# THE HOOKEY-POOLEY

Put your right hand in, put your left hand in, put your head through and SHAKE IT ALL ABOUT!

*Prepared for:*
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March 12, 2016

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# Executive Summary

## Problem

Elsa, an eight year old girl with arthrogryposis, cannot put on or take off a shirt on her own.

## Purpose and Scope

Our objective was to build a device that would be able to help our primary user, Elsa, put on and take off a shirt independently. At the same time the device should save her mother, Mary, time in the mornings and be safe to use.

Figure 1: The Hookey-Pooley

## Methodology

Through information gathered during client interviews, empathy testing and performance testing our team was able to design a variety of different mockups to test during user testing. Then based on feedback from Elsa, Mary and Meghan as well as our classmates during the Design Review we decided on our end design. The final prototype was chosen because it provides a very high level of independence to Elsa, while also being safe and having the potential to save Mary time in the mornings.

## Design and Benefits

The Hookey-Pooley (see Figure 1) is a wooden frame consisting of two sets of hooks which can be used to help put on and take off a shirt. Table 2 details the requirements of the design problem.

| Requirement | Description |
|---|---|
| Independence | Elsa can operate both the system to put on and take off a shirt completely independently. |
| Saves Mary Time | There is no set up for Mary to do and she can supervise its use from outside Elsa's room as the door can be left open while the device is in use. |
| No Permanent Damage | Using or setting up the device doesn't cause any damage to the room. |
| Safe | All corners are rounded and the dimensions are such that it is very hard for Elsa to bump her head. |
| Enables Elsa to Get Dressed | The two systems are integrated into one frame to enable Elsa to dress and undress herself using one device. |

Table 1: Requirements and Descriptions

# Introduction

## Problem

It can be difficult for children with disabilities to get dressed on their own. However, dressing oneself is a powerful step towards independence. Our user, Elsa, is an eight year old girl with arthrogryposis, meaning she has limited mobility in some of her joints, including her wrists, shoulders and elbows and is in a wheelchair. She cannot get dressed without help from her mother, Mary, and this often takes up a lot of time in the mornings.

## Project

Our team is working with the Rehabilitation Institute of Chicago in order to design a device which will help Elsa dress and undress herself. We want to enable her to become more independent in her daily life, while also saving Mary time in the mornings. The device should be safe to use and non-damaging to the room surrounding it. It would be preferable if it was portable but that is not required. As far as possible Elsa should be able to use it entirely on her own but Mary is prepared to do some brief set up if that is required (see Appendix A: Project Definition and Appendix B: Client Interview Summary).

## Current Designs

This project is quite unique due to the fact that arthrogryposis is a condition which affects different people in different ways and to different extents (see Appendix C: Background Research Summary) therefore there are no current designs that we could find which deal directly with a situation like Elsa's. However we were able to find some examples of designs used to solve similar problems.

Figure 2: The Dressing Tree
<https://www.youtube.com/watch?v=ntRZftyTE9s>

This design is called the Dressing Tree and is used to help a little boy with arthrogryposis put on and taking off a shirt using a set of hooks (see Figure 2). He also has limited mobility in his upper body, but is not confined to a wheelchair therefore he can move around a lot more and approach the hooks from opposite sides to use the hooks in different ways to put a shirt on and take it off.

Figure 3: The Dressing Stick
<http://www.essentialmedicalsupply.com/products/dressingbathing/wooden-dressing-stick>

Another device that is commonly used to help people get dressed is the ‘dressing stick’ which is effectively a hook attached to a long pole so as to increases the user’s reach when they are trying to get dressed (see Figure 3). This could be a useful component to add to our design but Elsa’s grip is not strong enough to hold onto a rod and use it to pull across as would be necessary to use the dressing hook.

## Our Design

The Hookey-Pooley (see Figure 4) is a frame with two separate but integrated systems for putting on a shirt and taking it off. The two different systems are attached to a free-standing frame which holds all the components at the optimal position for use.

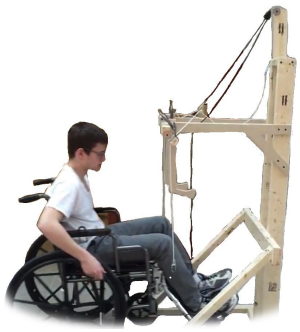

Figure 4: A User with the Hookey-Pooley

The hooks to put on the shirt are long, wide hooks with a rounded tip facing away from Elsa so that the shirt can slide off once it is on. They are angled at 20 degrees below the horizontal as

this is the optimal angle for the shirt to be able to stay on the hook until after Elsa has it on and then slide off (see Appendix D: Performance Testing Summary). Elsa places her shirt in her lap and puts her arms through the arm holes, she then swings the back of the shirt up onto the hooks. From there she simply leans forwards into the shirt and once her head is through the proper hole she sits back up. She then just has to wiggle a little bit to get the shirt to fall down all the way.

To take off a shirt Elsa places a hooks onto each side of her shirt then drives backwards so there is a better angle (minimum force required) (see Appendix D: Performance Testing Summary) to take off her shirt. She then leans forwards and pulls down on a knotted rope which is attached to the shirt via a pulley system. Once she gets to the point that the rope is pulled down as far as it will go she sits back up, keeping her head tucked, and the shirt comes off over her head. The rope will not fall back down because of a rachet pulley which allows it to only move in one direction.

## Report Overview

The rest of the report contains the following sections:

- Users and Requirements - gives a fuller description of our user and the major requirements we took into account
- Design Concept and Rationale - describes our design and why we decided on it in more detail
- Limitations and Next Steps - suggests where the design could be improved in the future
- Conclusion - gives a final summary of the project

# Users and Requirements

## Users and Stakeholders

Users and Stakeholders were established through discussion with the client during the client interview and user testing, for more information (see Appendix B: Client Interview Summary, Appendix E: User Observation Summary and Appendix F: User Testing Summary).

Primary Users:

- Elsa, an eight year old girl with arthrogryposis, which limits her mobility in her arms and shoulders as well as meaning that she has to use a wheelchair.

Secondary Users:

- Mary, Elsa's mother, who will have to set up the device in her room and supervise her using it at least during the first few times Elsa uses it.
- Health care professionals such as our client, Meghan, who may instruct Elsa or other children in a situation similar to hers on how to use the device.

Stakeholders:

- Rehabilitation Institute of Chicago
- DTC and Segal Design Institute

## Requirements

The major requirements were determined and adapted throughout the design process (see Table 2) but mainly during the client interview and user observation and testing (see Appendix A: Project Definition).

| Requirements | Specifications |
|---|---|
| Reduces the amount of time Mary spends getting Elsa ready in the morning | Shirt can be put on in 5 minutes or less |
| Mary only helps in setup of device | Mary only spends a maximum of 5 minutes setting up the device |
| Must be on door or free standing | Must take up a maximum of 3 square ft of space in the user's room |
| Cannot cause permanent damage to the room or doors | Must be light enough to be held up by a non-damaging method or be freestanding |
| Must allow her to put on her CPS uniform | Y/N |
| Must be safe to use | Y/N |

Table 2: Shortened Requirements and Specifications

These requirements were set forth by the client and user and are key to providing a successful prototype.

# Design Concept and Rationale

## Design Overview

### *What is it?*

The Hookey-Pooley is a design which can be used to help our user, Elsa, an eight year old girl with arthrogryposis, to put on and take off a shirt independently. It consists of a frame, a pulley system, two free-hanging hooks,  two rigid hooks (see Figures 5 and 6). Each pair of hooks fulfills a different function: the rigid hooks are used to put the shirt on and the free-hanging hooks are used to take the shirt off. The free-hanging hooks are operated using a pulley system powered by Elsa and all the components are held in position by a frame. For the measurements of our design please see (Appendix G: CAD Drawings).

We decided to use this design because it provides an integrated way to put the shirt on and take it off, using the same device. It also provides more independence for Elsa than some of our earlier designs (see Appendix H: Alternatives Matrix), which was one of the key requirements of our design.

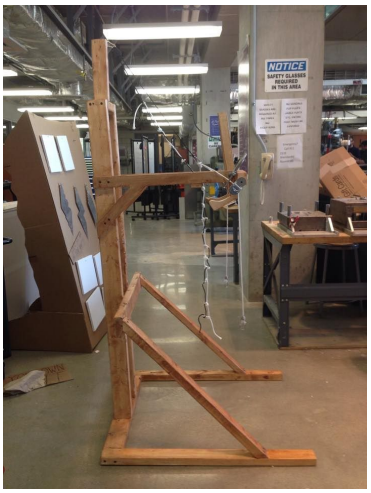


Figure 5: Side view of Hookey-Pooley

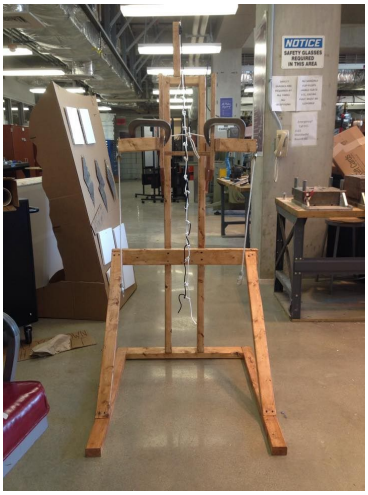


Figure 6: Front view of Hookey-Pooley

### *How does it work?*

To put a shirt on, Elsa approaches the rigid hooks, which are oriented facing away from her. Once she places her arms through the arm holes of the shirt, Elsa swings the back of the shirt onto the hooks. From there she leans forward into the shirt, which is held open by the weight of her arms. Once she has the shirt on all the way it slides off the hooks and she sits back up in her chair. She then wiggles in her chair to get the shirt to fall down (see Figure 7).

Figure 7: Using On Hooks

To take a shirt off, Elsa attaches the sides of her shirt to the free-hanging hooks, and drives her wheelchair backwards. Once she has driven back so that the angle between the rope and the horizontal is 45 degrees, which we determined in performance testing to be the angle with least force required to pull off a shirt (see Appendix D: Performance Testing Summary), she leans forward to grab the knotted rope. From there she pulls down to raise the hooks and pull her shirt up as high as possible. Once the shirt is as high as she can pull it she sits back with her chin tucked so that the shirt slides off her head (see Figure 8). The hooks will not fall down because a ratchet pulley only allows the rope to slide in one direction. (see Appendix I: Instructions for Use)

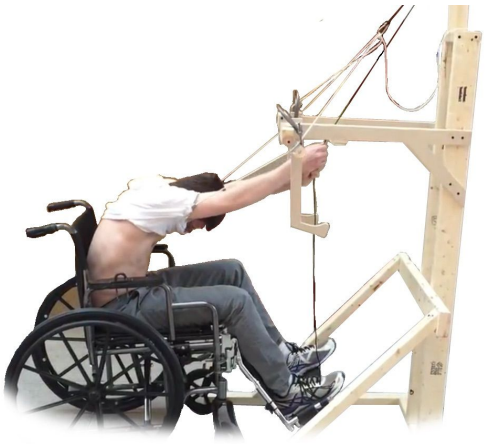

Figure 8: Using the Off Hooks

## Putting on Hook

### *Design Concept*

The hooks to put on the shirt are 5” wide and have rounded ends formed by using part of two circles of radii 4” and 0.5” (see Appendix G: CAD Drawings). The hooks are facing away from Elsa, angled at 20 degrees below the horizontal and are made out of plywood which has been sanded up to 220P grade and lacquered. The height of each hook is 15” and they are then connected to a 26.5” bar, separated by two 9” bars to hold them at the correct width. These bars are then screwed to the main frame of the device. All corners are rounded to minimize the safety risk or the possibility of damaging clothing whilst using the device. The hooks are placed at shoulder height for Elsa, 35” off of the ground (see Figure 9).

