SIT TO STAND ASSISTIVE DEVICE

STEM II: Assistive Technology

Final Design Study

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Introduction

Purpose of Document

The purpose of this document is to compare and contrast all prototypes and the current design as well as to document how each of them were prototyped, assembled, and tested with the reasoning behind each decision in the prototyping process. The final design will then be analyzed and summarized.

Motivation

Getting in and out of the seated position can put too much of a burden on joints, causing pain and discomfort for those who have weaker joints and muscles, such as elderly people or those recovering from injuries. A STS (sit-to-stand) assist device will be manufactured to reduce the burden on the limbs of individuals struggling to do so by utilizing a combination of springs, hydraulic/pneumatic actuators, and 3D-printed parts. The task of getting in and out of the seated position is known to be a struggle for many, especially the elderly, the injured, and the disabled communities.

Target Audience

This product is directed towards the elderly community in order to address the problem of easy mobility when getting in and out of chairs. The device is also beneficial to those with disabilities and injuries that limit leg mobility. Increased difficulty in this seemingly simple task can heavily impact the quality of life for many demographics. Currently, it is difficult for these communities to sit down and stand up due to the pressure it exerts on their lower limbs. In order to alleviate that pressure, our portable cushion will extend to an angle that doesn't cause our client to have to bend as much when moving. They will be able to keep their posture steady therefore generating less pain and struggle.

Summary of Market Research

Over time, muscles weaken with age and so it takes more effort to get up from a sitting position. In addition, bones become less dense and more brittle, making them more susceptible to injury. There is also some loss of flexibility in joints that allows easy movement. The STS involves a transition from an intrinsically stable three-point support to a dynamically stable two-point support. Difficulty in rising from a seated position may directly increase the risk of injury as STS transfers were found to be responsible for

41% of all falls in nursing homes (van Lummel et al., 2018). With this increased chance for STS related injuries, an accessible solution is necessary.

Building and Testing

Purpose of Testing.

A series of tests were performed in order to determine how well the seat would be able to support an individual. While using strong springs would provide more support for the client in the STS maneuver, the amount of comfort would decrease whilst in the seated position due to the constant upward force being applied. On the other hand, the pneumatic actuator provides comfort but presents difficulty in customization. Due to the numerous criteria, a series of tests were necessary to isolate the most desirable attributes.

Design Study #1: Spring Seat

Brief Overview.

The first design study that we conducted was on the Spring Seat prototype. We conducted this design study to determine the client's effort, pain, and comfortability while using our device. It is vital to take the client's response to these factors into account in order to guarantee a safe and helpful assistive device. If the seat-extension does not work as intended, the client's effort and pain will increase, while their comfort decreases, which, in turn, does not set this device apart from a regular chair.

Build Steps.

The steps to build the spring seat prototype are as follows:

1. Screw in a hinge between two pieces of plywood of desired size for the chair
2. Using eight brackets, screw in the set of four springs onto each side of the plywood, with the two shorter springs being placed near the hinge and the two larger springs being placed near the back of the chair
3. Make sure to bend the springs to adjust to the desired starting angle of the chair
4. Add 3D printed seat piece to the top piece of plywood

5. Add the cushion to the top side of the 3D printed seat piece

Variables.

Independent Variables.

The independent variable was which seat prototype was being tested. All prototypes had a wooden base and had the same seat dimensions. Differences were present in how the upward force was being applied. Seat 1 uses a spring, seat two uses a pneumatic actuator, and seat three uses a motorized scissor-lift system.

Dependent Variables.

The dependent variables that were measured were the amount of effort, on a scale of 1-10, that was reduced during the sit-to-stand maneuver (STS), the amount of pain, on a scale of 1-10, that was reduced in the STS maneuver, and the hoe comfortable the seat is, on a scale of 1-10.

Controlled Variables.

