THE PENNSYLVANIA STATE UNIVERSITY
SCHREYER HONORS COLLEGE

DEPARTMENT OF MECHANICAL AND NUCLEAR ENGINEERING

DESIGN IMPROVEMENTS TO ROBOTIC PARALLEL BARS FOR REHABILITATION

MEGAN DOERZBACHER
SPRING 2014

A thesis
submitted in partial fulfillment
of the requirements
for baccalaureate degrees
in Mechanical Engineering and Nuclear Engineering
with honors in Mechanical Engineering

Reviewed and approved* by the following:

Jason Moore
Professor of Mechanical Engineering
Thesis Supervisor

Domenic Santavicca
Professor of Mechanical Engineering
Honors Adviser

* Signatures are on file in the Schreyer Honors College.

ABSTRACT

For the millions of people relearning the basic skill of walking, robotic devices are increasingly becoming a part of the rehabilitation process. A need still exists, however, for improved monitoring and feedback about the patients' performance. On most devices, the patients' reliance cannot be measured; the therapist is not able to quantitatively measure how much body weight is supported by the device and how much the patient is supporting. This need also appears in the evaluation of geriatric patients: an accurate way to measure the patient's ability to walk could help to identify fall-prone individuals. This project seeks to satisfy that need by attaching force sensors to the Robotic Parallel Bars (RPB) device to measure the amount of weight the patient is applying to the parallel bars. This data will assist the therapists in monitoring the patient's progress and allow them to create more effective treatment plans. Other improvements to the device will allow for enhanced stability. This is done by changing the supporting bars from aluminum to stainless steel and by redesigning the height adjustment mechanism, which was previously very unstable. Better stability in the device will mean enhanced safety for the patient, which is a fundamental need. Safety is of utmost importance for this application. After making these improvements to the RPB, the device should make the patient's recovery faster and the therapist's job easier.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

I would like to thank Dr. Jason Moore for giving me the opportunity to work on this project. I greatly appreciate his help, guidance and patience with this thesis project. I would also like to thank Andrew Homich for his endless advice and help in making this project happen. Additionally, I would like to thank the staff at the Learning Factory for their manufacturing advice and patience.

Finally, I would like to thank my parents and siblings for their support and encouragement, not only during the writing of this thesis but throughout my life. Without their support, this thesis would not have been possible.

Chapter 1

Introduction

1.1 Background

For the millions of people in the world currently facing the difficult challenge of learning how to walk again, top-of-the-line rehabilitation is necessary to return them to their previous quality of living. Among the causes of adult disability are stroke, spinal cord injury and amputation. Each of these disrupts a patient’s life and sense of independence, and it necessitates costly physical therapy rehabilitation. With the help of current technology and skilled professionals, rehabilitation is an attainable feat; however, the process has room for improvement so that therapists can better assess the progress of their patients. A way to quantitatively measure the patient’s ability to walk would be extremely valuable. This project seeks to achieve this by measuring the amount of body weight supported by the device and, therefore, the amount of weight the patient is supporting.

A related issue is the need for gait assessment in the geriatric population. Fall events have a very high incidence rate in the elderly population and present a considerable health risk. Many therapists will utilize videos of the patient walking to identify at-risk patients, and there has also been progress in using various sensors to monitor the patient’s gait [1]. However, while there have been efforts to identify fall-prone individuals, these tests can be subjective and inconsistent at times [2]. A more advanced way to assess the walking proficiency of geriatric patients is necessary.

1.2 Rehabilitations Devices and Techniques

In more traditional rehabilitation processes, the patient generally begins the process using parallel bars. The patients are able to support much of their body weight using their arms, although the amount of reliance is unknown to the physician. This makes assessment of the patient's performance difficult [3]. The patient has only a short distance to walk and must do so in a straight line. Additionally, to identify gait abnormalities, the methods for assessment are currently to observe the patient or watch a video of the patient's session. This is very subjective, and physicians may overlook actions that need correction. There are multicamera systems that can be used to track the patient's gait, but these systems are very expensive and, as a result, are not used very often in practice [4]. Due to these shortcomings, a shift toward implementing technology, especially robotics, has occurred.

Figure 1: Parallel bars used for rehabilitation [image from www.especialneeds.com]

One of the recent methods is body-weight supported treadmill training (BWSTT), in which the patient can walk on a treadmill, with variable amounts of his or her body weight supported by wearing a harness. In BWSTT, the therapist, or often two therapists, can manually move the patient's legs to ensure correct gait. This is very labor-intensive for the therapists, which results in short training sessions due to high physical demands and time costs on the therapists [4]. The training sessions are limited by the physical fitness of the therapist, which may cause shorter sessions than are required for optimal recovery. This issue led to the idea that the assistance of the therapists could be automated with a robot.

Several different models of gait training robotic devices have been developed for use in conjunction with a treadmill. Among these, the Lokomat has become one of the leading devices, along with the GaitTrainer, LOPES and others [5]. While these devices certainly have their advantages, there are still some areas they fail to address. For example, the treadmill only allows the patient to walk straight. This is obviously very different from everyday life, where people are required to stop, turn or slow down very often. Additionally, there is a lack of variability in movement. While sometimes this is also a strength of the device, when considering the differences in step length, step width and center of mass encountered in everyday life, this is a vital element for skilled, adaptable walking [6]. It has been asserted that while repeatable motions can help to build muscle strength and endurance, people (especially stroke patients) need to practice with varying conditions so they can develop motor schemata and can adjust to the situations encountered in daily life [7].

Figure 2: The Lokomat gait training device [image from www.bronx.va.gov]

Another criticism for these devices is the unnatural forcing of the gait; they may promote laziness or reduce the subject to inattention. This can cause the patient to rely on the guidance like a crutch, instead of using it to learn how to walk [4]. This issue has been addressed by implementing patient-cooperative strategies [5]. The goal is for the robot to assist the patient only as much as necessary, much like a human therapist would. The hope is to inspire active participation in the patient. Overall, the effectiveness of robot assisted treadmill training is yet to be made clear. Many studies have been conducted, and they differ in their conclusions: some favor robot assisted training, some favor manual therapy and some find no difference in effectiveness [8].

As mentioned above, a goal of robot-assistance devices is for the robot to be transparent i.e., the robot would not induce any force on the human [8]. The opposite of this would be designs like the robot-assisted treadmill training devices, where it is possible for the patient to have a passive role. These machines would move the patient's legs without any effort on the patient's part. The transparent robot would allow patients to experience the actual dynamics of the task, which would aid in motor learning.

One such device that has been designed with transparency in mind is the KineAssist [9]. This is an overground training device, with a mobile base and partial body weight support and assistance for movements of the pelvis and torso. Training of balance during walking is not realistic in many of the current devices due to the limited degrees of freedom, which is one of the issues this device attempts to address [9]. The device also leaves the patient's legs unobstructed, which allows for an experience similar to that of everyday life. The design allows for a therapist to access the patient's legs in order to manually correct the patient's gait. This product shows a shift toward more transparent devices that also allow the patient to have more degrees of freedom, while still ensuring the patient's safety.

