BME Design-Fall 2020 - BENJAMIN LAWONN
Complete Notebook

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BENJAMIN LAWONN

on

Dec 11, 2020 @02:12 PM CST

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Team contact Information

NAMAN PATEL - Sep 07, 2020, 9:38 PM CDT

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Project description

BENJAMIN LAWONN - Dec 11, 2020, 2:10 PM CST

Course Number:

BME 400 - BME 402

Project Name:

Disabled exercise gimbal chair

Short Name:

Team X Chair

Project description/problem statement:

The client is unable to safely enter and operate the standing wheelchair with the manufacturer included restraints. There are currently 2.7 million wheelchair users in the U.S. [1] and within this population, there is a varying degree of upper extremity mobility, ranging from full movement to none. Without a large degree of mobility, many wheelchair users are unable to take advantage of the benefits of movement due to various movement challenges they encounter.
Moving the body has many benefits for the brain, muscles, bones, joints, intestines, heart, lungs and other organs[2]. Movement is also beneficial for a number of bodily functions such as blood flow, digestion, muscle strength, and bone health[3]. Existing standing wheelchair supports enable users to enter the upright position, but they lack autonomous accessibility for the user. The restraints require strength and dexterity to position into their slots, that mobility limited users may not possess. The cost of hiring a CNA or licensed physical therapist is quite expensive and usually is not covered by health insurance for those affected by a permanent disability. The goal of this project is to develop a device that enables the wheelchair user the ability to secure themself within their standing wheelchair independently.

About the client:

The client works as a senior programmer analyst in the Biostatistics and Medical Informatics Department at the UW - Madison School of Medicine and Public Health. They have been phenotypically diagnosed with Type II SMA and genetically diagnosed with Type III. They have been unable to walk throughout his life, and have used a wheelchair to assist with their movement for decades. The client has requested a design that enables him to move and exercise more easily, with autonomy being the most important criterion. Specifically, the ability to independently move between a seated and standing position is the task the team will address this semester.

2020.09.08 - Client Meeting 1

JENNA WARDEN - Sep 19, 2020, 4:20 PM CDT

Title: Client Meeting 1

Date: 2020.09.08

Content by: Jenna Warden

Present: Full Team + Client (Keith)

Goals: Get to know Keith and ask questions that we have about the project

Content:

About Keith

- Has spinal muscular atrophy - neuromuscular condition - when routine changes, muscles atrophy the most
- was more mobile when younger - would crawl until age 14
- looking for more ways to exercise than he does now
- maintains strength by not using power wheelchair
- only uses power wheelchair at work
- has 3 wheelchairs: standing wheelchair (cannot stand all the way because of hip contractions, trying to customize), power wheelchair, manual wheelchair
- wants intellectual property then to open source it
- eventually may want to do clinical trials

Ideas from Keith/ general talk

- lifecasting - making a mold of a person - sitting, stretched out, arms up, etc.
- person would like as much flexibility as possible to move wherever, whenever
- having different routines set could be helpful
- has ceiling lift - can arrange to see it in person if needed
- photogrammetry of hoyer lift
    - can be used to get into SUV or truck, wheels roll under car, need enough clearance for the top
- FDA spideroma? his current state of function/ mobility will not change
- can have circuits made for about $10
    - design PCB and spiderweb and what the circuit lookds like
    - generates gerver files and then there's websites that you can upload based on their specifications
    - they'll tell you if you have any mistakes
    - and they will make it and send it to you

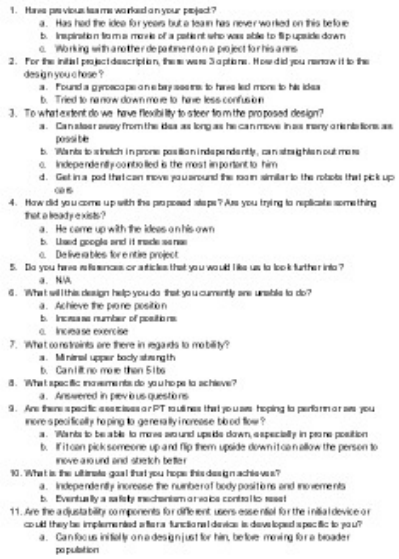
Answers to Question Doc - with notes

- See attached document containing questions and their respective answers

Conclusions/action items:

Team was able to meet with client and ask general questions and gain some basic information about the client and their wants/needs. The team will begin researching general aspects of the project to gain a deeper understanding of the client and the design that they want.

JENNA WARDEN - Sep 19, 2020, 4:08 PM CDT



1. Have previous teams worked on your project?
    a. Has had the idea for years but a team has never worked on this before
    b. Inspiration from a movie of a patient who was able to flip upside down
    c. Working with another department on a project for his arms
2. For the initial project description, there were 3 options. How did you narrow it to the design you chose?
    a. Found a gymacopic on ebay seems to have led more to his idea
    b. Tried to narrow down more to have less confusion
3. To what extent do we have flexibility to steer from the proposed design?
    a. Can steer away from the idea as long as he can move in as many orientations as possible
    b. Wants to stretch in prone position independently, can straighten out more
    c. Independently controlled is the most important to him
    d. Get in a pod that can move you around the room similar to the robots that pick up cars
4. How did you come up with the proposed steps? Are you trying to replicate something that already exists?
    a. He came up with the ideas on his own
    b. Used google and it made sense
    c. Deliverables for entire project
5. Do you have references or articles that you would like us to look further into?
    a. N/A
6. What will this design help you do that you currently are unable to do?
    a. Achieve the prone position
    b. Increase number of positions
    c. Increase exercise
7. What constraints are there in regards to mobility?
    a. Minimal upper body strength
    b. Can lift no more than 5 lbs
8. What specific movements do you hope to achieve?
    a. Answered in previous questions
9. Are there specific exercises or PT routines that you were hoping to perform or are you more specifically hoping to generally increase blood flow?
    a. Wants to be able to move around upside down, especially in prone position
    b. If I can pick someone up and flip them upside down it can allow the person to move around and stretch better
10. What is the ultimate goal that you hope this design achieves?
    a. Independently increase the number of body positions and movements
    b. Eventually a safety mechanism or extra control to reset
11. Are the adjustability components for different users essential for the initial device or could they be implemented after a functional device is developed specific to you?
    a. Can focus initially on a design just for him, before moving for a broader population

Questions_for_Client.pdf(57.8 KB) - download

Marissa Harkness - Oct 07, 2020, 8:29 PM CDT

Below is Keith's direct response to our questions:

1. Have previous teams worked on your project?

KMW: No.
2. For the initial project description, there were 3 options. How did you narrow it to the design you chose?
KMW: Having the more body orientations the more blood circulation there will be. In order to achieve this, having more degrees of freedom (or more gimbals) the better.
3. To what extent do we have flexibility to steer from the proposed design?
KMW: Let's review the project flexibility section of the project proposal. I think I might have forgotten to include control of the device. My hands should be freed up ideally unless the control is near the arms. There should be an easy way to bring the motors back to their origin after the device is engaged.
4. How did you come up with the proposed steps? Are you trying to replicate something that already exists?
KMW: Not really. I was going to buy a 3D printer about three years ago when I had the scale model prototype idea to keep the cost down. This summer, I accidently read about photogrammetry and figured that would make it easy to build virtually in CAD software or a scale model. You don't have to follow the steps exactly, but this seems like an easy way to approach the deliverables.
5. Do you have references or articles that you would like us to look further into?
KMW: No. The inspiration for this project was when I watched the movie Patch Adams many years ago and saw the patient in the hospital rotating in circles. But I've also seen human gyroscopes in the past and have always wanted to try them. My mobility has been extremely limited since age 14 when I had a Spinal Fusion surgery, so I thought an exercise gyroscope would be a better approach.
6. What will this design help you do that you currently are unable to do?
KMW: It will help me get into more body positions other than sitting, standing in my standing wheelchair and laying on my back or side. And I'll be able to move while doing so.
7. What constraints are there in regards to mobility?
KMW: Are you asking about my mobility with current abilities with current medical devices? I only have mobility in my arms. I can't lift much!
8. What specific movements do you hope to achieve?
KMW: I'd like to get into a prone position independently by controlling the device without my hands. Independent stretching.
9. Are there specific exercises or PT routines that you are hoping to perform or are you more specifically hoping to generally increase blood flow?
KMW: Yes, I'm hoping I can stretch my arms and get better blood flow with this.
10. What is the ultimate goal that you hope this design achieves?
KMW: Yes. More movement of my torso in different directions. We should discuss personal health information (PHI).
11. Are the adjustability components for different users essential for the initial device or could they be implemented after a functional device is developed specific to you?
KMW: We can keep the inner gimbal very simple if we took a mold of the patient and they were inside of a bed mattress-like foam.
12. Does your current wheelchair already have a lift that we can build off of?
KMW: No. I have two ceiling lifts and a travel hoyer lift we should use to build off. These are used for transferring in and out of the wheelchair. Explain independent transfer versus dependent transfer. Ceiling lifts are Guldmann GH2 and GH3. Hoyer lift is fairly standard.
13. How does the lift work in general? Does it just lift you or is it lifting the chair?
KMW: Let's discuss. Pictures are worth a 1000 words. Videos are worth 1000 pictures.
14. It was mentioned that you want it to be both assembled and disassembled. Would this be a feature that you would want to do independently?

KMW: Yes, the parts need to be disassembled for getting the device in and out of a house. It will be in my home.
15. Is there a limit for the weight of the design in regards to transportation?
KMW: Not really. Whatever a moving truck or trailer can hold.
16. What is the make and model of your wheelchair?
KMW: I have three wheelchairs. Quickie Titanium manual wheelchair with Alber E-Motion M12 power assist wheels, Quantum Pride power wheelchair, Permobil F5 standing power wheelchair
17. Do you have any previously captured photogrammetry that you could provide?
KMW: Not yet, but I plan to help with this effort on September 19. The design of this product would be difficult unless you could conceptualize the patient in CAD, so this was the best solution I could come up with.
18. Is there a specific device/software that you would prefer to use for the photogrammetry or would we use a phone camera?
KMW: Looks like if you would like to learn the entire process from creating a point cloud and a 3D mesh, most will do that. For a quick method, Display.Land might do the trick to get you moving.

PhotoScan (commercial license)
AutoDesk Recap (commercial license)
3D Zethyr Lite (open source)
Display.Land
Regard3D (open source)

19. How many degrees of movement is required in each direction (x.y,z axis)?
KMW: As many as possible. The more gimbals the better.
20. What is your preferred method of communication?
KMW: We can probably keep most discussions in our regular meetings, but you can email or call me anytime for quick questions.
21. How flexible is the budget?
KMW: I'd rather not pay for parts of the life size model until our miniature scale model has been agreed upon and we've purchased one motor and controller and have figured out how to control it well. $2000 is what I budgeted for. Less is better. More is okay if you have justification because health is worth more than wealth to me.
22. How do you prefer to structure the purchasing of materials and payment?
https://bmedesign.engr.wisc.edu/files/course/BPAG/BPAG_presentation.pdf (for reference)
KMW: Create a bill of materials with justification for each. I can purchase all parts if you have at least three estimates for each part.
23. For reference

2020.09.15 - Client Meeting 2

JENNA WARDEN - Sep 19, 2020, 9:08 PM CDT

Title: Client Meeting 2

Date: 2020.09.15

Content by: Jenna Warden

Present: All Team Members + Keith

Goals: Give updates on the work we completed this week. Answer any questions Keith has for the team / ask any questions that the team has for Keith

Content:

Updates

- Research - basic stuff, everyone researched their own things
- PDS - first draft is done, changes as the semester moves on
- Goals and Timeline put together
    - some companies make products that don't last as long so that you will buy their newer version - doesn't want that for this project - it should last a long time
    - he is willing to look at/ edit/ give advice/ clarification on PDS
    - look over PDS w/ Mitch - make necessary edits - send to Keith to look over

Manufacturing

- Manufacturing Methods - 9 methods - would make it high precision
    - look at best of best products so it will be medically sound
    - Keith sent an email regarding this
    - find a company that specializes in the type of manufacturing we want - this will minimize abnormalities
        - could be expensive - could use TEAM Lab workers

Timeline

- Just first semester
- 1st sem - development/ fabrication --> 2nd sem - testing and enhancements
- buy cheap tubes and one of the motors we want - test it out with electronics (this will still be very expensive)
- look for old materials - ECB/ Chamberlain
- TEAM Lab reduces cost of materials
    - is TEAM Lab open????
    - can we out source them for fabrication??

Math

- Marissa/Jonny - biomechanics and other ME classes
- we have lots of resources
- Keith read up on "the wheel" and its forces
    - torque doesn't really exist
    - it is applied by the universe as a result of spinning - humans cannot create torque

Photometry

- Keith has a friend coming over to do this for us

Challenges

- dissassemble-able
- forces being safe
- movement is good
- fabrication due to size

Can set up visit to see Keith's lift

- basically any day after 5:00
- showed us via videochat how it works
- controls are up, down, left, and right

- he rolls in wheelchair with lift attached and it will follow him via tracks on his ceiling

Action Items

- will send PDS as soon as it is concise
- progress report will be sent Thursday
- Timeline will also be sent to Keith

Conclusions/action items:

The team met with Keith to discuss the week's progress in research, the PDS, and the timeline. Discussed the challenges we have ahead of us and saw (via video) how Keith's ceiling lift works.

2020.09.25 - Client Meeting 3

JENNA WARDEN - Sep 25, 2020, 4:48 PM CDT

Title: Client Meeting 3

Date: 2020.09.25

Content by: Jenna Warden

Present: Team (minus Ben) + Keith

Goals: Discuss what BME design is about and its requirements, where we are at in the design process - looking for client validation, and the next steps of design.

Content:

Photogrametry

- first attempt will be taking place tomorrow
- hopefully by Sunday we will receive photos

Course Expectations

- BME kids get design projects each semester
- senior year is 9months
- our requirements
    - LabArchives
    - prototyping
        - covid is a limiting factor
    - preliminary presentations
        - 2-4 designs that are best meeting the needs
        - get peer and advisor feedback
        - one winner
            - doesn't HAVE to be the design
            - concept approval
    - overview of all the deliverables

Concerns and Limitations

- covid
    - limited resources
        - time on machines
        - access to machines
- time
    - this is only 9 months
    - we arent full time working on this
    - projects can be passed on team to team
- budget
- expertise
    - we arent professionals
    - we are just students
    - safety!!!
        - we don't want to put our nor clients safety at risk
            - upsidedown could be risky
    - we want to meet as many of your needs as possible
    - don't want to let you down but we do have limitations

Top Needs

- top 5 things - ranked
- understands why we are choosing the top two to go after
- having ability to get 'flipped over' everyday would be huge
- less focus on arms
- don't worry about vibrations
    - has machine for that

    - does help
    - redesigning parts of his standing wheelchair
    - prone position would be good

Side notes

- going to present to him on Tuesday what we will present to the class on friday
    - sketches on Tuesday are fine
    - CAD by friday
- we will continue research

Conclusions/action items:

The team met with the client to have a "let down" of their concept of what they wanted. As a design team in undergrad, the team faces many limitations to what the client wanted including a pandemic, safety precautions, and expertise. The team then confirmed what the clients top needs are and those will be the main focus for the preliminary designs that will be presented to the client on Tuesday (09/30) and to the class (10/02). The team also gave a better overview and explanation of BME design and the requirements and expectations of us.

2020.09.29 - Client Meeting 4

JENNA WARDEN - Sep 29, 2020, 6:08 PM CDT

Title: Client Meeting 4

Date: 2020.09.29

Content by: Jenna Warden

Present: Team + Keith

Goals: Discuss the four designs we have come up with and get feedback on them

Content:

Inversion Table

- would lay on back

Pressure Cuff

- goes around standing wheelchair

Roller Coaster

- how does it attach?
    - concern

Comments from Keith

- safety isn't a huge concern
- inversion table could be an option
- boa system has good potential
- roller coaster would be super helpful
- standing wheelchair has bluetooth
    - would be cool to use bluetooth

Conclusions/action items:

The team showed the client the four designs that we came up with and got feedback about the designs. The team will then use the feedback we got from the client to make the necessary changes to the presentation for friday.

2020.09.30 - Client Meeting 5

JONATHON MURPHY - Oct 07, 2020, 2:43 PM CDT

Title: Client Meeting 5

Date: 2020/09/30

Content by: Jonathon Murphy

Present: Marissa, Jonathon, Keith

Goals: meet Keith in person and see the standing wheelchair

Content:

Met Keith at his apartment for the first time

- took pictures of the wheelchair
  - 
- took measurements of the wheelchair
  - Seat to foot pedal 14.5
    Widest front part of seat 18.75"
    Bsck portion of seat 15.5"
    Seat to top of head rest 25"
    Mounts of chest restraint 23.25"
    Chest restraints 12.5 or 3/8"
    Chair to front of leg portion of constraint 6 or 5.75"
    Inner distance between leg constraints 7"
    Outside of leg to outside or leg 19"
    Rod to rod of chest 21.5"
    Rod to rod leg 17 "
    Width of back of chair 20.5"
    Floor to top of head rest when seated is 4ft
    Seat to legs 130 degrees hip flexor contractions

Back rest to seat 135 degrees hamstring contractions
Back rest to chest restraints 13.75"
Back of chair to bar of chest restraints 17"
Back of chair to bar of leg restraints 31"

- saw it go to standing position and sitting position
- learned Keith's abilities/limitations in terms of arm mobility and strength
    - he cannot lift his arms above his head
    - he cannot lift 5 lbs above his feet level
    - he can reach to his feet
- we were given the chest and leg restraints
- talked about the ability to build off of certain aspects of the wheelchair
    - the headrest
    - the arm rest
    - building underneath?

Conclusions/action items:

We learned a lot about what Keith is capable of doing with his arms, which changes our design ideas and strategies right before preliminary deliverables. Now that we have a decent understanding and a ton of pictures of Keith's wheelchair, we should be able to start brainstorming a design that will be able to be built off of the wheelchair. Keith is very nice and open to many ideas.

2020.10.06 - Client Meeting 6

JENNA WARDEN - Oct 06, 2020, 9:11 PM CDT

Title: Client Meeting 5

Date: 2020.10.06

Content by: Jenna Warden

Present: All Team Members and Client

Goals: Get feedback on preliminary presentation

Content:

Client created point cloud with photos Marissa took of the standing wheelchair

- looks a little funky bc some were in standing position and others were in sitting
- not high in detail either
- matches two pictures at a time based on where the program thinks they are relative to space
- bigger white dots on wheelchair would have helped
- need 5-6 photos to complete this but client used >100

Presentation

- spelling error - mentioned in email
- using chest to tighten against self?
    - current one is in a fixed position - how would boa work?
        - presentation was made prior to seeing the wheelchair
        - would not use existing restraint
- could mount to arms/back for chest
- harder for client to reach and pull things from the sides
- swap out elbow pad - would be easiest
- arm rests are connected - as one goes down the other goes up
- wants the chest restraint a little closer to his body but not touching him all the time
    - roller coaster would achieve this
- can mount on headrest

Conclusions/action items:

The client discussed concerns and new ideas with the proposed final design and its implementation to his wheelchair. The team asked some clarifying questions about mounting a device and the clients preferred aspects of the device.

2020.10.20 - Client Meeting 7

JENNA WARDEN - Oct 20, 2020, 5:48 PM CDT

Title: Client Meeting 7

Date: 2020.10.20

Content by: Jenna Warden

Present: All Team Members

Goals: Show client new design and discuss any worries that arise. Also, discuss a meeting time this week.

Content:

Ben showed his SolidWorks design of the proposed design - is working on the leg restraints in SolidWorks as well.

- maybe have the leg restraint be detachable?
- use the existing mount

Chest restraint

- worm gear can go both directions?
    - yes - based off the rotation of the motor
- additional component added to allow for the arms to be longer?
    - telescoping poles with different settings?
        - like crutches!
- metal bars having somewhere to rest on or just held by the pivot point
    - would be adjustable so nothing set to hold it in the restraint position
- very impressed with our progress! :)
- attaching from the arms or from the shoulder?
    - shoulder would be difficult to stay out of arms way
- the chair has attachments
    - going to call manufacturer to see if he can get additional things
- would our device be able to use the battery on the chair?
    - K: there should be different ports - added lights, etc (oxygen tanks or G tube etc etc that would need power) - will call manufacturer
    - this would decrease cost and size!
- buttons on back are the alternative to the joy stick
    - were on the arm rest but got moved bc clients arms continued to hit them
    - this also has power - this is another good sign
        - interface from this?
- Keith will call manufacturer sometime this week (probably Friday) to ask questions

Prototype supplies

- building a pvc model of chest restraint
- should be relatively cheap
- has a healthcare card with money
- upper end 40$
- future purchases will be more spreadsheet and specified

Conclusions/action items:

The team will continue research and prepare a "grocery list" for the prototype. The team will meet with the client at his house on Friday and go to Menards after to get prototype materials.

2020.10.23 - Client Meeting 8 - in person

JENNA WARDEN - Nov 09, 2020, 6:09 PM CST

Title: Client Meeting 8 - in person

Date: 2020.10.23

Content by: Jenna Warden

Present: All Team Members and Client

Goals: To meet the client in person, ask any specific questions regarding location and comfort of the current restraint, take additional measurements to then be able to calculate torque and forces.

Content:

The team traveled to the client's residence to see the standing wheelchair in motion

- used joystick to move chair around
- stood up, sat down
- basically played with the wheelchair to see what it could all do

Measurements

- the team then got additional measurements of the chair that the team did not have
    - these measurements are kept in a google doc on the team's drive
- the team helped the client get from his daily wheelchair into the standing wheelchair
- the team then got additional measurements to more accurately build the device so that it is in a comfortable position

Standing Wheelchair in Action

- the team adjusted the restraints with client in wheelchair
- then had client get to the standing position to make sure things were still in the right place
- asked questions about comfort and preferred location of new restraint
- then the team and client went outside and client drove in standing position up and down the block
    - video was approved by client and is saved
    - was a real joy being able to see the client moving around in the standing position
        - made the team realize the large impact this would make on the client's life
        - and could see the impact for further implementation of the device for other wheelchair users
        - overall was a happy moment

Conclusions/action items:

Being able to visit the client and help them get into the chair and move around as well as adjust the restraints to be comfortable and obtain measurements was critical in the progress for this design team. This will allow a more accurate SolidWorks, a more accurate free body diagram, torque calculation, as well as a better understanding of the "why" for this project as well as how beneficial it can be.

2020.11.03 - Client Meeting 9

JENNA WARDEN - Nov 03, 2020, 5:59 PM CST

Title: Client Meeting 9

Date: 2020.11.03

Content by: Jenna Warden

Present: All Team Members + Keith

Goals: Discuss progress so far and go over any questions the client (or team) has at this point

Content:

Leg Restraint

- Ben showed the current SolidWorks and explained the mechanism we plan on using
- mounted the same way the original restraint mounts
- pads the same as the other device?
    - similar styling - shape is copied but thought of doing a new pad
    - could attempt to use existing pads
- both restraints controlled separately?
    - yes - two different circuits
    - same microcontroller potentially - could use one
        - they're cheap so if two are needed its okay
    - two different buttons - one extends one retracts
    - same linear speed
    - is on a fixed path
        - pads are at the same angle etc - we would try to position them so they are comfortable and can go to the same location every time
- pads connected to the rod?
    - screwed into each rod
    - uses same leg pad mechanism
        - somewhat of a "plus sign" on the back of the pad and another connector piece on the other side and each have a bolt in them
            - this allows it to move and rotate on the rod
- could 3d print the connectors
- can we prototype this with the materials we currently have?
    - we could try with the PVC product we have
- adding a control module or interacting with the joy stick
    - just wiring the two circuits and putting buttons on the left arm rest (or right) in an accessible area
    - getting it to work is first goal
        - making it more tech savvy is second step
    - plug it in under the seat instead of at the top so that the leg restraint can still be removed

What do we need from Keith?

- working on calculations to determine specifics of design parts (torque and gear ratios for example)
- next 1.5 weeks will be based on component work and specifics
    - will be very busy
- biggest issue in the winter is a jacker
    - had a body blanket that he would put on the shoulder restraints so it falls down on him when he uses the restraint
    - could keep this in mind ?
- this is a cool design for everyone in wheelchairs
- can patent this idea and sell it to someone else which would also be cool
    - Keith can help with the paperwork
- voltage of the worm gear?
    - not totally sure - they vary
    - will be under what the battery can produce

Conclusions/action items:

2020.11.17 - Client Meeting 10

JENNA WARDEN - Nov 23, 2020, 3:06 PM CST

Title: Client Meeting 10

Date: 2020.11.17

Content by: Jenna Warden

Present: All Team Members + Client

Goals: Discuss progress over last two weeks and propose rest of semester's work

Content:

Marissa gave overview of what the rest of the semester will most likely look like

- no prototype
- begin prototyping beginning of spring sem
- fabrication plan and materials list
- working code

Calculations

- JM talked about torques, Ben looking into specific motors
- have preliminary motors
- chest: estimated worm gear.. this changes motor
    - good idea of the work gear - Keith
- leg: harder to calculate
    - hard to get exact weight
    - force of body doesn't create a moment on the screw
    - showed worm gear

Fab plans

- wrote the how to - mindful of services
- various assemblies (chest, motor, etc)
- added important measurements
    - and potential changes found
    - redesigning certain aspects
    - can also help mitigate potential fab issues that we would have come across
- using this opportunity to work out problems that we wouldn't have come across until fabrication

Material

- whats the weight of this going to be?
    - were using steal but wayyy too heavy (box alone was 40lbs)
    - we do not want to offset the COM of the wheelchair
- using 80/20 erector set for outlines and making the sides(walls) plastic?

Demos

- showed the resting position and deployed position of the PVC prototype
- showed pictures of prototype
- discussed calculations made thus far (torque and stuff) and motor options
- picture:
    - distance from head could be an issue
        - too far away means restricted arm movement
            - client needs to be able to grab things, open doors, push buttons, etc. - arms cannot be restricted
            - could also decrease ability to fully catch client should he fall forward
        - too close means no "wiggle" room

Future work:

- work on code
    - test it with microcontroller

- finish calculations
- maybe test side and dimensions of PVC on client?

Conclusions/action items:

The Team updated the client with the progress made in the last two weeks and updated about the final 3 weeks of class. Team will email client should any questions or concerns arise. The team will work on the future work bullets until next meeting.

2020.12.08 - Client Meeting 11

JENNA WARDEN - Dec 08, 2020, 5:42 PM CST

Title: Client Meeting 11

Date: 2020.12.08

Content by: Jenna Warden

Present: Team + Keith

Goals: wrap up the semester, discuss the final presentation

Content:

Presentation was completed

- had good feedback
- everyone was impressed
- so is Keith

This week

- working on final deliverables
    - final report
    - testing protocol
    - detailed fab plans - chest and leg
        - just needs a few more dimensions
    - gears and motors selected, materials just have some final dimensions needed
        - Keith wants to look over motors and gears
        - found through Mcmaster carr

Concerns

- replacement pieces
    - how standard are these items
        - how easily can he find these items and get them replaced
        - there are substitutes that can be used - just need to get the right combinations (pressure angles, pitch angles, gear modulus, etc.)
- have we looked at parallel drives?
    - they swapped out worm gears for parallel drives - ?
    - spur motors?
- No rush to ordering materials until the beginning of January
    - this gives us time to look into different things
- longevity
    - we want it to last for a few years at least

Color preferences

- send color options to Keith for him to look over

Another Meeting with Keith (12-17 of December)

- that works for him
- we want to test the dimensions of the PVC are to make sure it is accurate and reasonable and comfortable
- Dave Glancy
    - new charger plugs
    - he's coming to pick up the chair Friday
        - needs to call him back yet to know when he will get it back
        - will also get info on the battery part
        - how long will he have it?
            - maybe a week - can make sure he takes it after we come
            - Wednesday works? - dependent on time
- Will get back to him on a meeting time shortly
- Keith will watch the final presentation before we meet in person next
    - will give feedback on it if he has any

- can look over materials list as well
- rough total: unsure of 80/20 stuff but can send 80/20 information
    - realistically will be under 700 - closer to 500 hopefully
- wants more input on comfort stuff
    - would rather have a triangular look instead of square to allow to additional movement
        - makes sense - less impedance of movement the better
    - might be wearing for long periods of time and needs range of motion and for it to be comfortable
- will start working on this again at the beginning of next semester - before classes start
- any small improvement factors are welcome and will make the design better and better for user
- chest restraint will bow up to an inch or two
    - we can calculate this
    - we all learned about bending and deformation
    - we can add this to our testing protocol?
- Name change?
    - x chair stands for exercise not professor X from x men
        - this adds some more personality
- let's build it and test it! wooh!

Conclusions/action items:

The team wrapped up the semester with the client. We discussed the final presentation, the client's potential concerns, meeting with the client to determine measurements to be correct, and materials list. This will help us begin early next semester with ordering materials and fabricating this device.

2020.09.04 - Project Selection and Advisor Meeting

JENNA WARDEN - Sep 08, 2020, 2:21 PM CDT

Title: Project Selection/ First day of Class - Breakout Sessions with Advisors

Date: 2020.09.04 (Created 2020.09.08)

Content by: Jenna Warden

Present: Full Team

Goals: Go through usual first day items, find out who our advisor is, meet with advisor, determine team roles, team picture

Content:

Assigned advisor: Mitch Tyler

Joined BlackBoardCollaborate breakout room assigned to a professor Tyler, but he was unavailable to join at that time

The team then decided on roles - the specific roles are posted under Project Information -> Team contact information

Team sent headshots to Jonathon to be uploaded to the website

Ben sent out a form to fill out for availability to that we could contact the client and advisor with our full team availability

Created group chat for team to easily communicate

Conclusions/action items:

The team figured out the basics of the team dynamics and then proceeded to schedule the first team meeting as well as contacted the client and advisor to set up the first meetings with them.

2020.09.08 - Advisor Meeting 1

JENNA WARDEN - Sep 19, 2020, 8:43 PM CDT

Title: Advisor Meeting 1

Date: 2020.09.08

Content by: Jenna Warden

Present: All Team Members + Mitch

Goals: Meet our advisor for the semester, go over expectations, relay info from the first client meeting

Content:

Basic introductions

Each team member discussed what we took away from the first client meeting

Mitch's Mantra

- document EVERYTHING you do
- don't wait to write the report - you can start now
- live it as you write it
- keep the current focus on the first two parts of the mantra
    - what is the problem
    - why is it a problem
- why hasn't anyone solved this problem?
- are there things that can be cannibalized?
    - medical things that we can reuse to solve this problem
- are there things that somewhat solve this problem already?
    - there's probably something that exists and its probably very very expensive
- what can we repurpose and what do we have to invent?
- set the groundwork for 1&2

For next week

- have the first draft of PDS ready - doesn't have to be complete
    - its a living document
    - not graded
    - used to find where the gaps in our knowledge are - what are we missing
- make subteams
    - have at least two subteams - identify the key things that will need to be addressed
        - mechanics/ electronics?
        - make a timeline for each subgroup - some things will be quick and some will take more time
        - good to have milemarkers - keep everyone on track
- our weekly meetings with Mitch will be to address the things we haven't thought about yet
- think and then challenge our thinking
- don't miss things and don't forget about stuff
- Mitch is coming the weekend of the 25th
    - would love to meet with all of us
- when you have little "aha" moments - write them down!! they'll disappear fast
- send next meetings deliverables on Tuesday morning
- feel free to set up more meetings if we need or want them - just ask

Conclusions/action items:

Discussed the project in more detail along with the expectations that we have this semester. The team must have the first draft of the PDS ready for next week's meeting as well as a general timeline for the semester.

2020.09.15 - Advisor Meeting 2

JENNA WARDEN - Sep 19, 2020, 9:46 PM CDT

Title: Advisor Meeting 2

Date: 2020.09.15

Content by: Jenna Warden

Present: All Team Members + Mitch

Goals: Discuss first version of PDS, first two points of Mitch's Mantra, and beginning Blue Skying

Content:

Timeline

- add proof of concept (after 2020.10.02)
- work out kinks (1/10 scale or 1/5)
- movie Contact (1997) came to mind - big gimbal
- how is this going to work for this person?
    - is this really what client NEEDS? or could it be something else?
    - what else exists? we are contract machinists

The MANTRA

- first paragraph in PDS needs to be reorganized
    - all three elements are there but in the wrong order
- what is the problem/ unmet need? - whats the background
    - inability to move to different positions
- why is it a problem/ unmet need?
    - increases bloodflow, exercise, knows others who benefit
    - adds to health and quality of life
    - why doesn't this exist?
        - well what does
        - modifying an existing device can be easier
    - is what the client wants feasible - 1 2 or 3 axis
        - new challenge: stay away from Gimbals
            - inversion table?
- basically wants a therapeutic robot
    - enables his function
    - back to basics
    - inversion table
        - does he have this? would this work?
    - wants to fip upsidedown/ prone
    - wants to stretch but is constrained
    - does he need this?
        - how long can he safely be upsidedown? and is it safe?
        - could we use resistance bands instead of gravity for workouts
    - this is less exercise based and more position based
    - would need vocal safety measures in case he cannot get back to the remote
    - the more complex the device the more compensation it needs
    - law of parcimony
    - what is the purpose of the device and how can we achieve this?

PDS

- good start!
- what the client wants and what he needs - as well as how to keep it safe
- two routes for this semester
    - physical prototype
        - depends on covid
        - could someone else operate this for him?
        - could we make is manually controlled? - hand crank, gear, belt?
    - pure design

        - 100% theoretical
        - component analysis
        - needs to be ready to contract out
            - very detailed
- NO GIMBAL TALK
- safety features- will need more as the complexity of the device rises
- what kind of motion does he want?
    - ideals vs reality
    - reach out via email for more specific positions
    - build around chair?

More about Keith

- he has taken a very active role
- willing to help out - doing photometry for us - 7th teammate?
- asking him to do stuff to help us?
    - would feel appreciated but would take away from us
    - this is an academic project
    - he can have an input - be sensitive to his concerns
    - really rigorous PDS & capacity of that system
    - might be a reality check - might be disappointed but understanding
        - ballpark of cost
        - if things get hairy - call Mitch

Concluding Thoughts

- we have a better handle on whats necessary / realistic
- revise PDS - dynamic document - then evolve it
- don't NEED 3 designs - they must all be viable
- start small - will still be very helpful for client
- prepare to go down the road of preparing a document to hand off to a machinist to create the device
- ALL FRIDAY deadlines are now TUESDAY

Conclusions/action items:

Mitch declared there to be no gimbal talk this week. Update the PDS this week and start thinking about other ways to satisfy the client and meet their NEEDS while thinking outside of the gimbal idea.

2020.09.24 - Advisor Meeting 3

JENNA WARDEN - Sep 25, 2020, 4:51 PM CDT

Title: Advisor Meeting 3

Date: 2020.09.24

Content by: Jenna Warden

Present: All Team Members + Mitch

Goals:

Content:

What we need to do

- let him down from his idea but still satisfy him
- got a narrow email of what he wants but it widened back out
- two aspects of what he wants: vibration and inversion/prone
    - where do we go
    - do we go with both ways or just one
- references his standing up wheelchair a lot and his lift as well as voice automated aspect of his life
    - really follow the common themes
    - put these things at the center of the narrative
        - wants to do it on his own
        - can still be simple
- think about where client is coming from - being dependent on someone at all times
- spinal muscular atrophy
    - after puberty its more about comfort
    - what about his sensory input?
        - SMA - is it motor or sensory or both
        - has more upper body function than lower
        - lower body cannot do much of anything
        - different types of SMA
            - we think type 2
- we want to allow him to move - mental and physical - is still a level of comfort

Mitch outloud

- what benefit is there in meeting with him tomorrow if we are meeting with him Tuesday?
    - we have been pretty transparent about our abilities and constrains
    - has an over-expectation of what is possible of what he wants to do
    - use days until Tuesday to develop two or three design pathways - specifications and CAD
    - be well prepared for him to be dissapointed
        - we get that but this is our proposal based on our understanding of your needs along with our abilities and Covid
        - if things go crazy - no fab - we are SOL
            - in depth design specification narrative - report = cad and assembly directions
                - someone else can then build this
                - not the first option but be ready for that possibility
                - this could still be really beneficial
    - we build something with some of the things he wants OR we give him plans of exactly what he wants and then he finds someone to fabricate it - might be really pricy
    - client still doesn't get the whole gist of the course - timeline - these designs arent the end - can continue on
        - depending on our access to resources the first gen will be developed as a paper with specs and cad drawing for someone to manufacture it
    - meeting could be a time to clear up things and allow us to focus on specific things that we want to have in designs
    - trust our intuitions and don't allow our doubts to make us think we don't know something
    - gap between expectation and reality of this project
- between today and tomorrow/ next tuesday
    - spec out other things that exist
    - can we use them
    - how much are they

        - we can do x for y dollars
        - here's what we are thinking based on our understanding of what he wants
        - use tuesday meeting as a dry run for the prelim
        - TIME FRAME AND BUDGET - we can do one really really well so that it can be interfaced with further on semesters designs
            - make functional element(s) as the foundation
            - more teams in the future can add to it
- here are our concerns for our abilities - your abilities - the course- money - and covid
    - here's what we are looking at
    - we want you to think about this
    - let him take our ideas and turn them to be what he wants
- will this be safe enough? will the liability be too much - for us/ university?
- everyone do their own bluesky
    - what are his top things
    - 10 min max
    - what are the functional pieces of this
- purely academic
    - spec out every nut bold line of code etc etc
    - this will be a huge experience
    - a "fruitful exercise"
    - will made us work harder - but will teach us a lot

** Mitch investigate university liability - a student group under PE supervision at a well accredited university

1. concern - we think we understand the big picture - given resources - time - budget - skills ; we need to break this into a system that can be integrated together over further semesters

2. this is what we think - these 5 modules are the "most important" based on our understanding - which are the highest priorities - we pick the top one and made that module with the expectation that it will work with the further modules - will build his understanding, realistic expectations, and our report with him

3. we will create this first piece - will be the foundation and will be GREAT

4. handoff to a new team - use our thing and add to it - here's what your first steps could be

What does the client want? - team 5 min Bluesky

- greater independence
- up down standing
- prone
- vibration
- autonomy
- comfort - vibration
- ability to get different positions
- putting all of them together
- autonomous
- prone
- vibration
- spin - g word
- seamlessly control these actions
- autonomy/ accessibility
- positions unattainable in wheelchair
- vibration
- compatible with exercises
- rotational movements in other axis
- independence
- voice control
- inversion
- vibration
- standing

Design matrix

- use this in tomorrow's meeting
- use our top 5 things and rate them
- if you agree to this and understand this - this is our plan to work on things
- will have a draft of timeline and presentation

- can meet up with mitch again before meeting with keith
- can use what keith says on Tuesday for prelim design presentation on friday
- need to get this into shape - skillfully - so that by the end of prelim presentations
    - its a coherent narrative
    - its a legit concept
- 4 weeks after prelim we have something built and have testing protocol in place

Mitch is cool being the bad guy if things don't work out

debrief Mitch after meeting with Keith

Mitch can also be there tomorrow

Meeting at Keith's house

- not everyone go (2)
- take a video
- get tested
- wear a mask
- have someone who is regularly around him take a vide

Due dates

- send things on tuesdays
- prelim report - Tuesday if we can Wednesday is fine
    - at least a third of that is already written - its in the notebooks or our brains
    - someone be the draft master - evolve it over time
    - don't wait lol

Conclusions/action items:

The team discussed the many client emails we have received and talked about what was most important to the client in the design. Mitch gave advise on how to have a conversation with the client stating that we don't have enough time, money, expertise, and other limiting factors to be able to complete the device that they had in mind. The team is prepared to meet with the client tomorrow (09/25) to discuss where the design is at and where it will be going in the future.

2020.09.29 - Advisor Meeting 4

JENNA WARDEN - Sep 29, 2020, 5:04 PM CDT

Title: Advisor Meeting 4

Date: 2020.09.29

Content by: Jenna Warden

Present: Team and Mitch

Goals: Go over the shortened preliminary presentation and discuss any issues that arise with it

Content:

What we have done

- three adaptions and one standalone
- multiple matrices
    - standalone vs adaptation
        - leg and chest area

Mitch is available until 5:00pm Thursday

Meeting with Keith

- taking his feedback and changing it for friday
- can send what we have by noon Thursday for feedback
    - free consult to hopefully skip any discrepancies that may occur in the actual presentation
    - can send slides and video
        - video less important
        - more concerned with the slides and the narrative that they tell
- don't use umms and ahhs and hmms
    - if you need to pause, just pause and let the audience digest

Looking over slides

- PDS
    - focus on device itself
        - then go into sub categories for weight
        - the device wont be under 4 pounds
    - inversion table
        - modified from regular inversion table
    - pressure cuff
        - air mattress?
            - conceptual placeholder
            - series of inflatable rubber bladders
    - boa
        - graphic of some sort
        - coneptual
        - when presenting - go less detail with materials
        - concept less specific
    - roller coaster harness
        - most conceptual
        - more complex - less safety - harder to use
    - matrix 1
        - needs some additional background - what the last meeting with Keith was like
            - what he's about and what he wants
            - will make the presentation much more understandable as to why we are choosing what we are choosing - aka what the designs are
            - based off of extensive interviews we have identified these areas as a need and this is how we turned them into a specification
                - these are the design ideas that will accomplish all or most of these requirements

            - use project name into a joke that it wont happen anytime soon - but here's the chunk of it that we are going to do - this sets a framework for our presentation and designs
    - matrix 2
        - boa system for chest area
    - matrix 3
        - leg boa - has merit
            - key liabilities
            - we would have to manipulate the mechanism
            - motor or remote manipulator
            - adds mechanical complexity
                - can he reach down?
            - can run the system up to within reach
        - roller coaster leg
            - everything is simultaneous
                - mechanistic - would be cool
                - as long as its not too spiderman-y
    - final design
        - easiest to implement
        - can use the same restraints that are used - don't have to build off the wheelchair as much
        - can also possibly make it easier to use
        - works with high power and high durability as well as high accuracy and can withstand force
    - future work
        - would like to integrate multiple systems
        - automating the mechanical aspects if possible
        - ratchet systems - this could be the simplest thing - need to look into it more
    - thoughts?
        - quantum leap in terms of understanding and options for a solution
        - solidworks????
            - have concept drawings
            - wheelchair with bubbles showing how each system attaches

Conclusions/action items:

The team will continue work on the preliminary report to make it finalized for Friday. Mitch will be available to look over things starting Thursday morning until Thursday afternoon. Mitch was impressed with what the team was able to come up with

2020.10.09 - Advisor Meeting 5

JENNA WARDEN - Oct 09, 2020, 2:19 PM CDT

Title: Advisor Meeting 5

Date: 2020.10.09

Content by: Jenna Warden

Present: Team and Mitch

Goals: Discuss Preliminary deliverables and next steps in the design process

Content:

Prelim presentation

- why didn't we send a review for him? (mitch)
    - time ran out
    - had a lot to change in a small amount of time due to meeting with Keith on Wednesday night
- given the rocky start
    - what the client had in mind was a cool idea but time and resources limited this
    - did a good job of wrapping heads around what he wanted
        - good job taking feedback and talking to the client
        - dealing with client expectations and what we can really do
            - due to time and money
    - was a challenging situation
        - came away smarter more capable and more confident
        - KUDOS
    - the presentation was good but a little chunky
        - given a few extra days, the narrative would've been smoother but was still solid
        - came across that we understood the project and what we are going to work on
            - this set the tone
    - good job on setting the expectations
- specific critique
    - naman camera angle
    - just put a picture of ourselves - doesn't have to be a video
        - mitch is happy with just a picture and name - this would smooth out the "weirdness"
    - made a good impact but could be stronger
        - this doesn't exist and there's nothing like it
        - this is why we needed a set of priorities
    - the problem statement was one long narrative
        - can be short abstract or bullet points
        - get the essential elements
    - too much time on SMA
        - it's good but it took away from the rest of the narrative
        - the background is appreciated but find a better balance
        - the report should have more background to tell why the PDS and design requirements are what they are
    - individually
        - naman Marissa Jenna - a little flat
            - something to work on
            - can record and re-record so its "perfect' - makes it less personable
            - no immediate feedback - cant gauge the audience
            - will become more comfortable over time - could be the new norm
        - we all have great and dynamic personalities - we are all handsome
        - allow personalities and curiosity to come out
        - it's okay to inflect and add personality to our videos
            - show off
        - Jonathon - good poise and tone
            - allowed the story to come together
- the report has not been looked at
    - this will allow us to create a magnificent final report

        - next semester is peer-review publication format
        - last technical report
    - lots of edits are not bad - just helping us have a better report
    - will help us in the real world and potentially masters or industry

Planting a seed

- this semester is heavy lifting
- building testing validating
    - how it informs next semester
    - documented in a peer-review publication
- next week
    - fab plan and proof that it will work
    - prove to ourselves that it works, safe, reliable
    - data for the poster
    - how we test it may inform how we design it
        - can give us data sooner on how it will work in the end
    - do some thought experiments
        - all on paper
        - think about it to the nth degree
        - how it won't work
        - any ramifications
        - wear the black hat! and the green and white and some red
        - how are we going to make this happen and how do we know it will work?????

comments questions concerns

- meeting with mitch in person really helped us talk with the client to "let him down"
    - document his design ideas to pass onto other groups
        - add a lab archive for this so they don't get lost
- meeting in person with Keith changed everything
    - how were we going to do things after the preliminary presentation
    - gauged his abilities and limitation
- hold back on client meetings to really form the design and get rid of any issues we find
- keep up the good work!

Conclusions/action items:

The team discussed the preliminary presentation and got constructive feedback. Mitch advised that we start thinking about testing and how we are going to test our device and to write everything out on paper and analyze it thoroughly. The team will spend the weekend and Monday brainstorming design ideas and doing research on individual parts as well as how to test them.

2020.10.13 - Advisor Meeting 6

JENNA WARDEN - Oct 15, 2020, 12:46 PM CDT

Title: Advisor Meeting 6

Date: 2020.10.13

Content by: Jenna Warden

Present: All Team Members + Mitch

Goals: Discuss new design idea and get feedback on it

Content:

Time for the narrative to start getting to the good stuff

Current problems in the preliminary proposed final design

- how would we attach it - does not seem feasible
- we used pictures and measurements online
- could come from sides as that would be less distracting but coming over the top would be easier
    - wouldn't impede clients mobility
    - wouldn't need client to move at all

Roller Coaster Harness

- chest restraint would be automatics
- foot restraint would stay in place at all times
- allows for easy entry and exit
- bens solidworks was shared
    - use a worm gear to prevent excess rotation
    - use small gear with motor
        - large gear for greater torque
    - do force calculations ~75% of clients mass on the lower bar
        - calc torque
        - make sure our device can deliver twice that amount in the opposite direction
- do biomechanics and statics equations
- box might be large but wont pass wheels
    - still a concern
- locking mechanisms
    - Naman found masters thesis about roller coasters - had info in it
    - have a backup system
- chest must move really far down - make sure we know where it will end up in the relaxed position
- add locks between legs?
    - doesn't have the dexterity to do this
    - would be added safety - **could we somehow still incorporate this?**
- nucleo/arduino
    - forward backward buttons
    - bluetootyh with joystick - stick to our own buttons for now
- how much restraint is needed? - not as robust - most of the force is in the leg restraint and the seat
- typically client cannot use chair
    - would enable some exercise
    - safety feature
    - would offer massive amount of added movement
- must be discrete
- how will this be powered? - our own source or the chair's power source
- have an override system - electrical or mechanical
- wheelbase seems thing
    - device is upwards of 500 lbs
- risk of tipping? com? a concern that isn't our problem
- power?
    - tap into the wheelchair battery
        - what rating does it have

        - dies it have an auxiliary port?
        - will this violate manufacturing rules
        - we wont need a lot of power
            - higher torque lower velocity
    - have our own power supply? - where? charging?

Whats next

- design, research, torque calcs
- how to power the device
- developed refined model for client meeting and get feedback
- long term: ish? order components and build
    - harness welded or alternatively connected
- work on code
    - rocker switch or controller
    - rasp pi, arduino, nucleo
    - need motors
    - rotate forward and back
    - have locking and safety features
- electrical components
    - simulate in LTspice
    - make a block diagram
    - if signal up then close the relay and allow current
    - if signal down then open the relay and don't allow current
- break into teams
    - instrumentation and mechanical
    - these projects are parallel not one after the other

Conclusions/action items:

The team presented their new design idea to Mitch using solidworks and sketches on photographs of the client's standing wheelchair. Mitch gave feedback and asked/ brought up important aspects of the device that will be needed. He suggested we split into teams that are working in parallel with each other as there is a mechanical aspect and an electrical aspect to this design. The team is going to continue research as needed and prepare to present the design idea to the client during the meeting on Tuesday 10/20.

2020.10.20 - Advisor Meeting 7

JENNA WARDEN - Oct 20, 2020, 6:57 PM CDT

Title: Advisor Meeting 7

Date: 2020.10.20

Content by: Jenna Warden

Present: All Team Members and Mitch

Goals: Show updated SolidWorks, go over progress from this week and discuss the meeting with the client and prototyping plans

Content:

Give brief update

- new solidworks - super pretty!! and moves around
- fully automated
- roller coaster design
- keith was really impressed with our progress over the last two weeks
- liability concerns? - bring it up in design meeting this week

Ben's SolidWorks

- still doing research as we continue through prototyping and designing
- we are in different subteams
    - materials/ fab
    - hardware/ software
    - solidworks
- two servo motors
    - first works with the worm gear
    - 15:1 torque ratio onto the bar - reduce motor cost and size
    - second does the locking mechanism
- rachet will be attached for a locking mechanism
    - servo motor will put it in place to prevent motion
    - add manual key slot to move gear out of the way for getting out of it
    - safety feature: limit switches on the shaft that cuts the circuit (backup)
        - if software fails - there will be physical limits to prevent power from getting to the motor
- will be another diagram for leg restraints
    - different mechanism but conceptually on the same page
    - SolidWorks will be very useful
- Big issues
    - stability
        - wont add a lot of weight and its stable
        - be prepared to address this at the poster session
            - will this be a risk?
            - initiate this conversation
            - the moment this adds is minimal to the base of the wheelchair
                - be proactive!
                - mitigate this
    - power
        - how much of a draw will this be on the battery?
            - will it be powered only from retracted to deployed position
            - how much power will it take?
                - will be expected in poster presentation and final report
        - keith is going to call the manufacturer about aux ports on the battery
            - he has added lights and the button box
        - one of us students reaches out to an engineer
            - we are working on this project
            - "naive student"
            - we don't know the capabilities of this will you help us
            - they're going to want to help us
                - or ask what we are doing to our chair

                - this is a warning
                - do the back door!
                    - incorporate their will to give us insight
                    - send an email? - give them a heads up
                    - we should take the initiative to call them
                - Keith calling might worry them - explain these concerns to Keith about him calling
                    - if he puts up a stink then let him do it
                    - might be more efficient for us to call as well
                    - keith was going to keep it vague
                        - let him take the first shot at it and if we arent getting the info that we need then we should call
- Mitch is happy!!!!!
    - and is impressed at how quickly we have discovered the real issue for this project and the ownership we have taken with it
- Meeting for next week is up to the team
    - can decide sunday/ Monday on if we want or need a meeting
    - can decide after fabrication of prototype
    - as we build prototype - use for show and tell
    - this and this works but we didnt think about this - use for show and tell
        - can get good feedback and other ideas
        - catalyst for progress as well
- pretty solidworks picture, then pvc prototype, then final build
    - where are we at for final building?
        - naman researched many materials focused on stainless steel vs carbon fiber vs aluminum
            - carbon fiber is awesome - more expensive - can cut and use connector pieces
                - using epoxy-based adhesive - have similar strength to welding - can look more into this
            - aluminum - would need to weld
        - will know more after meeting with keith and prototype and the 80-20 website the Marissa found - mainly t slot stuff
        - probably wouldn't be much to have someone at the university to weld this for us
        - maybe just use carbon steel?
            - going to be least expensive to build (compared to aluminum)
            - can have thinner walls - due to tensile strength
            - each joint will have a bending moment
            - aluminum vs carbol steel will end up being the same weight
        - could theoretically have this job done by the team space
            - think of materials
            - calculate bending moment
            - calculate thickness of each material
            - can decide material from there
            - request for bid from welding shop
            - stainless would be nice - but not for first prototype - and its a pain to machine and weld
            - go with aluminum or carbon steel
                - carbon fiber is great but pricey
                - keep it cheap for the first prototype
                - not convinced a fancy metal is worth it at this point
        - down the road - once we are successful - per mobile may incorporate this design with their chairs
            - big bragging rights!!!!!
            - this is a huge compliment to engineering skills
- bending moments, pretty pictures, materials, free body diagrams for all key components, torque calculations - these will all be in the final report

Conclusions/action items:

The team will continue to work on the solidworks of both the chest and leg restraint as well as continue materials research. The team will begin work on free body diagrams and moment/ torque calculations. The team will also meet with the client on Friday at his house as well as going to Menards to gather materials for the first prototype of the device.

2020.11.03 - Advisor Meeting 8

JENNA WARDEN - Nov 03, 2020, 6:42 PM CST

Title: Advisor Meeting 8

Date: 2020.11.03

Content by: Jenna Warden

Present: All team members + Mitch

Goals: Discuss progress, show and tell, and go over any existing questions

Content:

Some Setbacks

- 3 people got Covid so we have a little bit of a setback
- were not able to create a prototype
- we have still made a lot of progress outside of our meeting
    - have a full leg restraint
    - this helps with fabrication and what materials to use
    - component and material research
        - Marissa looked into the 80/20 - this will be viable - yay!
        - Jonny started FBD and physical limitations
        - discussed electrical capabilities with Keith
            - he will be breadboarding with his chair
        - We decided on a microcontroller

Things to do

- Ben and Jenna meet and get a prototype together
- find motor torque resistance - type (we were looking at servo motor)
    - servo - yes but go for a modest version bc this doesn't need to be super super accurate
    - 4pi radians would be the necessary accuracy
        - will reduce size and power requirements and cost
- torque calculations
    - leg restraint started
    - need chest restraint solidworks
        - don't wait - we have rough dimensions
            - +/- cm or two
        - are we talking MN or N or dN per length
        - get a rough calc - this will tell us what type of stuff we need
    - being in the right ballpark is fine - we can fine tune this in the next 4 weeks to get all the right numbers
    - scratch paper calculations - this will dictate the drive ratio
        - higher drive = slower = smaller motor
        - whats a tolerable amount of time between resting and locked position
            - minute? 30 sec?
            - should be discussed - assume it will take 30 seconds and go from there
            - we can then tinker with it
            - this is a mathematical prototype
- sucks that people got sick but now how can we get the most out of what we can do
    - use our head first
    - we looked into all ramifications
        - first one is a pretty good approximation
        - just has to move once at the poster session
        - show that it works and we will have built something and we will know what needs to work differently next semester
- Ben showed the leg restraint and explained it
    - likes the adjustability but not sure if it needs to be as intense
    - copied from current adjustability
- power requirements
    - tap into the battery? how much power do we need?
        - port that plugged into the battery

            - calculations haven't been calculated yet bc or toque
            - shouldn't cause too much power draw
                - servo are 5-6V and battery is 12V 63Ah
                - use the same voltage rating on the servo motors so we don't have to convert power/ resistors
                - need to power our circuit - will need power converter (logic shifter)
        - location?
            - back of the leg support will have a wire hole and will have a connector plug so the restraint can be detached
            - main circuit would be located with upper body restraint or could also put a small board/ Arduino nano in the box for the legs
            - push button - motor moves until predefined point / sensor - sensor fails
            - lines of security
            - should be able to comment out 90 degrees and when the sensor is hit then it turns off
            - then also have a physical fail-safe
            - find a well-documented code with comments that I can follow and write new code or change the code/comment out parts and add what our specifications
            - hopefully we can find a well commented code - ours better be well commented
            - learn C/C++
- prelim report
    - did good job narrating the report
    - he went light on the fact that we were reporting on an "old" life
    - interested in how we document this phase
        - prototype can be chunky
        - how we tell the story from a technical analysis
        - what would we do and how if we had to job this out - contract work
        - could they do the job with the documentation we provide
        - is this a sufficiently robust document and someone could fabricate this for us
        - Naman is anointed to asking "is this enough" - black hat!
        - lockdown November 30????
            - can we fab?
            - what are the implications?
        - if we have a good well thought out report and all we have is pvc this may have to be good enough

Conclusions/action items:

2020.11.17 - Advisor Meeting 9

JENNA WARDEN - Nov 23, 2020, 3:54 PM CST

Title: Advisor Meeting 9

Date: 2020.11.17

Content by: Jenna Warden

Present: All Team Members + Mitch

Goals: Discuss progress since last meeting and proposed plans for the remainder of the semester

Content:

THE Update

- Marissa gave update
    - PVC prototype and photos
    - want to size it on him and have the correct dimensions
    - covid and limited lab times already + the end of the semester rush
        - this limits our abilities even more
- detailed fab plan, code, materials (ordered for begin Jan fab), beginning of test protocol, foot security
- fab to be done before spring sem/ when TEAM Lab opens
- is letting us workout the problems with our ideas before it is too late and we are halfway done fabricating
- todo:
    - FORMALIZE THE AGREEMENT
        - draft it, send it to Mitch, make edits, finalize it
        - basically put what Marissa said in a word doc
    - defend final report and presentation in it
    - wear the fabrication hat and critique everything
- what will we show at final presentation
    - how it is mounted / use black glove to move PVC around?
        - show path forward, and backward
    - animate the solidworks to show how gears move and turn
    - discuss fab plan, testing, expected results, what we learned, why we chose this route, code
    - use this "virtual" thing to our advantage

Concerns at this point

- Marissa
    - Weight!!
        - originally using steel but the component box was 40 pounds
        - no longer going to use steel
    - preassembly for fabrication will be important
        - taking it apart/ maintenance is important
        - hinged top / unscrew sides for component box(es)
- Ben
    - connecting everything
        - also will use preassembly
        - finding materials and components that fit all needed aspects as well as connect with other pieces is becoming difficult
    - two motors for chest? -MT
        - one motor moves it
        - second motor was to move the rachet system - will be smaller - was just a placeholder
- Naman
    - tutorials were promising and helpful
        - followed a few more STM32
        - ordering materials Nucleo F303K8
            - about 10$
            - make code and run it - debug and make sure it compiles
        - just buy it and become confident in the code and it working
- Jonny
    - working on calculations - torque and FBD

        - struggling with what assumptions to make and to not make about the device
            - currently using pen and paper
            - convert this into matlab to make it easier
- Jenna
    - was looking where to order steel components - no longer important
    - came across another safety issue - someone pushing the restraint button when it shouldn't be
        - toggle switch - protective cover over it (detend or ribs?)
            - easily activated/ unactivated
                - human factors
                - look into ADA Regulations - lends credibility

Future work:

- can meet with mitch next week but assuming we will not need to
- open for a dry run of final presentation week of presentations
- send over formal agreement asap
- continue working on the new final deliverable items

Conclusions/action items:

The team discussed progress for the rest of the semester and agreed upon the final deliverables. The team will write a formal agreement regarding the final deliverables. The team will continue work on the project and will begin work on the final presentation. Mitch stated he will be available for dry runs of presentations any point up until the day before presentations.

2020.12.2 - Advisor Meeting 10

JENNA WARDEN - Dec 02, 2020, 3:15 PM CST

Title: Advisor Meeting 10

Date: 2020.12.2

Content by: Jenna Warden

Present: All team members + advisor

Goals: Disucss final presentation and any edits that need to be made

Content:

Send final agreement contract, might need to edit it due to Marissa's situation

Just need final details for chest fabrication, and finalizing the code for deliverables

Conclusions/action items:

2020.09.07 - Team Meeting 1

JENNA WARDEN - Sep 08, 2020, 2:57 PM CDT

Title: Team Meeting 1

Date: 2020.09.07 (Created 2020.09.08)

Content by: Jenna Warden

Present: Full Team

Goals: Review Problem Statement and Create a document of questions to ask the client during tomorrow's meeting

Content:

- relooked at project proposal as it had changed from three options to one on how to go about the project
- reviewed the specific items that the client wants to be completed
- discussed questions we had for the client
- discussed potential difficulties we found in the given procedure for the project as given by the client
- questioned the goal of the project vs the title - exercise chair or increased mobility chair
- discussed means of obtaining measurements - need photos to recreate a model - find mass and center of mass - built-in functions
- range of adjustability - wheelchair sizes, user weight, and height, complete disassembly
- are we allowed to start small then work our way to the larger concept? how much variance do we have with this as a team
- questioned the budget - what kind of materials can we get for that price - the beginning of brainstorming - is this flexible?
- how does the client prefer to go about making purchases?
- what are the pros and cons of the device being completely disassembled?
- think about how to get three axes of rotation and the lifting aspect in our final device
- the controls of our device will have to be via Bluetooth in order for wires to not get tangled during use

Action Items:

- Add any further questions to the doc by tonight
- Email the client containing questions for him to review and prepare for the meeting
- Meet with client at 5 pm 2020.09.08
- Meet with an advisor at 6:30 pm 2020.09.08
- Start preliminary research surrounding the following ideas: gyroscopes, wireless communication, current lifts that are in use
- Fill out LabArchives contact page
- Stay on top of LabArchives entries throughout the year!!