The control variables are the person testing each prototype. The chosen client stayed consistent throughout our testing process and gave us feedback using the same criteria for each device. Our other control variable was the chair we tested on. This ensured fair results throughout our experiment.

Materials.

- Chair - One that the client struggles to use
- Spring Seat

Experiments.

Experiment #1.

First, we instructed the client to sit on the device and recorded their answers to a series of questions regarding our predetermined criteria. The questions were asked to determine the level of effort it took to sit, the amount of pain it took to sit, and the comfortability the user felt while completing the sitting motion. The testing environment is shown below.

(a) (b) (c)

Figure 1: Client completing the sit-to-stand maneuver for Design Study #1 Experiment #1.

Note: (a), (b), and (c) are different stages of our client completing the sitting process.

We followed the steps below to conduct this first experiment:

1. Place the spring seat on the chair.
2. Secure it in place with a buckle to increase safety.

3. Instruct the client to complete the sitting motion on the Spring Seat.
4. Ask the client questions from our criteria.
5. Record the clients answers to our criteria.

Experiment #2.

Secondly, we allowed the client to stay seated on the device for five minutes and asked the same questions from our criteria as we did in the first experiment.

We followed the steps below to conduct this second experiment:

1. Allow the client to stay seated for five minutes
2. Ask the client questions from our criteria.
3. Record the clients answers to our criteria.

(a)

Figure 2: Client sitting on Spring Seat for Design Study #1 Experiment #2.

Experiment #3.

Lastly, we instructed the client to stand using the device and recorded their answers to a series of questions regarding our predetermined criteria. The questions were asked to determine the level of effort it took to stand, the amount of pain it took to stand, and the comfortability the user felt while completing the standing motion. The testing environment is shown below.

We followed the steps below to conduct this last experiment:

1. Instruct the client to complete the standing motion on the Spring Seat.
2. Ask the client questions from our criteria.
3. Record the clients answers to our criteria.

(a) (b) (c)

Figure 3: Client completing the sit-to-stand maneuver for Design Study #1 Experiment #3.

Note: (a), (b), and (c) are different stages of our client completing the standing process.

Results.

From the three above experiments, the results can be found below.

Table 1: DS 1 Experiment #1 Results.

	Spring Prototype 1	**Spring Prototype 2**
How much effort is it to sit?	5	2
How much pain do you feel to sit?	4	0

Table 2: DS 1 Experiment #2 Results.

	Spring Prototype 1	**Spring Prototype 2**
How comfortable was sitting in this chair for the past few minutes?	9	9

Table 3: DS 1 Experiment #3 Results.

	Spring Prototype 1	**Spring Prototype 2**
How much effort is it to stand?	3	2
How much pain do you feel to stand?	4	0

Table 4: DS 1 Misc. Questions.

	Spring Prototype 1	**Spring Prototype 2**
How much do you like the chair's aesthetic?	9	4
Is the seat too large or too small?	The seat is too large.	The seat is the right size.
Can you hold the chair, or does it weigh too much?	The client can hold the chair.	The client can hold the chair.

Analysis.

From these results, we determined that the Spring Seat was very successful regarding our criteria. During our first round of testing with the primary prototype, the client felt a medium level of effort and pain of 4 and 5 while sitting but after modifications were made, the amount of effort and pain the client felt was reduced to 2 and 0 respectively. Similarly, the client felt a level of effort and pain of 2 and 0 while standing before improvements were put in place, but after the amount of effort and pain the client felt was reduced to 2 and 0 respectively. Whilst remaining seated, the client was consistently comfortable. These results support the use of the spring seat as a viable design for our client due to the significant reduction of the discomfort felt by the user throughout the STS maneuver.

The Spring Prototype #1 proved to be too tall for the client to use and in turn negatively affected the feedback for the pain, effort, and comfortability during the STS maneuver. After removing some of the components that were increasing the height and causing difficulties for our client, the feedback for the pain, effort, and comfortability the user felt while using the device became drastically more positive.