Figure 3: KineAssist overground training device [image from www.kineadesign.com]

1.3 Robotic Parallel Bars Device

The design project discussed herein is for robotic parallel bars (RPB) to be used for rehabilitation, which can be seen in Figure 4. The RPB will allow for realistic walking conditions, while retaining the stability of parallel bars. The system will allow for the patient's gait to be monitored or assisted by the therapist, and the force the patient is applying on the bars will also be monitored. This will allow for better assessment of the patient's progress. The device maintains its position relative to the patient, so constant support will be provided, and the patient's motion will be unobstructed. In the previous design of the RPB, the height adjustment did not hold the handle bars in place properly, and the bars could be moved up and down without loosening the adjuster. This was identified as a problem to be improved upon during this project. In this thesis, the portions of the project discussed are the improvement of the stability of the RPB and the addition of force sensors to monitor the patient's reliance on the device. These elements of the design are indicated in Figure 4. Once the needs for each of these designs were established, concepts for the designs were developed and evaluated. The final design was then chosen, and the manufacturing plan was established. The parts were then made and installed onto the device. These steps are discussed in detail in the next two chapters.

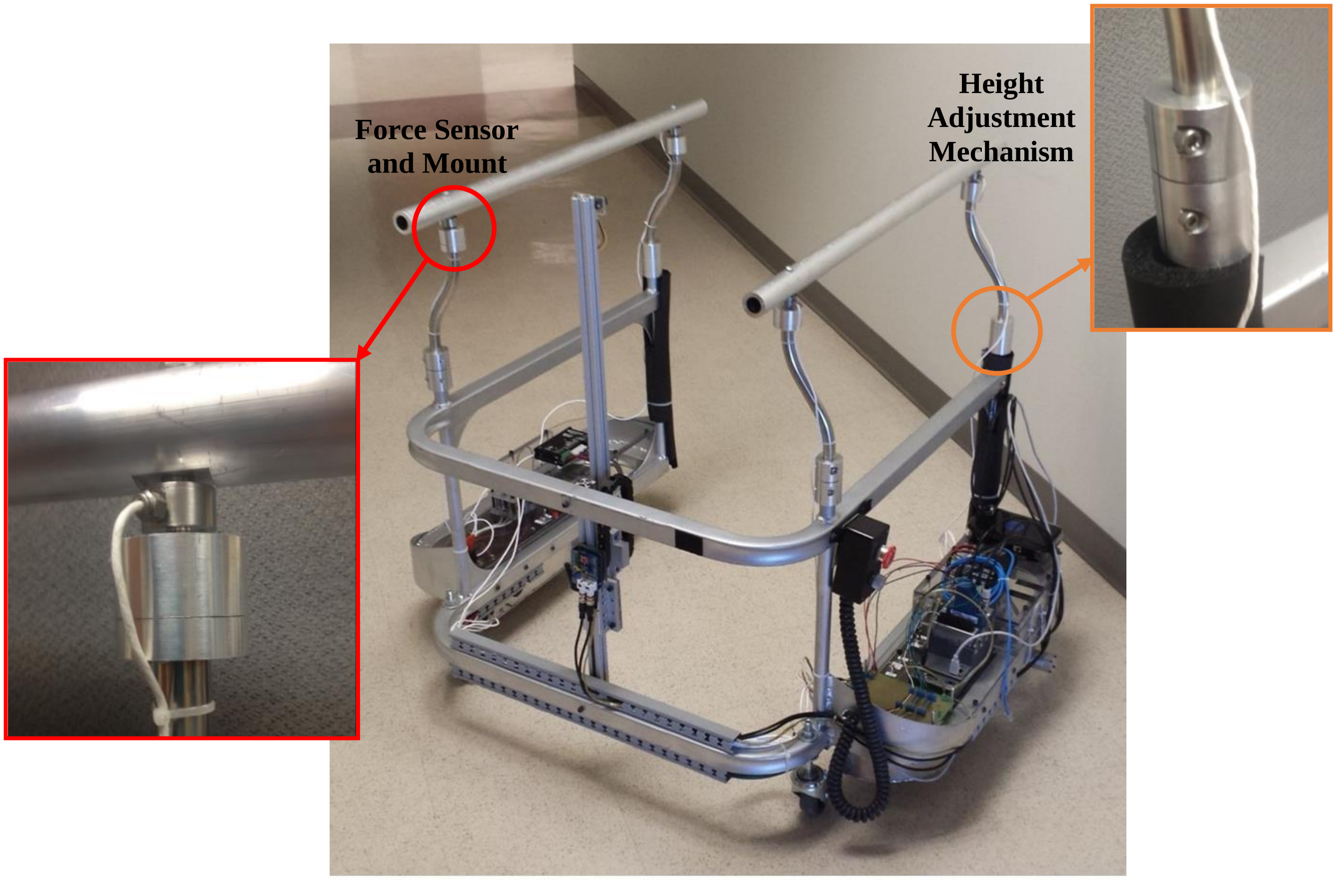


Figure 4: Current Robotic Parallel Bars Device

Chapter 2

Height Adjustment Mechanism

2.1 Problem Identification

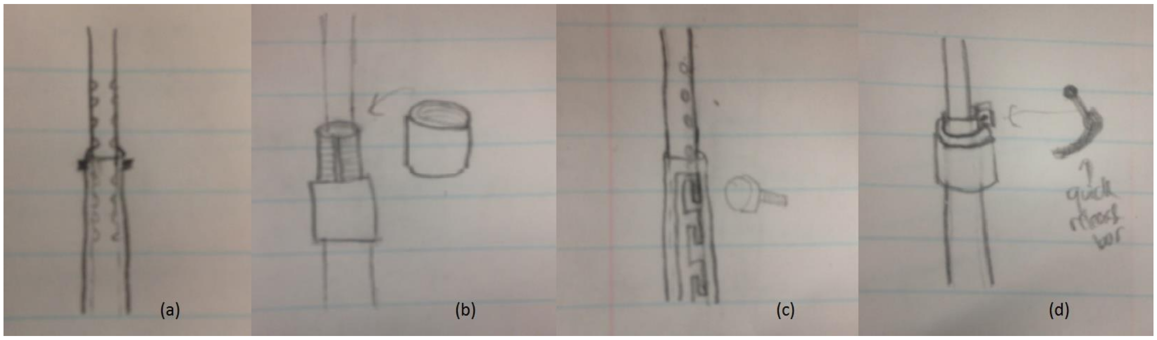
One of the issues with the height adjustment mechanism previously employed was a lack of stability and support. Previously, the handle bars could raise and lower without loosening the adjuster, which is obviously not ideal, and could lead to safety issues for the patient. The ease of adjustment had to be conserved, so that the device could be used for patients of varying heights.

Figure 5: Height adjustment before and after the redesign

The previous design used telescoping tubes with two slits in the bottom tube, which would be clamped together to tighten around the smaller, inside tube, as seen in Figure 5. The smaller tube did not have an outer diameter similar enough to the inner diameter of the larger, bottom tube. Therefore, it was not possible to get the necessary flexion to hold the top tubes, and consequently the handles, in a stationary position. This was identified as a major issue with the device, especially since it has implications for patient safety. A more stable design, which would retain the height adjustment capabilities, was sought. Related to stability, another issue with the previous design was that the smaller, inside tubes were made of aluminum. This material would scratch and deform when clamped. For additional strength and resistance to this deformation, the stainless steel tubes were purchased and bent. This was a simple way to improve the stability of the device.

2.2 Design Process

Several different methods of adjusting the height were considered. Many preliminary ideas were considered, but these were narrowed down early in the process. Quick sketches of these can be found in Figure 6. One of the main reasons that concepts (a) and (c) were rejected was that the continuous range of the height adjustment was lost, since the allowable heights would be discretized by the holes in the telescoping tubes. It would also likely be difficult to operate these height adjustments, given that both sides would have needed to be adjusted at the same time, since the tops of the tubes are fixed at the same height.



