, this is one of the sturdier potential configurations. The basic frame and fixed positions make the overall component very sturdy and use few components. Without the rails for sliding, this also eliminates all mechanisms, further simplifying the design and lowering the cost. Even with the rails, the movement is simple and the design inexpensive. The simplicity of the frame also allows for a great deal of 'play' with the back and seat of the chair, allowing any number of possible designs and materials for comfort. This even opens the possibility of having modular style seat and back cushions that the user could change out to fit their preference.

The weakness of this configuration is also its strength. The fixed position, while strong and inexpensive, could also hinder the ease of getting into the chair. At the steep recline of the back, and with the monitors overhead, there is only a little room for the user to enter and exit a piece of furniture which more closely resembles a bed in positioning than a chair. The configuration also lacks "wow" factor to attract a customer. It offers little customization and hardly looks like a standard desk chair.

3.4 Monitor Position Configuration Considerations

Second most important to the design is the position of the monitors. Apart from the spine, the eyes experience a lot of stress when working on computers for extended periods of time, and according to the Canadian Centre for Occupational Health and Safety (2009) bad positioning of the monitor "can lead to work elated musculoskeletal injury (WMSD)". To ensure the comfort and health of the user, a number of factors must come into play.

First, a series of calculations need to be done to determine the proper positioning of the monitors. This will lead the design process as this component is the single most constrained of all configurations. The monitors will also need to be suspended in this position securely, and due to the recline of the back of the chair, this position will be overhead. The frame holding the monitors must be able to securely mount them overhead in exactly the right position. Secondly, the monitor frame must be able to accommodate more than one monitor. Most modern workstations feature two or more monitors. For the purpose of the configuration concept drawings, only one will be drawn with the understanding that a second monitor to one side will be added once one monitor can be properly positioned. Depending on the overall design of the workstation, a third or more might be added. In order to add more however, the design must be able to shift in such a way that the user can easily get into and out of the workstation. Each monitor that is added will need to be carefully calculated as well, however before calculating it is known that they will need to be tilted toward the eyes of the user. If three monitors are added at the start, this will close off some of the maneuvering room of the user as some of the sides will become occupied by monitors.

Thirdly, constraints must be gathered from a number of sources and tested for viability. The comfortable area for viewing has a great deal of variation from user to user, but some general averages do emerge. According to NASA (1995) the optimal viewing area in 1 (earth gravity) is 10 degrees down from horizontal according to the viewer's straight forward eye angle. This will be used as a minimum, as any small than 10 degrees would make small text difficult to read, such as the text on this page; for example, if you are viewing this at a standard 8.5in x 11in size, place this paper over 4ft away. According to the Canadian Centre for Occupational Health and Safety (2009), the best viewing angle is between 15 and 30 degrees. With this data, 10 degrees will be used as the minimum, 30 degrees as the maximum, and the goal being between 15 and 20 degrees. Also, according to the Canadian Centre for Occupational Health and Safety (2009), the best viewing distance is between 30cm and 70cm. In order to allow the most maneuvering room for the user, 27in will be used as the viewing distance along the horizontal reference of the user's straightforward vision considering 12in as the minimum safe distance. In order to maximize the effectiveness of the further viewing distance, only monitors with 1080p resolution should be considered. Modern monitors also have a 16x9 aspect ratio. A quick reference of amazon shows that inexpensive monitors with that resolution range from about 19.5in to 24in diagonals, establishing a range for monitor sizes.

3.4.1 Monitor Calculations Set 1

This set of calculations (see appendix 1-C: Monitor Position Hand Calculations for hand drawn figures) was made using the maximum viewing angle and the minimum and maximum monitor sizes to determine if they meet the distance requirements. During these calculations, another potential constraint came up, that is the wide angle viewing distance (left to right). Upon further research into the guidelines set by the Canadian Centre for Occupational Health and Safety (2009), it was found that the recommended angle for this measurement was also 30 degrees. Calculations were done to see if the monitors fit this, knowing that they would not. The monitors used in that set of guidelines had a 1:1 aspect ratio as opposed to the modern 16:9. Purchasing modern monitors with the 1:1 ratio is both more expensive and less capable as many users play video games or watch movies, which are generally at minimum 4:5 and usually optimized for the 16:9 ratio. The results of these tests were that the smaller monitor would be placed 17.32in away from the viewer and the larger would be placed 20.78in away. Both of these distances are likely too small to allow for maneuvering, and larger monitors would increase the cost of the user to high as well as require a sturdier frame to hold the larger weight. Instead, further calculations would be made using other starting points and constraints.

$$H_{min} = 12in$$

$$H_{max} = 27in$$

Where Hmin is

Hmax is

$$\mathbf{19.5in\ Monitor = 10in\ x\ 17in}$$

$$SIN(30) = \frac{10}{x}$$

$$\frac{10}{SIN(30)} = x$$

$$x = 20in$$

$$SIN(60) = \frac{H}{20}$$

$$SIN(60) * 20 = H$$

$$17.32in = H$$

52.28° wide view

$$\boldsymbol{24in\ Monitor = 12in\ x\ 21in}$$

$$SIN(30) = \frac{12}{x}$$

$$\frac{12}{SIN(30)} = x$$

$$x = 24in$$

$$SIN(60) = \frac{H}{24}$$

$$SIN(60) * 24 = H$$

$$20.78in = H$$

53.62° wide view

3.4.2 Monitor Calculations Set 2

Further calculations were made using a different constraint for the starting point. Since neither of the monitors from the previous set seemed to correctly fit the needs of the workstation, it was decided to try and see which size monitor would fit. It was apparent from the previous set of calculations that a 30 degree vertical viewing angle 27in away would require a monitor too large to be practical, so a new vertical viewing angle was derived (see appendix 1-C: Monitor Position Hand Calculations for hand drawn figures). Using the 30 degree horizontal viewing angle and the 16:9 aspect ratio of the monitor in question, it was found that a 17 degree vertical viewing angle would be required. From this data, the size of the screen was calculated that would fit the new constraints. The screen size vertically was found to be 8.255in, which is a 16.84in screen diagonally using the 16:9 aspect ratio. This screen size falls below the threshold for high definition monitors, therefor these constraints also would not fulfill the needs of the design. Further calculations using what was learned from the previous two sets were needed.

Goals of Calculations:

30° wide viewing angle

27in viewing distance

17° height viewing angle

(Limitation of this set: research for angles from before the standard 16:9 aspect ratio)

$$180° - 90° - 17° = 73°$$

$$SIN(73) = \frac{27}{y}$$

$$\frac{27}{SIN(73)} = y$$

$$y = 28.2337$$

$$SIN(17) = \frac{x}{28.2337}$$

$$SIN(17) * 28.2337 = x$$

$$x = 8.255$$

Converting calculation findings into 16:9 aspect ratio

$$\frac{16}{9} = \frac{x}{8.255}$$

$$x = 14.6756$$

Finding diagonal monitor size

$$\sqrt{8.255^2 + 14.6756^2} = y$$

$$y = 16.84$$

Monitor size with goals listed above, 16.84in diagonal

3.4.3 Monitor Calculations Set 3

From what was learned from the previous two sets of calculations, the following constraints were used (see appendix 1-C: Monitor Position Hand Calculations for hand drawn figures). First, the monitor must be positioned 27in away from the viewer to allow for room to maneuver. Second, since the 30 degree viewing angle was too large for the vertical and too small for the horizontal, minimums and maximums were used in their place: 15 degree minimum and 30 degree maximum vertical, and 60 degree maximum horizontal (somewhat arbitrary). Using these guidelines, the largest size monitor was tested, the 24in. With a 24in monitor, it was found to have a 23.96 degree vertical viewing angle and a 43.02 degree horizontal. This fit both measurements quite well. The calculations were not made, but it can be inferred by the 2in vertical size difference from the 24in to the 19.5in monitor that the 19.5in monitor would also fit the constraints. This would give the user a range of options for their monitors and still fit the needs of the design. A final measurement was determined, and that was the distance from the viewer to the edge of the monitor. This measurement was more to see if the width of the monitor might impede on the user being able to get into and out of the chair. This distance was calculated at 28.97in, which should allow plenty of room for the user to get in and out of the workstation, regardless of whether or not the monitors could be moved, or the seat slid into position.

Assumptions and findings from previous calculation sets

27in viewing distance will allow maneuverability of the user into and out of the workstation

30° vertical viewing angle is to large

15° vertical viewing angle is minimum

60° wide viewing angle is maximum

Test 24in monitor at 27 in viewing distance

$$\sqrt{27^2 + 12^2} = c$$

$$c = 29.5466$$

$$SIN(A) = \frac{12}{29.5466}$$

$$A = 23.9624°$$

$$h^2 = b^2 + \left(\frac{1}{2}w\right)^2$$

$$h = \sqrt{27^2 + 10.5^2}$$

$$h = 28.9698in$$

$$SIN(x) = \frac{10.5}{h}$$

$$x = 21.51$$

$$2x = 43.02°$$

24in monitor at 27in viewing distance:

23.96° viewing angle height

43.02° viewing angle width

3.5 Monitor Position Configuration Considerations

With the calculations done to give a reference point for the concept design of the different possible configurations, there are a few more considerations which must be taken into account. The first consideration is that the frame or assembly holding the monitors must be strong enough to hold the monitors above the user's head. This means considering various support materials in the concept, even if they aren't necessarily found to be needed after material selection. The second consideration is to ensure that the frame itself does not impede on the movement of the user into and out of the chair. This can be easily done by keeping the frame to only one side allowing the user to use the other to enter and exit the workstation.

3.5.1 Monitor Position Configuration A

This configuration (see appendix 1-D: Monitor Position Configuration Design Hand Sketches) uses a separate frame which is attached to the frame holding the chair to hold up the monitor. The frame features a support beam to ensure that the component is balanced and stable. The frame is fixed to the rest of the assembly only to maintain its proper position, rather than relying on the rest of the assembly to support it. The monitor is held in place by an arm extending from the supporting frame by connecting through the standard connection threaded holes on the back of each monitor.

The advantage of this configuration is the separate frame. This separation allows more freedom in the rest of the assembly without sacrificing strength or ergonomic considerations. The design is simple and cost effective requiring as few as three parts in the frame and overhead arm, plus the connection plate for the monitor itself. This allows for a great deal of room to the user as the separate frame could potentially be positioned further off to one side allowing more room directly next to the chair. The disadvantage of this frame is a slightly increased cost. Having a completely separate assembly for the workstation increases materials and fabrication costs.

3.5.2 Monitor Position Configuration B

In this configuration (see appendix 1-D: Monitor Position Configuration Design Hand Sketches), the frame which holds the monitor is actually a part of the frame holding the chair. This is both a new configuration for the monitor stand, and a reconfiguration of the chair configuration C. The assumption of this data is that even with the chair and monitor positions fixed, the user will have more than enough room to get into and out of the workstation. There is no support material in the concept sketch, however the same vertical support beam as featured in the previous configuration could easily be implemented.

Low cost and efficient use of materials are the advantages of this potential configuration. Similar to monitor configuration A, the key difference is the integration into the chair frame. This allows for drastically reduced material and fabrication cost as a single bar can be used for both the chair and monitor frames. The only disadvantage of this configuration is the proximity of the frame to the user. Since this frame is a part of the overall assembly, it cannot be repositioned to give the user more room on that side.

3.6 Configuration Combination

After reviewing the various potential configurations, one particular combination of them lent itself to the full assembly. Working off of the idea posed in the monitor configuration B as a modification of chair configuration C, all that was left was to figure out which keyboard and mouse tray configuration worked well. By adding a support beam with holes drilled into it to the monitor frame, the keyboard and mouse configuration B would work with some slight modification. This full combination, shown in figure 6.1, of ideas gives the user ample room to get into and out of the workstation, as well as enable them to move the tray out of the way when not needed. Slight modifications to the keyboard and mouse tray are detailed in appendix 1-A Keyboard and Mouse Configuration Design Hand Sketches.

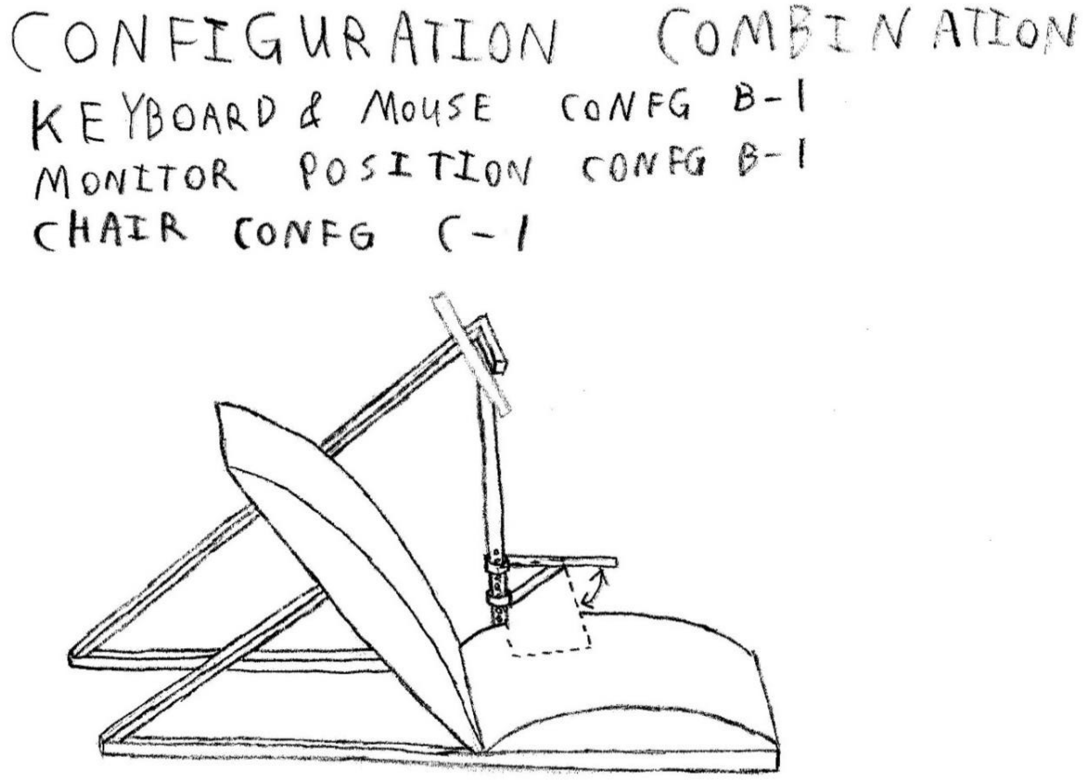

Figure 6.1 Configuration combination hand sketch

In order to allow vertical height adjustment as well as stability, pins through the holes in the round support beam will hold the tray at the user defined position. This adds the feature which was missing from the original configuration. By putting a V shaped slot into the ring that rests on the pins, when the user moves the tray into the correct position over their lap, it will drop slightly into the slot and gravity will help stabilize the tray from twisting out of position during use.

This combination of features and configurations optimizes the use of materials and maximizes accessibility to the user. The one key problem is that the assembly in no way looks like a standard desk or chair. This might cause some concern as the workstation is very much against the customer’s visual expectation. The other issue is the steep angle required of the back support beams on the frame. This causes part of the frame to extend quite a ways beyond the back of the seat. If this were to be setup in the traditional fashion, there the computer screen faced the wall of the office, this could cause a potential trip hazard in the room. In order to combat this, it is recommended that the workstation be setup in the opposite manner, more like a couch where the back of the seat faces the wall. This will add a before unknown advantage to the workstation. By setting it up in this fashion, employees can collaborate quite easily as their seats will be facing out into the room toward their co-workers rather than into the wall. The area behind the seat is also a potential storage location for the computer to be used at the workstation, further optimizing the use of space. These advantages will outweigh the initial potential negative reaction from some customers if the marketing is done to feature the advantages stated above.

Chapter 4: Final Design

4.1 Overall Design

The final design, rendering shown in figure 4.1, was created using Solid Works by combining all of the configurations of the key components. Parametric design of the non-critical components was created through material selection and the correct placement of the configurations that were predetermined before the 3-d modelling began. Based on a simple idea of 5 parts, the final assembly, including connectors and standard parts, such as the screws and nuts, is over 50 parts (technical drawings shown in appendix 2-A: Detailed Part Drawings).

Figure 4.1 Rendering of the full assembly

The process to model the final assembly followed these steps:

1. Configurations that were pre-determined were modelled and positioned
2. Parts that directly affect the body positioning of the user were added
3. Parametrics for the connecting pieces were derived, including brackets
4. Materials were selected using FEA (also used during other steps of the process)
5. Assembly was evaluated to test for fit within the findings of the background research and project goals.

4.2 Modelling of Configurations

The modelling of the configurations was a fairly straightforward process. Using the findings from chapter 2, two basic parts were created to represent the seat back and bottom then positioned at a 135° angle. This formed the foundation that all other parts were made from. At this point, the piece of software Jack was referenced to obtain a number of key dimensions representing the 95 percentile of the human body. The following is a list of those findings which were derived from the findings by Openshaw & Taylor, 2006:

Seat length – 16.9in minimum 95%

Seat width – 18.00in maximum 95%

Seat back height – 38.3in maximum 95%

Eye height from buttock – 27.6in minimum 95% (min used as it is better to have monitor below line of sight than above)

Waist depth – 11.4in maximum 95% (room for keyboard tray in front of user in working position)

Thigh Clearance – 6.9in maximum 95%

Leg height – 15.0in minimum 19.9in maximum 95% - 17.45in average of min / max

Eye position calculations both min and max 95%

Popliteal Height + sitting Height – sitting eye height = eye height from top of head

15in + 31.3in - 42.6in = 3.7in min

19.9in + 38.3in - 52.6in = 5.6in max

Sitting eye height - eye height from top of head = eye height from buttock

31.3in – 3.7in = 27.6in min

38.3in – 5.6in = 32.7in max

Buttock to Thigh Calculations both min and max 95%

Thigh clearance – Popliteal height = Buttock to thigh

21in – 15in = 6in min

26.8in – 19.9in = 6.9in max

Applying these measurements to the configurations which were determined during chapter 3 then formed the foundation of the design.

4.2.1 Overcoming Design Complications

At this point of the process, certain complications began to arise. The first complication was creating an armrest that would be able to be adjusted the same way as the keyboard and mouse tray, and still provide room for the user to enter and exit the workstation easily. To solve this problem, the same configuration that was applied to the keyboard and mouse tray, see figure 4.3 was used with very little modification, shown in figure 4.2. Instead of having the pin hold up the armrest which rested on a ring outside of the supporting beam, the beam of the armrest would have the same triangular cut at the bottom and rest on top of the pin inside of the supporting beam as seen below.

Figure 4.2 Detail view of the armrest in the final assembly.

Figure 4.3 Detail view of the keyboard and mouse tray locking mechanism in the final assembly.

This would allow the user to adjust the height of the armrest in the same way as the keyboard and mouse tray, as well as swivel it up with a lifting action to make it easier to get into and out of the workstation. The triangular cut with a large radius fillet allows the part to easily fall into the correct position and keep it there once the user is ready to work. The final design of the keyboard and mouse tray does not contain the extra support beam found in the configuration combination due to the materials selected. The material 1060 alloy aluminum provides adequate strength to retain its shape in this configuration with 100 newtons of force, a little over 20 pounds, with a safety factor over 3. Since most keyboard and mice will weight significantly less than this, and the weight of a user's arm should will have the majority of its weight closer to the connecting pin, the extra support beam was not needed.

The most difficult challenge to overcome at this point was connecting the circular bar of the keyboard and mouse tray to the square bar that supports the monitor. For all other angled connections, a bracket was sufficient to overcome the awkward angles, however designing a custom part to fit these two pieces together at this angle would be incredibly expensive to produce. To solve this, a hole was drilled into the square support bar at the appropriate angle for the round bar to slide inside. This allows for a screw and nut to be used to lock them together. While this design will likely leave some rotation in the product when it is fully assembled due to the high tolerances of a difficult cut, this small amount of rotation will not be problematic and will cost significantly less than a custom bracket or other connector.