In our various experiments, the final version of the prototype performed significantly well throughout the STS maneuver. This prototype passes all of the Level 1 requirements, after altercations were put in place, therefore, satisfying our client's needs.

Design Study #2: Pneumatic Seat

Brief Overview.

The second design study that we conducted was on the Pneumatic Seat prototype. We conducted this design study to determine the client's effort, pain, and comfortability while using our device, as we did before.

Build Steps.

The steps to build the pneumatic seat prototype are as follows:

1. Screw in a hinge between two pieces of plywood of desired size for the chair
2. Take your pneumatic actuators and mark out on the sides of the plywood where they will be placed (they should be placed near the edges of the wood to provide the most support but not too close to the edge so that the wood splits when screwing the supports in)
3. Screw in the supports (angle brackets) into the marked locations (there should be four: two at the back of the top piece of plywood and two at the front of the bottom piece)
4. Slide in metal rods into the slots of the pneumatic actuators and place them on the pieces of plywood
5. Tighten the fasteners and pump air into the actuators
6. Attach the cushion to the top piece of plywood

Variables.

Independent Variables.

The independent variable was which seat prototype was being tested. All prototypes had a wooden base and had the same seat dimensions. Differences were present in how the upward force was being applied. Seat 1 uses a spring, seat two uses a pneumatic actuator, and seat three uses a motorized scissor-lift system.

Dependent Variables.

The dependent variables that were measured were the amount of effort, on a scale of 1-10, that was reduced during the sit-to-stand maneuver (STS), the amount of pain, on a scale of 1-10, that was reduced in the STS maneuver, and the hoe comfortable the seat is, on a scale of 1-10.

Controlled Variables.

The control variables are the person testing each prototype. The chosen client stayed consistent throughout our testing process and gave us feedback using the same criteria for each device. Our other control variable was the chair we tested on. This ensured fair results throughout our experiment.

Materials.

- Chair - One that the client struggles to use
- Pneumatic Prototype

Experiments.

Experiment #1.

First, we instructed the client to sit on the device and recorded their answers to a series of questions regarding our predetermined criteria. The questions were asked to determine the level of effort it took to sit, the amount of pain it took to sit, and the comfortability the user felt while completing the sitting motion. The testing environment is shown below.

(a) (b) (c)

Figure 4: Client completing the sit-tos-stand maneuver for Design Study #2 Experiment #1.

Note: (a), (b), and (c) are different stages of our client completing the sitting process.

We followed the steps below to conduct this first experiment:

1. Place the pneumatic seat on the chair.
2. Secure it in place with a buckle to increase safety.
3. Instruct the client to complete the sitting motion on the Spring Seat.
4. Ask the client questions from our criteria.
5. Record the clients answers to our criteria.

Experiment #2.

Secondly, we allowed the client to stay seated on the device for five minutes and asked the same questions from our criteria as we did in the first experiment.

We followed the steps below to conduct this second experiment:

1. Allow the client to stay seated for five minutes

2. Ask the client questions from our criteria.
3. Record the clients answers to our criteria.

(a)

Figure 5: Client sitting on Spring Seat for Design Study #1 Experiment #2.

Experiment #3.

Lastly, we instructed the client to stand using the device and recorded their answers to a series of questions regarding our predetermined criteria. The questions were asked to determine the level of effort it took to stand, the amount of pain it took to stand, and the comfortability the user felt while completing the standing motion. The testing environment is shown below.

We followed the steps below to conduct this last experiment:

1. Instruct the client to complete the standing motion on the Pneumatic Seat.
2. Ask the client questions from our criteria.
3. Record the clients answers to our criteria.

(a) (b) (c)

Figure 6: Client completing the sit-to-stand maneuver for Design Study #1 Experiment #2. Note: (a), (b), and (c) are different stages of our client completing the standing process.

Results.

From the three above experiments, the results can be found below.

Table 5: DS 2 Experiment #1 Results.