Conclusions/action items:

The team prepared questions to send to the client to help facilitate the first client meeting tomorrow. The team began to do preliminary research on the large topics that will be involved in this semester's project.

2020.09.14 - Team Meeting 2

JENNA WARDEN - Sep 20, 2020, 10:03 PM CDT

Title: Team Meeting 2

Date: 2020.09.12

Content by: Jenna Warden

Present: All Team Members

Goals: Divide up the PDS sections to have written for the first draft

Content:

PDS

- the beginning is already written
- each team member will take 3-4 sections
- have completed by 2 pm 2020.09.15 to be sent to Mitch

Upcoming Meetings

- Meeting with Keith
    - compile any questions you have
    - continue general research
- Meeting with Mitch
    - discuss PDS
    - have the first two points of the Mantra answered
    - discuss progress so far

Action Items

- each member needs to complete their sections of the PDS prior to 2 pm
- think of any questions for the client

Conclusions/action items:

The team divided up the sections of the PDS to write individually and then come together to edit it as a group and discuss any changes that need to be made. The team is also preparing any lingering questions they have for the client and advisor during both of those meetings for this week.

2020.09.20 - Team Meeting 3

JENNA WARDEN - Sep 21, 2020, 12:17 PM CDT

Title: Team Meeting 3

Date: 2020.09.20

Content by: Jenna Warden

Present: All Team Members

Goals: Discuss emails from the client regarding the clarifications on needs for the device. Prepare any questions for Keith and Mitch.

Content:

Email from Keith

- first email is clear: vibration and inversion is what he wants
    - things already exist: baby vibration chairs, mall foot vibrator chairs
    - could make a different strap for his lift to allow gravity to pull his legs straight down
- take a step back - what is medically good
- the follow up emails make it more confusing - send to mitch and see what he thinks?
- the necessary safety devices are out of our scope/ liability
    - along with some of the things that he wants from us
- inversion table
    - strap in at waist/ body
- could we build something that attaches to one of his wheelchairs?
    - vibration pack for under his seat?
- most important aspect of the device is for it to be used independently

Seeing his lift in action

- could we ask him to have someone send us a video of it
- got a pretty good idea of it on video chat
- he invited us to come see him use it
    - is this safe?
    - is this a university liability?
    - are we comfortable?
    - is this right?
    - ask Mitch

Weekly client meetings

- is this necessary?
- what do we accomplish in the weekly meetings besides just getting more ideas from Keith about design - can be confusing
- move them to biweekly or as needed

Action Items for the next two days. (before Tuesday 09.22 meeting with Mitch)

- cancel meeting with Keith for Tuesday (09.22)
- look at PDS
    - is there anything we can make less specific to the 3-axis design idea
    - highlight things that are too specific but arent able to be replaced as of yet
    - change the intro to follow the mantra
- email Keith
    - changing meetings to be biweekly
    - ask which chair he would prefer if we go the route of an attachment
- email Mitch
    - moving 09.22 meeting to 5 as it might go longer
    - forward the email chain of Keith's clarifications on what he wants
    - when are weekly progress reports due?
- Meeting with Mitch talking points
    - thoughts on email chain
    - what we took out of it
        - vibration and inversion
        - should we pick one?

        - split into two subgroups and tackle both?
    - keith invited us to visit him to see his lift in action
        - is this safe/ smart/ allowed?? thoughts?
    - plan for the Keith let down of 3-axis design
        - we are just the first team
        - he can have the project continued with other students in years to come
        - these are the ideas we have as of now

Goals for the next week and a half

- get more specific for the PDS
- preliminary designs
    - make it a realistic approach
    - can have < or > 3 design ideas
- begin basic prelim report work - fill in what we know
- more research
    - Marissa - medical background, what is good for this condition
    - Naman - exercises and effects of SMA
    - Ben - existing devices that we could use
    - Jonathon - competing devices involving standing up/ sitting down and inversion
    - Jenna - competing devices that incorporate vibrations/ more rigorous shaking

Conclusions/action items:

The team discussed what the client really wants out of our device and strayed from the design ideas that the client had. We also discussed how often we should meet with our client and came up with a game plan for our advisor meeting for this week. We also looked at our timeline and decided to continue research, but divide it up so we are not all researching the same thing, and will begin work on the preliminary report by writing out the things that we know at this point.

2020.09.27 - Team Meeting 4

JENNA WARDEN - Sep 28, 2020, 12:41 PM CDT

Title: Team Meeting 4

Date: 2020.09.27

Content by: Jenna Warden

Present: All Team Members

Goals: Discuss meeting with Keith, come up with preliminary designs and create the presentation.

Content:

Meeting with Keith

- was a little disappointed but was very understanding
- he only cared to see the sketches - have until Friday for CAD drawings
- focusing on: prone, standing up, doing it on his own
- talk with Keith about visiting him
    - ask about tested etc
- adaptation to his wheelchair or a standalone device

Preliminary Designs

- have a third design be **inversion table** - but needs an assistant - **how often is someone there to help him?**
    - could have straps
    - could allow him to get in easily
    - could be "reversible" to allow him to be prone or (flip the strap) and allow him to go upsidedown
- helping him strap his legs in on his own
    - for standing wheelchair
    - **bloodpressure cuff**
        - pressure sensor
    - **replicating roller** coaster leg restraints - superman
    - close to a lap bar - raging bull
    - using a motor - pulls something tight/ loosens it
    - see what his straps currently are - we can modify it
    - snowboard boots with tightening wheel - could be - **boa system**
        - helmet system - with webbing - might be not comfy
            - could put this on the backside so it pulls chest piece down
        - how do we model this?
        - would need a buckle somehow - so he can get in and out
        - magnets?
    - padded thing (stick like) that goes under his arms and moves up and down to help him

Further Research

Ben: blood pressure, inversion

Jonny: roller coaster

Jenna: boa, inversion

Marissa: roller coaster

Naman: boa

Conclusions/action items:

The team came up with four possible designs, underlined and bolded in the content section. We discussed which are most plausible and assigned more people to research them while less researched the other ideas. The team will complete their research tonight and meet tomorrow (09/28) at 1pm to discuss the designs (with drawings?) and split up the work for the presentation and the preliminary report.

2020.09.28 - Team Meeting 5

JENNA WARDEN - Sep 28, 2020, 3:18 PM CDT

Title: Team Meeting 5

Date: 2020.09.28

Content by: Jenna Warden

Present: All Team Members

Goals: Discuss the designs we have come up with, make sketches, make presentation, divvy up the portions

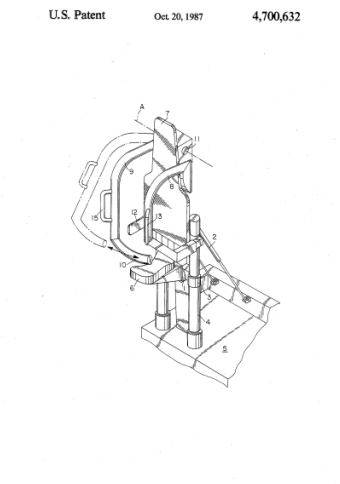
Content:

Boa System

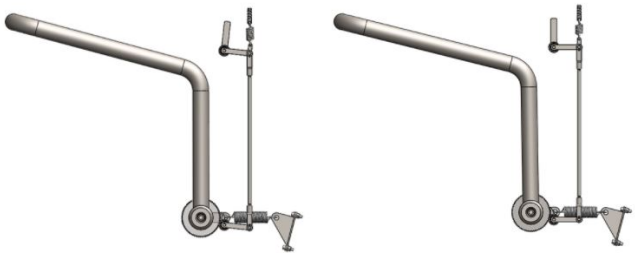
- components
    - three main components
- four different series
    - which one would we want?
        - H/M series would probably be better
        - more built for larger forces, larger impact, and maintain tightness better
        - con: lacks adjustability a little- would have to quick release and retighten
- using a ratchet system? to crank it to a tightness - no worry about open or closed loop
    - would it be too hard to latch and unlatch
- sent sketches
- is wire strong enough?
    - Jenna look into this
- use a buckle?

Roller Coaster

- patent for roller coaster harness



    - maintains the standing position
    - has a crotch position
        - could insert this to help him stand up right
        - lot of the forces go here- chest constraint can have an easier job bc a lot of the forces from the chest move to the seat
        - maybe his chair already does this?
    - chair only goes 80%



-
    - over the shoulder hydraulic harness
    - would prevent from getting into the chair with the lift
    - could we make it go further back
    - lever allows you to release the harness
    - add a strap so that he can pull on it and it will pull the lever
    - how do we connect this to the chair????
- ankle things from Superman
    - they go over the ankles when the shoulder thing closes

Concerns

- attaching things to the chair without seeing it
- discomfort in the groin area???? (the guys said this)
- gear system that would connect upper and lower parts of roller coaster
- not knowing how client gets in and out of standing wheelchair
- 80% standing - what does this mean?

Blood Pressure Cuff

- arent large scale pressure cuffs - mainly just "arm" size
- looked for series of smaller bladders
    - inflatable mattress
    - 
    - child edema?
        - project in BME
        - uses pressure cuff around infant arms - had a series of inflatable rubber bladders
            - similar to picture above
    - using a series of bladders would provide more support/ be better
- would still need BOA or ratchet systems to secure it
    - extra padding for boa system?
    - 3/4 closed circle for him to put his leg in
    - using an aircast?
- same as boa would just add more comfort
- use an automatic pressure cuff?
- wears shoes? makes adaptation to the shoes that will clip into the wheelchair?
    - how does he put shoes on? does he wear shoes?
- automatic pressure cuff?
    - could just push button

Inversion Table

- not viable
- will get kicked off after first matrix

How to chose?

- instead of design matrix we could do a system matrix
    - have two - one for upper body one for lower
- start with independent vs working off of standing wheelchair
    - go into the systems
    - then go into the upper and lower body matrices
- Ben talks about the design matrix - go fast

Conclusions/action items:

The team further discussed the design options after doing more research on the devices used. The team then split up portions of a smaller report for the client and then moved them into the preliminary report and added portions to be the full presentation. The team also split up the writing portions for the preliminary report.

2020.09.30 - Team Meeting 6

JENNA WARDEN - Oct 01, 2020, 12:55 PM CDT

Title: Team Meeting 6

Date: 2020.09.30

Content by: Jenna Warden

Present: All Team Members

Goals: Discuss Marissa and Jonathon's meeting at the client's house to see his standing wheelchair

Content:

- viewed video of all elements of standing wheelchair
- measured the angle that the standing position is set at
- took pictures of the standing wheelchair to then use for photogrammetry
- watched him do simple tasks during the meeting - allowed us to gain a better understanding of clients dexterity and ability to move around
- got to know the client on a more personal level

Conclusions/action items:

The meeting at the client's residence allowed the team to gain a better understanding of the abilities of the client within his house. It also gave us a better understanding of what his standing wheelchair looks like as well as how it functions. This was a crucial moment in the design process as the team now has a visual of what the possibilities of connecting our device to the wheelchair.

2020.10.01 - Team Meeting 7

JENNA WARDEN - Oct 01, 2020, 1:02 PM CDT

Title: Team Meeting 7

Date: 2020.10.01

Content by: Jenna Warden

Present: All Team Members

Goals: Discuss what work needs to be done and added to the preliminary presentation as well as dividing up who is saying what.

Content:

Presentation Division

- 1-5: Marissa
- 6-9: Jenna
- 10-12: Ben
- 13-15: Naman
- 16-end: Jonathon

Slides that need work

- client info: Naman
- PDS: Ben
- background: Marissa
- client requirements and design specifications: Ben and Jenna
- references: all

Final remarks

- ask Keith if the picture he has sent us in emails is okay to use in the client slide

Conclusions/action items:

The team met to make final touches on the preliminary presentation and discuss who is talking about what. The team will work on making final edits on the presentation during the day and meet up again at 9:00 to record the presentation in a Teams Meeting.

2020.10.06 - Team Meeting 8

JENNA WARDEN - Oct 07, 2020, 3:08 PM CDT

Title: Team Meeting 8

Date: 2020.10.06

Content by: Jenna Warden

Present: Ben and Jenna

Goals: Update the PDS

Content:

Ben and I ended up starting over with the PDS due to the large change in design idea. A lot of the PDS dealt with rotations and gimbals and motors which no longer was useful.

PDS aimed towards the final proposed design of the preliminary report

dealt more with Boa system, automating it, and looking into materials

this PDS would be added to the appendix of the preliminary report

PDS 2.0 can be viewed in the preliminary report

Conclusions/action items:

With the new PDS, it is more specific to the design route the team believes we will be going down. This was necessary to fix for the preliminary report as well as updating it in general as it is a living document. This will be the second version of the PDS and will hopefully only have small changes in the future compared to completely rewriting it.

2020.10.07 - Team Meeting 9

JENNA WARDEN - Oct 07, 2020, 2:20 PM CDT

Title:

Date:

Content by:

Present:

Goals:

Content:

Conclusions/action items:

2020.10.11 - Team Meeting 10

JENNA WARDEN - Oct 12, 2020, 1:59 PM CDT

Title: Team Meeting 10

Date: 2020.10.11

Content by: Jenna Warden

Present: All Team Members

Goals: Discuss changes that need to be made to the proposed final design and prepare to explain the new design concept to Mitch on Tuesday (10.13)

Content:

Changes to Proposed Final Design

- wine bottle opener idea for legs
- roller coaster harness design for chest
    - mount to headrest
    - motor + gear system
    - can use larger gears to get a larger torque
    - can get low-cost motor
- attachment can slide on with clamps or screw-on
- two pieces that encompass the bar and screw together

Marissa's link

- http://permobilus.com/product/bodilink-on-corpus/?hsCtaTracking=9e592335-c32d-4fe8-99ff-7bcd75be7af8%7C3d344ccb-25b4-4591-b903-a76b7807e477
- looking at the side restraints (look like wings)
- can use the connecting mechanism that is used for Permobil
- we would need a larger chest pad
- could use the mounts (or replicate them or use the same idea)
- would this impede the client's arm movement? would this impede getting through doorways?
- use a ball bearing system to connect attachment

Side frame would work better but overhead is more viable

mimic a lecture hall desk?

- comes up from the side and then "flops" in front of the client?
- would this be durable/ reliable?
- would have pinch points
- hard to control
- would need >1 hinge which would be added difficulty

Connect chest restraint to the leg area

- use a telescoping pole so it is adjustable
    - will this prevent the client from falling out of the wheelchair?
- it would either be too hard for the client to adjust or wouldn't secure the client in the wheelchair

Attaching the chest restraint to the back

- would have a slight bend in the "harness"
    - this would minimize how far it sticks out in the relaxed position
    - would also prevent the stomach from making contact with the harness first
- would have one hinge (above the shoulders)
- could use motor locks or gears to prevent the harness from moving once in the restraint position
- use stainless steel or aluminum for the harness
- use a worm gear
- will need an emergency mechanical release (wrench?)

Action Items

- Ben: start messing around with solid works, looking into motors
- Jenna: look into motors
- Jonny: look into the worm gear
- Marissa: look into materials for the harness (metals and padding)
- Naman: look into materials for the harness (metals and padding)
- present new design to Mitch on Tuesday

Conclusions/action items:

The team discussed any potential issues with the proposed final design and how to fix them as well as critiqued the implementation of the new design idea with the wheelchair. The team will do their own research to then propose the idea to Mitch on Tuesday (10.13)

2020.10.13 - Team Meeting 11

JENNA WARDEN - Oct 15, 2020, 12:54 PM CDT

Title: Team Meeting 11

Date: 2020.10.13

Content by: Jenna Warden

Present: All team members

Goals: Split into teams and discuss what to complete in the next week(s)

Content:

Solidworks Team

- Ben
    - continue work on the Solidworks model he has for this design

Software/Hardware team

- Naman
- Jenna
- Ben (when he isn't doing solid works
    - responsible for finding an appropriate microcontroller
    - writing code
    - designing the circuitry
    - testing on LT spice
    - building the circuit

Mechanical

- Marissa
- Jonny
- Ben (for Solidworks)
    - finding appropriate material
    - mounting plan
    - fabrication plan
    - gear ratios
    - free body diagrams (statics/dynamics work)

Conclusions/action items:

The team took the advice of Mitch and split into ~2 teams to combat the mechanical and automation aspects of the design. The team created a general list of what each team will need to do - in broad terms. The team will continue to prepare to show the client the new design idea.

2020.10.19 - Team Meeting 12

JENNA WARDEN - Oct 19, 2020, 4:25 PM CDT

Title: Team Meeting 12

Date: 2020.10.19

Content by: Jenna Warden

Present: All Team Members

Goals: Discuss further preparation for presenting final design idea to client during tomorrow's meeting (10.20)

Content:

Worm Gear:

- need to find gear ratio to thread ratio
- need to find distance of travel first
- servo motor has worm drive on it
- lose efficiency due to friction
    - but we get lots and lots more torque
- how many turns will it have to make to move the device small amounts
    - small torque or high torque?
    - each full rotation you move one tooth on the worm gear
    - use helical gears?
        - increases friction coeff

locking mechanism

- strong enough motor (60rpm)
    - will still take 40 sec ish
    - higher teeth number allow for more torque and more adjustability
    - wont slam closed
        - time could be a future work thing
        - future work could be programmed to a specific spot
- additional space can hold electronics
- locking
    - use a ratchet gear to go around the pipe and have a little lock that another motor would control
    - could it be spring loaded?
        - connected to same motor
    - second motor could make it automated and push a button
        - can turn lock on and off
            - when the worm is moving - unlocked
            - when worm stops moving - locked
        - wouldn't have to be a big motor
        - would be cool to only have one motor
            - is this possible?
    - make it programmable to specific spots?
        - could be future work
        - would be helpful - ease of use
- mechanical removal
    - would have a key that would basically stop it and unlock it all
    - would have to pull threads away from the gear
    - can shift servo motor back or left or right so it can get out of the gear path

What needs to be done

- we need to find the distance that the harness will travel
- Ben working on SolidWorks for the legs
- everyone get tested tomorrow
    - email keith about meeting on friday
    - will get results by Friday
    - can get measurements when he is in the chair
- for tomorrow's meeting

        - ben works on solidworks
        - everyone else continue research on materials and other things
            - pvc, aluminum, stainless steel
                - pvc for lifesize prototype
                    - will he pay for this? ask about this
- get things from Menards after meeting with Keith on Friday
    - can build on a weekday
- electronics team
    - look into servo motors!
    - how to code motors
- mechanical team
    - research materials
    - plan for prototyping
        - pvc pieces and what we need
-

Conclusions/action items:

2020.10.23 - Team Meeting 13

JENNA WARDEN - Oct 24, 2020, 5:48 PM CDT

Title: Team Meeting 13

Date: 2020.10.23

Content by: Jenna Warden

Present: All Team Members

Goals: Obtain materials to build a prototype of the device.

Content:

Jonny picked all team members up and we headed to Menards

We got 3/4 inch pvc pipe along with 90 degree and 45 degree connectors.

all items purchased are for the chest restraint and will be kept at Ben's house

Conclusions/action items:

The team purchased parts to make a prototype of the chest restraint. After the shopping trip the team them met at the client's house to get more measurements for the restraint to client relationship while in the standing wheelchair. These notes can be seen in the Client Meetings folder under 2020.10.23 - Client Meeting 8 - in person. This prototype will allow the team to debug any potential errors in design as well as have a hands on visual concept of what the device will look like. This will also prove beneficial to the client so that they are also able to gauge what the final design may look like.

2020.10.29 - Team Meeting 14

JENNA WARDEN - Oct 29, 2020, 7:49 PM CDT

Title: Team Meeting 14

Date: 2020.10.29

Content by: Jenna Warden

Present: All Team Members

Goals: Write post for the Piazza version of show and tell

Content:

The team decided that we wanted input from our classmates on two items: wireless connection and a separate leg restraint to ensure that our client's lower limbs didn't exceed the bounds of the foot pedals which is what the boundaries of the leg restraint is based on.

The team also drafted up a short summary of the reason and goals of this project.

Ben created a figure of both restraint designs in SolidWorks to add to the post.

Final Draft of Piazza post:

Currently, our client owns a sitting to standing wheelchair that requires additional help to secure the manufacturer included restraints in the correct locations to ensure safety during use. Our client was diagnosed with SMA type II. This disease has impacted their muscular strength which in turn limits their overall mobility. This limitation prevents repositioning of the lower limbs when entering the wheelchair via a ceiling lift. Due to our client's physical limitations and their desire for independent usage of the wheelchair, our team has been tasked with creating a device that attaches to the wheelchair and autonomously secures the client.

At this point in the design process, the team has successfully chosen a design and created an in-depth SolidWorks, as seen below. The chest restraint mimics a roller coaster harness and will make use of servo motors, worm gears, and a locking system to prevent back drive of the harness. The leg restraint utilizes a mechanism similar to a winged corkscrew with a rack and pinion system to extend the leg pads. The team will be using a Nucleo microcontroller to control the motors and they are currently looking into ways to power the microcontroller.

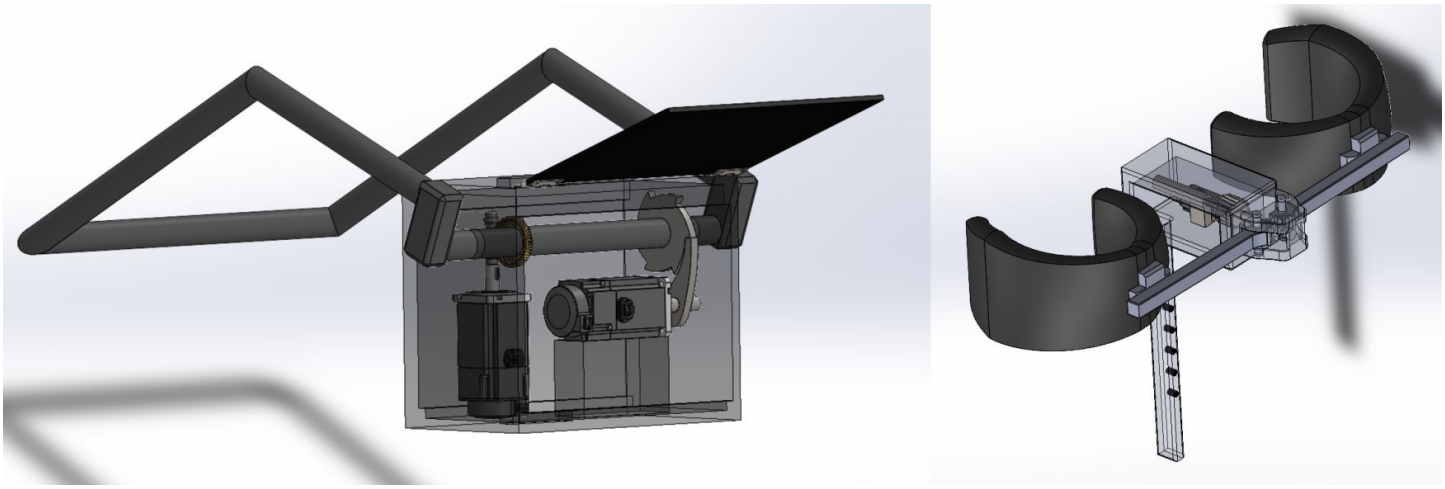


Figure 1: SolidWorks drawing of the chest restraint (left) and leg restraint (right) with their components displayed.

Call to action:

We are looking to eventually incorporate Bluetooth or wireless communication from our device to our client's wheelchair's joystick. We are looking for insight into security options/ wireless communication methods that anyone may know of.

Another issue we have come across is the foot and leg location of our client. Our current concern is that our client's legs and feet will exceed the boundaries of the foot pedals as well as our restraint when entering the wheelchair. The team is brainstorming ways to add an additional restraint

that would not interfere with the rest of our device nor our client's wheelchair. We are looking for ideas for a simple restraint to ensure our client's lower limb positions are properly located for the operation of the wheelchair.

For more information on our project, please see our website: https://bmedesign.engr.wisc.edu/projects/f20/gimbal_chair

Conclusions/action items:

This show and tell via piazza will benefit the team for not only future work that we already have planned but also will help us solve the hiccups we have already come across. With outside views and ideas, we may be able to incorporate future work items sooner. The team hopes that all designers find this show and tell helpful.The team will continue research into their specified areas and will prepare to meet with Mitch this coming Tuesday to show the progress we have made.

2020.11.09 - Team Meeting 15

JENNA WARDEN - Nov 09, 2020, 5:40 PM CST

Title:

Date:

Content by:

Present:

Goals:

Content:

Conclusions/action items:

2020.11.17 - Team Meeting 16

JENNA WARDEN - Nov 23, 2020, 4:04 PM CST

Title: Team Meeting 16

Date: 2020.11.17

Content by: Jenna Warden

Present: All Team Members

Goals: Prepare for client meeting, debrief client meeting, prepare for advisor meeting, discuss progress made

Content:

- discussed fab plans and the issues that arose from it
- discussed meeting outlines
- new problem:
    - how do we prevent someone random from engaging and disengaging the restraint?
        - two buttons and a switch
        - limit switch pops out
        - firmware + hardware

Meeting with Ketih

- went well - was accepting of final plans for semeseter

Meeting with Mitch

- need to do a lot of work before semester ends
- split up work to do:
- Naman - pseudocode & working final code

  Marissa - chest fab plan, ordering chest materials

  Jenna - semester proposal, testing protocol, back up coder (if needed)

  Jonny - leg materials, calculations

  Ben - leg fab plan, electronic materials

  All - brainstorm foot plates, report and presentation

Conclusions/action items:

The team will work on the items that were divided by team members. Both client and advisor meetings were successful in deciding how the rest of the semester will go. This will allow the team to work out any errors that may arise during fabrication during the writing of the fabrication plan. This will then prepare the team to begin fabrication over winter break and start testing and getting the device fully working second semester.

2020.11.24 - Team Meeting 17

JENNA WARDEN - Nov 24, 2020, 8:30 PM CST

Title: Team Meeting 17

Date: 2020.11.24

Content by: Jenna Warden

Present: All Team Members

Goals: Discuss Progress and Divide Final Deliverables

Content:

Jenna

- Finished edits to the agreement contract and will send final draft morning of 11.25
- Starting work on testing protocol
    - put this in future work?
    - in presentation?

Jonathon

- met with someone about making assumptions for calculations
- worked on shearing and bending moment in different locations
- hoping to finish leg restraint material and will calculate final torque (needs density and mass)
- can start helping with leg restraint materials and final report
- all calculations in a MATLAB file
    - Ben has list of all Permobile materials
        - only thing that we can get to from searching part numbers is back to the long list of materials

Naman

- Microcontroller - digikey buy it now
    - ship to Namans
- Coding is underway and will begin messing around with coding pins and getting outputs

Marissa

- putting pictures in with the fab plan for better understanding
- need to finalize specific measurements
- hand drawn sketch of what the box "should" look like with the connectors
- hoping to be done with fab plan by Saturday and will spend Monday only searching for materials
- how long will erector kit take to order and ship?

Ben

- want to get fab plans done by asap (Saturday?)
- having difficulty writing the fab plan without specific materials
- put welding in it where it could be easier?
    - we could all learn how to weld to gain a better understanding of fabrication

Plan to have done by next Tuesday:

- meet Sunday evening, Tuesday (probably everyday the following week)
- start presentation
- start final report
- Naman: instal the coding thing, working on the code - pseudocode
- Marissa: fab plan, types of things we will be using - 80/20
- Jenna: testing protocol, testing section of report
- Jonathon: calling Permobile/ sending an email

Conclusions/action items:

2020.11.29 - Team Meeting 18

JENNA WARDEN - Nov 29, 2020, 6:03 PM CST

Title: Team Meeting 18

Date: 2020.11.29

Content by: Jenna Warden

Present: Jonathon, Ben, Naman, Jenna (Marissa out due to emergency surgery)

Goals: Discuss progress made so far, begin work on presentation slides, split up the final report

Content:

Ben

- 99% done with leg fab plan
- finishing up final dimension numbers
    - all on drive - ~2.5 pages
    - made it as simple yet as precise as possible
    - used corrdinate plane for describing locations
        - ask Mitch about this
- need some numbers from Jonny to select a motor

Jonathon

- finished all calculations (besides moment of inertia - don't have density)
- started looking at materials but didn't finish
- MATLAB calculations is set up and can insert specific densities and all calculations will be finished
- need to calculate approx angular acceleration
- waiting for Permobile to return a call
- using full body weight for leg restraint calculations - to be safe as we do not know what percent of client's body weight pushes against leg restraint specifically

Jenna

- have testing for code set up
    - move forward
    - move backward
    - doesn't move when switch is off
    - 95% accuracy for code at least
- not sure what to test for the actual device
    - adding weight and letting it rest to detect movement
    - have others add ideas
    - testing that the lock switch works

Naman

- Processing downloaded
- watched tutorial for setup
- got it to start working
    - struggling with finding the things talked about in the tutorial as software has updated
    - getting the motor to work is just taking time
    - understanding how to do the major parts of the code
- once the code is working the microcontroller will work easily
- create block diagram of code - for presentation to explain what the code will do

Future Work

- email Mitch asking to review this our presentation on Wednesday - explain the circumstances
- splitting up presentation and final report

Conclusions/action items:

2020.11.30 - Team Meeting 19

JENNA WARDEN - Nov 30, 2020, 9:03 PM CST

Title: Team Meeting 19

Date: 2020.11.30

Content by: Jenna Warden

Present: All members minus Marissa (in recovery)

Goals: Work on the final presentation slides

Content:

Naman

- updates on the code
- general questions on the setup of the code flowchart we want - question was answered
    - changed things in the program - changed the clock configuration
        - why are we doing this?
        - this isn't really necessary - we can change these outputs using the code instead of changing the internal clock configuration
        - tutorial went over why this change was made and we decided that this was okay to do
    - edited code
- infinite while loop?
    - need to figure out specifics of how the code will get the motor to rotate
- two locations or variability
    - would not be too difficult for it to move when buttons are pushed
    - would be more functional for keith and would be good to do now instead of having two separate codes

Continued editing and working on the final presentation slides as a team

Conclusions/action items:

The team will continue working on final deliverables and the final presentation. The team's goal is to complete the presentation by Wednesday at 3pm which is when the team is meeting with Mitch to go over the slides and get feedback before the presentation.

2020.12.08 - Team Meeting 20

JENNA WARDEN - Dec 08, 2020, 1:41 PM CST

Title: Team Meeting 20

Date: 2020.12.08

Content by: Jenna Warden

Present: All team members

Goals: Discuss any problems so far, split up final deliverables, split up portions of final report, discuss any needed contract changes with Mitch

Content:

Naman

- having some troubles with the code compiler

Marissa

- have two versions of chest fab
- need drawing from SolidWorks
    - Jonny working on it but can only get 2D
    - Ben helping to get 3D
- general measurement questions

General

- should order by the end of first week of January
- meet with keith tonight at usual time
- should meet in person to verify dimensions
    - also get more dimensions if needed
- read over fab plan for chest to make sure it makes sense
    - leave comments
    - didn't put in sub or full assembly order for 80/20
        - not sure on measurements and don't want to have wrong sizes
- discuss color options with Keith for 80/20 things tonight

Who is working on what

- Marissa
    - good with fab plan
        - need to make some minor revisions
        - everyone read and make comments:)
    - ?: did solidworks design have a way to mount onto chair?
        - Jonny and Ben discussed this
            - there's a hole for the mounting pin/block
            - this would be bolted into the box
            - had rails to fit the holder that is on the wheelchair
- Ben
    - more tweaking of solidworks - edits in general for accuracy
    - finished materials list - pretty much done
    - final leg fab plan edits
        - everyone read it and add comments!
        - will read differently than Marissas but that's okay
    - will look over chest fab plan as well
- Jonny
    - design matrix for foot plate - so his feet and knees be in a good position for the leg restraint to close
        - design for his other wheelchair
        - secondary motion that folds up or pushes feet inward
        - thigh restraints - help with keeping knees in
        - make bigger foot plates
        - add a lip to the footplate to like "funnel" feet into the footplate
    - willing to help out elsewhere
- Naman

        - working on code using new compiler
        - have code working - to best of our abilities
        - ben knows what motor to use so this will make it easier when putting everything together
        - willing to help out in other places
        - new compiler is kinda working but some errors
            - code up on drive - everyone can debunk it
- Jenna
    - adding mechanical parts to the testing protocol
        - let her know if there's any specific tests to be added
        - seeing force exerted by keith - MTS testing - failure point testing - we know some of them
            - not sure if this is needed
        - not really sure that leg restraint works lol
            - leg restraints might interfere with keiths legs when moving into position - this could be a pinch point
                - make inner portion wider
                - actual measurements will also help and so will custom made foam
                - TEST THIS
        - does it clear his head/ shoulders/ leg x times in a row
        - does physical design work with keith
        - survey! assessed comfort
            - changes based on results
        - PINCH POINTS!!!
    - making an expected results doc
    - make google sheets for reporting results - one for each test or one total will all trials of each test

Agreement Contract

- everyone read through it and find things that are unattainable to complete this semester
    - discuss with Mitch tonight
    - restraint video - clarify what this means
    - code works with motor - don't have motor so cant prove it works

Future work

- sensor to sense the position
    - hall effect sensor
    - location in space sensor?
    - force sensor

Final Report sections

- Ben
    - sensor
    - fab plan
- Marissa
    - fab plan
    - materials
- Jonny
    - future work
- Naman
    - code stuff? or Jenna
    - sources of error
    - final prototype
- Jenna
    - testing and expected results
- Appendix
    - fab plan for chest and leg
    - materials list
    - code
    - testing protocol
    - testing results spreadsheet
    - expected results doc

Conclusions/action items:

the team discussed what needs to be done for the final deliverables in accordance to the contract agreement. The team also split up writing portions for the final report and plan to meet tomorrow around 8pm to discuss personal progress and to begin writing the report together in case anyone has questions or input from other team members. The team will meet with the client tonight to discuss progress and final deliverables as well as set up a time to meet in person to get additional measurements, determine color of the device, and bring pvc to check dimensions. The team will also meet with Mitch tonight to ask final report questions, get presentation feedback, and close out the end of the semester.

2020.12.09 - 12.11 - Team Meetings 21

JENNA WARDEN - Dec 11, 2020, 10:45 AM CST

Title: Team Meeting 21

Date: 2020.12.09- 2020.12.11

Content by: Jenna Warden

Present: All team members

Goals: Work on final deliverables collaboratively

Content:

The team worked independently on aspects of the final deliverables while discussing any problems as they were encountered.

Being on a call while working allowed the team to quickly resolve issues they came across.

Much of this time was spent working with minor questions being discussed.

Conclusions/action items:

The team met to work on final deliverables remotely to mitigate any problems and get immediate feedback if needed. The team also spent time outside of meetings working on the deliverables. The final deliverables will be sent to our advisor by 4:00pm December 11, 2020.

Force Calculations - Ongoing Throughout Process

JONATHON MURPHY - Dec 11, 2020, 12:13 PM CST

Title: Force Calculations

Date: ongoing

Content by: Jonathon Murphy

Present: N/A

Goals: solve for necessary forces needed for torques and failure analysis

Content:

To figure out necessary figures and possible failure points for the chest and leg restraints designs, I was tasked with calculating necessary forces and torques. In order to pick a correct motor that will be able to run both devices, we need a torque estimation on the bodies of the designs. I am working alongside Ben has he creates SolidWorks assemblies of these designs and searches for the specific motor. I will also being looking at potential positions of failure in our designs by calculating the bending and shear stresses on points of concern. I will be working on these calculations in Matlab so that if a variable changes, I can easily change it without having to redo the entire calculation. Some assumptions will need to be made in order to do these calculations, and they will be commented in the Matlab code. The Matlab code is attached to this page.

Calculations done:

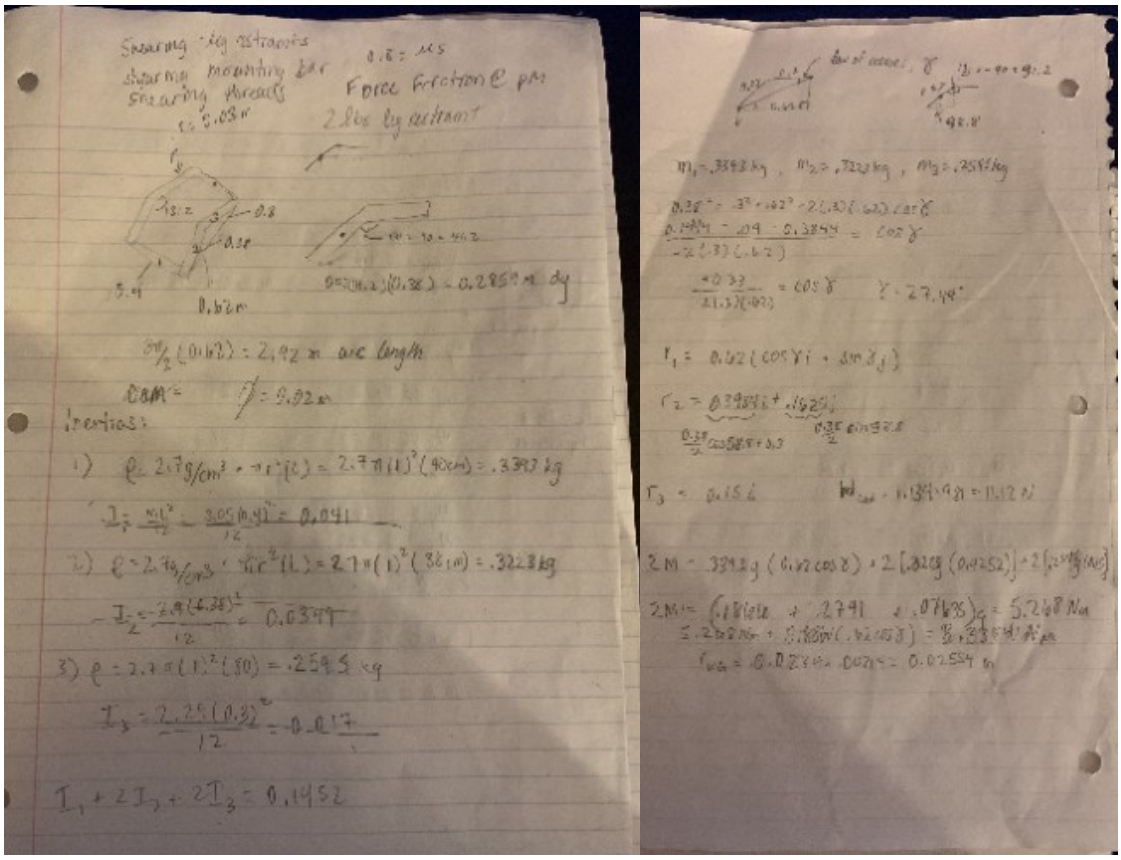
- torque calculations for chest restraint motor
    - mass moment of inertias, center of gravity
- Leg restraint motor torque calculations
    - mass moment of inertia, center of gravity
    - friction at pin, torque due to friction at pin
    - torque due to moment of inertia of arms and restraints
- Shear force at Rack and Pinion teeth
- Bending Stress at restraint support arms

Calculations in future: (added after talking at last Client Meeting 12/08/2020)

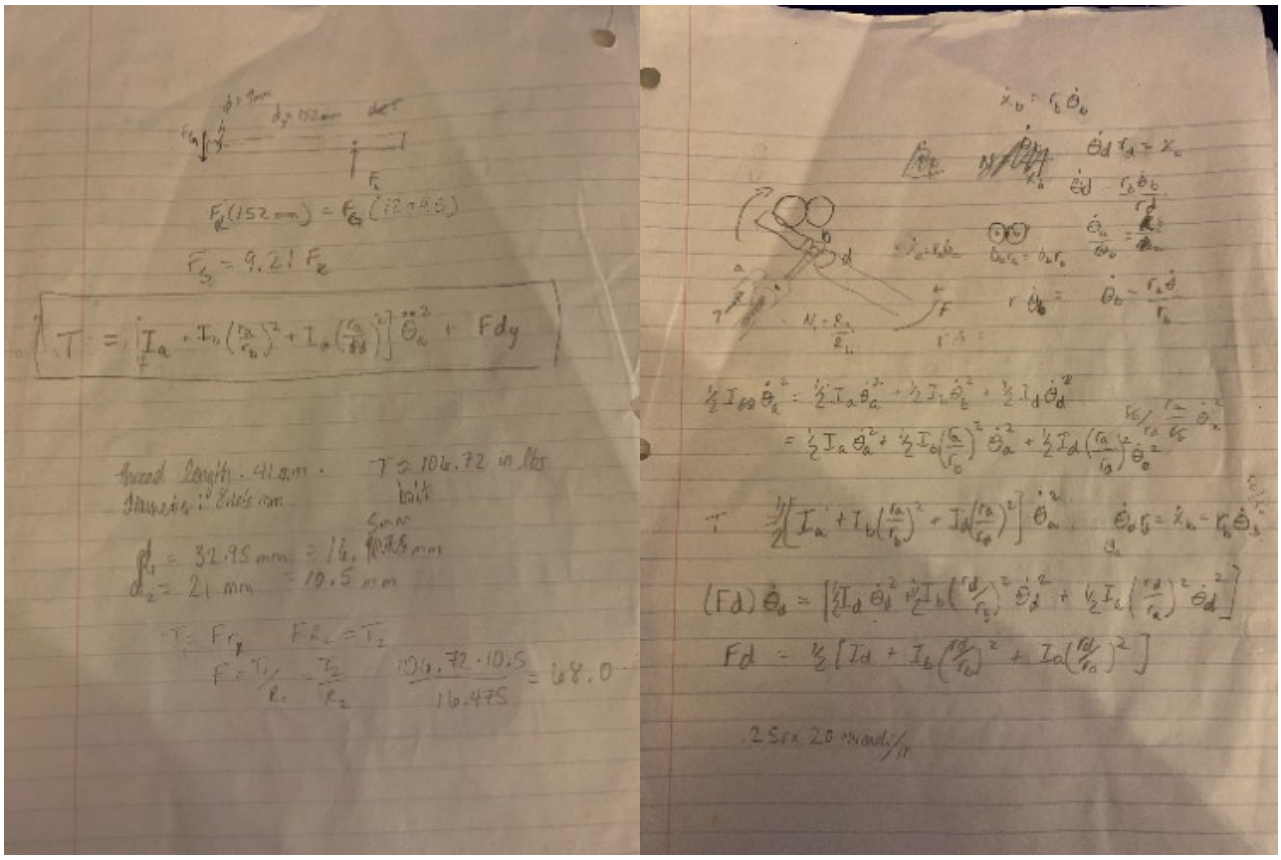
- displacement between worm gear teeth and worm drive
- displacement at chest pad due to previous calculation

Some initial calculations and attempts of calculations done by hand :

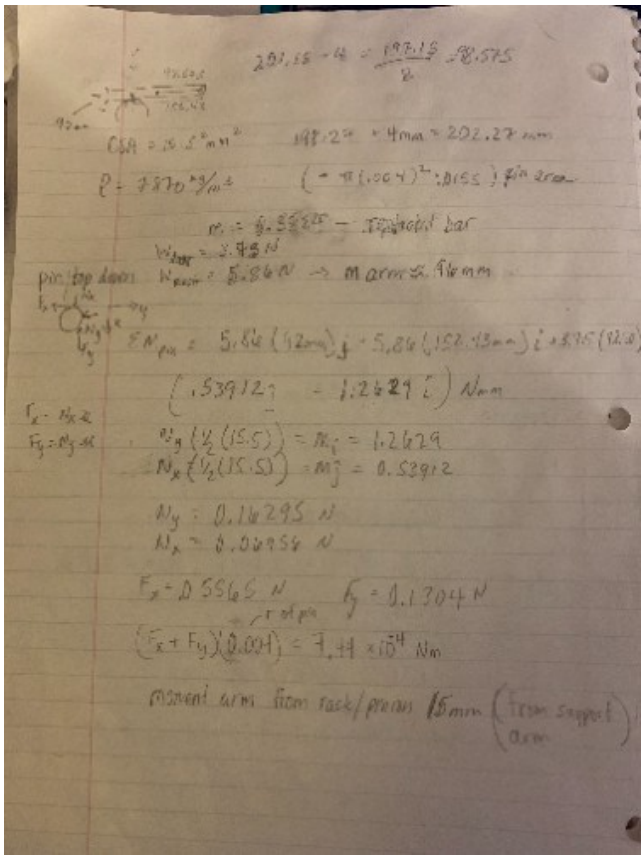
Initial attempts to calculate torque needed for chest restraint (old dimensions)



Initial attempt to calculate torque needed for leg restraint (old dimensions)



Friction and torque due to friction at leg restraint pin calculations



Conclusions/action items:

This code/calculations will need to be updated as the designs or variables change. As we move forward and think of other possible problems or changes, new calculations will also need to be completed. They will be added to the code and reuploaded.

JONATHON MURPHY - Dec 11, 2020, 12:13 PM CST

ForceCalculations.mlx(8.3 KB) - download

Code Flowchart and Source Code for Nucleo

NAMAN PATEL - Dec 11, 2020, 12:55 PM CST

Title: Code Flowchart and Source Code for Nucleo microcontroller

Date: 12/11/2020

Content by: Naman

Present: N/A

Goals: Show the code flowchart and the source code in LabArchives.

Content:

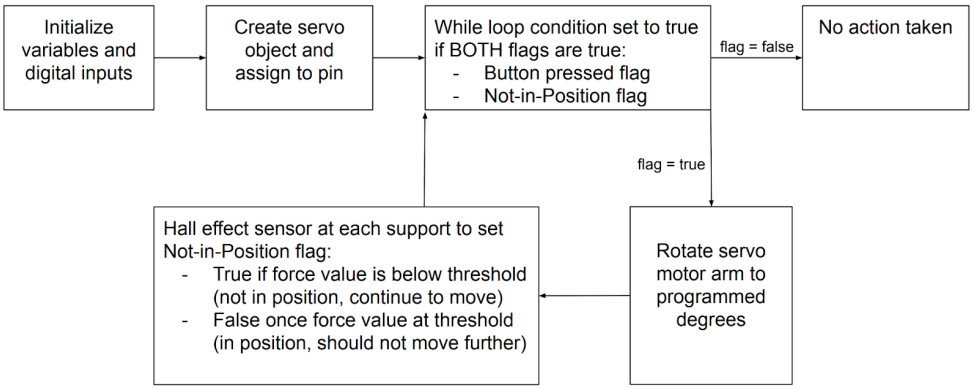


Figure: This code flowchart gives an overview of the steps taken in the code.

Source Code:

```
#include "Servo.h"
#include "mbed.h"

//inPosition flag: T = restraining position; F = at rest position
bool inPosition = false;
DigitalIn Dforward(D5);
DigitalIn Dbackward(D6);
DigitalIn hallEffect(D7); //Feedback from Hall effect sensor sets inPosition to T or F
Servo myservo(A5);

int main(){

  while(1){
    if(hallEffect == 1){
      //sensor reads that support is in restraining position
      inPosition = true;
```

```
        }
        else{
            inPosition = false;
        }

        //In at rest position and forward button is pressed
        if(inPosition == false && Dforward == 1){
            //move support into restraining position
            myservo.position(3000);
        }
        //In restraining position and backward button is pressed
        else if(inPosition == true && Dbackward == 1){
            //move support backwards into at rest position
            myservo.position(-3000);
        }
        else{}
    }
}
```

Conclusions/action items:

This submission shows the code flowchart and includes the full source code. This will be helpful to refer back to by the team when needed. This degrees of movement will change once the team is able to test, as it is currently set to an arbitrary 3000 degrees. This code successfully compiles without error and accomplishes the tasks the group is hoping to achieve with this wheel chair adaptation device.

Sources of Error

NAMAN PATEL - Dec 11, 2020, 1:11 PM CST

Title: Sources of Error

Date: 12/11/2020

Content by: Naman

Present: N/A

Goals: outline potential problematic areas when carrying out testing protocol.

Content:

Since the team did not reach the point of testing the final prototype in the first semester, this section will talk about potential problematic areas that the team may face during the testing phase. The first area of concern is the friction at the pin in the leg support. If the servo motor is unable to generate enough force to overcome this friction, a higher power motor will be required. Another concern is the shearing of the pinion teeth in the rack and pinion system. This is a physical safety mechanism to ensure dynamic system stability. The shearing of the teeth within the system could be a mode of failure, so it is important to confirm that it is working as expected. The potential backdrive of the chest support bar is something else we are keeping an eye on. This poses a danger to the user if there are any occurrences of backdrive occuring, and there is a concern that the gears may drive backwards to some extent at the onset of the force being applied to the chest support. Another source of error may be due to the dimensions used for the calculations. If the dimensions are not ideal for the client and need some changes, the calculations will need to be adjusted to maintain accuracy.

Conclusions/action items:

This sources of error submission outlines the areas that the group is most concerned with based on the design process and outlining of fabrication process. During the testing process, the team will refer back to this document to recall areas of most concern so that the team can keep an eye out for the issues that may arise.

Future Work

NAMAN PATEL - Dec 11, 2020, 1:31 PM CST

Title: Future Work

Date: 12/11/2020

Content by: Jonathon Murphy

Present: N/A

Goals: Outline the next steps the team will take in the design process, and discuss potential future iterations/additions to the design.

Content:

The next step for this project will be to fabricate the chest and leg support designs. The team spent the last month creating detailed fabrication plans for each design so that when the materials arrive, they may begin building and assembling the device. The team has also looked into upgrading their UW-Madison TEAM LAB passes to get the MIG welding pass. This will allow them to weld components themselves without having to outsource the parts and wait for the finished product. In some cases, it was found to be easier to outsource parts to save time or because the part was too complex to make. The rack and pinion system is a very complex part that will be most cost effective if outsourced. Once the materials and components arrive, the team will fabricate and assemble the chest and leg support designs.

Once fabrication is complete, testing will need to be done to ensure the devices function properly and safely. A testing plan was also written this semester in order to save time in the future. A list of tests can be seen in the Testing section above. Additional tests will be created and performed once the team can assess the most efficient way to test factors like potential failure points in a cost effective manner.

One concern of the design is the potential for the user or anyone around them to accidentally open or close the supports by bumping the buttons. The team would like to add a secondary safety measure in the code that would require the user to press the button multiple times or hold it down for an extended period. Another possible idea the team has considered is a protective covering for the buttons that would not take away from the ease of use of the design.

When meeting with the client and observing them get into their standing wheelchair, the team noticed the client’s struggle to properly position their feet and legs to stay on the foot plates. The team has already started strategizing possible adaptations to the wheelchair foot plates in order to better accommodate the client. A design matrix can be seen in the Appendix F and will be evaluated and acted upon in the coming semester.

To effectively determine which positions the supports are located at, the team would like to implement a few hall effect sensors for positional sensing. Hall effect sensors measure the magnetic flux that is applied to the sensor, and output a corresponding voltage. The team could attach permanent magnets to select positions on the device, so that while in a position, the magnet is applying a magnetic field to the sensor, causing a change in the voltage measured by the nucleo. The feedback from the hall effect sensor sets the position flag to true or false in the code, ensuring the safety measures operate effectively.

Conclusions/action items:

This future work section discusses the next steps the team will take, describes issues that may arise and the future solutions the team has brainstormed. This will be referred to throughout the upcoming semester as the team fabricates the device, performs the testing protocol, and makes design iterations.

Foot Plate Design Matrix

JONATHON MURPHY - Dec 11, 2020, 1:13 PM CST

Title: Foot Plate Design Matrix

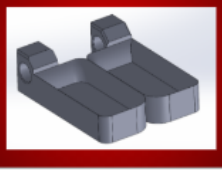
Date: 12/10/2020

Content by: Jonathon

Present: N/A

Goals: create a design matrix for foot plate ideas

Content:

Testing	Original Design 	Thigh Pads 	Enlarged Footplates 
Safety (25)			
Ease of Implementation (20)			
Ease of use (15)			
Cost (15)			
Comfort (15)			
Stability (10)			
Total (100)			

When meeting with our client and observing him get into his standing wheelchair, our team noticed our client's struggle to properly position his feet and legs to stay on the foot plates. We have already started strategizing possible adaptations to the wheelchair foot plates in order to better accommodate him.

Conclusions/action items:

This design matrix will be evaluated and acted upon in the coming semester.

Materials and Expenses Spreadsheet

Marissa Harkness - Dec 11, 2020, 12:33 PM CST

Title: Materials and Expenses Spreadsheet

Date: 12/8/20

Content by: Marissa Harkness

Present: Ben Lawonn

Goals: To create a spreadsheet with the part, part no., description, seller, cost, quantity, and link

Content:

Attached is a PDF containing the original draft fabrication plan.
Conclusions/action items:

We need to send the materials and expenses to Keith for approval.

Marissa Harkness - Dec 11, 2020, 12:33 PM CST

'

BME_400_Design_Materials_-_Sheet1.pdf(120.6 KB) - download

Version 1 - Draft Fabrication Plan

Marissa Harkness - Dec 11, 2020, 12:15 PM CST

Title: Version 1 - Draft Fabrication Plan

Date: 11/17/20

Content by: Marissa Harkness

Present: None

Goals: To develop an outline of the main assemblies that will be part of the chest restraint

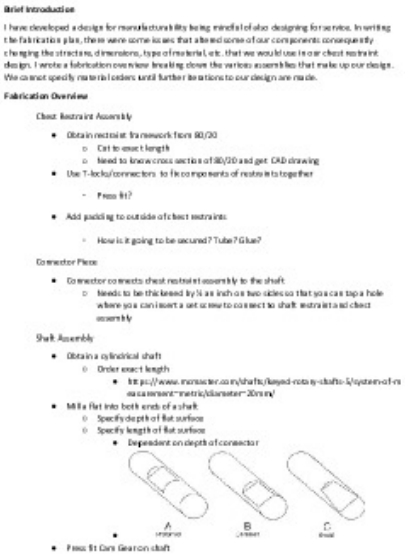
Content:

Attached is a PDF containing the original draft fabrication plan.

Conclusions/action items:

I need to review with the team so they understand why I broke the assemblies down the way I did. I also need to review the 80/20 framework extrusions, as well as obvious changes that will need to be made to our design.

Marissa Harkness - Dec 11, 2020, 12:15 PM CST



Brief Introduction

I have developed a design for manufacturability being mindful of also designing for service. In writing the fabrication plan, there were some issues that altered some of our components consequently changing the structure, dimensions, type of material, etc. that we would use in our chest restraint design. I wrote a fabrication overview breaking down the various assemblies that make up our design. We cannot specify material orders until further iterations to our design are made.

Fabrication Overview

Chest Restraint Assembly

- Obtain restraint framework from 80/20
  - Cut to exact length
  - Need to know cross section of 80/20 and get CAD drawing
- Use T-locks/connectors to fix components of restraints together
  - Press fit?
- Add padding to outside of chest restraints
  - How is it going to be secured? Tube? Glue?

Connector Piece

- Connector connects chest restraint assembly to the shaft
  - Needs to be thickness by ¼ an inch or two sides so that you can tap a hole where you can insert a set screw to connect to shaft restraint and chest assembly

Shaft Assembly

- Obtain a cylindrical shaft
  - Order exact length
    - http://www.mcmaster.com/shafts/keyed-rotary-shafts-1/system-of-measurement~metric/diameter~20mm/
- Mill a flat into both ends of a shaft
  - Specify depth of flat surface
  - Specify length of flat surface
    - Dependent on depth of connector
- Press fit Cam Gear on shaft

Version_1_Chest_Restraint_Fabrication_Plan.docx.pdf(70.5 KB) - download

Version 2 - Fabrication Plan

Marissa Harkness - Dec 11, 2020, 12:27 PM CST

Title: Version 2 - Draft Fabrication Plan

Date: 12/6/20

Content by: Marissa Harkness

Present: None

Goals: To develop an outline of the main assemblies that will be part of the chest restraint

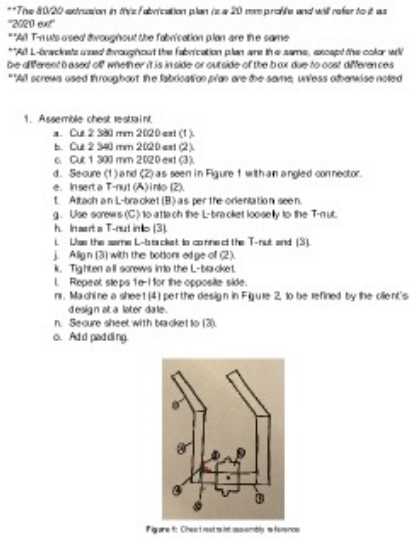
Content:

Attached is a PDF containing the original draft fabrication plan.

Conclusions/action items:

I need to incorporate the fabrication plan in our final report. The team will have to assess whether there are ways to alter the plan to make fabrication easier or costs lower.

Marissa Harkness - Dec 11, 2020, 1:49 PM CST



***The 80/20 extrusion in this fabrication plan is a 20 mm profile and will refer to it as "2020 ext"*
***All T-nuts used throughout the fabrication plan are the same*
***All L-brackets used throughout the fabrication plan are the same, except the color will be different based off whether it is inside or outside of the box due to cost differences*
***All screws used throughout the fabrication plan are the same, unless otherwise noted*

1. Assemble chest restraint
   a. Cut 2 380 mm 2020 ext (1).
   b. Cut 2 340 mm 2020 ext (2).
   c. Cut 1 300 mm 2020 ext (3).
   d. Secure (1) and (2) as seen in Figure 1 with an angled connector.
   e. Insert a T-nut (A) into (2).
   f. Attach an L-bracket (B) as per the orientation seen.
   g. Use screws (C) to attach the L-bracket loosely to the T-nut.
   h. Insert a T-nut into (3).
   i. Use the same L-bracket to connect the T-nut and (3).
   j. Align (3) with the bottom edge of (2).
   k. Tighten all screws into the L-bracket.
   l. Repeat steps 1e-l for the opposite side.
   m. Machine a sheet (4) per the design in Figure 2, to be refined by the client's design at a later date.
   n. Secure sheet with bracket to (3).
   o. Add padding.

Figure 1: Chest restraint assembly reference

Version2_Chest_Restraint_Fab_Plan.pdf(1.4 MB) - download

Leg Support Fabrication Plan

BENJAMIN LAWONN - Dec 11, 2020, 1:35 PM CST

Title: Leg Support Fabriucation Plan

Date: 12/11/2020

Content by: Ben Lawonn

Present: Team

Goals:

- PDF of the leg fabrication plan
- Provides step-by-step information about the fabrication

Content:

- PDF document of the leg fabrication plan attached below

Conclusions/action items:

- The leg fabrication plan will need to be updated following the addition of the SOLIDWORKS drawings. The figures were not previously available, so the leg fabrication plan was written in a less efficient way, with trying to describe the positions of the holes and cuts using a coordiante system. For the upcoming semester the team would like to reformat the leg fabrication plan to be more similar to the chest fabrication report using the images as references to dimensions. This will reduce the complexity and how verbose the fabrication plan is.

BENJAMIN LAWONN - Dec 11, 2020, 1:36 PM CST

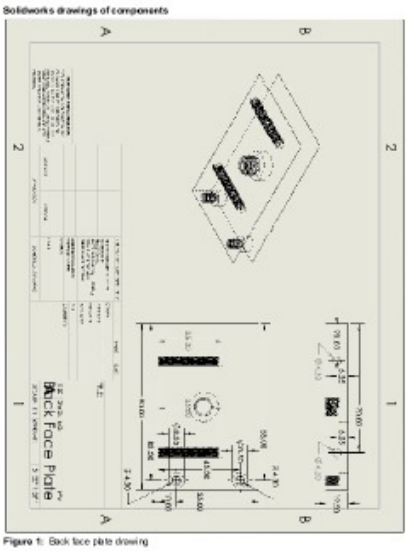


Figure 1: Back face plate drawing

Fabrication_plan_for_the_leg_Restraints.pdf(781.5 KB) - download PDF document of Leg Restraint Fabrication Plan

Testing Protocol - Code Validation

JENNA WARDEN - Dec 11, 2020, 12:22 PM CST

Title: Testing Protocol - Code Validation

Date: Completed 2020.12.11

Content by: Jenna Warden

Goals: Creating a Testing Protocol to test for code functionality

Content:

View Attached Document

Conclusions/action items:

The testing protocol will verify that the code compiles, functions, and works as expected.