4.3 Modelling around the human body

During the configuration design phase, all but one component of the human body was covered, the legs. This however was a minor detail in comparison to the spine alignment and head position due to the ease of adapting for this part of the body. The design chosen for this is a simple design that has the advantage of extremely low cost production, but the disadvantage of being difficult to change. Six legs were used, four for the seat section and two to support the beams behind the workstation. Each of these legs are composed of two parts which fit inside of each other. The holes in these parts are lined up at the desired height and a bin is put in to hold them there.

The main concern for this part of the model was the strength of the material being able to hold the body weight of a person with only a pin keeping the parts connected. FEA testing was done using 1300 Newtons of force, approximately 300 pounds, with a safety factor of 3, shown in figure 4.4. The minimum safety factor of the parts was found to be 4.96. This means that each one of the six legs is able to withstand the full weight of a person just over 300 pounds and remain within the factor of safety.

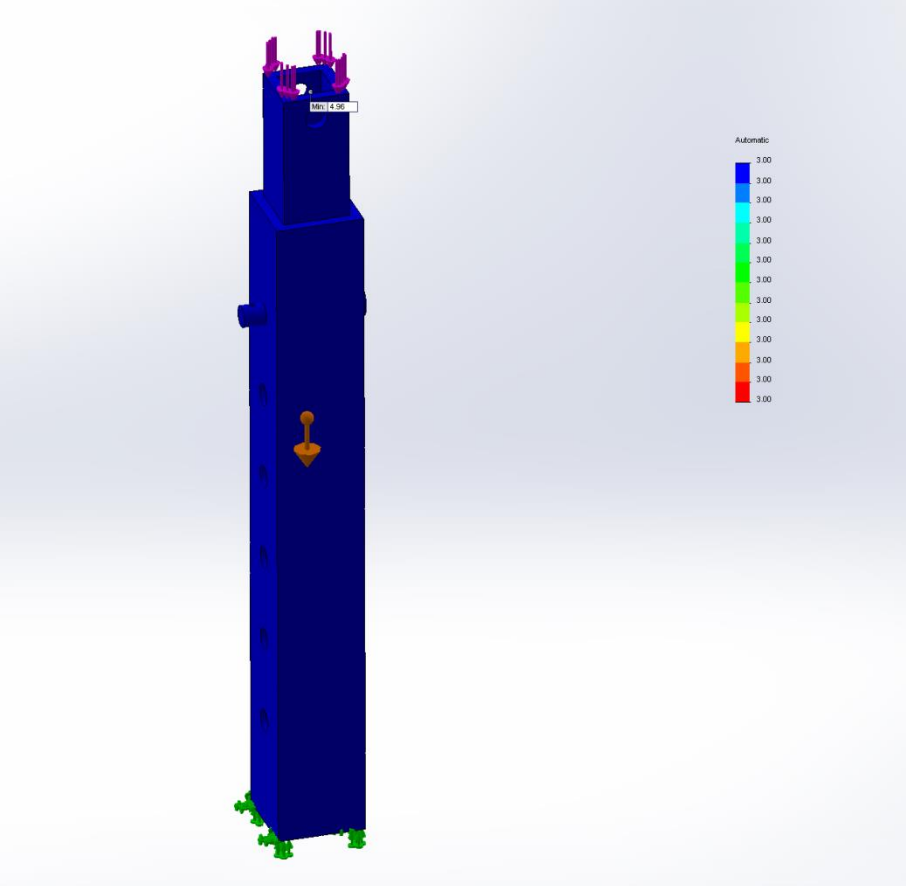

Figure 4.4 Factor of safety diagram featuring assembly legs created using Solid Works. Blue highlights areas where the factor of safety is greater than 3.

4.4 Parametrics and Connections

Once each of the key components had been created and tested where needed, the final step in the modelling was the connections. Many of the connections were straightforward, with the beams setup for each key component able to serve as a structural support for the next component. Four crossbeams were added to connect the left and right sides of the design as well as offer a place for the bottom and back of the seat to connect into the assembly. For the actual connectors, a standard socket head cap screw, 16-14 was used for all connections, in three cases a nut was also needed (when a circular beam intersected a square beam). This allows for minimal tools needed when assembling the product as well as low cost materials as no custom connections or screws are needed.

There are however four custom connectors through the entire assembly. Three of them were designed to use sheet metal steel with minimal bends and cuts shown in figure 4.5. They are used to hold the square beams at an angle against the bottom beams.

Figure 4.5 Brackets which hold the beams at angles in the full assembly.

The fourth custom connector is for the monitor itself, shown in figure 4.6. A square of sheet metal with holes drilled in the standard position for monitor mounting screws should be welded to a piece of square tubing of the size to fit over the supporting beam for the monitor. This piece will be held in place by a screw to ensure that it is in the proper position over the users head for optimal viewing.

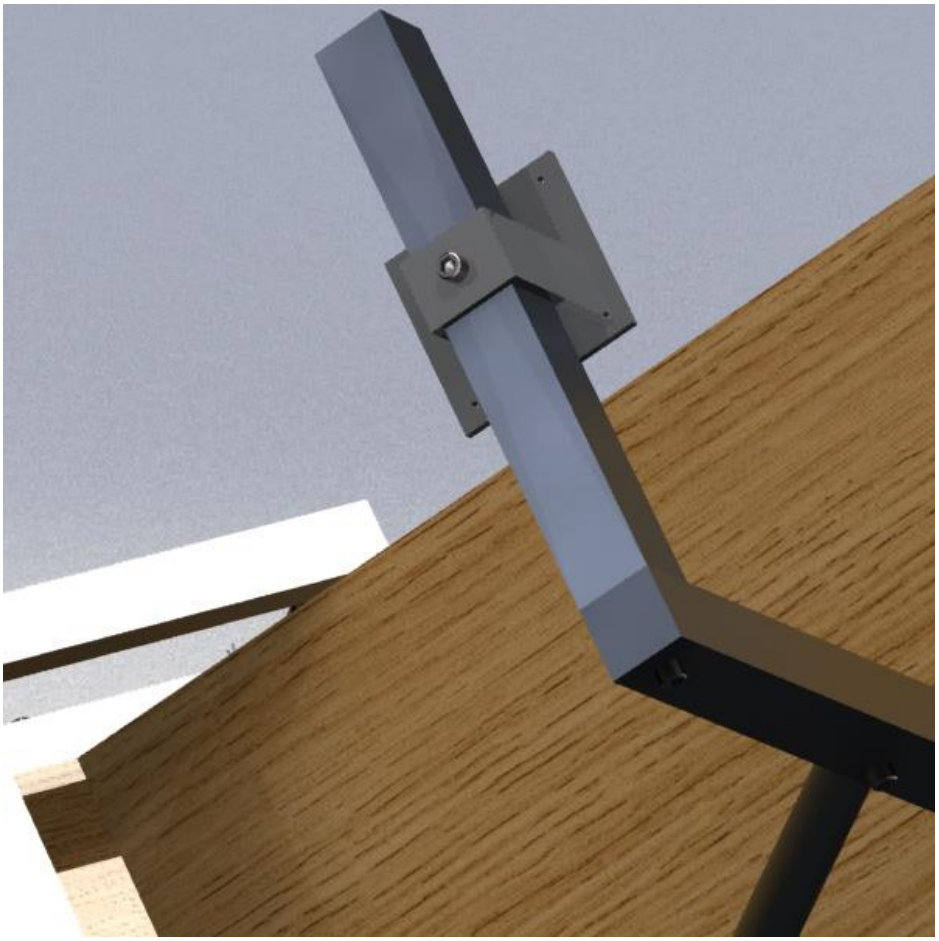

Figure 4.6 Monitor mounting bracket shown in the full assembly.

4.5 FEA and Materials

By this point in the design process, some of the materials were already selected to ensure the strength of the legs. 1060 alloy aluminum was used for the majority of the assembly with only a few components still undecided. These components were the seat bottom and back, as well as the brackets. The seat bottom and back have a very large variety of materials that are available and the material itself is fairly non-critical to the overall design. This part is simply a platform for the upholstery of the chair to reside on and connect to the full assembly. For the purposes of rendering, oak was selected, however in a manufactured design, plywood is likely the optimal choice for cost and ease of use.

The final parts in need of material selection was the brackets. While it was already determined that they would be easily manufactured out of sheet metal, the strength of the bracket was in question with some of the weaker alloys, namely aluminum. FEA testing, shown in figures 4.7 and 4.8, was done on the two brackets which would receive the most stress from the back of the chair using a thick, 11 GA., steel sheet metal. They were tested with 1000 Newtons of force, approximately 220 pounds, to ensure they remained within a safety factor of 3. Blue highlights areas where the factor of safety is greater than 3.

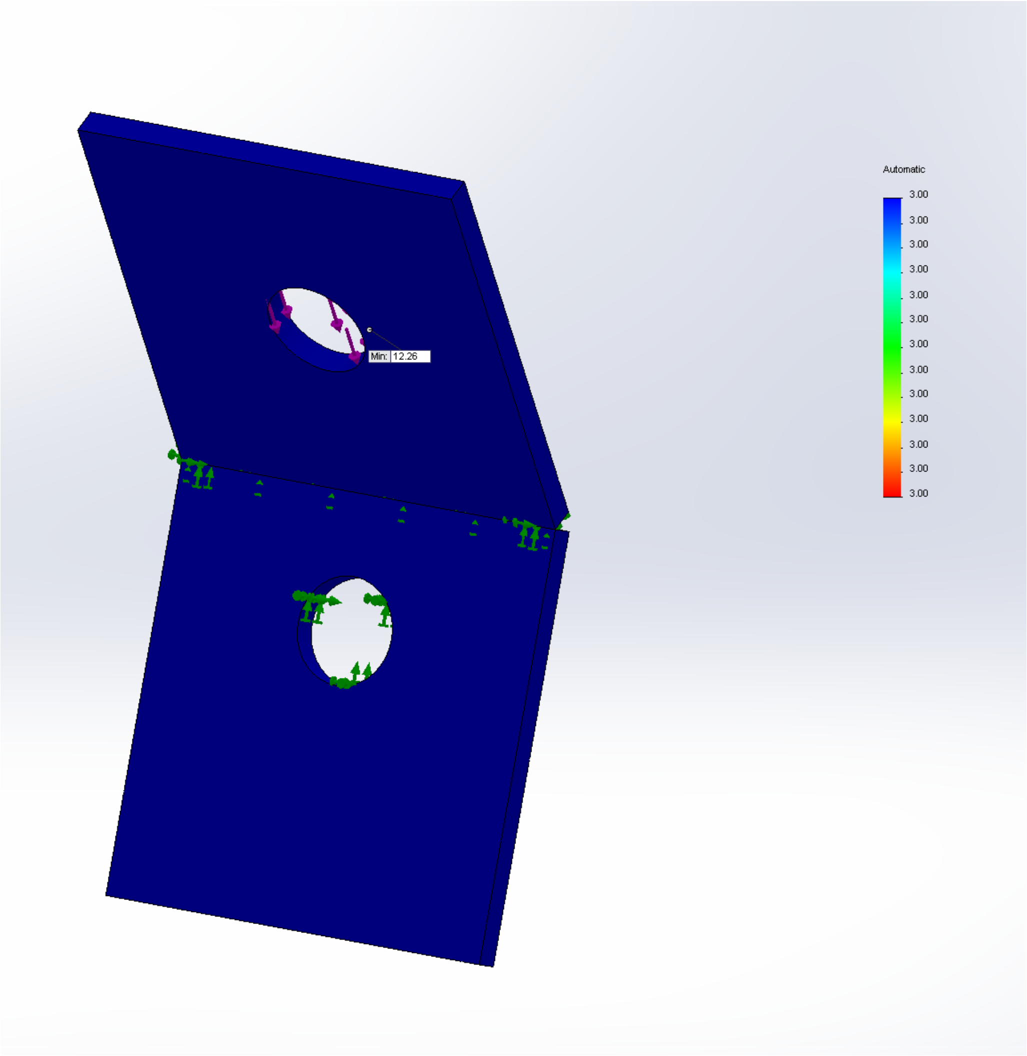

Figure 4.7 Factor of safety diagram featuring bracket two.

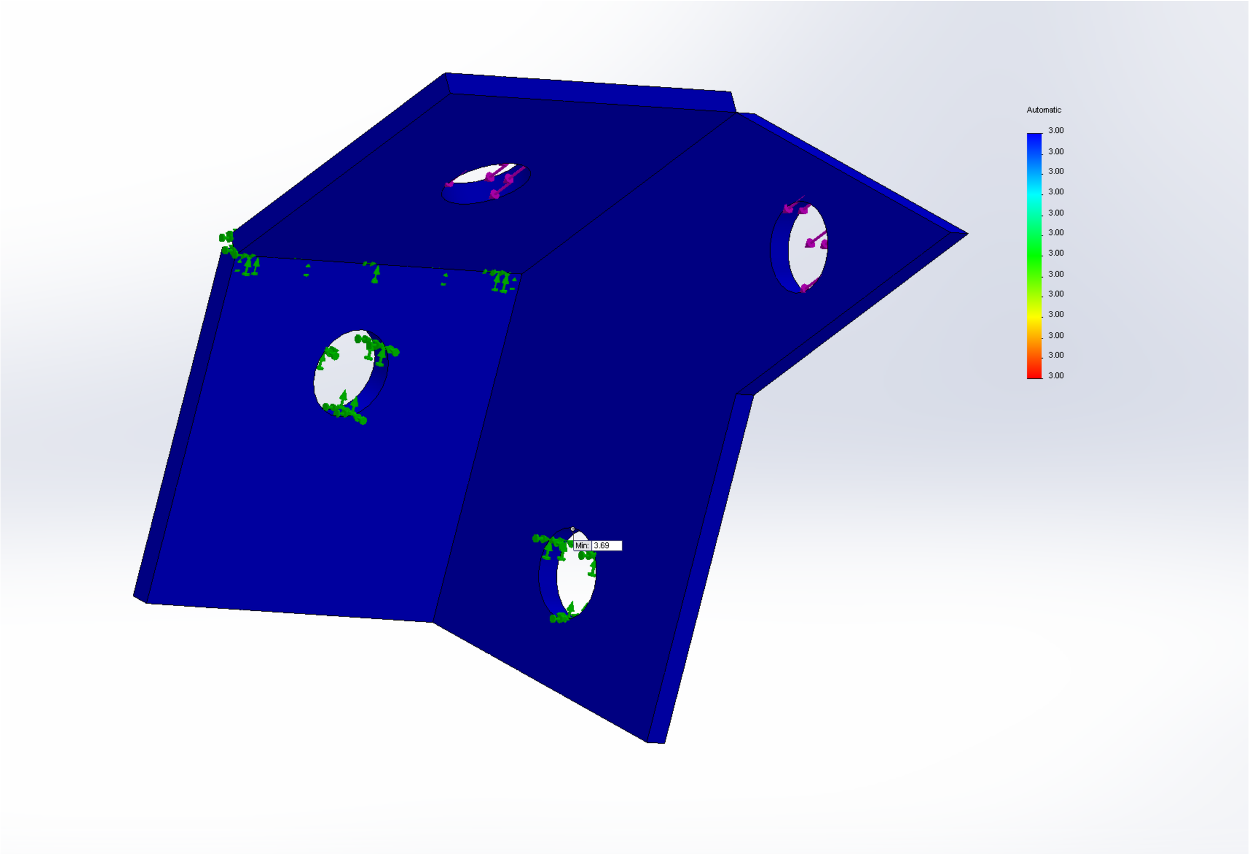

Figure 4.8 Factor of safety diagram featuring bracket one.

Both parts with this material passed the testing with a minimum factor of safety of 3.69 between the two parts.

4.6 Full Assembly Evaluation

The final step of the process was to ensure that the full assembly met the goals of the project. The easiest part of these tests was determining if the assembly fit within the parts limitations. As there were no hydraulics, springs, or tension screws that the structure of the assembly relied on, this test passed.

The second test is the cost of production. Unfortunately, the workstation is not in production, so a true test of this aspect is not possible. A very rough estimate of materials cost shows that the design is within the ballpark of our low cost goal, shown in table 4.1.

Table 4.1 Estimates of materials cost. Costs from Metalsdepot (sheet metal) and OnlineMetals.com (aluminum tubing)

Aluminum Tubing	$68.72 / 8ft	~$210
11 GA. Sheet metal	$28.2 / 1ftx2ft	~$10
Screws and Nuts	N/A	~$10

The rough estimation of materials cost brings the design to a little under $300 per unit, well within the goal of the project. The final test for the assembly is to make sure that each key ergonomic component meets the original goal of that component. This was tested using the evaluate tool of Solid Works as seen in figure 4.9.

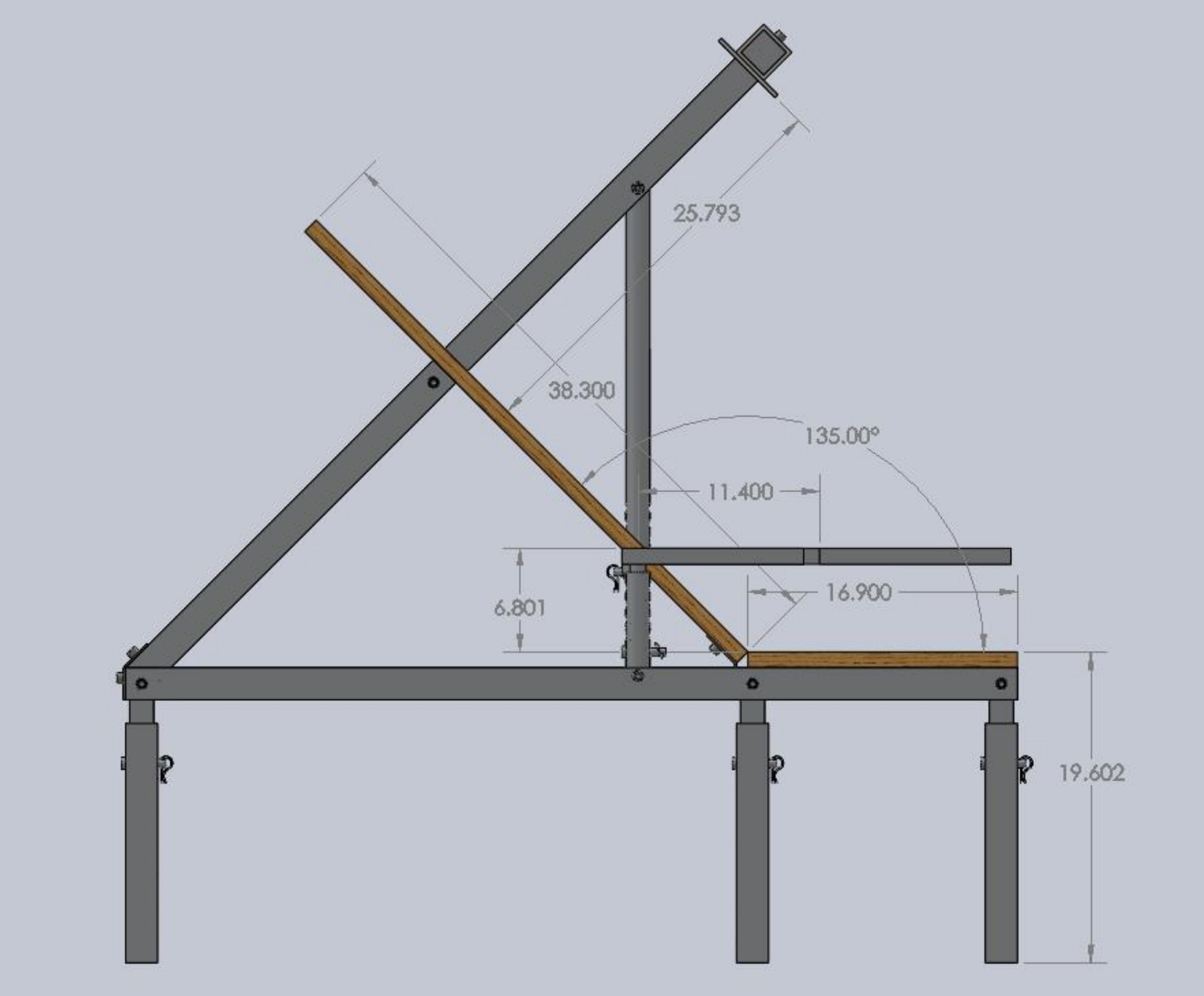

Figure 4.9 Full assembly with key measurements

This image show the minimum heights and settings available to the user. The one component which does not exactly fit the goals described in chapter 3 is the distance of the monitor from the users head. This is slightly under the 27in goal, but still far above the 12in minimum distance found during chapter 2. Since each component of the assembly fits within the 5th and 95th percentile measurements of the human body, the assembly passes this test as well.