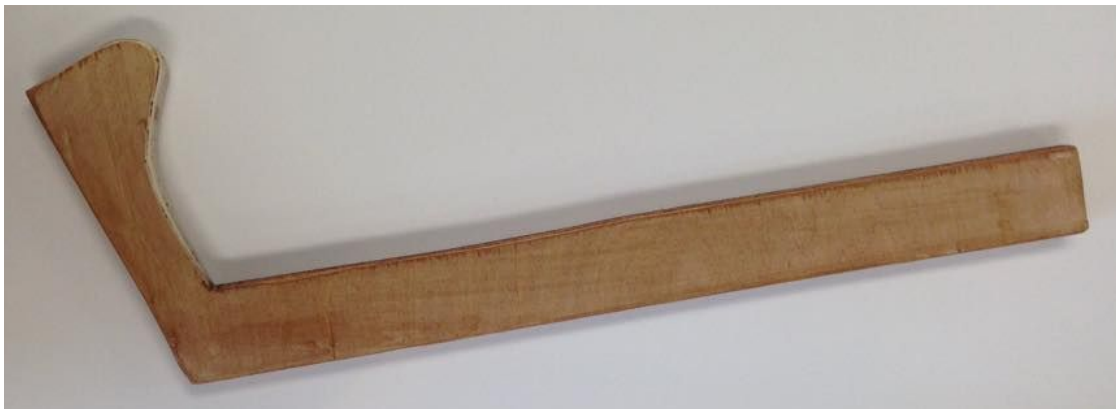

Figure 9: Putting On Hook

### *Design Rationale*

We needed a way for Elsa to put the shirt on that she could use by herself. The main problems were getting the shirt open so that she could put her head through the hole, getting the shirt in the right position so that she could lean forwards into it, and getting the shirt to come off the device once Elsa had it on.

The hooks we have are facing away from her so the shirt can slide off of the hooks once she has put the shirt on all the way. We decided to angle them at 20 degrees below the horizontal because this was the best angle we found in performance testing (see Appendix D: Performance Testing Summary) for the hooks in order for the shirt to only come off once the shirt was all the way on. Another advantage of them facing away from her is that by swinging the back of the shirt onto the hooks, as opposed to the neck (as would be necessary if the hooks were facing towards her), it is easier for Elsa to get the shirt onto the hooks because there is more fabric to be caught so it requires less accuracy.

The hooks are so long because that means the pulleys and the top of the hooks are in the same place, so the two systems can be integrated. The hooks are placed 9” apart so that there is plenty of space for her head to move between the hooks (her head has a diameter of 8” so we left half an inch on either side) and the wider hooks mean that the shirt is held wide open so it is easier for Elsa to put her head through it and that there is a larger area for the back of the shirt to reach, which also reduces the accuracy Elsa needs to have when using the system.

## Taking off Hook

### *Design Concept*

Two hooks to take off the shirt are attached to ropes which run through a pulley system to pull the shirt off. The actual hooks are 1.5” long with a radius of 3/4” in the curve of the hook, there is a curled part at the top designed to attach to a 3/16” rope. They are made out of steel with  tips coated in hot glue (see Figure 10). The hooks are able to be attached to her shirt by Elsa so when she pulls on the knotted rope attached to the pulley system her shirt will come off (see Appendix I: Instructions for Use).

Figure 10: Taking off Hook

### *Design Rationale*

The hooks are simple metal hooks with balls of hot glue on the tip. This means that they are light and don’t add much weight when Elsa is pulling off her shirt. It also means that the hooks are thin, so the area for gripping the shirt is relatively large while the hooks are small therefore the area to hook on the shirt is greater. The hot glue on the tips reduces the risk up injury and any risk of damaging the clothes while using the device.

The hooks are free-swinging because even though this means it takes a little longer for Elsa to put them on (10 seconds as opposed to 5, measured in user testing) as this means that we can use a pulley system to take the shirt off. (See Appendix D: Performance Testing Summary)

## Pulley system

### *Design Concept*

The pulley system contains two sets of pulleys attached to the frame 15” apart, as this is a little bit wider than Elsa’s shoulder width (12”). The pulleys have two different ropes running through them which are then tied to a carabiner attached to a third rope which goes through a rachet pulley and then is knotted hanging down in the middle of the back frame (see Figure 11). Before Elsa starts to pull down on the rope she has to back up so that there is an angle of 45 degrees between the rope and the horizontal. As the shirt is pulled up by the hooks attached to the sides, Elsa is pulling down on the knotted rope to provide the force to take off her own shirt. When she is done she just has to let go of the rope and sit back upright.

Figure 11: Pulley System

### *Design Rationale*

We decided to go for this design because Elsa can power it herself, this eliminates the need for any motors or counterweights which could be dangerous if something went wrong. It also increases her independence because she can use the whole system on her own, without any help from other people, which was one of our key requirements. (see Appendix A: Project Definition)

The pulley system also means that her body is held at a good angle to take the shirt off because one of the major issues we had was getting her arms out of the holes. When she is bent forwards to reach the rope and the pulley is at an angle of  35 degrees (see Appendix D: Performance Testing Summary) then the shirt comes off with the least force.

The pulleys are placed a little wider than her shoulder width apart because we found from performance testing that in order to get a shirt off you either need to pull it from the sides or the back and Elsa can't attach a hook to the back of her shirt without help.

## Frame

### *Design Concept*

The frame is a free standing, wooden structure 65" tall with a base width of 32" and length of 36".  The base has a triangular support at an angle of 45 degrees with the horizontal. It consists of a base in a square 'U' shape and the structure that the pulleys and hooks are attached to is formed by a longer, thinner 'U' (9" wide, 61.50" tall) attached to the middle of the base at the back. This has a board screwed to it 24" from the base which is what the triangular support beams are attached to. The whole structure is made out of wood and is held together by metal (brass) wood screws (see Appendix J: Bill of Materials). At the very top of the structure there is a 3.50" tall and 2.50" wide piece to which the rachet pulley is attached.

### *Design Rationale*

The frame is free-standing so that there is no danger of Elsa hitting her head on a door as she leans forwards to either put the shirt on or reach the rope to take the shirt off. It also means that it can be placed in a corner when not in use so that it is not in the way, which satisfies one of our requirements. When in use, the system can be positioned so that Elsa's door can remain open, therefore if Mary prefers she can keep an eye on Elsa even if she is not in the same room.

The structure is made of wood because it is both lightweight and cheap, it also makes it easy to round off corners so that there are no sharp edges, which improves safety. The wide base and triangular supporting structures improve the stability of the frame so that it will not fall over while in use. This is also why we are using a 'U' shaped arch to reach up to the top of the device. The base is 32" wide so that the frame can fit through a doorway (average width 32") while still accommodating Elsa's wheelchair's wheelbase.

The frame is 65" tall so the rachet pulley is high enough that Elsa does not need to pull on any unknotted rope when taking off the shirt and can fit through a door frame (minimum height 80"). This height also means that we can easily position the pulleys at 50" above the ground and he

hooks at 35” above the ground, which we determined based on performance testing results were the best heights (see above). We are assembling the structure using wood screws because they are specifically designed for this purpose, therefore they are strong enough to withstand the forces that are going through the frame whilst it is in use (see Appendix K: Manufacturing Instructions).

# Future Development

While we are confident that our design fulfills all the requirements of the design, below are a few areas that might be able to be improved further (see Appendix L: Design Review Summary).

## On Hooks

The hooks to put the shirt on are placed at the user's shoulder height. It could be helpful to place the hooks lower and develop a mechanism to raise the hooks higher after Elsa has put the shirt on the hooks. This would make it easier for Elsa to put the shirt on the hooks and mean that it doesn't take her as long to use the device.

## Pulley System

The pulley system provides a lot of independence to Elsa but also can be difficult to use because her shirt can get stuck under her arms and it can require her to exert a lot of force. Further developments could look into a way to make sure her arms do not get stuck or the force to take off the shirt could be exerted by some kind of external motor so that Elsa doesn't have to do as much work herself.

It may also be advisable to look into using magnetic strips on the ropes so that they are always held together even if we can't knot them above a certain point. This would make it easier for Elsa to grip the rope and pull downwards and mean that the frame doesn't need to be as high.

## Stability

The device is very stable in the forwards and backwards direction, but it is less so to the left and right. It is possible that this could be improved by attaching supports to the base of the device but this might also make it more bulky and mean it takes up more room or cannot fit through doorways.

Another way to improve stability could be to adapt the design so that it can attach to the back of a door. The door will keep the design stable and if it is also foldable then it can be stored behind the open door so it takes up almost no space in the room when not in use. It could also mean that the device could be used on the back of any door so it would be portable, assuming it is made out of material which is light enough.

## Further Testing

We based most of our design on performance testing. Therefore it would be useful to have more opportunities for user testing in order to ensure that everything works as well with Elsa as it did with us.

# Conclusion

In summary, the Hookey-Pulley provides an independent way for Elsa to put on and take off a shirt on her own.

It includes the following components:

- On hooks - 5” wide, 15” long wooden hook with a rounded tip to allow the shirt to be held on the hook until Elsa has it on all the way and it slides off.
- Off hooks - 1.50” long hooks with a rounded 3/4” diameter and hot glue on the tips which are free-hanging so that Elsa can attach them to her shirt while not risking damage to herself or her clothing.
- Pulley system - two sets of pulleys spaced 15” apart with a rope running through each of them and then tied to a third rope running through a rachet pulley which is then knotted and hangs down in the center back of the device.
- Frame - 61.50” high, 32” wide and 36” long free-standing frame to stabilize the device and hold the two separate systems together in the correct positions for the device to work optimally.

Our design focuses on providing as much independence as possible to Elsa. Everything from set-up to use can be done without help from Mary, which means that Elsa will be able to dress herself completely independently and also means it will save Mary time in the mornings.

Our design is built to improve the quality of life of Elsa and Mary by making their morning routine easier and giving Elsa more independence in her daily life.

# References

Rehabilitation Institute of Chicago. User interviews. 12,26 February 2016

O'Donnell, Meghan. Cleint Interview. 11 January 2016

# Appendix A: Project Definition

Project Name: Self-dressing device to help a user with Arthrogryposis put on a shirt
Client: Ms. Meghan O'Donnell, Rehabilitation Institute of Chicago
Team members: Azmain Alamgir, Yvonne Chart, Sebastian Dobon, Gideon Feifke, Gretchen Vogt
Date: February 8, 2016
Version: Two

## Mission Statement:

To design an innovative, movable, system to assist a our user, an eight-year-old with arthrogryposis, to independently put on and take off a pullover shirt within a reasonable time frame.