JENNA WARDEN - Dec 11, 2020, 2:07 PM CST

Autonomous Wheelchair Restraint Adaptations to Measure Code Accuracy and Reliability: Code eValidation Testing

I. **Parties Present for Testing / Data Analysis**

"By signing below the individual acknowledges that all test protocol instructions were followed directly and any deviations were recorded below properly. Additionally, singing below signifies that all information contained herein is accurate to the best of the reporting party's knowledge.

Name	Email	Signature	Date (MM/DD/YYYY)
Mitchell Tyler			
Ben Lawson			
Jonathon Murphy			
Nimon Patel			
Marissa Harkness			
Jenna Warden			

II. **Date(s) of Testing:**

Date Started: (MM/DD/YYYY)	Date Completed: (MM/DD/YYYY)

Testing_Protocol_-_Code_Validation_Testing_.pdf(820.9 KB) - download

Testing Protocol - Mechanical Testing

JENNA WARDEN - Dec 11, 2020, 12:24 PM CST

Title: Testing Protocol - Mechanical Testing

Date: Completed 2020.12.11

Content by: Jenna Warden

Goals: Create a Testing Protocol to determine mechanical stability and function of the final device

Content:

View Attached Document

Conclusions/action items:

This testing protocol will assess the mechanical stability of the device. It will also allow for immediate user feedback which will allow the team to make changes to the device.

JENNA WARDEN - Dec 11, 2020, 2:07 PM CST

Autonomous Wheelchair Restraint Adaptations to Test Mechanical Components

I. **Parties Present for Testing / Data Analysis**

**By signing below the individual acknowledges that all test protocol instructions were followed directly and any deviations were recorded below properly. Additionally, signing below signifies that all information contained herein is accurate to the best of the reporting party's knowledge.*

Name	Email	Signature	Date (MM/DD/YYYY)
Mitchell Tyler			
Ben Lawson			
Jonathon Murphy			
Naman Patel			
Marissa Harkness			
Jenna Warden			

II. **Date(s) of Testing:**

Date Started: (MM/DD/YYYY)	Date Completed: (MM/DD/YYYY)

Testing_Protocol_-_Mechanical_testing.pdf(113 KB) - download

Contract Agreement Version 1

JENNA WARDEN - Dec 11, 2020, 1:57 PM CST

Title: Contract Agreement Version 1

Date: Completed 2020.11.21

Content by: Jenna Warden

Goals: Create contract agreement that displays what the final deliverables will be for the fall 2020 semester

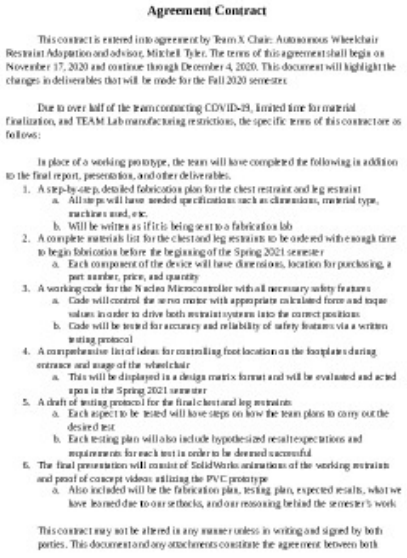
Content:

See attached document for version 1 of the contract agreement. Also see "Agreement Contract - Version 1" under Jenna's notebook in the Technical Documents folder.

Conclusions/action items:

The first version of the contract agreement will allow the team to be held accountable for final deliverables for Fall 2020.

JENNA WARDEN - Dec 11, 2020, 1:57 PM CST



Agreement Contract

This contract is entered into agreement by Team X Chair: Autonomous Wheelchair Restraint Adaptation and advisor, Mitchell Tyler. The terms of this agreement shall begin on November 17, 2020 and continue through December 4, 2020. This document will highlight the changes in deliverables that will be made for the Fall 2020 semester.

Due to over half of the team contracting COVID-19, limited time for material finalization, and TEAM Lab manufacturing restrictions, the specific terms of this contract are as follows:

In place of a working prototype, the team will have completed the following in addition to the final report, presentation, and other deliverables.

1. A step-by-step, detailed fabrication plan for the chest restraint and leg restraint
   a. All steps will have needed specifications such as dimensions, material type, machines used, etc.
   b. Will be written as if it is being sent to a fabrication lab
2. A complete materials list for the chest and leg restraints to be ordered with enough time to begin fabrication before the beginning of the Spring 2021 semester
   a. Each component of the device will have dimensions, location for purchasing, a part number, price, and quantity
3. A working code for the Nucleo Microcontroller with all necessary safety features
   a. Code will control the servo motor with appropriate calculated force and torque values in order to drive both restraint systems into the correct positions
   b. Code will be tested for accuracy and reliability of safety features via a written testing protocol
4. A comprehensive list of ideas for controlling foot location on the footplates during entrance and usage of the wheelchair
   a. This will be displayed in a design matrix format and will be evaluated and acted upon in the Spring 2021 semester
5. A draft of testing protocol for the final chest and leg restraints
   a. Each aspect to be tested will have steps on how the team plans to carry out the desired test
   b. Each testing plan will also include hypothesized result expectations and requirements for each test in order to be deemed successful
6. The final presentation will consist of SolidWorks animations of the working restraints and proof of concept videos utilizing the PVC prototype
   a. Also included will be the fabrication plan, testing plan, expected results, what we have learned due to our setbacks, and our reasoning behind the semester's work

This contract may not be altered in any manner unless in writing and signed by both parties. This document and any attachments constitute the agreement between both

BME400_XChair_AgreementContract_Ver1.docx(15.1 KB) - download

Contract Agreement - Final Version

JENNA WARDEN - Dec 11, 2020, 2:00 PM CST

Title: Contract Agreement - Final Version

Date: Completed 2020.12.03

Content by: Jenna Warden

Goals: Making edits to the first version of the contract

Content:

See attached document for the final agreement contract

See "Agreement Contract - Final Version" under Jenna's notebook in the Technical Documents folder

Conclusions/action items:

Edits were made to the contract agreement. Both advisor and team agree on all parts of the contract.

JENNA WARDEN - Dec 11, 2020, 2:01 PM CST

Agreement Contract

This contract is entered into agreement by Team X Chair: Autonomous Wheelchair Restraint Adaptation and BME 400 Design advisor, Mitchell Tyler. The terms of this agreement shall begin on 17 November 2020 and continue through 31 December 2020. This document will highlight the changes in deliverables that will be made for the Fall 2020 semester.

Despite taking all necessary precautions, 3 of the 5 team members contracted and experienced symptoms COVID-19 in the Fall 2020 term. Consequently, because of the requirement to quarantine after exposure and TEAM Lab access restrictions, there was limited time for materials finalization, and fabrication of a fully functional prototype. To address this situation, the specific terms and deliverables of this contract are as follows:

1. In place of a working prototype, the team will have completed the following in addition to the final report, presentation, and other deliverables.
2. A step-by-step, detailed fabrication plan for the chest restraint and leg restraint
   a. All steps will have needed specifications such as dimensions, material type, machines used, etc.
   b. Will be written as if it is being sent to a fabrication lab.
3. A complete materials list for the chest and leg restraints to be ordered with sufficient time to begin fabrication before the beginning of the Spring 2021 semester. Each component of the device will have appropriate dimensions, location of vendor for purchasing, a part number, price, and quantity.
4. A working code for the Nucleo Microcontroller with all necessary safety features:
   a. Code will control the servo motor with appropriate calculated force and toque values in order to drive both restraint systems into the correct positions
   b. Code will be tested for accuracy and reliability of safety features via a written testing protocol.
5. A comprehensive list of ideas for controlling foot location on the footplates during entrance and usage of the wheelchair. This will be displayed in a design matrix format and will be evaluated and acted upon in the Spring 2021 semester
6. A draft of testing protocol for the final chest and leg restraints:
   a. Each aspect to be tested will have steps on how the team plans to carry out the desired test.
   b. Each testing plan will also include hypothesized result expectations and requirements for each test in order to be deemed successful.
7. The final presentation will consist of SolidWorks animations of the working restraints and proof of concept videos utilizing the PVC prototype. Also included will be the fabrication

BME400_XChair_AgreementContract_Ver2.docx(15.3 KB) - download

9/7/2020 - Motorized Human Gyroscope

BENJAMIN LAWONN - Sep 08, 2020, 2:07 PM CDT

Title: Motorized Human Gyroscope

Date: 9/7/2020

Content by: Ben Lawonn

Present: N/A

Goals:

- Learn more about existing human sized gyroscopes
- Learn more about how motors are utilized in gyroscopes to control rotation

Content:

- There are a number of commerical, human sized gyroscopes available for purchase. The gyroscopes commercially available vary in the number of rotational axes, amount of motors, and methods of securing the user. These gyroscopes have been used for a number of years as exercise machines or entertainment devices, but have rarely been wheelchair accessible. There was an older article I found regarding a custom built human gyroscope, but this was a unique device and the company that produced the device appears to no longer exist[1].
- I found a bachelor's thesis that was conducted regarding the development of a motor driven, multi-axis gyroscope for the purpose of virtual reality simulations from 2012[2]. The thesis has a large amount of information that is related to the design project and can be a great reference. "The Human Gyroscope", the device's name in the thesis, consists of three concentric rings that utilize motors to control the pitch, yaw, and roll of a chair mounted to the innermost ring. The device utilizes an arduino microcontroller to communicate between the user and the three motors, one for each axis of rotation, by using a joystick controller to signal the desired device rotation. The circuitry utilizes 3 separate slip rings to transmit power and data from the joystick to the microcontroller without impeding the rotational capabilities of the device. These slip rings allow the signals from the joystick to travel to the microcontroller located in the ourtermost ring even during operation, which our project is required to do as well. The figure below shows the final proposed design of "The Human Gyroscope". When initially brainstorming design ideas we had considered using a half circle as the furthest outer ring to all the client to enter from above via a lift, and this design concept will help us visualize intuitive ways to design our gyroscope.

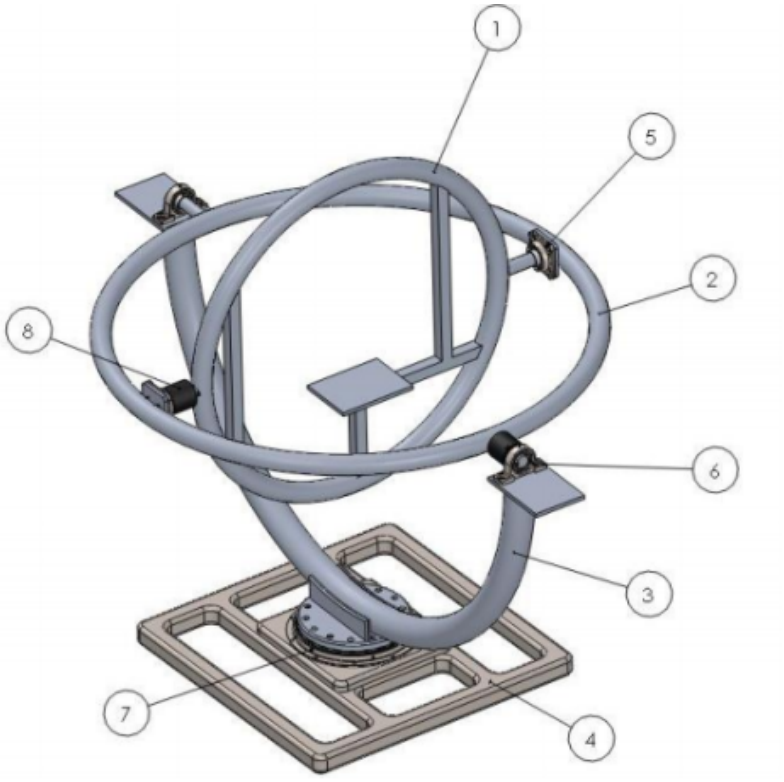


Figure 19 – Construction design full scale model.

Conclusions/action items:

- Finding existing human sized gyroscopes has already helped me view this project differently. When thinking about the multiple axes of rotation, I was fairly confused on what the device would look like or how it could potentially function. After seeing more examples of gyroscopes I am having a much better time grasping the design problem and already have a few design ideas to potentially implement. Finding the 2012 thesis is fantastic, it will be a very good point of reference for us and already has helped answer a few questions regarding the device. We were initially unsure how to wire the microcontroller to the motors effectively with the rotating concentric rings, but the thesis talked about slip rings which would be a viable approach and may allow us to approach the project in different ways than we had thought. I'm going to continue researching humnan gyroscopes, motors, and motor control methods, specifically with joystick controllers which seem like a good option.

References:

[1] Web.archive.org. 2020. Human Gyroscopes. [online] Available at: <https://web.archive.org/web/20061118130302/http://www.gyrogym.com/custombuilds.html> [Accessed 7 September 2020].

[2] Kjellin, A. and Runevad, M., 2020. The Human Gyroscope Motor Driven Simulator With A Gyroscope Design. [online] Diva-portal.org. Available at: <https://www.diva-portal.org/smash/get/diva2:618643/FULLTEXT02.pdf> [Accessed 7 September 2020].

9/14/2020 - Gimbal Lock Research

BENJAMIN LAWONN - Sep 14, 2020, 8:47 PM CDT

Title: Gimbal Lock Research

Date: 9/14/2020

Content by: Ben Lawonn

Present: N/A

Goals:

- Learn more about Gimbal Lock, a topic our client mentioned in our initial meeting
- Determine if gimbal lock prevention mechanisms may be needed in our device

Content:

- Gimbal lock is a phenomena that causes the loss of one degree of freedom in a three-dimensional, three-gimbal mechanism when two of the gimbals enter a parallel orientation. Once the two gimbals have entered the parallel configuration, there is effectively one less degree of freedom because two of the gimbals are rotating around one axis of rotation. There is no physical "locking" of the gimbal, but the orientation prevents any changes in the locked rotational axis to be unmeasurable by the "locked" gimbal system.
- Gimbal lock presents a large problem in navigational systems that rely on the gyroscope for navigational information. While the gimbals are locked the system is unable to detect changes in an axis of rotation. An example given is regarding an aircraft in flight, "Consider a case of a level-sensing platform on an aircraft flying due north with its three gimbal axes mutually perpendicular (i.e., roll, pitch and yaw angles each zero). If the aircraft pitches up 90 degrees, the aircraft and platform's yaw axis gimbal becomes parallel to the roll axis gimbal, and changes about yaw can no longer be compensated for."
- There are only two exact orientations that cause a complete gimbal lock, but most physical gimbals begin to encounter problems while approaching these points due to a number of factors. As the gimbal approaches closer to the complete gimbal lock, there is an increasingly disproportionate amount of inertia required to rotate the inner gimbal platform with the outer gimbals, and factors such as physical acceleration limits, bearing friction, air resistance, and other engineering constraints prevent the motion of the platform.
- Attached below is an image showing a gimbal lock of an airplane, where the yaw and roll axis gimbals have entered a parallel orientation and an axis of rotation is lost.

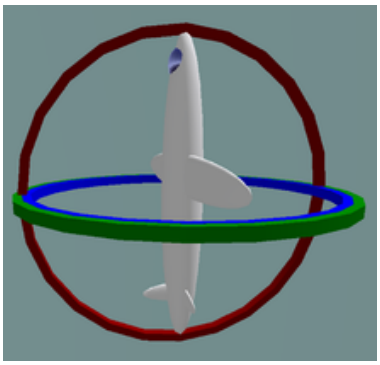


Figure 1: Plane in gimbal lock, with the yaw and roll gimbals locked in the a parallel orientation

- A solution to gimbal lock is the inclusion of a 4th gimbal that is actively oriented perpendicular to the innermost gimbal. This fourth gimbal allows the gyroscope to re-orient if it were to begin to enter a gimbal lock position by providing a redundant axial gimbal. The redundant gimbal can still determine the information from the innermost gimbal and prevents the device from attempting a physically impossible repositioning to maintain the orientation of the device as it passes through gimbal lock

Conclusions/action items:

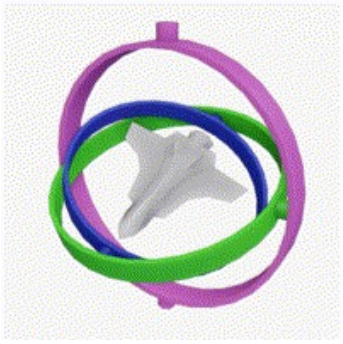
- Based off of the information I could find, I do not believe we will need to implement a fourth gimbal or gimbal lock prevention components for our device. The main problem the gimbal lock creates is the inability to accurately measure positional information for the gyroscope due to the loss of axial rotation. Since our device is not using the gyroscope to derive positional information, and instead using it as a movement device, gimbal lock should be preventable and I believe would not cause failure of the device. The inclusion of a fourth gimbal would increase the size and cost of the device by a decent margin, due to the redundant gimbal needing to be actively powered to be perpendicular to the innermost gimbal. Since size and cost are two of the projects main concerns (at the time of this research) I believe it would not be practical to include a fourth gimbal. In modern engineering practices, the use of gimbals is avoided in providing navigational data, in favor of devices that utilize quaternion (3 dimensional complex number) coordinate devices. The imu that our device will most likely utilize, will use the quaternion coordinate system to determine orientation, thus mitigating the navigational problems from gimbal lock. Gimbal lock may need to be considered for the device during operation,

but if the motorized gimbals have enough torque to rotate a human operator safely, they should theoretically be able to remove themself from a gimbal lock orientation.

References:

[1] “Gimbal lock,” Wikipedia, 27-Jun-2020. [Online]. Available: https://en.wikipedia.org/wiki/Gimbal_lock#:~:text=Gimbal lock is the loss,misleading: no gimbal is restrained. [Accessed: 14-Sep-2020].

BENJAMIN LAWONN - Sep 14, 2020, 8:21 PM CDT



Gimbal_Lock_Plane.gif(1.7 MB) - download A GIF of gimbal lock occuring to a plane with 3 axis-gimbal rotation

9/14/2020 - Motor Research

BENJAMIN LAWONN - Sep 14, 2020, 10:40 PM CDT

Title: Motor Research

Date: 9/14/2020

Content by: Ben Lawonn

Present: N/A

Goals:

- Learn more about the different types of motors and their pros/cons
- Try and determine which motor would be most applicable for our design project

Content:

- Motors work by converting electrical energy to mechanical energy, and there are a number of different types of motors, which are designed to best fit their specific applications. The main two types of motors are DC motors and AC motors, which utilize different forms of electrical current, direct current & alternating current, respectively. Within DC motors,

Conclusions/action items:

9/24/2020 - Wheelchair user accessible exercise devices

BENJAMIN LAWONN - Sep 24, 2020, 11:54 AM CDT

Title: Wheelchair user accessible exercise devices

Date: 9/24/2020

Content by: Ben Lawonn

Present: N/A

Goals:

- Learn more about wheelchair user exercise devices, including how they are adapted
- Learn about the benefits provided from each workout device to determine if they could be applicable to our project
- Find a device that we can utilize components of for our design project purposes

Content:

- There are a growing number of exercise equipment and devices that are designed to be accessible for wheelchair users, allowing them to acheive the many benefits of various exercises. Most of the accessible equipment is similarly designed to the standard workout equipment, but they allow the user to remain in their wheelchair during operation. The main accessibility changes are the removal of chairs and repositioning of equipment that would impede operation from a wheelchair, and the addition of straps and other restaints to secure the user during operation. Below are a series of figures from the Equlalizer Exercise Machines which were designed by a parapelic with the goal of being usable by non-disabled users and wheelchair users.

Figure 1: Equalizer Exercise Machine in Lateral Deltoid configuration for both a non-disabled user and a wheelchair user

Figure 2: Equalizer Exercise Machine in Bench Press configuration for a wheelchair user

- I was able to find a limited number of wheelchair user workout devices that allowed the user to rotate or move outside their wheelchair. One of the devices that I found that allowed rotational movement during exercise was an adapted inversion table. There were a couple of videos I found of paraplegics using the inversion tables to work on their core strength, as well as relieve pressure on their spine. The main adaption to the inversion chairs was the addition of a strap that prevented the table from reaching vertical while in rest, which allowed the users to lift themselves onto the horizontal table and place their legs in the restraints. Once the user was secured in the restaints they were able to invert themselves for a short period of time and then, by using the handles, pull themself back to the horizontal resting position. Below are a few figures captured from the videos, they show the inversion tables at rest and during operation.

Figure 3: Adapted inversion table at rest with user secured in the restraints

Figure 4: Adapted incersion table while inverrted during operation

Conclusions/action items:

- Our client has stated that being able to lie prone is one of the most important design requirements for the device. The vast majority of exercise devices I came across simply do not provide this rotational movement. Our client would like to be able to stretch and exercise in positions not normally attainable from within their wheelchair. Most of the devices require the user to stay in their wheelchair, which does not provide the variation that our client is looking for in this device.

BENJAMIN LAWONN - Sep 28, 2020, 12:07 AM CDT

Conclusions/action items continued:

- The inversion table would allow our client to rotate within the sagittal plane, and provide them an opportunity to straighten out more. There are not inversion tables that are designed specifically for wheelchair users, and the one pictured above and the one pictured below are standard inversion tables that have been modified by the user. These adaptations would not work for our client due to his limitated upper body strength. With our client able to lift no more than 5lbs, they would not be able to transition themself into the chair using their upper body strength as the users mentioned in this article. Our client would also not be able to utilize the leg restraints at the base of the table due to his leg muscles being atrophied and unable to adequately secure him in the chair during operation. Another challenge of the standard inversion tables is the required upper body strength to right yourself vertically after becoming inverted. The client would most likely be unable to pull themself back to rest after inverting and this would be a potentially dangerous situation if they were to become stuck in this position. While inversion tables can provide a large amount of benefits by reducing pressure on the spine and by allowing our client to straighten themself, as well as rotate, it would need to be adapted greatly to accomodate them in a safe and effective manner.
- Following our meeting with our client to determine the most important design functions, they stated their top two movements would be #1 straightened vertically and #2 prone. This could be potentially achieved with the inversion table. We could potentially modify an inversion table to allow the client to rotate forward instead of inverting themself. They could enter while the table is in a horizontal position and then be able to rotate forward into a standing position and then continue rotation into a prone position. There would need to be additional restraints implemented to adequately secure them, especially due to the inability to use the feet restraints. There would also need to be a method of securing the table while the client transitions into and out of the chair, and modifications that weould allow them to rotate prone, while preventing them from rotating too far forward. Further research and brainstorming is needed for the inversion table idea to be an adequate design option for our client and their specifications.

9/27/2020 - Pressure Cuff Design Idea

BENJAMIN LAWONN - Sep 28, 2020, 9:06 PM CDT

Title: Pressure Cuff Design Idea

Date: 9/27/20

Content by: Ben Lawonn

Present: N/A

Goals:

- Brainstorm ideas about the pressure cuff preliminary design
- Try and establish a rudimentary design and consider the potential pros and cons

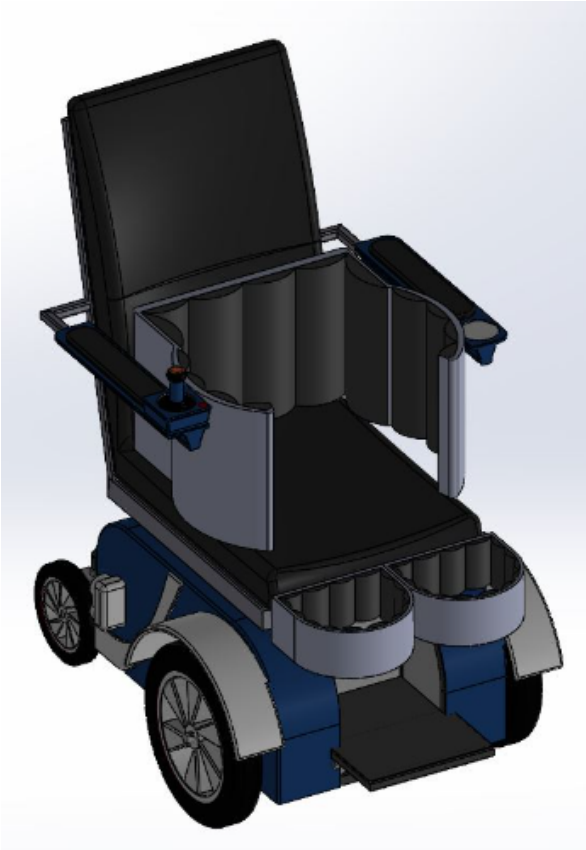
Content:

- The pressure cuff design would be an adaptation to our client's existing Permobil F5 chair. The focus of this design is to allow our client to operate and utilize their standing wheelchair on a more frequenct basis. They are currently unable to attach the leg and chest restraints without assistance due to bulky design of the restraints and the system used to secure them, which is a peg & hole style system. The goal of this preliminary design is to provide a safe, comfortable, and convenient adaptation for our client to secure themself in the Permobil F5 without external assistance.
- The pressure cuff preliminary design would incorporated a BOA system to secure the lower leg restraints (in a similar fashion to the BOA system preliminary design). The main difference between the pressure cuff design and then BOA design would be the chest restraints in the wheelchair.

Conclusions/action items:

BENJAMIN LAWONN - Oct 05, 2020, 2:07 AM CDT

Content Continued:



- The figure above is the SOLIDWORKS model of the pressure cuff system attached to a model wheelchair. This is the final version of the preliminary design the team developed. The design incorporates pressure cuffs on both the leg restraints and the chest restraints to provide comfort and security for the user. The restraints would act similar to blood pressure cuffs and would inflate via a series of connected rubber bladders to various pressures. The leg restraints would be mounted to the wheelchair using the existing peghole for the current leg restraints to allow them to be removable and alleviate the need for permanent mounting on the wheelchair. The two leg restraints would be mounted onto a bar that would fit in the peghole, but each restraint would be completely enclosed, similar to how pictured above. The restraints would only encompass a portion of the lower leg, from slightly below the knee to below the middle of the lower leg, and would be large enough the client could lower their entire foot through the opening while deflated for ease of use. The chest restraint would be secured to the chair using a strap that would encompass the back of the chair and would fit through the rear of the chest restraint. The restraint would be able to open to allow the client to enter the wheelchair and then would close via tightening a strap across the restraint. Due to the maximum angle of standing the client can reach within their wheelchair, the chest restraint will not have to bear as robust a load as the leg restraints and is more in place for added comfort and support during operation of the chair. The system would inflate with a portable air compressor that would be secured to the chair, and would be controlled by a control panel located within arms reach of the user. The inflation and deflation would be controlled by the control panel which would be connected to a microcontroller to allow variability in the level of inflation the client would like.

Conclusion/action items:

- The pressure cuff system could be a cost effective solution for the design project and a more comfortable restraint for our client during wheelchair operation. When speaking with our client, they mentioned that the padding of the chair is inflatable and it is one of the most comfortable chairs they have used. Using the series of inflatable rubber bladders, the restraints can provide comfort and an adjustable level of support to our client. The material costs of the device would be well within the budget, and the fabrication should be a fairly straightforward process. The main areas that could be challenging would be the control of the inflation and the deflation. First off, finding where to mount the air compressor may be challenging due to the limited space available on the wheelchair, but there are small enough air compressors that this could potentially not be problematic. Controlling the inflation and delfation of the device may be challenging since the device is supposed to be removable from the wheelchair. We would have to look at wireless control for the inflation and deflation of the cuffs since hardwiring the control to the cuffs would not be a viable option. The device may be a vialbe option, but there are a few potential challenges we would have to solve before it would be the most promising design for this project.

10/5/2020 - Inversion Table Design Idea

BENJAMIN LAWONN - Oct 05, 2020, 2:41 AM CDT

Title: Inversion Table Preliminary Design Idea

Date: 10/5/2020

Content by: Ben Lawonn

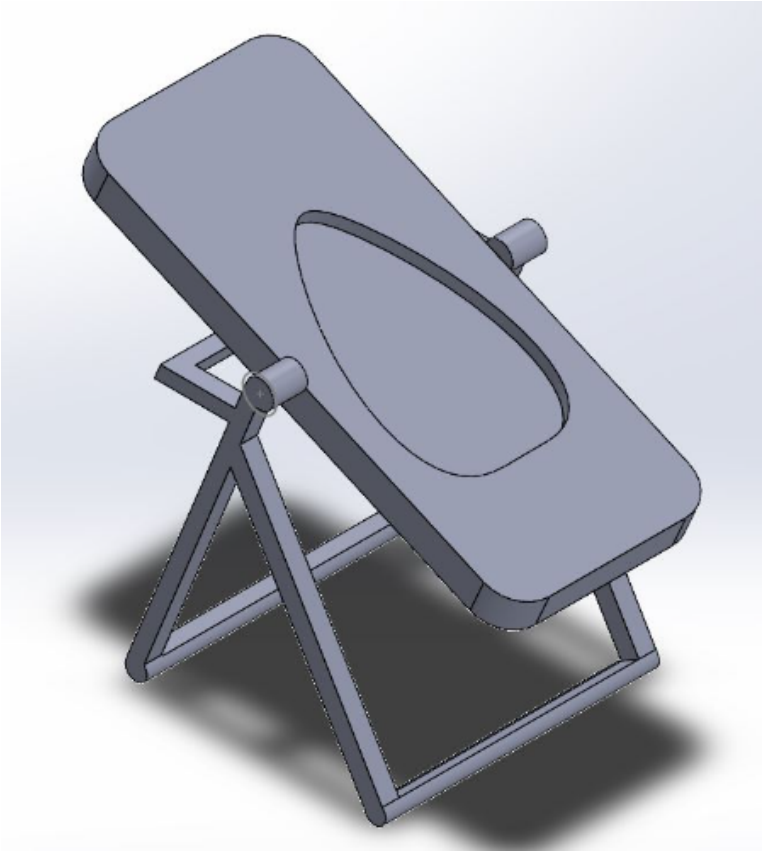
Present: N/A

Goals:

- Describe in detail the inversion table preliminary device
- Consider the potential challenges of the inversion table design

Content:

- The inversion table design focuses on adapting an existing inversion table design to provide a standalone device for the client to achieve both prone and vertical positions of rotation. While current inversion tables are designed to start with user oriented vertically and then allow them to invert themself, the adapted design would begin oriented horizontally and then allow the user to move to a vertical orientation and then a prone orientation. There are not many existing adapted inversion tables and they are incompatible with our client's requirements because they cannot be entered safely with a ceiling lift.



- The figure above is a basic SOLIDOWORKS model of the inversion table design. The design would be motorized to allow controlled rotation during operation and would be controlled by the user with a controller. The controller would be the user input to a microcontroller and would control the high torque motor used to rotate the table. As of now, the team is unsure if independent operation would be safe for the user, and a second person would be required to assist in applying the restraints and ensuring the user is safe during device operation. To allow the device to remain horizontal for entry a locking mechanism would be engaged and the table would rest on the rear horizontal support while the user enters. There would be an ergonomic indent in the chair that would fit the figure of the client to help support the client and increase the comfort during operation. The user would be secured in using a series of straps that would go across their body and tighten with the table to allow the user to safely rotate to prone. The horizontal support bar prevents the table from rotating further than the prone position as well as support the table while the user enters the device. The frame would be rigid and shaped to ensure the table is stable while rotation occurs.

Conclusions/action items:

- The inversion table does meet our client's requirements to be able to reach vertical and prone positions, but it does not satisfy their requirement of autonomous operation. The team is not confident as of now that the device could be operated safely by the user on their own, due to their dexterity limitations and the amount of restraints needed to adequately secure the user to the chair. There is the potential that the team could develop automated restraints for the inversion table, but that may simply be beyond the scope of the project this year and may be slightly too challenging to implement. Our team has determined from our extensive interviewing of our client that the autonomy of the device is much more important than being able to go prone, and as a result we are focusing on meeting that design requirement for this year's design project. There is a potential that a continuing design team could implement a style of restraints that we design this year to an adapted inversion table, which could allow independent usage from the client. Another downside of this design is the overall cost. While the cost of the materials and components would most likely be within budget, it is much higher than the other designs due to the need for a decent amount of materials and a high torque low RPM motor to control rotation.

10/11/2020 - Design Adjustments and Gear Research

BENJAMIN LAWONN - Oct 11, 2020, 6:33 PM CDT

Title: Design adjustments and gear research

Date: 10/11/2020

Content by: Ben Lawonn

Present: N/A

Goals:

- Determine what adjustments are required of the proposed final design
- Work on creating and new final design to meet the adjusted design requirements
- Research more about Gear systems
- Work on developing a gear system for our device to aid in automation

Content:

- Following meeting with our client in person we have learned a large amount about the limitations of the client's wheelchair and their movement. These factors have caused us to have to adapt our design to ensure usability by the client in a safe and convenient manner. The device will need to be completely automated to allow the client to control the device with either their currently attached joystick or another conveniently located control system. The device will also need to be designed in such a way that it can be effectively attached to the client's wheelchair, which the current final design would most likely be unable to accomplish. There are a limited number of locations that a device could be mounted onto the wheelchair, so the new design will need to be designed intelligently to utilize either existing restraint mounts or the limited number of other mounting locations.
- The client has stated that we could mount a device for the chest to the bar that the headrest is mounted on. This location seems promising as we could potentially have a box to contain the motor and electronics components that would slide over the headrest and be secured to the headrest mount. For the leg restraints, the team believes we could utilize the current mounting hole, which would prevent any additional attachments to the wheelchair. The main limitations for mounting the restraint to the leg area are the large amount of components mounted below the base of the seat and the mounting cannot impede the chair from entering the standing position. Attached below is a figure that shows the base ideas for the chest (upper left drawing) and the leg (lower right drawing) restraints to meet the new design requirements.

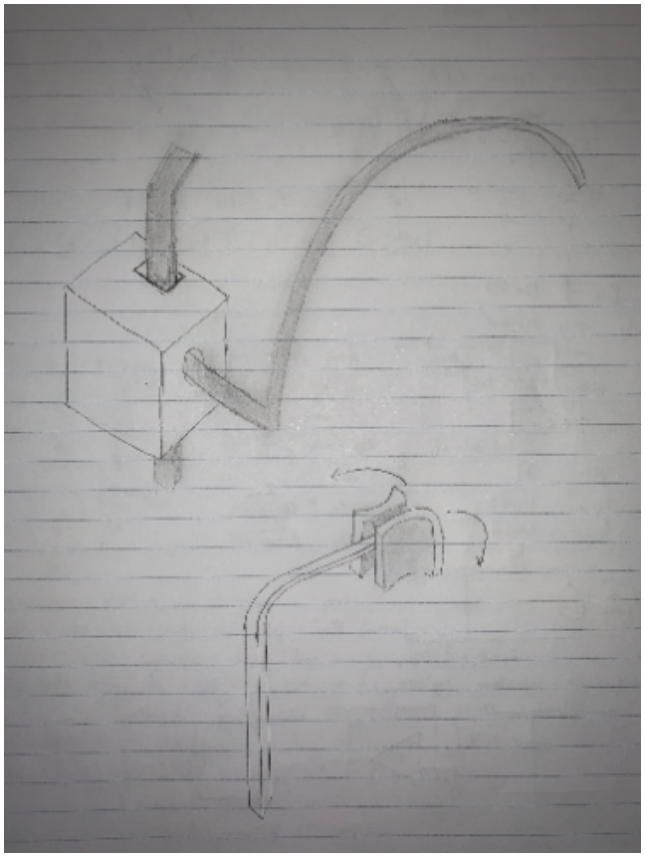


Figure 1: Preliminary drawing of the chest restraint (upper left) and leg restraint (lower right)

- The chest restraint design would feature a box that would contain a motor, gearbox, and microcontroller or wireless communicator for a microcontroller. The box would have slot that would allow the headrest bar to pass through, securing it to the chair and ensuring stability. The device would have a mechanism in place to secure the device to the headrest bar. The actual restraints would extend out of the side of the box (in the image, one of the bars is pictured coming out of the right side of the box))and would then arc over the top of the wheelchair similar to an overhead roller coaster harness. The bars would be shaped in a way that when positioned, there would be space between the client and the restraint, since this is a requirement of the client. The restraint would retract to a position behind the back of the chair to allow the client to enter the chair from an overhead lift.
- The leg restraints would use an L shaped bar that would fit into the exisiting mount of the wheelchair for simplicity. The backs of the pads would remain parallel with the bar while at rest to allow the client to enter and exist the wheelchair without requiring the removal of the restraints, and when activated, the pads would become perpendicular with the bar (pictured at rest above, and the arrows demonstrate the direction the pads would take when activated). Similar to a wing corkscrew bottle opener, there would be a gear system that would be connected to the pads, which would open up as a motor or solenoid is utilized to open and close the device. Pictured below on the left is the bottle opener at rest and on the right is the bottle opener when the wings are extended perpendicularly to the body. The wing system would allow the client to enter the chair from an overhead lift without needing to remove the chair, and when they wanted to use the leg restraints they could then extend and provide support and security.

Figure 2: Image of wing corkscrew bottle opener, with opener at rest (left) and extended with wings perpendicular to body (right) [1]

- Due to the overall size limitiation the motor that will be used for the overhead restraints cannot be too large, so a gear system will most likely be used to increase torque generated from the motor. Gears are an efficient method of increasing the torque a motor can generate while also slowing the rotational speed, which would ensure precision of the restraints and safety while entering position. Below is an example of a gear problem where the smaller gear is able to generate a large torque on the larger gear, with the same amount of force.

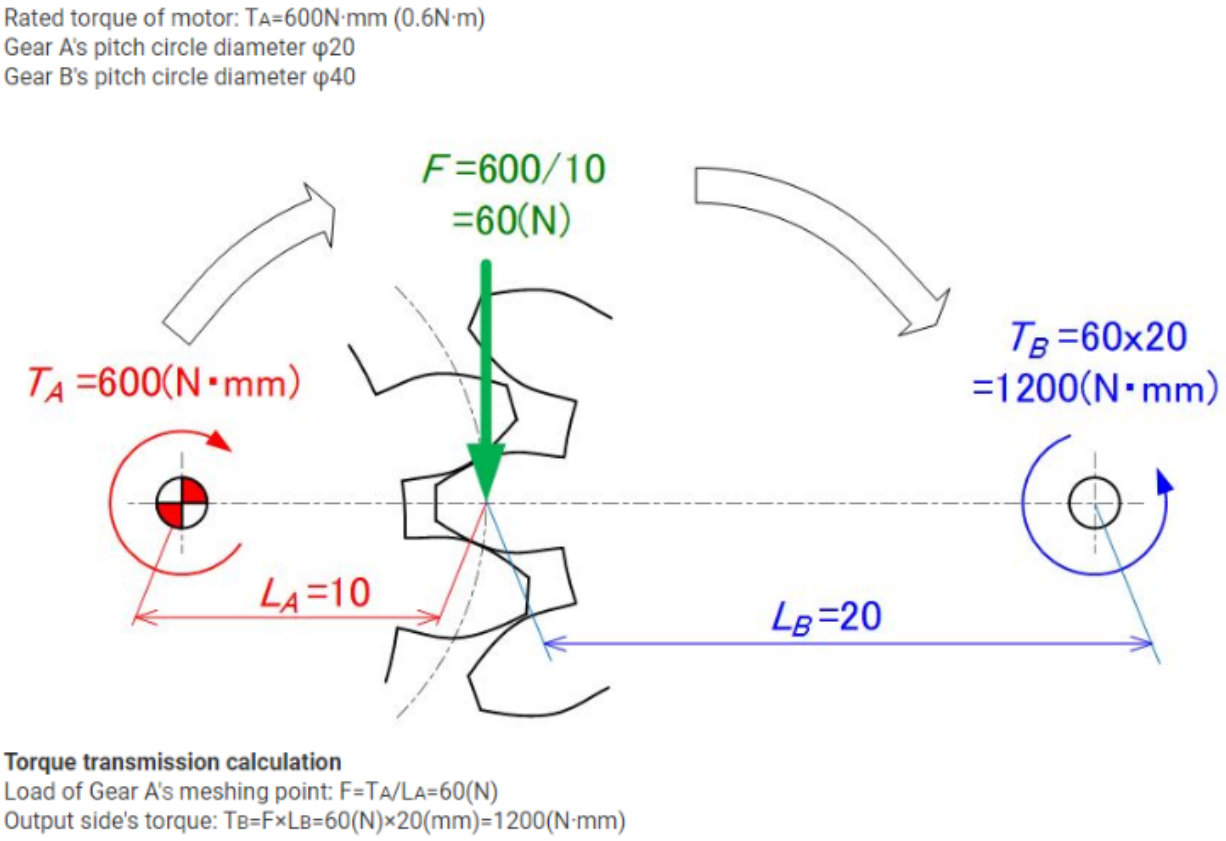


Figure 3: Example problem of a gear system with torque calculations [2]

Conclusions/action items:

The adapted designs would have a good chance of working and being implemented on the client's wheelchair. The

Refernces:

1. “Corkscrew and Cap Lifter,” WebstaurantStore, 18-Jul-2020. [Online]. Available: https://www.webstaurantstore.com/corkscrew-and-cap-lifter/2081250.html?utm_source=google. [Accessed: 11-Oct-2020].

2. “Know about gear transmission torque,” KHK Gears. [Online]. Available: https://khkgears.net/new/gear_knowledge/the-first-step-of-mechanism-design-using-gears/know-about-gear-transmission-torque.html. [Accessed: 11-Oct-2020].

11/10/2020 - Battery and Electrical Components Research

BENJAMIN LAWONN - Nov 10, 2020, 1:25 PM CST

Title: Battery and Electrical Components Research

Date: 11/10/2020

Content by: Ben Lawonn

Present: N/A

Goals:

- Learn more about the limitations of the battery
- Determine what the ideal component characteristics are for the device

Content:

- The battery in the client's wheelchair is a M24 SLD G FT 12V74AH@20HR, this means that it is capable of supplying 3.7A each hour for 20 hours of run time before the battery is discharged. The longer you discharge the battery for, the higher the effective rating will be, as seen by the battery also being rated at 12V63AH@5HR meaning the battery supplys 12.6A each hour for 5 hours, which is a smaller amount of charge output by the battery.
-

Conclusions/action items:

11/10/2020 - Device Materials Ideas

BENJAMIN LAWONN - Nov 10, 2020, 6:31 PM CST

Title: Device Materials Ideas

Date: 11/10/2020

Content by: Ben Lawonn

Present: N/A

Goals:

- Continue to research more about potential materials for the device
- Document potential materials that can be used for the device

Content:

- There are a wide variety of materials and components that the team will need to acquire to fabricate the final design. The chest restraint and leg restraint have individual, unique mechanisms requiring different components.
- The chest restraint has a large bar that is similar to a roller coaster bar, which will secure the user into the wheelchair. Due to the pandemic, the team's initial approach of fabricating the bar, welding, may not be easily accessible to the team, so another method may need to be utilized.A potential fabrication approach for the bar, that would not require welding, would be to use threaded poles and connectors to form the bar. By having the pole sections be threaded, they could screw into 90-degree and 45-degree threaded connectors and be secured into place. The cost of 3/4" cold rolled steel is relatively cheap, and there are connectors for a good price. The team will have to thread the tubes of cold rolled steel to allow them to thread into the connector pieces. Below are some link to threaded connectors and cold rolled steel.

Stainless steel 90-degree threaded pipe - https://www.amazon.com/Stainless-Steel-Fitting-Degree-Female/dp/B001VXVZ9U/ref=sr_1_16?c=ts&dchild=1&keywords=Pipe+Fittings&qid=1605053065&refinements=p_n_feature_four_browse-bin%3A3052062011%2Cp_11%3A3%2F4%22&rnid=1247282011&s=industrial&sr=1-16&ts_id=383612011

Stainless steel 45-degree threaded pipe - https://www.amazon.com/Stainless-Fitting-Degree-SP-114-Female/dp/B003GXF4NQ/ref=sr_1_2?dchild=1&keywords=45-degree+3%2F4%22+threaded+elbow&qid=1605053439&s=industrial&sr=1-2

Cold rolled steel tube - https://www.speedymetals.com/pc-3428-8242-34-od-x-072-wall-dom-steel-tube.aspx

Cold rolled steel tube - https://www.metalsupermarkets.com/metals/cold-rolled-steel/cold-rolled-steel-c1010-crew-round-tube/

Conclusions/action items:

11/10/2020 - SOLIDWORKS Models - Chest Restraint

BENJAMIN LAWONN - Nov 13, 2020, 1:29 PM CST

Title: SOLIDWORKS Models - Chest Restraint

Date: 11/10/2020

Content by: Ben Lawonn

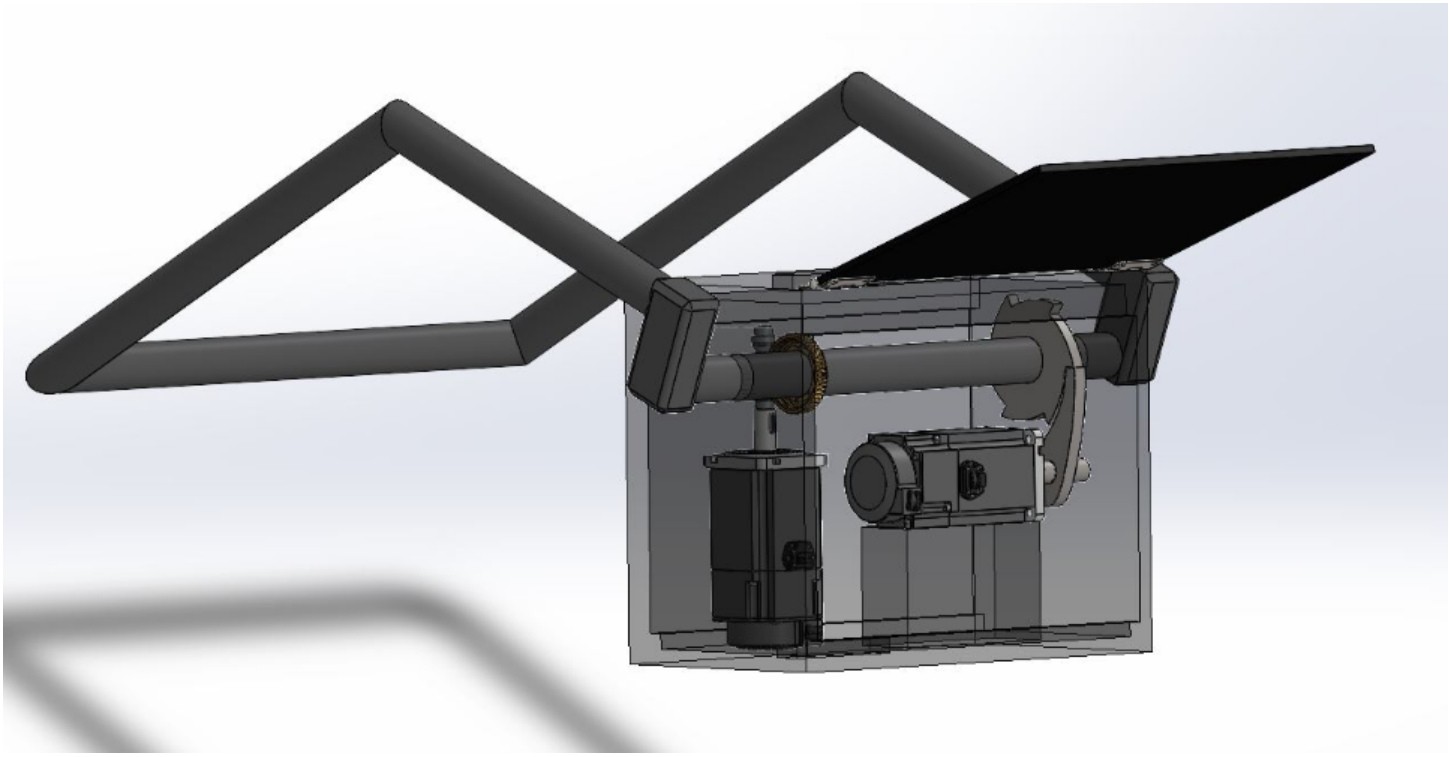
Present: N/A

Goals:

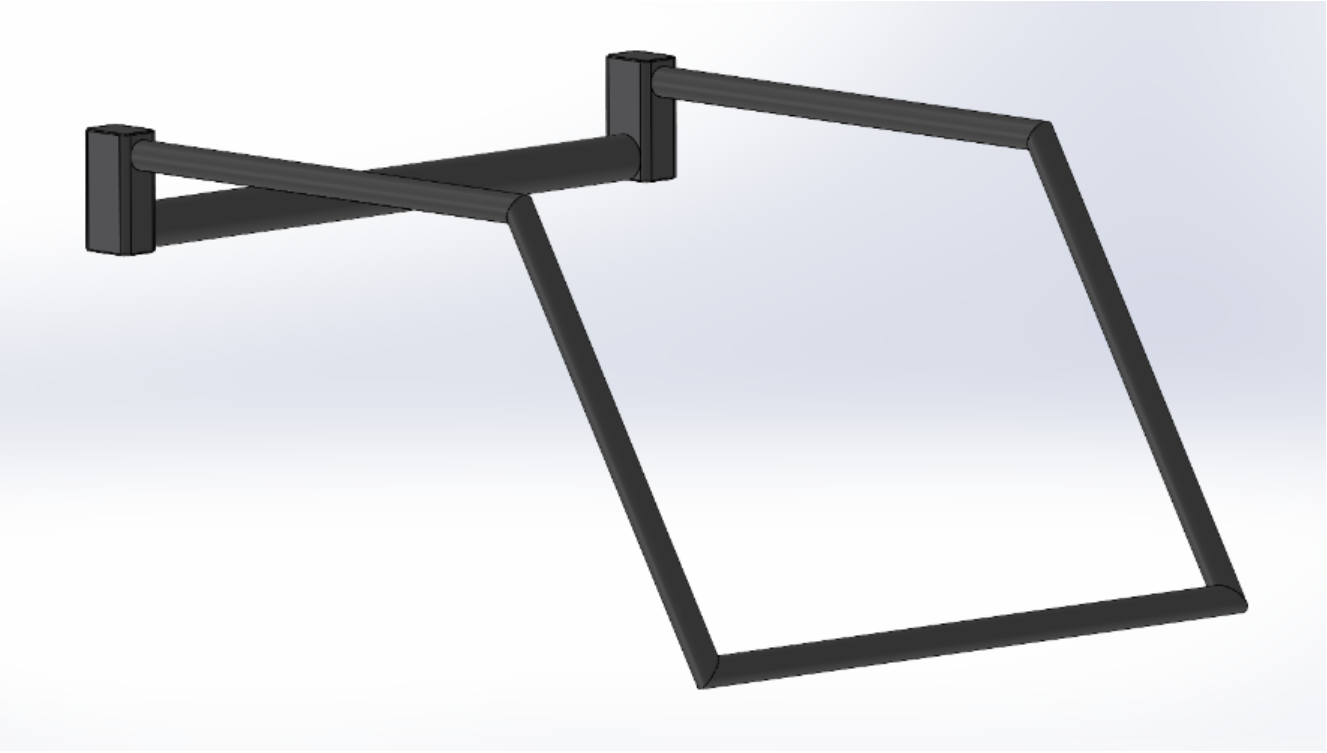
- Highlight the various components of the chest restraint
- Mention potential fabrication methods or adjustments

Content:

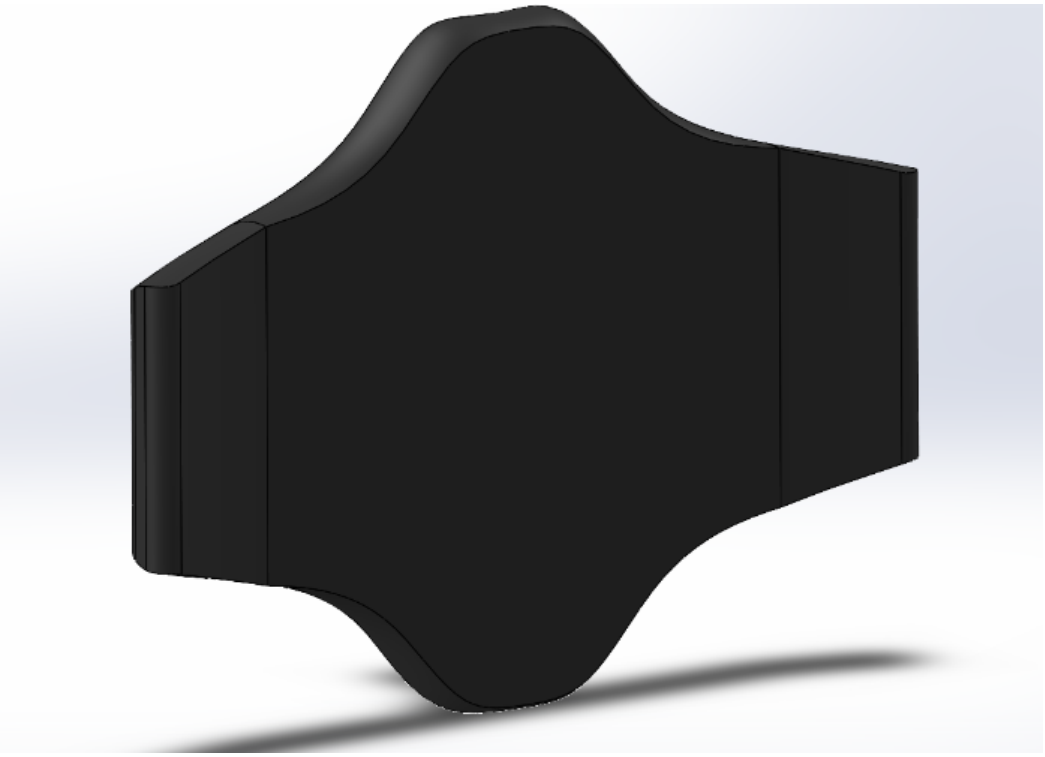
- The chest restraint is composed of many different components that work together to accomplish multiple tasks. The chest restraint mainly operates by having a servo motor drive a worm shaft, which spins a worm gear attached to the restraint bar, allowing the overhead restraint to rotate into/out of position. The inherent design of the worm shaft/worm gear, backdrive is prevented in static conditions, but since the device will be used dynamically there is an additional safety measure. There is a ratchet system that acts as a secondary locking system that prevents the restraint from rotating backwards while locked in position.



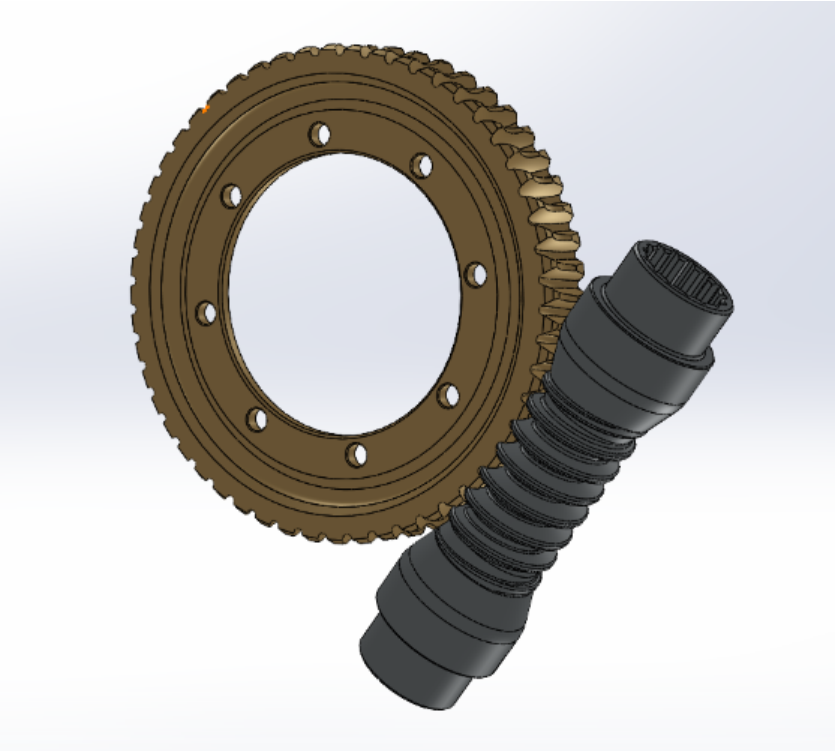
- The overhead bar model is the actual restraint bar for the chest restraint device. The bar extends 0.38m outward before extending downard at a -59.6 degree angle for 0.336m. These measurements are based off the measurements recorded in the second client meeting, they may need to be adjusted after testing the device on the chair due to potential positional changes when moving into the standing position.



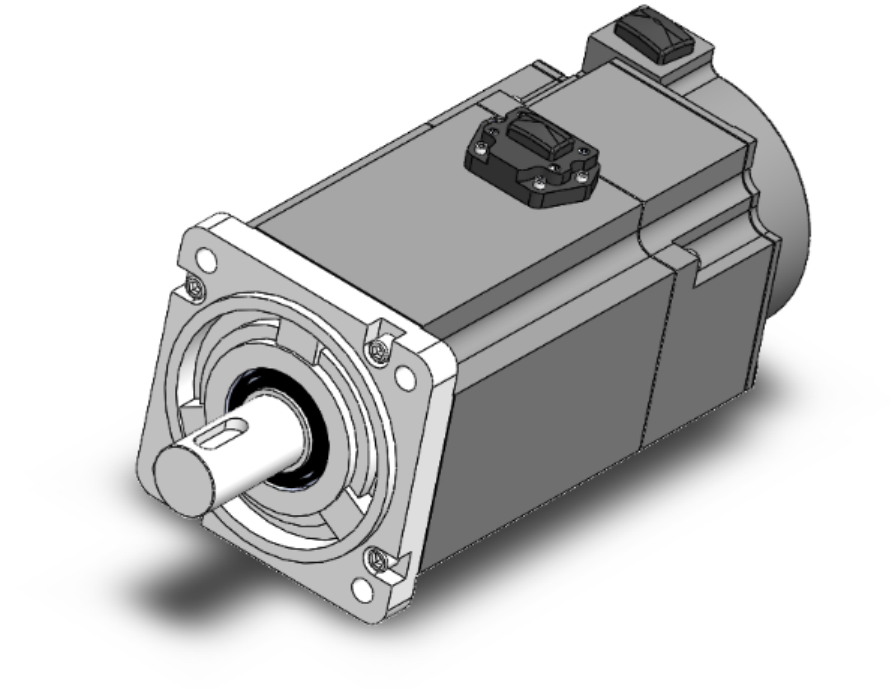
- The chest restraint pad model is the main pad that will be center mounted on the overhead bar. The pad will mimic the manufacturer included pad, or may even utilize the exact same pad to reduce costs.