	Pneumatic Prototype 1	**Pneumatic Prototype 2**
How much effort is it to sit?	5	5
How much pain do you feel to sit?	8	0

Table 6: DS 2 Experiment #2 Results.

	Pneumatic Prototype 1	**Pneumatic Prototype 2**
How comfortable was sitting in this chair for the past few minutes?	7	6

Table 7: DS 2 Experiment #3 Results.

	Pneumatic Prototype 1	**Pneumatic Prototype 2**
How much effort is it to stand?	4	2
How much pain do you feel to stand?	5	0

Table 8: DS 2 Misc. Questions.

	Pneumatic Prototype 1	**Pneumatic Prototype 2**
How much do you like the chair's aesthetic?	5	4
Is the seat too large or too small?	The seat is too large.	The seat is the right size.
Can you hold the chair, or does it weigh too much?	The client can hold the chair.	The client can hold the chair.

Analysis.

From these results, we determined that the Pneumatic Seat was subpar regarding our criteria. During our first round of testing with the primary prototype, the client felt a medium level of effort and a high level pain of 5 and 8 while sitting but after modifications were made, the amount of effort remained at 5 though the amount of pain the client felt was reduced to 0. The client felt a level of effort and pain of 4 and 5 while standing before improvements were put in place, but after the amount of effort and pain the client felt was reduced to 2 and 0 respectively. Whilst remaining seated, the client was mildly uncomfortable and the comfort level went down with the modifications. These results do not support the use of the pneumatic seat as an effective design for our client due to the significant reduction of the discomfort felt by the user throughout the STS maneuver.

The Spring Prototype #2 proved to be too abrupt for the client to use and in turn negatively affected the feedback for the pain, effort, and comfortability during the STS maneuver. The actuators did not provide a strong enough force and in turn did not provide a soft landing. After adding a spring to soften the descent, the feedback for the pain and effort the user felt while using the device became more positive but not by much.

In our various experiments, the final version of the prototype performed at mediocre level well throughout the STS maneuver. This prototype does not pass all of the Level 1 requirements, because the seat of the device was not able to lift the average human body weight at least 6 inches. The actuators were too weak to pass this requirement.

Design Study #3: Motorized Scissor-Lift Seat

Brief Overview.

The third design study that we conducted was on the Motorized Scissor-Lift Seat prototype. We conducted this design study to analyze our engineering process and review any issues we came across.

Build Steps.

The steps to build the (incomplete and failed) motorized scissor-lift seat prototype are as follows:

1. Screw in a hinge between two pieces of plywood of desired size for the chair
2. Connect the two scissor lifts by the shaft (this is where the prototype failed because of the reverse threading in the shaft and its short length)
3. Attached the motor to the shaft via berings
4. Screw in the motor and battery into the bottom piece of plywood
5. Attach the connected pair of scissor lifts to the top and bottom piece of plywood via brackets
6. Attach the cushion to the top piece of plywood

Conflicts

Our third prototype, the motorized scissor-lift seat, presented many problems that made the feasibility of engineering the idea difficult. One major conflict was the weight. Utilizing two scissor lifts along with a battery to power the added motor created a very bulky device. This would prove to be very difficult for the regular person to transport and even more so for our target audience.

Another problem presented by this prototype was the requirement of constant charging or changing of the battery. This device relies on the battery to complete any movement and so the need for charging causes an issue if the user forgets or the battery runs out of power mid use. This could leave the client in a dangerous situation.

The scissor lifts, even in their most condensed form, stand at at least four inches. Similar to the first spring prototype, this caused a problem with our client due to the height. The user was not able to comfortably mount the device and was put in increased danger attempting to. There was no way to combat this height problem since the seat base was not able to be modified in a way so that the lifts could be embedded.