Chapter 5: Discussion, Future Testing, and Closing

5.1 Advantages of the Design

The design posed here offers a low cost and effective way to increase the health and productivity of employees who require extended time on the computer. This design incorporates new findings in ergonomic research to create the best fit for people with the 5th to 95th percentile. Each piece of the design is low cost, and low maintenance to the end user, meaning that the workstation should be cost effective for corporations to adapt in a large scale.

One, unforeseen advantage of the design is the overall structure. With the back of the workstation sticking out so far behind the back of the user, it would be best to position the workstation with the back against the wall instead of facing it. This opens up a new possibility as the user in the workstation will be facing outward towards their co-workers or clients rather than facing a wall as is seen in many common cubicle style workstations. The height of the monitor and lack of obstructions underneath will also encourage the user to be more engaged with their environment as opposed to facing a wall.

The design of the armrest and keyboard and tray to easily rotate allows the user simple access to the workstation. This allows users who have back problems, or require the use of a wheelchair to easily slide in and out of the station as needed. Since the mechanism also features the triangular cuts to fall into the correct forward position, the users to not need to worry about taking the time to reposition everything every time they need to get up or get back in.

5.2 Disadvantages of the Design

The size of the overall assembly is one key problem. While the solution for having the back of the workstation against the wall creates a new opportunity for collaboration, this does mean that more room will be taken up by it than a standard desk and chair. Many cubicles are quite small, but will still allow the room for the workstation inside, however the user might need to sacrifice a great deal of space to fit it.

The biggest disadvantage of the workstation however is the single purpose design. While being ergonomically well suited for computer work, it might prove difficult to read or write on anything other than the computer while using the workstation. While this does not necessarily effect the intended customer, this does block off a large market of potential customers who use their desks for note taking or reading printed documents.

This design is intended for a single user, and it would be quite difficult to adjust it between different users. With the legs designed to hold their height each using an individual pin, changing from one user to another would require each pin to be adjusted to fit their height. As the total assembly is quite heavy, this would require it to be laid on its side and the computer would need to be unhooked to protect the monitor from damage during the movement. This workstation is not easily adjustable, which for a single user is not an issue, but this would become problematic in situations where multiple users share the same computer workstation.

5.3 Future Validation of the Design

There are several potential ways to further verify and test the design posed here. The first test would be to take this design and run diagnostics of the effects on a human body using computer software such as Jack. The next logical step of this process will be to produce a prototype of the product for testing in live situations. This will allow the product to be tested for ease of access and use, two tests which the software used is not capable of. Producing the product will also allow for a closer estimation to the cost by giving insight into the labor needed to produce each part.

5.4 Closing

Throughout this process, there were three key goals to accomplish. The first goal was to remain within the limitations set, no hydraulics, no springs, and no tension screws. The second goal was to keep costs below $500. The third, and main, goal was to design a product using the latest in ergonomic research to improve the health of customers who use a computer for greater than four hours at a time. Each one of these goals was met by the design.

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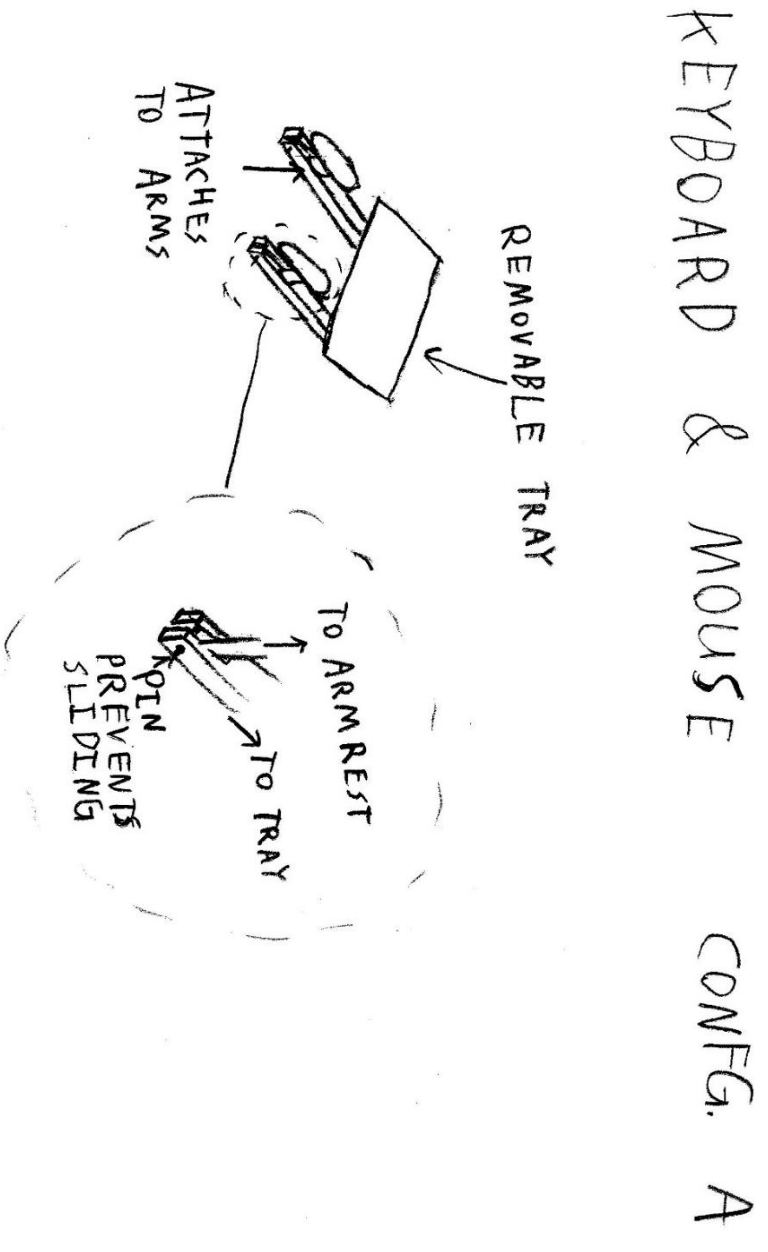
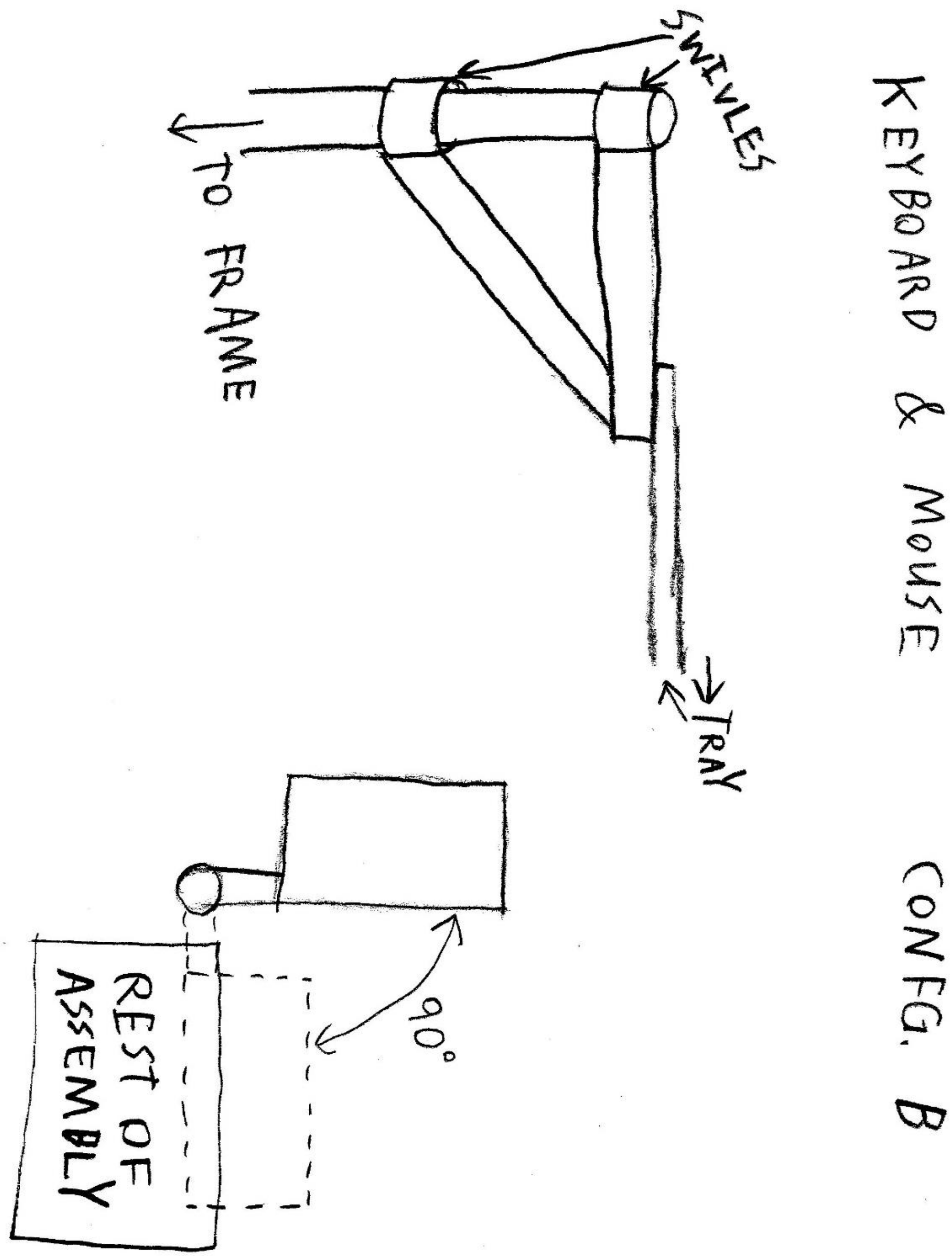
Appendix

1-A: Keyboard and Mouse Configuration Design Hand Sketches

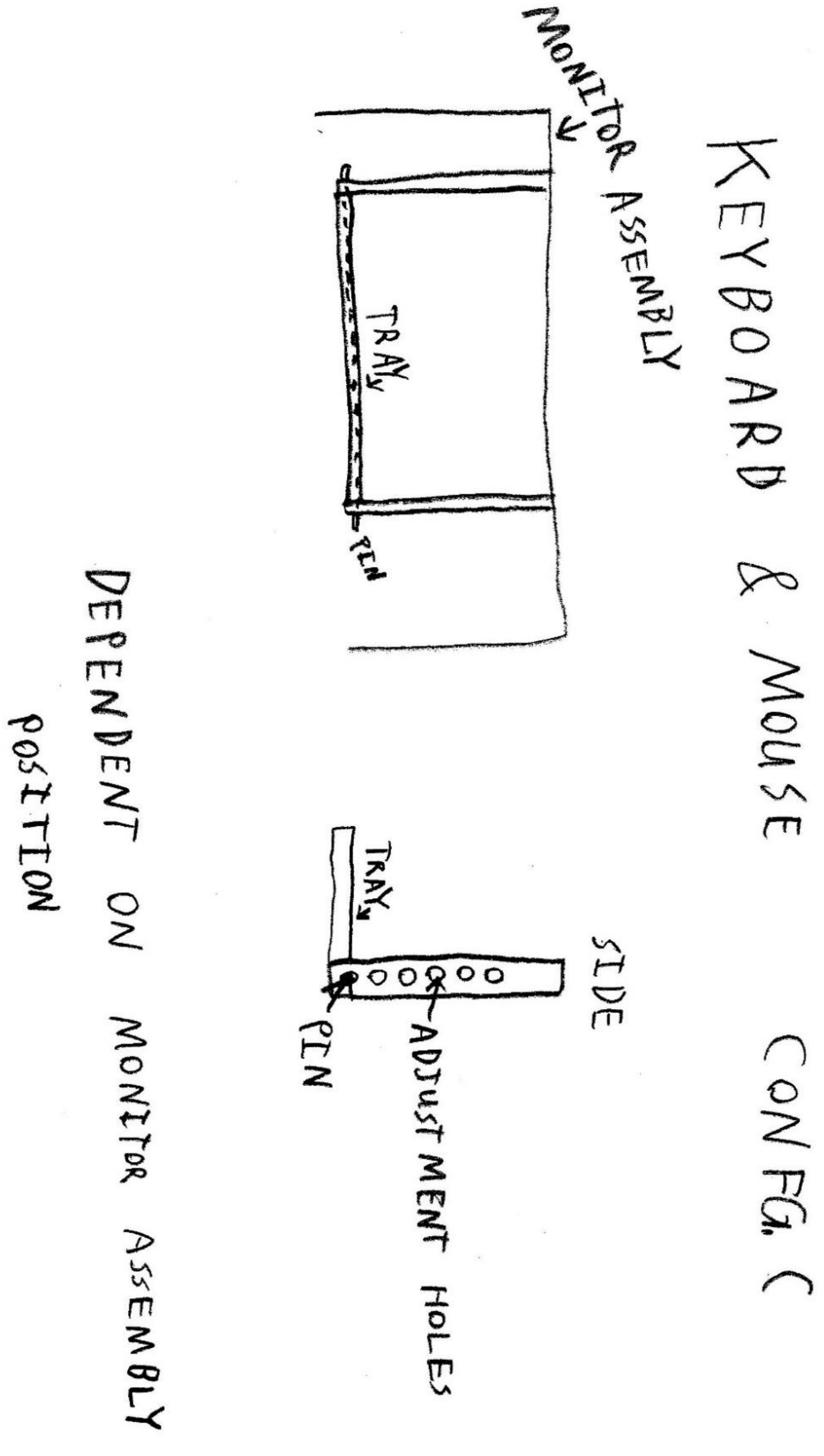
Keyboard and Mouse Configuration Design Hand Sketch A



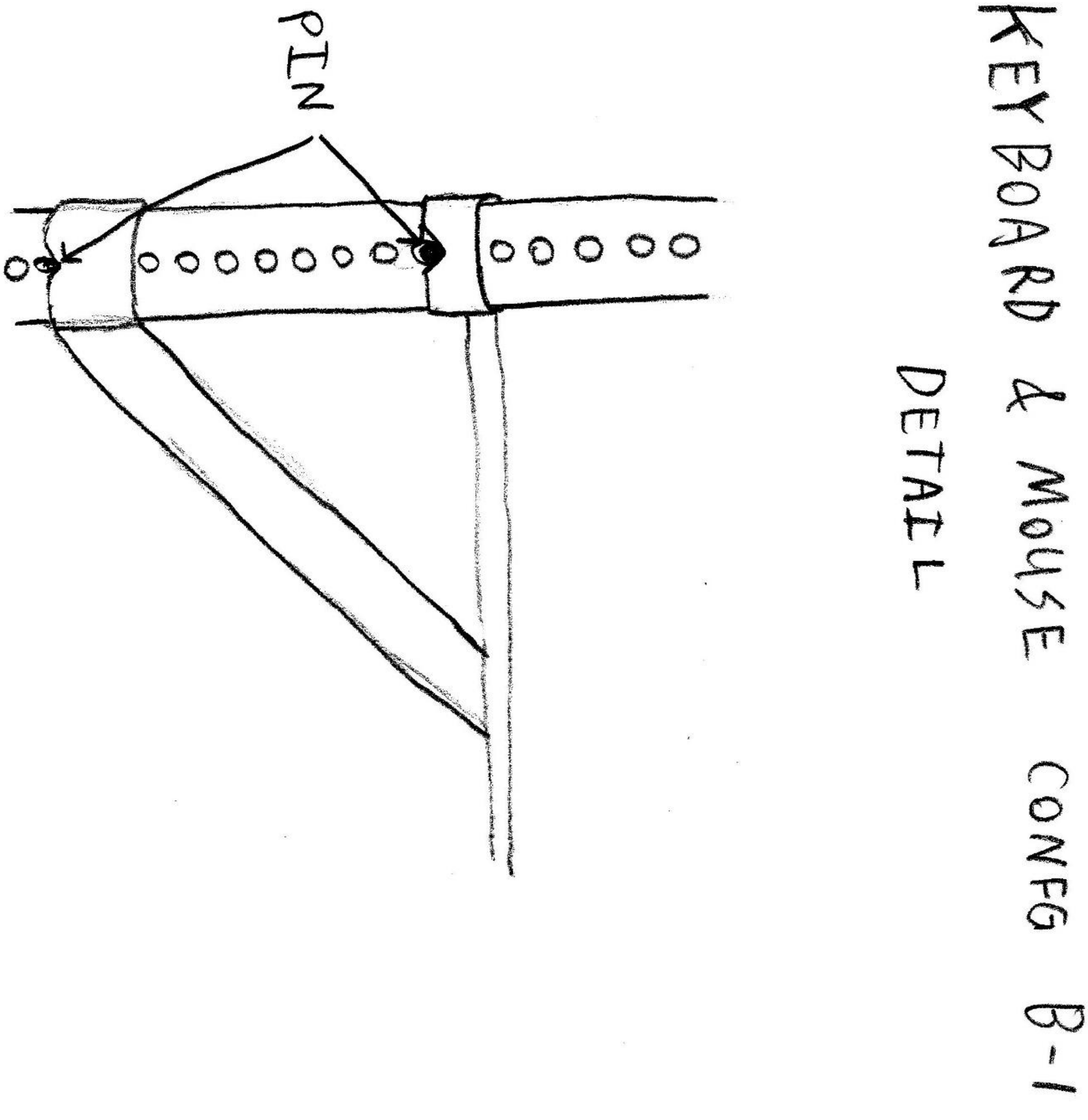
Keyboard and Mouse Configuration Design Hand Sketch B