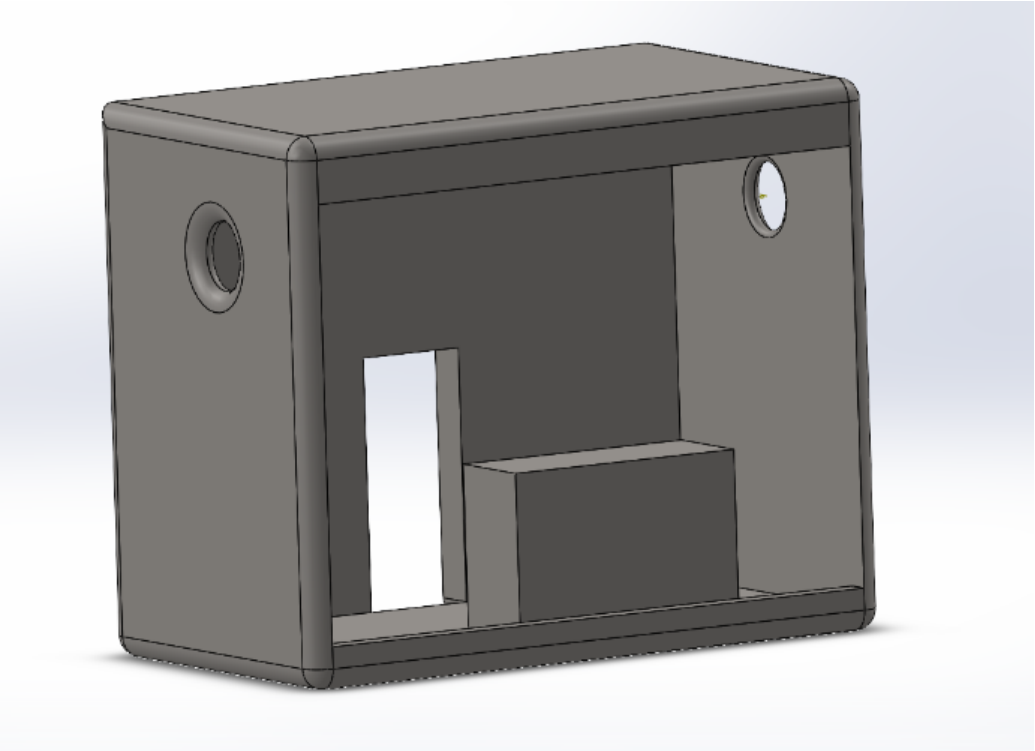
- The Worm gear and worm shaft models are the models of the main active component of the chest restraint. The current ratio between the worm shaft and worm gear is 1:52 due to the worm gear having 52 teeth. This provides an estimated 1:15.6 ratio of input torque of the shaft to output torque of the gear from an estimated power transmission effectiveness of 30%. The ratio of the worm shaft and worm gear being high is both beneficial and problematic. The high ratio reduces the required torque of the servo motor, but the high ratio also means the rate at which the restraint will rotate into place may be quite slow. The ratio may be adjusted depending on performance testing.



- The servo motor models are not exact representations of the servo motor we are using, they are placeholders for the actual servo motors which are being selected currently. The exact strength of the servo motor is not known since we have not finalized the exact materials for the restraint. The motor strength will have a factor of safety of strength to ensure it can drive the restraint during operation.



- The box model is the holder of all the electrical components and the main point of attachment to the wheelchair. The box will have an attached mount at the front that fits into the manufacturer included headrest mount. The box will also hold the servo motors and the microcontroller that will controller the two servo motors.



Conclusions/action items:

- The chest restraint design is not completely finalized and may still be adapted to better fit the needs of the client as the team learns following fabrication and testing. The fabrication of the device should be manageable and provided restrictions do not increase surrounding the fabrication lab, the team should have access to the necessary resources to build the device.The team is finalizing the materials and components to purchase for the device to begin fabrication. The team has been researching the different components over the past week and will be deciding upon them in the immediate future.

11/23/2020 - Leg Pad Research

BENJAMIN LAWONN - Nov 23, 2020, 10:14 PM CST

Title: Leg Pad Research

Date: 11/23/2020

Content by: Ben Lawonn

Present: N/A

Goals:

- Research about the leg pads and specifically determine the material that they are for force calculations

Content:

- There is not a lot of information about the knee stop component of the client's existing wheelchair. Previous searches have not been successful in finding either aftermarket or replacement versions of the components, let alone much information regarding them. Since they are included in the power wheelchair, they aren't sold separately, and the market is so limited that there is not a large amount of information about this product or additional listings.
- The team is currently intending to use the manufacturer included restraints, but the team needs the material information to develop an accurate mass moment of the intertia. The team has the mass of the pads measured, but the material density is needed to determine the torque required to thread/unthread the bolt into the leg restraint.
- I found a parts list that includes all of the individual components, but when trying to look up the components by part number or description, there have been no other references to the specific part number in this context. The part list is attached below for reference. There have been a limited number of listing for the knee stop, and the current listings do not include the correct pads.
- I was able to find a listing for a few similar style knee pads, but I was unable to find the information about the material used for the pad.

[1] https://easystand.com/product/py5680-swing-away-knee-pads/

[2] https://www.southwestmedical.com/Standing-Frames/EasyStand-Standing-Frames/Bantam-Accessories/Swing-Away-Kneepads-for-Small/30104p

Conclusions/action items:

I have been unable to find any information regarding the knee pads materials for the client's existing wheelchair. The team will continue to research more about the pads, but will most likely assume the material is a heavier density foam and will continue with calculations. While this may be less exact for these specific pads, the pads we are researching may not be the final pads utilized after this iteration of protoype. The team will continue to try and find specific figures, but if we are unable to we will use a higher assumed value to ensure there is a factor of safety for the client's usage.

References:

[1] “PY5596-1 Swing-Away Knee Pads,” EasyStand, 24-Jul-2019. [Online]. Available: https://easystand.com/product/py5680-swing-away-knee-pads/. [Accessed: 24-Nov-2020].

[2] “Standing Frames,” Southwest Medical. [Online]. Available: https://www.southwestmedical.com/Standing-Frames/EasyStand-Standing-Frames/Bantam-Accessories/Swing-Away-Kneepads-for-Small/30104p. [Accessed: 24-Nov-2020].

BENJAMIN LAWONN - Nov 23, 2020, 10:15 PM CST

Parts Price List

permobil

Part Number	Part Description	CAD Retail
3099-2081A	FOOT CONTROL MOUNTING BRACKET	$416.32
3099-7085A	FOOT CONTROL - PROP, OMNI+ W/BRACKET	$5,174.77
3025-7086A	CABLE PWR, 3A XLR, DC PLUG (5.5X2.1) V.2	$73.20
3027-2079A	PERMOFIX ROD 5/16" X 2" L (8MMX50MM)	$14.20
3027-2081A	PERMOFIX ROD 5/16" X 3" L (8MMX75MM)	$15.19
3027-2083A	PERMOFIX ROD 5/16" X 4" L (8MMX100MM)	$16.13
3027-2083A	PERMOFIX ROD 5/16" X 6" L (8MMX150MM)	$18.12
3027-2084A	PERMOFIX ROD 5/16" X 8" L (8MMX200MM)	$20.09
3027-2083A	PERMOFIX, PANEL MNT ADAPT 16MM-8MM, 107.250MM	$42.87
3027-2086A	PERMOFIX, OMNI MOUNTING ADAPTER, EACH	$33.61
3027-2127A	PERMOFIX, R-NET/VR2 ,8M MOUNTING ADAPTER RING	$74.95
3027-7084A	PERMOFIX, BASE JNT +5/16" (8MM) THRU MOUNT	$127.19
3027-7085A	PERMOFIX, BASE JNT +45° SWIVEL END, EACH	$127.19
3027-7086A	PERMOFIX, BASE JNT AND ROUND FLAT PLATE	$126.66
3027-7087D	PERMOFIX, SWING-AWAY JOINT W TWO 90° SWIVEL	$525.95
3027-7087A	PERMOFIX GOOSENECK ROD 5/16" X 8" L (8MMX200MM)	$232.95
3027-7025A	PERMOFIX, BASE JNT +COMBI 90° SWIVEL END	$127.19
3027-7027A	PERMOFIX, BASE JNT +9/16" (14MM) THRU MOUNT	$127.19
3027-7088A	PERMOFIX, BASE JNT & UT ADJ, DISC ADAPTER	$127.19
3027-7065A	PHA, PERMOFIX ADPTER FOR SWING-AWAY POST	$216.20
3033-2088A	KEYPAD, CJ ADVANCED	$62.69
3033-7089A	CJA - HAND SUPPORT KIT	$391.86
3035-2084A	PERMOFIX, HOLDER PLATE CJ W/ GSNECK SWITCHES	$52.71
3035-7087A	PERMOFIX, MTNG BRKT FOR GOOSENECK SWITCH	$37.23
3035-7088A	SWITCH, GOOSENECK, 6' L, 6"(150M) CBL, 3.5MM PLUG	$385.69
3035-7089A	PERMOFIX, CJ(A) PLATE TO 8MM ROD (L=50MM)	$234.26
3035-7061A	SWITCH ASSY CBL GOOSENECK FOR COMPACT	$662.33
3035-7012A	SWITCH, GOOSENECK, 6" L, 55"(1.4M) CBL, 3.5MM PLUG	$242.95
3035-7014A	SWITCH ASSY, DOUBLE FIXED FOR COMPACT JOYSTICK	$274.86
3037-7003A	TOUCH CONTACT, 3.5MM PLUG W/CR2032 BATTERY	$556.86
3044-5014A	SPLITTER 3.5MM JACK MALE STEREO > 2XJACK FEM.	$64.59
3049-7019A	REMOTE BUTTON INTERFACE	$1,721.84
3055-2029A	PHA, LATERAL PAD COVER ONLY	$57.84
3055-2039A	PHA, SOLID LAT PAD ONLY (NO PLATE/JOINT)	$44.46
3055-7068A	PHA, PROX SENSOR ONLY, LTERAL L = 55CM (LONG)	$354.52
3055-7016A	ADJUSTABLE SWIVEL OPTION FOR OCCIPITAL PAD	$694.79
3055-7031A	PHA, LTERAL ARM ONLY, LNG - LEFT	$363.85
3055-7021A	PHA, LTERAL ARM ONLY, LNG - RIGHT	$363.85
3055-7024A	PHA, LAT PAD ASSM W/JNT & PRX SNSR, L = 55CM	$541.12
3055-7026A	PHA, LAT PAD ASSM W JNT - SOLID PAD (NO SW/SNSR)	$251.90
3055-7027A	PHA, LAT PAD ASSM W/JNT & EGG SWITCH	$491.19
3055-7028A	PHA, OCPTAL PAD W/ HDWR, SMALL	$117.89

Permobil Inc.

Effective 09/09/2019
Prices subject to change without notice.

1 of 1

Permobil-Parts_Retail_Price_List-09_09_2019-MSRP-CAD.pdf(1.3 MB) - download Parts list of the permobil inventory MSRP (2019)

11/30/2020 - Continuous Servo Motors

BENJAMIN LAWONN - Dec 01, 2020, 2:18 PM CST

Title: Continuous servo motor

Date: 11/30/2020

Content by: Ben Lawonn

Present: N/A

Goals:

- Find the motor types the design team will need for each application
- Discuss the differences in continuous and non-countinuous servo motors

Content:

- Servo motors are able to accurately rotate to positing based on the pulse wave that is communicated. The standard servo motor has a 50Hz frequency by checking the pulse wave signal every 20ms. Depending on the duration of the pulse wave signal input the servo motor will either rotate to a designated position, or a certain amount of degrees.
- The two main types of servo motors are continuous and non-continuous. The continuous servo motors are able to rotate a full 360

Conclusions/action items:

12/11/2020 - Updated Leg Support SOLIDWORKS

BENJAMIN LAWONN - Dec 11, 2020, 1:03 PM CST

Title: Updated Leg Support SOLIDWORKS

Date: 12/1/2020

Content by: Ben Lawonn

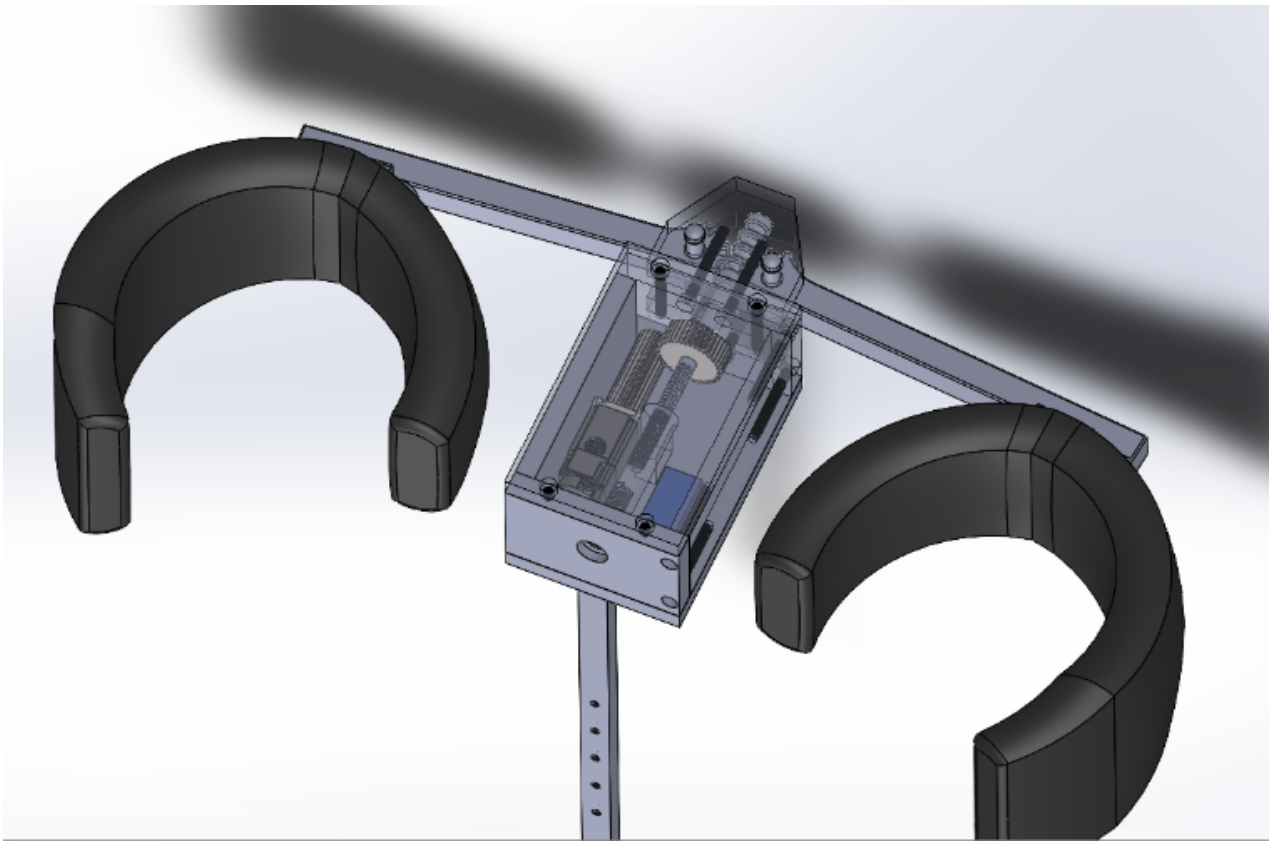
Present: N/A

Goals:

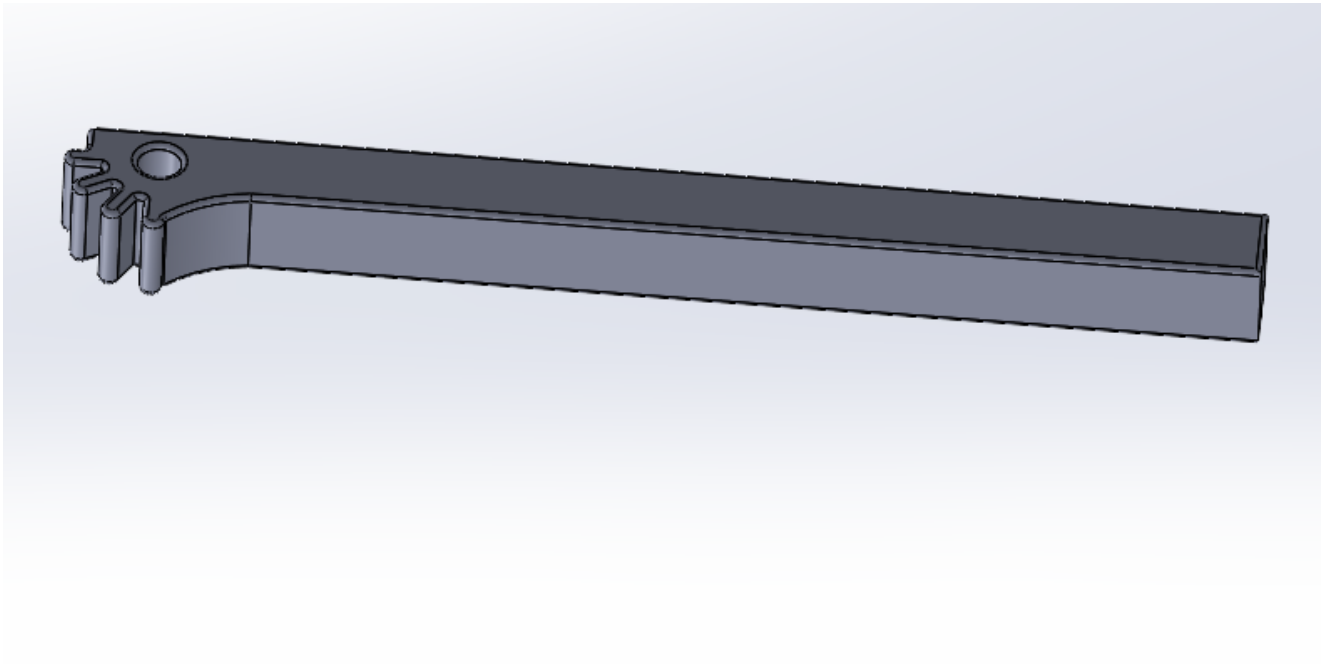
- Upload SOLIDWORKS models of the updated leg support components

Content:

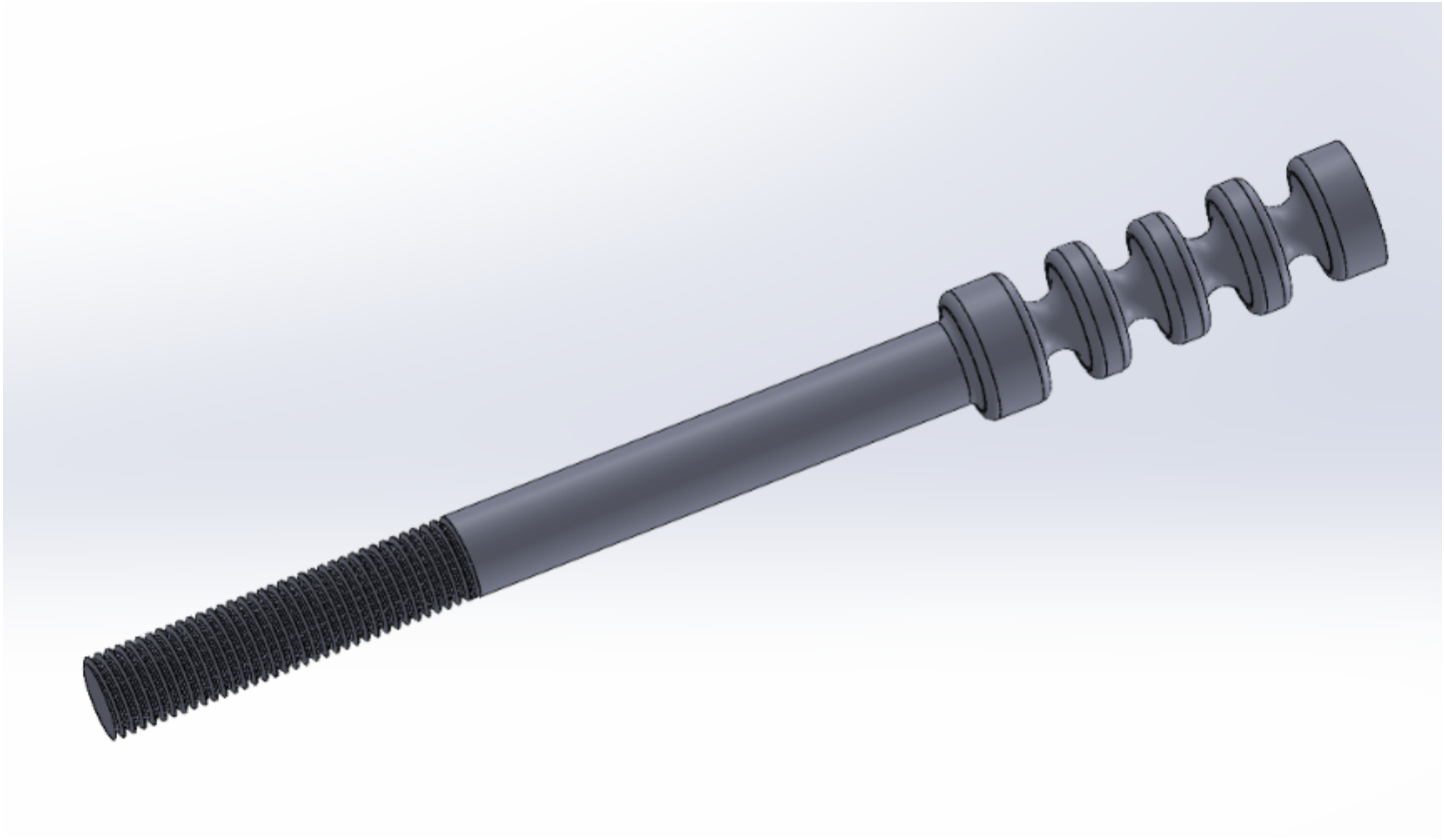
- I updated the leg restraint model to help better represent the design from a fabrication perspective. The individual plates are screwed together to form the box of the leg support and other than a few welds, the device can be taken apart for maintenance and easy access.



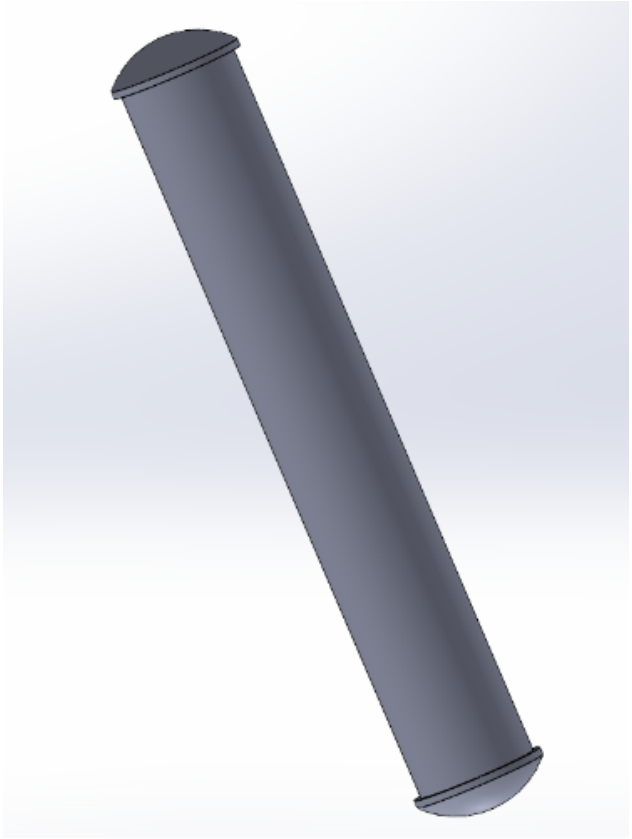
Here is a image of the completed leg support model. There are a number of components that interact with each other for the device to operate correctly. The servo motor drives the gear system, that in turn unthreads or threads the threaded bolt, and the support arms are rotated as a result. The legu support should be able to be far enough out of the way in the retracted position that the client may be able to enter and exit their wheelchair without issue.



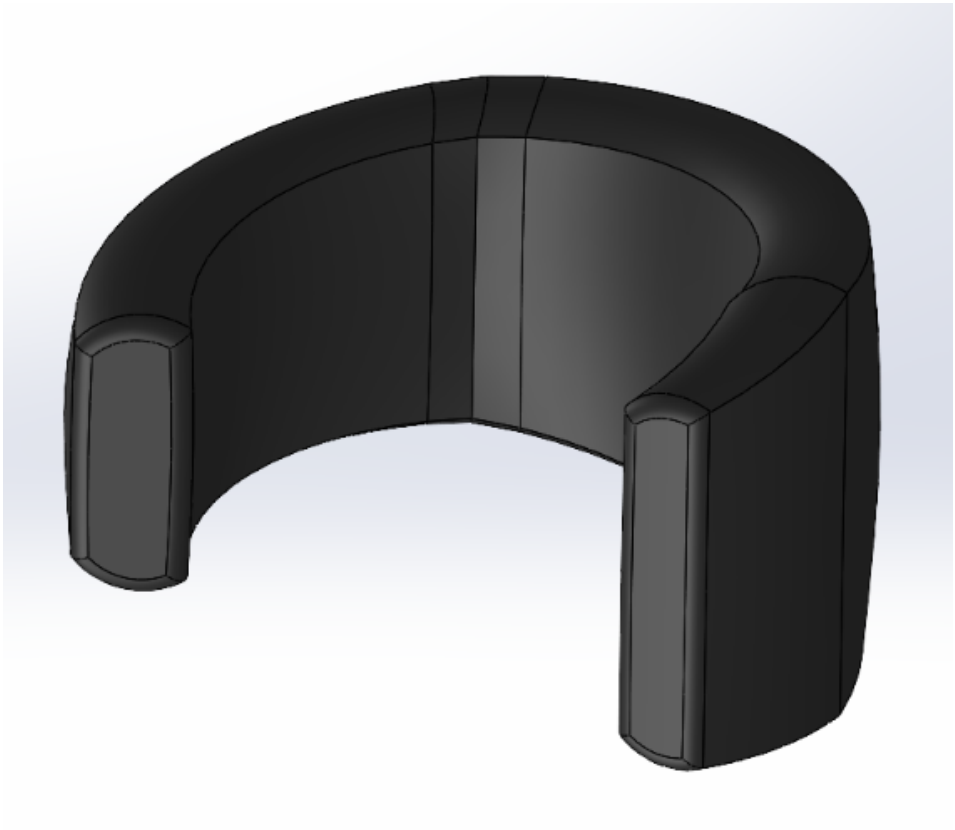
The support arm holds the leg pad itself and is rotated by the threaded bolt. It acts as the pinion in the rack and pinion system.



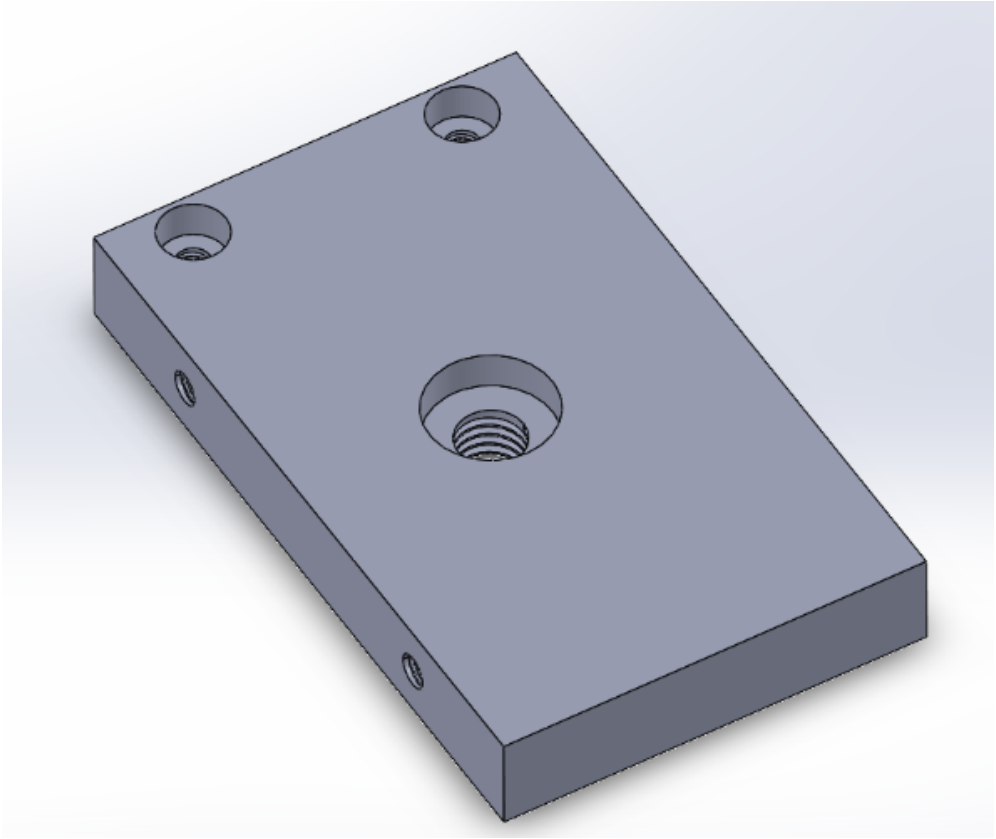
The threaded bolt is responsible for moving the support arms by threading or unthreading into the box's support. The grooves on the upper region of the threaded bolt function as the rack for the rack and pinion system.



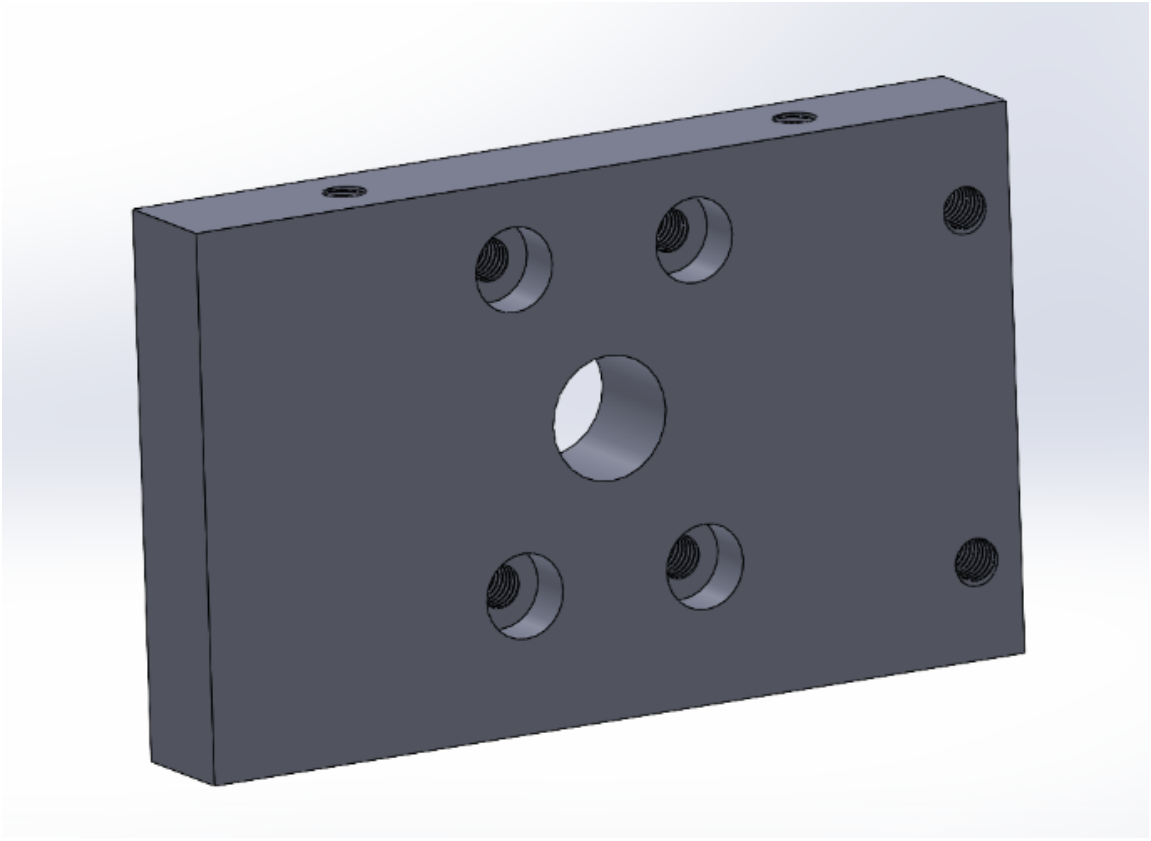
The mounting pin is used to secure the support arm to the leg support box while still allowing rotation to occur.



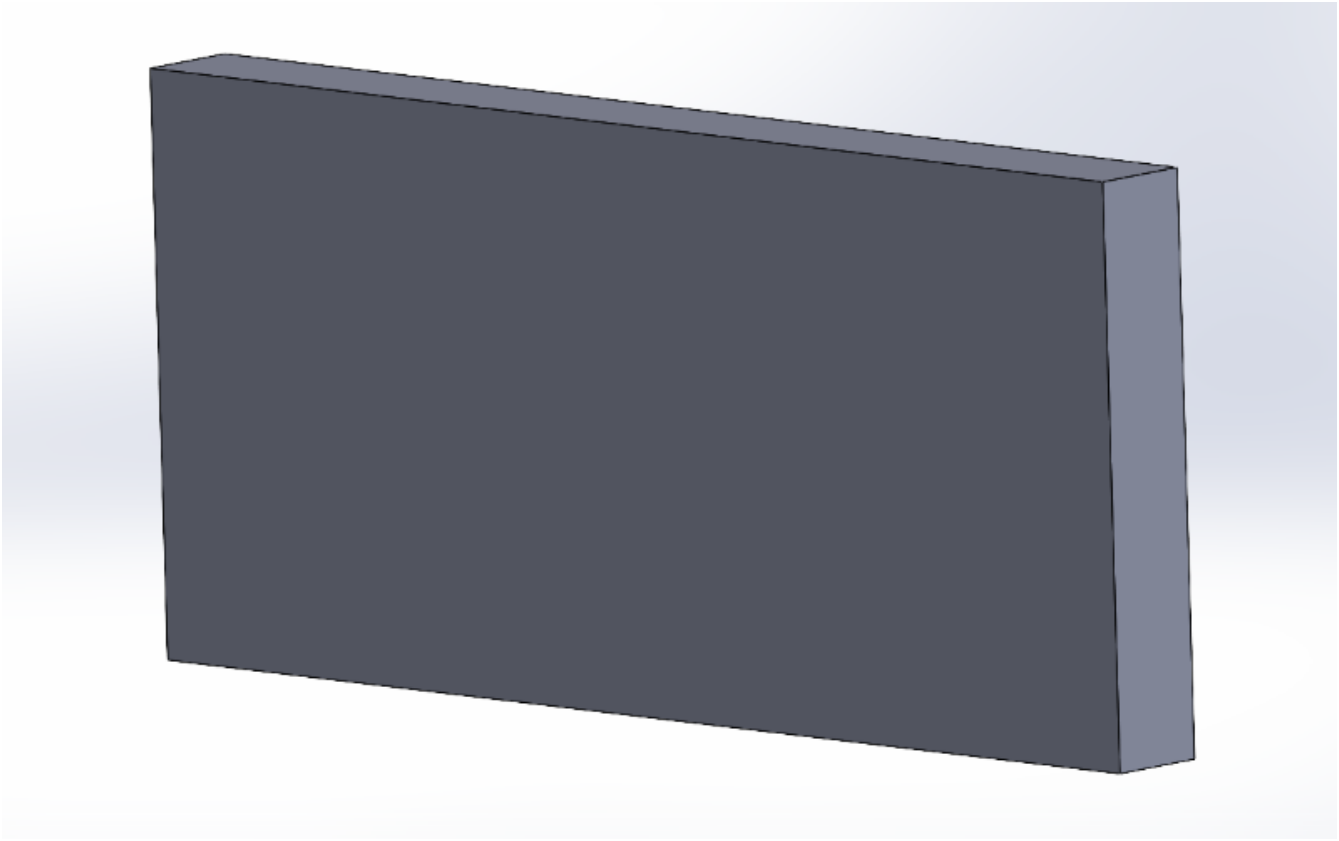
The leg pad is composed of a high density foam material that will be comfortable for the user, but still ensure they are secured during device operation.



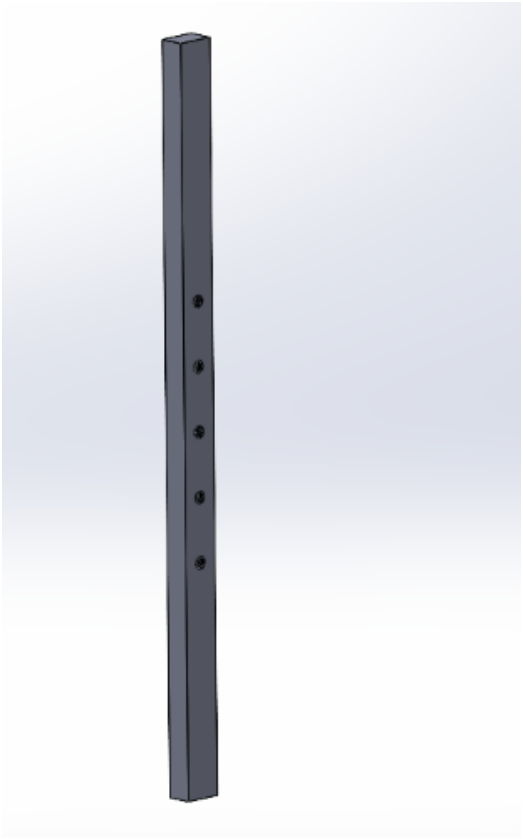
Above is the back face plate which has the large center threaded hole. The hole allows a bolt to be fed through into the back of the threaded support, where it threads in and secures the support.



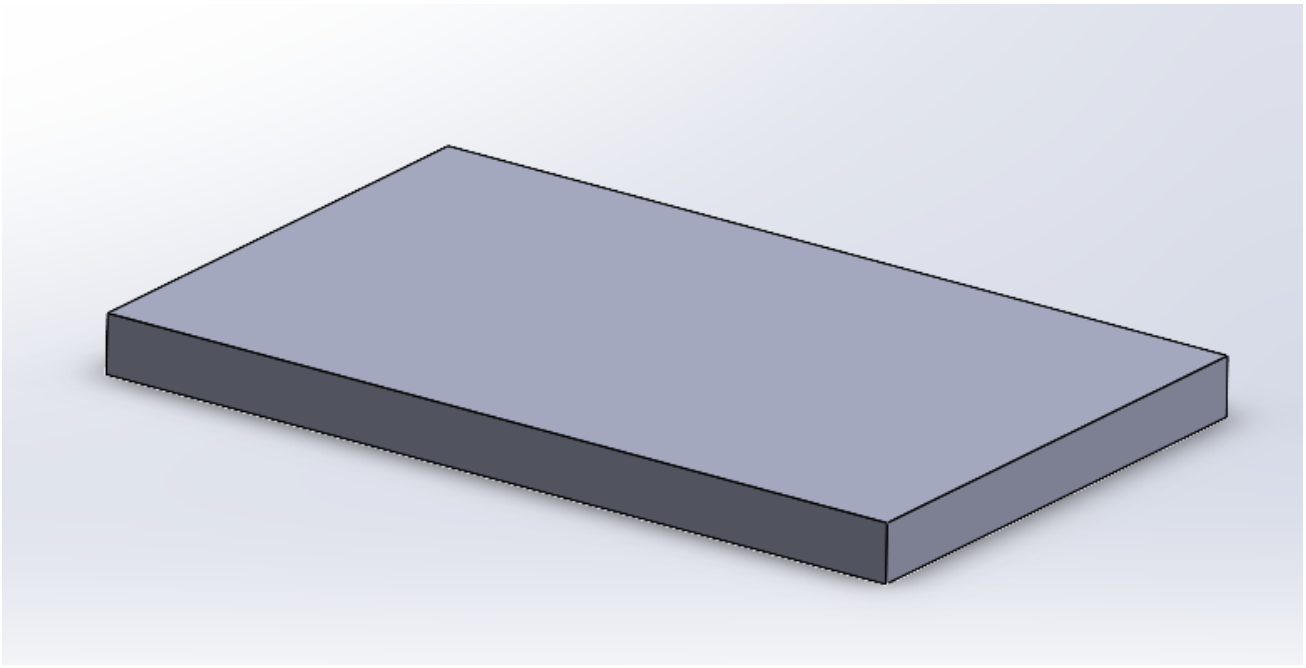
Here is the front face plate, which has a number of threaded holes incorporated into it. The four threaded holes in view that are counterbored are for the front holder plates, the components that secure the support arms to the device.



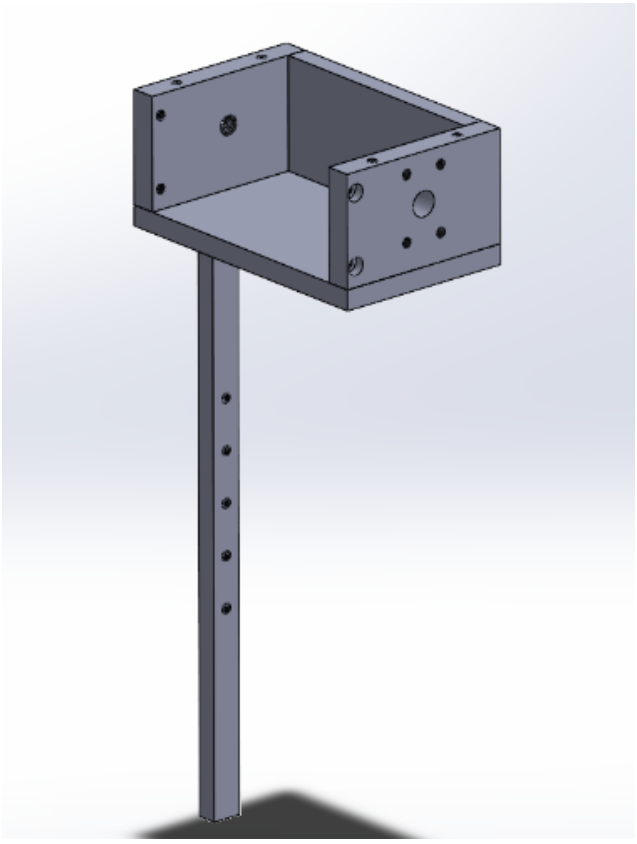
The non threaded side plate does not have any additional holes or modifications to it. It is welded in place on the bottom face plate and is welded to the front and back plate.



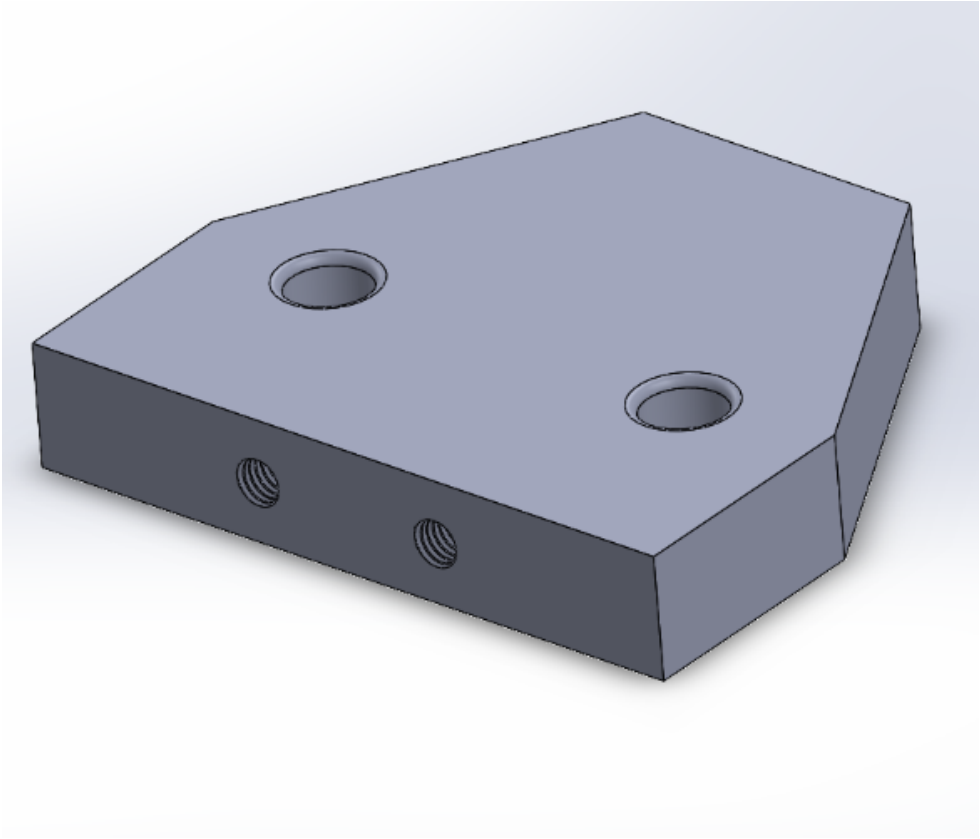
The support bar allows for the height of the leg support to be adjusted while positioned on the wheelchair, and it also allows the support to secure into the mounting place already present on the wheelchair.



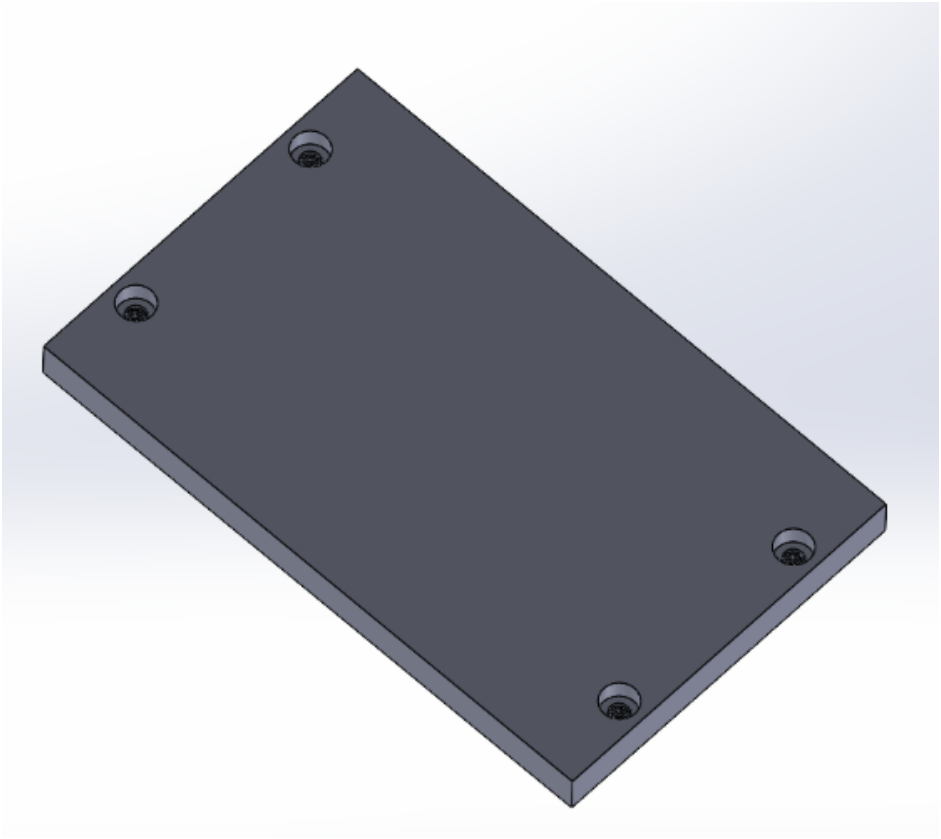
The bottom face plate is the base of the leg support box and a number of components are welded to it for ease of fabrication. The front, back, and one side plate, along with the support rod are all welded onto the base plate as seen in the solidworks model below of the welded components.



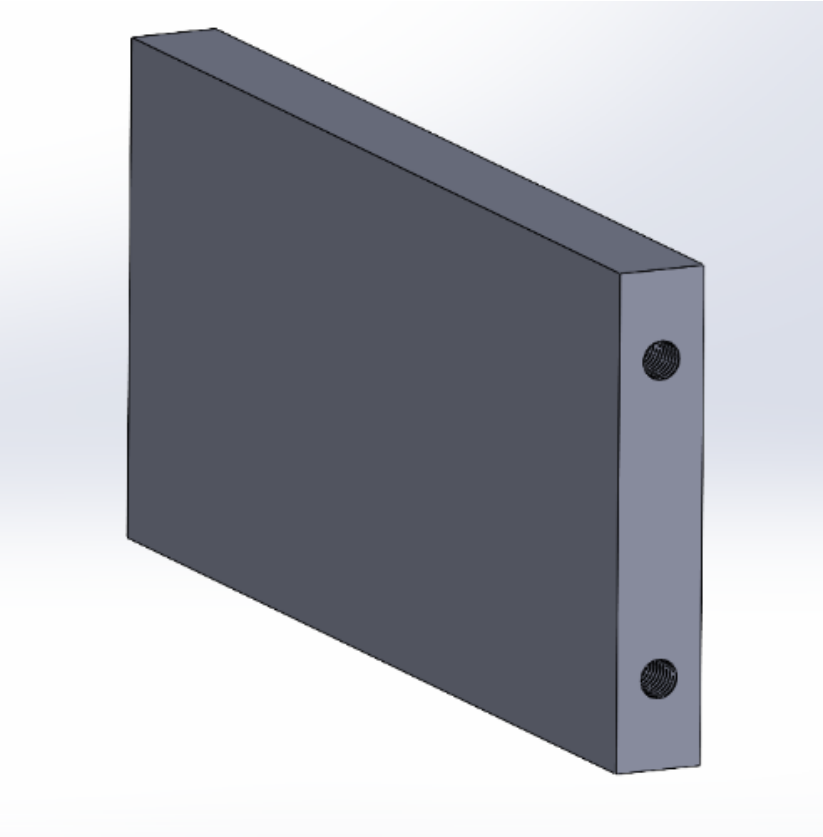
The components welded together look like this, with the top and one side remaining non-permanent attachment points. The detachability of the top and the side are helpful in alleviating the hastle of accessing the device components for maintenance.



The front holder pieces are mounted to the front of the support through the front plate. The front holder secures the support arms to the device by having nut and bolt pass through the through-hole with the support arm between the two plates.



The top plate threads into the front and back plates to secure the plate to the top of the device. The plate can be easily removed to allow for access to the components for maintenance



The side plate is threaded into the front and back plates, similar to the top plate, to allow the device to be disassembled. Having the side piece as well as the top piece removable, allow the components located inside to be easily removable and replacable if needed.

Conclusions/action items:

The leg restraint is a complex mechanism that may have a few problems associated with it. The thickness of the plates needs to be enough to allow bolts to thread in, but cannot compromise the overall structural integrity. I am not sure how to completely verify that the location of the holes are structurally feasible for their purposes. For the next semester, the team would like to re-design the front holder component to include bearings or a similar component to reduce the friction present at the pin. The largest potential problem is the high frictional force present at the pins, due to the weight of the support arms. The support arms weight generates a moment, that is opposed by the pin acting on the front holder frame, and the opposing frictional force must be overcome by the servo motor to move the bolt. The amount of torque required to turn the bolt is significantly smaller than the torque to overcome friction, so that is the team's main concern about problem areas. Another potential problem we have to test for is to ensure the pinion teeth do not shear off when a force is applied to the support pads.

12/11/2020 - Leg Restraint Fabrication Drawings

BENJAMIN LAWONN - Dec 11, 2020, 1:25 PM CST

Title: Leg Restraint Fabrication Drawings

Date: 12/11/2020

Content by: Ben Lawonn

Present: N/A

Goals:

- **Solidworks drawings of components**

Content:

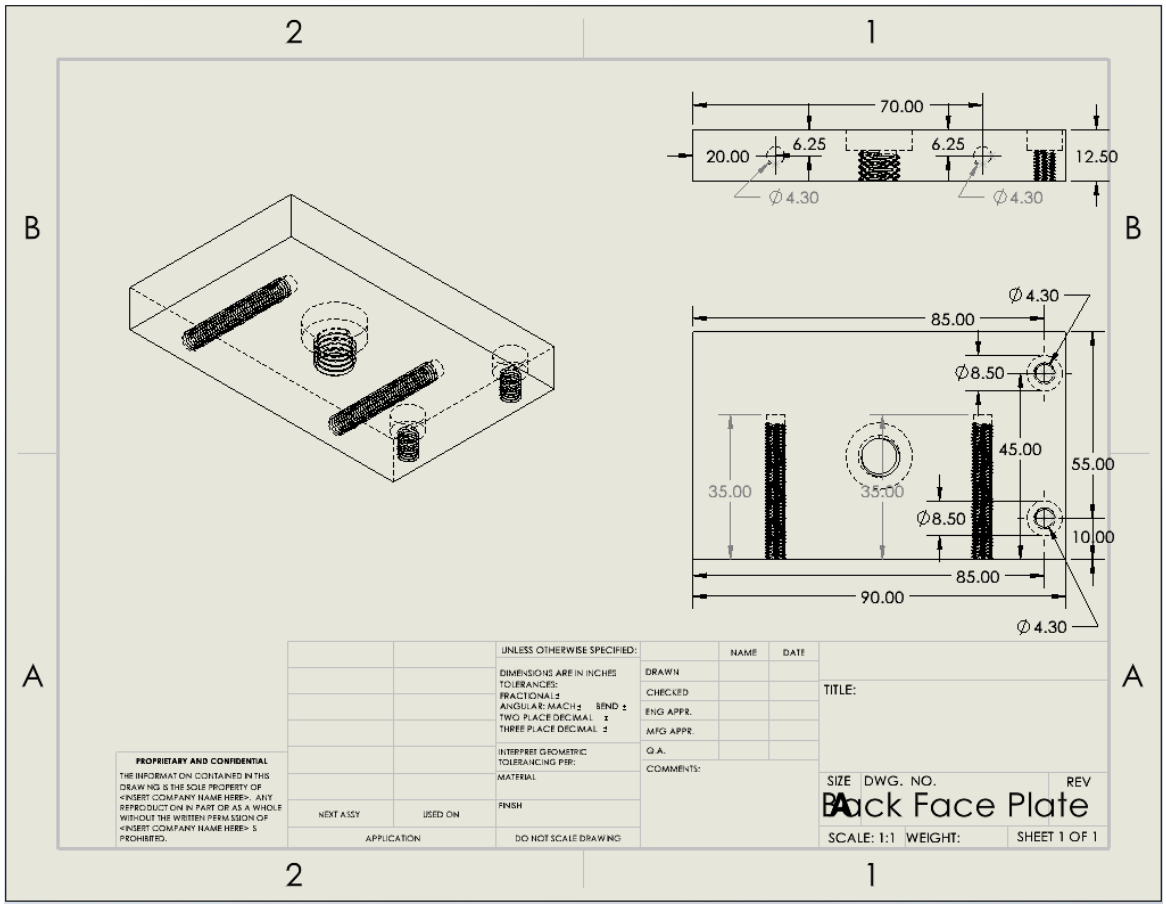
- 

Figure 1: Back face plate drawing

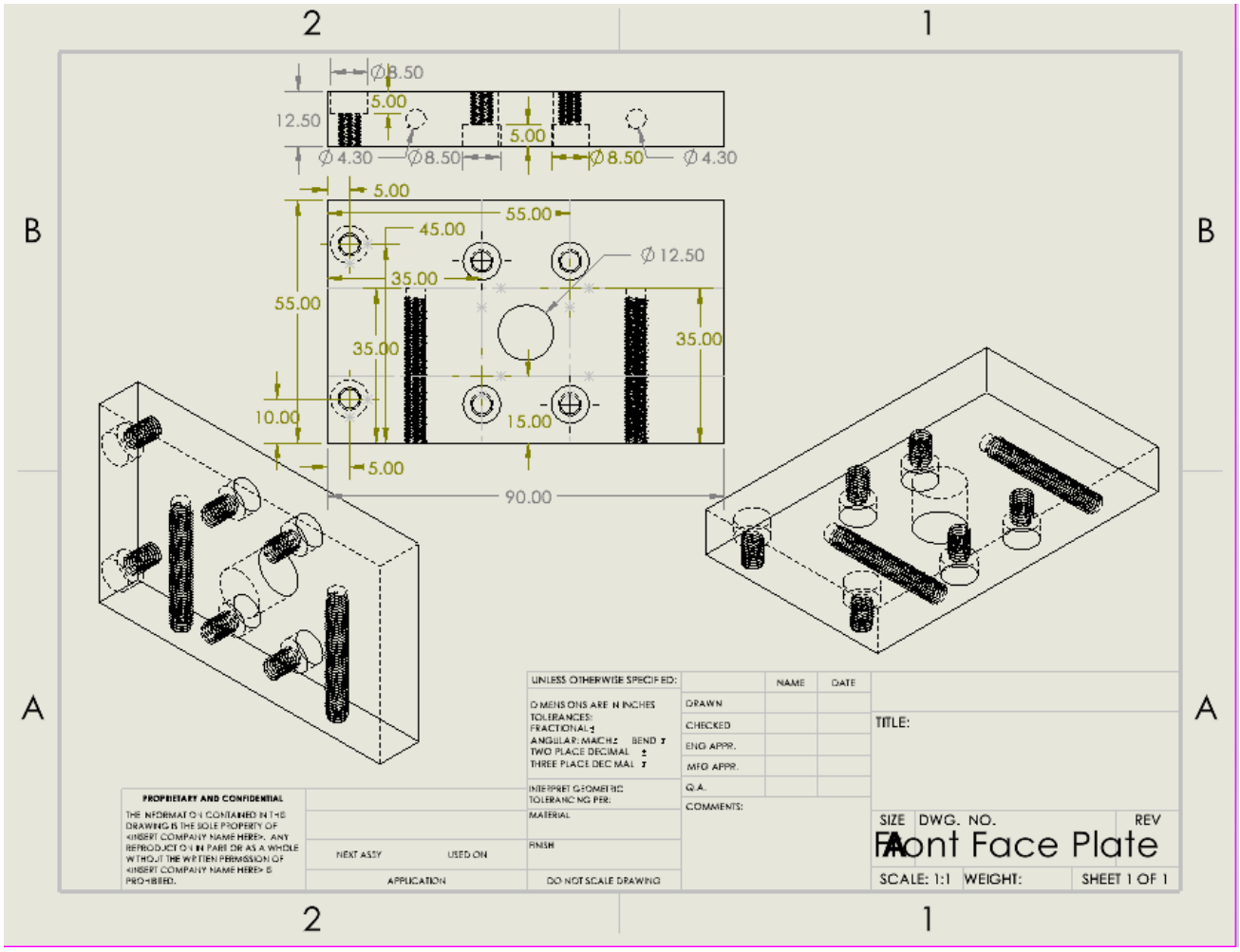


Figure 2: Front face plate drawing

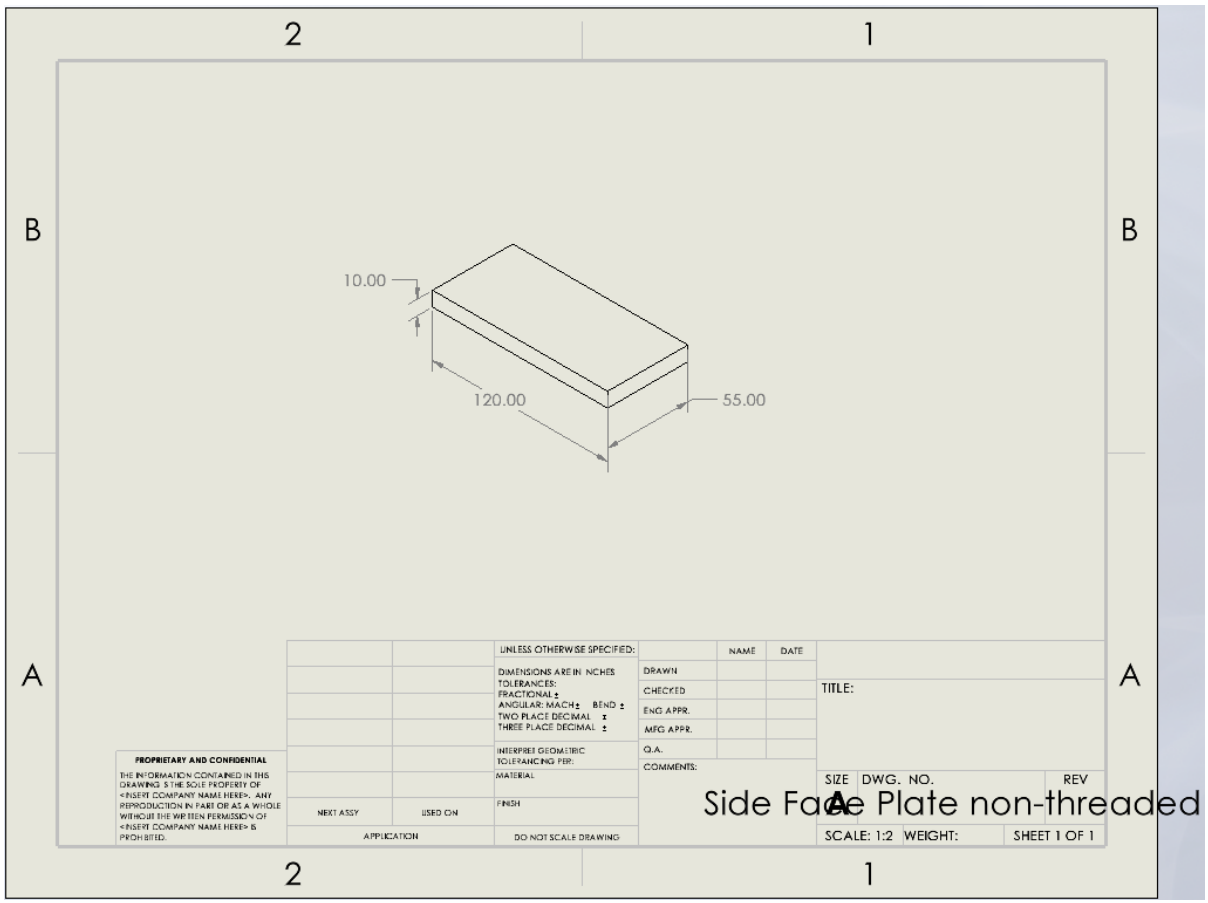


Figure 3: Non-threaded side plate drawing

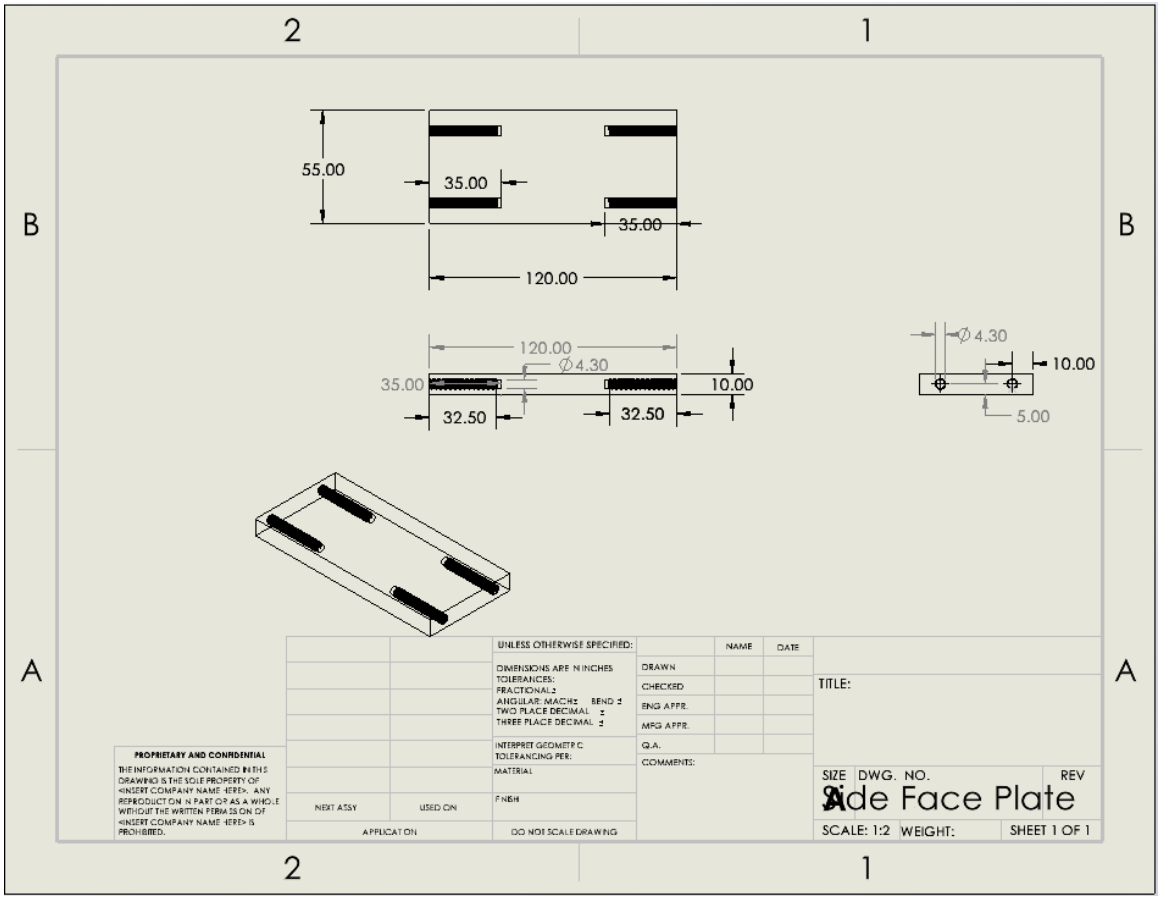


Figure 4: Threaded side plate drawing

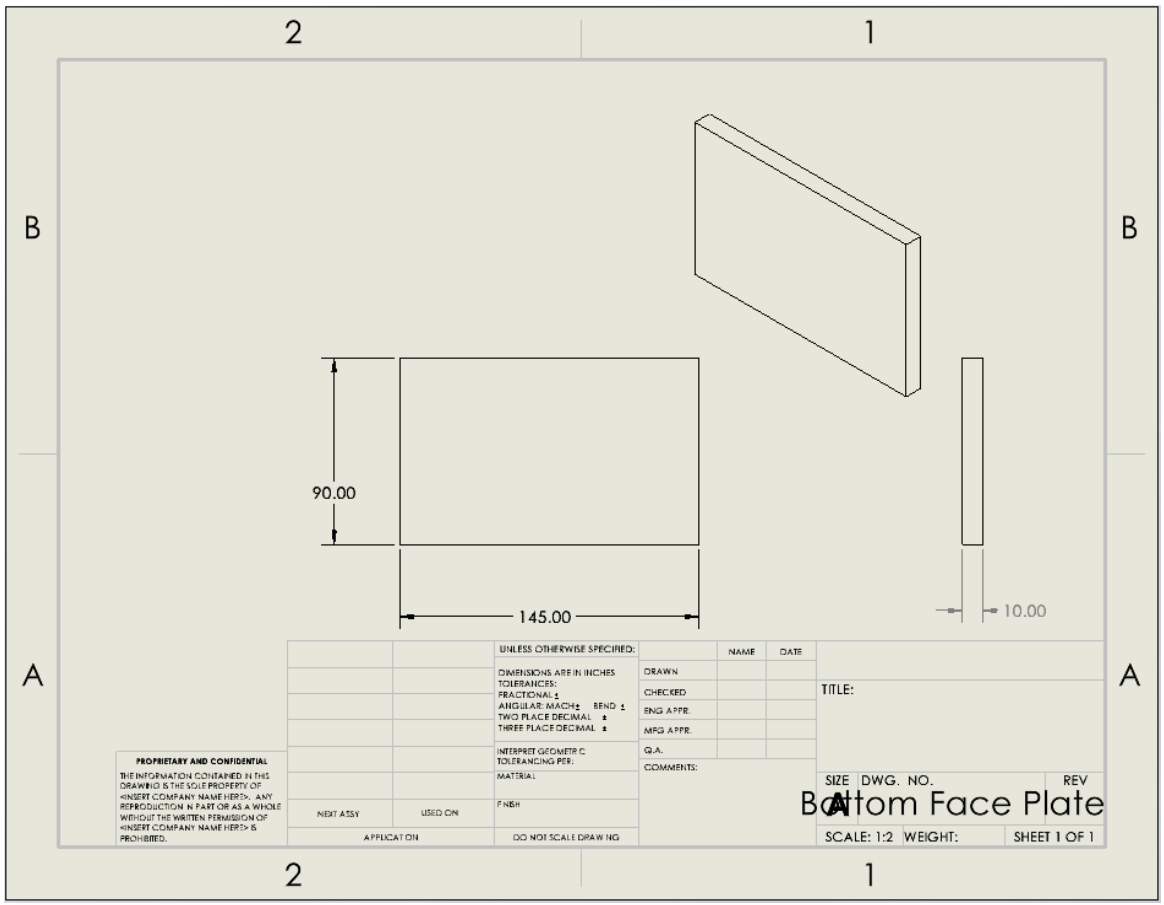


Figure 5: Bottom face plate drawing

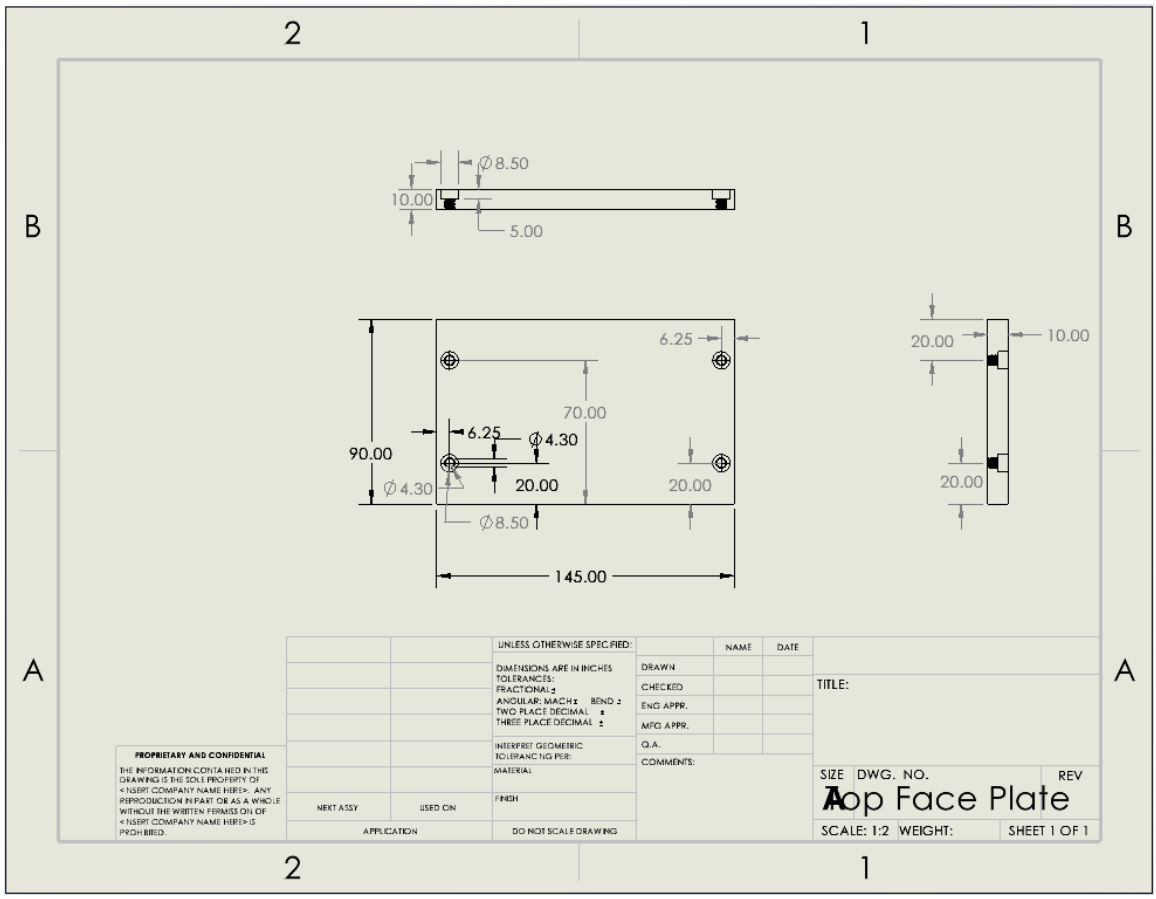


Figure 6: Top face plate drawing

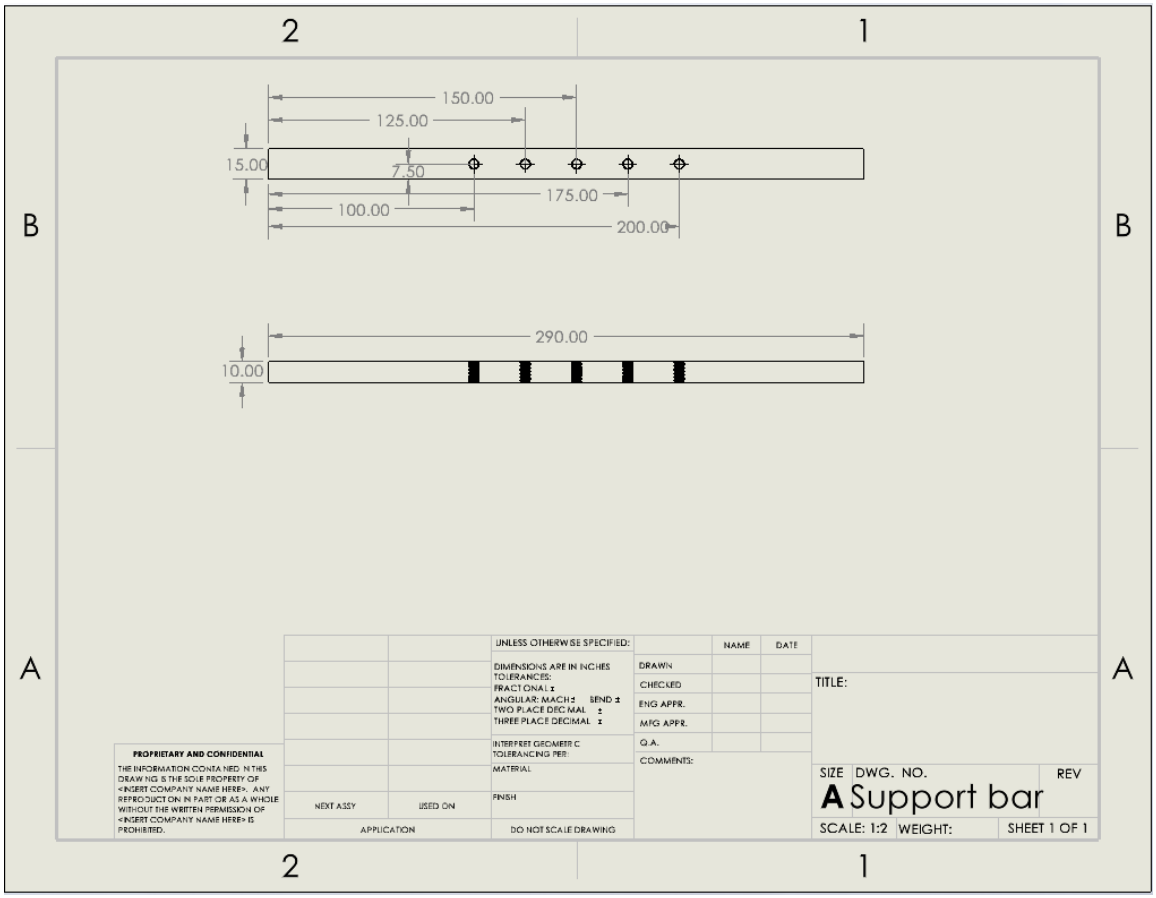


Figure 7: Support rod drawing

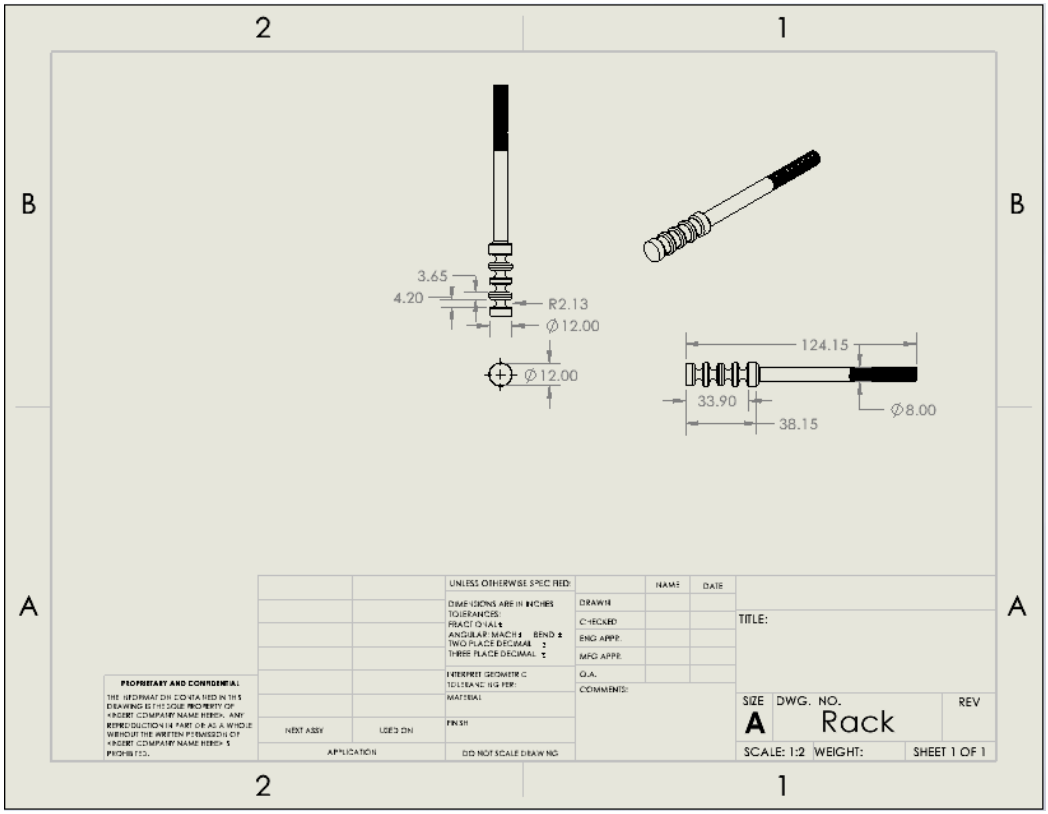


Figure 8: Threaded Bolt drawing

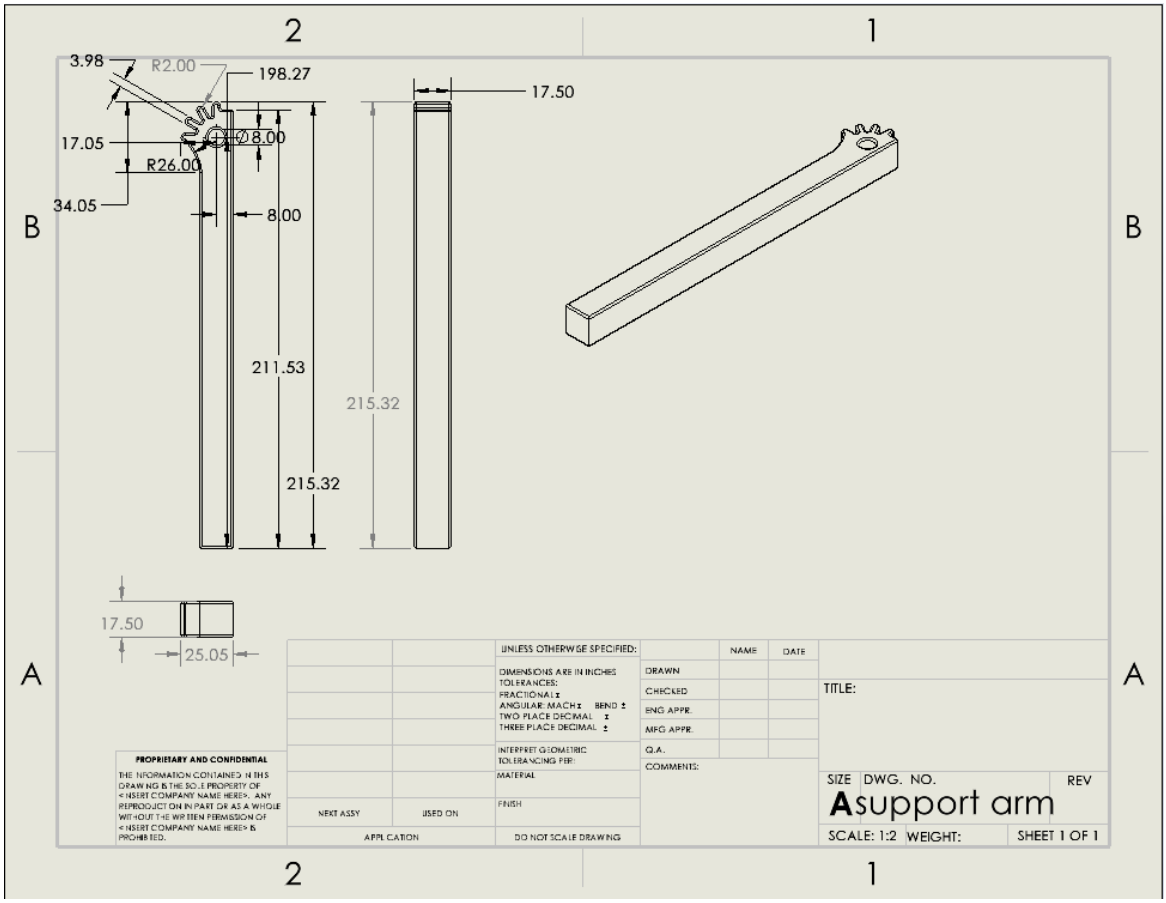


Figure 9: Support arm drawing

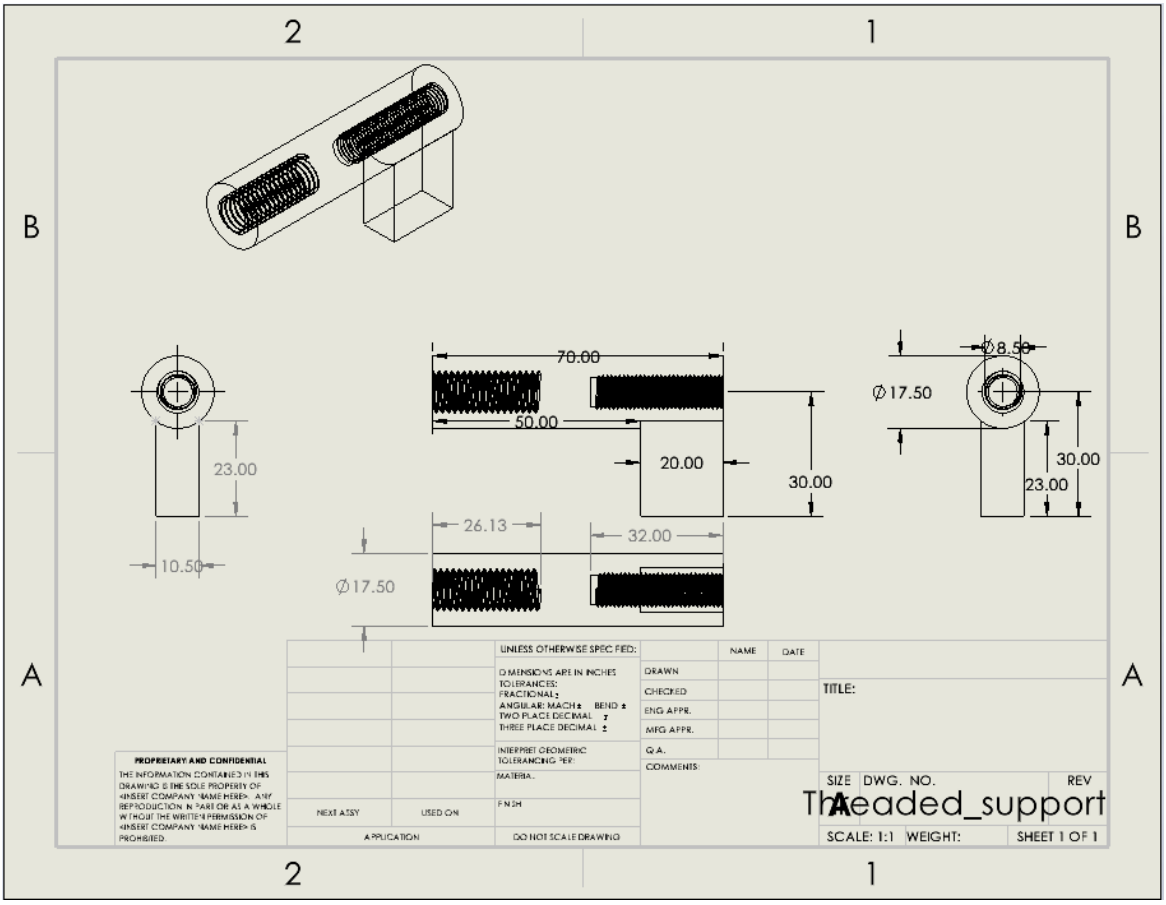


Figure 10: Threaded support drawing

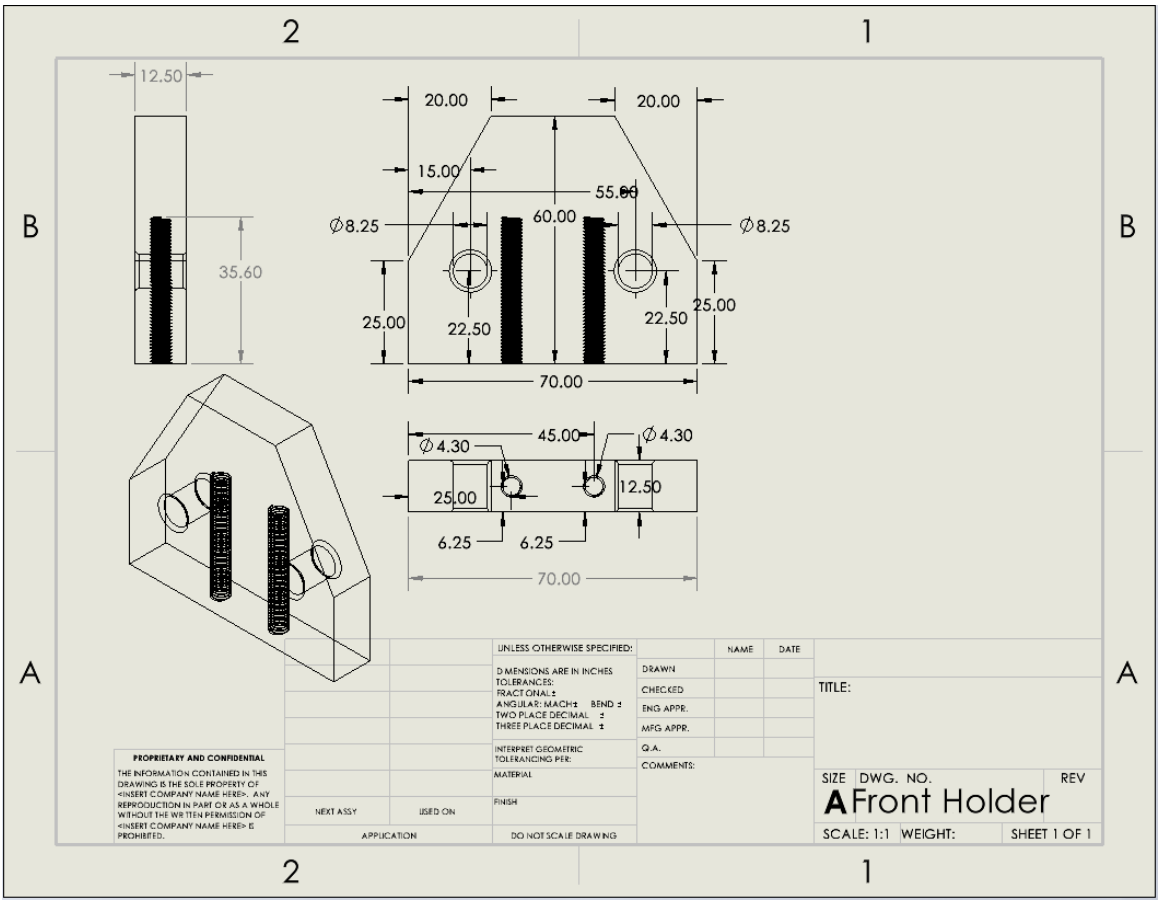


Figure 11: Front holder drawing

Conclusions/action items:

- The drawings for the leg supports will help immensly in providing supporting information for the fabrication plan. The components have many fabrication steps invovled and the dimensioned drawings do an effective job of showing all the cuts and holes that need to be made.

Green Pass

BENJAMIN LAWONN - Mar 04, 2019, 7:33 PM CST

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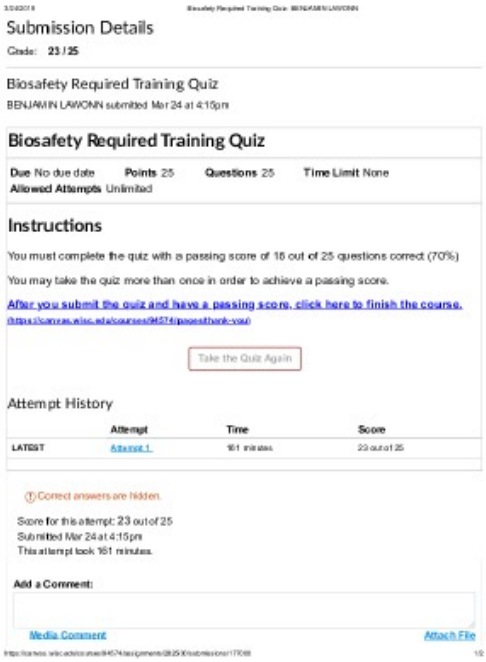
Biosafety Training

BENJAMIN LAWONN - Mar 26, 2019, 4:33 PM CDT



Submission Details

Grade: 23 / 25

Biosafety Required Training Quiz

BENJAMIN LAWONN submitted Mar 24 at 4:15pm

Biosafety Required Training Quiz

Due No due date **Points** 25 **Questions** 25 **Time Limit** None
Allowed Attempts Unlimited

Instructions

You must complete the quiz with a passing score of 18 out of 25 questions correct (70%)

You may take the quiz more than once in order to achieve a passing score.

After you submit the quiz and have a passing score, click here to finish the course.

Take the Quiz Again

Attempt History

	Attempt	Time	Score
LATEST	Attempt 1	161 minutes	23 out of 25

Correct answers are hidden.

Score for this attempt: 23 out of 25
Submitted Mar 24 at 4:15pm
This attempt took 161 minutes.

Add a Comment:

Media Comment Attach File

Biosafety_Required_Training_Quiz__BENJAMIN_LAWONN.pdf(105 KB) - download

9/28/2020 - Project Impact

BENJAMIN LAWONN - Sep 28,

Title: Project impact

Date: 9/28/2020

Content by: Ben Lawonn

Present: N/A

Goals:

- Learn more about the overall impact of the project
- View the project from a broader perspective and from different lenses

Content:

- Our client suffers from Spinal Muscular Atrophy (SMA) which is a neuromuscular disease that causes muscle atrophy and weakness. SMA can manifest in one of four types, with Type 1 most severe, causing death in most infants and toddlers. Those who have either Type 2, 3, or 4 are able to survive past infancy, but will experience debilitating muscle atrophy that may them being unable to walk and perform other necessary activities without assistance throughout their life. There are approximately 10,000 - 25,000 children and adults in the United Stat that are affected by SMA, with around one in 6,000 to one in 10,000 children being born with one of the types of SMA [1].
- There is an immense amount of people across the United States and the world that need to utilize a wheelchair on a daily basis, with approximately 75 million wheelchair users worldwid million wheelchair users in the United States [2] [3]. Similar to our client, many wheelchair users could benefit from a device that would allow them to move themselves in previously una positions to aid in blood flow, digestion, physical health, and mental health. Helping provide the opportunity to move in positions such as prone or vertical, positions that many non-disab take for granted, could help immensly in improving the lives of those affected by diseases that require them to utilize a wheelchair. Our client stated that they have been unable to lay pr decades, and the development of a device that would allow the user to move in positions they are incapable of currently, and in an independent manner would help improve their menta physical health. The main goal of our device is to help remove obstructions from our clients lives and allow them to live more of the life they would like to. Our device could benefit peopl by a variety of diseases who require wheelchairs, this includes those affected by SMA, Osteoarthritis, Spina Bifida, Spinal Cord Injuries, and many others. By allowing the user to adjust of their body they are able to alleviate pressure to their spinal cord due to prolonged sitting, they can improve their digestions by providing light movement to the GI tract, and they could

Conclusions/action items:

References:

[1] SMA Foundation. [Online]. Available: https://smafoundation.org/about-sma/#:~:text=SMA has generally been believed,are born with the disease. [Accessed: 28-Sep-2020].

[2] “Disabled People in the World in 2019: facts and figures,” Inclusive City Maker, 24-Oct-2019. [Online]. Available: https://www.inclusivecitymaker.com/disabled-people-in-the-world-in-2019-fa [Accessed: 28-Sep-2020].

[3] https://www.physio-pedia.com/Wheelchair_Users#:~:text=In%20the%20United%20States%20of,new%20wheelchair%20users%20every%20year.&text=However%2C%20they%20all%20need%20an%20appropr

BENJAMIN LAWONN - Oct 05, 2020, 1:20 AM CDT

Content Continued:

- By allowing the user to adjust the position of their body they are able to alleviate pressure to their spinal cord due to prolonged sitting, they can improve their digestions by providing light movement to the GI tract, and they can improve their overall quality of life.*
- While the scope of our project has adjusted to providing a usable restraint for our client to utilize their standing wheelchair, as stated by them, the device would still be greatly beneficial. A number of wheelchair users are unable to place their restraints themselves and require assistance to secure themself into their standing wheelchair, but our automated device could provide a simple and accessible method to use their standing wheelchair more independently.

Conclusions/action items:

- As we continue to interact with our client more, our team continues to realize how challenging many tasks are that we completely take for granted. As our team members interacted with our client they gained a much deeper understanding of many of the challenges they face with everyday tasks. The team learned much more about their dexterity limitations, and how challenging many movements are, such as reaching their legs or raising their arms above their lap. Our team is hopeful that we can develop a cost-effective and efficient solution to our client's design problem so the resulting device may be utilized to benefit many others experiencing challenges with using their standing wheelchair independently. Being able to provide a safe and effective method for users to restraint themself in their standing wheelchair could help make one facet of their life easier and enable them to be more autonomous.

References:

[3]“Wheelchair Users,” Physiopedia. [Online]. Available: https://www.physio-pedia.com/Wheelchair_Users#:~:text=In the United States of,new wheelchair users every year.&text=However, they all need an appropriate wheelchair. [Accessed: 05-Oct-2020].

2020.09.15 - Inversion Tables

JENNA WARDEN - Sep 23, 2020, 2:30 PM CDT

Title: Inversion Tables

Date: 2020.09.15

Content by: Jenna Warden

Present: N/A

Goals: Discover the benefits of using an inversion table, current products on the market.

Content:

Benefits [1]

- respiratory system, circulatory, digestive, immune systems
- relieves back pain - reducing the effect of gravity on the spine
- maintain posture - sitting at a desk, in a chair with poor posture
- relaxes muscles - using gravity to release pressure on the lower back
- lymph system - "lymph system only flows one direction, waste may begin to collect and build up over time" so inverting the body can help to release the waste that is backed up and allow your body to rid of it in a natural way
- blood circulation - gravity pulls blood to your upper extremities more than when not inverted
- brain function - helps circulation in brain creating a larger flow of oxygen and nutrition - "brain operates 14% more accurately when you're inverted" [2]
- insomnia, depression, reduced stress are also factors that could be improved by inversion [2]

Types of inversion [1]

- gravity boots - boots hook into bar that is secured in doorway - not feasible
- inversion table - standing with flat surface at your back and leaning backwards to invert yourself
    - most feasible - **what would need to be adjusted to make this work for our client?**
- yoga sling - use ariel yoga materials to put yourself in new positions - not feasible

Precautions to inversion [1]

- don't use if you have high blood pressure, heart disease, other circulatory conditions, pregnant, or overweight
- contact doctor

Best Products

- Teeter EP-960 [2]
    - acupuncture nodes on the table
    - lifting arms returns you to starting position
        - this would be really important if client is not able to pull their body weight back up
    - marked at 20, 40, and 60 degrees of inversion

Figure 1: Teeter EP-960 inversion table [2]

How long to invert [2]

- beginners - use a few times a day @ short time periods of inversion
    - increase time as you get comfortable
    - start with small inversion angles up until 60 degrees - study shows you don't need more than this
    - invert twice a day for best results

What to do while inverted [start standing]

- deep breathing
- neck stretching
- crunches
- inverted squats
- twist (using handlebars)

How can we accommodate this for our client?

- youtube video of T-12 para using an inversion table - https://www.youtube.com/watch?v=pOHBAOUPgQI
    - attaches strap to head side of the board so that it cannot go to the upright position and always stays near horizontal
- how would we be able to ensure client could return to upright position if they are unable to pull themselves up
    - would this safety factor be too in depth and too risky for our team to implement?
    - could the ceiling lift be incorporated with this?
        - attached at the chest instead of waist? - used to pull client up which would allow the inversion table to return to normal positon

References

[1] Providence. 2018. *Change Your POV: Can Hanging Upside Down Improve Your Health?*. [online] Available at: <https://blog.providence.org/archive/change-your-pov-can-hanging-upside-down-improve-your-health> [Accessed 23 September 2020].

[2] Fiorenzi, R., 2020. *Best Inversion Tables For Back Pain*. [online] Start Standing. Available at: <https://www.startstanding.org/sitting-back-pain/best-inversion-tables-for-back-pain/#> [Accessed 23 September 2020].

Conclusions/action items:

Inversion tables are thought to be good for circulation along with many other aspects of health, many of which would be beneficial to our client. Inversion is something that our client wants to be able to do and inversion tables can be a great resource for our final design, however, there are many safety and usability factors that will come into play. The team would need to ensure that the client can return to the beginning position and the client would need to easily get in and out of our device.

2020.09.22 - Vibration Therapy

Title: Vibration Therapy

Date: 2020.09.22 (edited 2020.10.07)

Content by: Jenna Warden

Goals: Discover the benefits to vibration therapy as well as what devices exist on the market

Content:

What is Vibration Therapy? [1]

- invented in 1867 by Russian physician Gustav Zander
    - originally used weights and pulleys
- Dr. John Harvey Kellogg used vibration therapy in 1895
    - claimed to help circulation and constipation
- NASA uses vibration therapy to prevent bone loss in astronauts

Types of vibration therapy [1]

- localized
    - small vibration device will be placed on specific muscles of the body
    - vibrations cause muscles to contract and relax
    - can help produce more osteoblasts
    - can be vertical vibrations, up and down, front and back, as well as sideways
        - up and down are thought to be the most useful for rapid muscle contraction
- whole body
    - sit stand or lay on vibration place

Benefits [1][2]

- increase bone density
- increase muscle mass
- improve circulation
- reduce joint pain
- reduce back pain
- alleviate stress
- boost metabolism

Risks [1]

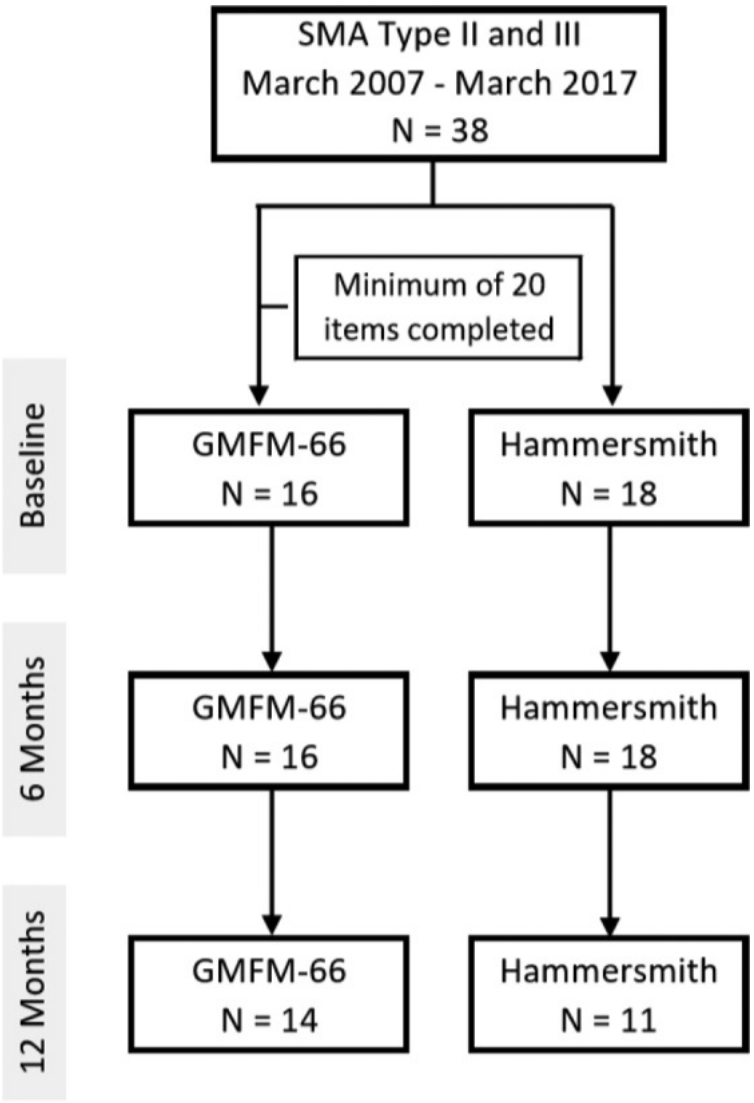
- consult doctor if using blood thinners, have advanced diabetes, heart disease or are pregnant

Wheelchair-based exercises [3]

- putting feet on vibration plate while sitting in chair
    - increases circulation to lower extremities
    - by rubbing ankles can help move lymph fluid in the ankles and reduce swelling
- leaning forward with elbows on knees
    - helps reduce back shoulder and neck pain
    - increases circulation in upper body.

Relation to SMA [4]

- study done on children with SMA types II and III using at home vibration therapy
- took 12 months
- assessments at months 0,6, and 12
- mobility was assessed using the Gross Motor Function Measure 66 and Hammersmith Functional Mobility Scale
- were able to determine if there was a significant difference in mobility but long-term benefits require longer testing and more investigation
- participants were children with an average age of 4.64 years, 44.7% were male, 73.7% were type II, 21% were type III and 5.3% were type IIIa
- 38 children in total



- above shows the flowchart sample selection and criteria that they were tested on
- results determined that the training program showed significant improvement in mobility
    - this could be very useful for our client if made to be autonomous

References

[1] Fanous, S., 2016. *What Is Vibration Therapy?*. [online] Healthline. Available at: <https://www.healthline.com/health/vibration-therapy%23procedure&sa=D&ust=1602089533802000&usg=AFQjCNHXEY6eiAgKoXw9C65a52C 2020].

[2] Laskowski M.D., E., 2020. *Is Whole-Body Vibration An Effective Workout?*. [online] Mayo Clinic. Available at: <https://www.mayoclinic.org/healthy-lifestyle/fitness/expert-answers/whole-body-vibration/faq-20057958#:~:text=Advocates%20say%20that%20as%20little,decrease%20the%20stress%20hormone%20cortisol> [Accessed 22 September 2020].

[3] GForce Vibration. 2020. *Wheelchair-Based Exercises For Whole Body Vibration Machines*. [online] Available at: <https://gforcevibration.com/blogs/wbv-exercises/wheelchair-exercise#:~:text=Even%20customers%20who%20are%20in%20wheelchairs%20can%20benefit%20from%20Whole%20Body%20Vibration!&text=Circulation%20to%20Lower%20Extremities%20%E2%80%93%20While,togeth [Accessed 22 September 2020].

[4] Stark, C., Duran, I., Cirak, S., Hamacher, S., Hoyer-Kuhn, H., Semler, O. and Schoenau, E., 2018. *Vibration-Assisted Home Training Program For Children With Spinal Muscular Atrophy*. [online] National Center for Biotechnol <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6024344/> [Accessed 22 September 2020].

Conclusions/action items:

Vibration therapy can be extremely useful for all people. It can help blood circulation and reduce pain along with many other positive benefits. Specifically for SMA, if the team is able to incorpo device that can be used autonomously, there is potential that the vibration therapy could improve mobility. Although the study only did research on children, it is still possible that it would work, Vibration therapy could be an easy implementation into our final device and could provide many benefits for the client.

2020.09.25 - Boa System

JENNA WARDEN - Dec 11, 2020, 11:07 AM CST

Title: Boa System

Date: 2020.09.25

Content by: Jenna Warden

Goals: To understand and incorporate the boa system into a functional design

Content:

- Exists on snowboard boots
    - along with many other sports-related footwear
    - also included on medical braces for the back, hip, wrist, and leg
- The system has three components
    - wire, wire guides, and cap
    - wire runs through wire guides within cap
    - as you twist the cap, the wire wraps inside the cap making the wire tighter
    - to lock in place, push down on cap
    - to release, pull up on cap
        - will the client be able to do this given limited dexterity?
- Has multiple classes - depending on what device it is being used on
    - H-series
        - known for high power and capacity
            - this series is built for thicker and stiffer applications that would normally be difficult to close
    - M-series
        - known for durability and power
            - mainly used for workwear and outdoor activities
            - can withstand hard weather conditions
- Could be used in chest and leg
    - issue would be getting the system to be easily accessible by client
    - can put mount and cap wherever and loop the wire to it
- Could use existing medical devices for the chest restraint
    - attach to the chair somehow
    - would need one side to be open
        - latch with a u-hook?
- cost: one set (two systems) is 10$

Conclusions/action items:

The Boa system is an easy to use device that will secure the restraints to clients preferred tightness. The Boa system is a cheap option and would be easy to incorporate into a functioning design. It may be difficult for the client to operate as the system is kind of small (about the size of a half-dollar - according to my snowboard boots). I think this system is one that should be looked into more and incorporated into a potential device. It is cost-effective and small/ lightweight.

References:

Boafit.com. [Online]. Available: https://www.boafit.com/sites/default/files/2019-03/M4_CS3_Tongue_1000346_web.pdf. [Accessed: 25-Sept-2020].

2020.09.27 - Boa system design sketch

JENNA WARDEN - Oct 07, 2020, 3:08 PM CDT

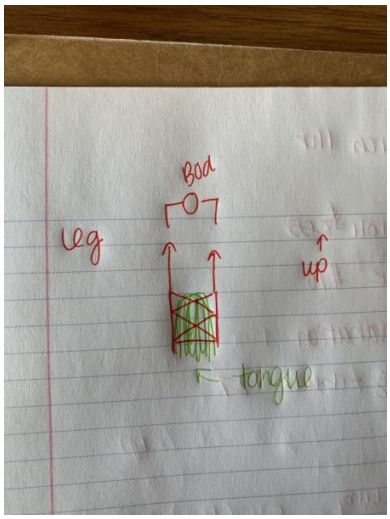
Title: Boa system design sketch

Date: 2020.09.28

Content by: Jenna Warden

Goals: Sketch design idea for how to implement boa system to the leg restraint

Content:



the boa system would lace up the shin

the green "tongue" would be used from a medical boot so there is padding built into it

Conclusions/action items:

This basic sketch is one design idea of how to implement the boa system into the leg restraint. This would be an attachment to the wheelchair. This would require the client to slide their legs into the leg region of the boot (loosened) when entering the standing wheelchair. This could potentially be an issue for the client as mobility in the legs may not allow for insertion. This design idea is very basic and can easily be changed to better suit the client.

2020.10.06 - Roller Coaster Chest Restraint Design Addition

JENNA WARDEN - Dec 11, 2020, 11:54 AM CST

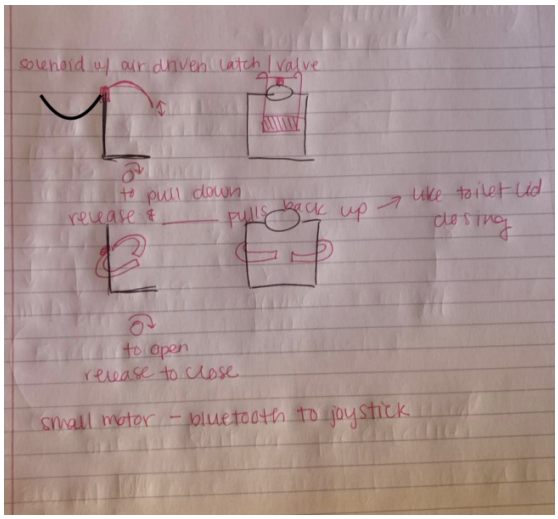
Title: Roller Coaster Chest Restraint Design Addition - using Boa System

Date: 2020.10.06

Content by: Jenna Warden

Goals: Edit the roller coster chest restraint design using the Boa System

Content:



- using the boa system to engage the roller coaster chest harness
- also sketched a chest harness that came in from the sides - sort of like a hug
- twisting the boa system would engage the harness and pull it down (or in)
    - would this be strong enough
    - how would it all connect
    - what would prevent the harness from releasing
- would need to contact boa or determine how much tensile force the system could handle
    - I think the boa system alone would be too weak to ensure the safety of the client
        - could still look into it

Conclusions/action items:

The boa system could be incorporated into the roller coaster design by using the boa to activate the harness. There would need to be more research done on the boa system and how much force it can handle before going any further with this design.

2020.10.06 - Wine Bottle Opener (Leg Restraint Design)

JENNA WARDEN - Dec 11, 2020, 12:49 PM CST

Title: Wine Bottle Opener (Leg Restraint Design)

Date: 2020.10.06

Content by: Jenna Warden

Goals: Use the mechanisms of a wine bottle opener to engage the leg restraints

Content:

- reversing the mechanism of the wine bottle opener will then engage the the leg restraint
- the wings of the opener will be the leg restraints
- use some sort of motor to pull or push the top of the wine bottle opener
    - when this moves, the leg restraints will open
- the core of the "opener" will be in between the users legs
- the restraints will be straight out from the wheelchair when in the relaxed position
    - use a motor to activate them?
    - the restraints will fan outward about 90 degrees to be in front of users legs
- how will this stay in place?

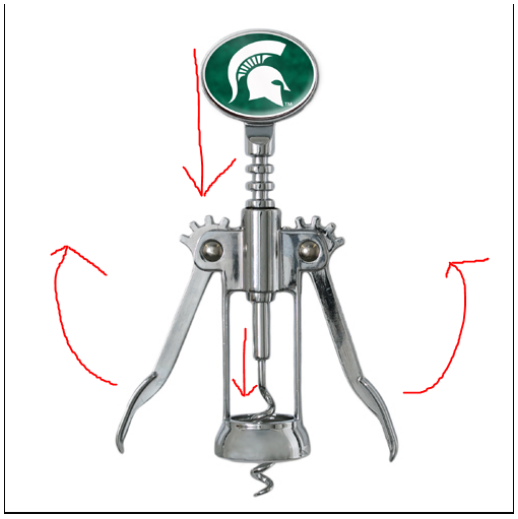


Figure above shows subsequent movements of a wine bottle opener

Conclusions/action items:

Using the mechanical ideas and mechanisms of the wine bottle opener could be useful when thinking of how to implement the leg restraint. We could make use of motors to spin the cork screw portion and then engage the wings which will be the leg restraints.

Current Training Documentation

JENNA WARDEN - Sep 04, 2020, 2:15 PM CDT

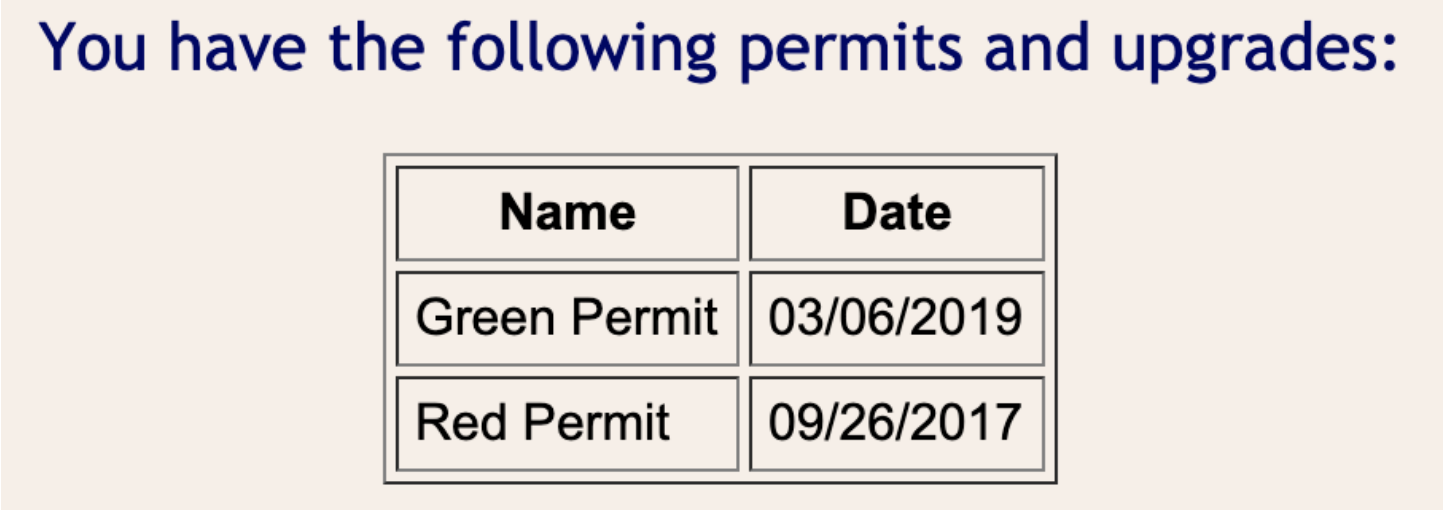
Title: Current Training Documentation

Date: 2020.09.04

Content by: Jenna Warden

Goals: To display proof of training documentation

Content:



Conclusions/action items: The above photo shows proof of training in the TEAM LAB that will allow me to use machinery that may be necessary for prototyping.

2019.4.30 Biosafety Training

JENNA WARDEN - Sep 04, 2020, 2:16 PM CDT

Title: Biosafety Training

Date: 2020.09.04

Content by: Jenna Warden

Goals: To pass the biosafety training exam in order to work in the lab.

Content:

See PDF attached

Conclusions/action items:

Understanding the safety precautions and procedures in the ECB lab will allow me to work with my team in the lab as well as it will teach me how to properly use lab items and practice good technique.

JENNA WARDEN - Apr 30, 2019, 11:51 AM CDT

Biosafety_Required_Training_Quiz__Biosafety_Required_Training.htm(290.6 KB) - download

Testing Protocol Writing - Code

JENNA WARDEN - Dec 11, 2020, 1:32 PM CST

Title: Testing Protocol Writing - Code

Date: Completed 2020.12.11

Content by: Jenna Warden

Goals: Creating a testing protocol to test the functionality,

Content:

This testing protocol was made to test only the code function. It will test if the code compiles, if the code correctly moves the motor in the right direction, the time it takes to move the restraint, and a future test for testing the physical limit switch to allow buttons to work and not work.

See the attached document for the protocol document

Conclusions/action items:

Creating the testing protocol at this point in the design process will be beneficial. This will allow for the team to fabricate and then jump right into testing. This will cut off time that it would take to make the protocol after fabrication.

JENNA WARDEN - Dec 11, 2020, 2:07 PM CST

Autonomous Wheelchair Restraint Adaptations to Measure Code Accuracy and Reliability: Code eValidation Testing

I. **Parties Present for Testing / Data Analysis**

**By signing below the individual acknowledges that all test protocol instructions were followed directly and any deviations were recorded below properly. Additionally, singing below signifies that all information contained herein is accurate to the best of the reporting party's knowledge.*

Name	Email	Signature	Date (MM/DD/YYYY)
Mitchell Tyler			
Ben Lawson			
Jonathon Murphy			
Nimish Patel			
Marissa Harkness			
Jenna Warden			

II. **Date(s) of Testing:**

Date Started: (MM/DD/YYYY)	Date Completed: (MM/DD/YYYY)

Testing_Protocol_-_Code_Validation_Testing_.pdf(820.9 KB) - download

Testing Protocol Writing - Mechanical

JENNA WARDEN - Dec 11, 2020, 1:40 PM CST

Title: Testing Protocol Writing - Mechanical

Date: Completed 2020.12.11

Content by: Jenna Warden

Goals: Creating a testing protocol to test the mechanical stability

Content:

This testing protocol was made to test for mechanical components as well as receiving verbal feedback on comfort, range of motion, and other aspects of using the final device.

See the attached document for the protocol document.

Conclusions/action items:

Creating this testing protocol will also help the team move from fabrication directly into testing next semester. Tests will need to be added as fabrication continues, however, having a start to the protocol will allow some of the team to do testing and others can add additional tests.

JENNA WARDEN - Dec 11, 2020, 2:07 PM CST

Autonomous Wheelchair Restraint Adaptations to Test Mechanical Components

I. **Parties Present for Testing / Data Analysis**

**By signing below the individual acknowledges that all test protocol instructions were followed directly and any deviations were recorded below properly. Additionally, singing below signifies that all information contained herein is accurate to the best of the reporting party's knowledge.*

Name	Email	Signature	Date (MM/DD/YYYY)
Mitchell Tyler			
Ben Lawson			
Jonathon Murphy			
Nanan Patel			
Marissa Harkness			
Jenna Warden			

II. **Date(s) of Testing:**

Date Started: (MM/DD/YYYY)	Date Completed: (MM/DD/YYYY)

Testing_Protocol_-_Mechanical_testing.pdf(113 KB) - download

Agreement Contract - Version 1

JENNA WARDEN - Dec 11, 2020, 1:50 PM CST

Title: Agreement Contract Version 1

Date: Completed 2020.11.21

Content by: Jenna Warden

Goals: Create an Agreement Contract to lay out the revised deliverables for the Fall 2020 semester

Content:

Due to the numerous problems the team encountered, typical final deliverables became unattainable. This contract was made to create an agreement between Team and Advisor for the semesters final deliverables.

See attached document for first version of agreement contract.

Conclusions/action items:

This contract agreement will be a written version of this semesters final deliverables. This is necessary for grading purposes as well as holding the team accountable for the work that can be completed now that is typically done in the spring.

JENNA WARDEN - Dec 11, 2020, 1:51 PM CST

Agreement Contract

This contract is entered into agreement by Team X Chair: Autonomous Wheelchair Restraint Adaptation and advisor, Mitchell Tyler. The terms of this agreement shall begin on November 17, 2020 and continue through December 4, 2020. This document will highlight the changes in deliverables that will be made for the Fall 2020 semester.

Due to over half of the team contracting COVID-19, limited time for material finalization, and TEAM Lab manufacturing restrictions, the specific terms of this contract are as follows:

In place of a working prototype, the team will have completed the following in addition to the final report, presentation, and other deliverables.

1. A step-by-step, detailed fabrication plan for the chest restraint and leg restraint
   a. All steps will have needed specifications such as dimensions, material type, machines used, etc.
   b. Will be written as if it is being sent to a fabrication lab
2. A complete materials list for the chest and leg restraints to be ordered with enough time to begin fabrication before the beginning of the Spring 2021 semester
   a. Each component of the device will have dimensions, location for purchasing, a part number, price, and quantity
3. A working code for the Nucleo Microcontroller with all necessary safety features
   a. Code will control the servo motor with appropriate calculated force and torque values in order to drive both restraint systems into the correct positions
   b. Code will be tested for accuracy and reliability of safety features via a written testing protocol
4. A comprehensive list of ideas for controlling foot location on the footplates during entrance and usage of the wheelchair
   a. This will be displayed in a design matrix format and will be evaluated and acted upon in the Spring 2021 semester
5. A draft of testing protocol for the final chest and leg restraints
   a. Each aspect to be tested will have steps on how the team plans to carry out the desired test
   b. Each testing plan will also include hypothesized result expectations and requirements for each test in order to be deemed successful
6. The final presentation will consist of SolidWorks animations of the working restraints and proof of concept videos utilizing the PVC prototype
   a. Also included will be the fabrication plan, testing plan, expected results, what we have learned due to our setbacks, and our reasoning behind the semester's work

This contract may not be altered in any manner unless in writing and signed by both parties. This document and any attachments constitute the agreement between both

BME400_XChair_AgreementContract_Ver1.docx(15.1 KB) - download

Agreement Contract - Final Version

JENNA WARDEN - Dec 11, 2020, 1:53 PM CST

Title: Contract Agreement Revised

Date: Completed 2020.12.03

Content by: Jenna Warden

Goals: Making revisions suggested by advisor

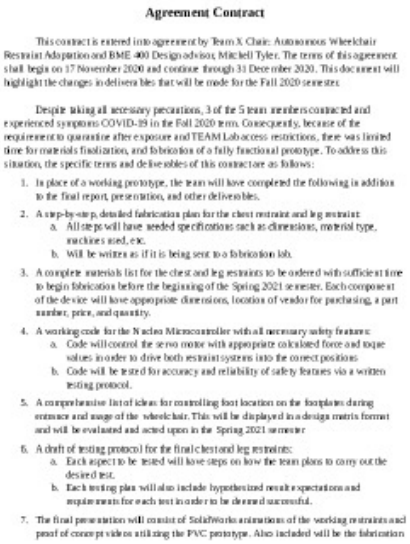
Content:

See attachment for finalized Contract Agreement

Conclusions/action items:

Making the revisions suggested will finalize the contract agreement. If any deliverables change, it must be also changed in the contract agreement.