The lifts also had a high probability of failing under stress. Unlike our more developed prototypes, these scissor lifts are not as weight bearing and due to the more flimsy materials that make them up, the client was at risk of a mechanical failure that could put them in harm's way. The scissor lifts bear a majority of the weight on two thin sheets of metal at the top, which bend under minimal pressure. Subjecting our client to testing such a device would be dangerous.

Another reason why the prototype was not further developed was due to the slow speed it would operate at. The motors we had on hand operated at a medium power which, when connected to the lifts, would work at a slow rate due to the force being applied from the client. This would interfere with the efficiency of the product and become uncomfortable for the client who is suspended in a semi-sitting position for an extended period of time.

Lastly, the feasibility was reduced due to the difficulty of engineering this prototype. The seat would have live wires beneath the seat which would be dangerous due to the fact the base and the seat and made of highly flammable materials as well be difficult to place. Additionally, the screws that condensed and extended the lifts would have to be rethreaded in order for the lifts to move in the same direction.

With the allocated time and the materials in possession, the motorized scissor-lift seat was not able to be developed further due to a plethora of issues.

Preliminary Designs

Spring.

Figure 7: Images of the preliminary spring design.

The first design is a base with springs that are attached to the platform the user will be seated on. Without weight pushing them down, the springs stay in the formation in which we implement them: a large spring with a forwards curve, and a smaller spring. This will allow the platform to tilt forward at its highest phase. When pressed down due to weight sitting on the platform, the springs' heights are around the same, allowing removing the angle from the platform at the lowest phase. The spring coefficients of each of the springs are enough to provide some support during STS. The range at which the platform can tilt is about 70° (labeled as θ), following the same average knee flexion angle of our target audience (Lou et al., 2021).

Pneumatic.

Figure 8: Images of the preliminary pneumatic design.

The second design uses a pneumatic actuator rather than springs in order to lift the user up, powered by compressed air rather than elastic energy. The seating platform is attached to a base via a hinge. Meanwhile, the back end will begin to lift up due to the continued push by the pneumatic actuator, anchored at two places on each plate (the seat plate and the base plate). This creates a tilt ($\theta = 70°$) of the platform providing the optimal angle for the user to stand from.

Engineering Matrix

Requirement	Type	Level	Prototype 1 - Spring Platform	Prototype 2 - Hydraulic/Pneumatic Actuator	Prototype 3 - Double Hydraulic/Pneumatic Actuator	Competitor 1 - Carex Upeasy Seat Assist	Competitor 2 - Parallel Manipulator	Competitor 3 - The Intelligent Sit-to-Stand	Current Design
The device shall significantly decrease the effort it takes the client to sit by 5 points on a 10-point scale (with 10 being uncomfortable and 1 being comfortable).	functional	1	Pass	Fail	Pass	Pass	Pass	Pass	Fail
The device shall significantly decrease the effort it takes the client to stand by 5 points on a 10-point scale (with 10 being uncomfortable and 1 being comfortable).	functional	1	Fail	Fail	Pass	Pass	Pass	Pass	Pass
The device shall be able to lift (push up) the average human body weight at least 6 inches (180 pounds).	functional	1	Pass	Pass	Pass	Pass	Fail	Pass	Pass
The client shall have access to a control panel/remote that controls the device features.	functional	1	Fail	Fail	Pass	Fail	Fail	Fail	Fail
The device shall significantly decrease pain felt by the client when standing/sitting by 5 points on a 10-point scale (with 10 being uncomfortable and 1 being comfortable).	functional	2	N/A	N/A	N/A	Pass	Pass	Pass	Pass
The device shall significantly decrease pain felt by the client when sitting by 5 points on a 10-point scale (with 10 being uncomfortable and 1 being comfortable).	functional	2	N/A	N/A	N/A	Pass	Pass	Pass	Pass
The seat shall be comfortable to sit in for long periods of time, acting as a cushion for the ascent and descent during sitting. This is a rating above 5 on a 1-10 point scale for level of comfort after five minutes of being seated.	functional	2	Pass	Pass	Pass	Fail	Fail	Pass	Pass
The device shall be able to provide heated/cooled seats for the user to achieve even more comfort.	functional	3	Fail	Fail	Fail	Fail	Fail	Fail	Fail
The device shall be available in a variety of different colors/designs so the user can match their aesthetic.	functional	3	Pass	Pass	Pass	Fail	Fail	Fail	Fail
The seat shall be large enough for comfortable seating. This means it's area is exeeds the average human leg width and length.	physical	1	Pass	Pass	Pass	Pass	Pass	Pass	Pass
The device shall weigh less than 20 pounds so the caregiver/client can comfortably carry the device.	physical	2	Pass	Pass	Pass	Pass	Fail	Pass	Pass
Have integrated arm rests	physical	3	Pass	Pass	Pass	Fail	Pass	Pass	Pass
The seat is transportable. This means it is does not require outlets, and has not need to stay in one location.	physical	1	Pass	Pass	Pass	Pass	Pass	Pass	Pass
The device shall be cost effective to build (and therefore purchase), costing at most $200 in materials and construction.	cost	2	Pass	Pass	Pass	Pass	Fail	Fail	Pass
The device shall be easy to use (can be mastered within three minutes, meanigng the user can preform STS in under 10 seconds).	user	2	Pass	Pass	Pass	Pass	Fail	Fail	Fail
The device shall include a user manual for the client to reference if they need help operating the machine.	documentation	3	Pass	Fail	Pass	Pass	Pass	Pass	Pass