Keyboard and Mouse Configuration Hand Sketch C

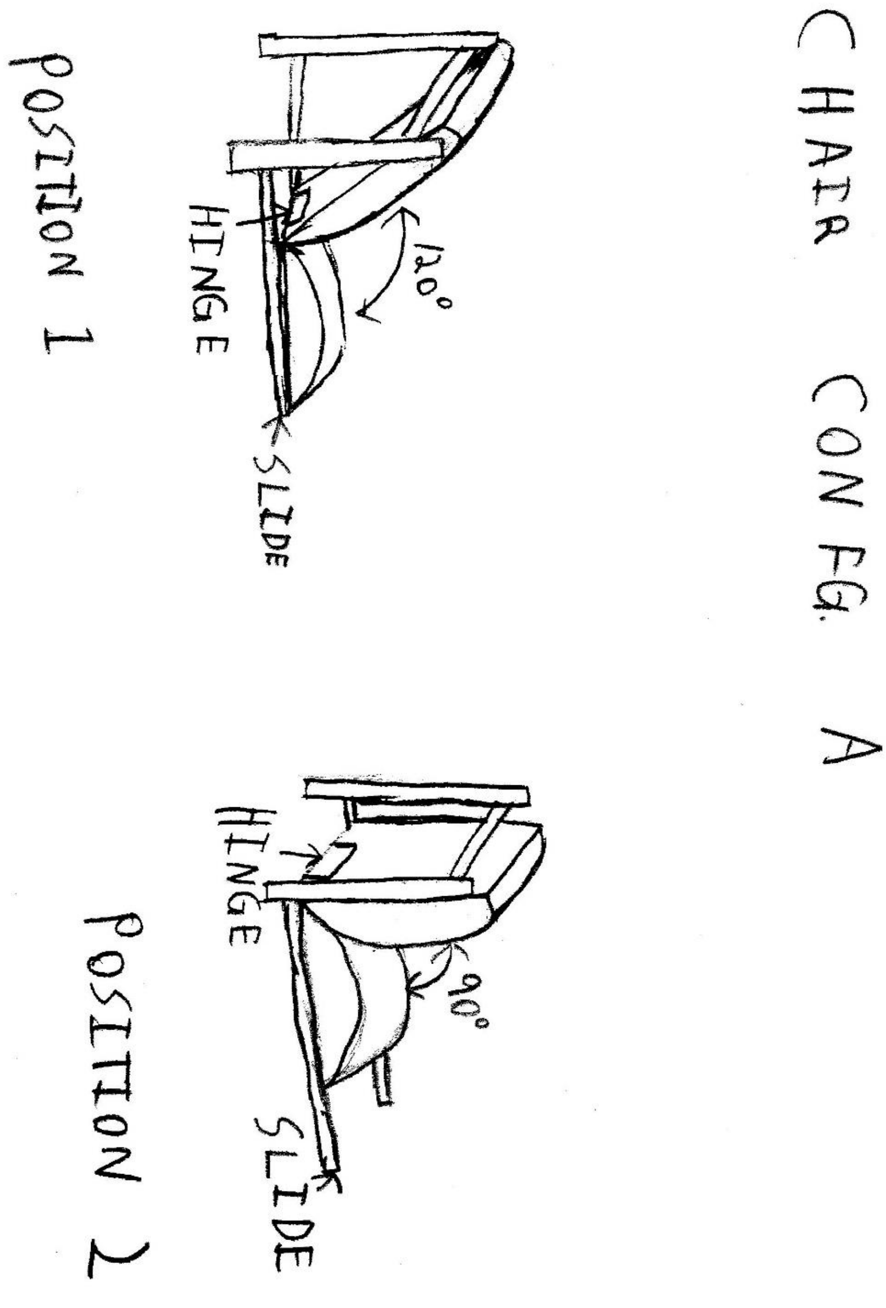


Keyboard and Mouse Configuration Hand Sketch B-1

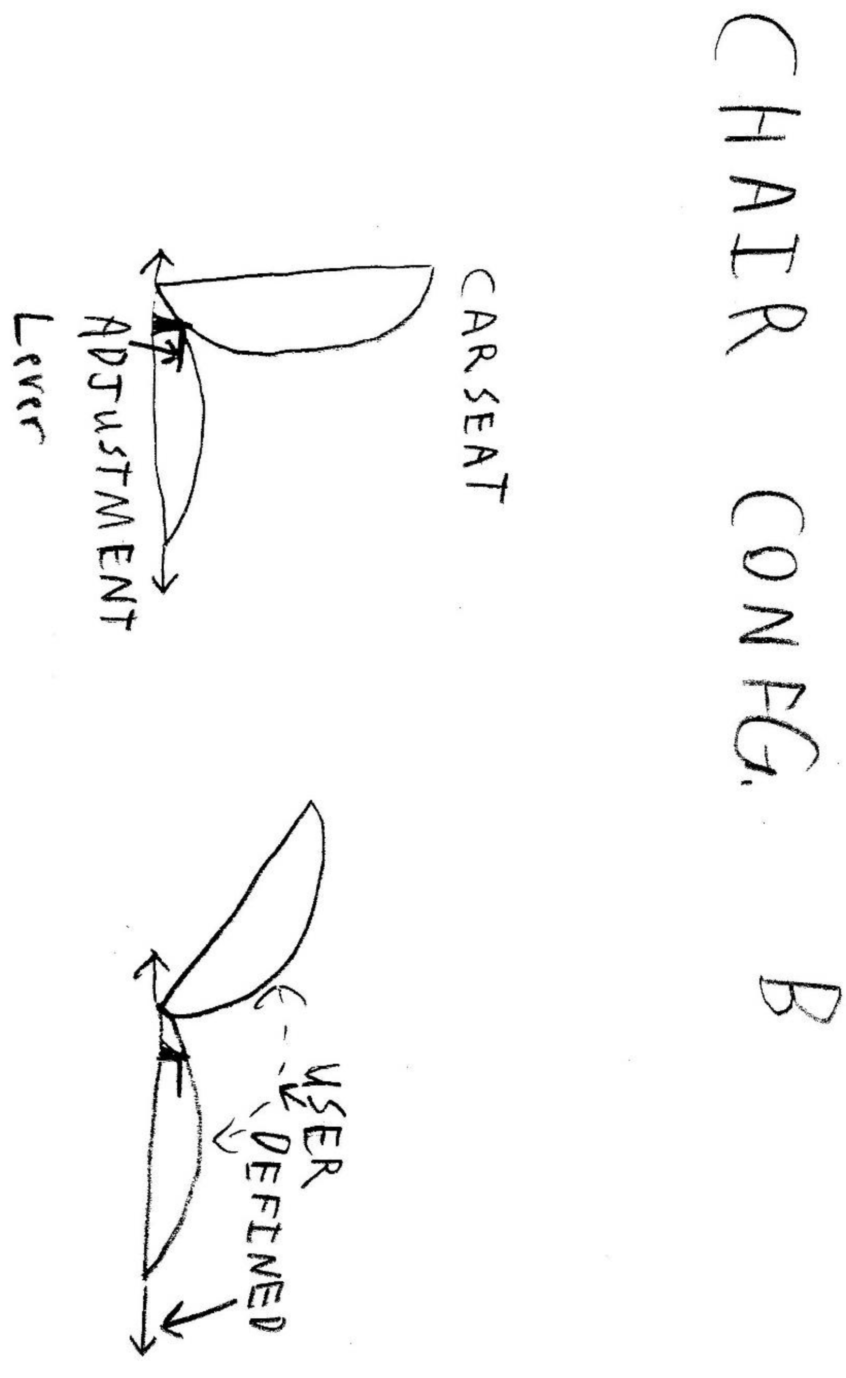


1-B: Chair Configuration Design Hand Sketches

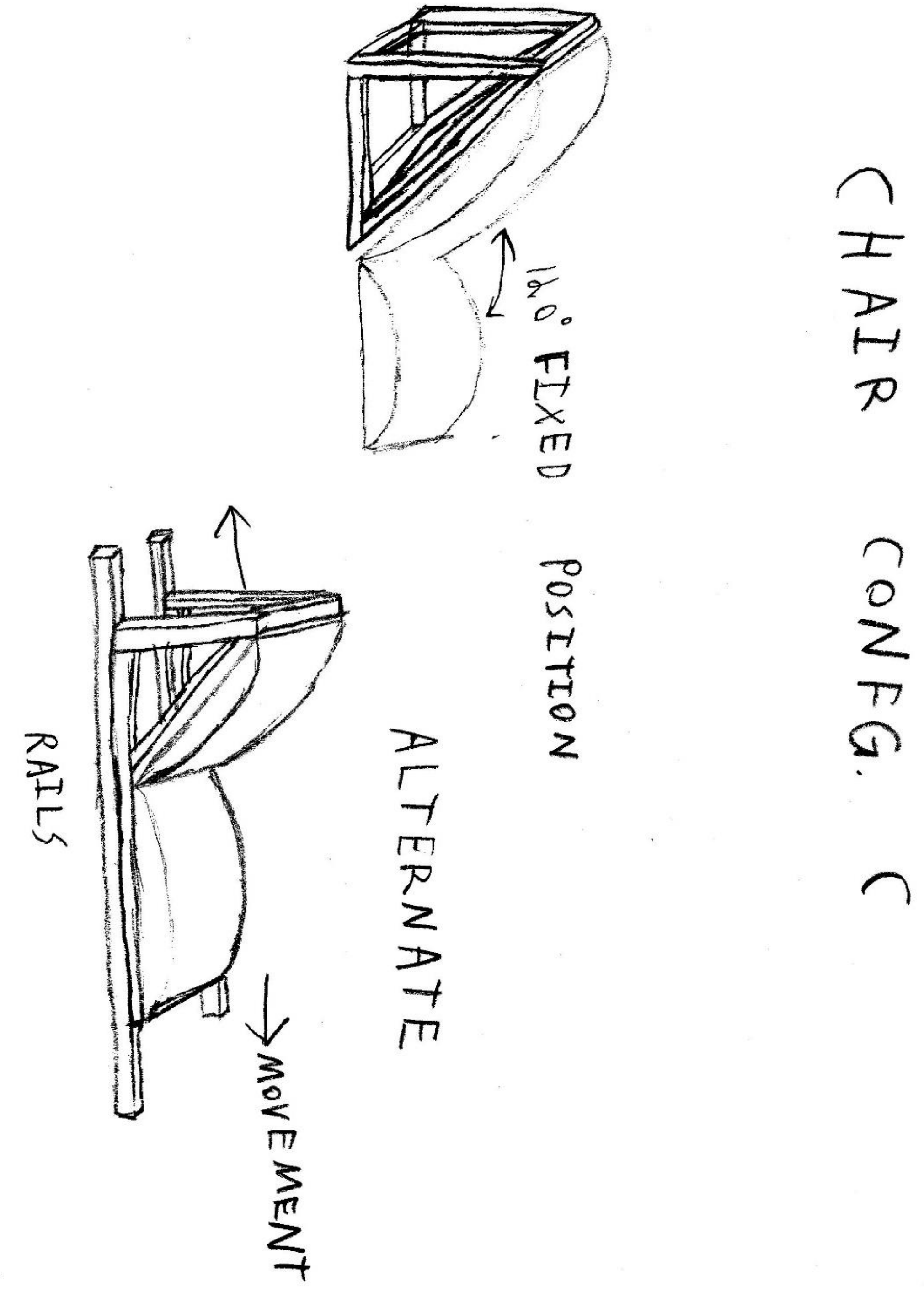
Chair Configuration Design Hand Sketch A



Chair Configuration Design Hand Sketch B



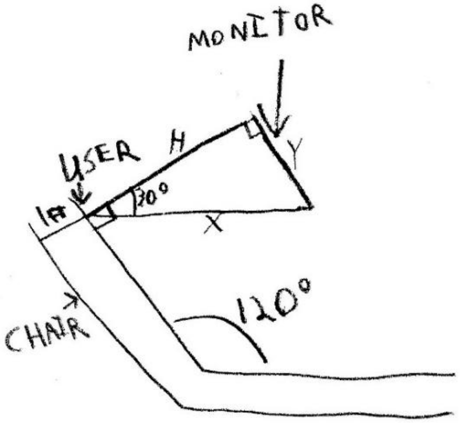
Chair Configuration Design Hand Sketch C

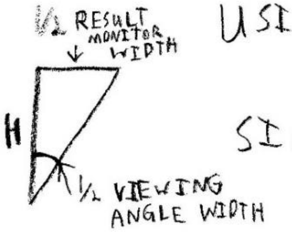


1-C: Monitor Position Hand Calculations

Monitor Position Hand Calculations Set 1

MONITOR POSITION CALCULATIONS





USING 19.5 IN MONITOR (10x17)

$\mathrm{SIN}(30) = \frac{10}{X}$

$\frac{10}{\mathrm{SIN}(30)} = X$

$X = 20$ IN

$\mathrm{SIN}(60) = \frac{H}{20}$

$\mathrm{SIN}(60) \cdot 20 = H$

$17.32 = H$

52.28° WIDE VIEW

USING 24 IN MONITOR (12x21)

$\mathrm{SIN}(30) = \frac{12}{X}$

$\frac{12}{\mathrm{SIN}(30)} = X$

$X = 24$ IN

$\mathrm{SIN}(60) = \frac{H}{24}$

$H = \mathrm{SIN}(60) \cdot 24$

$H = 20.78$

53.62° WIDE VIEW

CALCULATE DISTANCE FROM MONITOR SIZE

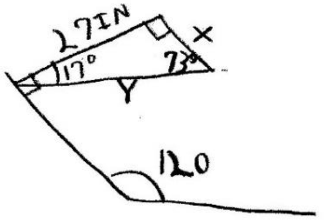
$H_{\mathrm{MIN}} = 12$ IN

$H_{\mathrm{MAX}} = 27$ IN

Monitor Position Hand Calculations Set 2

MONITOR POSITION CALCULATIONS CONT.

MONITOR SIZE
WITH GOALS
16.84 IN
DIAGONALLY



$180-90-17=73$

$\text{SIN}(73)=\frac{27}{Y}$

$\frac{27}{\text{SIN}(73)}=Y$

$28.2337=Y$

$\text{SIN}(17)=\frac{X}{28.2337}$

$\text{SIN}(17)\cdot 28.2337=X$

$8.255=X$

GOALS

30° VIEWING ANGLE WIDTH

27 IN VIEWING DISTANCE

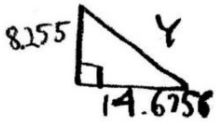
17° VIWING ANGLE HEIGHT

GOAL DATA TAKEN FROM
DATED RESEARCH, BEFORE
16:9 ASPECT RATIO STANDARD

SCREEN
DIAGONAL
CALC.

$\frac{16}{9}=\frac{X}{8.255}$

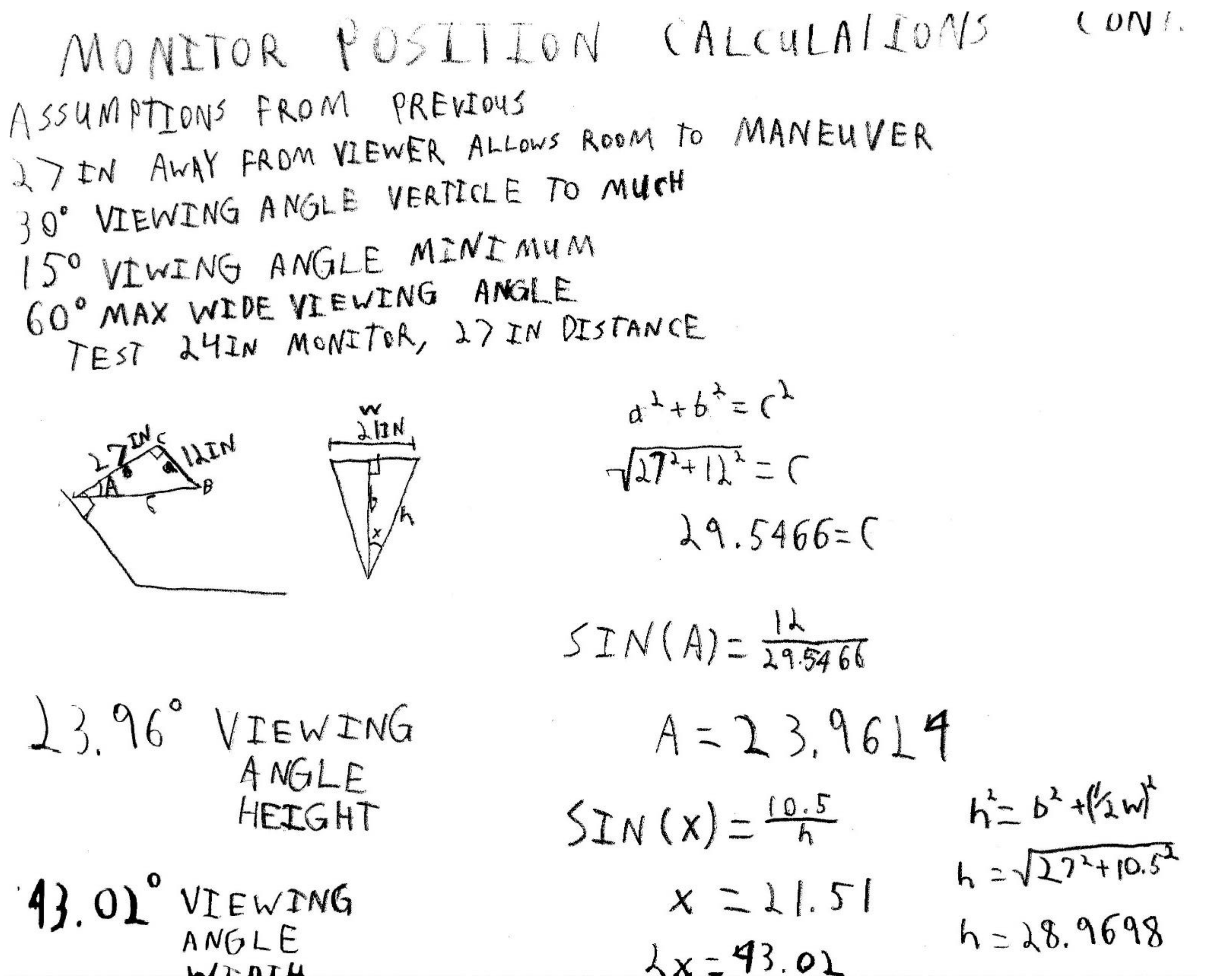
$X=14.6756$



$\sqrt{8.255^2+14.6756^2}=Y$

$Y=16.84$

Monitor Position Hand Calculations Set 3



MONITOR POSITION CALCULATIONS CONT

ASSUMPTIONS FROM PREVIOUS
27 IN AWAY FROM VIEWER ALLOWS ROOM TO MANEUVER
30° VIEWING ANGLE VERTICLE TO MUCH
15° VIWING ANGLE MINIMUM
60° MAX WIDE VIEWING ANGLE
TEST 24IN MONITOR, 27 IN DISTANCE