(a) (b) (c) (d)

Figure 6: Preliminary concepts for height adjustment

One design that was considered further was to have a twist-lock adjustment mechanism, which are commonly used in canes and camera tripod height adjusters, found in concept (b) above. The SolidWorks drawing for this design can be seen in Figure 7. In the end, it was decided that this might be difficult to manufacture so that it would work effectively.

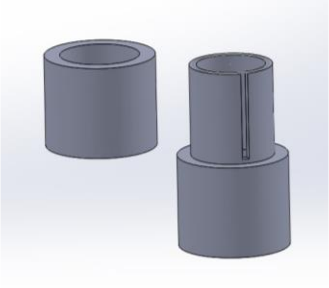


Figure 7: Design for twist-lock adjustment

The final design was decided to be a part that would flex onto both the top and bottom tubes, which was developed from concept (d) in Figure 6. This way, each portion could be machined to closely match the outer diameter of the tube that it was holding in place. This allows a force to be applied to the outer diameter of each tube, effectively holding them in place. The original design of this part included a quick release adjuster, seen in concept (d), but only a few moments would be saved in adjustment time by substituting this piece instead of a screw. Therefore, it was decided that a standard Allen wrench could be used to adjust the height with sufficient ease. This also will look more aesthetically pleasing than the quick release bar. The design was also reevaluated for the feasibility of manufacturing; these changes can be seen between the drawings in Figure 8 and Figure 9. Given the small amount of machining experience prior to this project, Dr. Moore, the Thesis Advisor, advised some design changes that would allow for an easier, more feasible manufacturing process. The top portion of this part was modified to be ¾”

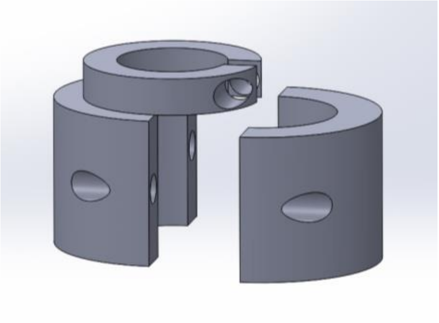


Figure 8: Design prior to changes for easier manufacturing

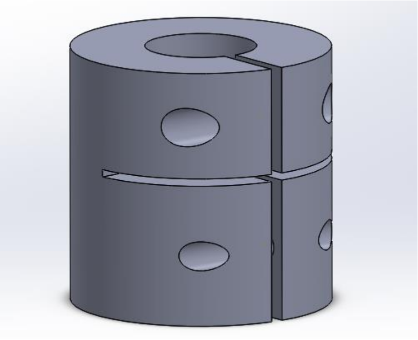


Figure 9: Final design of height adjustment mechanism

tall; this allows more surface area to contact the upper bar and hold it in place more effectively. This change also allows the screw holes to be more easily drilled, since before they were very close to the edge of the material; it also improves the aesthetics of the part. The outside diameter of this part was changed to stay the same for both the top and bottom elements. This again improves the aesthetics of the part, and also eliminates a machining process. This also allows for only one vertical slot to be cut; previously the entire bottom portion would have needed to be halved, and then a vertical slot would need to be cut into the top portion. These changes helped to simplify the manufacturing process, making it feasible for even someone with very minimal experience to make the parts.

2.3 Manufacturing Process

The final part can be seen in Figure 9. The manufacturing of this part is described below in Table 1; the shop drawing for this part can be found in Appendix A. Many difficulties were encountered in this process, and therefore many lessons learned. Given the minimal previous experience with both the lathe and the mill, these were challenging parts to make. For each process though, by the time the fourth part was finished, the process was easily performed. This enforced the presumption that these parts could be machined relatively easily. For the first part, it was discovered after the part was removed from the lathe that the holes were not drilled to the proper depth. Since the holes had to be concentric, the part could not be replaced on the lathe to deepen the holes, so there is one part that is shorter than the others. After this part, careful attention was directed towards ensuring that the proper length was drilled. Another lesson learned was that the holes should be tapped right after they are drilled, before the position of the part or the mill is changed. This allows the use of a tap assist, which ensures that the tap is straight. The first hole was tapped after taking the part out of the mill, and this made the tapping process much more difficult than it needed to be. Overall, even though some mistakes were made along the way, four functional parts were manufactured.

Table 1: Manufacturing Process for Height Adjustment Mechanism

Step	Process	Machine/Tool Used
1	Drill/bore the holes to match the ODs of the bars	Lathe, drill bits, boring bar
2	Face the OD of the part	Lathe, facing tool
3	Cut the part to the proper length	Horizontal saw
4	Face the top and bottom to create flat finishes	Lathe, facing tool
5	Drill and tap holes through the sides	Mill, drill bits, tap
6	Cut slits (both horizontal and vertical)	Horizontal saw, band saw
7	Drill out the threads in the top half of the hole (until the slit)	Mill, drill bits
8	Drill counterbores for the screws	Mill, end mill

Chapter 3

Force Sensors

3.1 Problem Identification

The force sensors are a useful tool for determining patient progress. The amount of body weight that is being supported by the device can be measured, and therefore the amount of body weight that the patient is supporting can be measured. In order to effectively utilize these sensors, they need to be properly mounted to prevent damage and to ensure that accurate data is received. The force sensors are expensive, so making sure that they are not damaged is a high priority. These were the basic needs identified for the design of the force sensor mounts. Additionally, aesthetics and ease of manufacturing were considered when conceptualizing and evaluating designs. The previous design and the redesign, which accommodated the force sensors, can be found in Figure 10.

Figure 10: Before and after the redesign to accommodate the force sensors

3.2 Force Sensors

The force sensors will provide useful data for the therapist, so that the patient's progress can be readily identified and quantified. This data will help the therapist to create better treatment plans that could speed the recovery process. It also could help to identify fall-prone geriatric patients, by monitoring their level of reliance on the device. Factors that were taken into consideration when choosing the force sensors were the force rating, accuracy, size of the sensor, cost and whether the signal could be self-amplified. Many companies were researched and compared to find a sensor that could accommodate all of these needs. The comparison of these sensors can be found in Appendix B. The chosen company was Stellar Technology Incorporated (STI), and the chosen sensor was the MIN802. The specifications for this sensor can be found in Appendix C.

The force sensors purchased from STI have inline amplifiers, so that the output signal is +/- 5V; this allows the signal to be easily read. The compression is rated at +100lb and tension at -50lb, which will satisfy the amount of weight possibly applied by the patient. This will hold 200 lb on each side, for a total of 400 lb. This is sufficient for practically any patient to support his or her entire body weight on the device, if need be. Female-female threading was chosen for the sensors so that their orientation could be easily chosen.

Figure 11 shows the wiring diagram for these sensors. This was wired and soldered onto a circuit board. A voltage source, the same source that provides voltage for the wheel motors, provided the excitation for the force sensor. The signals generated by the force sensors are amplified by an inline amplifier, allowing the signal to be easily read by the cRIO, which then sends the signal into the computer. While the wiring and soldering has been completed, values have yet to be read. In the future, a way to display the force values will be created such that the information can be easily interpreted.