Figure 9: Engineering Design Matrix comparing the prototypes, current design, and competitors, made in Google Sheets.

Conflicts with Prototypes

Spring.

The original design for the spring, though it provided a sufficient enough upward force for the client, was too tall to meet our other criteria. The client was unable to comfortably descend onto the chair, not allowing for the springs to serve their intended purpose. They provided the upward force but the client was not able to situate themselves as high on the chair as needed. This was due to multiple thick blocks of wood supporting the springs.

Pneumatic.

The pneumatic actuators provided some difficulty in the amount of force exerted on the client. No matter how much air was pumped into the actuators, over time they would eventually get weaker. Even at full air capacity, the descent was too harsh for the client. The inclined seat-component would go down too quickly, and since there was no padding to cushion the fall, the client would be subjected to the shock of the collision between the seat-component and the base.

Final Modifications

Spring.

In order to combat the height issue of the spring prototype, the blocks of wood supporting the springs were removed. The hinges were attached to the base of the actual chair. The positions of the front and back springs remained the same. This reduced the height of the spring chair and therefore made it easier for the client to use and comfortably sit on the device, while the force provided by the springs stayed constant.

Pneumatic.

To solve the issue of the shock caused by the collision of the seat-component and the base, an additional spring was added on the center of the base. It was placed in such a way that the pneumatic actuators were unaffected and fully functional with the new component. This made the descent, when force was applied, to be much softer and less harsh for the client. This also provided a stronger upward force when the client decided to leave the seat, allowing for stronger support.

Final Device Summary

Determining the Final Design.

The final design of the first spring prototype for this project was determined through feedback from the client as well as the engineering design matrix. The spring prototype was the most stable design, had the largest seat, and was also the cheapest to prototype and create. It also passed the greatest number of requirements compared to all other prototypes. Through the long process of testing with our client and modifying the prototype iteration to accommodate their needs, the spring prototype became the best one and our final assistive device for this project.

Pros and Cons of the Final Design.

Pros: cheap, light, significantly decrease the effort it takes the client to stand by 5 points on a 10-point scale, lifts at least 180 pounds at least 6 inches from the seat, significantly decrease pain felt by the client when standing/sitting by 5 points on a 10-point scale, comfortable, has the ability to attach armrests if the original chair does not have them (modularity), is large enough for comfortable seating, among the other passes in the final engineering design matrix shown below.