## Project Deliverables:

- A working prototype of a self-dressing device that the user can operate
- A final report explaining the design and how it is used
- A poster and presentation to demonstrate our device at the Design Expo

## Constraints:

- Total cost of all materials must be below $100
- Must fit in the user's room
- Cannot permanently change/damage any part of the user's room

## Users/Stakeholders:

- Our user Elsa
- Other people involved in the aiding of Elsa to dress herself (mother and client)
- Rehabilitation Institute of Chicago (user's therapy clinic)
- Other children with arthrogryposis or another disability who have trouble getting dressed

| **Requirements** | **Specifications** |
|---|---|
| Must reduce the amount of time her mother spends in the morning helping her get dressed | Must allow shirt to be put on in 5 minutes or less |
| User must be able to put shirt on without help from mother except for the setup of device | Maximum of 5 minutes spent by mother in set up |
| Must be on door or free standing (cannot be attached to walls or ceiling) | Must take up a maximum of 3 square ft of space in the user's room |

| | |
|---|---|
| Cannot cause permanent damage to the room or doors (no nails or screws to hold in place) | Must weigh less than 50 pounds so that it can be held up by a non-damaging method eg hooks, or be freestanding |
| Must allow her to put on her CPS uniform (polo shirt and pullover) | Y/N |
| Can have nothing sharp or jagged as to injure the user | Y/N |

Table 3: Requirements and Specifications

# Appendix B: Client Interview Summary

## Introduction

This appendix contains a summary of the information gathered during the first client interview on January 1st, 2016 at 7pm. Our client is Ms Meghan O'Donnell, an occupational therapist at the Rehabilitation Institute of Chicago (RIC). The main purpose of the client interview was to learn more about what the client and user were looking for from our product and what the user's abilities are.

## User Profile

Name: Elsa
Age: 7 or 8 years old
Height: roughly 4 feet standing up
Shirt size: age 8-10

Elsa is an only child with a single mother who is currently in nursing school. Her first language is Spanish but she also speaks English very well. She likes to draw and has very good handwriting despite having limited mobility and strength in her joints due to arthrogryposis. Meghan described her as being 'fake quiet', explaining that she doesn't talk much until you get to know her but still likes attention. She is generally fairly easy-going and innovative in navigating her life. It should be noted that her mother may also have some ideas for how to help. She has come up with creative ways to help Elsa in the past.

Elsa likes:

- Frozen
- Pink/purple
- Stickers
- "Girly stuff"

## Problem

Right now Elsa requires a lot of help from her mother to get dressed and undressed. The goal of the project is to design a device which will give her more independence by allowing her to put on and take off shirts without assistance.

## User's Abilities

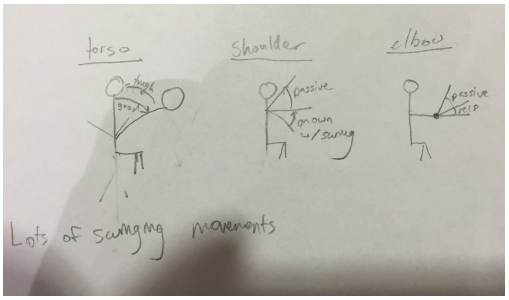


Figure 12: Sketch of User's Abilities

In terms of her upper body the user has internally rotated shoulders and limited movement in her wrists, elbows and fingers. The muscles in her arms are also quite weak so she cannot voluntarily move her arms at the elbow, but can swing her full arm up to approximately 45 degrees by using momentum from swinging her shoulders. Her arms can be moved up to 180 degrees involuntarily, without any pain, and her elbows can be moved to 90 degrees. Her wrists have almost no movement in them (maybe 5 or 10 degrees) and she has little movement or grip strength in her fingers. She usually grips between her thumb and first finger but the webbing in her hand is short so she can only grip objects which are fairly narrow (see figure 1 for visualisation of these motions).

She also has a weak core, which is an issue when she leans down and tries to straighten back up again. When she bends down past a certain point she can only sit back up again by using momentum from swinging her head backwards (see figure 1). She has mild scoliosis in her back which means her spine is slightly curved. Her legs are stuck in a bent position, which is why she is in a wheelchair, however she can put weight through them in order to bounce in her wheelchair.

When she is not in her wheelchair she can get around by shuffling sideways on her knuckles. She gets in and out of her wheelchair using a board from the wheelchair to her bed or other surface and shuffling in this way. She is very good at using her own momentum to move around and is also able to roll side to side by swinging her head.

## Wheelchair

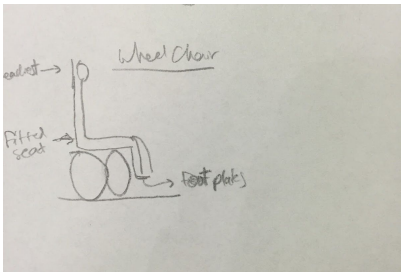


Figure 13: Sketch of User's Wheelchair

The user has a motorized wheelchair which is controlled using a joystick and buttons to change speed/direction. She has very good control of it. It has a custom seat to support her back, which means it is very tight-fitting and the armrests must be removed by her mom in order for her to get in and out of the chair. There is a footplate for her feet and a high back which may go all the way up to a headrest or stop at her shoulder blades (client couldn't remember). The chair is very large and heavy, with a large turning circle. There is also no tilt or vertical movement in the chair's seat.

## Requirements

The system must be able to be used within a reasonable time frame to accommodate a busy morning (approximately 5 minutes) and should be designed with her school uniform in mind, which includes a polo shirt and a pullover. It should be designed for use in the user's bedroom but it does not matter whether she needs to be in or out of the wheelchair to use it. It can require set-up by her mother but she needs to be able to use it on her own.

In addition, the system could have other features which would be helpful but are not a requirement:

- portability
- adjustable for growth
- no required parental set-up

Solutions which involve adaptive clothing could also be an option. The key is that the user gains independence.

## Conclusion

The interview helped us to better understand the problem and gain a clear direction for the project. At the user interview we hope to gain a quantitative measure of the user's abilities by

videoing her as she goes through various different motions and learning if there is anything she wants from the product that the client didn’t mention.

# Appendix C: Background Research Summary

One of the preliminary steps we took at the start of our project was to compile background research on the specific terms and conditions set forth by our client, an occupational therapist at the Rehab Institute of Chicago (RIC). Our project consists of designing a self-dressing device that will enable the user of our given project, a 7 year old girl named Elsa with arthrogryposis, to independently put on a shirt with minimal time and effort. Gathering information about the project helped us to better understand the user's perspective and needs as well as the specific elements of the project itself. The components of our research includes: (1) symptoms of arthrogryposis; (2) psychological effects arising from arthrogryposis; (3) existing wheelchair capabilities; and (4) current systems that facilitate in dressing.

## Symptoms of Arthrogryposis

### *Physical symptoms*

Arthrogryposis is a congenital condition that affects the joints and renders them to have limited mobility.The joints may be stiff or even completely immobilized due to the formation of joint contractures when a person is born. Often times, the affected areas are surrounded by weak or missing muscles, webbed skin, or extra tissue that holds the joint to one spot ("Arthrogryposis"). In our project's case, the user Vanessa has limited flexion primarily in her elbows and shoulders. Figure 14 illustrates the physical characteristics of a typical baby with arthrogryposis.

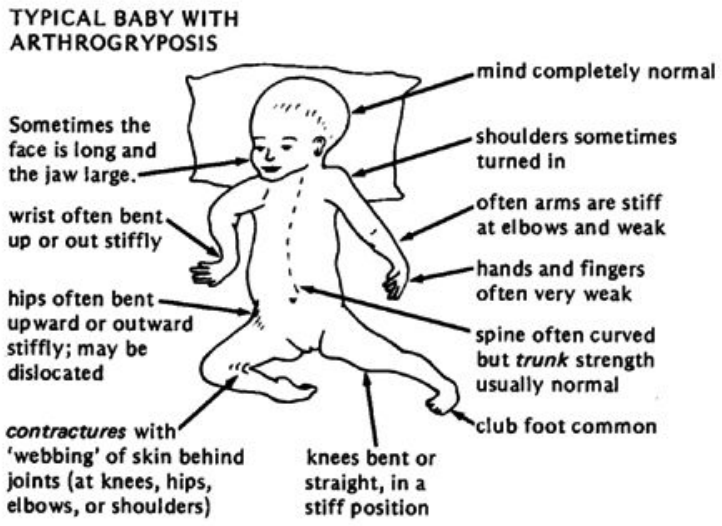


Figure 14: Common physical symptoms of a baby with arthrogryposis
Source: Arthrogryposis: "Exploring Treatment Strategies To Reduce Pain & Improve Mobility" <http://healingfeet.com/surgery/arthrogryposis>

### *Cause and treatment*

The main cause of arthrogryposis is fetal akinesia, a term used to describe less than normal baby movement in the womb. Approximately 1 in 3000 babies are born with arthrogryposis, and the condition varies in severity from one person to another. Many with arthrogryposis require assistance (sometime even lifelong assistance) with everyday activities such as walking or, in the case of our client, dressing. Although debilitating, arthrogryposis isn't degenerative, and a combination of occupational and physical therapy can greatly improve the range of motion of the affected joints ("Arthrogryposis: Exploring Treatment Strategies To Reduce Pain & Improve Mobility").

## Psychological effects arising from arthrogryposis

Arthrogryposis is a physical disease that impedes only a child's mobility and not any cognitive functions. In fact, most children born with arthrogryposis have normal language skills and possess average intellect, and most go on to live happy and fulfilling lives as adults ("Arthrogryposis"). However, the emotional strain, medical expenses, and the time required of children with any disability to cope with their condition can put a significant burden on the children themselves as well as their families. Feelings of embarrassment and guilt can often times have a profound effect on a child's mental health and well-being, and family members may struggle with providing the care and time that is required of them. As such, it is important to note the psychological aspects associated with arthrogryposis as they can greatly define the way in which the people with the disability think and interact with others (Reichman, et. al., 2008).

## Existing wheelchair capabilities

Based on the description of the project given to us by our client, we know that the user Vanessa uses an electric wheelchair as her primary mode of transportation (see Figure 15).

Figure 15: Typical electric wheelchair
Source: "Electric Wheelchairs: Types & Reviews of Powerchairs"
<http://www.disabled-world.com/assistivedevices/mobility/wheelchairs/electric/>

Electric wheelchairs have large metal frames for support and cost about $7000 on average, which is the most expensive of any type of wheelchair on the market. The wheelchair itself is powered by a motor and a battery and controlled by a joystick or directional buttons; the battery of the wheelchair, however, cannot be used to power other devices. As far as customization goes, users can individualize the exact dimensions, reclinability, stability, and even the turning radius of the electric wheelchair to suit their specific needs (“Wheelchairs: Information & Reviews”). One of the few peripheral devices we found that can be attached to wheelchairs are simple storage units, which can be added to the back, armrest, or the bottom of the wheelchair ("Wheelchair Bags, Totes, Back Packs & Pouches") .

## Current Systems

Although there are no commercially available self-dressing devices specifically made for people with arthrogryposis, there are many types of dressing aides and dressing alternatives available for those with range of motion in certain areas of the body or for those who are wheelchair-bound. Three such examples include the dressing tree, the dressing stick, and adaptive clothing.

## Dressing Tree

The dressing tree provides a way for a user to use the hooks on the device to hold a shirt in place while the user slides adjusts his or her body position to slide right into the shirt through the opening. Figure 2 shows a screenshot from a Youtube video of a 6 year old boy with arthrogryposis demonstrating how the dressing tree operates.