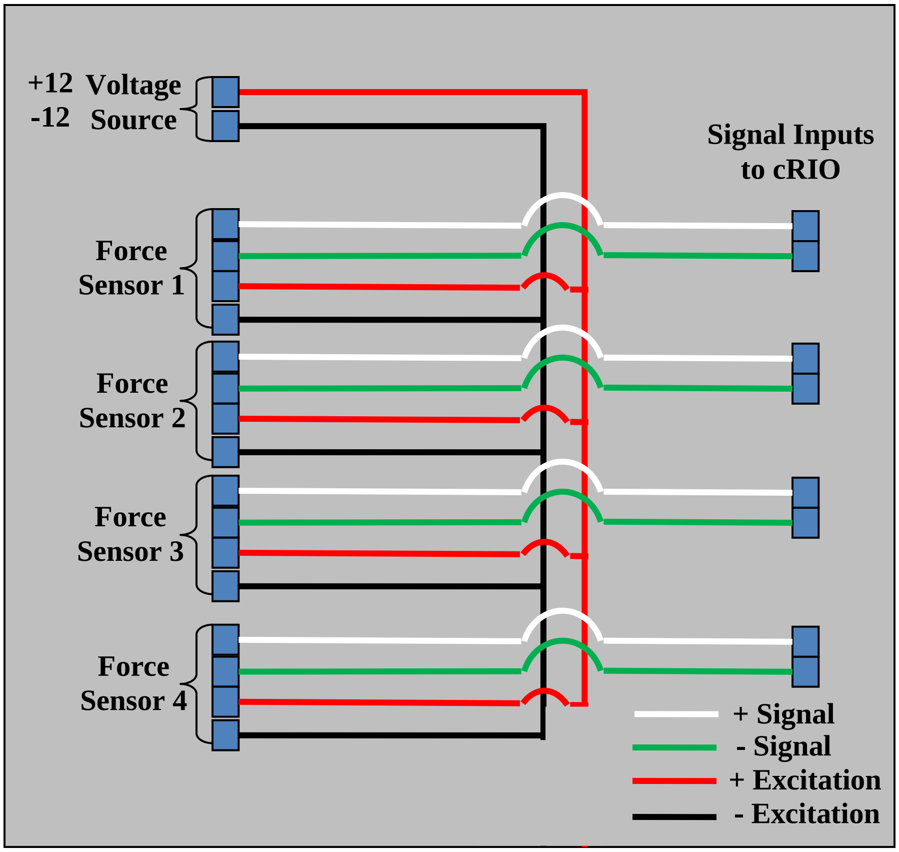


Figure 11: Diagram of inputs and outputs of the force sensor

3.3 Design Process

The force sensors measure the inline force, so they must be mounted underneath the handles, where the supporting bars connect. The supplier of the sensors, STI, was consulted to gage the robustness of the sensors. Figure 12 was the preliminary design for mounting the force sensors.

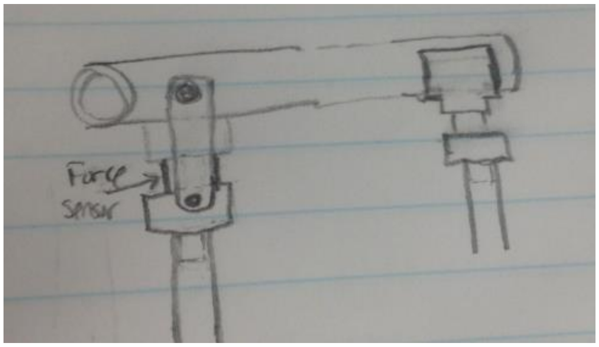


Figure 12: Preliminary concept for force sensor mounts

It was a concern that the force sensors might be bound if they were rigidly connected to the handles and bars below, so in the preliminary stage, one force sensor on each side was mounted on a hinge, and the other was mounted such that the handle bar could slide back and forth. In conversation with STI, this was determined to be not a concern.

Since there was little concern about binding the force sensors, a less complicated version of the force sensor mounts could be utilized, as seen in Figure 13. The supplier also advised which portions of the force sensor could bear weight and which should be avoided. For this reason, the force sensor mounts allow the weight to be placed on the bottom of the threaded bases, instead of on the thin, welded walls of the force sensor. This was how the design was previously sketched, as seen in Figure 12 and Figure 13. Another minor change was decided to improve the aesthetics of the mounts. The side of the sensor with the long threaded portion was originally decided to be facing upwards. However, it would look much cleaner if the shorter portion was on top, and the longer portion would sit partly in the mount. Additionally, since the weight can and should be placed on the threaded bases instead of the larger base, Figure 14 was decided to be the final design.

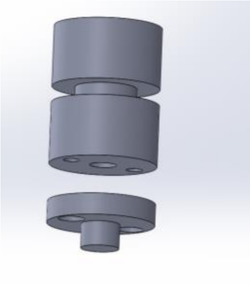


Figure 13: Design prior to consultation with STI

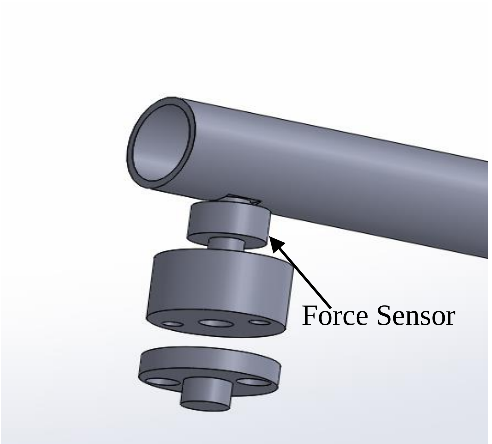


Figure 14: Final design of force sensor mount

The design includes two parts to be manufactured. The lower part was made such that the portion that goes into the telescoping tubes is just larger than the inner diameter of the tubes. This piece will then be hammered into the tube with a mallet. Two screw holes, with counterbores, will connect this lower part with the upper part. The upper part has a screw hole with a counterbore that connects to the force sensor. Additionally, the top of this part has a hole with the same diameter as the threaded portion of the force sensor. This way, the sensor will sit partially in the piece, which will effectively shorten the long threaded piece.

3.4 Manufacturing Process

The final parts can be seen in Figure 14. These were constructed by using the process described in Table 2; the shop drawings for these parts can be found in Appendix A. One of the first lessons learned was for the facing of the outer diameter (OD) of the parts. The length that was faced for the first part was much longer than the first part itself would be. When the first parts were cut and the bar was replaced into the lathe to begin the second pair of parts, this was found to be a mistake. When trying to face the entire length of the second part, the portion that was faced previously was not concentric, and so a large amount of material had to be removed in order to ensure the whole length of the part had the same OD. As a result, this pair of parts has a smaller OD than the other three. To make the counterbores, an end mill was used; the existence of a counterboring tool was not identified until the very end of the machining process, and the proper size was not readily found. If this were known earlier, though, this process would have been much easier. Getting the counterbore in the proper position was difficult, and it had to be redone for many of the parts. One lesson learned here was that it was a good idea to try to fit screws into the holes while the part is still in position.

Table 2: Manufacturing Process for Force Sensor Mounts

Step	Process	Machine/Tools Used
1	Face the length of both parts	Lathe, facing tool
2	Remove material to match the ID of bars	Lathe, facing tool
3	Cut to length for the bottom piece	Horizontal saw
4	Drill holes: screw hole through and hole for where force sensor will rest	Lathe, drill bit
5	Cut to length	Horizontal saw
6	Face both ends	Lathe, facing tool
7	Drill screw holes and tap holes in top piece	Mill, rotary table, drill bit, tap
8	Counterbores (for force sensor screw and two attaching screws)	Mill, end mill

Chapter 4

Conclusions

4.1 Summary of Work Completed

During the completion of this thesis, the height adjustment mechanism, seen in Figure 5, was redesigned and force sensors, seen in Figure 10, were installed to measure the amount of weight supported by the device. The hardware was designed, manufactured and installed onto the device. Force sensors were ordered from a vendor, and these were installed onto the device in the designed mounts. The wiring for the force sensors has been completed; however, values have yet to be read.