Cons: not motorized, does not significantly decrease the effort it takes the client to sit by 5 points on a 10-point scale, does not have heated/cooled seats, not available in a variety of colors easily for the caretaker, and cannot be mastered very quickly

Design Matrix for Final Design.

Requirement	Type	Level	Current Design
The device shall significantly decrease the effort it takes the client to sit by 5 points on a 10-point scale (with 10 being uncomfortable and 1 being comfortable).	functional	1	Fail
The device shall significantly decrease the effort it takes the client to stand by 5 points on a 10-point scale (with 10 being uncomfortable and 1 being comfortable).	functional	1	Pass
The device shall be able to lift (push up) the average human body weight at least 6 inches (180 pounds).	functional	1	Pass
The client shall have access to a control panel/remote that controls the device features.	functional	1	Fail
The device shall significantly decrease pain felt by the client when standing/sitting by 5 points on a 10-point scale (with 10 being uncomfortable and 1 being comfortable).	functional	2	Pass

The device shall significantly decrease pain felt by the client when sitting by 5 points on a 10-point scale (with 10 being uncomfortable and 1 being comfortable).	functional	2	Pass
The seat shall be comfortable to sit in for long periods of time, acting as a cushion for the ascent and descent during sitting. This is a rating above 5 on a 1-10 point scale for level of comfort after five minutes of being seated.	functional	2	Pass
The device shall be able to provide heated/cooled seats for the user to achieve even more comfort.	functional	3	Fail
The device shall be available in a variety of different colors/designs so the user can match their aesthetic.	functional	3	Fail
The seat shall be large enough for comfortable seating. This means its area exceeds the average human leg width and length.	physical	1	Pass
The device shall weigh less than 20 pounds so the caregiver/client can comfortably carry the device.	physical	2	Pass
Have integrated armrests	physical	3	Pass
The seat is transportable. This means it does not require outlets, and does not need to stay in one location.	physical	1	Pass
The device shall be cost effective to build (and therefore purchase), costing at most $200 in materials and construction.	cost	2	Pass
The device shall be easy to use (can be mastered within three minutes, meaning the user can perform STS in under 10 seconds).	user	2	Fail
The device shall include a user manual for the client to reference if they need help operating the machine.	document ation	3	Pass

Figure 10: Engineering design matrix for the final prototype.

Reasoning for Level 1 Failures.

The final prototype failed to improve the effort our client had to use to get into a chair (by 5 points on a 10 point scale) because of its lack of strength and support when being compressed under a load. New springs were not pursued in order to fix this issue because if they were strong enough to support this load, upon getting up and pursuing the STS manual, the springs would push our client up too quickly. The only way to fix this issue is to use a motorized system which does not utilize passive methods of energy.

The final prototype failed to have a remote system because it was not motorized and did not need to use electricity. There is no way to make a spring system motorized because of the potential energy stored in the springs.

Client Images.

Figure 11: Client testing the final prototype. Note: the cover for the cushion is not shown here, but it serves no mechanical purpose.

Materials.

The materials in the final design are as follows:

- Plywood for the base
- Plywood, sheet metal, PETG 3D printed plastic, foam cushion, and cotton cover for the seat
- Steel alloy springs for propulsion

- Steel screws, nuts, bolts, and brackets for assembling the chair

Figure 12: Image of the final prototype with the cover for the cushion shown.

Cad Models and Drawings.

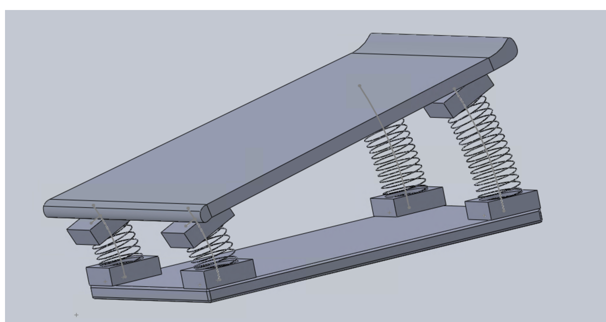

Figure 13: CAD 3D rendering of V1 of the final prototype (includes the wooden blocks instead of brackets).