Figure 2: The Dressing Tree
Youtube <https://www.youtube.com/watch?v=ntRZftyTE9s>

## Dressing Stick

The dressing stick is designed for use by those with limited mobility in their arms and shoulders. The dressing stick has a C-shaped hook on one end and and a push-pull hook on the other (see Figure 3). These hooks allow for the user to pull an article of clothing over the head and adjust it accordingly onto the body.

Figure 3: Dressing stick
1 800 Wheelchair <http://www.1800wheelchair.com/product/dressing-stick/>

## Adaptive Clothing

Adaptive clothes are made for wheelchair users in particular, so, as a result, these clothes are designed to be comfortable and easy to put on. Adaptive clothing usually have simple locking mechanisms such as zippers and “snap-backs” to accommodate for any dressing difficulties (see Figure 16).

Figure 16: Adaptive clothing
Silverts <”http://www.silverts.com/adaptive-clothing/”>

## Conclusion

After conducting extensive background research on the problem given to us by our client, we were better able to understand the user Vanessa’s condition and divert our attention to answering specific questions regarding the design of our project, such as the relative ease of use required of our device for children with arthrogryposis to operate. In addition, we were prepared to bring up key issues and questions to our client during our client interview, and the answers we received further refined the components of our overall project definition.

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Reichman, Nancy E., Hope Corman, and Kelly Noonan. "Impact of Child Disability on the Family." *Maternal and Child Health Journal Matern Child Health J* (2007): 679-83. *Medscape*. Springer Science Business Media. Web. 13 Jan. 2016

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"Wheelchair Bags, Totes, Back Packs & Pouches." *Storage Solutions for Wheelchair Users*. Wright Stuff, n.d. Web. 13 Jan. 2016.

# Appendix D: Performance Testing Summary

## Purpose

The focus of our performance testing was to determine specific measurements that would be critical to the success of our design. It consisted of 3 tests. We were trying to determine 1) The ideal angle of depression for the hooks to put a shirt on, 2) The ideal positioning of a person's back to take a shirt off, and 3) the ratio of (distance seat to head):(distance the shirt needs to move to take off). The last test's data would be extrapolated to Elsa's body dimensions to determine the exact amount of travel in the pulleys necessary to take her shirt off.

## Methodology

For the first test, angles were tested in 10 degree steps by 3 criteria: time to put on, whether or not the shirt stayed on the hooks long enough to put the shirt on, and whether or not the shirt would come off the hooks after the shirt was put on. The ideal angle would keep the shirt on the hooks through the entire process, slip off afterwards, and require a reasonable amount of time to complete the process (see Figure 17).

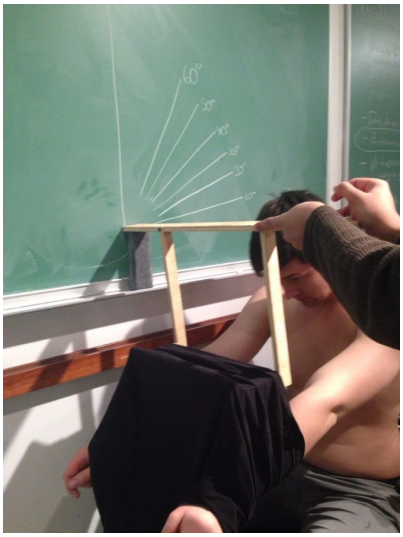
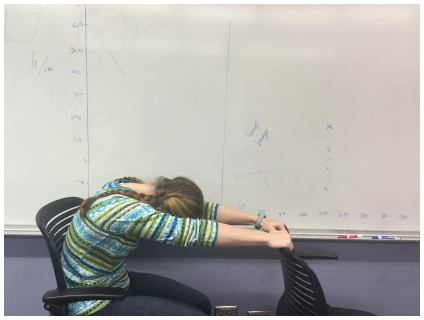


Figure 17: Hook Angle Performance Testing

For the next test, the maximum amount of force necessary to take a shirt off was measured with different angles between a team member's back and the floor. The angle with the lowest maximum force is the ideal angle (see Figures 18, 19, and 20).


Figures 18,19,20: Off Angle Testing

For the last test, we measured the distance from a sitting team member's head to the seat. Then we held the shirt in place and measured the distance the chair would need to be pulled backward to get the shirt off (see Figure 21).

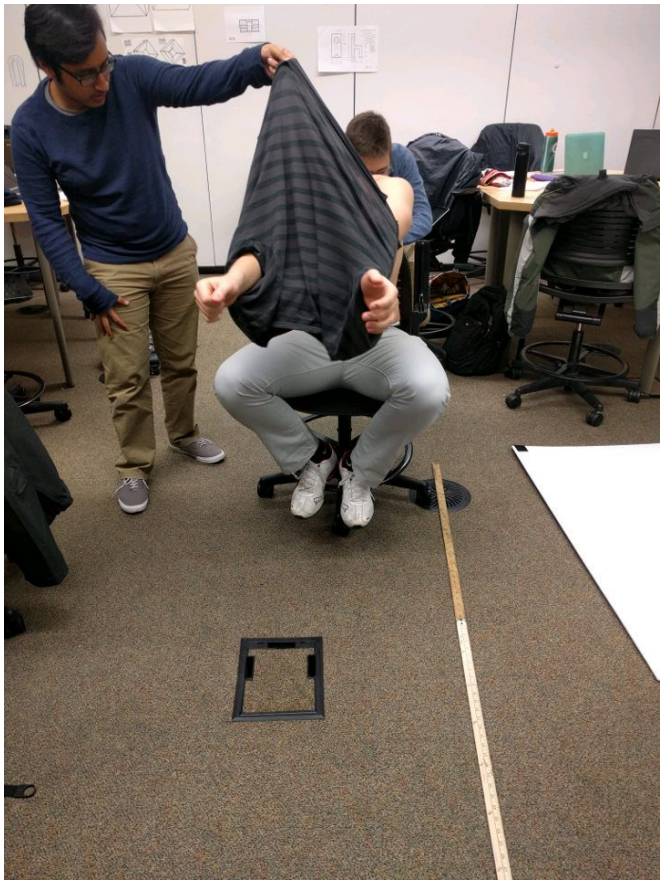


Figure 21: Backward Distance Testing

## Results

Test 1

- **-20 degrees** was the most successful test
- The average time to complete was 3.37 seconds

Test 2

- **35 degrees** was the most successful test
- Observations: Works better if test subject has arms bent ~30 degrees down from plane with their torso

Test 3

- The ratio is 36 : 57.3, or **1 : 1.6**
- We will plan on a ratio of at least 1 : 1.75 to be on the safe side

# APPENDIX E: USER OBSERVATION SUMMARY

We had our initial user observation of our client Elsa and her mother at RIC's Center for Health and Fitness on Thursday, January 14th, 2016 at 6:30 p.m. Her mother, Mary, and her therapist, Megan O'Donnell, were present. The purpose of the meeting was to see Elsa's range of motion and her wheelchair mobility. This appendix explains the methodology used to conduct the observation, what we learned about Elsa's physical abilities, the mobility and dimensions of the wheelchair, requirements for the design, and her current method of dressing. Two members of our team were present Sebastian Dobon and Gretchen Vogt.

## Methodology

The observation took place in a wing of RIC for children with physical disabilities. Elsa was first asked to move from her wheelchair to the edge of a bed. She and her therapist demonstrated the method of putting on a shirt that they had been practicing together, with Megan holding the shirt and Elsa putting one arm, then the other, and finally leaning through to put her head through and pulling up to put it on.

## Physical Abilities

Elsa's arthrogryposis severely limits her mobility in her arms and legs. Her core strength is comparatively strong. We tested the range of movement in her arms by having her hold onto a 3 foot long, 1 ½ inch diameter PVC pipe and raising it. Her wrists were turned inward but straightened when holding the pipe. She was able to lean forward and pull herself back to a sitting position by using the momentum from swinging her head.

Figure 22: Elsa's Wheelchair.
<http://www.easymobility.co.uk/junior-skippi/>

## Mobility and Dimensions of Wheelchair

Elsa uses a Skippi brand wheelchair that weighs 50 kilograms and can move at a speed up to 7.2 kilometers per hour. See Figure 1. Its dimensions are 35 inches long with the footrest, 24 inch wheelbase, 24 inches from the floor to the armrest, and 12 inch seat width (see Figure 22). When sitting in the wheelchair, Elsa's measurements include:

- 45 inches from the floor to the top of her head,
- 14.5 inches from her shoulder to her fingertips,
- 11 inches from the armrest to her shoulder,
- 27 inches from the seat to the top of her head,
- 13 inches from her hips to the edge of the seat,
- 23 inches from the seat to her neck when she leans over,
- 30 inches from her back to the ground when she leans over.

## Current Method of Dressing

In the morning Elsa's mother puts her shirts on by moving her arms into place while Elsa sits still. Her therapist demonstrated what she and Elsa had been practicing, which was a method similar to [insert youtube video] where the therapist's fingers replaced the hooks. Elsa still required much coaching and help with this process.

## User Requirements

Elsa's mother would like the device to be transportable from room to room and have no lasting impact on the house itself. She can set up the device itself but would like it to save time and give Elsa independence by being able to put on a shirt herself. Her mother also said adaptive clothing would be an option as a solution.

## Conclusion

From this meeting we could begin to think of solutions for her need. We saw her limitations and know what her mother would like in a solution.

# APPENDIX F: USER TESTING SUMMARY

## Purpose

The purpose of our first round of user testing was to determine if our user could perform tasks that would be crucial to our potential designs. This included 4 tests. Firstly we tested if she can put her arms through the arm holes while a shirt lies on her lap. Secondly we tested if she could attach hooks to her shirt. Thirdly, we tested if she could park her wheelchair accurately in reverse and forward. Lastly, we tested if we could drive her vehicle using a static arm that would be pushed forward.

We used two mockups at user testing. The first one, displayed in Figure 23, is a foam core hook. We used it to check if Elsa could hook her shirt onto a hook that would pull her shirt off.

Figure 23: Mock up Hook

The second mockup is displayed in Figure 24. It is a foam core arm that goes over Elsa's wheelchair controls. We used it to check if Elsa's wheelchair could be accurately driven by an arm shaped similarly to the mockup used.