JENNA WARDEN - Dec 11, 2020, 1:54 PM CST



Agreement Contract

This contract is entered into agreement by Team X Chair: Autonomous Wheelchair Restraint Adaptation and BME 400 Design advisor, Mitchell Tyler. The terms of this agreement shall begin on 17 November 2020 and continue through 31 December 2020. This document will highlight the changes in deliverables that will be made for the Fall 2020 semester.

Despite taking all necessary precautions, 3 of the 5 team members contracted and experienced symptoms COVID-19 in the Fall 2020 term. Consequently, because of the requirement to quarantine after exposure and TEAM Lab access restrictions, there was limited time for materials finalization, and fabrication of a fully functional prototype. To address this situation, the specific terms and deliverables of this contract are as follows:

1. In place of a working prototype, the team will have completed the following in addition to the final report, presentation, and other deliverables.
2. A step-by-step, detailed fabrication plan for the chest restraint and leg restraint
   a. All steps will have needed specifications such as dimensions, material type, machines used, etc.
   b. Will be written as if it is being sent to a fabrication lab.
3. A complete materials list for the chest and leg restraints to be ordered with sufficient time to begin fabrication before the beginning of the Spring 2021 semester. Each component of the device will have appropriate dimensions, location of vendor for purchasing, a part number, price, and quantity.
4. A working code for the Nucleo Microcontroller with all necessary safety features
   a. Code will control the servo motor with appropriate calculated force and toque values in order to drive both restraint systems into the correct positions
   b. Code will be tested for accuracy and reliability of safety features via a written testing protocol.
5. A comprehensive list of ideas for controlling foot location on the footplates during entrance and usage of the wheelchair. This will be displayed in a design matrix format and will be evaluated and acted upon in the Spring 2021 semester
6. A draft of testing protocol for the final chest and leg restraints:
   a. Each aspect to be tested will have steps on how the team plans to carry out the desired test.
   b. Each testing plan will also include hypothesized result expectations and requirements for each test in order to be deemed successful.
7. The final presentation will consist of SolidWorks animations of the working restraints and proof of concept videos utilizing the PVC prototype. Also included will be the fabrication

BME400_XChair_AgreementContract_Ver2.docx(15.3 KB) - download

10/6/2020 Project Impact

JONATHON MURPHY - Oct 06, 2020, 8:56 PM CDT

Title: Project Impact

Date: 10/06/2020

Content by: Jonathon

Present: N/A

Goals: learn more about the reasons behind the problem

learn about what/who this device will impact

Content:

Our client has spinal muscular atrophy (SMA). He has never been able to walk and has been stuck in a wheelchair almost all his life. He has type II of five different types[1]. Our client has expressed interest in the fact that he cannot use his standing wheelchair by himself. This was a very expensive purchase and is often not used because he needs someone to help him with the restraints. Giving him the ability to use the standing wheelchair by himself will help him change positions, use muscles he otherwise wouldn't use, and straighten out a few times a day. This is the more specific view of our client's needs and requirements.

Patients unable to move or reposition themselves may develop pressure ulcers after prolonged periods in the same position [2]. These patients could benefit from something that moves and repositions them, which would help them with increased blood flow, digestion, strength, and just their overall health. There is an estimated 65 million people around the world that require the use of a wheelchair - 3.3 million of those users live in the United States [3]. This is the scope of the population this device could impact and help.

Conclusions/action items:

[1] 2020. *Spinal Muscular Atrophy*. [online] WebMD. Available at: <https://www.webmd.com/a-to-z-guides/spinal-muscular-atrophy#5> [Accessed 13 September 2020]..

[2] Moore, Z. and van Elten, M., 2020. [online] Woundsinternational.com. Available at: <https://www.woundsinternational.com/uploads/resources/content_10095.pdf> [Accessed 7 September 2020].

[3] “Wheelchair Users,” *Physiopedia*. https://www.physio-pedia.com/Wheelchair_Users (accessed Oct. 06, 2020).

09/07/2020 Repositioning and pressure ulcer prevention in the seated individual

JONATHON MURPHY - Sep 07, 2020, 8:50 PM CDT

Title: Repositioning and pressure ulcer prevention in the seated individual

Date: 09/07/2020

Content by: Jonathon

Present: N/A

Goals: research the importance of repositioning a seated individual

Content:

patients unable to move or reposition themselves may develop pressure ulcers after prolonged periods in the same position

pressure ulcers develop do to

- local ischaemia - inadequate blood supply
- reperfusion injury - tissue and cell damage caused when blood supply returns
- impaired interstitial fluid flow and lymphatic drainage
- deformity of cells

external forces that also increase probability of devloping pressure ulcers include

- excess forces
- microclimatic factors (build up of temp and humidity)

Type of chair that will decrease development of ulcers

- chair must adapt posture of individual
- increases contact area and decreases pressure
- must be correct width for patient

Sitting position to decrease development of ulcers

- pelvis should be in similar alignment as when standing
- upper body in similar alignment as when standing
- legs positioned so legs and heels are at front of seat
    - without this, increased tension in hamstring muscles will force pelvis backward (sliding pelvis/excess force)

Moore, Z. and van Elten, M., 2020. [online] Woundsinternational.com. Available at: <https://www.woundsinternational.com/uploads/resources/content_10095.pdf> [Accessed 7 September 2020].

Conclusions/action items:

research different chairs that will accommodate the client

research other ways to reposition patient

09/13/2020 Spinal Muscular Atrophy (SMA)

JONATHON MURPHY - Sep 13, 2020, 7:42 PM CDT

Title: Spinal Muscular Atrophy (SMA)

Date: 09/13/2020

Content by: Jonathon

Present: N/A

Goals: learn more about the neuromuscular disorder our client has

Content:

2020. *Spinal Muscular Atrophy*. [online] WebMD. Available at: <https://www.webmd.com/a-to-z-guides/spinal-muscular-atrophy#5> [Accessed 13 September 2020].

SMA breaks down the nerve cells in the spinal cord and brain, which inhibits the brain from sending messages to muscles. The individual's muscles become weak and begin to deteriorate. There is no cure to this NMD, but there are ways to slow the atrophy and improve symptoms. SMA is a genetic disorder.

Types of SMA:

- Type 0 - rarest, most severe form. Babies do not usually survive due to complications with breathing
- Type 1 - very severe. Child may live up to 2 years. Also have breathing problems
- Type 2 - moderate to severe, Children ages 6-18 months. usually involve leg and arm problems
- Type 3 - mildest form, children 2 -17 years. most are able to stand and walk but may have problems running, climbing stairs, etc
- Type 4 - starts during adulthood. symptoms such as muscle weakness, twitching, or breathing problems

there is a large amount of variation of symptoms from patient to patient

Treatment:

- Medication - two types of medication targeting the genes that create the missing proteins for controlling the muscles
    - nusinersen
    - onasemnogene abeparvovec-xioi
- Breathing - breathing problems may need special mask or mouthpiece
- Swallowing/nutrition - some individuals have weak mouth/throat muscles and may need a feeding tube
- Movement - physical and occupational therapy

Conclusions/action items:

Our client likely has type 2 SMA.

we will need to research specific movement therapies and what doctors prescribe to SMA patients in terms of exercise

09/13/2020 Exercise in neuromuscular disorders

JONATHON MURPHY - Sep 13, 2020, 7:14 PM CDT

Title: Exercise in neuromuscular disorders

Date: 09/13/2020

Content by: Jonathon

Present: N/A

Goals: learn more about the importance of exercise in people with neuromuscular disorders and what kind of exercises are helpful

Content:

VOET, N., 2020. *Exercise In Neuromuscular Disorders: A Promising Intervention*. [online] PubMed Central (PMC). Available at: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6955632/#:~:text=Exercise%20in%20neuromuscular%20disorders%20is%20safe,-In%20the%20past&text=Because%20of%20the%20weakness%20of,muscle%20contractions%20during%20strength%20training.> [Accessed 13 September 2020].

Many individuals with a neuromuscular disorder (NMD) may find themselves in a "circle of inactivity." This happens when the individual lowers their physical activity due to lack of energy. This reduction in activity weakens the muscle and cardiovascular condition even more quickly. Average maximal oxygen uptake is abnormally low in patients with NMD. Low activity also increases body fat which impairs mobility even more.

Training and exercise has never been found to be unsafe for the patient, within reason. Eccentric exercises and high-intensity muscle contractions should be avoided. There is no proof this type of training is any more helpful than moderate exercise. It can also overload the muscles and worsen the NMD. This exercise/training is very dependent on the individual's personal state.

Conclusions/action items:

our product should stay away from eccentric exercise and push more toward increase in movement or aerobic exercise

this article provides a lot of research behind why exercise is important for NMD patients. great for background section of final report

09/23/2020 Standing/Sitting with SMA

JONATHON MURPHY - Sep 23, 2020, 9:55 PM CDT

Title: Standing/Sitting with SMA

Date: 09/23/2020

Content by: Jonathon

Present: N/A

Goals: learn more about the ability of standing and sitting with SMA

Content:

- any type 1/2 SMA patient are not able to walk
- type 1 SMA usually means no independent sitting.
    - need help sitting up straight using a wheelchair or other helpful therapy options [1]
- lower extremity muscles and limbs are weakened more than upper extremities
    - loss of range of motion and contractures (shortening/hardening of muscle/tendon/tissue, creating rigid joints) in hip and knee cause decrease in moto function [2]
- early movement/therapy will help maintain function
    - if patient is able to bear some weight on their legs, they should in order to keep that ability
    - use of braces and ankle-foot orthoses are useful
    - swimming/aquatic therapy slow degeneration
- scoliosis is very prominent in SMA
    - spinal bracing does not prevent scoliosis
    - affects comfort in sitting and standing position
    - surgery may be required

Conclusions/action items:

most information and research found on standing and sitting with SMA is on children and younger patients. It is very tough to find anything on adults, probably because once they lose the ability to stand, it is very difficult to get back. Our client has never had the ability to walk. Research other possible solutions to help our client to the standing position.

[1] Onlinelibrary-wiley-com.ezproxy.library.wisc.edu. 2020. *Access Library Resource - UW Libraries*. [online] Available at: <https://onlinelibrary-wiley-com.ezproxy.library.wisc.edu/doi/full/10.1002/mus.24497> [Accessed 24 September 2020].

[2] Www-sciencedirect-com.ezproxy.library.wisc.edu. 2020. *Access Library Resource - UW Libraries*. [online] Available at: <https://www-sciencedirect-com.ezproxy.library.wisc.edu/science/article/pii/S0960896617305771?via%3Dihub> [Accessed 24 September 2020].

9/7/2020 - Aerotrim

JONATHON MURPHY - Sep 07, 2020, 8:28 PM CDT

Title: Aerotrim

Date: 09/07/2020

Content by: Jonathon Murphy

Present: N/A

Goals: research similar designs to what the client would like

Content:

En.wikipedia.org. 2020. *Aerotrim*. [online] Available at: <https://en.wikipedia.org/wiki/Aerotrim> [Accessed 7 September 2020].

aerotrim (Multi-Axis Trainer or MAT) is used for workouts and working on balance for pilots and astronauts

"wheeling" uses every muscle evenly to control the users movement.

it is said to improve balance, coordination, and spatial awareness in neurological disorders

very similar variations have come up over the years

Conclusions/action items:

look for designs using motors for neurological disorders

research ways of creating an opening to accommodate the lift

09/23/2020 SMA braces/standers

JONATHON MURPHY - Sep 23, 2020, 9:53 PM CDT

Title: SMA braces and standers

Date: 09/23/2020

Content by: Jonathon

Present: N/A

Goals: research ways patients with SMA get help standing

Content:

Standers

- Standers help patients bear small amounts of weight on their legs while keeping them in a standing position
- They can be stationary or mobile depending on the design
- also aid with digestion/circulation/breathing

Braces

- three different types
    - Ankle-foot orthoses (AFO)
        - helps stabilize and position the motion of ankle
    - Knee-ankle-foot orthoses (KAFO)
        - support and position joint alignment to the knee, foot, and ankle.
        - protect foot/lower limb
    - Thoraco-lumbo-sacral orthosis (TLSO)
        - back braces
        - underneath arms and around lower back/hips
        - straighten spine

Stander

KAFO

Conclusions/action items:

our client is unable to bear weight on his lower limbs. He has a standing wheelchair, but the simplistic design of the standers could be implemented in a design to aid our client into the standing position by himself.

Almeida, M., 2020. *Specialized SMA Equipment: Braces And Standers*. [online] SMA News Today. Available at: <https://smanewstoday.com/specialized-sma-equipment-braces-and-standers/> [Accessed 24 September 2020].

09/27/2020 Personal Restraint hydraulic Lock LE

JONATHON MURPHY - Sep 27, 2020, 11:19 PM CDT

Title: Personal Restraint hydraulic Lock LE

Date: 09/27/2020

Content by: Jonathon

Present: N/A

Goals: hopefully learn how to build a similar product that can be connected to the client's wheelchair

Content:

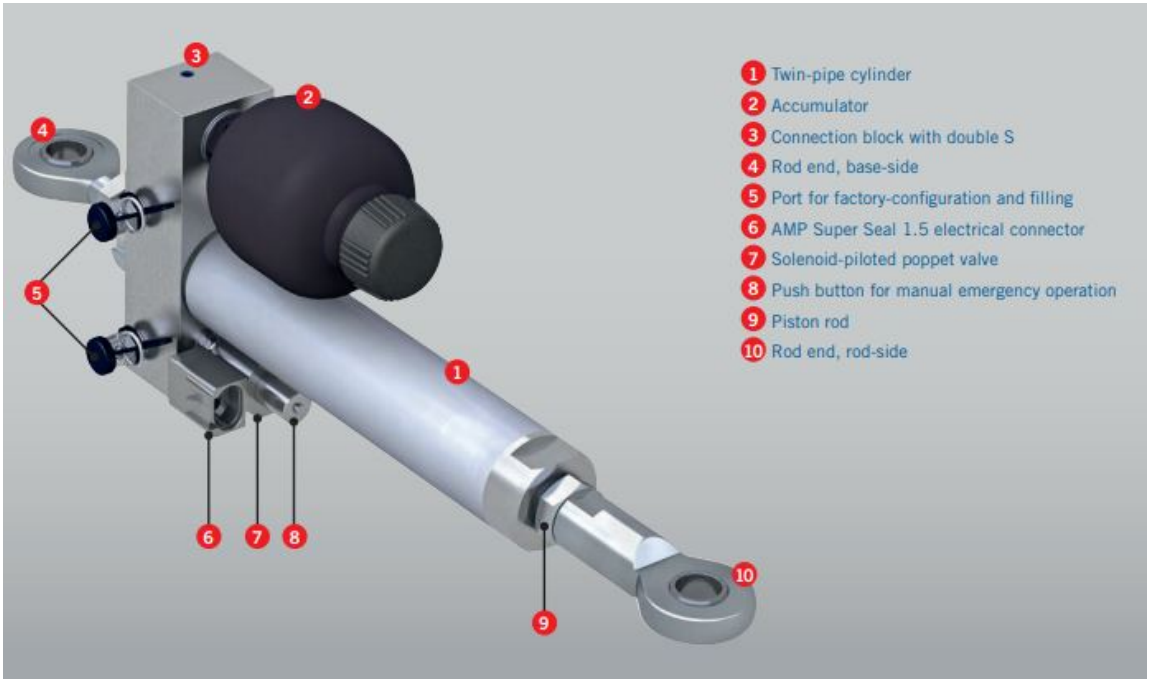
complies with any safety standards

self-contained and low-maintenance hydraulic system

infinitely variable position and silent bar adjustment

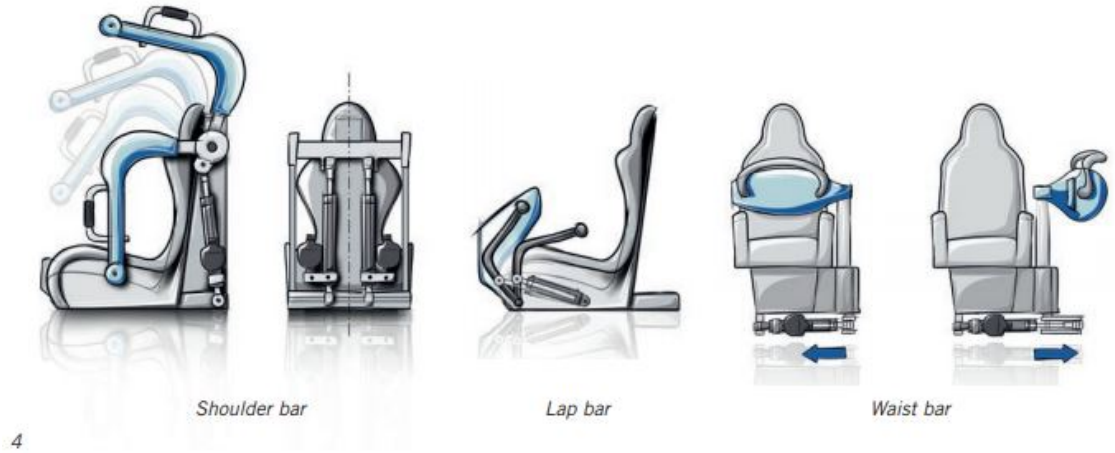
Main components:

- bolted twin-pipe cylinder
  - inner pipe guides piston rod with piston
  - outer pipe conducts oil from rod side to connection block on cylinder base
- connection block
  - holds diaphragm accumulator
  - electromechanically controlled or manually operated check valve and two pressure ports
- diaphragm accumulator
  - precharges unit to predefined pressure and accepts oil volume displaced by piston rod
- poppet valve
  - allows oil flow only in one direction
  - oil flow possible in both directions by electromechanical activation during normal operation or manual activation in emergency
- pressure ports
  - used for filling unit with oil and setting pressure configuration at factory



Advantages

- bar lock blocks movement of cylinder, locking restraining bar
- comfort - hydraulic cylinders have large variability for bar adjustment
- reliability - extreme low-leak specialty valve creates reliable porduct
- one system (no attachments) - no gas springs, spring systems, pneumatic drives required



4

Conclusions/action items:

this design is complex and would be hard to add to a standing wheelchair

hydraulic may not be the way to go

look into possible gear/ratchet systems

Hoerbiger.com. 2020. [online] Available at: <https://www.hoerbiger.com/upload/file/325_051_hoe_bro_verriegelungssystem_2017_16_seite_dina4_e_ds_rz.pdf> [Accessed 28 September 2020].

10/1/2020 Roller Coaster System

JONATHON MURPHY - Oct 06, 2020, 8:36 PM CDT

Title: Roller Coaster System

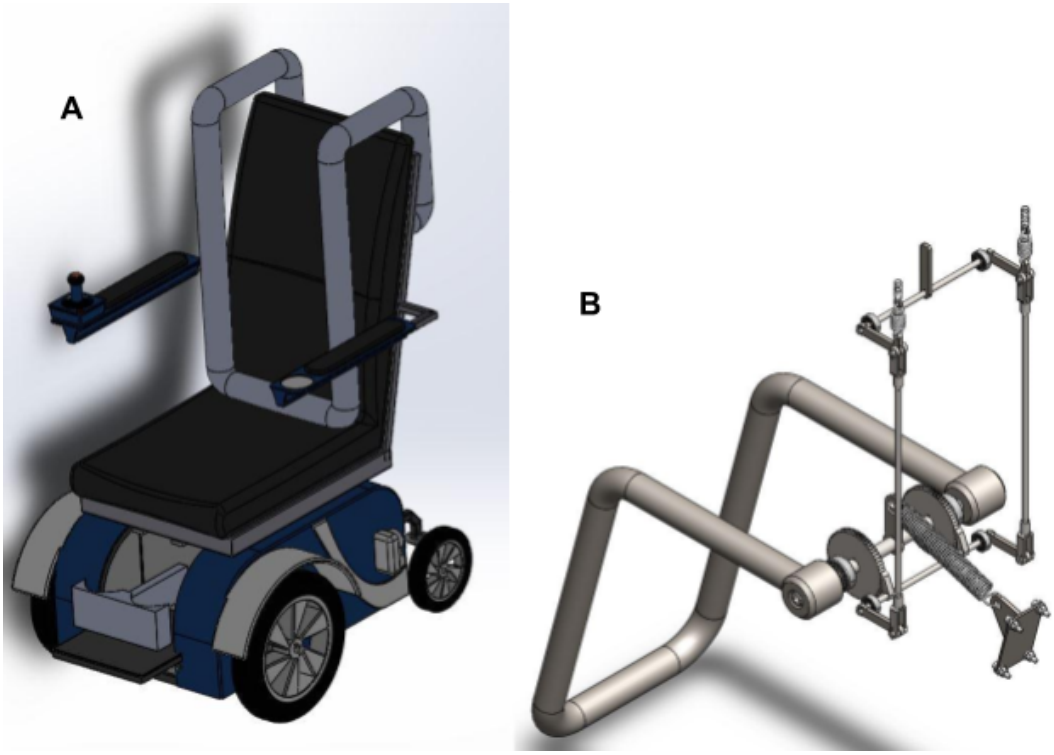
Date: 10/1/2020, updated 10/6/2020

Content by: Jonathon

Present: N/A

Goals: explain the roller coaster system idea

Content:



Picture A is a rough SOLIDWORKS model of the roller coaster system idea, while picture B is an example of the locking rachet idea.

- The roller coaster system consists of a system that is similar to the restraints on the SUPERMAN: Ultimate Flight ride at Six Flags Great America. As the over-the-shoulder restraint is pulled down tight to the user's body, the leg restraints would also fold out from the middle and over the legs to prevent them from falling away from the chair.
- This synchronous, linked system would create a much easier restraint system for the user, as he/she would only need to worry about the upper restraint. The chest restraint would use a locking ratchet mechanism similar to the one shown picture B above. A lever would release the ratchet mechanism and the spring-loaded system would return to the chest restraint to resting position above the user. The leg restraints would also return flat against the bar protruding from in between the user's legs. This is a simple, well known system that is trusted on high intensity rides and attractions.

Conclusions/action items:

The roller coaster idea may be a bit complex and hard to integrate to the standing wheelchair, but it is known to work. If we automate it and make it bluetooth compatible, Keith could use his joystick on the wheelchair to control it. Since meeting with Keith in person, we learned he cannot raise his arms over his head. So, for this to work, it must be automated.

09/27/2020 Roller Coaster Restraints

JON

Title: Roller Coaster Restraints

Date: 09/27/2020

Content by: Jonathon

Present: N/A

Goals: learn more about roller coaster restraints to possibly implement them in our design

Content:

Two types of restraints - Lap bar and over-the-shoulder

Lap Bars

- padded bar connected to the floor that sits over rider's lap
- used when ride lacks inversions
- gives more movement

Over-the-Shoulder

- u - shaped padded bar swings downward over rider
- can cause headbanging if rough ride
- Design
    - dual ratcheting mechanism or hydraulic design
    - controlled by computers

Conclusions/action items:

we will need to look for a design that we could add to the client's wheelchair...I will also research some competing designs.

Over the shoulder restraint is probably a better idea.

En.wikipedia.org. 2020. *Train (Roller Coaster)*. [online] Available at: <https://en.wikipedia.org/wiki/Train_(roller_coaster)#:~:text=Roller%20coaster%20trains%20also%20have,and%20over%2Dthe%2Dshoulder.&text=On%20over%2Dthe%2Dshoulder%20restr [Accessed 28 September 2020].

En.wikipedia.org. 2020. *Accelerator Coaster*. [online] Available at: <https://en.wikipedia.org/wiki/Accelerator_Coaster#Restraints> [Accessed 28 September 2020].

Pointbuzz.com. 2020. *Ask Rideman #5 - Restraints | Pointbuzz*. [online] Available at: <https://pointbuzz.com/content/ask-rideman-restraints> [Accessed 28 September 2020].

10/11/2020 Worm Drive

JONATHON MURPHY - Oct 12, 2020, 12:20 AM CI

Title: Worm Drive

Date: 10/11/2020

Content by: Jonathon

Present: N/A

Goals: learn more about possible gear systems that have locking features

Content:

composed of a worm and a worm gear [1]

- worm is a gear in the form of a screw
- worm gear is turned along worm threads

used for their ability in large speed reduction and high torque multiplication [1]

self - locking means the system cannot backdrive in the opposite direction [1]

worm drive is a self-locking system due to friction [1]

- coefficient of friction between gear and worm is larger than the tangent of the worm's lead angle

advantages of self-locking worm drivers [2]

- large reduction ratios as large as 200:1
- used where loading against gravity is required
- used when input and output shafts are perpendicular

disadvantages [2]

- heat generation is a concern
- high contact force over small contact area
    - enveloping worm gear is one solution of the problem

Conclusions/action items:

this system could be driven by a motor and could make sure once the restraint is down, that it cannot be pushed back up.

we will need to do some math with gear ratios and distance to figure out the type of worm gears and worms we will need.

research enveloping worm gear as a solution to high contact stress problem

[1] Collins, D., 2020. *Self-Locking In Worm Gears: How Does It Work And Where Is It Useful?*. [online] Motioncontroltips.com. Available at: <https://www.motioncontroltips.com/when-are-worm gears-self-locking-and-where-is-this-useful/#:~:text=Self%2Dlocking%20means%20that%20the%20gear%20cannot%20drive%20the%20worm.&text=In%20theory%2C%20as%20long%20as,and%20will%20not%20back%20driv [Accessed 11 October 2020].

[2] Brighthubengineering.com. 2020. *Self Locking Worm Gear – Operation, Applications, And Advantages Of Self-Locking Worm Gears*. [online] Available at: <https://www.brighthubengineering.com/machine-design/65703-what-is-a-self-locking-worm-gear-how-does-it-work/> [Accessed 12 October 2020].

10/12/2020 Enveloping Worm Gear

JONATHON MURPHY - Oct 12, 2020, 12:29 AM CDT

Title: Enveloping Worm Gear

Date: 10/12/2020

Content by: Jonathon

Present: N/A

Goals: research enveloping worm gear as a solution to a worm drive disadvantage

Content:

enveloping worm gear design

- contour of gear teeth and/or worm threads are modified to increase surface contact
- increased accuracy from worm gear
- decreased contact stress

single enveloping worm gear example

- only one aspect has been modified
    - gear teeth are modified and curved to match profile of worm thread
- only one thread is fully engaged

double enveloping worm gear example

- both aspects have been modified
    - worm threads have been modified to circular shape of teeth
    - teeth also modified to create better engagement
- multiple threads are fully engaged

Conclusions/action items:

we may need FBDs to look at internal forces of the gear system we design and decide if we need enveloping worm gears and if we do, whether we should use a single or double enveloping worm gear

Brighthubengineering.com. 2020. *What Is An Enveloping Worm Gear? What Is A Worm Gear Assembly?*. [online] Available at: <https://www.brighthubengineering.com/machine-design/62736-enveloping-worm-gear-design-advantages/#:~:text=design%20concepts%20arose.-,What%20is%20a%20Enveloping%20Worm%20Gear%3F,accuracy%20from%20the%20worm%20gear.> [Accessed 12 October 2020].

Force Calculations - Ongoing

JONATHON MURPHY - Dec 11, 2020, 1:19 PM CST

Title: Force Calculations

Date: ongoing

Content by: Jonathon Murphy

Present: N/A

Goals: solve for necessary forces needed for torques and failure analysis

Content:

To figure out necessary figures and possible failure points for the chest and leg restraints designs, I was tasked with calculating necessary forces and torques. In order to pick a correct motor that will be able to run both devices, we need a torque estimation on the bodies of the designs. I am working alongside Ben has he creates SolidWorks assemblies of these designs and searches for the specific motor. I will also being looking at potential positions of failure in our designs by calculating the bending and shear stresses on points of concern. I will be working on these calculations in Matlab so that if a variable changes, I can easily change it without having to redo the entire calculation. Some assumptions will need to be made in order to do these calculations, and they will be commented in the Matlab code. The Matlab code is attached to this page.

Calculations done:

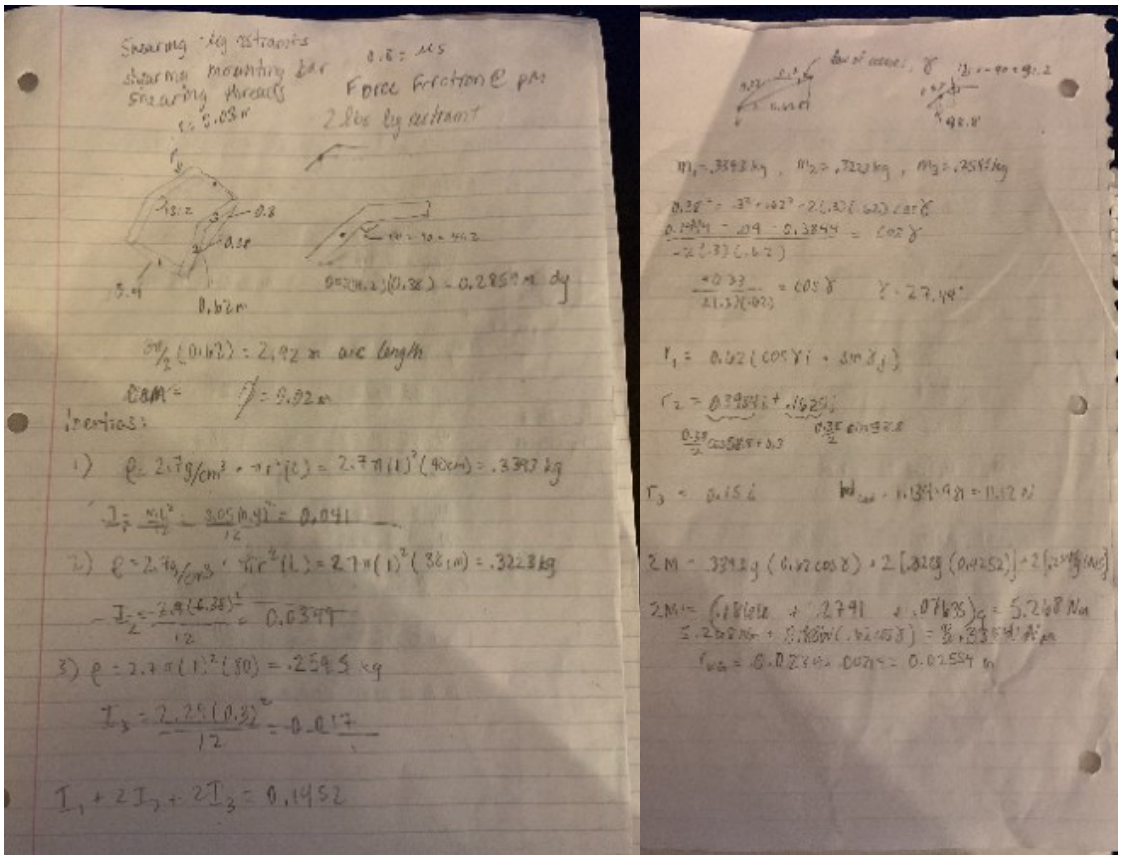
- torque calculations for chest restraint motor
    - mass moment of inertias, center of gravity
- Leg restraint motor torque calculations
    - mass moment of inertia, center of gravity
    - friction at pin, torque due to friction at pin
    - torque due to moment of inertia of arms and restraints
- Shear force at Rack and Pinion teeth
- Bending Stress at restraint support arms

Calculations in future: (added after talking at last Client Meeting 12/08/2020)

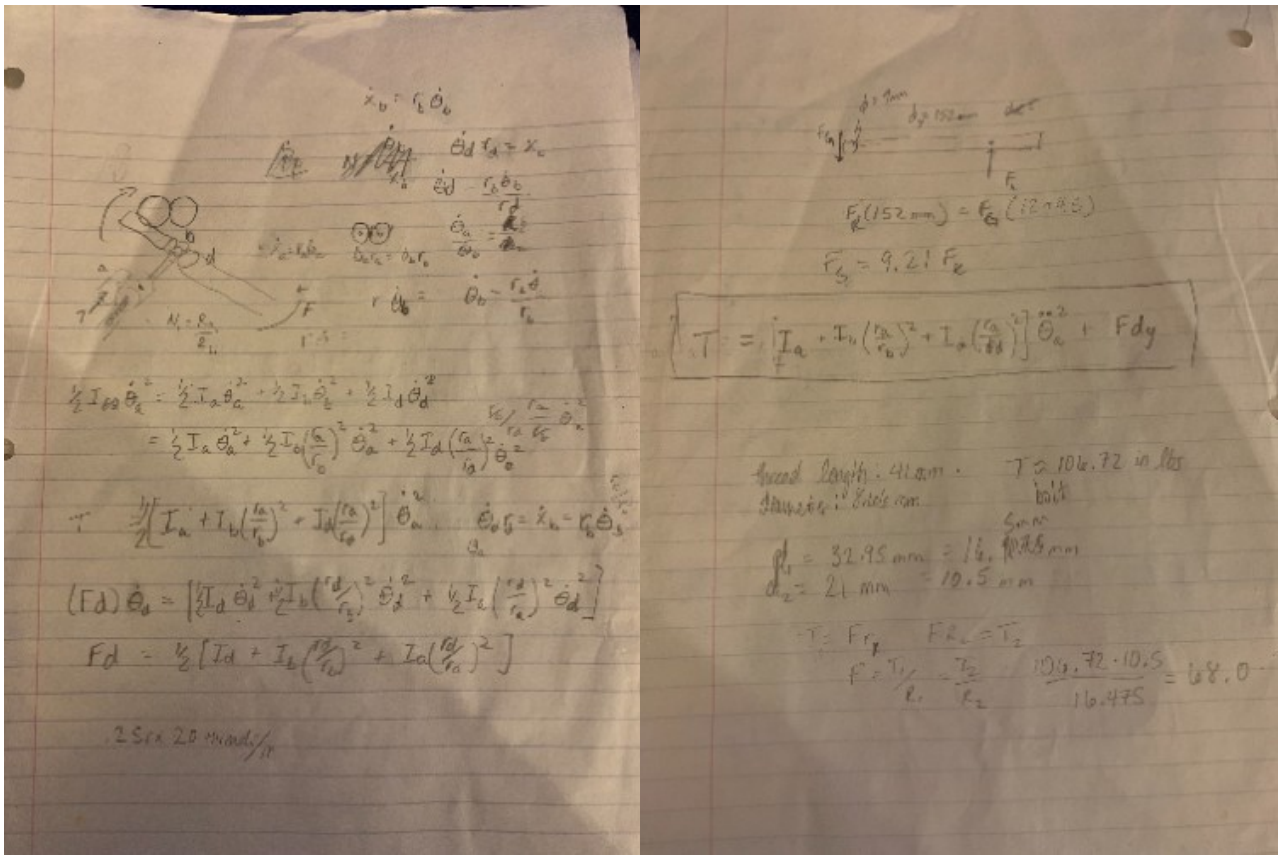
- displacement between worm gear teeth and worm drive
- displacement at chest pad due to previous calculation

Some initial calculations and attempts of calculations done by hand :

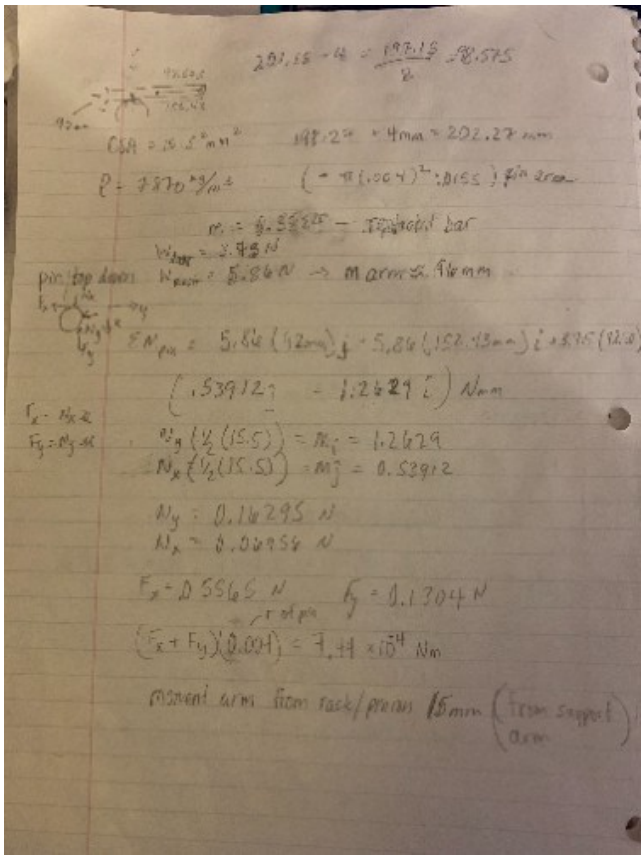
Initial attempts to calculate torque needed for chest restraint (old dimensions)



Initial attempt to calculate torque needed for leg restraint (old dimensions)



Friction and torque due to friction at leg restraint pin calculations



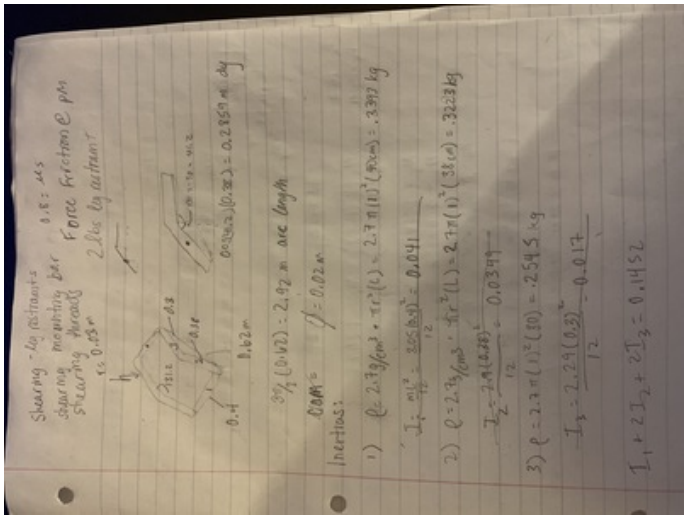
Conclusions/action items:

This code/calculations will need to be updated as the designs or variables change. As we move forward and think of other possible problems or changes, new calculations will also need to be completed. They will be added to the code and reuploaded.

JONATHON MURPHY - Dec 10, 2020, 4:33 PM CST

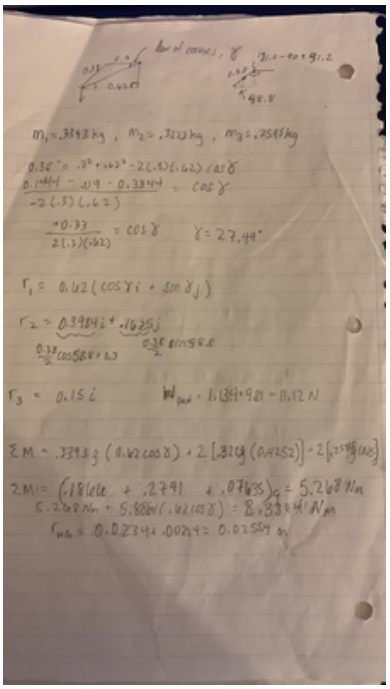
ForceCalculations.mlx(8.3 KB) - download

JONATHON MURPHY - Dec 11, 2020, 1:21 PM CST



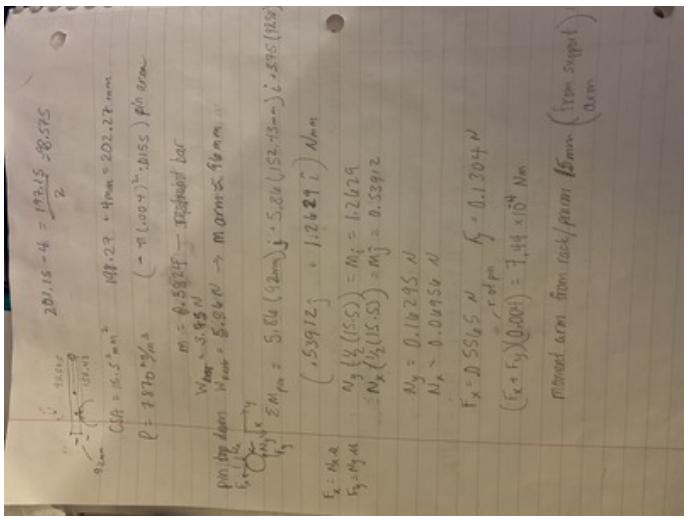
Initial_Chest_restraint_torque_calc_1.jpg(2.5 MB) - download

JONATHON MURPHY - Dec 11, 2020, 1:21 PM CST



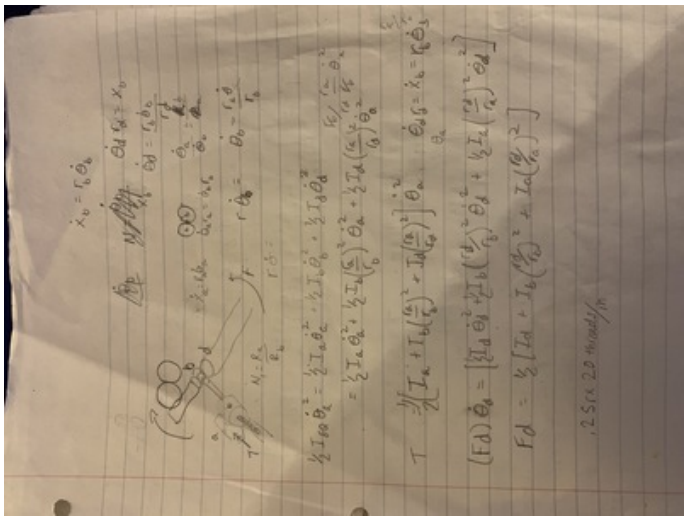
Friction_and_torque_due_to_friction_at_pin_leg_restraint_.jpeg(2.9 MB) - download

JONATHON MURPHY - Dec 11, 2020, 1:21 PM CST



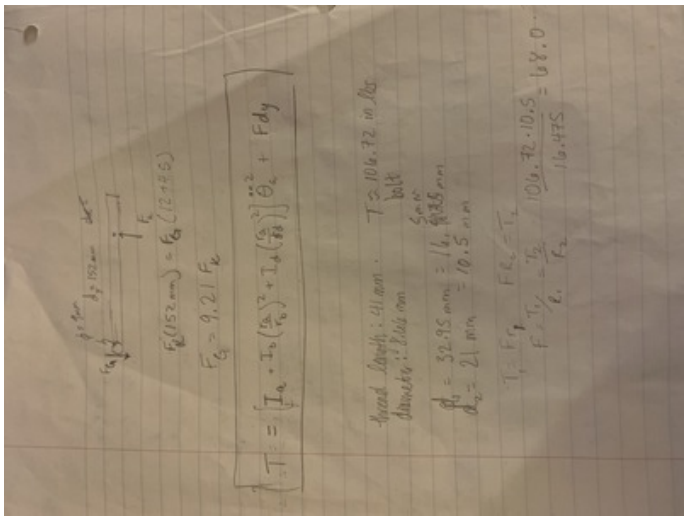
Initial_Chest_restraint_torque_calc_2.jpg(2.5 MB) - download

JONATHON MURPHY - Dec 11, 2020, 1:21 PM CST



Initial_Leg_restraint_torque_calc_1.jpg(2.5 MB) - download

JONATHON MURPHY - Dec 11, 2020, 1:21 PM CST



Initial_Leg_restraint_torque_calc_2.jpg(2.1 MB) - download

Green Pass and Red Pass

JONATHON MURPHY - Oct 06, 2020, 8:38 PM CDT

Title: Tech shop passes

Date: N/A

Content by: Jonathon

Conclusions/action items:

Green and Red passes may be need if we are able to fabricate. Taking into account the online semester as well as COVID, we may or may not need these.

2020/09/07- Exercise in Neuromuscular Disorders

NAMAN PATEL - Sep 07, 2020, 10:53 PM CDT

Title: Exercise in Neuromuscular Disorders

Date: 09/07/2020

Content by: Naman Patel

Present: myself

Goals: Learn about exercise in Neuromuscular Disorders and the mechanisms by which they aid the body.

Content:

- There is evidence that aerobic exercise has a positive effect for NMD patients, however strength training does not show the same evidence.
    - The lack of evidence for strength training is largely due to limited studies conducted, as well as difficulty in measuring the outcome of such studies in a consistent manner.
- Aspects to consider when creating a training program (in our case, an exercise machine): the diagnosis, the progressiveness of the condition, the condition of the heart and lungs, complaints of fatigue and pain, age, past and current activity level, and kinesiophobia
    - Kinesiophobia: comes from years of belief that training is harmful to muscles
        - This phenomena leads many NMD patients into what is referred to as the "Vicious circle of inactivity"; in which the patient experiences loss of muscle strength, leading to inactivity, which deteriorates cardiovascular health and increases fatigue, which leads to more inactivity, leading to further loss of muscle strength.
    - For the scope of the project as introduced, this device should be designed for use by multiple different NMD patients, and thus these are all conditions to consider when designing our prototype.
- Physical activity vs Physical exercise
    - Physical activity: “any effort of skeletal muscles resulting in higher energy consumption than in resting conditions"
    - Physical exercise: "planned, structured and repetitive exercises with an increasing magnitude and intensity in order to maintain or improve physical fitness or aerobic capacity"
    - The scope of the project will require us to choose a mode of exercise that the NMD patient will be trying to achieve, and build our prototype with the aim of achieving that movement
- Eccentric contractions
    - the possibility for eccentric and high-intensity muscle contractions should NOT present in the design
    - In animal NMD models, it is known that eccentric muscle contractions cause a greater cell injury to dystrophic muscle fibers
    - Eccentric contraction studies have not been done in humans, because of the dangers anticipated
    - The device we design MUST be tested to avoid eccentric contractions and loading
        - Possible places this may occur is when patient is entering or exiting the gimbal chair, towards the end of a given exercise, or any point in which the patient is actively moving and using the chair

Voet, Nicoline B M. “Exercise in Neuromuscular Disorders: a Promising Intervention.” *Acta Myologica : Myopathies and Cardiomyopathies : Official Journal of the Mediterranean Society of Myology*, Pacini Editore Srl, 1 Dec. 2019, www.ncbi.nlm.nih.gov/pmc/articles/PMC6955632/.

Conclusions/action items:

This document can serve as reference for aspects to consider when coming up with the design of our device. The effects of Neuromuscular Disorders vary across a large range, and there are a number of aspects to consider when designing an exercise chair for NMD patients. Further, this article outlines the dangers of eccentric contractions (load on muscle once already flexed), and this is known to stress muscle fibers. This should be implemented as part of the testing plan to be sure that this is not a possibility during the use of the exercise chair.

Content from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6955632/

2020/09/08 - Spinal Muscular Atrophy

NAMAN PATEL - Sep 09, 2020, 10:49 AM CDT

Title: Spinal Muscular Atophy

Date: 09/09/2020

Content by: Naman

Present: myself

Goals: Learn about SMA and become familiar with the disorder. The first version of our design is for our client, who has Spinal Muscular Atrophy.

Content:

- Disease-causing gene: SMN1 (survival motor neuron 1)
- SMA is described by the degeneration of motor neurons of spinal cord
    - results in Hypotonia and muscle weakness
- SMA divided into 3 classifications of severity (IV is recently added mild classification)
    - Type I: Severe, age of onset 0-6 months; Highest function = never sit, death prior to age 2
    - Type II: Intermediate, age of onset 7-18 months; Highest function = Sit, never stand
    - Type III: Mild, age of onset >18 months; Highest function = Stand and walk
    - Type IV: Adult, age of onset = 2nd or 3rd decade; Highest function = walk during adulthood
- SMA type is commonly defined by highest level of motor function (ie, sitter, walker)

Lunn, Mitchell R, and Ching H Wang. “Spinal Muscular Atrophy.” *The Lancet*, Elsevier, 19 June 2008, www.sciencedirect.com/science/article/pii/S0140673608609216.

Conclusions/action items:

For our purposes, this research article serves as a guide for general information regarding SMA. Much of the article dives deep into the disease from the gene and motor neuron perspective, as well as comparing and contrasting a vast number of clinical trials with various drug treatments. For our project, this info is not directly related or important for our knowledge base. We do need to be precisely aware of SMA and its effects. Further, it is useful to understand the different types of SMA and related information. This will help us in further research into specific types, and the directly affected muscle weaknesses, so that we can focus on specific muscle movements that are beneficial for SMA patients. Becoming familiar with this information will help guide us in deciding which kinds of movements we need to/should implement in our design and which movements we need to be sure to avoid. Beyond this semester, classifying which types of SMA our device is suitable for may be an important next step (or designing the device to be suitable for the different types).

Content from: https://www.sciencedirect.com/science/article/pii/S0140673608609216

2020/09/23- SMA Beneficial Exercises and Movements

NAMAN PATEL - Oct 07, 2020, 2:32 AM CDT

Title: Beneficial Exercises and Movement for Spinal Muscular Atrophy

Date: 09/23/2020

Content by: Naman

Present: myself

Goals: Learn about the exercises that would be beneficial in regards to blood flow for Spinal Muscular Atrophy, paying special attention to the movements our team knows our client is interested in (standing up straight/ prone position/ upside down position).

Content:

- Exercise can help with: improving range of motion, preventing contractures, strengthening muscles, helping breathing to keep respiratory muscles strong, boosting flexibillity, helping maintain posture, and improving mood and mental health. [1]
    - Contractures (common SMA complication): stiffening of joints that is a result of tightening of muscles, tendons, skin and other tissues
    - Mental health: our client has told us about some experiences he has had in which he went on an outing on action track wheelchairs, as well as a separate occasion where he was on a gator vehicle; He explained that after both experiences, he felt better than he had in years.
        - Increased blood flow and the increase in the release of adrenaline as a result of the activation of the sympathetic nervous system caused by exercise allows an NMD patient to get the feelings they may not have the ability to feel on a regular basis
- Review of studies conducted regarding SMA and exercise [2]
    - Exercise can often be more difficult for individuals with an NMD
        - weakness, pain, fatigue and contractures make it difficult for studies to get patients, plus SMA is a rare disease
    - Exercises can be grouped into 2 categories:
        - strength training: moving increased weights (through lifting)
        - aerobic exercise (highly repetitive movements with no or minimal weight added)
    - Study 1: Strength training using "progressive resistance training" in young (10 year old patients)
        - Exercises consisted of 45-60 minute sessions 3x a week
        - Started with exercises without weight, but then ankle and wrist weights were added once each individual managed to complete two sets of exercises in a week
        - over 12 weeks, only a small improvement in muscle strength overall, especially for those who already have some muscle weakness (our client would fall under the circumstance in which muscle weakness is already present)
        - There was a significant improvement in how well muscles are able to perform particular tasks
            - Our client is an active, well-functioning member of the community with a full time job as a data analyst for UW-Hospitals; many tasks require functionality that our client has, but can be improved with such exercises that implement a level of resistance.
    - Study 2: Aerobic training study that looks at 6 individuals with SMA Type 3, and compared to 9 individuals without SMA
        - Special type of exercise bikes used for these studies
        - 30 minute sessions, 2-4 times a week for 12 weeks
        - Study measured how much oxygen could be used by the body during exercise - measurement of "V02 max"
            - Focused on learning how the body improves oxygen intake during exercise
            - Note: study explains that SMA type 2 results in weaker breathing muscles, while this is not a feature of SMA Type 3
        - Conclusion of study: Showed some benefit in terms of oxygen intake, however no gain in muscle strength or ability to perform specific tasks; Therefore, how beneficial this may be to an SMA patient is hard to say
- Conclusion from review of studies [2]:
    - Few studies are able to be performed on SMA patients due to the rarity of the disease, combined with the number of SMA patients who are eligible to participate in such a study.
    - For the purposes of application to our client, the gradual buildup of strength via resistance bands seems to be most beneficial based on this review of studies

- However, with conversations with our client, the team understands that movement into various positions and the ability to get the blood flowing may prove to be the most beneficial for the client.

[1] “Physical Therapy Guide to Spinal Muscular Atrophy.” *American Physical Therapy Association*, 16 June 2020, www.choosept.com/symptomsconditionsdetail/physical-therapy-guide-to-spinal-muscular-atrophy.

[2] “Exercise and Spinal Muscular Atrophy - Spinal Muscular Atrophy UK.” *Spinal Muscular Atrophy Support UK*, smauk.org.uk/exercise-and-spinal-muscular-atrophy.

Conclusions/action items:

The results of the research done in this article largely describe the limited number of studies that are available to understand beneficial movements in SMA patients. This is due to the rarity of SMA, as well as the number of SMA patients that have the ability to perform such exercises in these studies safely. For our client, the team has recognized, through conversations, how beneficial it can be for him to get the opportunity to get the blood flowing. Through multiple examples, he explained he has "never felt better" than when he was able to go do an activity that was out of the ordinary for him, and provided a way for him to move around in a way he is not able to do on a regular basis. For the client, simply being in a standing position, and being able to do so autonomously would be a great benefit, and allow for blood flow to areas that he is not able to get blood flow to regularly.

2020/09/15: Inversion Tables Research -

NAMAN PATEL - Oct 07, 2020, 1:08 AM CDT

Title: Inversion Tables Research

Date: 09/15/2020

Content by: Naman

Present: myself

Goals: To research about inversion tables and look for ways they can be implemented in a design that would help our client.

Content:

- Research article seeks to determine whether or not inversion tables can help relieve back pain
- Study subjects: 47 women that have been suffering from lower back pain for 23.0 +-5.45 weeks [1]
    - Groups: Supine group (n=15), inversion at -30 degree angle group (n=18), inversion at -60 degree group (n=14)
- Study required each participant to invert 3 min x 3 repetitions for 4 days a week for 8 weeks.
    - rest time among inversion tractions was 5 mins
- Pain measured using VAS (visual analogue scale)
    - self-reported pain assessment tool that requires subject to place V in a 10 cm long straight line with stops on each end. Left end means "no pain" and right end means "the worst pain"
    - Scale can then be broken down and expressed numerically from 0 to 100 nm
    - VAS has been widely used in various studies as a method to measure Lower back pain, and has also shown to be valid and reproducible as a highly sensitive tool to evaluate lower back pain.

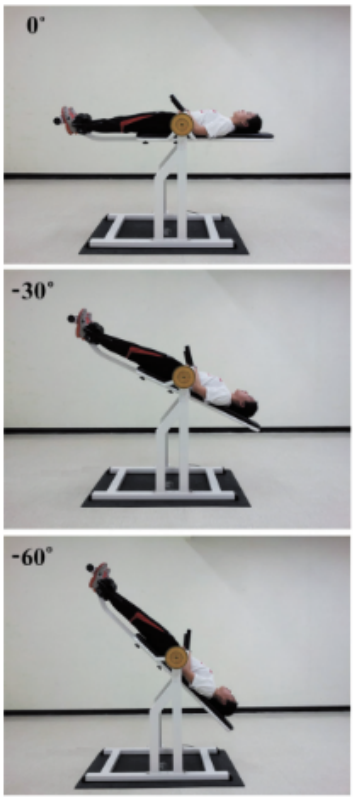


Fig. 3. Angles of inversion traction. (Colours are visible in the online version of the article; http://dx.doi.org/10.3233/IES-130506)

Angles of inversion for different groups for study.

Study Results:

- The 8-week inversion traction program significantly improved the poor VAS scores to a nearly perfect score
- This study also took baseline measures on lumbar flexibility and isokinetic torwues
    - Within the I30G (-30 inversion) and I60G (-60 inversion) groups, both these tests significantly improved (significantly higher flexibility in the patients)

- Additional notes: flexibility is important to overall health and fitness as it allows a joint to move through its full range of motion
    - Connecting this to the application for our client, while he may have major limitations on flexibility, allowing him to get into an inverted position may allow him to continuously work on his flexibility where possible and improve blood flow to areas that do not normally receive blood flow
    - The fact that this study showed such a vast improvement in the flexibility of the participants, it is a promising idea that may greatly benefit our client in the long term.
- Found that the -60 degree inversion group found more relief in Lower Back pain, and greater increases in flexibility
    - Implementing this piece of knowledge into our design may allow for our client to invert to 60 degrees as it seems to be more beneficial to the spine and provide increased benefits as opposed to 30 degree inversion (though 30 degree inversion also showed great benefits)
- Overall conclusion: 8 week inversion traction program significantly improved VAS scores, trunk flexibility, trunk muscles strength, and muscle mass.

Other notes from article discussion:

- Inversion allows for increased spacing between the disks and also allows for gravitational compression pressure to be removed between the disks for a short period at a time

[1] Kim, Jae-Deung, et al. “The Effect of Inversion Traction on Pain Sensation, Lumbar Flexibility and Trunk Muscles Strength in Patients with Chronic Low Back Pain.” *Isokinetics and Exercise Science*, vol. 21, no. 3, 2013, pp. 237–246., doi:10.3233/ies-130506.

Conclusions/action items:

This article performed a study to compare the -30 degree inversion vs -60 degree inversion vs supine (horizontal) in order to determine the effects on participants who had been experiencing lower back pain for about half a year. The study found, through various measures outlined above, that the participants in the -30 and -60 degree inversion groups experienced reduced lower back pain, as well as an increase in flexibility and lower back strength (measured by trunk flexibility and trunk muscles strength). Further, the -60 degree inversion seemed to lead to even better results for alleviating back pain, and increasing strength and flexibility. For the purposes of the design project, this article outlines the degrees of rotation that may be most beneficial for our client when we implement a design. Further, this article shows that inversion tables and the use of inversion can greatly reduce back pain, and improve flexibility and strength in the back muscles. This can greatly benefit our client as he is unable to move into a position of inversion greater than the supine (horizontal). This article explains how this sort of inversion can be beneficial, and for our client who is sitting in a wheelchair, the increased blood flow and alleviation of gravitational compression pressure on the lower back disks could prove to be very beneficial. Further, after this 8 week program, the participants in the inversion groups all experienced lower back pain relief. With this device potentially being in the client's home, he would be able to use it on a regular basis similar to the way the study was set up. This would greatly improve the quality of life for the patient, especially if it is able to increase flexibility in aspects of his back that normally do not get any sort of movement or blood flow.

2020/09/28- BOA Fit System Research

NAMAN PATEL - Sep 28, 2020, 2:30 AM CDT

Title: BOA Fit System Research

Date: 09/28/2020

Content by: Naman

Present: myself

Goals: Learn more about the BOA Fit System so that we can incorporate the concept into a design that would allow our client to tighten his own restraints in our design solution.

Content:

- Fit configurations deliver concentrated closure to different areas to different zones to give the ability to customize the fit.
- Components
    - micro-adjustable dial
    - super-strong lightweight laces
    - low friction lace guides
- Tested in a variety of environments
- Product platforms
    - H-Series: High power and high capacity,
        - built for thicker, stiffer applications for large, difficult-to-close equipment
        - HOW IT WORKS:
            - Push in to engage
            - Turn to tighten
            - Pull up for quick release
    - M-Series: Focus on durability and powerful closure
        - engineered for workwear and outdoor; withstand force and impact in harsh conditions
        - HOW IT WORKS:
            - Push in to engage
            - Turn to tighten
            - Pull up for quick release
    - L-Series: Lightweight and lower tension
        - low cut footwear for running, golfing, and cyclists
        - HOW IT WORKS:
            - Push in to engage
            - Turn to tighten
            - Turn to loosen
            - Pull up for quick release
    - S-Series: Low-profile and lightweight
        - used in helmet, medical, and cycling applications to provide precise adjustment
        - turn to tighten, turn to loosen interface
        - HOW IT WORKS:
            - Turn to tighten
            - Turn to loosen
- Recommended Platforms and why:
    - H-Series
        - Currently, the size of the restraint and mechanism of it is unknown until our team visits the client to take a look at the restraint mechanism
        - This has high power and high capacity, and allows for larger, bulkier equipment to be tied down (used for snowboarding)
            - This may be needed depending on what the current restraint looks like
            - This also provides assurance and safety due to high capacity and power
        - Cons: Lacking in adjustability, because no loosening mechanism, must quick release and re-tighten if adjustments are needed; this may prove to be a benefit because it cannot accidentally get loosened
    - M-Series
        - This series focuses on a powerful closure and durability; this is key in designing a restraint (or device) so that it can be safe enough for the client to use by themselves

        - made to withstand high force and impact, of which high force may be the only relevant aspect; Regardless, this is a durable high force option that would fit our design needs
    - Cons: Lacking in adjustability, must be quick released and retightened if adjustment is needed
- Not recommended: L-series and S-series
    - These are lightweight and for different applications than what we are interested in; any restraint we use must be over the top in terms of durability and capacity to hold and withstand high forces
        - Though this state of high force may not be consistently present, the restraint needs to account for the worst possible case scenario

All information from:

“Innovation.” *Technology: Dials, Laces, Guides & Configurations | BOA®*, www.boafit.com/en-us/innovation.