$a^2 + b^2 = c^2$

$\sqrt{27^2 + 12^2} = c$

$29.5466 = c$

$SIN(A) = \frac{12}{29.5466}$

$A = 23.9614$

23.96° VIEWING ANGLE HEIGHT

$SIN(x) = \frac{10.5}{h}$

$h^2 = b^2 + (\frac{1}{2}w)^2$

$h = \sqrt{27^2 + 10.5^2}$

$h = 28.9698$

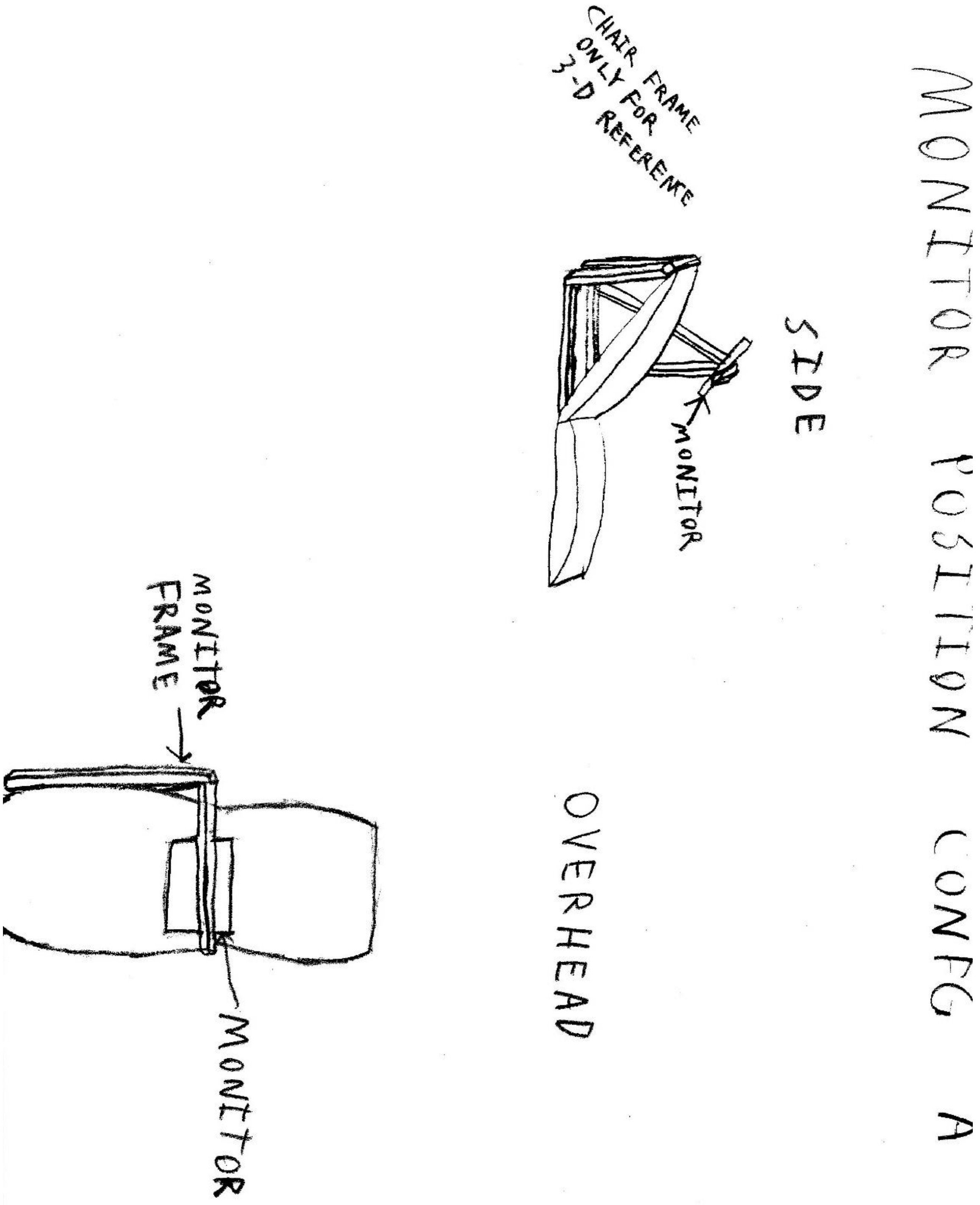
$x = 21.51$

$2x = 43.02$

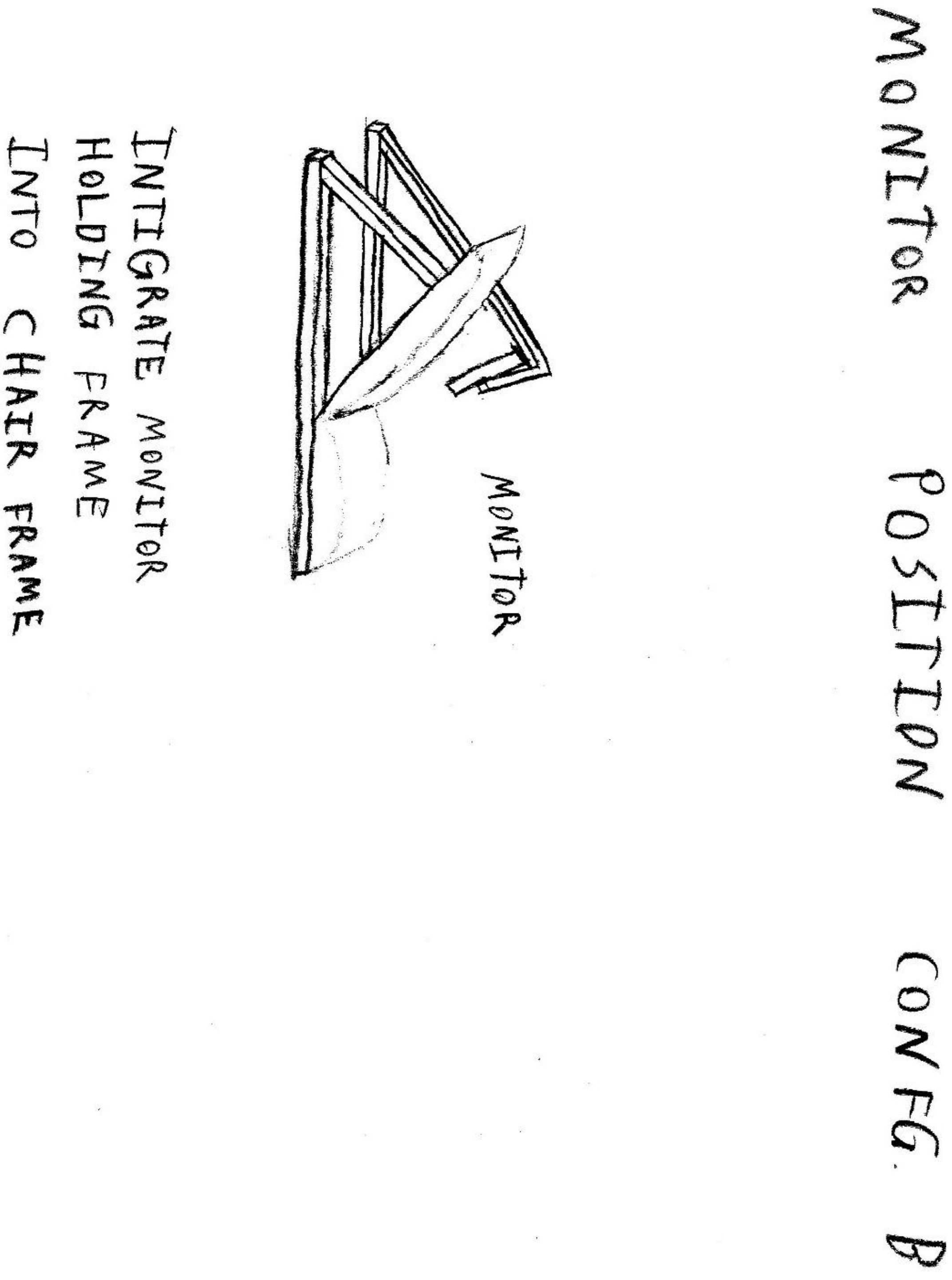
43.02° VIEWING ANGLE WIDTH

1-D: Monitor Position Configuration Design Hand Sketches

Monitor Position Configuration Design Hand Sketch A

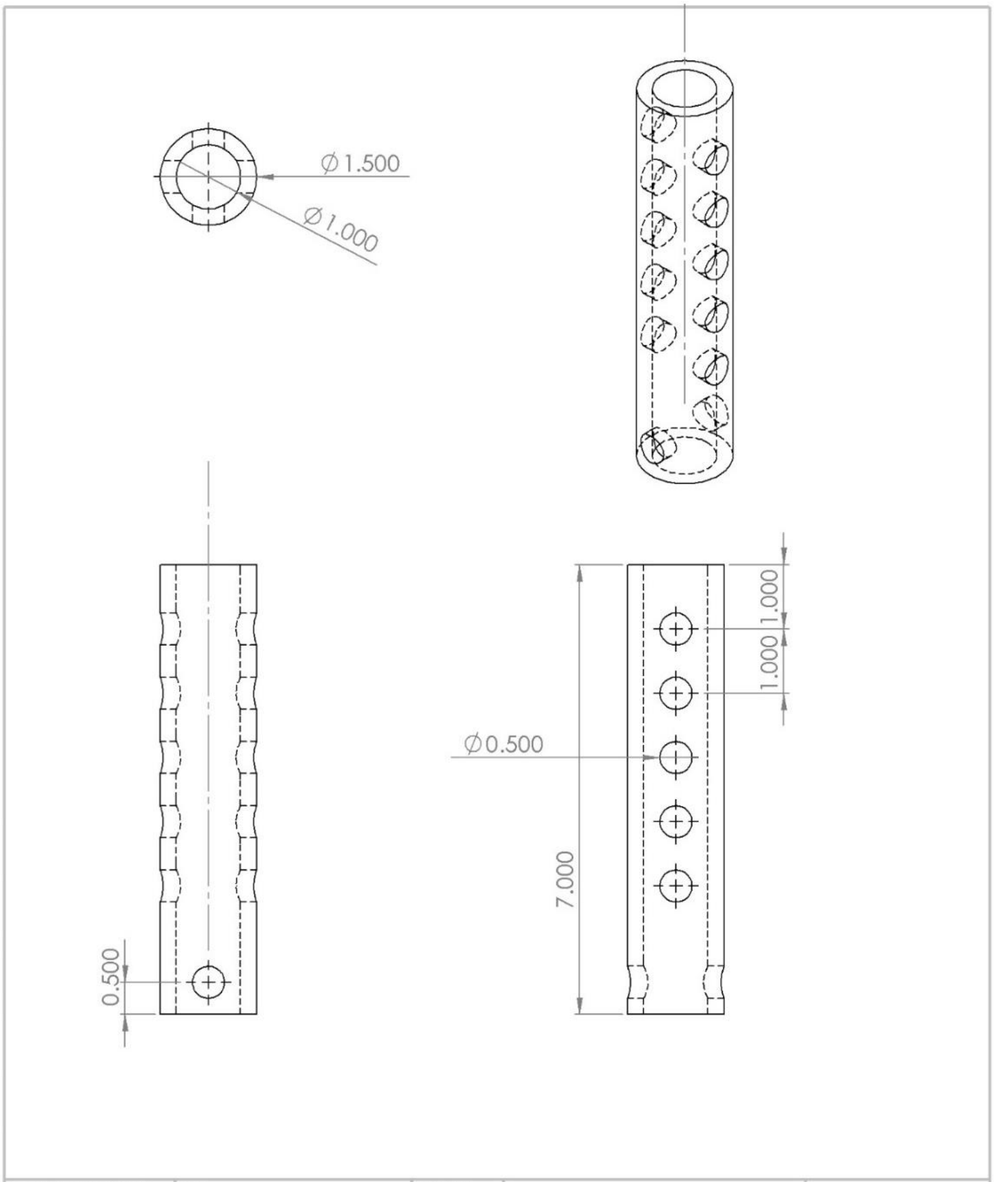


Monitor Position Configuration Design Hand Sketch B



2-A: Detailed Part Drawings

Armrest Bottom Support



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
SURFACE FINISH:
TOLERANCES:
LINEAR: ± 0.005
ANGULAR: ± 0.5

FINISH:

DEBUR AND
BREAK SHARP
EDGES

DO NOT SCALE DRAWING

REVISION

APRIL 2015

APPLICATION OF MODERN ERGONOMICS IN
COMPUTER WORKSTATIONS TO ALLEVIATE HEALTH
RISKS FROM EXTENDED COMPUTER USE

TITLE:
armrest bot sup

JOHN MICHAEL AWBREY

MOREHEAD STATE UNIVERSITY

MATERIAL:

DWG NO.
1

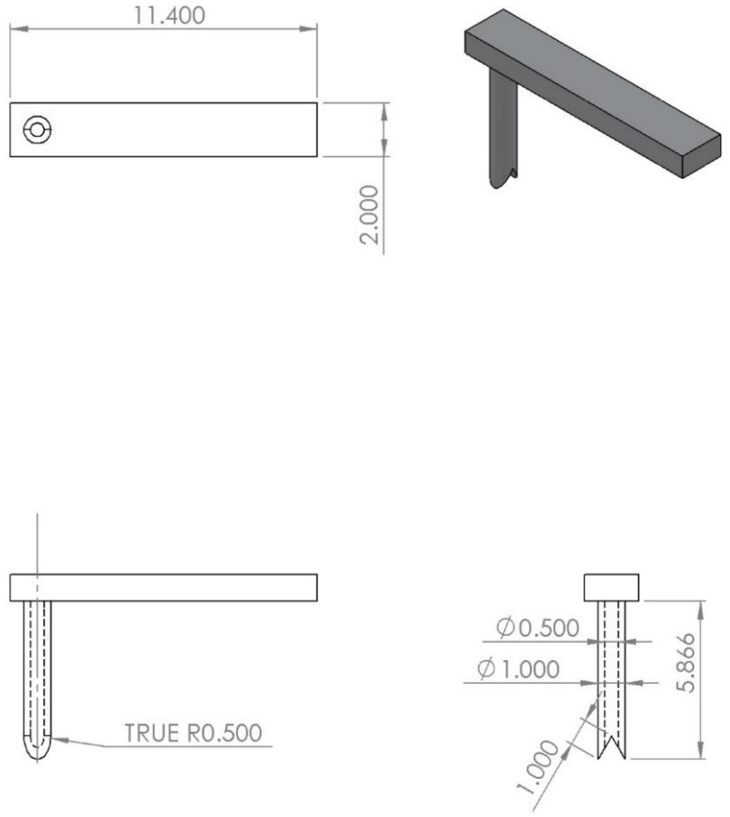
A4

WEIGHT:

SCALE:1:2

SHEET 1 OF 1

Armrest



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FINISH:

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TITLE:

ARMREST

JOHN MICHAEL AWBREY

MOREHEAD STATE UNIVERSITY

MATERIAL:

DWG NO.

2

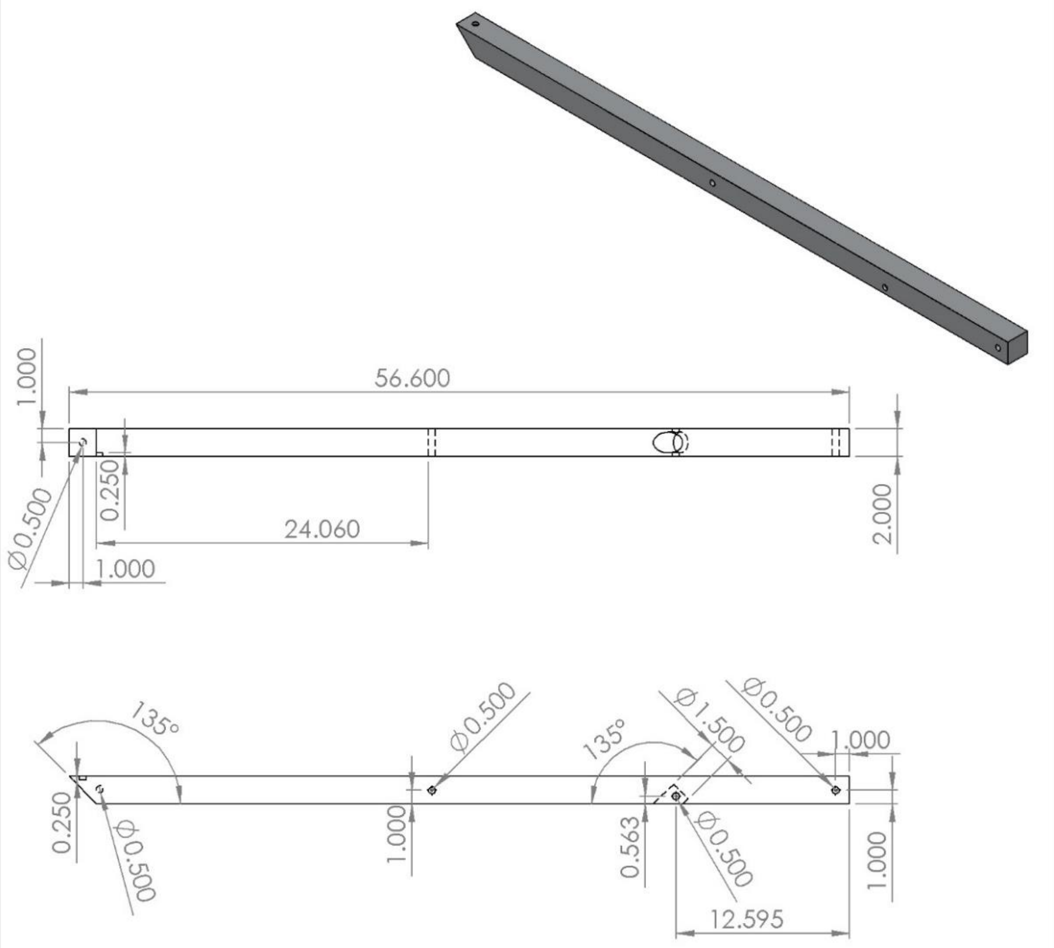
A4

WEIGHT:

SCALE:1:5

SHEET 1 OF 1

Back Support Bar, Long



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JOHN MICHAEL AWBREY

MOREHEAD STATE UNIVERSITY

MATERIAL:

TITLE:
BACK SUP BAR LONG

DWG NO.
3

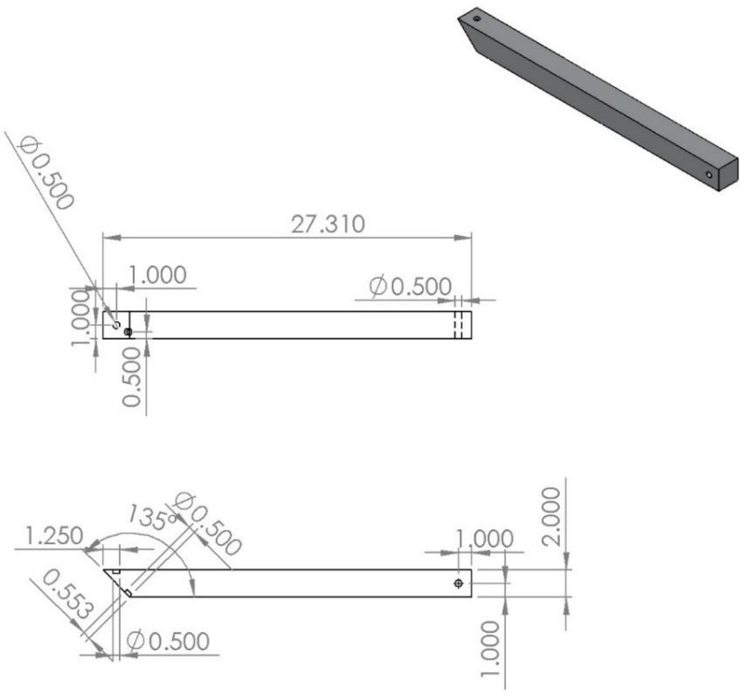
A4

WEIGHT:

SCALE 1:10

SHEET 1 OF 1

Back Support Bar Short



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ANGULAR: ± 0.5

FINISH:

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BREAK SHARP
EDGES

DO NOT SCALE DRAWING

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COMPUTER WORKSTATIONS TO ALLEVIATE HEALTH
RISKS FROM EXTENDED COMPUTER USE

TITLE:
BACK SUP BAR SHORT

JOHN MICHAEL AWBREY

MOREHEAD STATE UNIVERSITY

MATERIAL:

DWG NO.
4

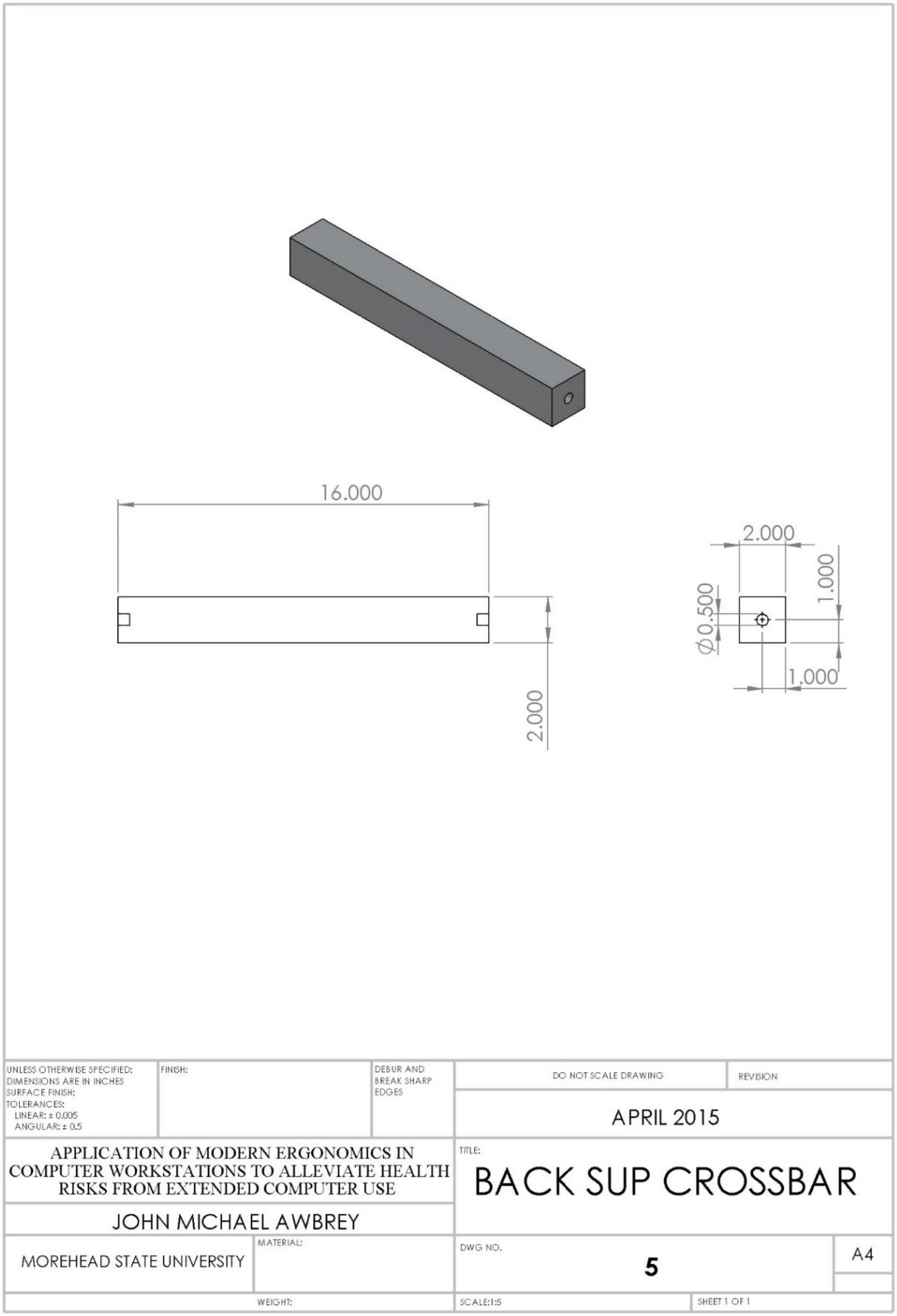
A4

WEIGHT:

SCALE:1:10

SHEET 1 OF 1

Back Support Crossbar



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ANGULAR: ± 0.5

FINISH:

DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

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TITLE: BACK SUP CROSSBAR

JOHN MICHAEL AWBREY

MOREHEAD STATE UNIVERSITY

MATERIAL:

DWG NO. 5

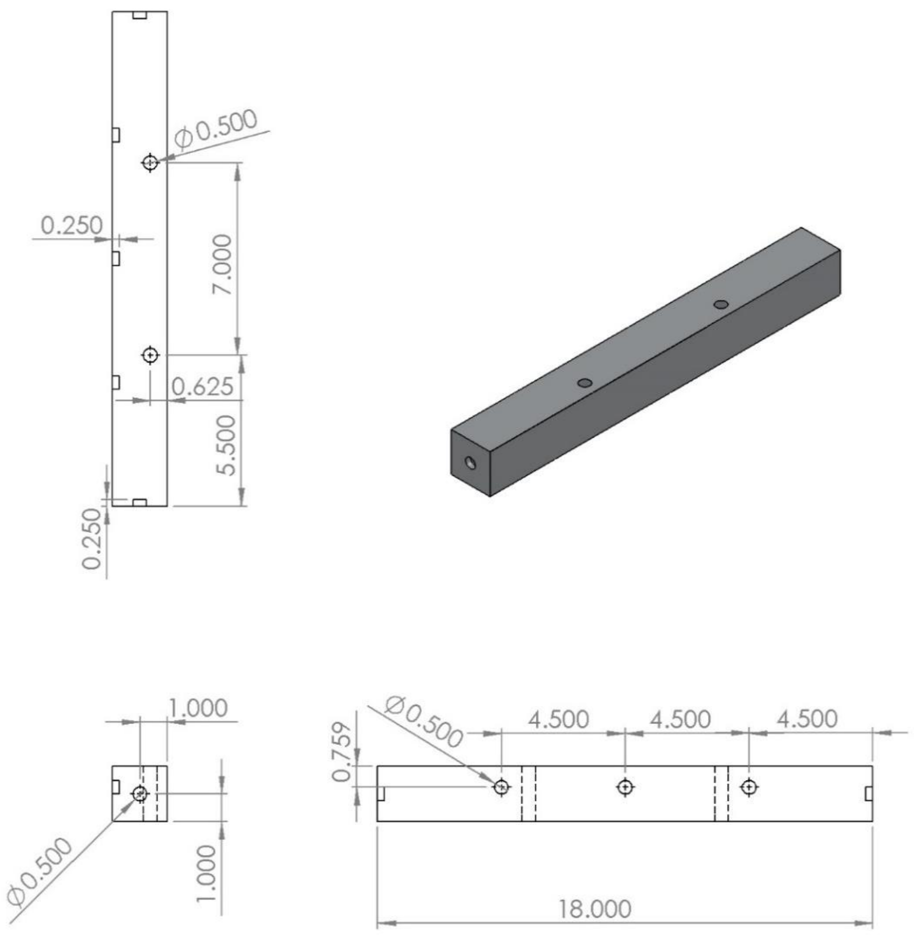
A4

WEIGHT:

SCALE:1:5

SHEET 1 OF 1

Bottom Support Bar Back



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ANGULAR: ± 0.5

FINISH:

DEBUR AND BREAK SHARP EDGES

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JOHN MICHAEL AWBREY

TITLE:

BOT SUP BACK

MOREHEAD STATE UNIVERSITY

MATERIAL:

DWG NO.

6

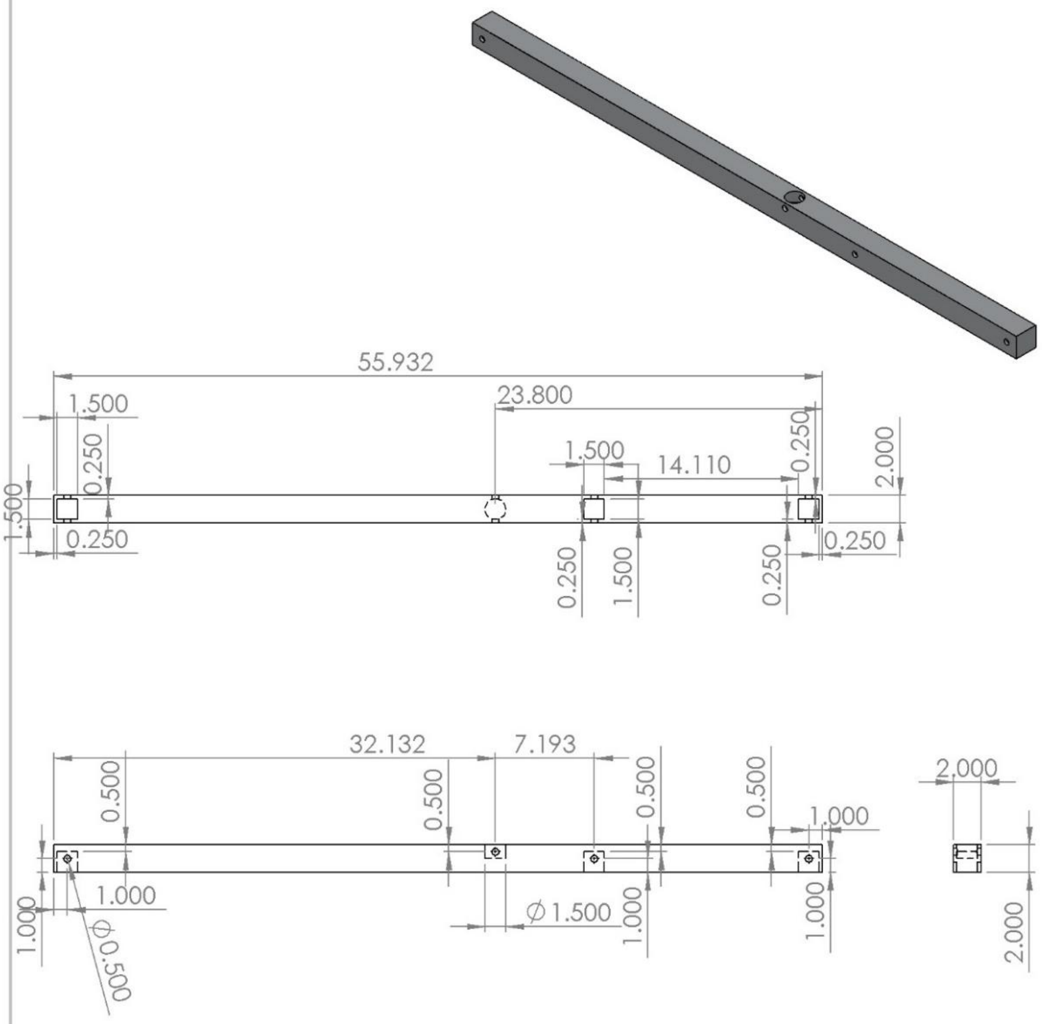
A4

WEIGHT:

SCALE:1:5

SHEET 1 OF 1

Bottom Support Bar Two



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ANGULAR: ± 0.5

FINISH:

DEBUR AND
BREAK SHARP
EDGES

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TITLE:

BOT SUP BAR 2

JOHN MICHAEL AWBREY

MOREHEAD STATE UNIVERSITY

MATERIAL:

DWG NO.

7

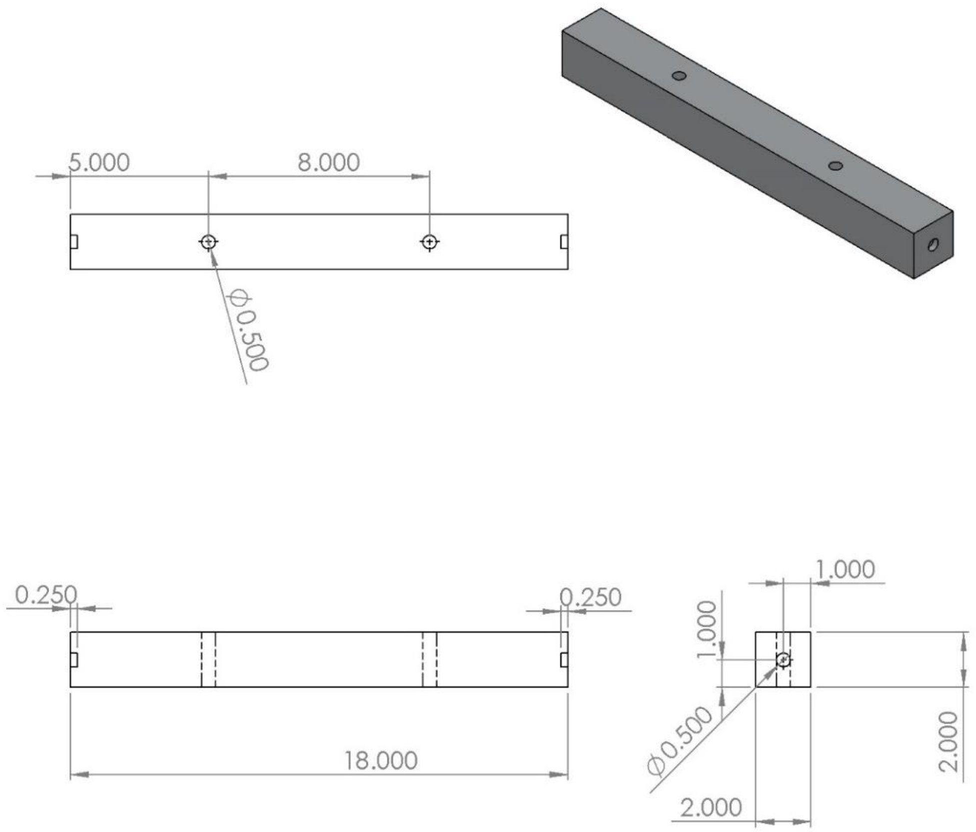
A4

WEIGHT:

SCALE: 1:10

SHEET 1 OF 1

Bottom Support Bar Front



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EDGES

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APPLICATION OF MODERN ERGONOMICS IN
COMPUTER WORKSTATIONS TO ALLEVIATE HEALTH
RISKS FROM EXTENDED COMPUTER USE

TITLE:

BOT SUP BAR FRONT

JOHN MICHAEL AWBREY

MOREHEAD STATE UNIVERSITY

MATERIAL:

DWG NO.

8

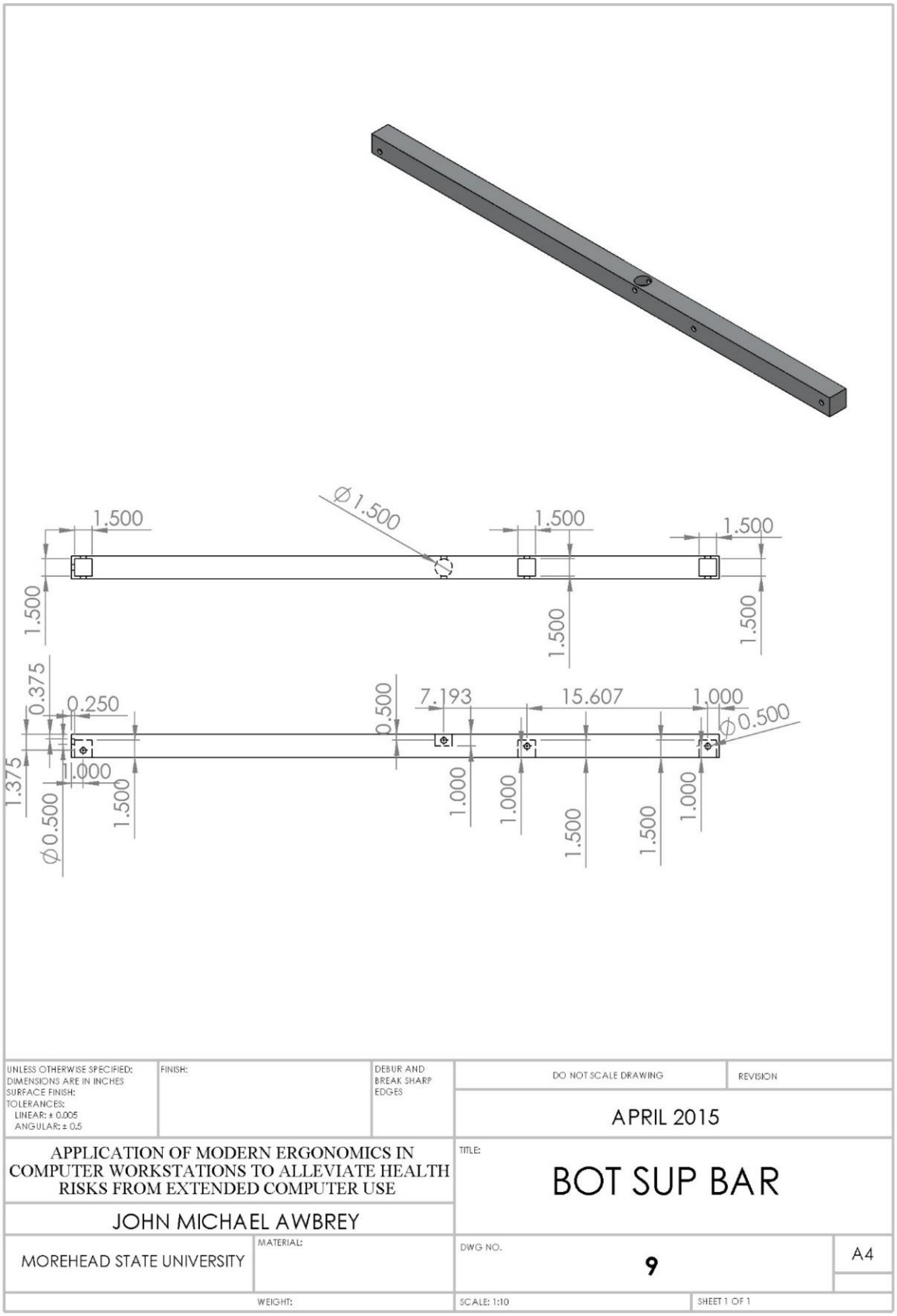
A4

WEIGHT:

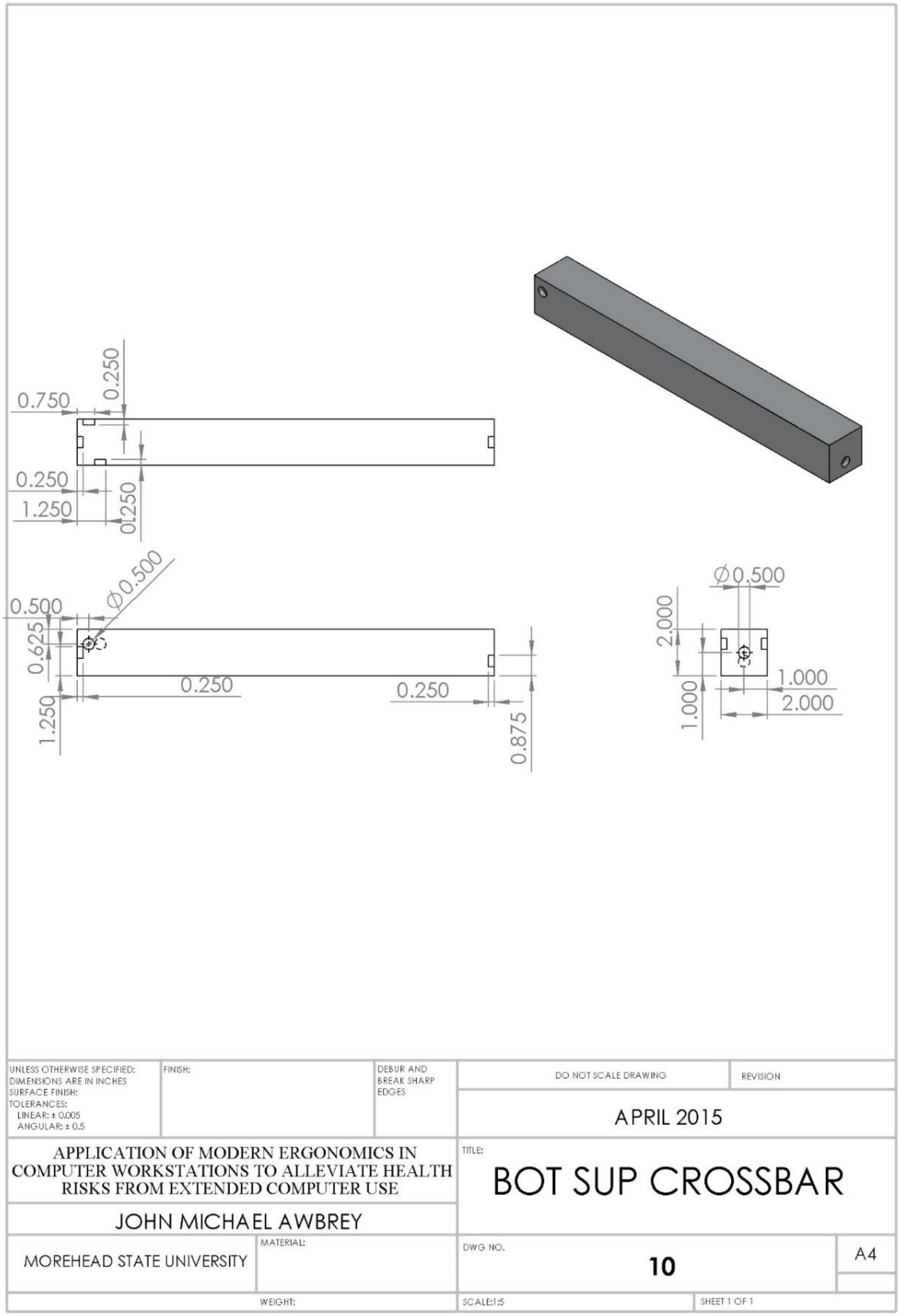
SCALE:1:5

SHEET 1 OF 1

Bottom Support Bar



Bottom Support Crossbar



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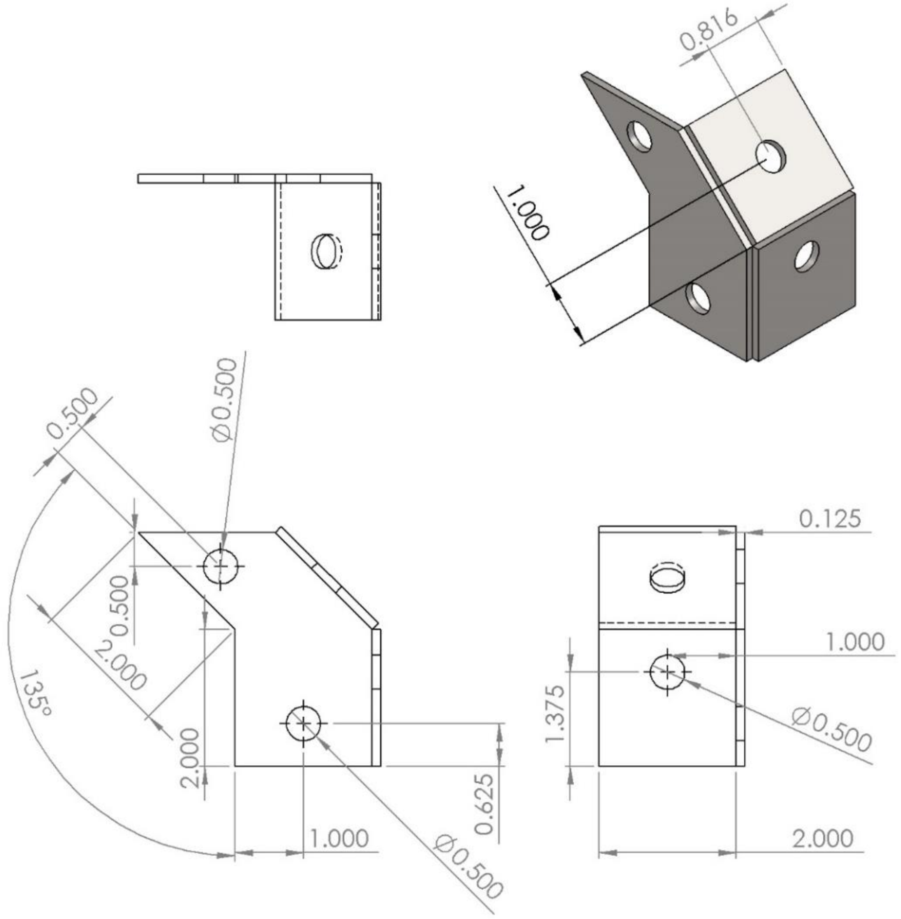