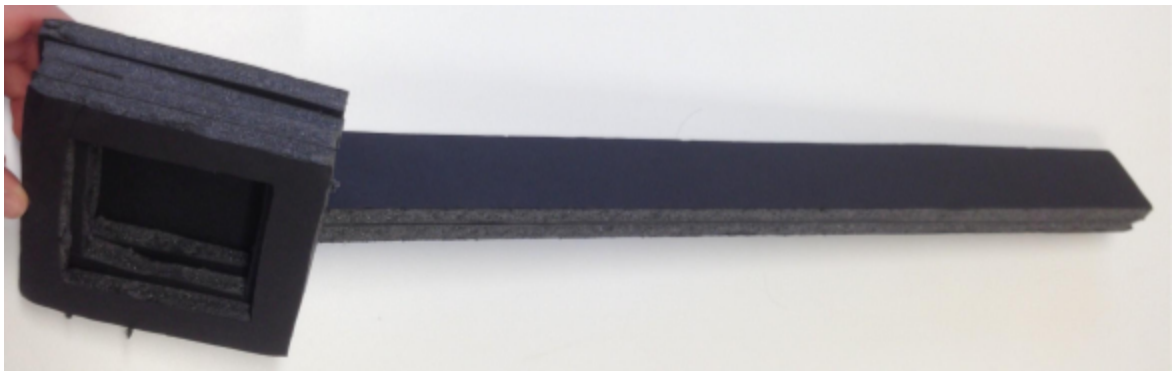
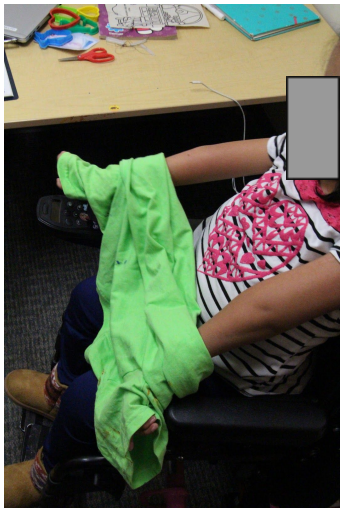
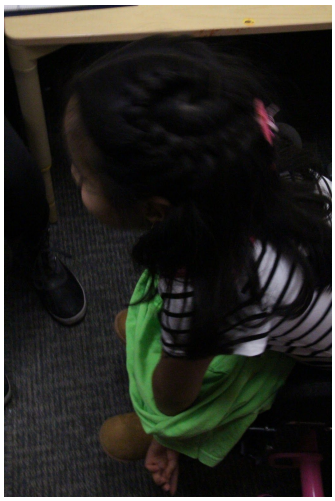


Figure 24: Mock up used to test remote driving

## Methodology

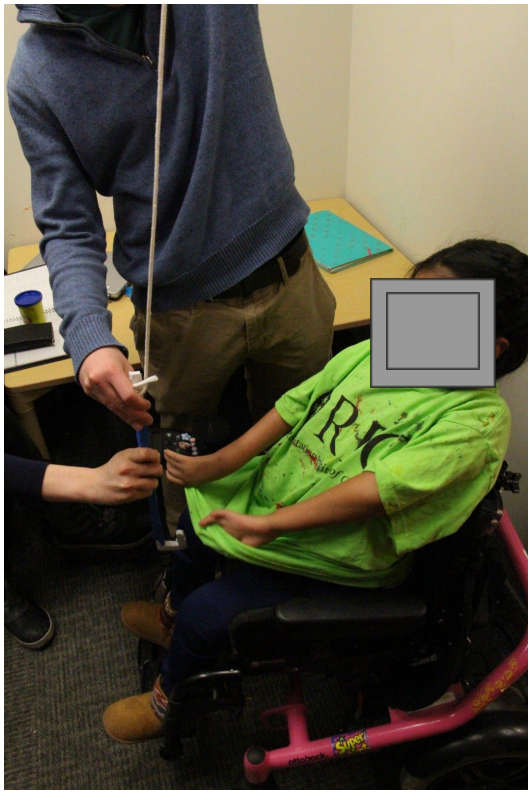
In the first test, a crumpled shirt that had the holes facing the correct direction was put on the user's lap. The user was asked to put her arms through the shirt holes. The amount of time it took her to do this was recorded (see Figures 25, 26, and 27).





Figures 25,26,27: Series of Images Showing Elsa in User Testing

In the second test, a hook was held stationary in front of the user by a team member, and she was asked to hook her shirt onto the hook. After doing this, she was asked to hook her shirt onto the same hook, but this time it was left hanging from the string rather than being stationary. For this test, a foam core hook was used with a string attached to it (see Figure 23). The time it took her to do this was recorded (see Figures 28 and 29).



Figures 28,29: Elsa Using the Mock up Hook

In the third test, the user was asked to line up the front right corner of her wheelchair on a straight piece of tape. She was then asked to do the same thing except while reversing. Her distance from the pieces of tape were measured with a ruler and recorded.

In the fourth test, a team member used a foam core mock up to test if the user's wheelchair can be accurately moved by a remote arm that would be powered by the user pushing against a bar. The user remained in her seat, and the present team member attempted to move the wheelchair forward and then backward by pushing the mockup forward and backward while it sat over the controls of the wheelchair. The mockup used is shown in Figure 24.

The tests were conducted at the Research Institute of Chicago. They were done in an exam room along side the user, her mother, and her occupational therapist. Only one team member was present, so that member conducted tests while members of the other teams took pictures and helped with timing.

## Results

Test 1

- Success
- Time: 27 seconds
- Hypothesized time (how long it took Gideon): 4 seconds

Test 2

- Success
- Time to put shirt on stationary hook: 5 seconds (success on first attempt)
- Hypothesized time to put shirt on loose hook:
- Time to put shirt on stationary hook: 10 seconds (success on third or fourth attempt)
- Hypothesized time to put shirt on loose hook:

Test 3

- Forward parking wheel distance from target tape: 0 inches
- Reverse parking wheel distance from target tape: 0 inches

Test 4

- At speed 3: Movement extremely jerky, very difficult to control with arm
- At speed 1: Still very jerky and difficult to control with arm
- Wheelchair deviated from straight line about 6 inches in either direction horizontally

## Results Analysis

Test 1 indicated that Elsa can successfully put her arms through the shirt holes. However, she needs to have the shirt oriented in the correct way on her lap in order for this to occur. It is also not easy for her to do this, as it takes her 23 seconds longer than hypothesized to put it on.

Test 2 indicated that Elsa can put her shirt on stationary hooks as well as loose hooks that are in front of her. She can more reliably do it when the hooks are stable, and it takes her multiple tries to get it on when they are loose.

Test 3 indicated that Elsa is a very skilled driver of her wheelchair, and can park it in any position needed.

Test 4 indicated that moving the wheelchair using an arm similar to the mockup is very inaccurate, jerky, and potentially dangerous.

## Conclusion

Given the results, we can come to a few design conclusions.

Firstly, the results suggested that if the designed device requires Elsa to put her arms through the arm holes of a shirt without assistance, she would be able to do this in less than 30

seconds. So, any further designs should assume that this is a movement/ability that the user has and does not need to be helped with.

The results also suggested that stationary hooks would be easier for Elsa to use, so those should be preferred over hanging hooks. However, if any device requires there be only a string attached, then the user would still be able to put her shirt onto a loose hook.

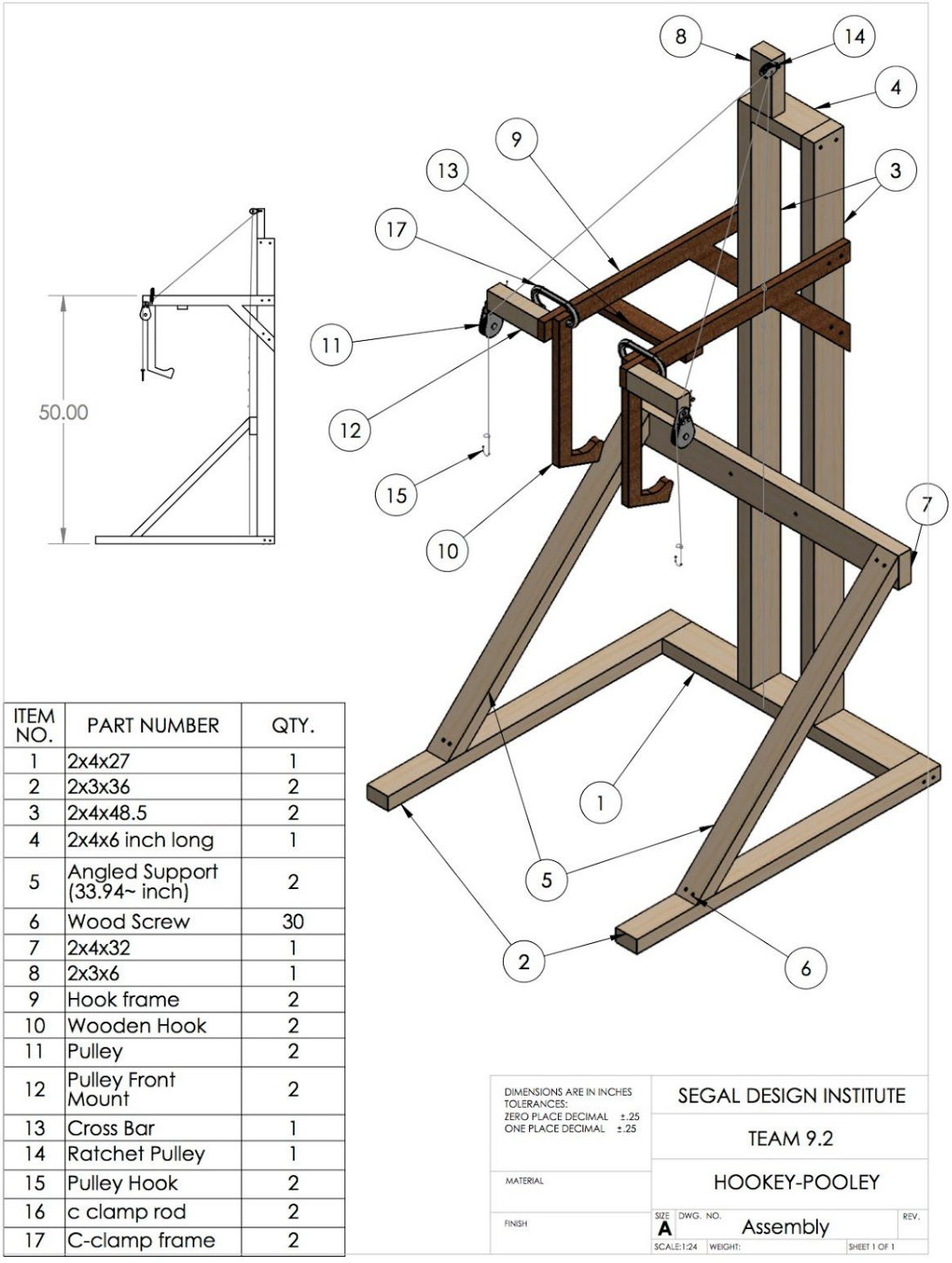
In addition, the results suggested that if Elsa can park her wheelchair in any specific position to use a device. The system that we design does not have to be constrained by being difficult to park next to or in the correct position.

Lastly, the results suggested that we should not pursue a drive through system, because moving the wheelchair with the arm was extremely inaccurate. Without constant access to the wheelchair it would be very difficult to design something compatible with it. In addition to being difficult, it would be dangerous to have Elsa's wheelchair moving in a jerky and unpredictable way while she is driving around hooks.

## Limitations

Getting more than one data point for each test was impossible, because the user did not want to do multiple tests. In addition, the measurements for the movement of the wheelchair in test 4 were inaccurate, because instead of going off to one side as expected, the wheelchair jerked and zig-zagged, so the measurements were more of estimates rather than hard data.

# Appendix G: CAD Drawings




| ITEM NO. | PART NUMBER | QTY. |
|---|---|---|
| 1 | 2x4x27 | 1 |
| 2 | 2x3x36 | 2 |
| 3 | 2x4x48.5 | 2 |
| 4 | 2x4x6 inch long | 1 |
| 5 | Angled Support (33.94~ inch) | 2 |
| 6 | Wood Screw | 30 |
| 7 | 2x4x32 | 1 |
| 8 | 2x3x6 | 1 |
| 9 | Hook frame | 2 |
| 10 | Wooden Hook | 2 |
| 11 | Pulley | 2 |
| 12 | Pulley Front Mount | 2 |
| 13 | Cross Bar | 1 |
| 14 | Ratchet Pulley | 1 |
| 15 | Pulley Hook | 2 |
| 16 | c clamp rod | 2 |
| 17 | C-clamp frame | 2 |

DIMENSIONS ARE IN INCHES
TOLERANCES:
ZERO PLACE DECIMAL ±.25
ONE PLACE DECIMAL ±.25

SEGAL DESIGN INSTITUTE

TEAM 9.2

MATERIAL

HOOKEY-POOLEY

FINISH

SIZE A | DWG. NO. Assembly | REV.