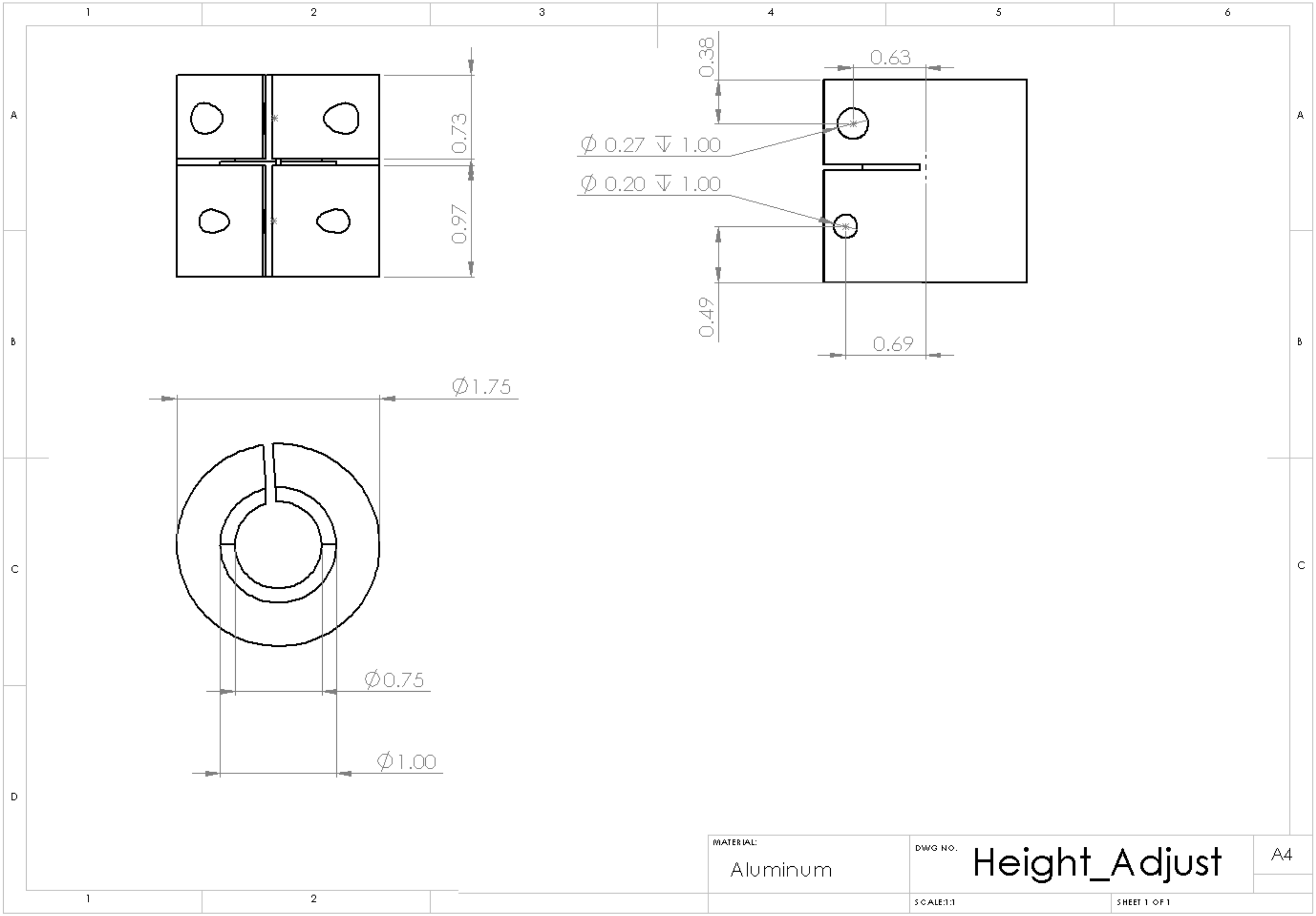
The redesign of the height adjustment was a necessary task for the device to be used in the future. If the device does not have the stability needed to support a patient's weight, it is effectively useless. Switching the material of the telescoping tube from aluminum to stainless steel also enhanced the sturdiness of the design. This, along with the change of the height adjustment mechanism, has made the device functional. The patient's safety is a nonnegotiable need in the device's design; after implementing these improvements, the need is satisfied.

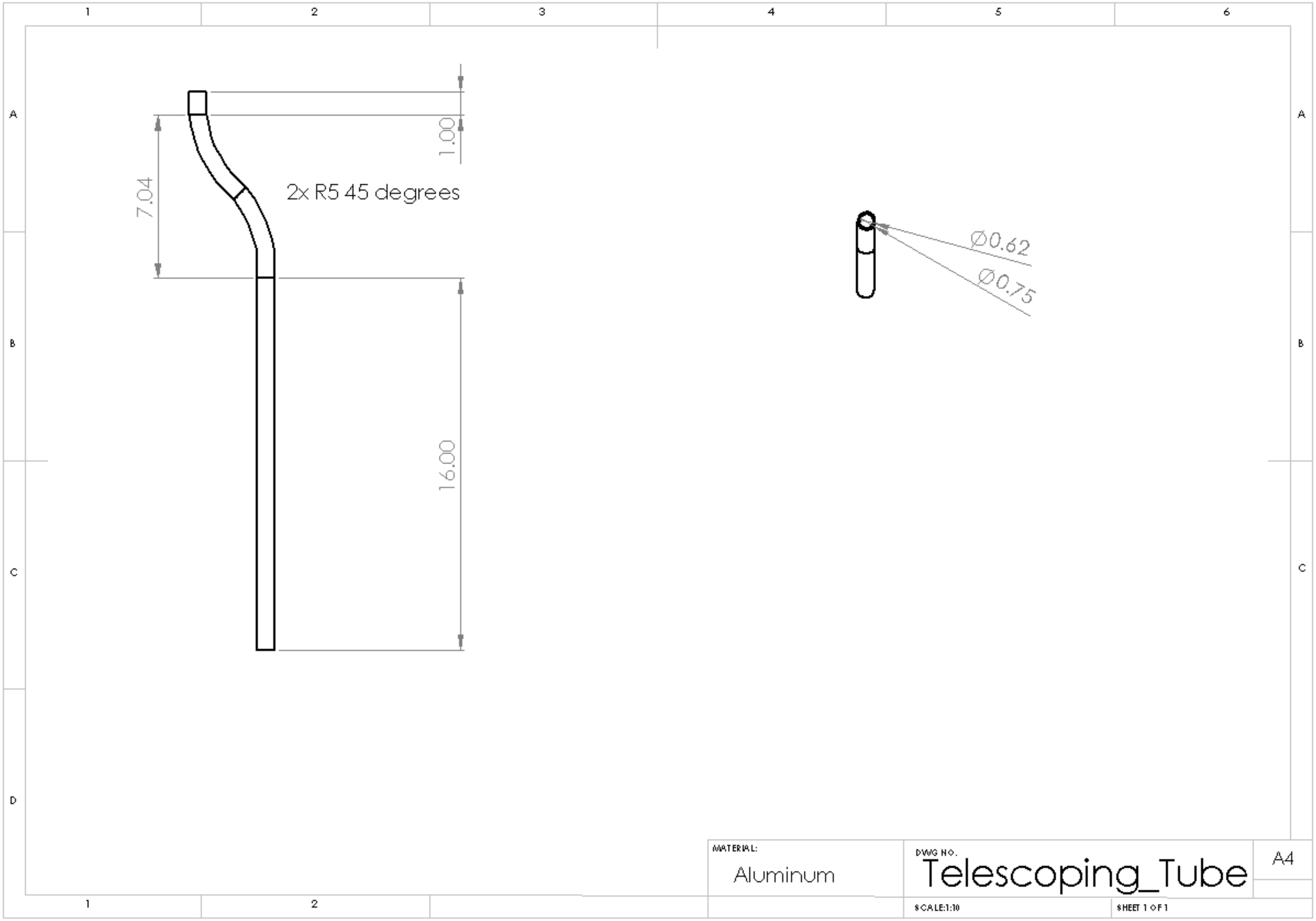
The force sensors will allow useful information about patient performance to be seen in real time and also stored for post analysis. This will allow the therapists to quantify the progress of the patient and evaluate the level of assistance required for ambulation. The mounting of the force sensors was the first step to gaining this useful information. Since the circuit board has already been wired and soldered together, the next step is to connect the force sensors with the voltage and the cRIO and begin reading in values.