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ANGULAR: ± 0.5

FINISH:

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BREAK SHARP
EDGES

DO NOT SCALE DRAWING

REVISION

APRIL 2015

APPLICATION OF MODERN ERGONOMICS IN
COMPUTER WORKSTATIONS TO ALLEVIATE HEALTH
RISKS FROM EXTENDED COMPUTER USE

TITLE:
BRACKET 1

JOHN MICHAEL AWBREY

MOREHEAD STATE UNIVERSITY

MATERIAL:

DWG NO.
11

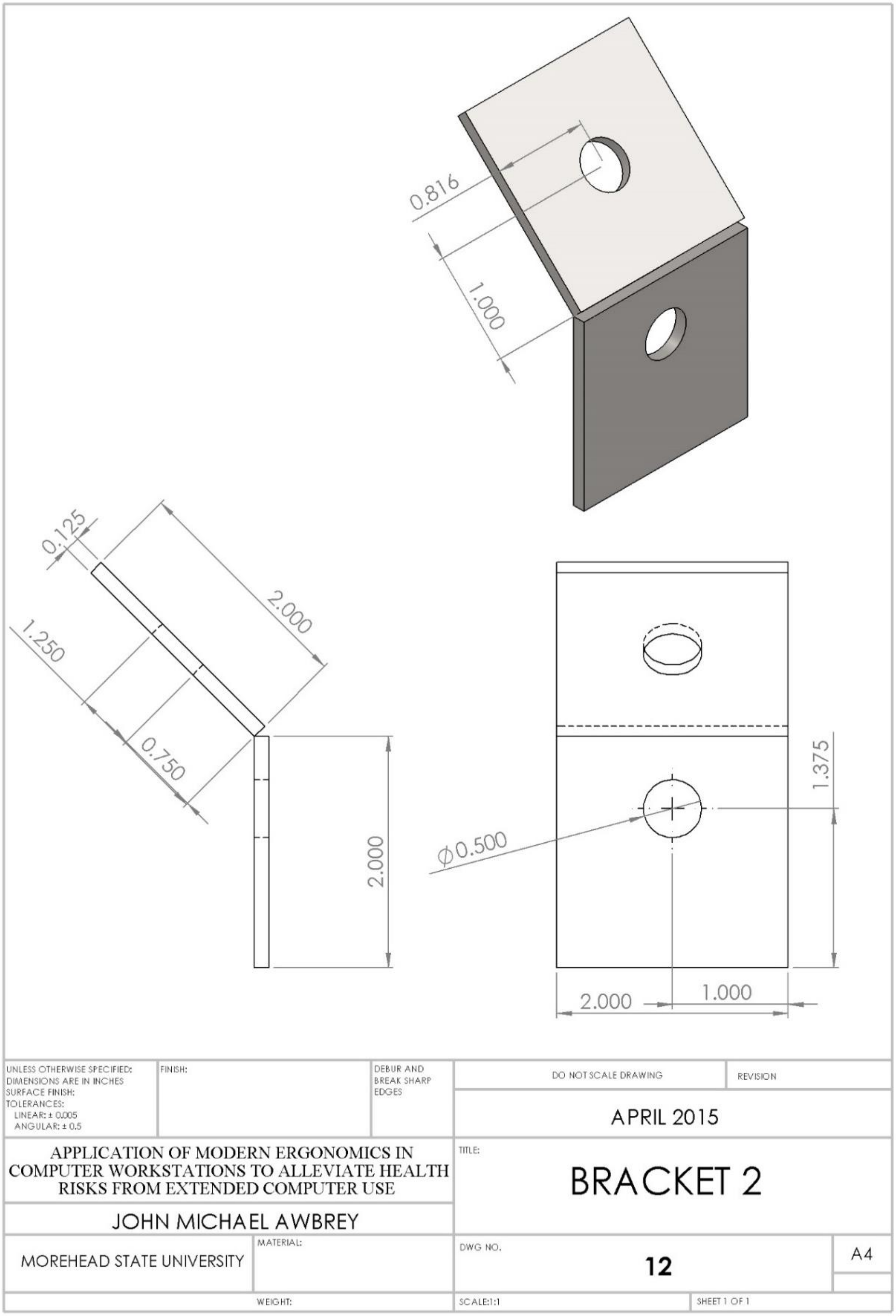
A4

WEIGHT:

SCALE:1:2

SHEET 1 OF 1

Bracket Two



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
SURFACE FINISH:
TOLERANCES:
LINEAR: ± 0.005
ANGULAR: ± 0.5

FINISH:

DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

APRIL 2015

APPLICATION OF MODERN ERGONOMICS IN COMPUTER WORKSTATIONS TO ALLEVIATE HEALTH RISKS FROM EXTENDED COMPUTER USE

JOHN MICHAEL AWBREY

MOREHEAD STATE UNIVERSITY

MATERIAL:

WEIGHT:

TITLE: BRACKET 2

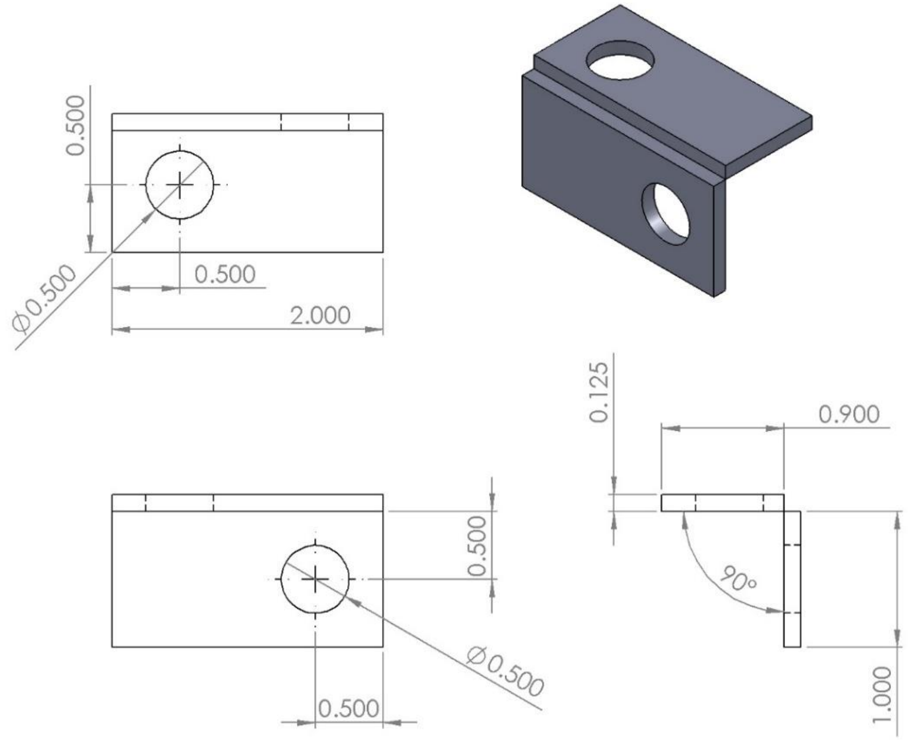
DWG NO. 12

A4

SCALE:1:1

SHEET 1 OF 1

Bracket Three



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
SURFACE FINISH:
TOLERANCES:
LINEAR: ± 0.005
ANGULAR: ± 0.5

FINISH:

DEBUR AND
BREAK SHARP
EDGES

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APRIL 2015

APPLICATION OF MODERN ERGONOMICS IN
COMPUTER WORKSTATIONS TO ALLEVIATE HEALTH
RISKS FROM EXTENDED COMPUTER USE

TITLE:

BRACKET 3

JOHN MICHAEL AWBREY

MOREHEAD STATE UNIVERSITY

MATERIAL:

DWG NO.

13

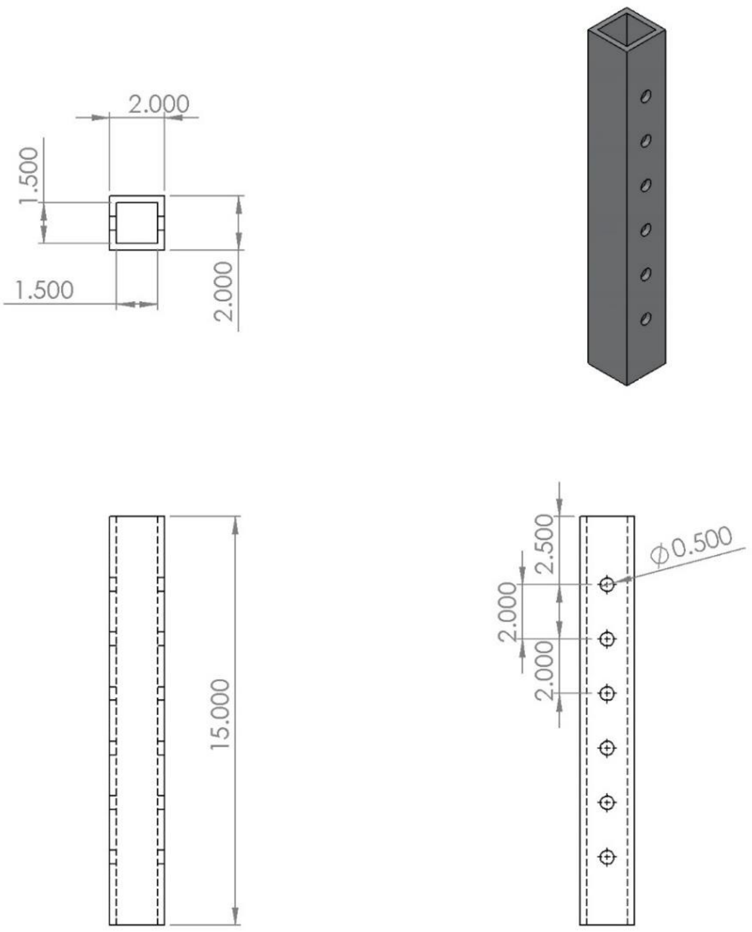
A4

WEIGHT:

SCALE:1:1

SHEET 1 OF 1

Leg Bottom



UNLESS OTHERWISE SPECIFIED:
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TOLERANCES:
LINEAR: ± 0.005
ANGULAR: ± 0.5

FINISH:

DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

APRIL 2015

APPLICATION OF MODERN ERGONOMICS IN COMPUTER WORKSTATIONS TO ALLEVIATE HEALTH RISKS FROM EXTENDED COMPUTER USE

TITLE:

LEG BOT

JOHN MICHAEL AWBREY

MOREHEAD STATE UNIVERSITY

MATERIAL:

DWG NO.

15

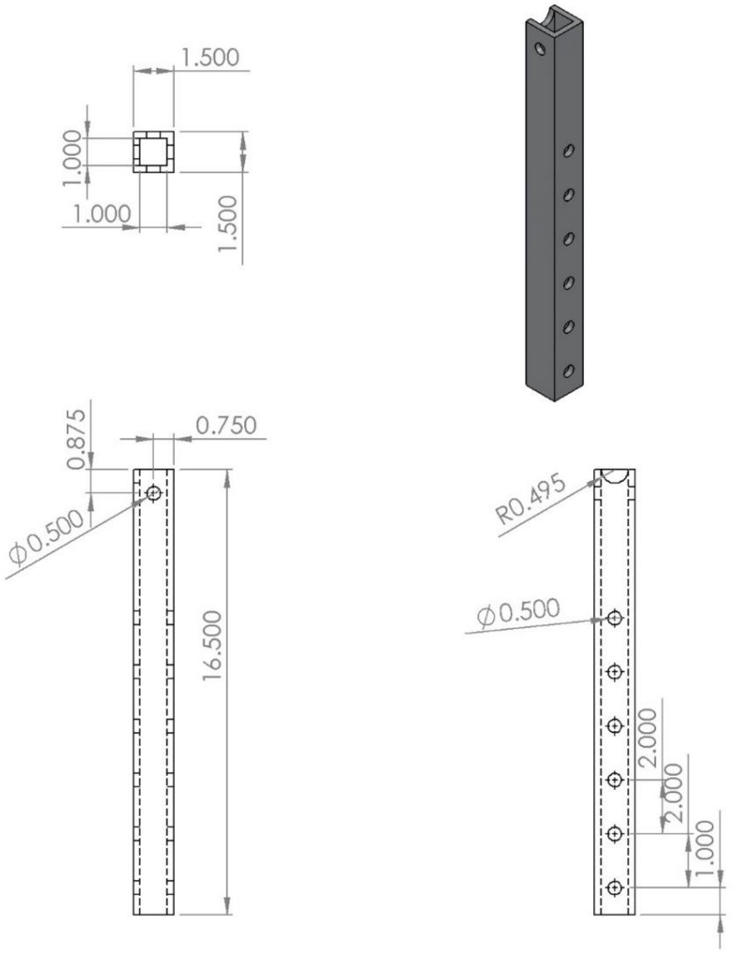
A4

WEIGHT:

SCALE:1:5

SHEET 1 OF 1

Leg Top Two



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
SURFACE FINISH:
TOLERANCES:
LINEAR: ± 0.005
ANGULAR: ± 0.5

FINISH:

DEBUR AND BREAK SHARP EDGES

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REVISION

APRIL 2015

APPLICATION OF MODERN ERGONOMICS IN COMPUTER WORKSTATIONS TO ALLEVIATE HEALTH RISKS FROM EXTENDED COMPUTER USE

TITLE:

LEG TOP 2

JOHN MICHAEL AWBREY

MOREHEAD STATE UNIVERSITY

MATERIAL:

DWG NO.

16

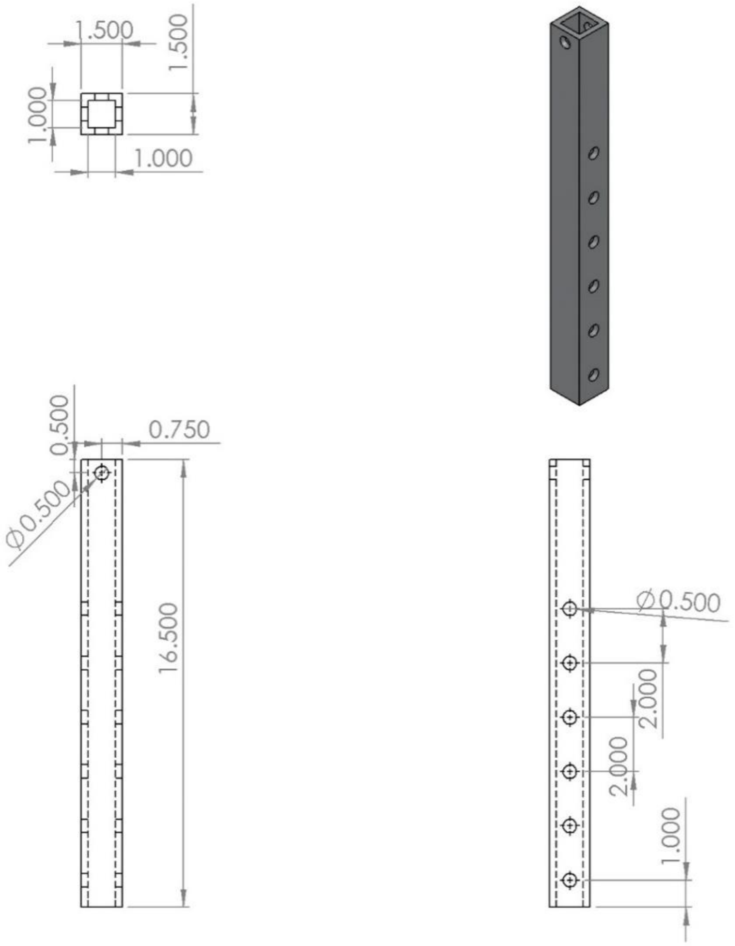
A4

WEIGHT:

SCALE:1:5

SHEET 1 OF 1

Leg Top



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
SURFACE FINISH:
TOLERANCES:
LINEAR: ± 0.005
ANGULAR: ± 0.5

FINISH:

DEBUR AND
BREAK SHARP
EDGES

DO NOT SCALE DRAWING

REVISION

APRIL 2015

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TITLE:

LEG TOP

JOHN MICHAEL AWBREY

MOREHEAD STATE UNIVERSITY

MATERIAL:

DWG NO.