SCALE:1:24 | WEIGHT: | SHEET 1 OF 1

Figure 30: Overall CAD

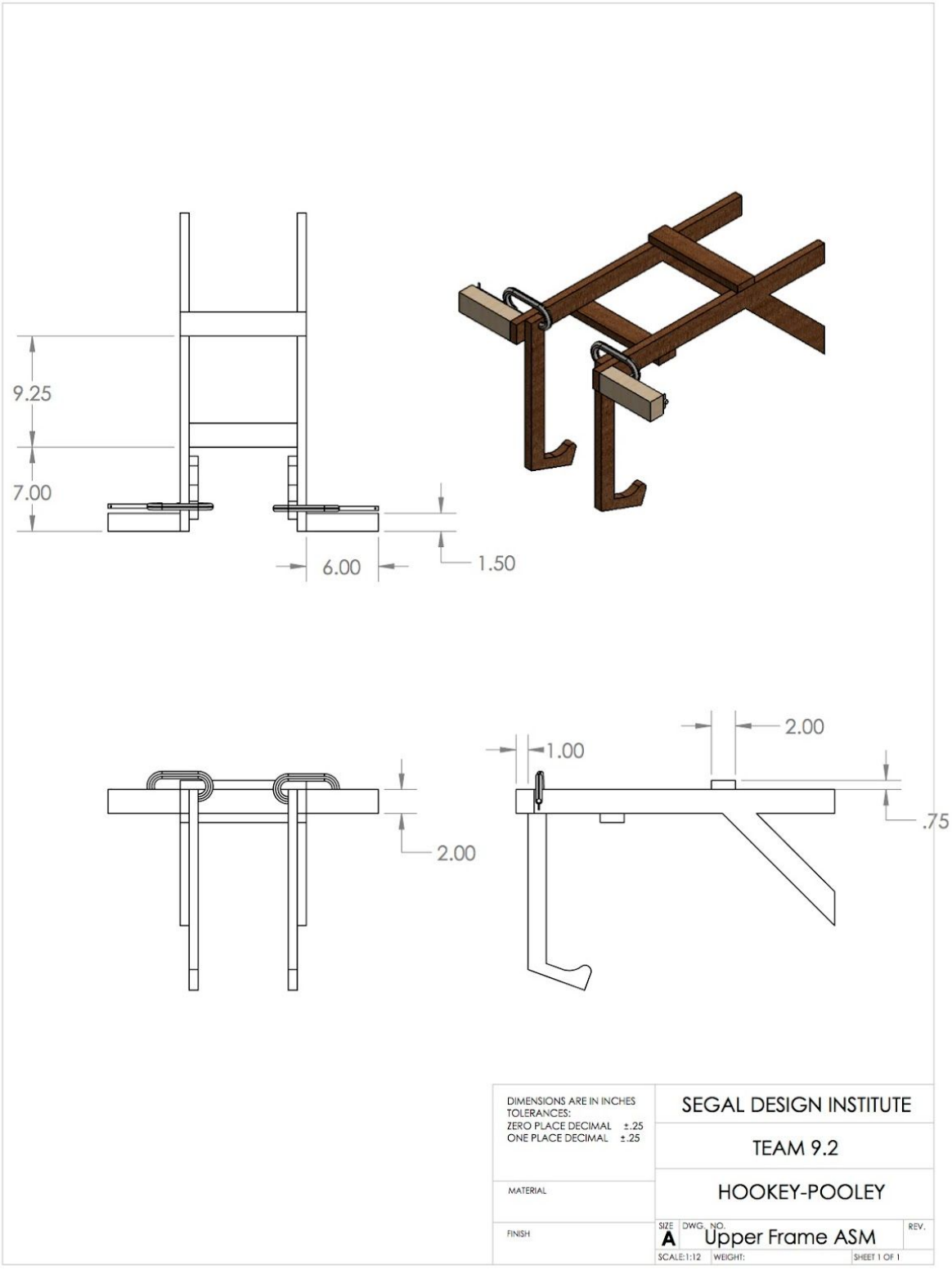



Figure 31: Frame CAD

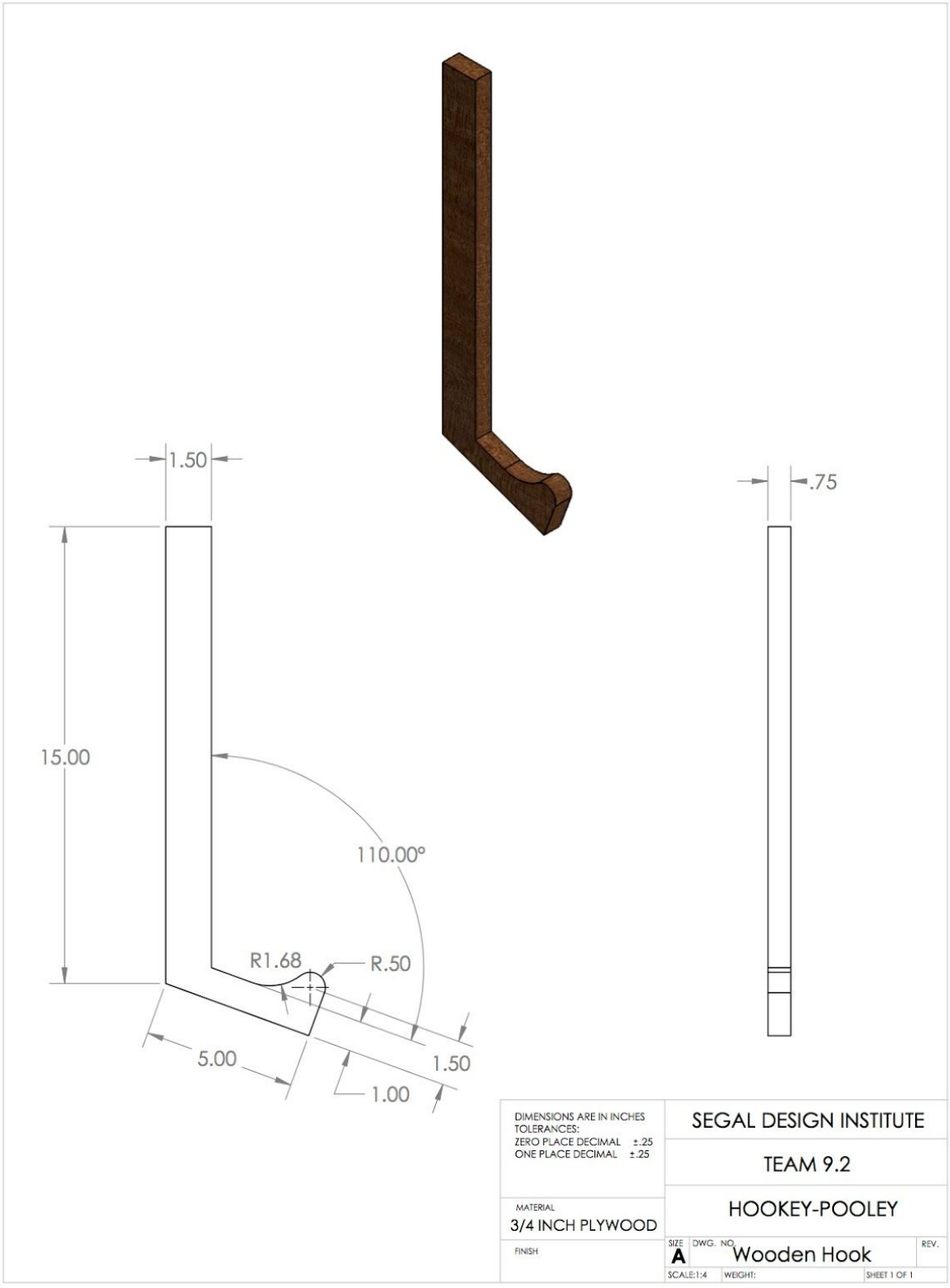



Figure 32: On Hook CAD

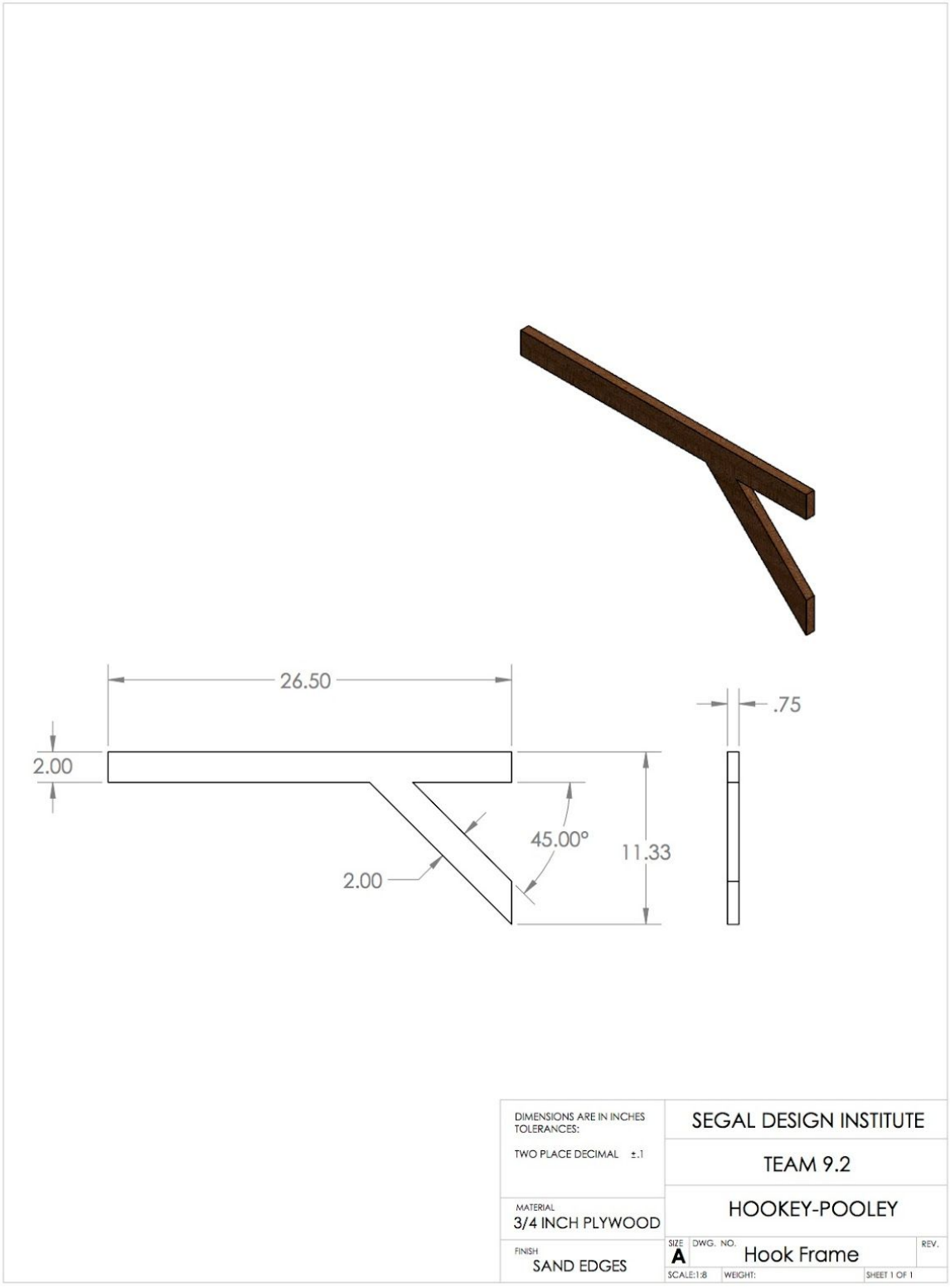



Figure 33: Hook Frame CAD

# Appendix H: Alternatives Matrix

| | Safety | Independence | Portability | Ease of Use |
|---|---|---|---|---|
| **Hooks** | | User can set hooks to guide shirt onto her body | | All user has to do is sit still while hooks lower shirt onto her body via some type of automated system |
| **Bar** | No sharp edges or other elements than could cause harm to the user | User can grab onto the bar while shirt is lowered onto her body | Device can be designed to be small enough so that the user may take it wherever she wishes | |
| **Control Arm** | None of the elements are capable of causing physical harm to the user | User can control her wheelchair to drive into her shirt | | Shirt is held open while user simply guides her wheelchair so that she can fit through shirt |