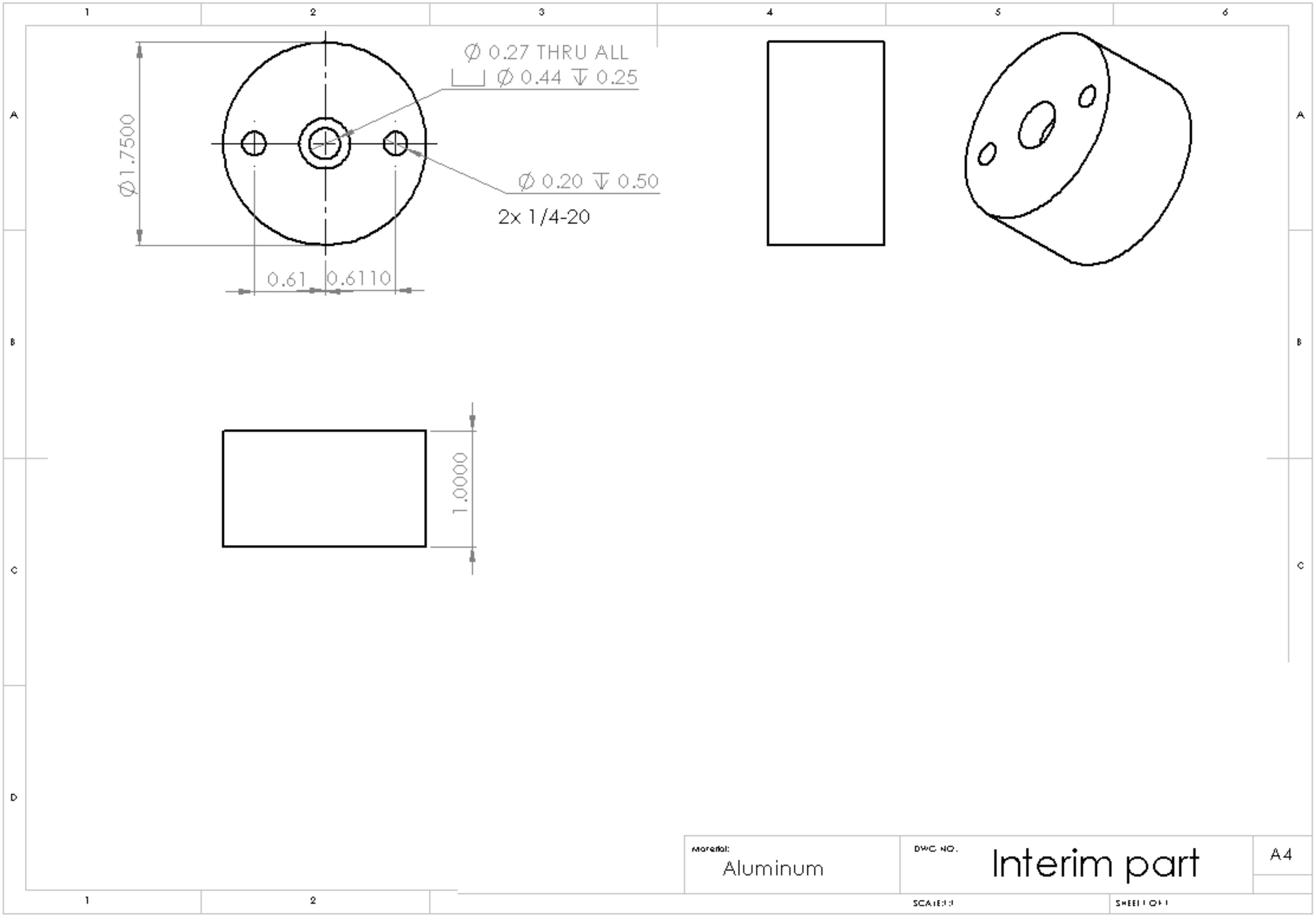
4.2 Recommendations for Future Work

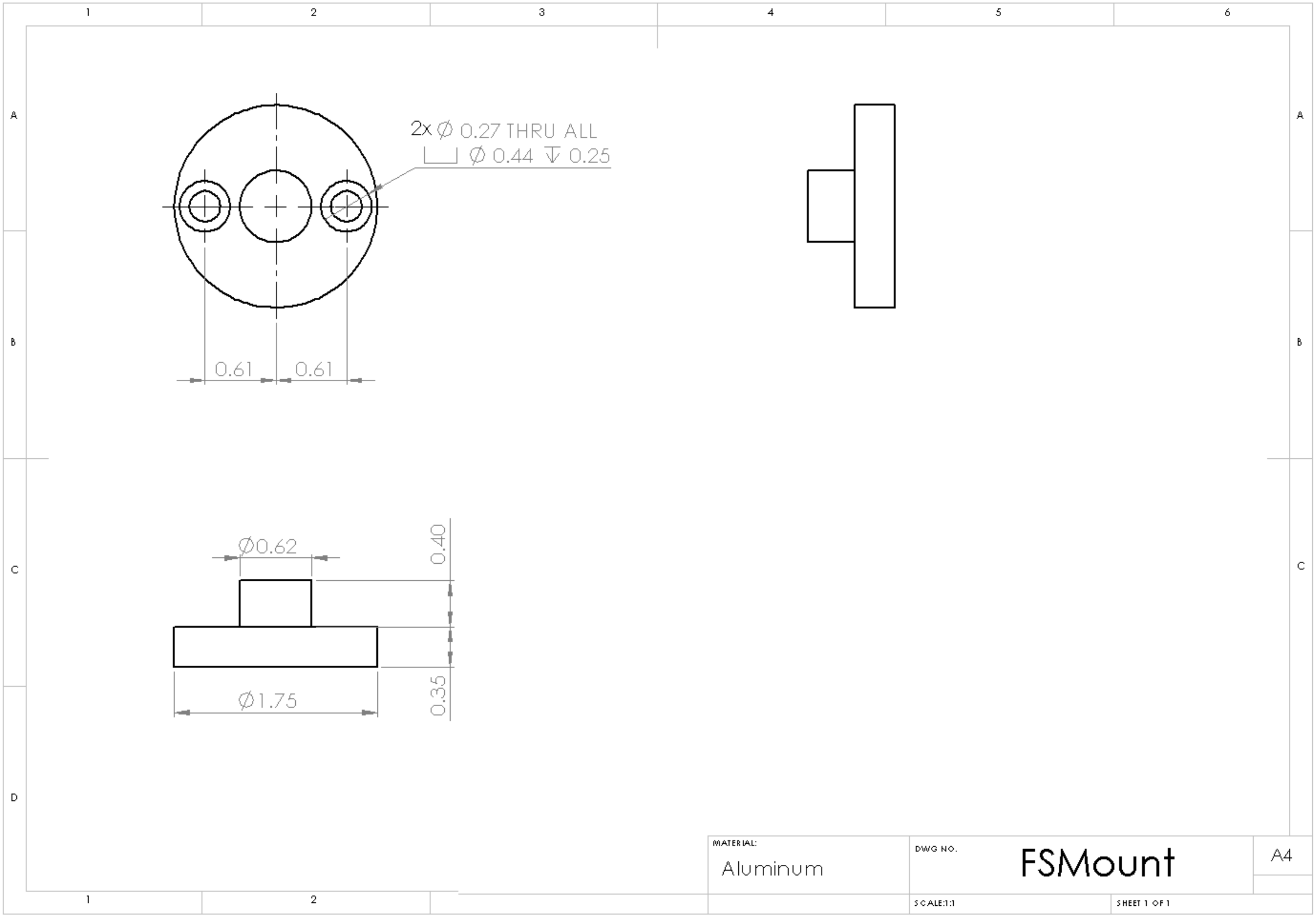
The next step for this device will be to read in the force sensor values and provide a display that is valuable and intuitive for the therapist to use. This work is already underway, and will be completed in the near future. This quantifiable information about the patient’s progress will be very useful; however, there are many other opportunities for this device to gain information about the patient’s ambulation. For instance, sensors could be installed on the device to measure gait characteristics of the patient like cadence and step length. This could remove some of the subjective observations currently used to evaluate the patient’s gait. The RPB device has a lot of potential, and it could provide a significant amount of quantifiable information related to the patient’s gait and progress. The force sensors are certainly a start, but there is room for the device to be improved so that it will transform the rehabilitation process.