17

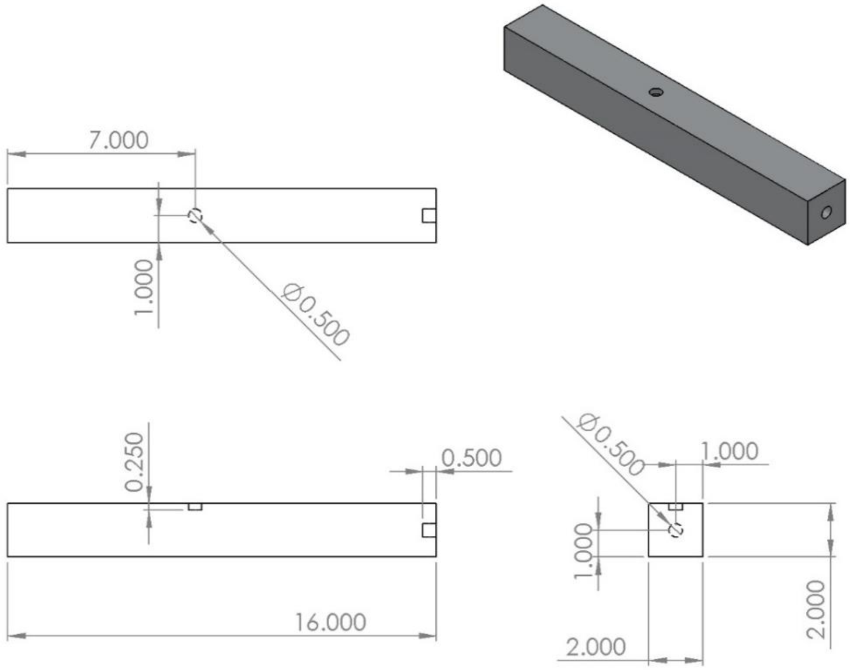
A4

WEIGHT:

SCALE:1:5

SHEET 1 OF 1

Monitor Crossbar



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RISKS FROM EXTENDED COMPUTER USE

TITLE:
MONITOR CROSSBAR

JOHN MICHAEL AWBREY

MOREHEAD STATE UNIVERSITY

MATERIAL:

DWG NO.
18

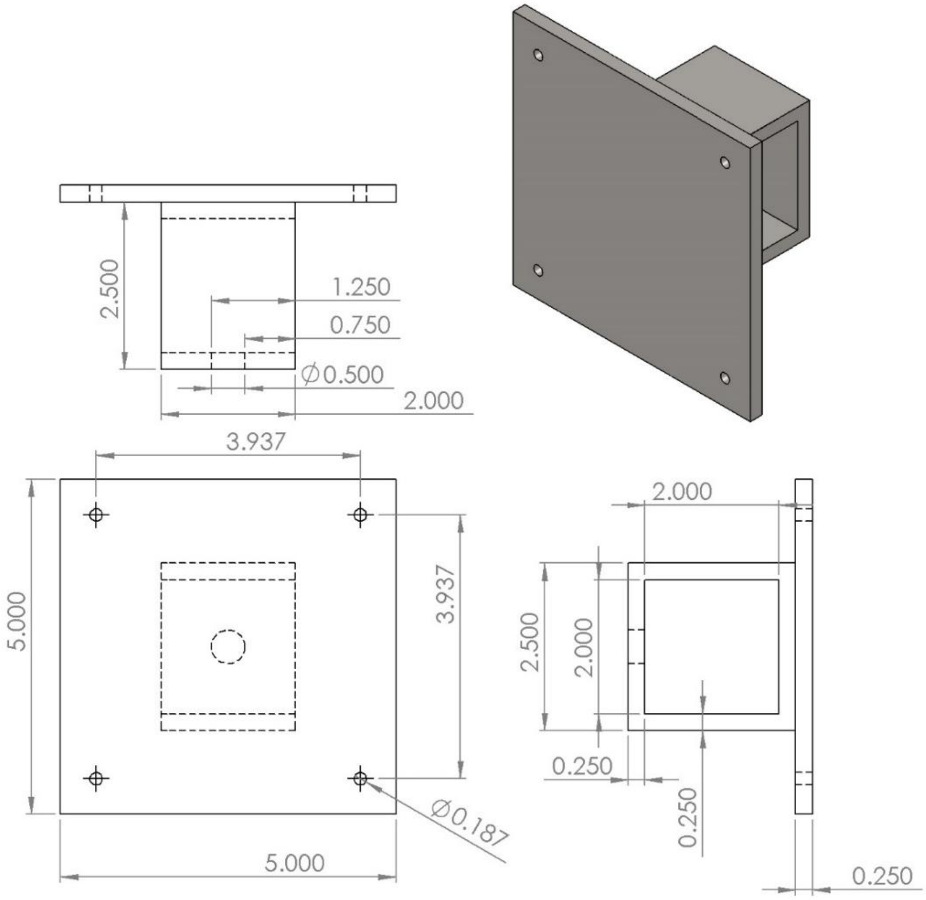
A4

WEIGHT:

SCALE:1:5

SHEET 1 OF 1

Monitor Mounting Bracket



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TITLE:
MOUNTING BRACKET

JOHN MICHAEL AWBREY

MOREHEAD STATE UNIVERSITY

MATERIAL:

DWG NO.
19

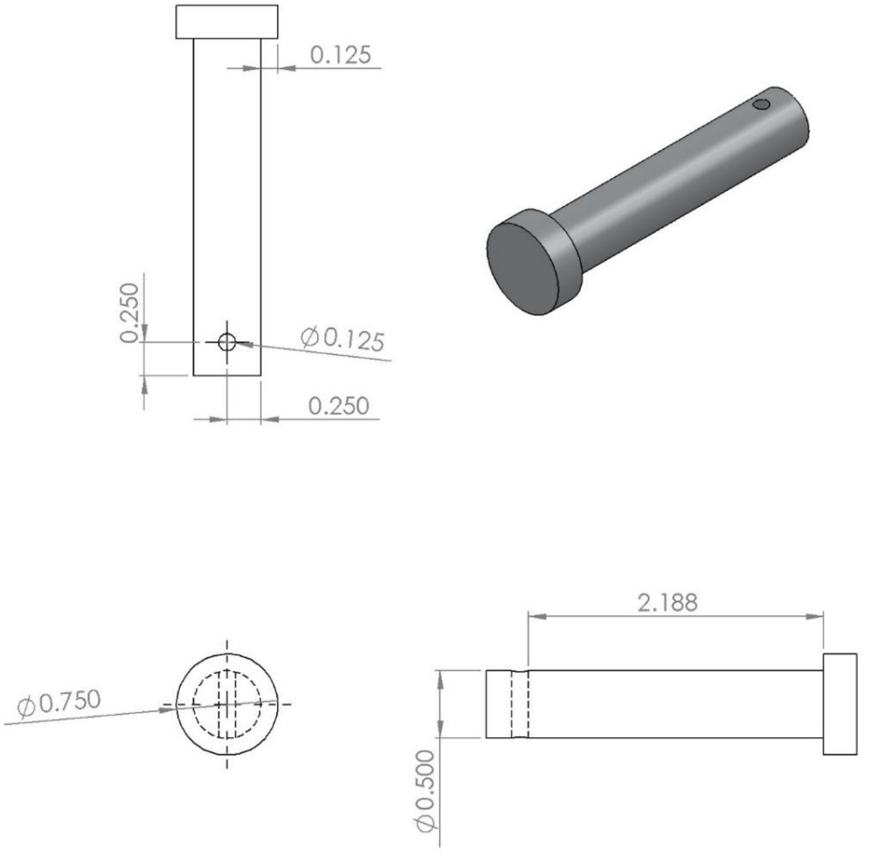
A4

WEIGHT:

SCALE:1:2

SHEET 1 OF 1

Pin



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RISKS FROM EXTENDED COMPUTER USE

TITLE:

PIN

JOHN MICHAEL AWBREY

MOREHEAD STATE UNIVERSITY

MATERIAL:

DWG NO.

20

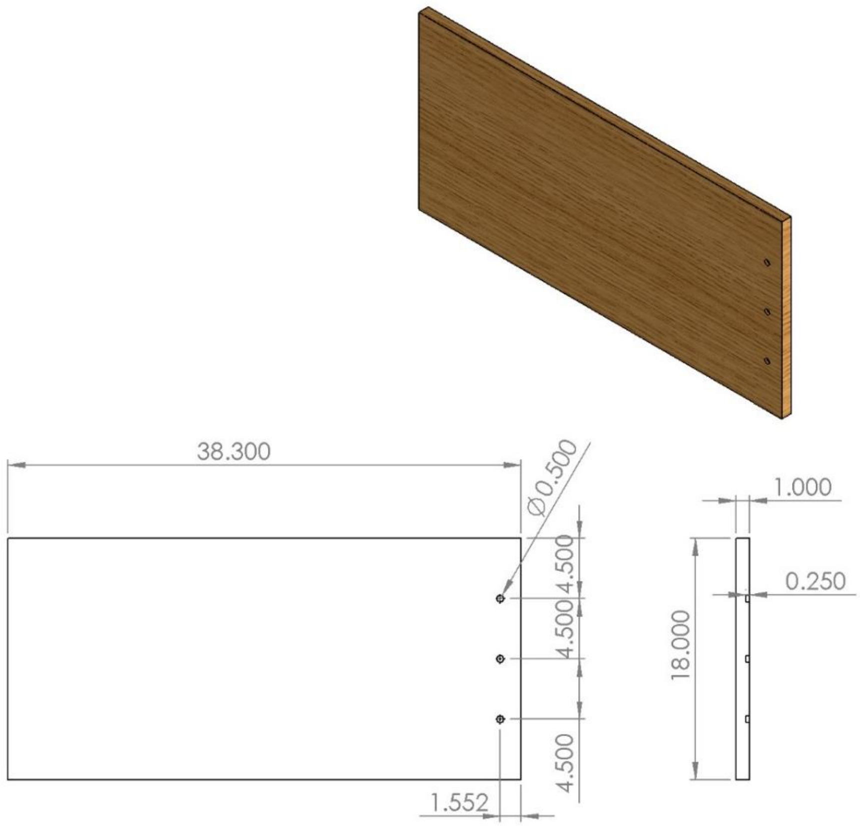
A4

WEIGHT:

SCALE:1:1

SHEET 1 OF 1

Seat Back



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APRIL 2015

APPLICATION OF MODERN ERGONOMICS IN COMPUTER WORKSTATIONS TO ALLEVIATE HEALTH RISKS FROM EXTENDED COMPUTER USE

JOHN MICHAEL AWBREY

MOREHEAD STATE UNIVERSITY

MATERIAL:

TITLE:

SEAT BACK

DWG NO.

21

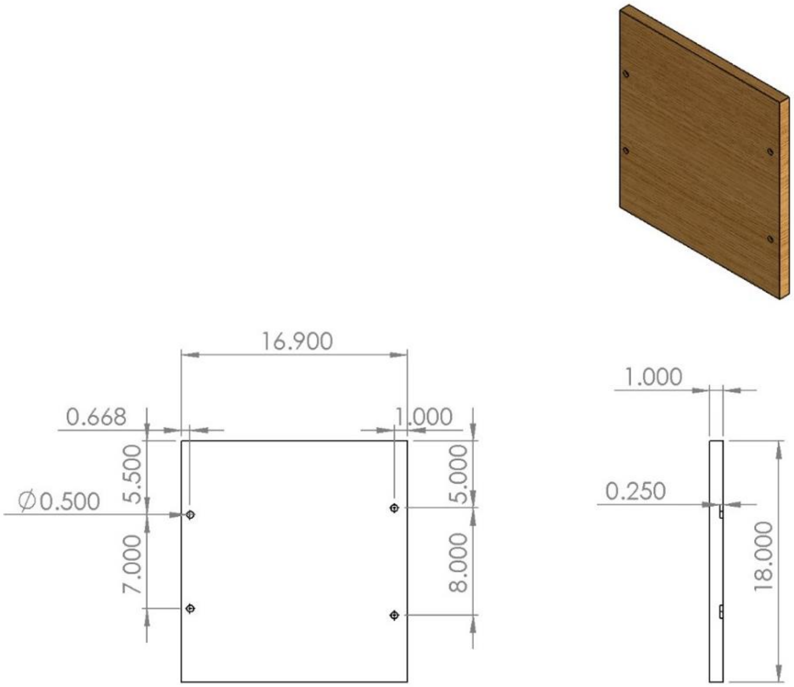
A4

WEIGHT:

SCALE: 1:10

SHEET 1 OF 1

Seat Bottom



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APPLICATION OF MODERN ERGONOMICS IN
COMPUTER WORKSTATIONS TO ALLEVIATE HEALTH
RISKS FROM EXTENDED COMPUTER USE

TITLE:

SEAT BOTTOM

JOHN MICHAEL AWBREY

MOREHEAD STATE UNIVERSITY

MATERIAL:

DWG NO.

22

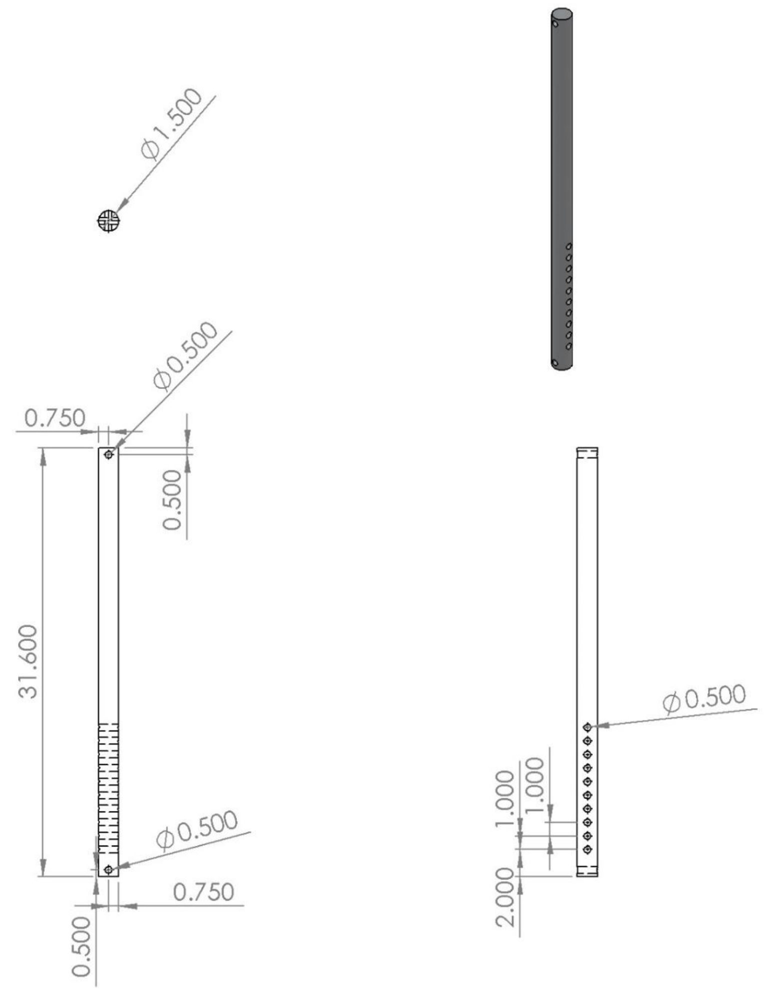
A4

WEIGHT:

SCALE:1:10

SHEET 1 OF 1

Tray Bar



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REVISION

APRIL 2015

APPLICATION OF MODERN ERGONOMICS IN
COMPUTER WORKSTATIONS TO ALLEVIATE HEALTH
RISKS FROM EXTENDED COMPUTER USE

TITLE:

TRAY BAR

JOHN MICHAEL AWBREY

MOREHEAD STATE UNIVERSITY

MATERIAL:

DWG NO.

23

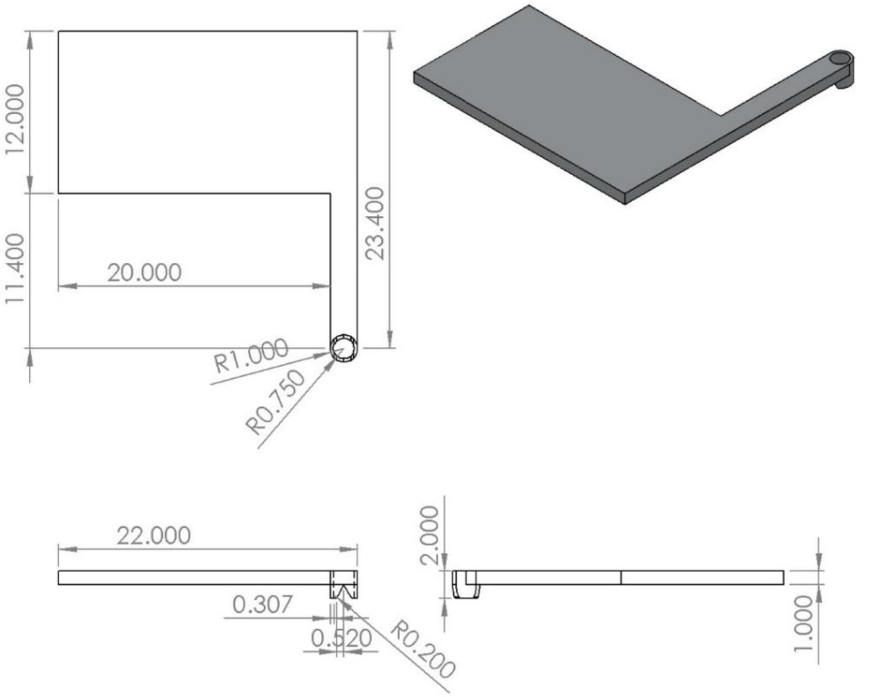
A4

WEIGHT:

SCALE:1:10

SHEET 1 OF 1

Tray

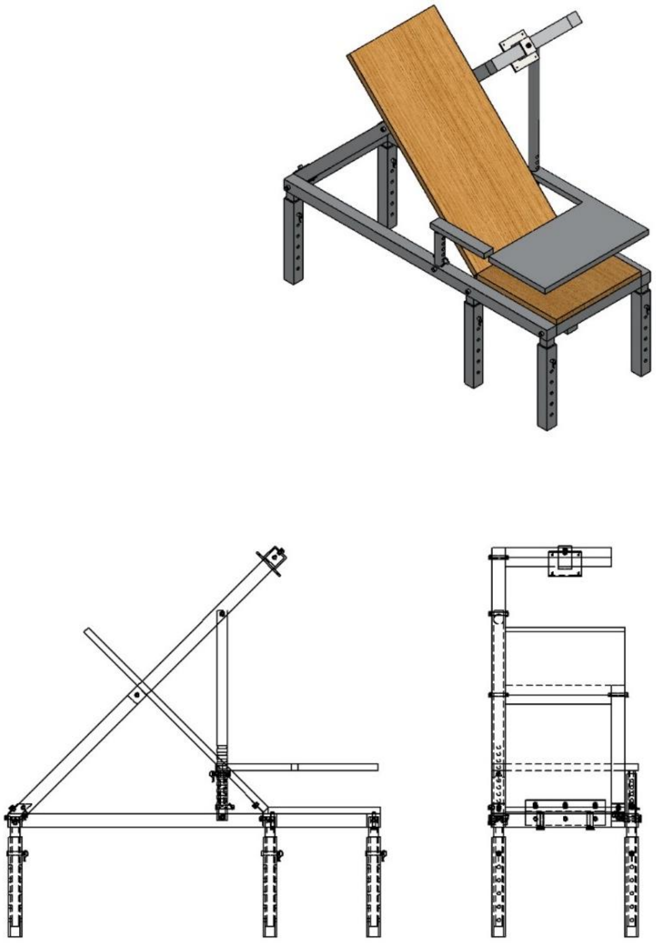


UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES SURFACE FINISH: TOLERANCES: LINEAR: ± 0.005 ANGULAR: ± 0.5	FINISH:	DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING APRIL 2015	REVISION
APPLICATION OF MODERN ERGONOMICS IN COMPUTER WORKSTATIONS TO ALLEVIATE HEALTH RISKS FROM EXTENDED COMPUTER USE JOHN MICHAEL AWBREY			TITLE: TRAY	
MOREHEAD STATE UNIVERSITY	MATERIAL:		DWG NO. **24**	A4
	WEIGHT:		SCALE: 1:10	SHEET 1 OF 1

2-B: Full Assembly Drawings and Renderings

Full Assembly and Parts List Technical Drawing

ITEM NO.	PART NUMBER	Default/QTY.
1	SEAT BACK	1
2	SEAT BOTTOM	1
3	BOT SUP BAR	1
4	BACK SUP BAR SHORT	1
5	BOT SUP CROSSBAR	1
6	BACK SUP BAR LONG	1
7	BACK SUP CROSSBAR	1
8	TRAY BAR	1
9	TRAY	1
10	ARMREST BOT SUP	1
11	ARMREST	1
12	LEG TOP	5
13	LEG BOT	6
14	PIN 1	8
15	BRACKET 1	1
16	BOT SUP BAR 2	1
17	BRACKET 2	1
18	BRACKET 3	1
19	BOT SUP BACK	1
20	BRACKET 4	1
21	BOT SUP BAR FRONT	1
22	LEG TOP 2	1
23	SMALL SPRING	8
24	MONITOR CROSSBAR	1
25	MOUNTING BRACKET	1
26	HX-SHCS 0.4375-14x2.25x1.625-N	12
27	HX-SHCS 0.4375-14x2.5x1.375-N	3
28	HX-SHCS 0.4375-14x0.4375x0.4375-N	15
29	HNUT 0.4375-14-D-N	3



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REVISION

APRIL 2015

APPLICATION OF MODERN ERGONOMICS IN COMPUTER WORKSTATIONS TO ALLEVIATE HEALTH RISKS FROM EXTENDED COMPUTER USE

TITLE:

FULL ASSEMBLY

JOHN MICHAEL AWBREY

MOREHEAD STATE UNIVERSITY

MATERIAL:

DWG NO.

25

A4

WEIGHT:

SCALE:1:20

SHEET 1 OF 1

Exploded View of Assembly