Table 4: Alternatives Matrix

## Holding shirt in place

- Velcro
- Magnets
    - It should be noted that with the above two ideas the clothes themselves may require some altering
- Hooks

## Moving user into a better position

- Raising bar (small motor)
    - User must be able to hold on to the bar but she has a weak grip, therefore methods such as those below could be used:
        - elastic bands
        - cloth wrist-grips (circles of cloth)
        - narrow bar

- Remote driving into a pre-set-up area
- Climbing up a ladder

## How the device will be set up/stored

- Free-standing, with base wide enough for wheelchair to drive in
- Hanging on back of door using hooks

## How to get the shirt to move towards the user once in correct position

- Have it fixed to a ladder so user can ‘climb’ in
- Have wind-up coils that are attached to the shirt and pull the shirt in the right direction
- Use springs to pull the shirt towards the user and over her head

## Ensuring the device is light and cheap (materials)

- Plastics
- Aluminum

## Safety Considerations

- Use rubber on any hooks
- Do not include any sharp corners
- Make sure that any moving parts have an accessible ‘off switch’
- Do not make any moving parts move too fast

## Controls

- Button to switch off/on a coil motor
- Over-the-joystick system to remotely control the wheelchair from another position

# Appendix I: Instructions for Use

The design of the Hookey-Pooley integrates a method for putting on a shirt and for taking off a shirt. Hence, the instructions for use are divided into two separate sections:

- To put on shirt
- To take off shirt

It is worth noting that because the mechanisms of the device involve possible safety hazards such as hooks and cables, caution should be exercised at all times.

## To put on shirt:

1. Drive up to the frame so that the big, wooden hooks are facing away from you.
2. Put your arms through the holes of the shirt while the shirt is in your lap.
3. Swing your arms up so the back of the shirt is on the hooks. You may want to move around a little bit so that the shirt is in the best position.
4. Lean forward into the shirt and put your head through the head hole.
5. Continue leaning forward until the shirt falls off the hooks, then sit back up.
6. Wiggle! Until the shirt falls down all the way.

## To take off shirt:

1. Drive up to the frame and put the free hanging hooks onto the left and right sides of the shirt. Make sure that the ropes go outside of your arms.
2. Once the hooks are attached, drive back a little bit so that the ropes attached are at a 45 degree angle to upright.
3. Lean forward and grab onto the knotted rope.
4. Pull down on the rope to move the hooks upwards.
5. Continue pulling on the rope until your shirt is completely off. You need to make sure your head is tucked to your chest so that the shirt will come off, you may need to wiggle a little bit too to help!

Instructions for Use Video:

# Appendix J: Bill of Materials

| Item | Description | Qty | Source | Part # | Unit Cost | Total Cost | Link |
|---|---|---|---|---|---|---|---|
| 2”x3”x8’ lumber | 2”x3”x8’ Grade 2 Stud and Better, Untreated, Spruce, Pine or Fir | 8 | Shop | 1021020 | $1.95 | $15.60 | https://www.menards.com/main/building-materials/lumber-boards/studs/2-x-3-x-8-stud-or-better-lumber/p-1444422058023-c-13125.htm?tid=14365702143630429 1 |
| Pulleys (2) | Steel Pulley for Wire Rope, Hanging Pulley, for 3/16” Rope Diameter, Rigid Eye | 2 | Shop | 3099T54 | $8.39 | $16.78 | http://www.mcmaster.com/#3099t54/=11bsemd |
| Rachet Pulley | 1/8" Adjustable-Height Grow Light Fixture Ratchet Hangers with Steel Hooks, 7' Nylon Ropes, Max Weight 150lb | 1 | Shop | N/A | $6.95 | $6.95 | http://www.amazon.com/247Garden-Adjustable-Height-Horticulture-Reflectors-Hydroponics/dp/B00K600K2M/ref=sr_1_sc_2?ie=UTF8&qid=1456703138&sr=8-2-spell&keywords=ratcheted+pullies |
| 3/4”x4’x8’ plywood | 3/4”x4’x8’ Rated Sheathing, Constructed with Douglas Fir and other Western Species, Exposure 1 Rated | 1 | Shop | 1231182 | $19.78 | $19.78 | https://www.menards.com/main/building-materials/panel-products/construction-panels/sheathing/plywood-sheathing/3-423-32-x-4-x-8-plywood-sheathing/p-1444452503860-c-13331.htm?tid=608257036143134816 |
| Hooks | Hook for plastic cord, | 2 | Shop | 3862T51 | $5.09 (pack of | $5.09* | http://www.mcmaster.com/#3862t51/=11bskxp |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Black Plastic-Coated Steel for 3/16” Diameter | | | | 10)* | | |
| 3 ½” Wood Screws | Screw for Wood, Phillips, Brass, Number 10, 3-1/2" Long | 20 | Shop | 92114A259 | $8.64 (pack of 10)* | $17.28* | http://www.mcmaster.com/#92114a259/=11h3g7a |
| 3” Wood Screws | Screw for Wood, Phillips, Brass, Number 10, 3" Long | 10 | Shop | 92114A257 | $6.62 (pack of 10)* | $6.62* | http://www.mcmaster.com/#92114a257/=11h3iib |
| 1 ½” Wood Screws | Screw for Wood, Phillips, Brass, Number 10, 1-1/2" Long | 6 | Shop | 92114A251 | $7.93 (pack of 25)* | $1.90* | http://www.mcmaster.com/#92114a251/=11h3jfz |
| Rope | 7’ Braided Polypropylene Nylon Rope, Holds up to 150 lbs./68 kgs Max Weight | 12 m | Shop | N/A | Comes with Rachet | $0 | http://www.amazon.com/247Garden-Adjustable-Height-Horticulture-Reflectors-Hydroponics/dp/B00K600K2M/ref=sr_1_sc_2?ie=UTF8&qid=1456703138&sr=8-2-spell&keywords=ratcheted+pullies |
| OD 1.5” ID 0.25” Washers | Type 18-8 Stainless Steel Oversized Flat Washer, Number 12 Screw Size, 0.250" ID, 1.500" OD | 3 | Shop | 98370A111 | $14.33 (Comes as pack of 10) | $14.33 | http://www.mcmaster.com/#98370a111/=11hewz4 |

# Appendix K: Manufacturing Instructions

## Introduction

The following set of instructions will serve as a guide for the construction of the Hookey-Pooley.

The instructions for construction are divided as follows:

- Preparing Materials
- Attaching the Cross Beam
- Building the Square U Frame that sits on the ground
- Attaching the Uprights to the U Frame
- Attaching the cross beam
- Attaching the Diagonal Supports
- Creating the Arm and Hook Assembly
- Attaching the pulley
- Attaching the String System
- Building and Attaching Putting-On Hooks
- Attaching hooks and pulleys

## Materials List

| Item | Quantity |
|---|---|
| 2”x4”x8’ lumber | 8 |
| Pulleys | 2 |
| Rachet pulley | 1 |
| 3/4 ”x4’x8’ Plywood | 1 |
| 3/16” Hooks | 1 |
| 3 ½ ” Wood Screws | 20 |
| 3” Wood Screws | 10 |
| 1 ½” Wood Screws | 6 |
| 3/16” Rope | 15 ft |
| Washers: 1.5” OD, 0.25 ID | 3 |

Table 5: Materials for Construction

The following tools are required for construction:

- Electric Drill
- Miter/Chop Saw
- Band Saw
- Orbital or Belt Sander
- Sandpaper (P120 and P220)
- 4 Large Bar Clamps
- 2 large C-Clamps
- Robertson (Square) Head Bit
- Phillips Head Bit
- 1/8” (width) x 5.5” (length)  Drill Bit
- 1/16” (width) x 2.25” (length)  Drill Bit

## Preparing Materials

1. Cut the following pieces of wood from the 2” x 4” lumber.
    a. (2) 60”
    b. (1) 27”
    c. (1) 32”
    d. (2) 6”
    e. (1) 12” (piece at top)
    f. (2) 36”
    g. (2) 33.94”
    h. (2) 6”
2. Using a bandsaw, saw off one inch of wood from the rougher end of each of the pieces cut in part f, g, and h.

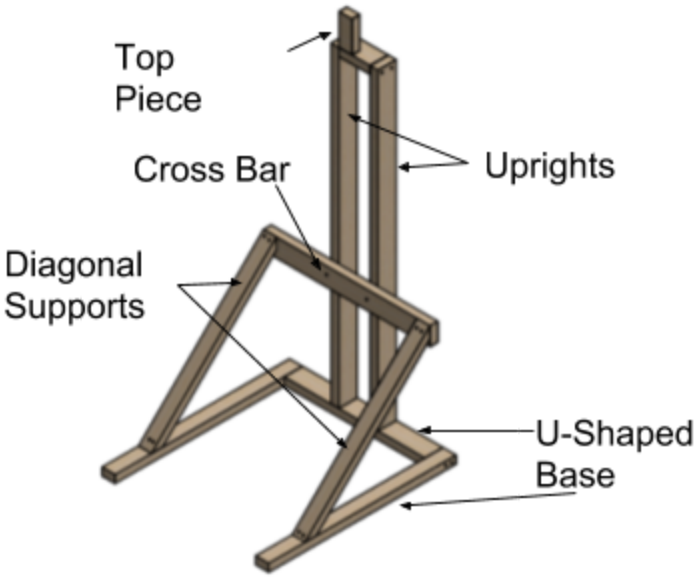



Figure 34: Names for Parts of the Frame

## Building the U-Shaped Base

1. Assemble both 36 inch 2”x3”s next to the sides of the 27 inch 2”x4” and clamp them to the table.
2. Drill 2 pilot holes at both joints using the 1/8 inch drill bit.
3. Using the electric drill, put two 3.5 inch screws into the pilot holes you just created on each side.