Appendix A
SolidWorks Drawings


1
2
3
4
5
6
A
B
C
D
0.73
0.97
0.38
0.63
Ø 0.27 ↧ 1.00
Ø 0.20 ↧ 1.00
0.49
0.69
Ø1.75
Ø0.75
Ø1.00
MATERIAL:
Aluminum
DWG NO.
Height_Adjust
A4
SCALE:1:1
SHEET 1 OF 1


1.00
7.04
2x R5 45 degrees
16.00
Ø0.62
Ø0.75
MATERIAL:
Aluminum
DWG NO.
Telescoping_Tube
A4
SCALE:1:10
SHEET 1 OF 1

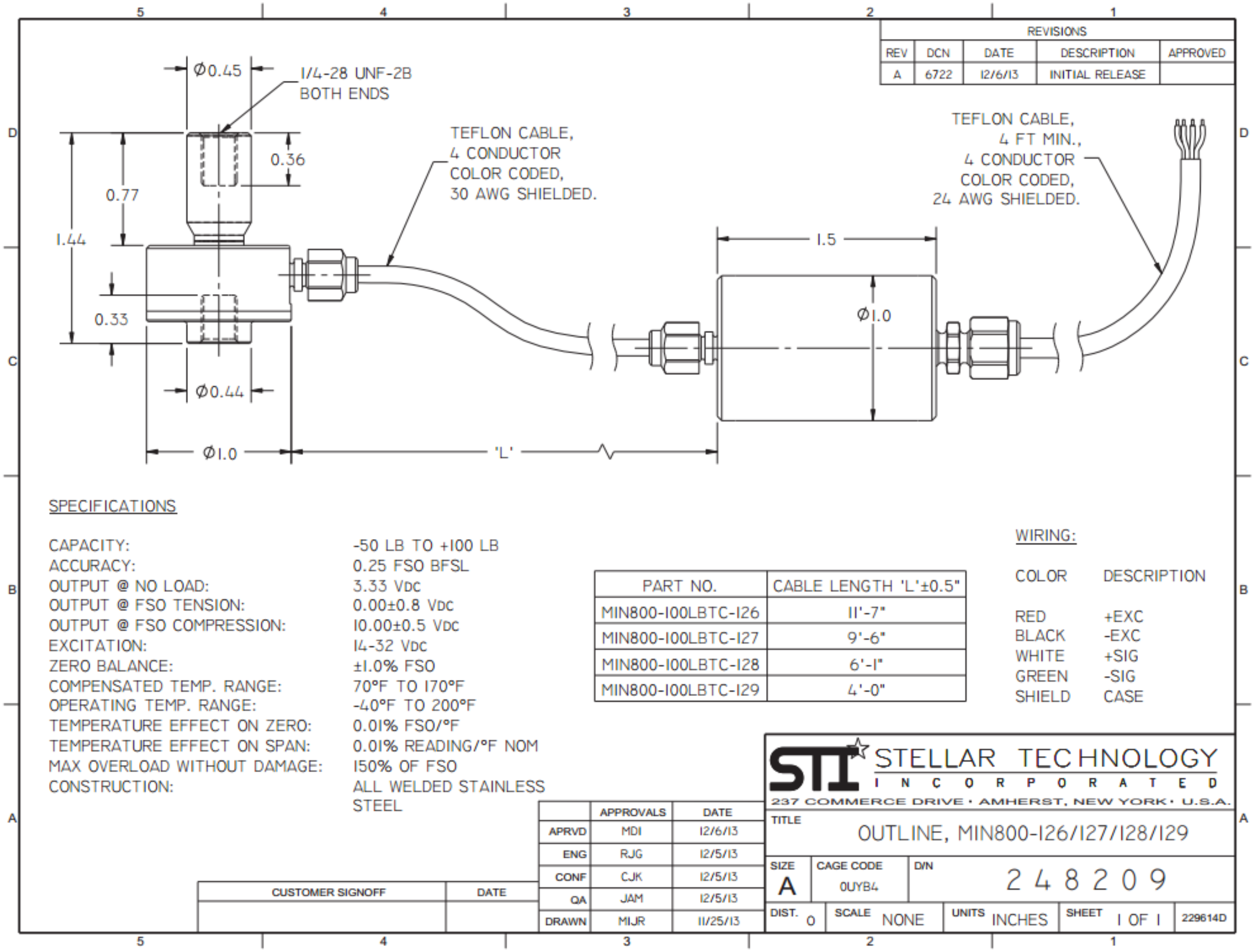

Ø 0.27 THRU ALL
⌴ Ø 0.44 ↧ 0.25
Ø1.7500
Ø 0.20 ↧ 0.50
2x 1/4-20
0.61
0.6110
1.0000
Material:
Aluminum
DWG. NO.
Interim part
A4
SCALE:1:1
SHEET 1 OF 1


2x ∅ 0.27 THRU ALL
⌴ ∅ 0.44 ↧ 0.25
0.61
0.61
∅0.62
0.40
0.35
∅1.75
MATERIAL:
Aluminum
DWG NO.
FSMount
A4
SCALE:1:1
SHEET 1 OF 1
1
2
3
4
5
6
A
B
C
D