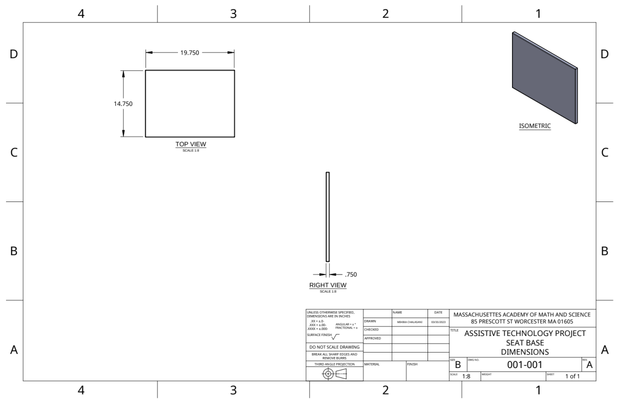

Figure 14: CAD drawing of the plywood pieces which make up the bottom of the spring prototype and part of the top.

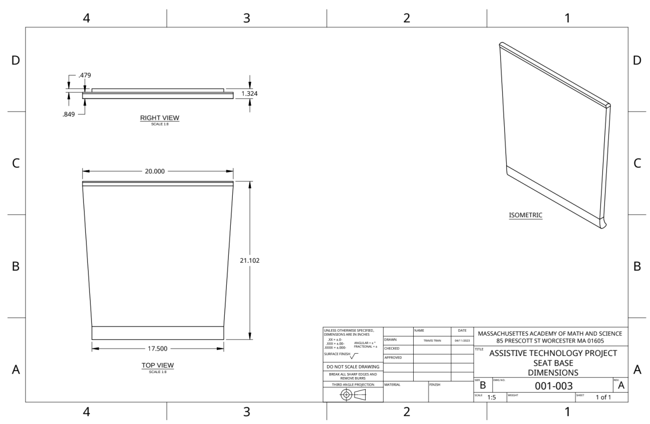

Figure 15: CAD drawing of the 3D printed seat. Note: All dimensions in all CAD drawings are in inches.

Future Work

With the extension of time, a future work would be to continue to develop the motorized scissor lift that was deemed faulty due to various factors. This could be accomplished by engineering an add-on that attached the two lifts together without interfering with the height and weight of the product. Another extension would be utilizing hydraulics in place of pneumatics. Though hydraulics need a power source, they can provide a much stronger upward force, effectively applying more support for the client. The current pneumatics need to be constantly filled with air to provide that upward force, which is why a power source does not present a conflict in this scenario. It does provide other concerns with our criteria, such as transportability due to the power as well as the weight.

Appendices

Appendix A: Budgets

Table 9: Spring Prototype Budget Estimations (Prototype 1)

Item	Supplier	Catalog #	Quantity	Unit Price	Total
Filament (wood)	MAMS	n/a	2 x 5cm x 20 x 20 cm	$0 (school provided)	$0 (school provided)
Springs	MAMS	n/a	2	$0 (school provided)	$0 (school provided)
Buckle with straps	Amazon	B0B4W26K8N	1	$5.99	$5.99

Note: Some components were also used for prototype 2 (pneumatic) and the pneumatic actuators used in prototype 2 were provided for no cost by the WPI robotics lab.

Table 10: Scissor Lift Budget Estimations (Prototype 3)

Item	Supplier	Catalog #	Quantity	Unit Price	Total
Filament (wood)	MAMS	n/a	2 of the following dimensions: 5cm x 20 x 20 cm	$0 (school provided)	$0 (school provided)
Hydraulic actuator	Amazon	B07T8FM85H	2	$16.64	$33.28

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