FIgure 35: U-Shaped Base

## Attaching the Uprights to the Base

1. Clamp the U frame to table so that the the arms are pointing upwards.
2. Clamp two pieces of 6 inch 2” x 4”s between the upright beams so that the edges of the uprights are flush with the edges of uprights.
3. Have another person push the uprights against the U frame. Make sure to measure first to ensure the uprights are centered on the U frame.
4. Use the 1/8 inch drill bit to make 2 pilot holes going through the U frame and each upright. (4 holes total)
5. Screw two 3.5 inch screws into the holes.
6. Remove the 6 inch pieces of 2”x4” and line one up so that it is flush with the top of the uprights.
7. Drill two pilot holes in each side with the ½ inch drill bit .
8. Screw in four 3.5 inch screws, one into each hole.

Figure 36 : Attachment of Uprights to Base

## Attaching the cross beam.

1. Line up and clamp the 32 inch piece of 2”x 4” so that it is centered on the uprights.
2. It should be ___ inches from the bottom of the structure.
3. Drill 4 holes through the cross beam and into both uprights (2 holes in each) using the 1/8 inch bit. Use a belt sander or orbital sander to round off the sharp edges.
4. Set a 45 degree angle on the miter saw. Cut these angles on both sides of the 33.94 so that each piece is now a trapezoid.

Figure 37: Attachment of Cross Bar to Uprights

## Attaching the Diagonal Supports

1. Put the existing structure on the floor. The uprights should be lying across the ground and the U frame should be sticking up.
2. Clamp one end of the support using a C-clamp. Make sure that the other, angled end is in good contact with the face of the U frame. **You should be working with the joint that is against the U frame, not the cross beam.**
3. Drill two holes using the 1/16 inch drill bit (at a 90 degree angle to the diagonal support, **not** the U frame). Make sure that the holes go through both pieces of wood.
4. Screw a 3 inch screw into each hole.
5. Remove the C-clamp and place it on the other 45 degree angle-joint that is against the cross beam.
6. Repeat steps 3 and 4, this time **work with the joint that is against the cross beam.**

Figure 38: Attachment of Diagonal Supports at Base

Figure 39: Attachment of Diagonal Supports at Crossbar

## *Creating the Arm and Hook Assembly*

1. Use the dimensions in the CAD drawings to draw an outline of the rigid hook and arm onto a piece of 3/4” plywood.
2. Cut out the shape using a bandsaw.
3. Also cut out a 6”x2” piece. This will be a crossbar.
4. Repeat steps 1 and 2 to create the second arm.
5. Clamp the top of the arms to the uprights 6 inches from the bottom of the structure.
6. At the end of the long part of each arm, use the 1/8 inch drill bit to make 2 pilot holes going through the U frame and each upright. (4 holes total)
7. Screw a 3.5 inch screw into each hole. (2 screws)
8. Clamp the two 6 inch 2’x3’s to the end of the arms.
9. Drill two 1/8 inch pilot holes through each piece and attach them using 3.5 inch screws.
10. On the outside of each piece attach the regular (not ratchet) pulleys at a 45 degree angle using a washer. Make 1/8 inch pilot holes and use 3.5 inch screws.
11. 6 inches from the front of the bars attach a crossbar between the two arms. Make 1/16 inch pilot holes and use 1.5 inch screws.

Figure 40: Attachment of Hook Support to Frame

Figure 41: Attachment of Pulley Arm to Hook Arm

Figure 42: Pulley Attachment

## Attaching the pulley

1. Clamp an 8” long piece of wood to the top of the structure so that one edge is in the middle.
2. Drill two holes using the 1/8 inch drill bit through the cross-bar of the uprights and into the 8 inch piece.
3. Screw two 3.5 inch screws into the holes.
4. Drill a hole using the 1/16 inch drill bit into the side of the top piece in the middle of the uprights. (This hole is used to attach the ratchet pulley, so make sure the hole is in the near top corner.)
5. Attach the pulley using a 1.5” OD, 0.25” ID washer and a 1.5 inch screw.

Figure 43: Attachment of Top Piece to Uprights

Figure 44: Attachment of Ratchet Pulley

## Attaching the String System

1. Put a dollop of hot glue on the tip of both hooks and let .
2. Attach a string to each metal hook.
3. Send each string through the regular pulleys, and attach them to the carabiner coming from the ratchet pulley. See figure 12 on the next page.
4. Tie a 6ft long piece of string to the back part of the ratchet string.
5. Tie knots along the strings so they’re easier to grip.

Figure 45: Attachment of String to Hook

Figure 46: Attachment of Strings to Carabiner

Figure 47: Tying knots along string

1. Trace the outline of the hooks given in the drawings.
2. Cut the shape out using the bandsaw.
3. Use a belt sander to sand the part of the hook that the shirt will be attached.
4. Use 120 P and then 220 P sandpaper to smooth the hook so that the shirt can slide off.
5. Clamp the hooks to the bars 1 inch from the bars.
6. Put 3 Zip Ties around each clamp as shown in figure 48.

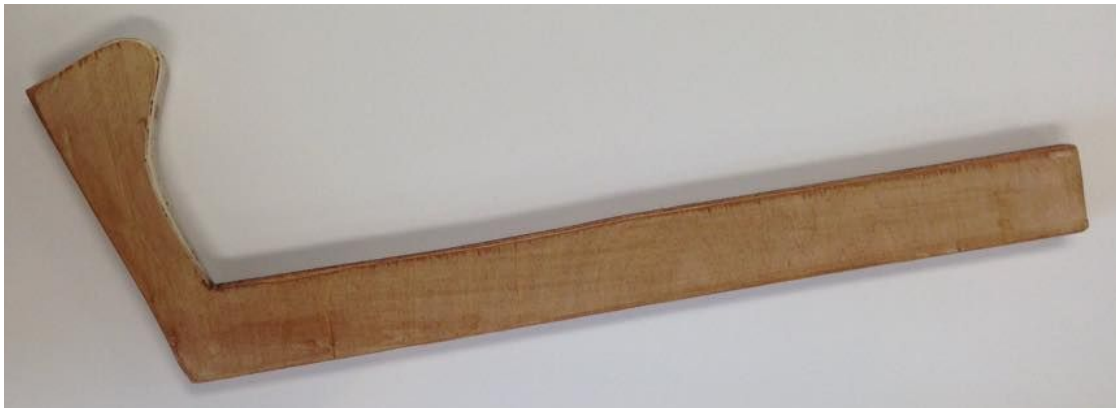


Figure 9: Putting on Hooks

Figure 48: Attachment of Hooks Using Clamps

# Appendix L: Design Review Summary

Our group presented our design to the other team on Tuesday, February 16th. Due to feedback received at user-testing we redesigned both the mechanisms to take off and put on the shirt. During the Design Review we presented the two mechanisms as separate ideas but we hope to incorporate the two into one device for our final prototype.

During the Design Review we handed out a questionnaire. Table 6 below details the feedback we received.

## Questionnaire Comments/Results:

| Reviewers Like | Reviewers Dislike | Features to be Added | Features to be Removed/ Modified | Additional Comments/ Questions |
|---|---|---|---|---|
| INDEPENDENCE<br>Self-sufficient system<br><br>Having her attach hooks herself<br><br>Having Elsa power it herself (leaning forward and pulling on a rope)<br><br>ON DESIGN<br>Hook shape/ design, long arm and rounded (big)<br><br>Putting shirt on to hooks facing away from her<br><br>Putting arms through holes in chair<br><br>Wide hooks for | ON DESIGN<br>Back-facing hooks<br><br>Getting shirt on the hooks<br><br>Shirt might fall off hooks when pushing forwards<br><br>May not be able to actually reach the hooks<br><br>The shirt needs to be able to come off the hooks at the right time<br><br>OFF DESIGN<br>Getting shirt off the hooks<br><br>Getting her arms out of the shirt | Maybe use velcro for added friction on hooks<br><br>Something to help her get the shirt on the hooks<br><br>Knots in rope so it's easier for Elsa to grab/climb<br><br>Consider clips instead of hooks | Use stronger materials<br><br>Make free standing so it doesn't need to be mounted away from door<br><br>Have hooks coming from sides as opposed to above so she doesn't hit her head<br><br>Integration of both designs<br><br>Make sure Elsa can actually reach hooks- find correct hook height | Need to consider safety more<br><br>Putting shirt on is creative and easy!<br><br>The swinging hook idea is great!<br><br>Arms through first is a good idea |

| | | | | |
|---|---|---|---|---|
| safety<br><br>Using arm swing for putting on<br><br><u>OFF DESIGN</u><br>Bending down<br><br>Taking off shirt with pulleys<br><br>Self powered using rope - motors and counterweights are dangerous<br><br>Attaching hooks to bottom of shirt<br><br>Finding the best angle to take off the shirt<br><br>Attaching to the door | Pulling and getting arms out at the same time<br><br>Use strength to pull<br><br>Hard to bring hooks to the side<br><br>Difficult to use<br><br><u>OVERALL</u><br>Make sure hooks aren't sharp<br><br>Placement of device in relation to door<br><br>Could obstruct the room | | Exact angle to take off shirt<br><br>Make hooks removable/ storable<br><br>Structure/ Mechanism of taking off shirt (where should the pulley(s) be<br><br>Work out how to get the hook to the outside of the shirt<br><br>Test different rope materials | |

Table 6: Design Review Questionnaire Results

## Below are the results of the numerical data we collected in the questionnaires:

| | 1/ Poor | 2/ Moderate | 3/ Fair | 4/ Good | 5/ Very Good |
|---|---|---|---|---|---|
| Ease of Use | 0 | 2 | 4 | 4 | 1 |
| User Independence | 0 | 0 | 3 | 4 | 6 |
| Saves Time | 0 | 3 | 7 | 2 | 1 |
| Putting on Shirt | 0 | 1 | 3 | 6 | 1 |
| Taking off Shirt | 0 | 2 | 4 | 4 | 1 |

Table 7: Design Review Numerical Results

From the data in Table 7 it is possible to see the areas the design is stronger and weaker in. The lowest scoring area was ‘Saves Time’, therefore this is possibly an area we need to try to improve. However, we are trying to save Mary time rather than Elsa, therefore by making the device entirely usable by Elsa on her own it is possible that we will still save time for Mary in the morning. For this reason, while we will try to reduce the time it takes to use our design, we will not do so at the detriment of other aspects such as user independence.

We can also see that ‘Ease of Use’ and ‘Taking off the Shirt’ have very centralized distributions around a value of 3.5 or between ‘Fair’ and ‘Good’. This suggests that while these aspects of the design are passable they could still use some improvement if possible. It is also worth noting that the score of ‘Putting on the Shirt’ has its median at 4 or ‘Good’ which suggests that if we were to chose to focus on one aspect of the design the putting on design may be the way to go.

Finally, ‘User Independence’ received very good reviews, with almost half of the responders choosing ‘Very Good’. Therefore as we move forward with our design we will try to maintain the same level of independence as we displayed during our Design Review.

## Conclusion:

After having reviewed feedback from the Design Review there are definitely some areas that we need to work on and possibly nail down values with hard numbers. Specific things that we need to look at include; whether the shirt will be able to slide off the hook at the right time when she is putting the shirt on, how high the hooks should be, where the pulleys should be positioned when taking off the shirt, and what type of materials we are going to use for the different parts of the device.

We should also consider whether we are going to try to integrate both parts of our design together or focus on taking the shirt off or putting it on. If we decide to focus on one then we need to consider results from the Design Review and our own feelings of how our designs are progressing in order to make an unbiased decision.