Conclusions/action items:

The BOA Fit system seems like a promising concept and aspect that we can incorporate into our design of the restraints. The recommended series provide for high durability and high force capacity that align with the requirements of this aspect of our device. The restraints must be extremely safe, durable, and effective, with a high factor of safety. In order to allow our client to utilize such a system, we also need to add a method of controlling the BOA fit system that extends beyond the normal use. Considering our client's dexterity with fingers, it may be difficult to turn the dial, and especially difficult to "quick release" the system. Further, this restraint would be used towards the bottom of the body, as a restraint for legs/lower body. As a result, the control system we design for the client to be able to control must extend up his body so that he can control it by waist-chest level, so that there is no additional movement requirement for him to be able to tighten the restraint system.

2020/10/13- Roller Coaster Restraint Materials

NAMAN PATEL - Oct 19, 2020, 5:05 PM CDT

Title: Do research into roller coaster restraints

Date: 10/13/2020

Content by: Naman

Present: myself

Goals: Do research into roller coaster restraints, including the materials used for the metal frame.

Content:

- Mechanisms for locking the restraint can happen either mechanically, hydraulically, or magnetically [1]
- Roller coasters always use more than just one mechanism to prevent accidents in the case of failure.
    - Each system works independently and is able to hold the rider by itself
    - Greatly reduces the risk of accidents as it is statistically unlikely for all systems to fail in between routine maintenance checks
- In older coasters, opening the restraint is often done using a mechanical switch on the car itself
    - Most modern coasters use an electronically controlled mechanism, which requires an external power source
    - Electricity is fed into the locking mechanism via conductors (usually near wheel bogies from which the roller coaster seat is attached to the track)
- Restraint systems are passive systems
    - Without external power, the restraint either remains in place or can only be tightened
    - For our client's purposes, this is something to consider as we want no chance for the restraint mechanism to release while the client is using the wheelchair in standing position.
        - We also want to be sure that the client is comfortable, so we may want to opt for a restraint mechanism that locks in a pre-determined location that does not change (tighten or release) once the chair is in standing position.
        - This position can be set using the client's preferences and comfort levels

Roller Coaster Restraint (metal frame) Materials:

- Options:
    - Stainless Steel
    - Aluminum
    - Carbon Fiber
- Stainless Steel vs. Aluminum
    - Tensile Strength & density [2]
        - Aluminum: 276 MPa & density: 2.81gcm-3
        - Steel: 505 MPa & density: 8 gcm-3
        - Steel is heavier than aluminum and a stronger material
    - Cost
        - Aluminum is cheaper than steel when compared by volume (stainless steel about 30% more expensive for same volume)
        - Steel is cheaper when compared by weight
    - Malleability [3]
        - Stainless steel is more likely to retain shape due to increased strength
        - Aluminum is more able to be bent into the desired shape
    - Rust/Corrosion
        - Aluminum has inherent corrosion resistant properties while steel has a higher chance of rusting
    - CONCLUSION:
        - Aluminum seems to be a better material for the purposes of the chest restraint (between aluminum and stainless steel)
        - It is lighter and cheaper by volume, and easier to bend into the desired shape
        - The force felt by the chest restraint is not expected to be excessive, as most of the time it will be about 6 inches away from the client's chest
        - The lighter the material, the less force will be required by the gear system, thus making it more reliable
- Carbon fiber vs Aluminum vs Steel
    - Carbon fiber has high tensile strength due to its crystalline structure
    - Modulus of Elasticity comparison [4] [5]

        - Steel: 200 GPa
        - Carbon Fiber: 150-760 GPa (depends on manufacturing process)
        - Aluminum: 69 GPa
    - Component made of same thickness (aluminum vs carbon fiber)
        - 31% more rigidity for carbon fiber sheet than aluminum
        - 42% less weight
        - 60% more strength
    - Machining/cutting
        - Carbon fiber can be easily cut using CNC machines or manual tools due to low density
        - Aluminum elements are combined using welding, riveting or with inserts
        - Carbon fiber: gluing is used most often, with reinforcing rivets and inserts if necessary
            - modern day epoxy adhesives provide a similar bonding strength to welding
        - For our project, the carbon fiber seems most beneficial due to ease of machining, and an easier method of joining elements together (gluing via epoxy adhesive vs welding)
    - COST
        - Biggest reason more product implementations do not use carbon fiber
        - Carbon fiber is more expensive than aluminum
            - Carbon fiber is more than 10x the cost of aluminum

[1] Väisänen, Antti. *Master's Thesis: Design of Roller Coasters*. Aalto University School of Engineering, aaltodoc.aalto.fi/bitstream/handle/123456789/33706/master_V%C3%A4is%C3%A4nen_Antti_2018.pdf.

[2] Warehouse, Shop. “Aluminum vs Stainless Steel: Which Is Better?” *ShieldCo*, ShieldCo, 1 Dec. 2017, www.shieldcoart.com/custom-metal-business-signage-blog/2017/12/1/aluminum-vs-stainless-steel-which-is-better-for-your-metal-sign.

[3] Spinning, Wenzel Metal. “Steel versus Aluminum Weight, Strength, Cost, Malleability Comparison.” *Steel vs Aluminum: Weight, Strength and Cost Differences - Aluminum Vs. Stainless Steel | Wenzel Metal Spinning*, www.wenzelmetalspinning.com/steel-vs-aluminum.html.

[4] Morabito, Andy. “Carbon Fiber vs. Steel: Element 6 Composites.” *Element6 Composites*, Element 6 Composites, 10 Sept. 2020, element6composites.com/carbon-fiber-vs-steel-which-is-stronger/.

[5] Dexcraft, et al. “Carbon Fiber vs Aluminum - Comparison.” *Carbon Fiber Blog*, 18 Aug. 2020, www.dexcraft.com/articles/carbon-fiber-composites/aluminium-vs-carbon-fiber-comparison-of-materials/.

Conclusions/action items:

For the material of the metal frame of the chest restraint, aluminum or carbon fiber is going to be the best material to use. If Carbon fiber is a material that can fit within the team's budget, it is a better choice as it provides a higher strength and rigidity while being the lightest of the three materials. An additional benefit is that it can be easily cut and machined using CNC machines, which we have access to in the TeamLab. Aluminum may require welding to secure parts together (where there is a bend in the metal frame), while carbon fiber elements can be put together using an epoxy bonding adhesive. Carbon fiber is far more expensive than aluminum, at around 10x the cost per volume. This requires additional research and specifications of geometry and size in order to determine whether carbon fiber fits within the budget, or if we should go with the cheaper aluminum. In terms of strength, all 3 materials will provide sustainable strength for the chest restraint. The lighter material is more beneficial because the heavier the material is, the more torque the gear system has to generate to be able to rotate the restraint, and a lower torque requirement will make it easier on the gear system, and reduce the amount of wear over time.

2020/10/25: Servo Motors and Stm32 Microcontroller

NAMAN PATEL - Dec 11, 2020, 2:04 AM CST

Title: Servo motors with Nucleo microcontroller

Date: 10/25/2020

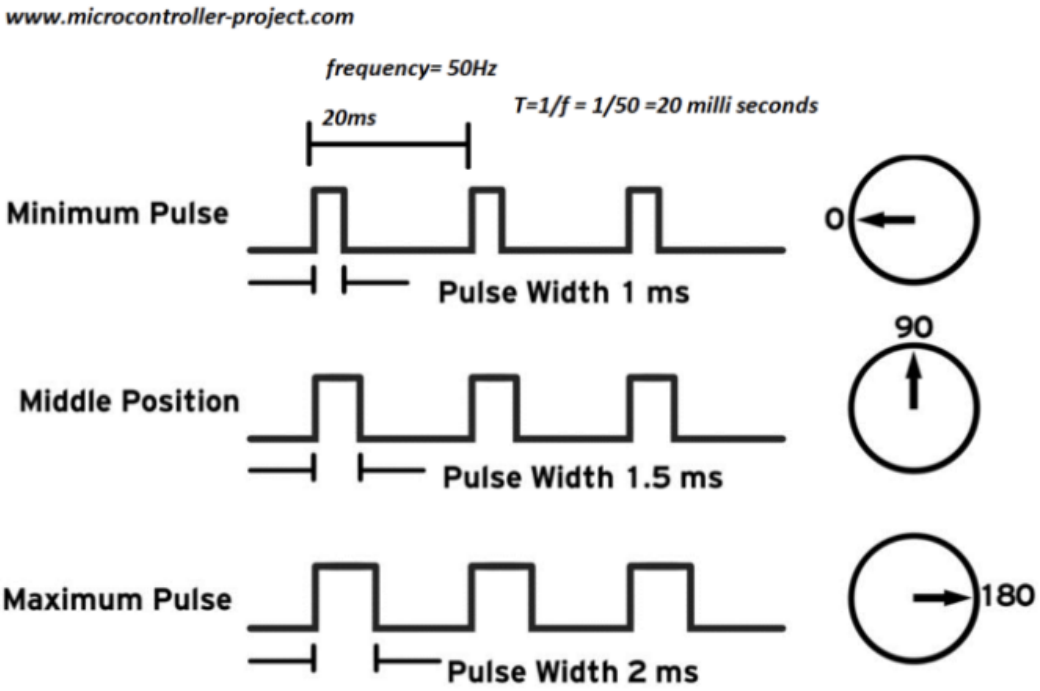
Content by: Naman

Present: myself

Goals: Learn about some simple coding methods for servo motors using a nucleo microcontroller.

Content:

- Servo Motor introduction [1]
  - Servo motors: small motors that generate high torque
  - In ideal state, servo motors consume little power, but during load moving power increases and the servo motor begins to use more current
  - Servo motors work on PWM (pulse width modulated) signals
  - The arm rotates when there is sufficient voltage, current, and pwm signal applied to motor
  - Two types: AC and DC
    - AC can move even heavier loads and are used for industrial applications
    - DC motors are best for smaller applications
    - Article uses DC servo motor with stm32 microcontroller (Nucleo)
  - Most DC servo motors require 50 Hz frequency for operation with a variable duty cycle



Servo motor pwm duty cycle and frequency requirement

Figure: shows the standard requirement wave forms; pwm duty cycle and frequency requirement.

- With a period of 20 ms and duty cycle of 2 ms, the servo motor rotates the arm to 180 degrees.
- With a period of 20 ms and duty cycle of 1.5 ms, the arm rotates to 90 degrees.
- With period of 20 ms and duty cycle of 1 ms, the arm rotates to 0 degrees.

Interfacing servo motor with stm32 microcontroller [1]

- For rotating the arm of a servo motor, there are 3 pins on the microcontroller that are used as input.
  - One pin used for outputting pwm signal
- Port-A pins 0, 1, and 2 are used as inputs
- Port-B pin #6 is used to output the pwm signal

The following article explains how to set up and initialize the ports that are being used as inputs or output (pwm signal). This uses StmCubeMx and Keil MDK ARM. [2]

- Keil IDE is included when the MDK ARM kit is installed, link provided:
    - http://www2.keil.com/mdk5
- Installing StmCubeMx (download StmCube from this link):
    - http://www.st.com/en/development-tools/stm32cubemx.html
- You may have to sign in to StmCube software?

After program installation: [2]

- packages for each stm32 series (or the ones we want to work with) must also be installed
    - StmCubeMx is different from the stm32 series packages
    - Can install packages from the StmCubeMx software
        - Under **Help --> Install New Libraries**

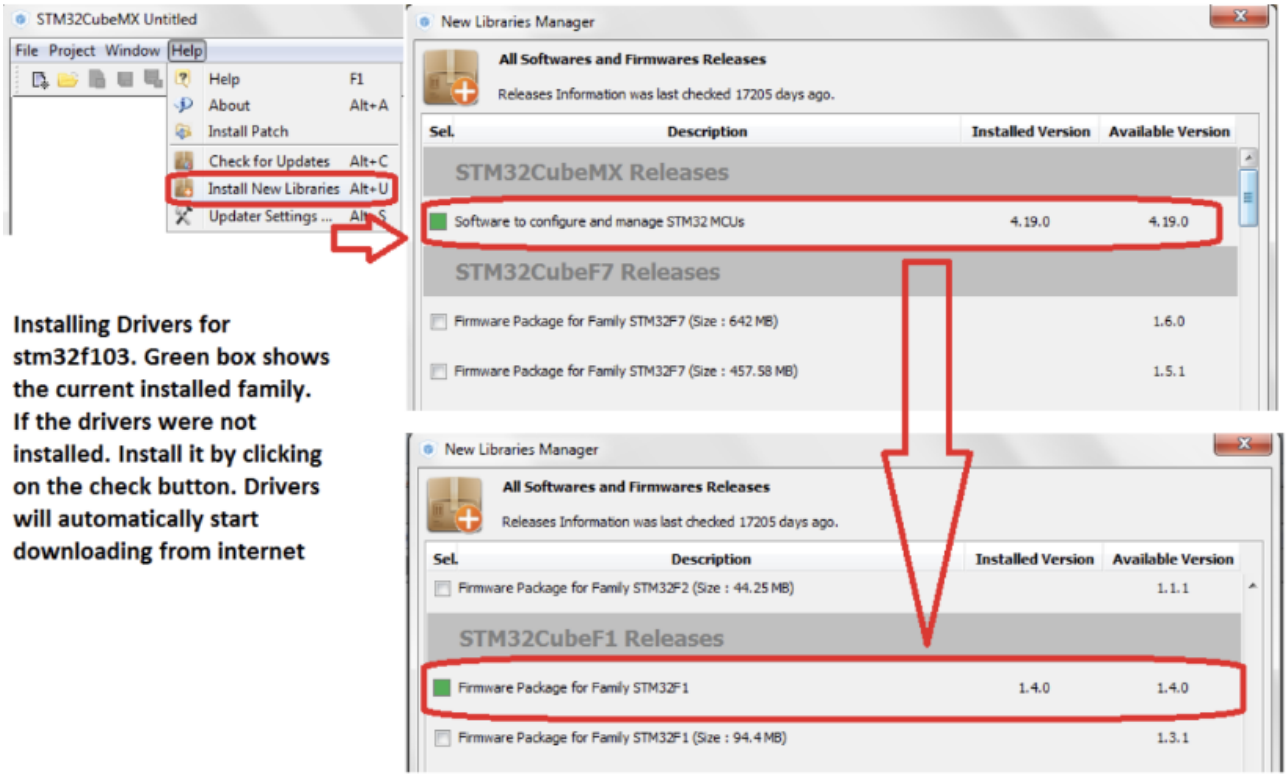


Figure: This figure explains and shows how to install packages in **StmCubeMx**. This example is using an **stm32f103 microcontroller**, so the package to install is **stm32f1 series**

Stm32 Microcontroller Pins: [2]

- Stm32 microcontrollers I/O pins can be used in five different modes:
    - Input mode
    - Analog mode
    - Output mode
    - Alternate function mode
    - External interrupt/event lines

Creating a new Project in StmCubeMx: [2]

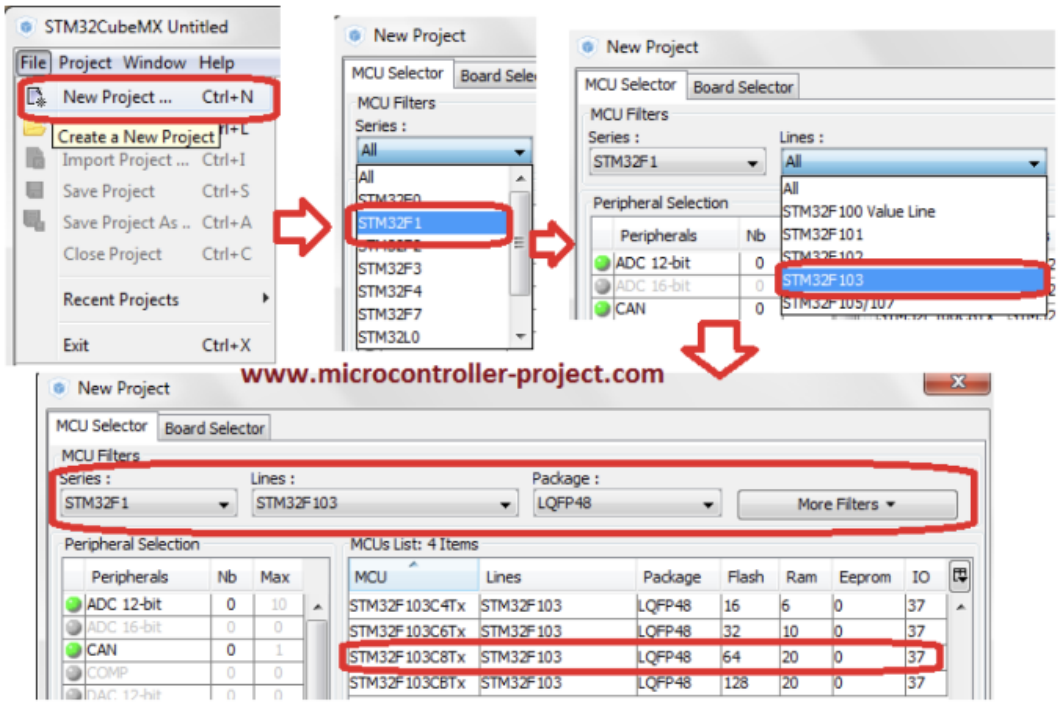


Figure: To create a new project, go to File --> New Project; A window appears that asks you to select microcontroller series, series lines and package. After selecting package, you can click on the microcontroller that is being used for the project. (This case uses STM32f103C8Tx)

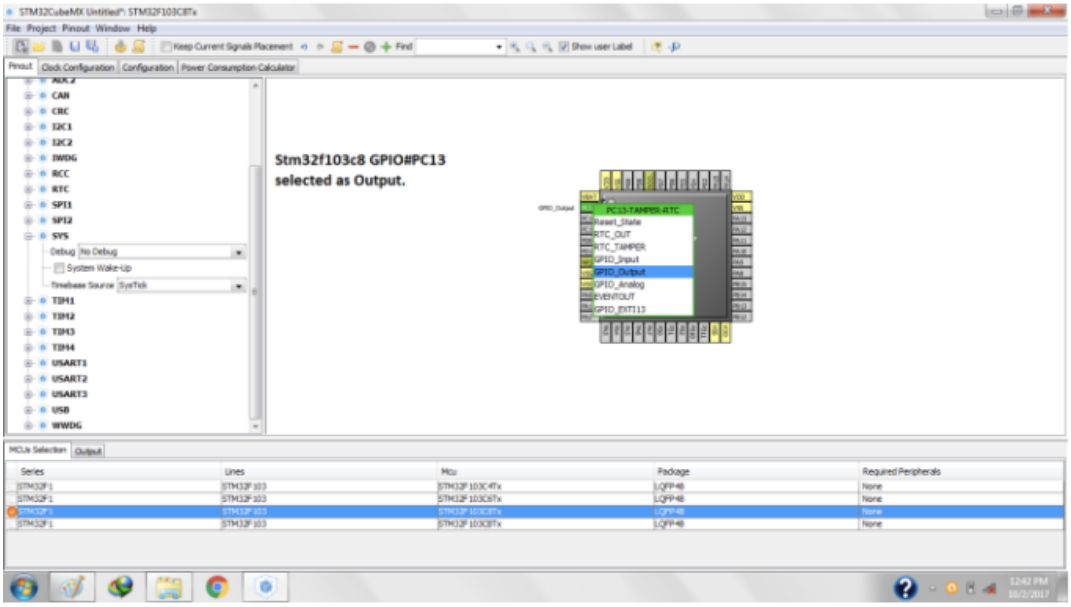


Figure: Next, a window will appear that contains an mcu diagram. Click on pin #13 and set the GPIO as output.

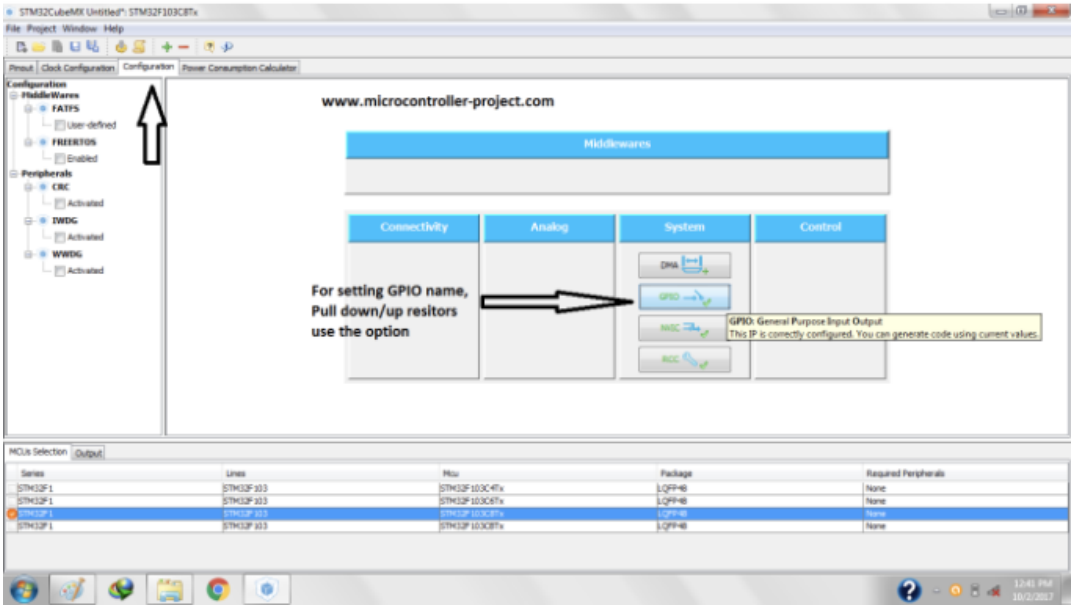


Figure: To configure the GPIO, click the configuration tab and then GPIO button.

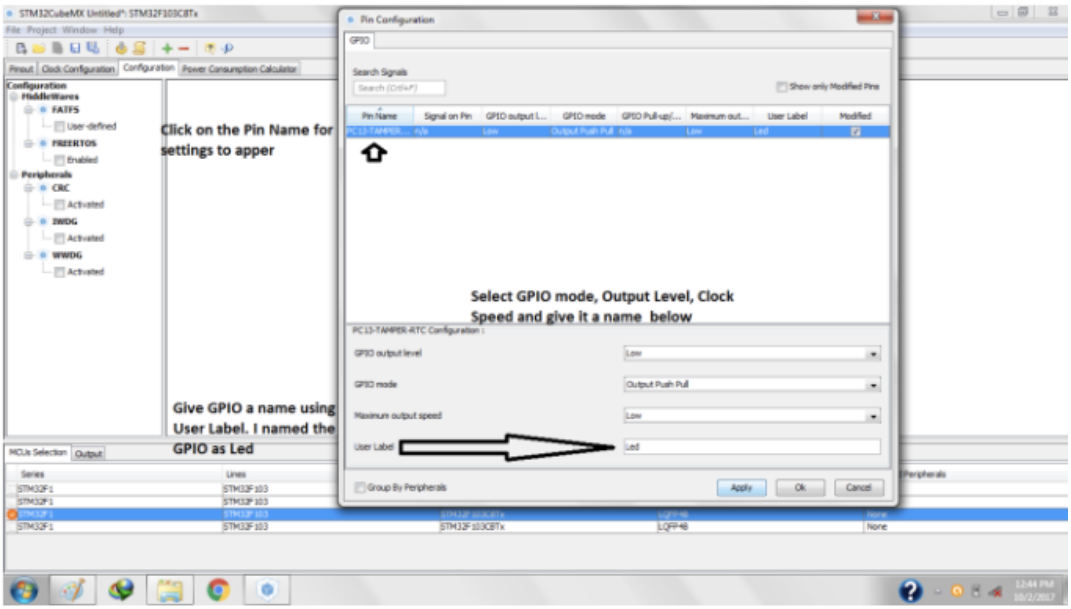


Figure: Click on the pin names for its settings to appear. In the setting window, set the gpio mode, output level, clock speed, and give gpio a name. Press apply to save changes.

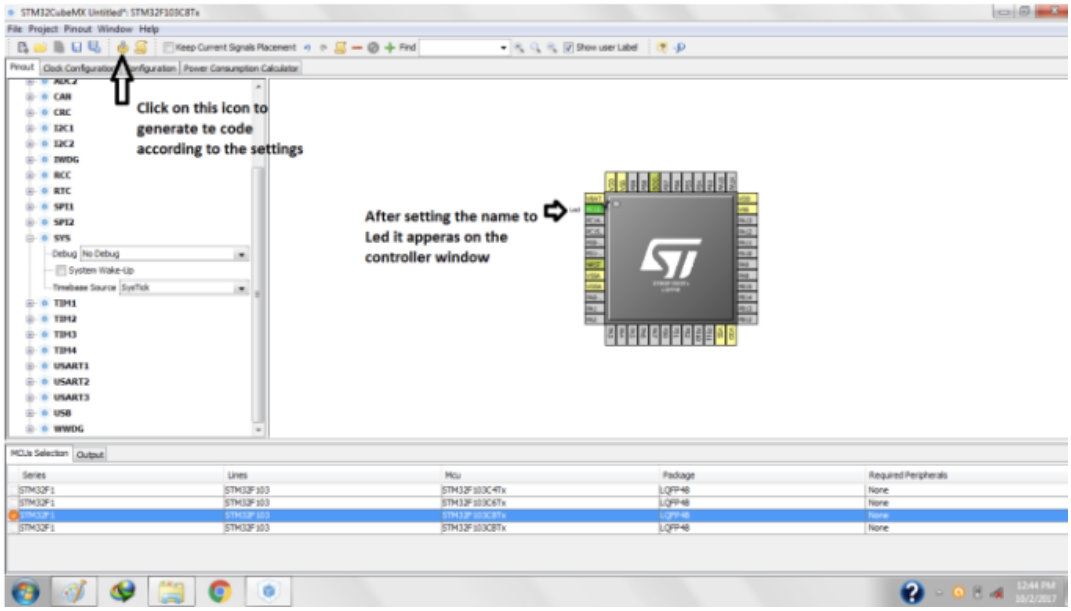


Figure: The name that we set now appears on the pin that was changed. We can use the gpio in code with this name. Next, click on the gear icon to generate code.

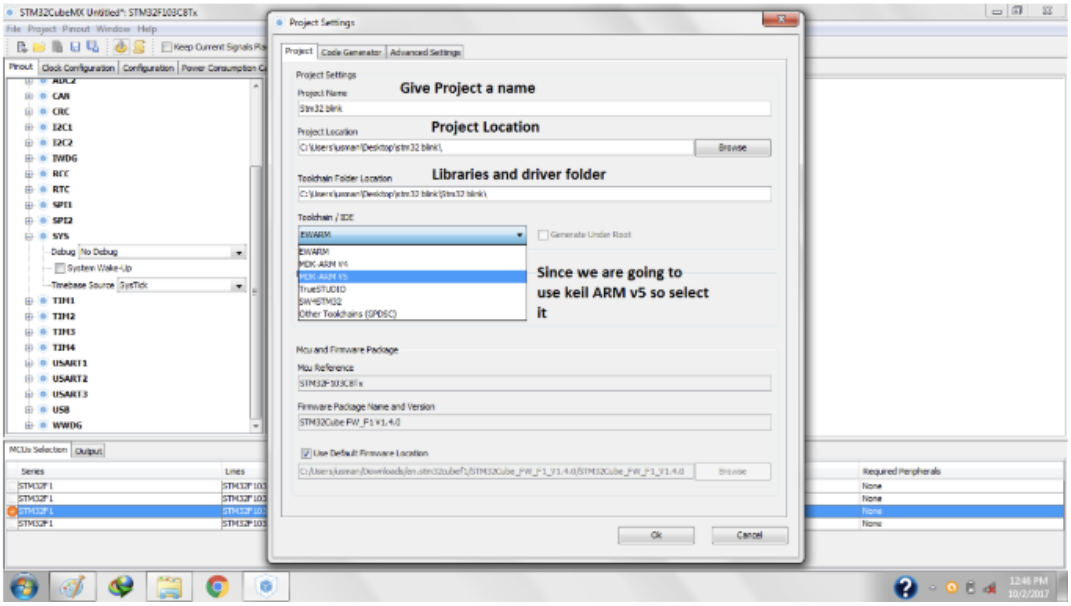


Figure: This window appears after clicking gear icon; Now, fill out the Project name and select Project location. This example uses MDK-Arm V5, so select MDK-ARM V5 under the Toolchain/IDE drop down. Click Ok to generate code.

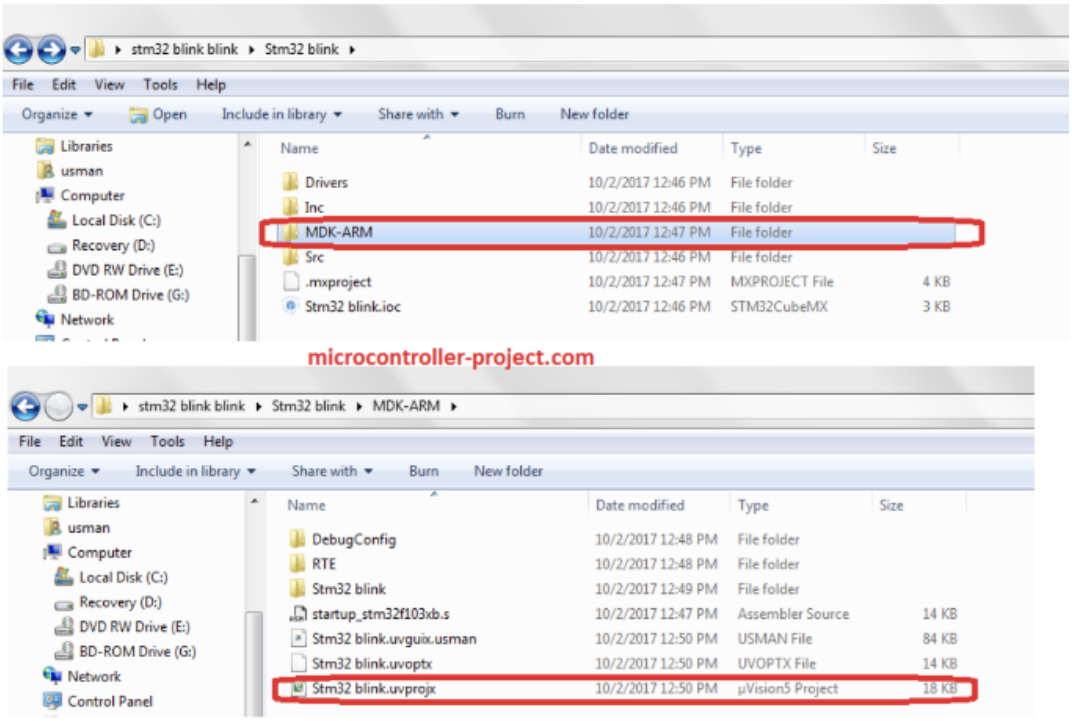


Figure: After clicking Ok, the code will be generated at the selected Project location. Four folders will appear in the selected location (top screenshot). The MDK-ARM folder contains the Keil IDE code. The StmCubeMx project file is the .ioc file (stmcubemx file). Inside the MDK-ARM folder (bottom screenshot), there is a .uvprojx file that is the Keil IDE file. Now, this file can be opened to make changes to the code.

```
1
2  #include "stm32f1xx_hal.h" //This header contains all the functions prototypes for the HAL module driver.
3  void SystemClock_Config(void);   //Initizing System Clock 8Mhz
4  void Error_Handler(void);        //Error Handler- We are not going to use it.
5  static void MX_GPIO_Init(void);  //GPIO Initialization function
6  HAL_Init();                     //Initialize the Hal Drivers
7  HAL_GPIO_TogglePin(Led_GPIO_Port,Led_Pin);      //Toggle Gpio
8  HAL_Delay(1000);                                //Delay 1second
9  __HAL_RCC_GPIOC_CLK_ENABLE();                   //Enable GPIO Clock
10 HAL_GPIO_WritePin(Led_GPIO_Port, Led_Pin, GPIO_PIN_RESET);  //Initialize the GPIO Pin Output Level
11   GPIO_InitStruct.Pin = Led_Pin;                //Pin name we give in StmCubeMx Configuration
12   GPIO_InitStruct.Mode = GPIO_MODE_OUTPUT_PP;   //Pin Mode Puch Pull
13   GPIO_InitStruct.Speed = GPIO_SPEED_FREQ_LOW;  //GPIO speed frequency Low
14   HAL_GPIO_Init(Led_GPIO_Port, &GPIO_InitStruct); //Pass the setting perimeters for initialization
```

getting-started-with-stm32f103.c hosted with ♥ by GitHub view raw

Figure: StmCubeMx translates code that contains the HAL libraries functions with it. HAL are libraries that are released by STM to work with its microcontrollers. The code that is generated by stmcubemx has the statements shown above, the author of the article has added descriptive comments to explain the meaning of each statement.

HAL libraries funtions and definition datasheet available at: http://www.st.com/en/development-tools/stm32cubemx.html

Manipulating the Code: [2]

main.c

```
71  /* Reset of all peripherals, Initializes the Flash interface and the Systick. */
72  HAL_Init();                                              //Initialize the Hal Drivers
73
74  /* Configure the system clock */
75  SystemClock_Config();
76
77  /* Initialize all configured peripherals */
78  MX_GPIO_Init();                                          //Calling GPIO initializing functions
79
80  /* USER CODE BEGIN 2 */
81
82  /* USER CODE END 2 */
83
84  /* Infinite loop */
85  /* USER CODE BEGIN WHILE */
86  while (1)
87  {
88  /* USER CODE END WHILE */
89    HAL_GPIO_TogglePin(Led_GPIO_Port,Led_Pin);             //Togle Gpio
90    HAL_Delay(1000);                                       //Delay 1second
91
92  /* USER CODE BEGIN 3 */
93
94  }
95  /* USER CODE END 3 */
```

Figure: The stmcube only generates configuration code, so all logic based code needs to be written by the user. This article sets up a blinking LED, and this is the Stm32 blink led code associated with it. For blinking the LED, add the **HAL_GPIO_TogglePin(Led_GPIO_Port,Led_Pin);** and **HAL_Delay(1000);** lines to the empty while (1) loop.

```
1
2   #include "main.h"
3   #include "stm32f1xx_hal.h"  //This header contains all the functions prototypes
4                               //for the HAL module driver.
5
6   void SystemClock_Config(void);   //Initizing System Clock 8Mhz
7   void Error_Handler(void);        //Error Handler- We are not going to use it.
8   static void MX_GPIO_Init(void);  //GPIO Initialization function
9
10  int main(void)
11  {
12
13    HAL_Init();                                  //Initialize the Hal Libraries
14
15    /* Configure the system clock */
16    SystemClock_Config();
17
18    /* Initialize all configured peripherals */
19    MX_GPIO_Init();                              //Calling GPIO initializing functions
20
21    /* USER CODE BEGIN WHILE */
22    while (1)
23    {
24      HAL_GPIO_TogglePin(Led_GPIO_Port,Led_Pin);              //Toggle Gpio
25      HAL_Delay(1000);                                                  //Delay 1 second
26    }
27
28  }
29
```

Figure: In line 21, where it says /* USER CODE BEGIN WHILE */, this is where the input information goes to blink the LED. The rest of this source code file is below:

Source code for STM32:

https://gist.githubusercontent.com/d-boz-wtwh/2d68c082defb520202a052c9e565e4e1/raw/03dbd40334b6a91d7fc2a564b89c37418e041dd1/getting-started-with-stm32f103.c

Uploading the code to stm32 microcontroller: [2]

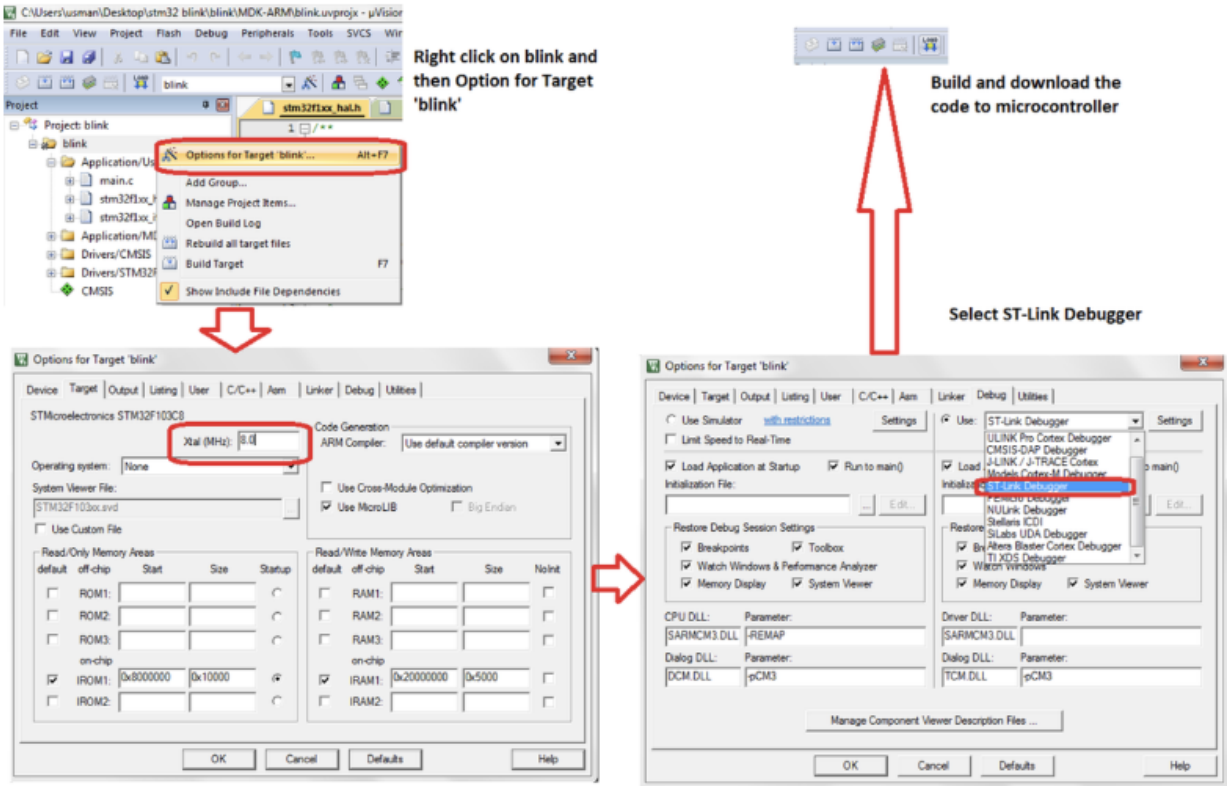


Figure: The development board has no on build programmer, so the author used an external stlink programmer to upload the code onto the board. To do this properly, the correct settings in kiel must be used. Follow above steps to upload the code.

Note: After uploading the code, you must press the reset button on the board, or else the code will not work.

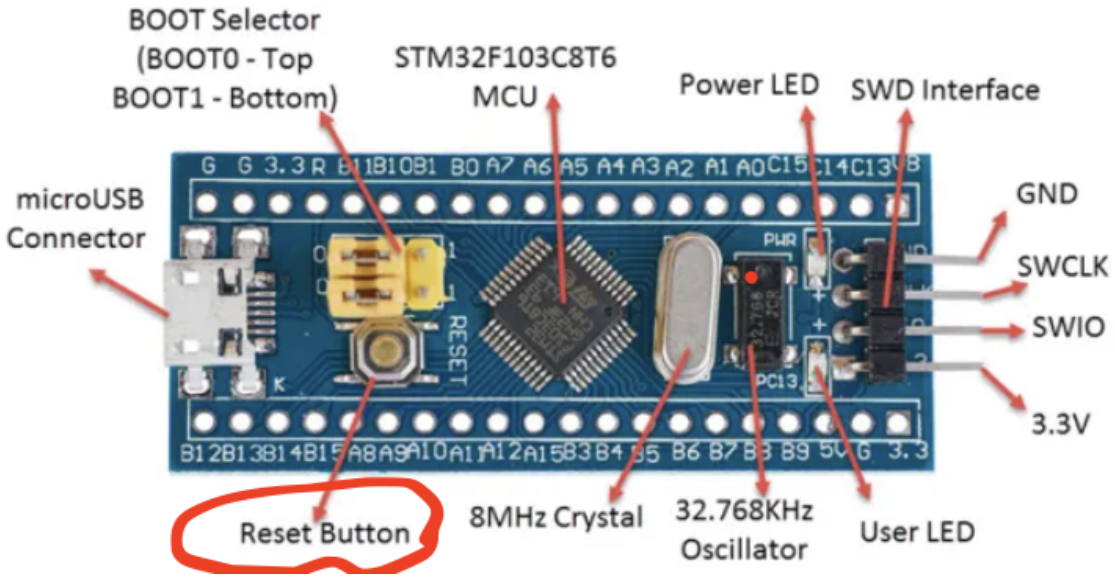


Figure: This figure shows where the reset button is located on the Stm-32 microcontroller (and other labeled parts of the board).

References:

[1] Projects, EG, and Usman Ali Butt. “Controlling Servo Motor with Stm32f103 Microcontroller Using stm32cubemx Code Configurator by STMicroelectronics and Keil Uvision 5 Ide for Cortex m1 Series Microcontrollers.” *Engineers Garage*, 28 Oct. 2020, www.engineersgarage.com/stm32/interfacing-servo-motor-with-stm32/.

[2] Projects, EG, and Usman Ali Butt. “Blink Led with Stm32f103c8 Microcontroller Keil and Stmcubemx.” *Engineers Garage*, 28 Oct. 2020, www.engineersgarage.com/electronic-projects/getting-started-with-stm32f103/.

Conclusions/action items:

This tutorial explains how to get started with Stm32CubeMX and Keil ARM-V5 IDE. It walks through how to set pins to specific inputs and outputs. This [2] tutorial was found within the [1] tutorial which is a more advanced tutorial that interfaces a servo motor with the nucleo microcontroller. This 2nd tutorial was linked within the first, and is necessary information to understand the next article. This tutorial will help me get started with this software, so I can build up to the point of understanding the servo motor tutorial, and eventually programming it myself in the software.

2020/11/08: Stm32 Pulse Width Modulation signal generation

NAMAN PATEL - Nov 15, 2020, 6:43 PM CST

Title: Stm32f103 Pulse Width Modulation signal generation using internal timers, keil MDK-ARMv6 and Stmcubemx IDE

Date: 11/08/2020

Content by: Naman

Present: myself

Goals: To learn about generating pwm (pulse width modulation) signals using the same softwares used in earlier research. The pwm signal is used to control a servo motor, and this article serves as prerequisite information that will help me understand and research the tutorial article that lays out how to power and program a servo motor to work with a Nucleo (Stm32) microcontroller.

Content:

Introduction to pwm and duty cycle:

- A simple led can be derived from a fixed pwm signal output
- the LED will dim and blink according to the duty cycle and frequency of the the pwm pin that is outputting
- This article generates an output with following calculations:
    - Output signal: 1 Hz frequency and 50% duty cycle pwm signal
        - uses timer-4 of stm32f103 microcontroller
    - Timer-4 channel-1 used to output signal
    - "Channel-1" corresponds to the PB6 pin of the stm32f103 microcontroller
        - LED connected to PB6 where the pwm output can be seen
- 1 Hz frequency with 50% duty cycle refers to an LED that blinks every half second
    - 1 Hz in frequency --> T = 1/f --> 1 second in time
    - 50% duty cycle results in blink rate of half a second

How to Generate Desired/Specific PWM Frequency [1]

- Formula requires knowledge of a few terms outlined here:
    - Timer Tick frequency: frequency at which the timer is completing one instruction cycle
    - Counter frequency: frequency that we want our timer tick counter to increment-
    - PWM resolution: number of pwm steps required to generate the required counter frequency
        - Usually an arbitrary number that is adjusted as needed
        - Pwm resolution must be between 0-65535 (due to maximum 16-bit count)

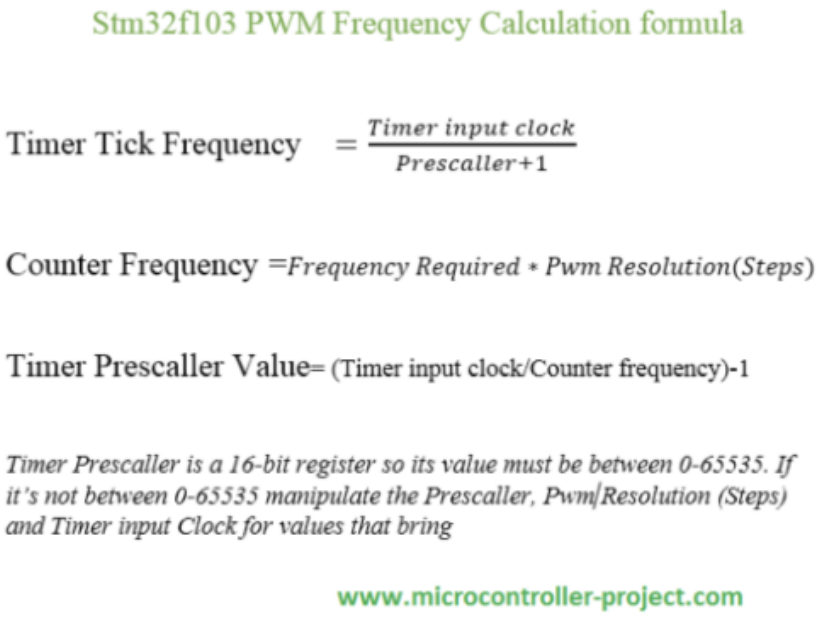


Figure: Stm32f103 Pwm (pulse width modulation) frequency calculation formula

Next, we need to plug in the counter frequency with its formula into the Timer Prescaller Value equations to get this equation:

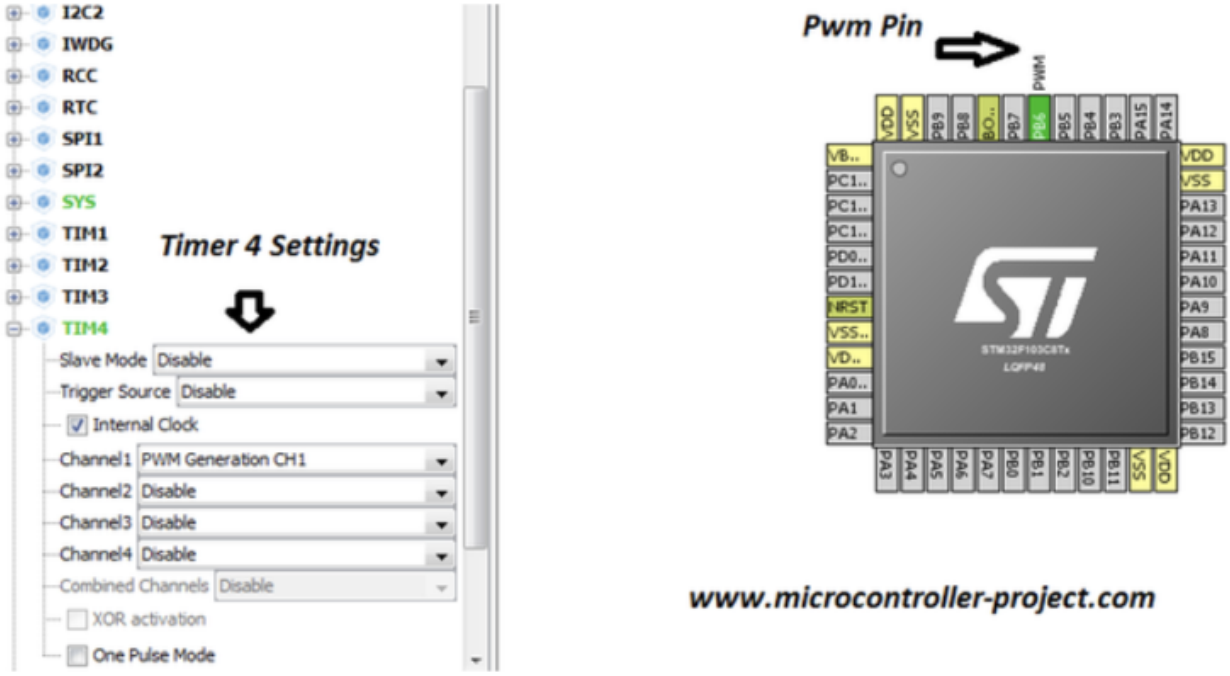
Replacing Counter Frequency. The Final formula to calculate the Timer Prescaller comes out to be.

$$\text{Timer Prescaller Value} = (\textit{Timer input clock} / (\textit{Frequency Required} * \textit{Pwm Resolution(Steps)})) - 1$$

Figure: Final formula to calculate Timer Prescaller Value

Next, we need to assign either Timer Prescaller Value or Pwm Resolution (steps) as a fixed value, so that we can calculate the other parameter.

Stmcubemx code initializing steps and generating Keil MDK-ARM code



Stm32f103 timer 4 configuration using input HSI Clock

Figure: The 4 16-bit timers for stm32f103

- Stm32f103c8t6 has 4 16-bit timers, TIM1, TIM2, TIM3, and TIM4.
- Timers 1 and 2 have peripheral functions, while Timers 3 and 4 do not have any other function
    - All 4 timers can be used to generate pwm signal, but safe option is timer 3 or 4.
- Tutorial uses timer 4, channel 1 for pwm output
    - Channel 1 corresponds to pin B6 of stm32f103
- HSI (High Speed Internal) oscillator/clock store used
    - Final clock supplied to timer 4 is 0.0625MHz
    - Final timer input frequency: 62500 Hz

Calculating values for 1Hz frequency and 50% duty cycle pwm signal output

- Given values:
    - Timer Input clock = 0.0625 Mhz or 62500 Hz
    - Required Frequency = 1 Hz (1 second in time domain)
    - Counter Period/Pwm Resolution (Steps): randomly picked value (3906)
- Counter Frequency = frequency required * Counter period
    - Counter freq = 1 Hz * 3906 = 3906 Hz
- Timer Prescaller value = (Timer Input Clock/Counter frequency) - 1

    - Timer Prescaller value = (62500 Hz / 3906 Hz) - 1 = 15

- With these calculations, we have the Timer Prescaller value and Counter period/pwm resolution (steps)
- We can input these values into the timer 4 configuration (whichever timer chosen)

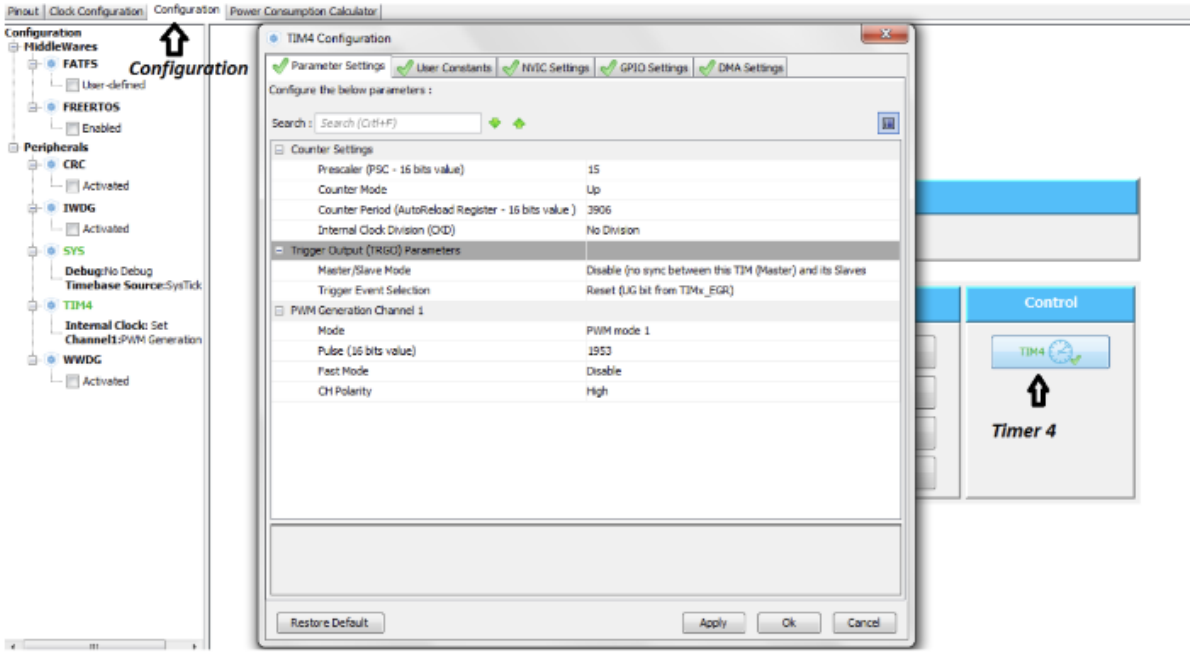


Figure: Inputting the calculated values into the timer 4 configuration.

Source code associated with pwm timer initialization:

https://gist.githubusercontent.com/d-boz-wtwh/81d0b2cb32798a4be68ee38e26d403d3/raw/56b7ff41428a10fb08460fd56e2619f0e145e526/stm32-pwm-generation-using-timers.c

Stm32f103 Variable pwm signal output with timers, keil arm-mdk and stm32cubemx ide [2]

- Circuit Diagram:
    - simple connection between positive anode of led to pin PB-6 and the ground to the negative cathode
- Tutorial will increment duty cycle of output signal from 0 to 100% and back from 100% to 0%.
- The function of incrementing up to 100% or down to 0% is controlled by a for loop in the following code:
    - https://gist.githubusercontent.com/d-boz-wtwh/deaf13b78607d86be3161c28f2ad3b13/raw/d26ebd1d25bebbb906aaa61357e2f1d6c03a5dfa/stm32-variable-pwm-with-timers.c

Reference:

[1] Projects, EG, and Usman Ali Butt. “Stm32f103 Pwm(Pulse Width Modulation) Signal Generation Using Internal Timers, Keil MDK-ARMv6 and Stmcubemx Ide.” *Engineers Garage*, 27 Aug. 2019, www.engineersgarage.com/stm32/stm32-pwm-generation-using-timers/.

[2] Projects, EG, and Usman Ali Butt. “Stm32f103 Variable Pwm(Pulse Width Modulation) Signal Output with Timers, Keil Arm-Mdk and Stm32cubemx Ide.” *Engineers Garage*, 14 Apr. 2019, www.engineersgarage.com/stm32/stm32-variable-pwm-with-timers/.

Conclusions/action items:

This article outlines how to calculate necessary values to configure the StmcubeMx software internal timer to generate the desired pwm signal that will eventually control the servo motor. This will be very important for us when we write the code to control the servo motor.

2020/11/16: Controlling Servo Motor with Stm32f103 micrcontroller

NAMAN PATEL - Dec 11, 2020, 2:09 AM CST

Title: Controlling Servo Motor with Stm32f103 micrcontroller using stmcubeMx

Date: 11/15/2020

Content by: Naman

Present: myself

Goals: Learn how to control a servo motor with an Stm32f103 microcontroller.

Content:

Servo with stm32 microcontroller: [1]

- Rotating servo motor arm: three pins of microcontrollers used as input
    - Port-A pins 0,1, and 2
- Output pwn signal: one pin used
    - Port-B pin #6
- The tutorial uses 2 different servo motors and goes through the set up for both. Since they have different power sources and values associated with them.
    - As a result, one of the servo motors requires an inserted circuit to convert the voltage to the appropriate value
    - The below figure depicts this circuit as well as the ports on the microcontroller

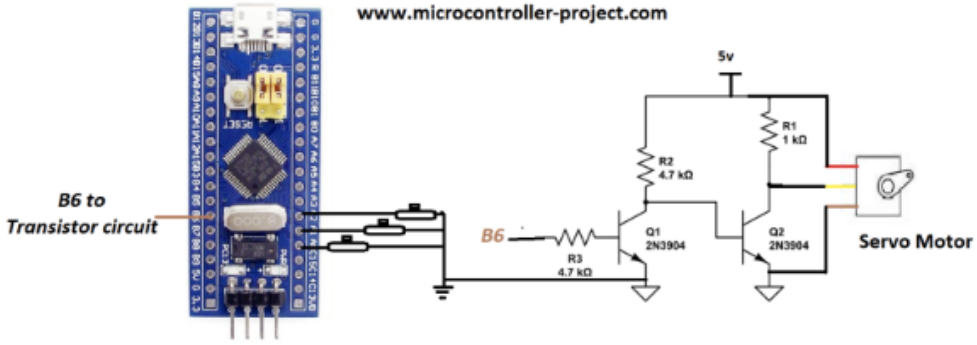


Figure: This figure depicts the stm32f103 microcontroller, the pin locations on the microcontroller, and the circuit used to alter the voltage so that it is compatible with the power source of the servo motor. The grounds of both motor and microcontroller should be common.

Next, initialize the 3 Port-A pins (1,2, and 3) in stm32cubeMX. The instructions to do this are located in a prior LabArchives entry under the Electronics Components folder.

Output pwm signal:

- The pwm signal will be output on PB6 (Port-B pin 6)
    - This requires some configurations in the settings
- Here, an understanding of pwm settings and formulaic calculations is needed
    - There is a LabArchives entry on how to do so in the Electronic Components folder
- Set up:
    - The internal stm32 microcontroller oscillator is used in the project
    - Uses internal oscillator (external oscillator present but internal is what is used)
    - Final clock to timer 4 is 1 MHz

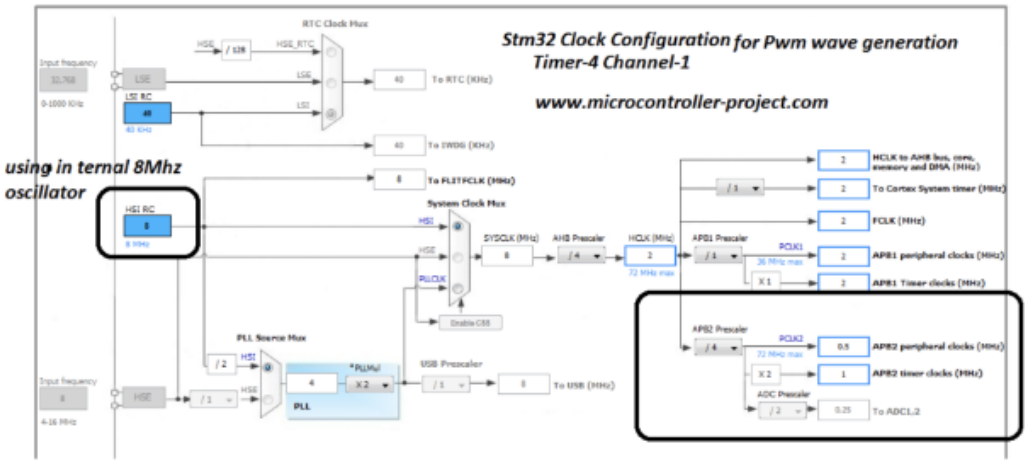


Figure: This figure shows the settings configuration for the stm32 clock for timer 4 channel 1 in stm32cubemx.

Next, input other required values into the timer 4 configuration. These values and calculations are outlined in the earlier LabArchives entry (in Electronic Components folder).