Appendix B
Force Sensor Comparison

	1	2	3	4	5	6
Company	Stellar Tech	Stellar Tech	Stellar Tech	Stellar Tech	Megacraft	Omega
Model #	MIN802	MIN822	PNC720	PNC770/772	KMB52	LC302
Wt Rating	100,250	100,250	100,250	100,200,300	225	100,250
Accuracy	0.25%	0.15%	0.10%	0.05%		0.50%
Diameter	1"	1"	3"	2.75"		.75"
Output	2mV/V	2mV/V	3mV/V	2mV/V		1mV/V
Option for Self-Amp?	Yes	Yes	Yes	Yes		Not Advertised
Cost	Not Advertised	Not Advertised	Not Advertised	Not Advertised	Not Advertised	305
	7	**8**	**9**	**10**	**11**	**12**
Company	Omega	Omega	Omega	Omega	Omega	Omega
Model #	LC305	LC307	LC401	LCGB	LCKD	LCGD
Wt Rating	100,200,300	250	100,250	100,250	100,250	100,250
Accuracy	0.25%	0.75%	0.25%	0.25%	0.25%	0.25%
Diameter	2"	.5"	2.62"	1.25"	.38"	1.25"
Output	2mV/V	1.5mV/V	3mV/V	2mV/V	2mV/V	2mV/V
Option for Self-Amp?	Not Advertised	Not Advertised	Not Advertised	Not Advertised	Not Advertised	Not Advertised
Cost	490	385	605	500	560	500

Appendix C
Force Sensor Specifications



REVISIONS

REV	DCN	DATE	DESCRIPTION	APPROVED
A	6722	12/6/13	INITIAL RELEASE	

SPECIFICATIONS

CAPACITY:	-50 LB TO +100 LB
ACCURACY:	0.25 FSO BFSL
OUTPUT @ NO LOAD:	3.33 VDC
OUTPUT @ FSO TENSION:	0.00±0.8 VDC
OUTPUT @ FSO COMPRESSION:	10.00±0.5 VDC
EXCITATION:	14-32 VDC
ZERO BALANCE:	±1.0% FSO
COMPENSATED TEMP. RANGE:	70°F TO 170°F
OPERATING TEMP. RANGE:	-40°F TO 200°F
TEMPERATURE EFFECT ON ZERO:	0.01% FSO/°F
TEMPERATURE EFFECT ON SPAN:	0.01% READING/°F NOM
MAX OVERLOAD WITHOUT DAMAGE:	150% OF FSO
CONSTRUCTION:	ALL WELDED STAINLESS STEEL

PART NO.	CABLE LENGTH 'L'±0.5"
MIN800-100LBTC-126	11'-7"
MIN800-100LBTC-127	9'-6"
MIN800-100LBTC-128	6'-1"
MIN800-100LBTC-129	4'-0"

WIRING:

COLOR	DESCRIPTION
RED	+EXC
BLACK	-EXC
WHITE	+SIG
GREEN	-SIG
SHIELD	CASE

	APPROVALS	DATE
APRVD	MDI	12/6/13
ENG	RJG	12/5/13
CONF	CJK	12/5/13
QA	JAM	12/5/13
DRAWN	MIJR	11/25/13

CUSTOMER SIGNOFF	DATE

STI STELLAR TECHNOLOGY INCORPORATED
237 COMMERCE DRIVE • AMHERST, NEW YORK • U.S.A.

TITLE OUTLINE, MIN800-126/127/128/129

SIZE	CAGE CODE	D/N
A	0UYB4	248209

DIST.	SCALE	UNITS	SHEET	
0	NONE	INCHES	1 OF 1	229614D

BIBLIOGRAPHY

1. Hamacher, D., et al., *Kinematic measures for assessing gait stability in elderly individuals: a systematic review*. J R Soc Interface, 2011. **8**(65): p. 1682-98.
2. Marschollek, M., et al., *Sensors vs. experts - a performance comparison of sensor-based fall risk assessment vs. conventional assessment in a sample of geriatric patients.* BMC Med Inform Decis Mak, 2011. **11**: p. 48.
3. Sabe, R., *Visual Feedback System Showing Loads on Handrails for Gait Training*, in *IEEE/SICE International Symposium on System Integration (SII)*. 2012: Kyushu University, Fukuoka, Japan.
4. *Neurorehabilitation Technology*. 2012: Springer.
5. Riener, R., et al., *Patient-cooperative strategies for robot-aided treadmill training: first experimental results.* Neural Systems and Rehabilitation Engineering, IEEE Transactions on, 2005. **13**(3): p. 380-394.
6. Alberto Esquenazi, A.P., *Robotic-Assisted Gait Training and Restoration.* Am J Phys Med Rehabil, 2012.
7. Colombo, R., et al. *Motor Performance Evaluation to Improve Patient's Compliance During Robot-Aided Rehabilitation*. in *Biomedical Robotics and Biomechatronics, 2006. BioRob 2006. The First IEEE/RAS-EMBS International Conference on*. 2006.
8. Pennycott, A., et al., *Towards more effective robotic gait training for stroke rehabilitation: a review*. J Neuroeng Rehabil, 2012. **9**: p. 65.
9. Peshkin, M., et al. *KineAssist: a robotic overground gait and balance training device*. in *Rehabilitation Robotics, 2005. ICORR 2005. 9th International Conference on*. 2005.

ACADEMIC VITA

Megan Doerzbacher
2636 Lansdale Dr
Wexford, PA 15090
mad5560@psu.edu

Dual Major in Mechanical Engineering and Nuclear Engineering
The Pennsylvania State University, University Park, PA
College of Engineering, Graduating May 2014

Honors and Awards:

Schreyer Honors Scholar and Scholarship, Fall 2010 – Present
- Honors College at Penn State

Leonhard Honors Program and Scholarship, Spring 2011 – Present
- Engineering Honors Program at Penn State

Shuman Scholar, Spring 2012 – Present
- Research fellowship at Penn State

Work Experience:

Bechtel Plant Machinery, Inc., Monroeville, PA May – August 2013

Mechanical Engineering Intern – Reactor Plant Heavy Equipment
- Developed a procedure and corresponding validation and verification plan for corrective pressurizer maintenance. Prepared a detailed technical recommendation to incorporate this procedure into a technical manual.
- Evaluated the technical feasibility, return on investment and risk of supplier cost reduction proposals. Developed a recommendation letter prioritizing these business cases based on benefit to BPMI contracts.

Westinghouse Electric Company, Cranberry, PA May – Aug, Dec 2011; May – August 2012

Project Management Intern – China Projects (construction of four nuclear plants)
- Acted as contact point between China Projects group and a sub-supplier
- Resolved issues associated with shipping-readiness for many components and small shipments

The Pennsylvania State University, University Park, PA

Learning Assistant, Mathematics Department Spring 2011 – Present
- Led review sessions for students in Calculus I and II
- Promoted the development of teamwork among students

Research Mentor, MNE Department Fall 2012 – Present
- Conducted research regarding the friction between catheters and needles

- Attended Design of Medical Devices conference and was published in ASME-Journal of Medical Devices
- Involved in research for robotic walker to assist in rehabilitation process

Teaching Assistant, MNE Department Spring 2013

- Assisted with teaching junior level mechanical engineering design class (ME 340)
- Created and graded quizzes, presented lessons learned, and aided students in daily work

Activities and Volunteer Experience:

- Women's Ultimate Frisbee Team, Fall 2010 – Present
  - Treasurer and player
- Women in Nuclear, Fall 2013 – Present
  - Communications Chair
- American Nuclear Society, Fall 2012 – Present
  - Outreach Chair