Figure: The timer-4 configuration settings; this shows the setting of pwm counter period and duty cycle

- The used counter period is 1000
  - This means that at 1000, the pwm duty cycle will be 100% with period 20 milliseconds or 50 Hz frequency
  - At 500 pwm duty cycle, it will be be 50% which translates to 10 milliseconds
  - At 5%, it will be 1 millisecond
  - At 10%, it will be 2 milliseconds
  - At 7.5%, it will be 1.5 milliseconds

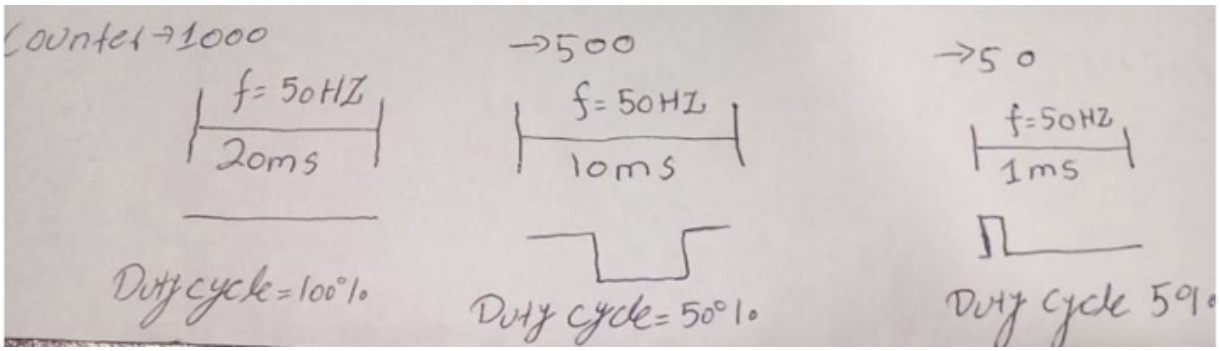


Figure: The relationship between counter period, frequency, time, and duty cycle.

In code, the counter value is used to move the servo motor arm. In the code shown below:

- when button-3 is pressed, the motor moves to 180 degrees.
- when button-2 is pressed, the motor moves to 90 degrees.
- when button-1 is pressed, the motor comes back to 0 degrees.

```
1
2   if(HAL_GPIO_ReadPin(GPIOA,G180_Pin)==GPIO_PIN_RESET)
3   //2ms Pwm - Servo motor arm rotates to 180 degree
4   __HAL_TIM_SetCompare(&htim4, TIM_CHANNEL_1, 100);
5
6   if(HAL_GPIO_ReadPin(GPIOA,G90_Pin)==GPIO_PIN_RESET)
7   //1.5ms Pwm - Servo motor arm rotates to 90 degree
8   __HAL_TIM_SetCompare(&htim4, TIM_CHANNEL_1, 75);
9
10  if(HAL_GPIO_ReadPin(GPIOA,G0_Pin)==GPIO_PIN_RESET)
11  //1ms Pwm - Servo motor arm rotates to 0 degree
12  __HAL_TIM_SetCompare(&htim4, TIM_CHANNEL_1, 50);
```

interfacing-servo-motor-with-stm32.c hosted with ❤ by GitHub view raw

Figure: Shows the code used to associate the 3 buttons with an angle of servo motor arm movement.

[1] Projects, EG, and Usman Ali Butt. “Controlling Servo Motor with Stm32f103 Microcontroller Using stm32cubemx Code Configurator by STMicroelectronics and Keil Uvision 5 Ide for Cortex m1 Series Microcontrollers.” *Engineers Garage*, 28 Oct. 2020, www.engineersgarage.com/stm32/interfacing-servo-motor-with-stm32/.

Conclusions/action items:

This tutorial outlines the process by which you send an output pwm signal to a servo motor. The previous labArchives submission refers to a tutorial in which the author explains how to calculate the values needed for this pulse width modulation signal. Further the author includes the code that is generated from Stm32CubeMX with comments included to explain different aspects of the code. The full source file is provided, and I will be able to generate my own signals and code, and then be able to compare my source code file to his, while also being able to utilize the comments to understand the various parts of the code. This tutorial is great starting point in generating the correct code to perform the desired actions.

2020/12/10: Code Flowchart and Source Code for Nucleo

NAMAN PATEL - Dec 11, 2020, 12:54 PM CST

Title: Code Flowchart and Source Code for Nucleo microcontroller

Date: 12/10/2020

Content by: Naman

Present: myself

Goals: Show the code flowchart, give a brief description of the code, and include the code in LabArchives.

Content:

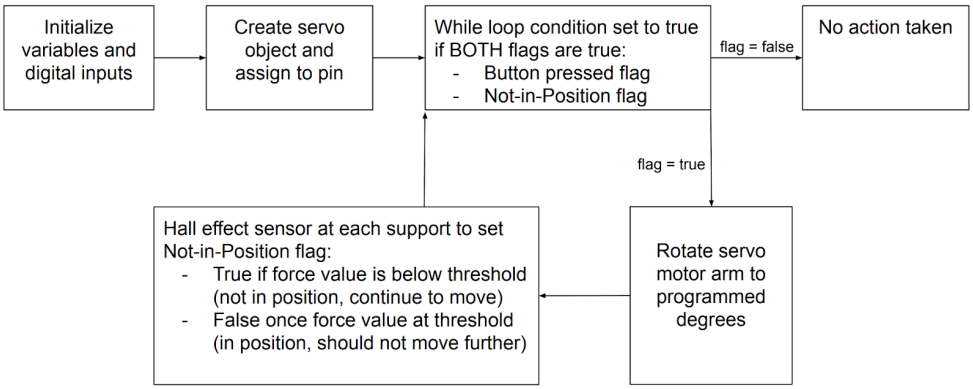


Figure: This code flowchart gives an overview of the steps taken in the code.

The code first initializes a boolean variable that tracks the positioning of the support. This boolean is set to true or false based on a Hall effect sensor. The hall effect sensor will set boolean inPosition to true when the sensor reads that the support is in restraining position. The boolean will be set to false if the support once in the at rest position, behind the client's wheelchair. Based on the positioning of the support (in restraining position or at rest position) and whether the forward or backward buttons are pressed, will allow the support to move. The forward and backwards buttons are the digital inputs initialized at the beginning of the code. If the inPosition flag is set to true, and the forward button is pressed, then only the support will move from restraining to at rest. If the inPosition flag is set to false, and the backward button is pressed, then only the support will move from at rest to restraining. The servo motor arm is moved using the position() function, which is defined in the "servo.h" library.

Source Code:

```
#include "Servo.h"

#include "mbed.h"


//inPosition flag: T = restraining position; F = at rest position

bool inPosition = false;

DigitalIn Dforward(D5);

DigitalIn Dbackward(D6);

DigitalIn hallEffect(D7); //Feedback from Hall effect sensor sets inPosition to T or F
```

```
Servo myservo(A5);


int main(){


    while(1){
        if(hallEffect == 1){
            //sensor reads that support is in restraining position
            inPosition = true;
        }
        else{
            inPosition = false;
        }


        //In at rest position and forward button is pressed
        if(inPosition == false && Dforward == 1){
            //move support into restraining position
            myservo.position(3000);
        }
        //In restraining position and backward button is pressed
        else if(inPosition == true && Dbackward == 1){
            //move support backwards into at rest position
            myservo.position(-3000);
        }
        else{}
    }
}
```

Conclusions/action items:

This submission shows the code flowchart, gives a brief description of what the code does and explains some of the variables, and includes the full source code. This will be helpful to refer back to by the team when needed. This degrees of movement will change once the team is able to test, as it is currently set to an arbitrary 3000 degrees. This code successfully compiles without error and accomplishes the tasks the group is hoping to achieve with this wheel chair adaptation device.

2020/09/26: Ceiling Lift Chair

NAMAN PATEL - Oct 07, 2020, 12:28 AM CDT

Title: Design Idea based on ceiling lift

Date: 09/26/2020

Content by: Naman

Present: myself

Goals: Describe a design idea that uses the existing ceiling lift that our client has.

Content:

This design can be described as a chair that the patient can sit in, and that can be lifted by the existing ceiling lift that the client already has.

- Idea comes from seeing client maneuver the ceiling lift with ease, explaining that he is able to move it back and forth with relatively low force, and it is able to slide back and forth very easily.
- Chair would include padding that is form-fitted to the client's body.
- The Ceiling lift is capable of holding up to 1500 pounds according to the client, and also has a high factor of safety on top of that.
- Would allow for chair to be raised in the same way the ceiling lift raises the client currently.
    - The ceiling lift has rails that go along the ceiling, and attached to the rails is a cord that comes down; at the end of the cord there is this clothes-hangar-type device by which the client is able to insert the harness that he wears all the time into.
    - Then, he is able to use the controller to raise himself into the air, and go wherever he needs to go, and then finally lowering himself into wherever he wants to end up.
    - This design idea would include a similar lifting mechanism, however instead of a cloth harness/sling, it would be a fabricated heavy duty chair.
        - The "hangar" would lift up using a metal frame that goes around the chair (above the head of the client), and would be positioned carefully so that it accounts for the client's center of mass, thus being positioned somewhere closer to the back, but in the middle so that the client has no worry or risk of tipping over.
    - Finally, this chair would allow us to implement a simple 1axis gimbal system that would allow for the client to move around in plane, 360 degrees. The client would be able control the chair the same way that he is able to control the ceiling lift, and would allow him to spin, achieving one aspect of the client's requirements/desires.

Conclusions/action items:

After discussion with the team, this design seemed less possible to implement using the ceiling lift because of concerns regarding how this would be implemented without disturbing the normal usage of the ceiling lift. The client relies on the ceiling lift to get from place to place by himself on a daily basis. The usage of this device may prove to be difficult to maneuver around using the ceiling lift. Further, the other design ideas that the team came up with seem to have much more potential for implementation. There are other concerns regarding this device such as, what if the client replaces his ceiling lift, or moves to a different area? Then, this device may no longer be compatible with the new system. This also only achieves one of the client's desires, allowing him to be able to spin in 360 degrees, and allowing him to do some exercises that can get him into different positions. Further, the device may be too wide once fabricated to fit through the client's door frame. Because of these reasons, the team decided to pursue other designs.

2020/10/7: Green Pass

NAMAN PATEL - Oct 07, 2020, 3:05 AM CDT

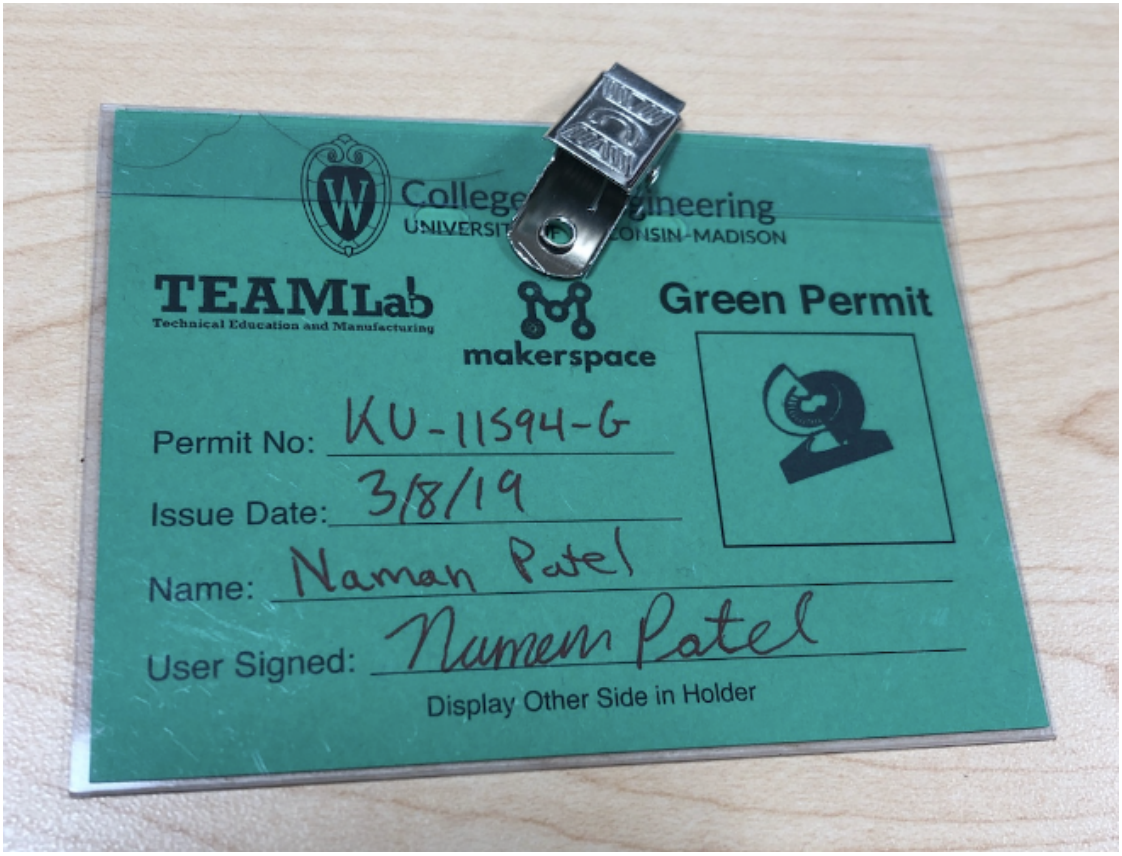
Title: Green Pass certification

Date: 10/7/2020

Content by: Naman

Goals: To display certification of Green pass

Content:



Conclusions/action items:

This green pass permit allows me to use the Team lab in the Engineering Centers Building.

2020/09/14: Core Dump from first meetings

NAMAN PATEL - Oct 07, 2020, 1:38 AM CDT

Title: Core dump from first meetings with client and advisor

Date: 09/14/2020

Content by: Naman

Present: myself

Goals: To get all the information possible out after meeting with client and advisor for the first time (2-2.5 hours of meeting time)

Content:

- This is going to be a very exciting semester
- Will be learning all sorts of new things regarding bioinstrumentation and biomechanics
- Will learn ins and outs of Spinal Muscular Atrophy
- We can use arduino microcontrollers
- Slip Thing that allows for concentric circles (gyroscope) to be motor controlled
- Keith was able to crawl until age 14
    - This is how he got everywhere
    - Never been able to walk
    - Misses feeling of being able to crawl
    - As a child, could get into any position except being able to walk
- Takes a supplement recently approved by FDA that allows for his condition to not progress
- Designing the chair/device so that he has the ability to go upside down
- He is able to stand up about 75% of the way
    - This is kind of how he stands in his stand up wheel chair
- He has lots of friends that he knows that have the same or a similar NMD condition
    - Has the potential to help a lot of people
    - He knows a lot of people that would love to be able to use such a device
- Some patients with NMD disorders would struggle to be able to get into the chair using the hoyer or ceiling lift
    - Forgot the name of the disorders but in cases the bones are brittle and can break easily
    - Some patients require 200 surgeries over their lifetime because their bones break so easily
- Will be using solidworks
- Photogrammetry will be used to be able to capture his body so that we can input it into a CAD software, and model it based on that
    - Thoughts include introducing OR modeling based on the image, some padding that is specifically made for him
    - For future references, this device could be something that is custom made for each patient, allowing for very comfortable padding that supports specific aspects of the patient’s body

        - This would allow for additional customization and making it easier and specifically intended for certain patients
            - Could introduce special case or changed design for someone who has very brittle bones and would be unable to get into the device with a hoyer or ceiling lift
- Facelifting is a cool thing we could use
    - 4 different orientations of life size models of people to design the device
- Mitch will be there for us as an additional team member, but will fill many roles
    - Keeping us on track- asking for deliverables to be sure we are planning and using our time well
    - Providing counseling when needed
    - Providing guidance or access to resources
- Very excited to be able to help someone very directly

Conclusions/action items:

Use this core dump to refer back to the things immediately on the mind following the extensive meetings of the day; lots of information given to us, and this allows for as little of that information to be lost as possible

2020/10/06: Project Impact

NAMAN PATEL - Oct 07, 2020, 3:01 AM CDT

Title: Project Impact

Date: 10/6/2020

Content by: Naman

Present: myself

Goals:

Learn about the impact that this project can have, and how spinal muscular atrophy affects patients

Learn about the existing problem and how a device can provide a solution to the problem

Content:

- Our client has been diagnosed with Type 2 Spinal Muscular Atrophy. He has never been able to walk, but was able to crawl up until age 14. At that point, he was unable to do so, and needed a wheelchair to get around. He explained to us that he has never been able to crawl since then, and this is a feeling that he misses quite a bit. One of the client requirements/desires was for us to build him a device that would allow him to get into the prone position, and that request comes from this desire to be able to go into the crawling-like position once again. Spinal muscular atrophy comes in 5 types, generally classified by age of onset. With SMA, the earlier you are diagnosed, the more severe the case is, with type 1 being the most severe (age of onset 0-6 months; death generally prior to age 2) [1]. Our client explains that he knows many people who have been diagnosed with a Neuromuscular disorder and could greatly benefit from a device that allows them to move around in various positions. The main goal of such a device is to allow the patient to be able to get into positions they would normally be unable to get into. This allows for bloodflow to areas that normally do not receive it and can allow for increased flexibility, and overall a very good feeling for the patient. When our client was able to go on an action track wheelchair, or use a gator (golf-cart type vehicle) he felt "better than he ever felt before". We believe this is largely due to the rush of adrenaline that he got after being able to experience these things- something he regularly is not able to participate in.
- Exercise can help with: improving range of motion, preventing contractures, strengthening muscles, helping breathing to keep respiratory muscles strong, boosting flexibility, helping maintain posture, and improving mood and mental health. [2] Contractures are described by the stiffening of joints that is a result of tightening of muscles, tendons, skin and other tissues. This is a common SMA complication as many SMA patients are in wheelchairs and unable to get into positions on a regular basis that result in limited bloodflow to certain areas. With our device, we hope to be able to give him the opportunity to autonomously use his standing wheelchair so that he can get into a standing position by himself, and at his own time. This will allow for him to be able to make much better use out of his wheelchair, as well as be able to increase bloodflow throughout his body, especially to those areas that normally would see limited blood flow. With this device, we hope to be able to greatly improve his quality of life, and further, many others that have been diagnosed with similar neuromuscular disorders.

Conclusions/action items:

[1] Lunn, Mitchell R, and Ching H Wang. “Spinal Muscular Atrophy.” *The Lancet*, Elsevier, 19 June 2008, www.sciencedirect.com/science/article/pii/S0140673608609216

[2] “Physical Therapy Guide to Spinal Muscular Atrophy.” *American Physical Therapy Association*, 16 June 2020, www.choosept.com/symptomsconditionsdetail/physical-therapy-guide-to-spinal-muscular-atrophy.

9/6/20 Spinal Muscular Atrophy (SMA)

Marissa Harkness - Sep 27, 2020, 2:20 AM CDT

Title: Spinal Muscular Atrophy

Date: 9/6/20

Content by: Marissa Harkness

Present: Marissa Harkness

Goals: To understand what SMA is and discomforts or physical limitations that may be experienced

Content:

What is SMA?

- Genetic disease that affects voluntary muscle movement
- The name "spinal muscular" is attributed to the fact that most voluntary muscle movement is controlled by nerves in the spinal cord and the muscles do not receive signals from the the nerve cells
- Atrophy is the progressive decline or shrinkage of the muscles as a result of them not remaining active

What causes SMA?

- There is a deficiency of a motor neuron protein called SMN (survival of motor neurons) which effects the motor neurons and the muscle cells
- Severity typically correlated with age of onset
- Age of onset correlated with number of SMN

SMN related SMA

- Type 1
    - Most severe
    - Earliest age of onset, birth
    - Usually only live several years
    - Ventilator and feeding tube may be required
    - Emotional and mental abilities are there
- Type 2
    - Onset between 8-16 months
    - Child can start by sitting with no support
    - Proximal muscles effected much sooner than distal
        - I.e. thighs weaker than lower legs and feet
    - Legs weaken before arms
    - Hands remain strongest
    - Children benefit from PT and aids
    - Most serious danger is loss of function with respect to breathing
        - Must pay special attention to infections
    - Scoliosis is another major problem
- Type 3
    - Least severe
    - Latest age of onset
    - Onset is usually after 18 months or the child has taken at least 5 independent steps
    - Many can walk until their 30s or 40s
        - Although some can stop walking as teens
    - May use canes, walkers, etc.
        - With the wheelchair only being needed for longer distances
    - Can survive long into adulthood
- Type 4
    - Begins in adulthood
    - Lumps some of the traits seen in Type 3
- Genetic effect on chromosome 5
- Professionals observe those with SMA to be unusually intelligent

Spinal-bulbar muscular atrophy

- Genetic defect on X chromosome

Non-SMN related SMA

- Has a variety of severities and effects
- Some areas effected the most are the distal body parts like the hands and feet
- Progressive muscular atrophy: unknown origin is effected and motor neurons in spine and lower brain are hindered
- ALS: condition involves motor neurons in upper portion of brain

Respiratory muscle weakness

- Main cause of death for those with type 1 and 2 SMA
- When respiratory muscles weaken, air does not move into and out of the lungs well

Swallowing muscle weakness

- Weakness of mouth and throat muscles
- Can make eating difficult
- Can increase changes of choking

Back muscle weakness

- Curvature of spine as a child can lead to scoliosis
    - Progression can be slowed with a brace
    - Usually spinal fusion surgery is desired once the child is done growing
        - However, often times children cannot wait this long because their immune system can become compromised
- Anethesia concerns
    - Concerns in how the body will respond to muscle relaxing drugs

Best exercises

- Exercise without pushing it to the extreme for physical and mental well-being
- Protect joints from stiffness or injury
- Preserve range of motion
- Maintain circulation
- Exercising in a warm pool can be beneficial

Diagnosing SMA

- Physical examination and family history
- Blood work for creatine kinase (CK) enzyme
    - High numbers indicate muscle damage
- Genetic testing
    - Requires blood sample from you and family members
- Occasionally a muscle biopsy is recommended for further analysis
- Electromyogram (EMG) to see the speed at which nerves respond to signals

Conclusions/action items:

I learned about what SMA is, specifically the four different types of SMA. There are a variety of methods used to diagnosis a person with SMA. It is important to understand the prognosis, as well as methods of treatment and exercise to best meet the patients needs and retain as much function as possible. I need to do further research on ways to exercise and stretch a patient who suffers from being confined to a wheelchair due to SMA.

Reference:

Mda.org. 2020. [online] Available at: <https://www.mda.org/sites/default/files/publications/Facts_SMA_P-181.pdf> [Accessed 6 September 2020].

9/12/20 Exercises for Patients with SMA

Marissa Harkness - Oct 06, 2020, 11:02 PM CDT

Title: Exercises for Patients with SMA

Date: 9/8/20

Content by: Marissa Harkness

Present: Marissa Harkness

Goals: To better understand exercises for increasing movement and blood flow for patients with SMA

Content:

The exercises and adaptive equipment listed below are beneficial for children with SMA. Children with SMA typically lose movement and flexibility with age. While the article was predominately geared towards children, the exercises can possibly be implemented in our design. The extent of all the described are dependent on age, developmental stage, and neuromuscular involvement.

Therapeutic exercise in SMA is used to improve function, range of motion, independence, and overall quality of life. Functional exercise is the performance of movements that one would like to accomplish throughout the day. Rolling, reaching, and sitting are all functions that can help improve daily activities.

Range of motion is movement and flexibility of the joints. ROM is maintained through stretching and without stretching, these muscles get tight. When the tightness becomes permanent, this is called a contracture. Contractures can prevent normal movement and increase discomfort.

Weightbearing is beneficial for muscles and bones. Standing can improve bone strength, respiratory, and bowel functions. Devices are used to help a person achieve a standing position. Some standers help a person lie on their belly; this is called the prone position or their backs which is the supine position.

Water therapy allows for your body to be lighter and easier to move due to buoyancy in the water.

Chest physical therapy can help with respiratory function as it helps with clearing lung secretions.

Conclusion/Action Items:

We need to reevaluate the most critical design components to improve Keith's well being. This article indicates prone and supine position, as well as standing, to be critical for patients with SMA. We also need to clarify the location of Keith's contractures and how this can interfere with our design.

Reference:

Columbiasma.org. 2020. *Living With Spinal Muscular Atrophy (SMA), Physical Therapy*. [online] Available at: <http://columbiasma.org/pt-ot.html> [Accessed 12 September 2020].

9/30/20 Understanding SMA through Images

Marissa Harkness - Oct 07, 2020, 12:15 PM CDT

Title: Understanding SMA through Images

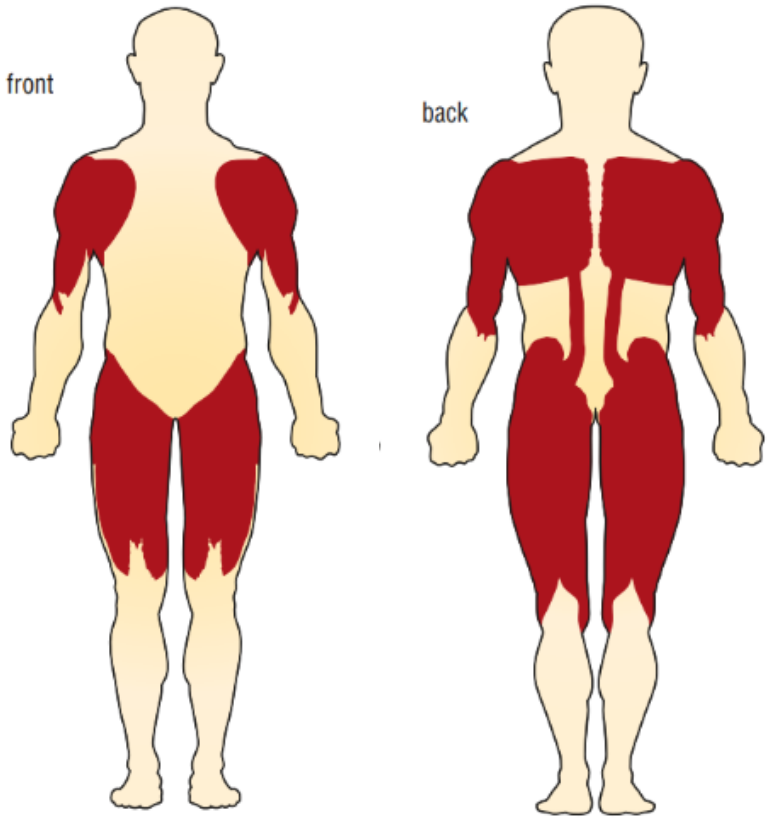
Date: 9/30/20

Content by: Marissa Harkness

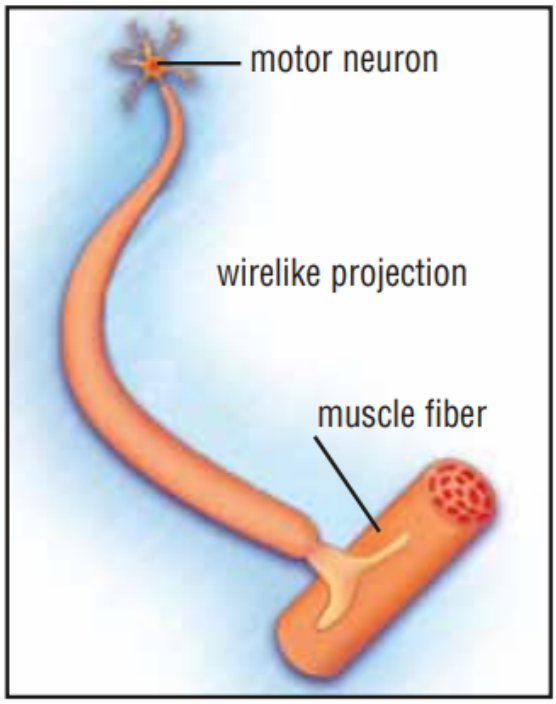
Present: Marissa Harkness

Goals: Find images that can simplify our understanding of SMA

Content:

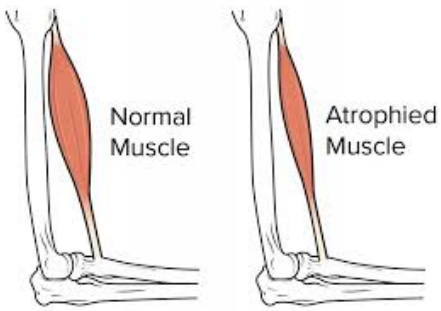


The proximal muscles, those closer to the center of the body, are usually more impacted by SMA. Distal muscles, those further from the body, are typically affected less and more slowly than the proximal. [1]



Motor neurons are connected by wirelike projections to muscles. Signals from the neuron to muscle typically relay contraction. However, in SMA patients motor neurons are lacking so muscles don't function properly and as a result they atrophy. [1]

Patients with SMA may also develop scoliosis. Scoliosis is a curvature of the spine that can be improved with exercises, therapy, or surgery. [1]



This is a normal muscle in comparison to an atrophied muscle. Atrophy is the deterioration and weakening of the muscle. [2]

Conclusions/action items:

I will implement these images in either my preliminary presentation, preliminary report, or both.

Reference:

[1] Mda.org. 2020. [online] Available at: <https://www.mda.org/sites/default/files/publications/Facts_SMA_P-181.pdf> [Accessed 30 September 2020].

[2] 2020. *U.S. FOOD AND DRUG ADMINISTRATION: FDA Approves Innovative Gene Therapy To Treat Pediatric Patients With Spinal Muscular Atrophy, A Rare Disease And Leading Genetic Cause Of Infant Mortality*. [online] Fdahealthnews.com. Available at: <https://fdahealthnews.com/stories/512568803-u-s-food-and-drug-administration-fda-approves-innovative-gene-therapy-to-treat-pediatric-patients-with-spinal-muscular-atrophy-a-rare-disease-and-leading-genetic-cause-of-infant-mortality> [Accessed 2 October 2020].

9/16/20 F5 Corpus VS Standing Wheelchair

Marissa Harkness - Oct 06, 2020, 11:57 PM CDT

Title: F5 Corpus VS Standing Wheelchair

Date: 10/6/20

Content by: Marissa Harkness

Present: Marissa Harkness

Goals: To better understand the specific standing wheelchair that Keith has

Content:

- Benefits
    - Is a power standing wheelchair
    - Allows for face to face interaction
- Fully programmable
    - Supine, semi-reclined, sit to stand techniques
- Restraints
    - Adjustable chest pad
    - Moldable knee supports
    - Power articulating footplates
- Suspension
    - Absorbs terrain
    - Minimal translation to user
- Height and Reach
    - Seat elevator
    - Tilts forward and back
- Comfort Seat
    - Leading ergonomic seating system
- LED lights
    - Change color
- Permobil Connect
    - Bluetooth capability

Model Highlights:

- Seat height 450 mm
- Seat height with electric seat lift 450–800 mm
- Max. user weight 136 kg
- Seat width 420–570 mm (by 50 mm)
- Seat depth 370–570 mm (by 25 mm)
- Backrest width 360/410/460/510 mm
- Backrest height 470, 545–670 mm (by 25 mm)
- Distance between armrests 380–480/480–580 mm
- Backrest angle – adjustable 120°(manual),150° & 180°(power)
- Armrest height 185–320 mm
- Legrest angle – adjustable 90°–180°
- Range 25–35 km*
- Max. speed 12 km/h
- Turning in corridor 1140 mm
- Obstacle capability 70–100 mm
- Electric tilt adjustment (posterior) 50°
- Crash tested

Conclusions/action items:

We will need to schedule a visit with Keith to see the wheelchair in person. From there, we will be able to determine mounting points or ways to implement the use of the current restraints independently.

References:

Permobil. 2020. *F5 Corpus VS - Permobil F-Series*. [online] Available at: <https://permobilus.com/product/f5-corpus-vs> [Accessed 16 September 2020].

10/1/20 Roller Coaster System

Marissa Harkness - Oct 07, 2020, 2:10 PM CDT

Title: Roller Coaster System

Date: 10/1/20

Content by: Marissa Harkness

Present: Marissa Harkness

Goals: To review a standing roller coaster harness patent

Content:

Passengers ride the roller coaster in a standing position. The system that holds the passenger in place consists of a seat between their legs, a back member with a headrest, and two harnesses. The harnesses provide retention in the front and lateral directions of the body to secure the passenger in place. One harness can be swung upward for easy access of the passenger. Another ventral bar is locked in position against the passenger's abdomen. The current standing harness system allows for riders of all heights and sizes. It also provides security in a variety of orientations during the roller coaster ride. While the passenger is secured, they still have freedom of movement within the harness and can experience a sensation of fear. [1]

The claims directly listed in the patent are as follows below.

"What is claimed:

1. A device for retaining passengers on a roller coaster train having a chassis, which enables a passenger to ride in a standing position regardless of their orientation in space and the acceleration to which the passenger is subjected, characterized in that it is comprised of a sliding carriage which is vertically displaceable and lockable on columns, each having a base, which columns are affixed at their base to the chassis of the train, said carriage supporting at least one seat and further comprising a back member on said carriage, a fixed harness disposed on one lateral side of the back member, and a movable harness which has a ventral bar and is disposed on the other lateral side of the back member.

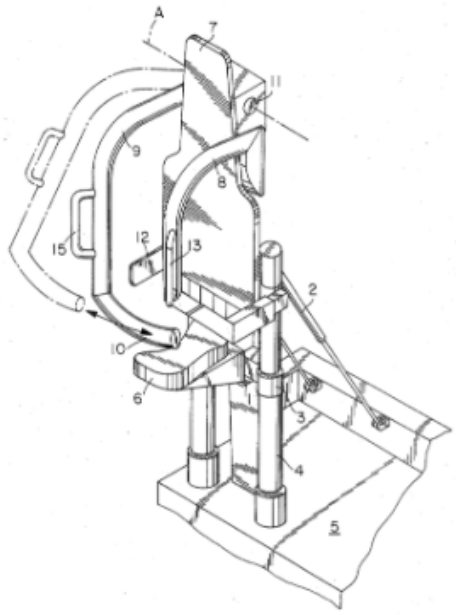
2. A device according to claim 1, characterized in that the seat has a saddle shape so as to be easily inserted between the legs of the passenger and so as to impede forward exit of said passenger.

3. A device according to claim 1, characterized in that the two harnesses have top and frontal bars, that in addition the fixed harness has a lower lateral bar, and the movable harness has the ventral bar on a lower region thereof.

4. A device according to claim 1, characterized in that the movable harness is connected to a lockable rotation arm disposed behind an upper part of the back member, whereby the movable harness can be swung upward in order to allow free entry into the device, and whereby said harness can then be lowered until the ventral bar is in tight contact with a passenger's abdomen." [1]

The image below is the patented design. [1]

U.S. Patent Oct. 20, 1987 4,700,632



The image below is a ride, Superman, from Six Flags Great America.

Conclusions/action items:

In regards to the patent, the seat being located between the legs could be implemented in Keith's design. The chair can absorb a significant portion of the force and allow the restraints to have more flexibility and less force being exerted on them. The limitations would be the seat needing to be

removable or easily retractable as the position of his chair changes from sitting to standing.

Also pictured above was the roller coaster, Superman. Implementing leg restraints that automatically cover the person's legs with a simple mechanical system or automated with the push of a button can also be beneficial.

References:

[1] Patents.google.com. 2020. *US4700632A - Device To Retain Roller Coaster Passengers In Standing Position - Google Patents*. [online] Available at: <https://patents.google.com/patent/US4700632A/en> [Accessed 1 October 2020].

[2] SEO, G., 2020. *Coroner: 'Natural Death' Ruling After Chicago Man Collapses Exiting Great America Coaster | Good To SEO*. [online] Good To SEO. Available at: <https://www.goodtoseo.com/coroner-natural-death-ruling-after-chicago-man-collapses-exiting-great-america-coaster/> [Accessed 1 October 2020].

10/8/20 Permobil Flexible Hinge Joint

Marissa Harkness - Oct 13, 2020, 3:34 PM CDT

Title: Permobil Flexible Hinge Joint

Date: 10/8/20

Content by: Marissa Harkness

Present: Marissa Harkness

Goals: To determine whether we can utilize the Permobil flexible hinge joint

Content:

- The standing wheelchair can have added accessories, such as flexible hinge joints, to provide added locations for body placement and increased flexibility/comfort. Comfort can be met by allowing an array of positioning needs.
    - The location of these hinge joints can help the team determine stable points of fixation for our design.
    - The hinge itself also may be utilized in creating our chest restraint.
        - This will help to create a more customized and fitted harness.
        - It also helps for breaking the harness up into multiple components so that the harness does not stick out beyond the width of the wheelchair.
    - Four supports that utilize the hinge joint
        - Head support

        - Lateral trunk supports

- Lateral/Pelvic Thigh Supports

- Medial knee / thigh support

Conclusions/action items:

I will discuss the hinge joint and the locations of fixation are on the Permobil standing wheelchair. If we determine it is a route that we wish to pursue, I will do further research on how these hinge joints are best implemented.

References:

"BodiLink® on Corpus Seating System," *Permobil*. [Online]. Available: http://permobilus.com/product/bodilink-on-corpus/?hsCtaTracking=9e592335-c32d-4fe8-99ff-7bcd75be7af8%7C3d344ccb-25b4-4591-b903-a76b7807e477. [Accessed: 13-Oct-2020].

9/8/20 Photogrammetry

Marissa Harkness - Sep 14, 2020, 7:15 PM CDT

Title: Basics of Photogrammetry

Date: 9/8/20

Content by: Marissa Harkness

Present: N/A

Goals: To understand photogrammetry and its various uses

Content:

Photogrammetry is the process of obtaining metric information through photographs of an object. The image captured establishes geometric relationships between the picture and object in order to get metric information. Photogrammetry typically produces a map, drawing, measurement, or 3D of an object or scene. The maps we use today are typically derived from photos taken by aircraft.

Photogrammetry is achieved by the principle of triangulation. Photos are taken from at least two different locations and the lines of sight from where the photo was taken intersect to produce 3D coordinates of the points of interest. Triangulation is also the way your eyes work together to perceive distance or depth.

There are three branches of photogrammetry: aerial photogrammetry, terrestrial photogrammetry, and space photogrammetry. For the focus of our project, we will be looking at terrestrial photogrammetry which is where the photographs are taken from a fixed position on or near the ground. The camera is kept at a horizontal and the position and orientation of the camera is captured at the time of exposure.

The two requirements necessary for photogrammetry are:

- Overlapping image for stereo view which is needed for 3D viewing and measurement
- Ground control points (XYZ) for establishing the relationship between the position of where the photo was taken and the ground

Conclusions/action items:

I need to determine how we will implement photogrammetry and how we will analyze the data collected.

Reference:

Resources, 2020. *Basics Of Photogrammetry - GIS Resources*. [online] GIS Resources. Available at: <https://www.gisresources.com/basic-of-photogrammetry_2/> [Accessed 15 September 2020].

9/27/20 Preliminary Design Ideas

Marissa Harkness - Oct 07, 2020, 2:55 PM CDT

Title: Preliminary Design Ideas

Date: 9/27/20

Content by: Marissa Harkness

Present: Marissa Harkness

Goals: To brainstorm solutions to allow Keith to independently go from a seated to standing position by building off the restraints of his current wheelchair

Content:

- Roller coaster harness
    - Develop something similar to a roller coaster harness
        - Have a pull down restraint with a locking mechanism to secure the patient in place
        - Difficulties
            - Not sure if Keith could reach or has that range of motion
                - May have to add a cord to pull down on or automate
        - Have an inner harness that is soft and cushioned for comfort and an outer harness for support
        - Harness should prevent or heavily limit frontal or lateral movement
    - Implement a roller coaster system similar to Superman
        - When you pull down on the upper harness, the leg constraints automatically close
        - Leg constrains permanently secured on the wheelchair between the legs of the patient
            - Resting position is extended in front
            - Closes with a mechanical gears
            - Can be connected to upper harness
- Pressure cuff
    - Develop a harness that fills around the patient
    - Can be inflated and deflated with a pump or hydrolics
    - Provides added comfort
    - Some examples: pressure cuff, air mattress, inner tube
    - Can be individually secured around each leg
    - Difficulties
        - Closing the entire pressure system
        - Providing enough stability
- Elevator door
    - An added form of stability
    - Can be used in tangent with the pressure cuff
    - Something that can be extend in front of the patients chest and legs
    - Restraints would close like an elevator door
    - Once the elevator door is closed, it is locked into place
    - Difficulties
        - Would likely need to be automated
- Ratchet system
    - Keep it simple stupid
        - Well known implementation
    - Can be used for securing the chest restraint
    - Can be used in tandem with another design
    - Difficulties
        - May be hard to open or close for the patient

Conclusions/action items:

I will share the ideas with the team during our brainstorm meeting. I will also need to find feasible ways of implementing the design ideas into actual chest and leg restraints.

Version 1 - Draft Fabrication Plan

Marissa Harkness - Dec 11, 2020, 12:52 PM CST

Title: Version 1 - Draft Fabrication Plan

Date: 11/17/20

Content by: Marissa Harkness

Present: None

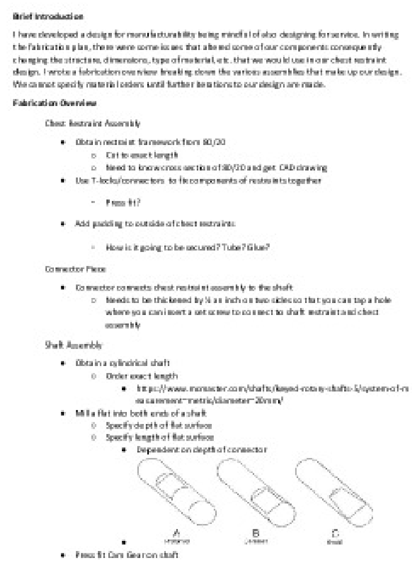
Goals: To develop an outline of the main assemblies that will be part of the chest restraint

Content:

Attached is a PDF containing the original draft fabrication plan.
Conclusions/action items:

I need to review with the team so they understand why I broke the assemblies down the way I did. I also need to review the 80/20 framework extrusions, as well as obvious changes that will need to be made to our design.

Marissa Harkness - Dec 11, 2020, 12:52 PM CST



Brief Introduction

I have developed a design for manufacturability being mindful of also designing for service. In writing the fabrication plan, there were some issues that altered some of our components consequently changing the structure, dimensions, type of material, etc. that we would use in our chest restraint design. I wrote a fabrication overview breaking down the various assemblies that make up our design. We cannot specify material orders until further iterations to our design are made.

Fabrication Overview

Chest Restraint Assembly

- Obtain restraint framework from 80/20
  - Cut to exact length
  - Need to know cross section of 80/20 and get CAD drawing
- Use T-locks/connectors to fix components of restraints together
  - Press fit?
- Add padding to outside of chest restraints
  - How is it going to be secured? Tube? Glue?

Connector Piece

- Connector connects chest restraint assembly to the shaft
  - Needs to be thickened by ¼ an inch on two sides so that you can tap a hole where you can insert a set screw to connect to shaft restraint and chest assembly

Shaft Assembly

- Obtain a cylindrical shaft
  - Order exact length
    - https://www.mcmaster.com/shafts/keyed-rotary-shafts-1/system-of-measurement~metric/diameter~20mm/
- Mill a flat into both ends of a shaft
  - Specify depth of flat surface
  - Specify length of flat surface
    - Dependent on depth of connector

- Press fit Cam Gear on shaft

Version_1_Chest_Restraint_Fabrication_Plan.docx.pdf(70.5 KB) - download

Version 2 - Fabrication Plan

Marissa Harkness - Dec 11, 2020, 12:56 PM CST

Title: Version 2 - Draft Fabrication Plan

Date: 12/6/20

Content by: Marissa Harkness

Present: None

Goals: To develop an outline of the main assemblies that will be part of the chest restraint

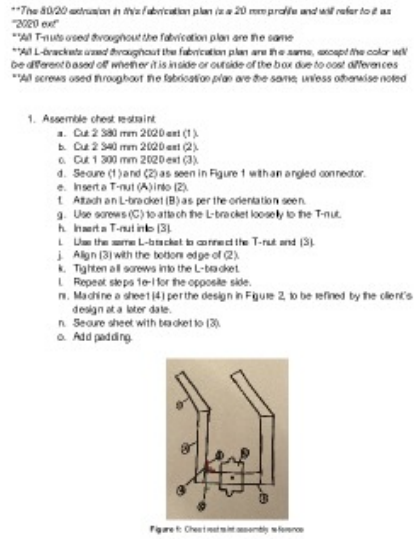
Content:

Attached is a PDF containing the original draft fabrication plan.

Conclusions/action items:

I need to incorporate the fabrication plan in our final report. The team will have to assess whether there are ways to alter the plan to make fabrication easier or costs lower.

Marissa Harkness - Dec 11, 2020, 1:49 PM CST



***The 80/20 extrusion in this fabrication plan is a 20 mm profile and will refer to it as "2020 ext"*
***All T-nuts used throughout the fabrication plan are the same*
***All L-brackets used throughout the fabrication plan are the same, except the color will be different based off whether it is inside or outside of the box due to cost differences*
***All screws used throughout the fabrication plan are the same, unless otherwise noted*

1. Assemble chest restraint
   a. Cut 2 380 mm 2020 ext (1).
   b. Cut 2 340 mm 2020 ext (2).
   c. Cut 1 300 mm 2020 ext (3).
   d. Secure (1) and (2) as seen in Figure 1 with an angled connector.
   e. Insert a T-nut (A) into (2).
   f. Attach an L-bracket (B) as per the orientation seen.
   g. Use screws (C) to attach the L-bracket loosely to the T-nut.
   h. Insert a T-nut into (3).
   i. Use the same L-bracket to connect the T-nut and (3).
   j. Align (3) with the bottom edge of (2).
   k. Tighten all screws into the L-bracket.
   l. Repeat steps 1e-l for the opposite side.
   m. Machine a sheet (4) per the design in Figure 2, to be refined by the client's design at a later date.
   n. Secure sheet with bracket to (3).
   o. Add padding.

Figure 1: Chest restraint assembly reference

Version2_Chest_Restraint_Fab_Plan.pdf(1.4 MB) - download

Brainstorming Footplates

Marissa Harkness - Dec 11, 2020, 1:21 PM CST

Title: Brainstorming Footplates

Date: 12/6/20

Content by: Marissa Harkness

Present: None

Goals:

Keith's foot placement when entering the wheelchair from the ceiling lift is not consistent. His feet sometimes hang off the edge of his current footplates, so when going from sitting to standing a danger can be present if his feet are not fully on the footplates. I need to brainstorm methods for keeping his feet centered on the footplate.

Content:

Option 1: Make the footplates bigger. If the footplates are bigger, there is a greater landing pad that his feet can go on.

Option 2: Adding thigh restraints. If thigh restraints are added, it can bring his knees together and possibly presents bowing out of his feet.

Conclusions/action items:

After reviewing these ideas with the team, we think it could be beneficial to add slanted edges to the sides of the footplate. This will account for the fact that if his feet are not centered, the edges will help funnel his feet onto the footplate. Option 2 likely does not solve the problem but it can be used in parallel with another method. We will need to create design matrixes and determine a method of fabrication for this component in Spring 2021.

Chest Fabrication Plan Figures

NAMAN PATEL - Dec 11, 2020, 1:50 PM CST

Title: Chest Fabrication Plan Figures

Date: 12/8/20

Content by: Marissa

Present: None

Goals: To include figures within the fabrication plan with labeled components

Content:

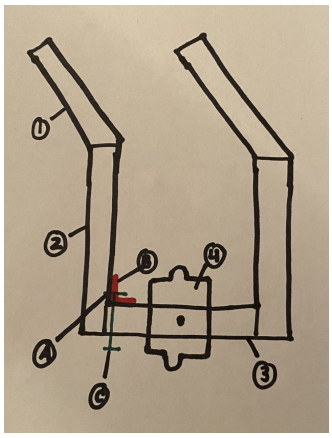


Figure 1: Chest restraint assembly reference

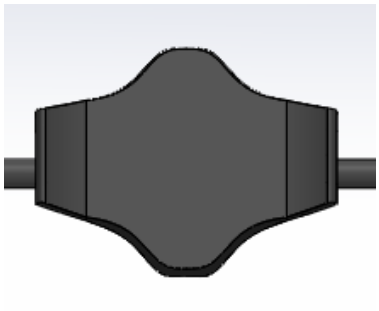


Figure 2: Solidworks drawing of the sheet used for the chest restraint

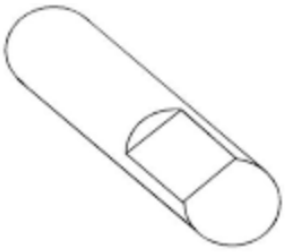


Figure 3: Mill flat onto shaft

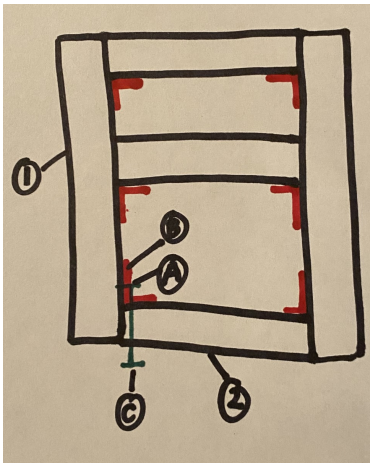


Figure 4: Side frame assembly reference

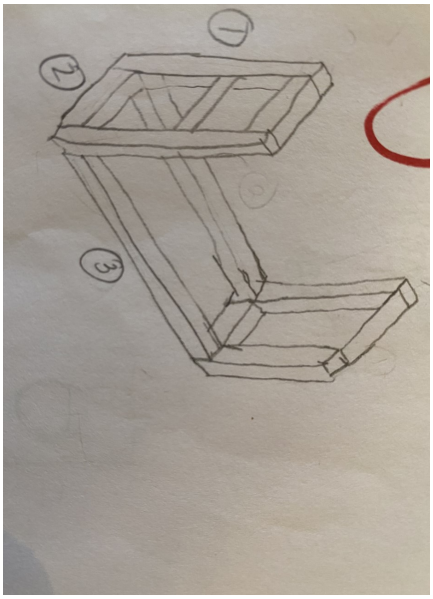


Figure 5: Side frames with bottom cross member extrusions reference

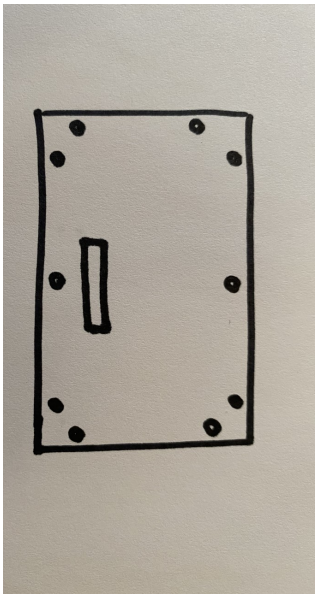


Figure 6: Bottom plate drawing

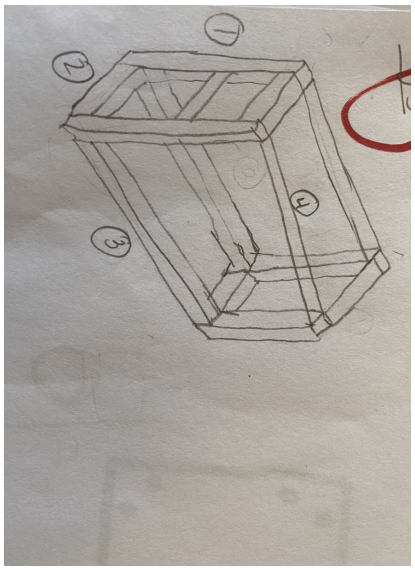


Figure 7: Side frames with top cross member extrusions reference

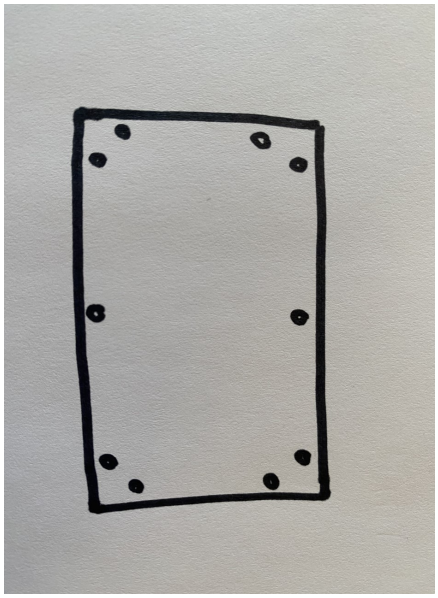


Figure 8: Front and back plate drawing

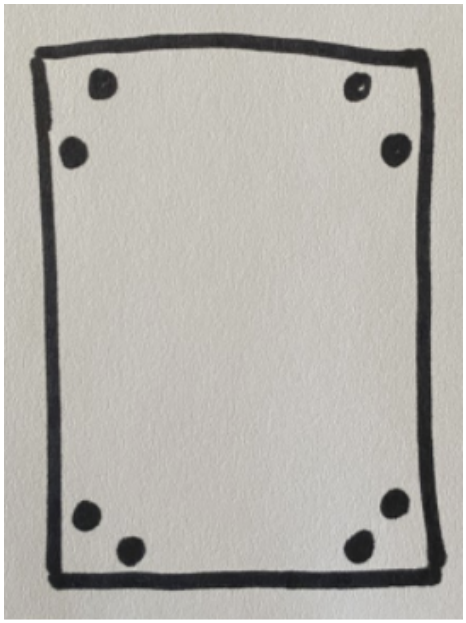


Figure 9: Side plate drawing

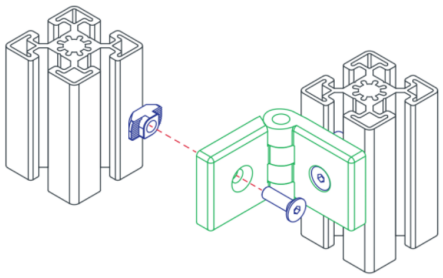


Figure 10: Details on how to attach hinge

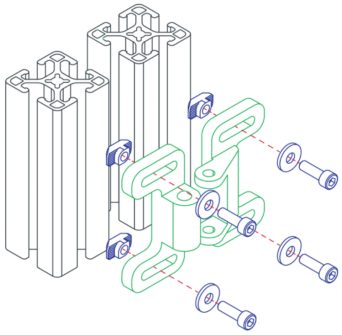


Figure 11: Details on how to attach catch and latch

Conclusions/action items:

Bearing Diameter

Marissa Harkness - Dec 11, 2020, 1:44 PM CST

Title: Bearing Diameter

Date: 12/5/20

Content by: Marissa

Present: None

Goals: To determine the dimensions of the wearing that we will do.

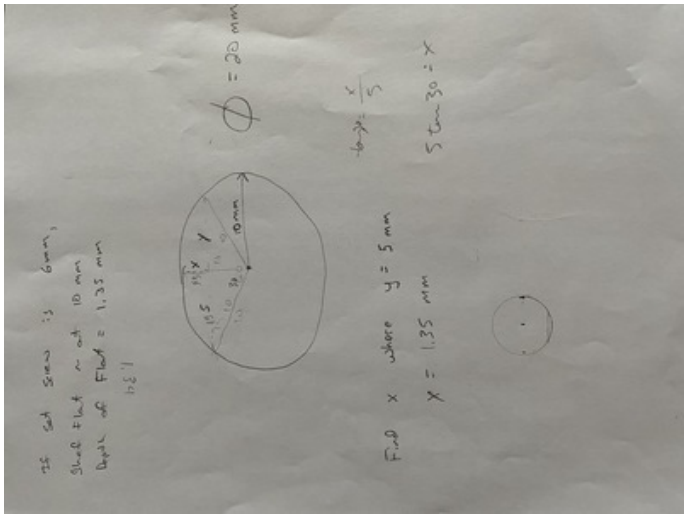
Content:

Attached is a PDF of the calculations I did.

Conclusions/action items:

I need to find a pillow block bearing that reflects these dimensions.

Marissa Harkness - Dec 11, 2020, 1:49 PM CST



IMG_4635.jpg(2.7 MB) - download

Permits

Marissa Harkness - Oct 07, 2020, 2:17 PM CDT

Title: Workshop Permits

Date: 2017 and 2019

Content by: Marissa Harkness

Present: N/A

Goals: To review the permits obtained through the COE

Content:

- Obtained the Red Permit in Spring 2018
- Obtained the Green Permit in Spring 2019

Conclusions/action items:

I need to determine if I will need to obtain any future permits for the purpose of this project and if so, begin training.

Core Dump

Marissa Harkness - Oct 07, 2020, 2:22 PM CDT

Title: Core Dump

Date: 9/8/20

Content by: Marissa Harkness

Present: N/A

Goals: To highlight the key features and goals that we discussed for the course of this project

Content:

- Initially the project seemed daunting, requiring a lot of electrical and coding expertise that we don't have
- Met with the client, Keith
- Realized the magnitude that our project can have on his life, and those with similar NMD
- Keith has not crawled since age 14 and wishes that he had that freedom to move in that way again
- Puts things into perspective and realize the little things we take for granted
- Makes me want to work that much harder to make an impact in his life
- The project becomes more than just a project when you have a name, face, and story behind it
- Recognize the proposed design by Keith could be difficult and much research will still be required

Conclusions/action items:

The team needs to create a timeline and plan of action to achieve the goals we discusses and have put into place.

Mitch's Mantra

Marissa Harkness - Sep 15, 2020, 4:18 PM CDT

Mitch's Mantra: Answering important, relevant questions towards our project, client, and expected goals for the semester

- What is the problem or unmet need?
  - Our client, Keith, wants more freedom to stretch, move, and exercise more than he currently does. His current chair forces him to sit stagnant for 18 hours of the day. He wants increased mobility, so his muscles can experience different movements. He specifically is unable to achieve a prone position with his current chair. If he were able to position his body upside down, there would be increased blood flow.
- Why is it a problem or unmet need?
  - It is a problem because Keith's receives decreased blood circulation. His quality of life is currently inhibited because of his inability to freely move around and achieve whatever position he desires. He also has limited ways of stretching out and having an increased range of motion. He wants and needs more independence to move freely in whichever position, direction, or location that he so chooses.

Project Impact

Marissa Harkness - Oct 07, 2020, 2:41 PM CDT

Title: Project Impact

Date: 10/7/20

Content by: Marissa Harkness

Present: Marissa Harkness

Goals: To document the impact that our project could have in Keith's life, as well as those with SMA, similar NMD, or those confined to a wheelchair

Content:

Spinal muscular atrophy affects voluntary muscle movement limiting what a patient with SMA can do independently. Movement is important for range of motion, flexibility, bone strength, muscles, digestive system, as well as a plethora of other bodily functions. However, many patients with SMA are limited in the amount of movement they can receive, especially independently. Our client, Keith approached us with the desire to have more freedom and autonomy. His main areas of focus were the up down standing motion, prone position, stretching and increasing range of motion, and muscle relief through vibration. For the course of this semester, our team will focus on allowing Keith to independently achieve the up down standing motion. In order to do this, we will be building off of his standing wheelchair.

Not only will this project impact Keith and his ability to independently stand up and sit down, but it also has the potential to impact others. For example, other patients with SMA. There are also other NMD where this increased freedom is currently lacking and would be beneficial. Patients can be confined to wheelchairs for a variety of reasons. Those confined to wheelchairs who can not independently stand or sit without assistance from a CNA, physical therapist, family, or friend can also be positively impacted by our design.

Conclusions/action items:

The team will build this project tailored towards Keith. Through proof of concept and production on a small scale, we have the ability to make an impact on a wide range of people in the future. With that being said, it is important to be mindful when developing our design on how to make it user friendly and adaptable for different skill sets and body sizes.

Materials and Expenses

Marissa Harkness - Dec 11, 2020, 12:57 PM CST

Title: Materials and Expenses Spreadsheet

Date: 12/8/20

Content by: Marissa Harkness

Present: Ben Lawonn

Goals: To create a spreadsheet with the part, part no., description, seller, cost, quantity, and link

Content:

Attached is a PDF containing the original draft fabrication plan.
Conclusions/action items:

We need to send the materials and expenses to Keith for approval.

Marissa Harkness - Dec 11, 2020, 12:57 PM CST

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BME_400_Design_Materials_-_Sheet1.pdf(120.6 KB) - download

2014/11/03-Entry guidelines

John Puccinelli - Sep 05, 2016, 1:18 PM CDT

Use this as a guide for every entry

- Every text entry of your notebook should have the **bold titles** below.
- Every page/entry should be **named starting with the date** of the entry's first creation/activity, subsequent material from future dates can be added later.

You can create a copy of the blank template by first opening the desired folder, clicking on "New", selecting "Copy Existing Page...", and then select "2014/11/03-Template")

Title: Descriptive title (i.e. Client Meeting)

Date: 9/5/2016

Content by: The one person who wrote the content

Present: Names of those present if more than just you (not necessary for individual work)

Goals: Establish clear goals for all text entries (meetings, individual work, etc.).

Content:

Contains clear and organized notes (also includes any references used)

Conclusions/action items:

Recap only the most significant findings and/or action items resulting from the entry.

2014/11/03-Template

Marissa Harkness - Dec 11, 2020, 12:07 PM CST

Title:

Date:

Content by:

Present:

Goals:

Content:

Conclusions/action items: