Project Proposal

Scissor Lift

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Mechanical Engineering Design - ME 4550 [Section 02]
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I. Problem Statement

Repairs and renovations are a critical part of home ownership. These tasks often involve hard-to-reach places, whether it's a routine job such as cleaning the gutters or a more ambitious project like repainting a home's exterior. Any job high above the ground is inherently dangerous, especially for older adults and those with physical impairments. This risk is amplified when using a ladder, which can be extremely unstable if improperly secured. The following proposal describes a safe, efficient way to reach the heights required for household maintenance. While not as economical as a ladder, the Scissor Lift prioritizes safety and accessibility, giving everybody the independence to work on their own home.

II. Background Research

<u>Existing Solutions</u>

The self-propelled scissor lift is an elevated platform that can be found in use at many warehouse stores including The Home Depot. These are designed for inside use, mainly to reach shelves and to move products.

Figure 1: Self-Propelled Scissor Lift

These types of lifts are battery operated and steered using a remote. Their maximum platform heights can range from 19 to 45 feet. With general maintenance and care, these lifts can sustain 500 to 1000 hours of normal use [1]. The load capacities of these lifts can range from 500 to over 1000 lbs [2]. The weight of the lifts themselves range from 2000 to 7000 lbs [2], [3]. The cost of these lifts can range anywhere between $2500 up to $76,000 [3], [4]. Due to the high cost per unit, these types of lifts are usually reserved for commercial or industrial applications.

For the non-commercial applications, ladders are a primary solution. However, this solution caries its own non-monetary costs. Center for Disease Control statistics show that 43% of fatal falls in the last decade involved a ladder, and among construction workers, an estimated 81% of fall injuries treated in U.S. emergency departments involve a ladder [5]. Even from lower rungs, falls can be extremely dangerous. While this is one of the cheaper solutions to reaching elevated positions, it does incur a higher level of risk.

The Scissor Jack will be different from traditional ladders (and other rising platforms) due to its priority on safety and accessibility. Traditional ladders are designed under the assumption that an able-bodied adult will be operating the equipment. It will also provide a cheaper alternative to self-propelled scissor lifts.

III. Overview

The motorized scissor lift outlined in this report is made up of four subassemblies: top plate, lift mechanism, base plate, and drive system. The top plate consists of the lift that the user and any necessary equipment will stand on and will include railings along with a controller that will guide the lifting mechanism. The lift mechanism includes the two sets of linkages that are responsible for the vertical movement of the lift, arranged in an X formation. The base plate is the section of the assembly that rests on the ground and interacts with the linkages through slots to carry out the vertical movement. Lastly, the drive system is composed of a power screw, gear train, and motor assembly which is responsible for driving the vertical movement. The initial sketch of the top-level assembly can be seen below in the raised position, Figure 2, as well as the lowered position, Figure 3.

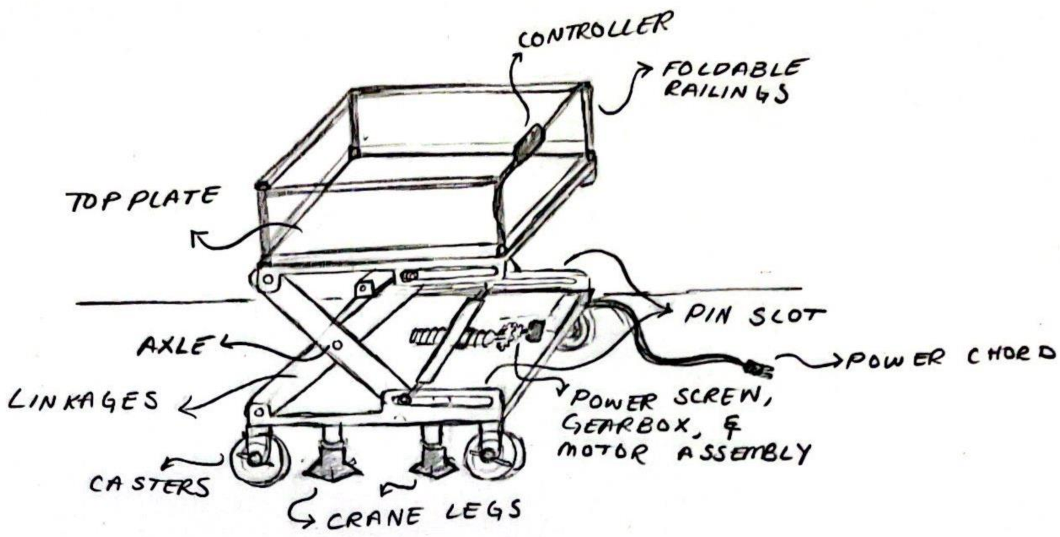

Figure 2: Concept sketch for scissor lift, raised

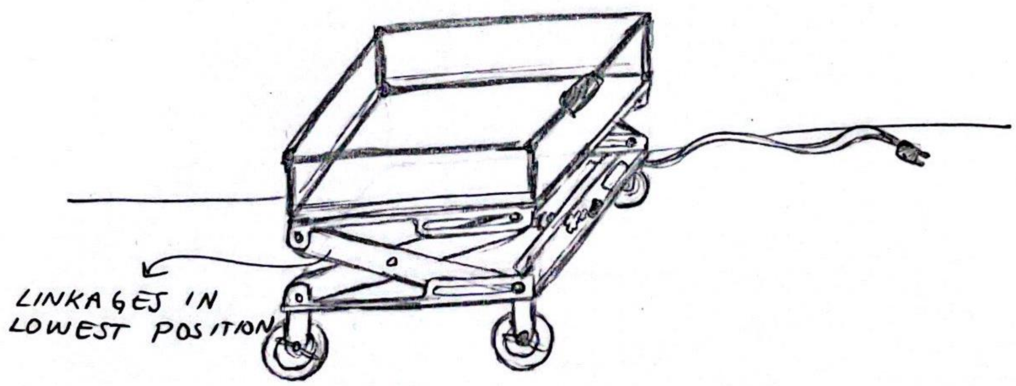

Figure 3: Concept sketch for scissor lift, lowered

Top Plate

The top plate will be a 5’ x 5’ square surrounded by a railing on all sides. The platform will be metal with a rubber mat sealed to the top face to provide grip for the user. Just underneath the platform will be the connection to the lift mechanism. This interface will contain 2 pins on one side of the square with 2 slotted pins on the opposite side. The mechanics of the slotted pin system are described in the lift mechanism and drive system sections. The railings will be lightweight and storable, using a hinged design to collapse onto the top plate for easy storage. They will lock into the upright position with a simple spring button mechanism. Once locked they will be 3 feet high, providing enough safety for a tall user without restricting the movement of a shorter adult. Attached to the railing will be the platform’s control panel, which will have a low-profile wire extending down the railing to the motor. This panel will have two simple buttons, up and down.

Lift Mechanism

The lifting mechanism will be a symmetrical set of scissor linkages as shown in the sketches above. There are two members, crossed and fixed in the center, that “open” and “close” with as the lead screw turns. The left-hand side of the linkages are free to rotate in place, and the right-hand side is free to move in only the x-direction. This means that as the links are driven horizontally with the lead screw, the top platform rises. The lead screw mechanism is described below in the Drive System section, and it will be attached to a crossbar that connects the lower, horizontally translating pins to maintain consistent travel and prevent racking. The pins will run on bearings to facilitate smooth motion. Additionally, the linkage material and cross section will be selected based on the load requirements of the jack to prevent buckling and bending of the members while they are under load.

The offset nature of the fully extended scissor lift, particularly with the height we want to achieve, could present an issue when it comes to stability. To counter this, we propose that the top platform either be counterweighted or that the number of linkages be doubled to a stacked X formation, to minimize horizontal lead screw travel and thus maintain a more centered scissor configuration.

Base Plate

The base plate will share similar features to the top plate, with a pin and slot for the linkages to lock into. The base plate will be larger than the top plate to allow for additional supports. At each corner of the baseplate, a support leg in the shape of a tube will be held with a slot channel through the base plate. The leg will be held in the up position during transport and dropped to the down position during operation. The tube will be held in place using a tube clamp. At the base of each leg is a rectangular plate with high friction cover to better stabilize the leg. This plate is attached to the leg with a ball-socket joint to account for some variability in the terrain. The plate will also have four wheels, one at each corner inside the support legs, to aid in transportation. These wheels will have locks to engage during operation to prevent movement.

Drive System

The scissor lift will be driven using a power screw, gear train, and motor assembly. Every component in the drive system will be corrosion resistant by selecting either specific materials or material finishes. The linkages on each side will be connected to each other by a bar which will be moved along the power screw using a flange nut. The power screw will be located on the base plate and the connecting bar will allow it to actuate both sides of the lift simultaneously. The power screw will be selected such that it has a sufficient load capacity, maximum travel, and speed requirement. The power screw will be driven by a motor and gearbox assembly. The motor will be selected based on the power and speed requirements of the system, and a gear reduction will be used from the power screw to the motor. This gear ratio will be selected based on the nominal torque rating of the motor as well as the calculated maximum torque of the system. A factor of safety will be considered to keep the maximum torque well within the limits of the motor. In addition, the calculation for the linear speed of the power screw based on the motor rotational speed will be taken into account when determining the gear ratio so that the 5 in/min specification can be met.

IV. Design Specifications

a. Design Specifications Overall

- System must employ a scissor forklift to raise and lower top plate
- Design must be portable and easily compacted in lowered position for transportation
- Bottom plate must meet the size requirement of approximately 5 ft by 5 ft
- Scissor lift must be able to handle a load capacity of 300 lbf
- System must be raised and lowered at a linear vertical speed of 5in/min
- System must have a maximum height of 4 ft
- Must be stable, meaning that if the user moves on the top platform, the assembly does not sway.
- Must use power screw to drive linkages in raising/lowering the jack.
- Will include wheels to avoid the user carrying a potentially very heavy device.
- Light enough to transport in typical cargo van; max load capacity typically ~1500 lbf.
- Life expectancy of 10,000 hours before mechanical failure occurs (approximately 5-10 years)

b. Design Specifications Components

<u>Top Plate</u>

- Top platform will be made of structural steel, powder coated to prevent rusting
- Platform where person stands will be covered with high-friction rubber matting to prevent potential user injury due to slippery surface
- Collapsible guide rails will be made of hollow aluminum extrusion to minimize weight and ensure user can effectively move them.

<u>Lift Mechanism</u>

- Linkages will be made of structural steel, powder coated to prevent tarnishing
- Cross section of beam will be selected based on load requirements of jack, upon performing finite element analysis, the cross section will be selected accordingly.
- All joints the require rotational motion will use sleeve or ball bearings
- The slots that the linear motion occurs in will use pins and plastic bearings to ensure smooth motion.

Base Plate

- The base plate, wheel holders, support leg tubes, and support leg base will be made of structural steel, powder coated to prevent tarnishing.
- The covering on the bottom of the support leg will use a high friction material.
- The plate will have a thickness such that it can support the intended load of 300 lbf without deformation.
- Ribbing may be added to the underside of the base plate after finite element analysis has been conducted.
- The wheels will be capable of locking and supporting the intended load during transport.

Drive System

- The length of the power screw will be dictated by the length of the horizontal motion of the linkages needed to achieve the desired height
- Motor must be small enough to fit within the base plate
- Motor power must be sufficient to hoist the 300 lbf load requirement
- Motor rotational speed must be such that the linear speed requirement is met

V. Conclusions

The Scissor Lift will be a powered, scissor-type jack designed to safely access hard-to-reach places for home maintenance. The machine needs to support 300 pounds and extend 4 feet above the rest height while maintaining stability. It also needs to be portable enough to be moved by a single adult. The main priority in this design is safety and accessibility. Life expectancy and cost are also factors to consider. The team does not expect the scissor lift to be the most economical solution on the market, but it will target the significant population of people who are unable or unwilling to use a ladder.

The team will approach the design process with many potential innovations in mind. Through multiple rounds of iteration, the team will decide which innovations have the greatest benefit to safety and accessibility while minimizing costs. Research will be conducted to better understand the needs of those who would be in the market for a safer alternative to ladders, as nobody on the team has first-hand experience in this area. There are other basic considerations to have concerning our target audience. When compacted, the top platform must be close enough to the ground that an older adult is still capable of stepping up. All exposed edges and moving parts must be significantly smoothed or highlighted. There will also be emergency shut-off switches at both the top and bottom platforms.

There are a few significant risks in this design. The scissor-type jack is not the most compact mechanism, and it is very important to keep things portable. If the weight ends up being unreasonably high, we can reduce the load by changing dimensions and material compositions on a component-by-component basis. Some ideas already presented include detachable legs, hollow railings, and lighter motor components. A second design risk is stability. A scissor-type jack mechanism inherently unbalanced as one side of the mechanism moves inward in order to raise the platform. To account for this instability, multiple ideas have been suggested. Some of these are innovative, such as an extendable section of the top platform. Others are simple but arguably as effective, such as adding dead weight at the bottom platform. Stability of the user should also be considered. In windy and rainy conditions, a user on the raised platform could slip and fall. This issue will be addressed using railings and high-friction mats.

VI. Appendix A

Brainstorm Innovations

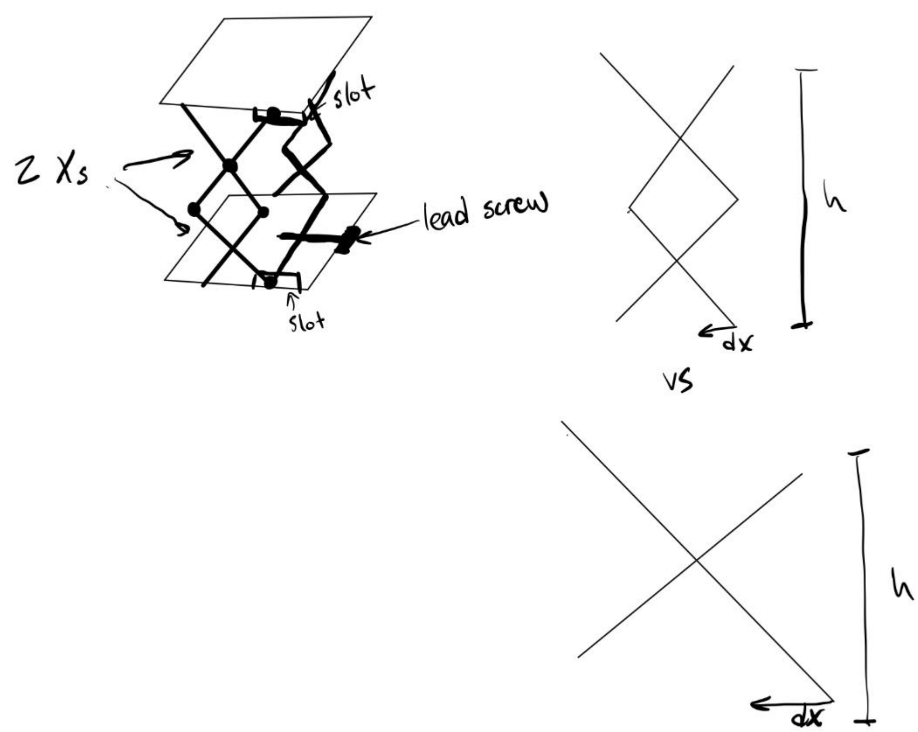

Figure 4: Add Extra Linkages to Minimize Horizontal Lead Screw Travel

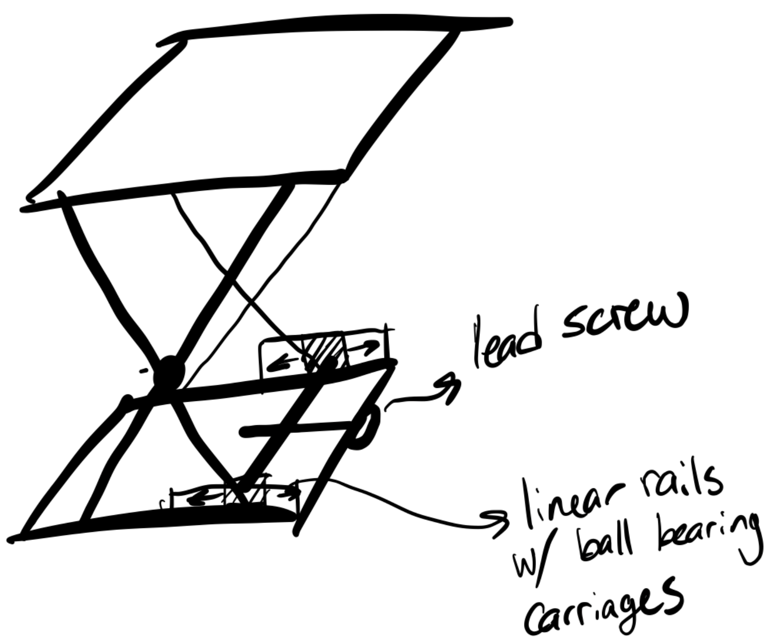

Figure 5: Change Slots to Linear Rails and Ball Bearing Carriages for Smoother Motion

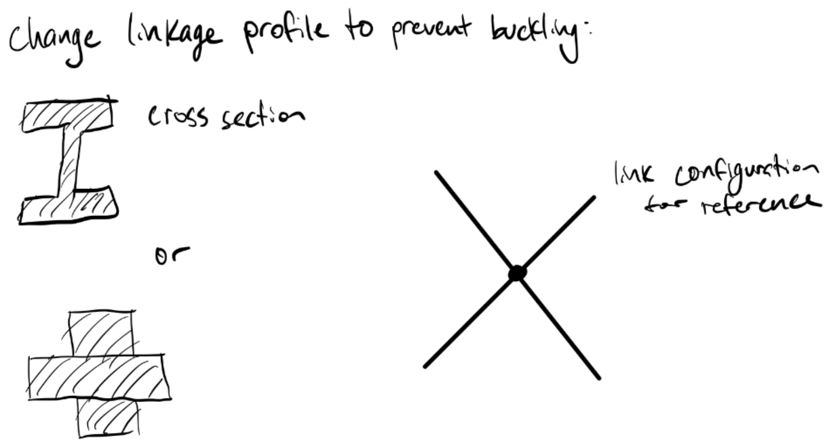

Figure 6: Linkages Ribbed for Added Stiffness

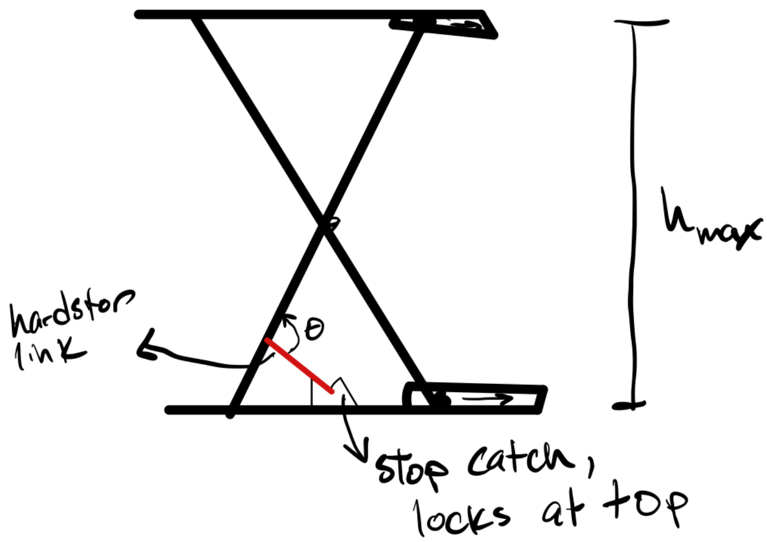

Figure 7: Deployable Hard Stop Links For Extra Stability in Highest Configuration

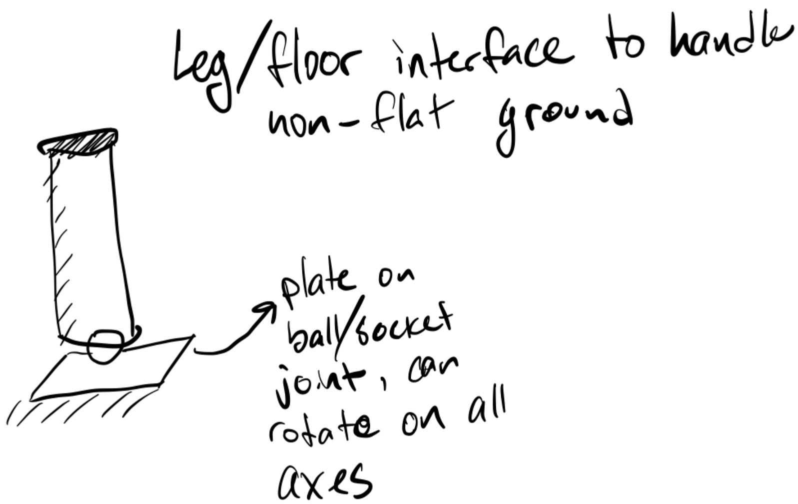

Figure 8: Plate on the Bottom of Support Legs to Handle Unstable Terrain

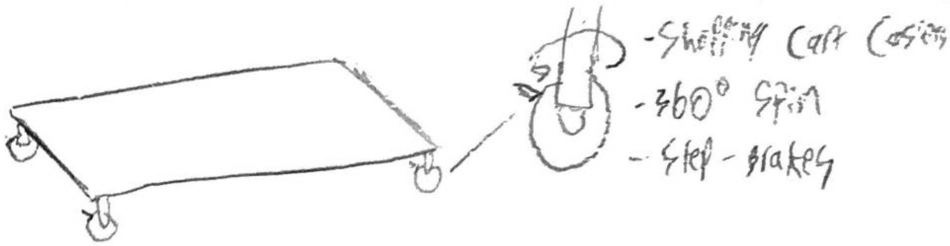

Figure 9: Adding Casters for Mobility

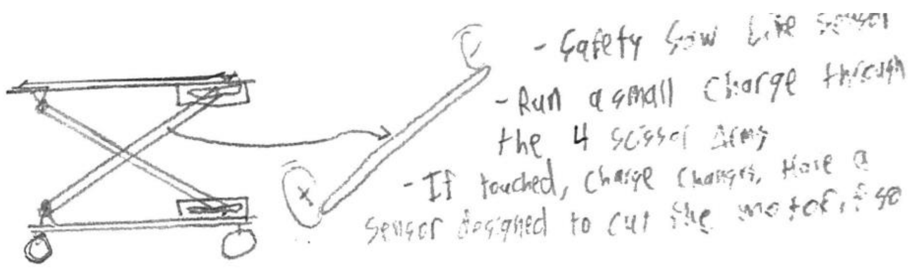

Figure 10: Automatic Safety Shutoff

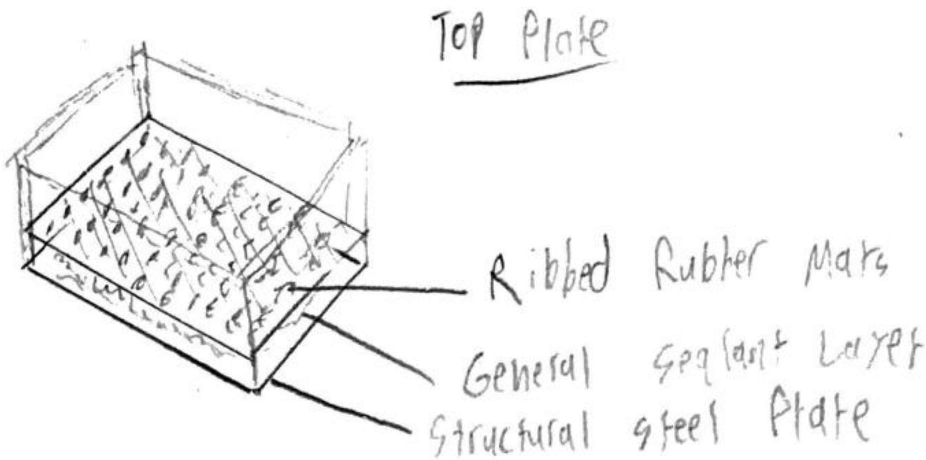

Figure 11: Rubber Grip Mat on Top Platform

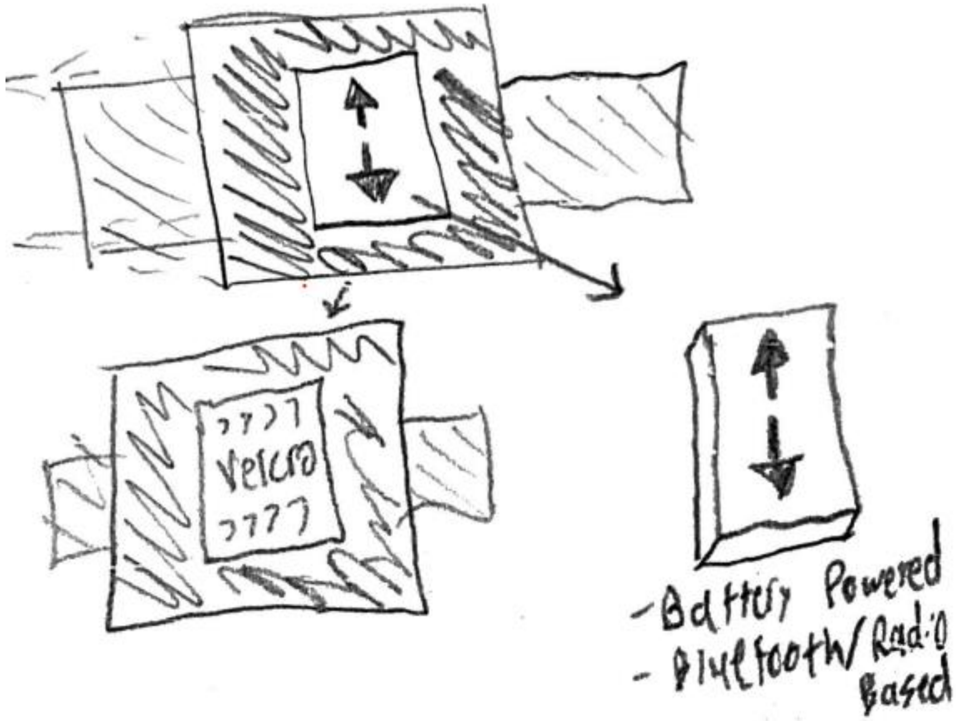

Figure 12: Adding a Remote Controller

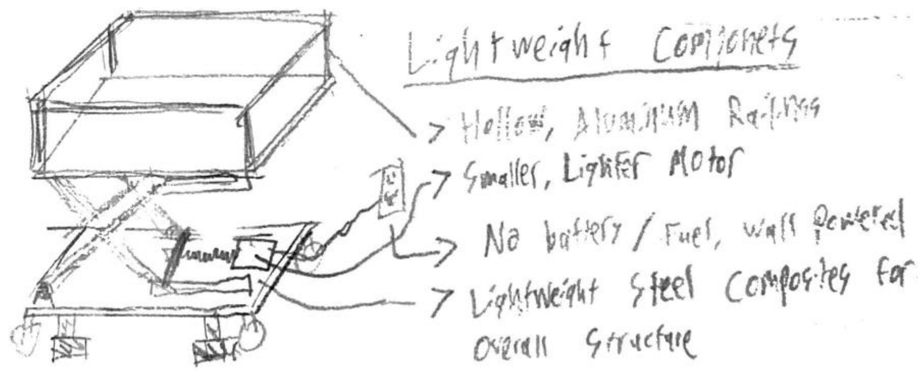

Figure 13: Use lightweight/composite materials for portability

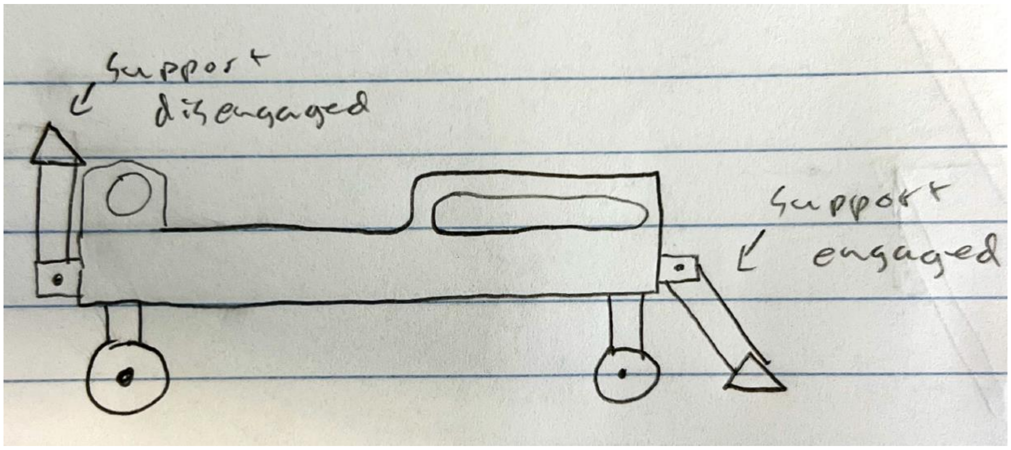

Figure 14: Legs folding down on each side of the base plate for added stability

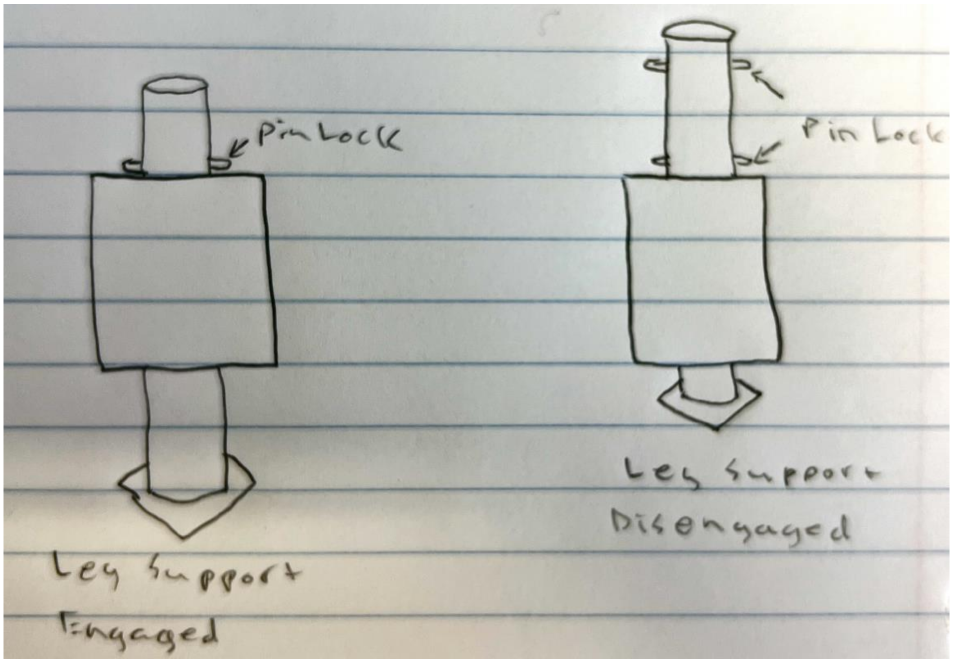

Figure 15: Support legs held in place using a slot and pin

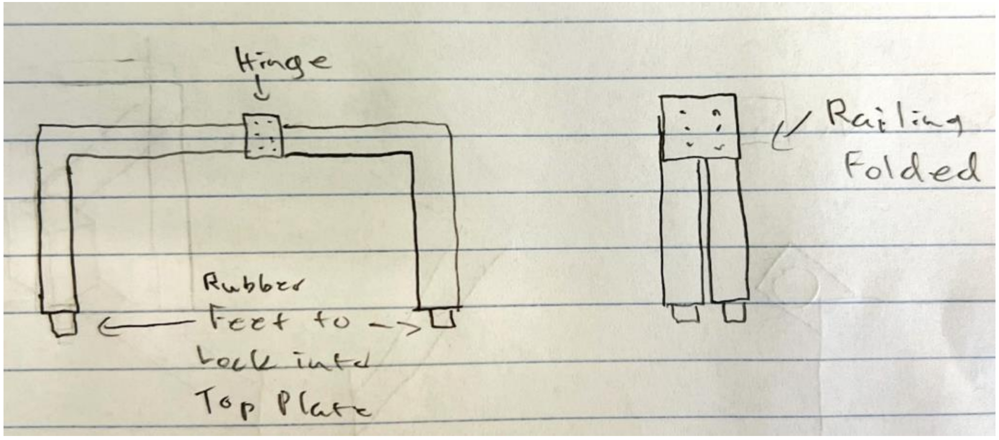

Figure 16: Foldable and detachable railings

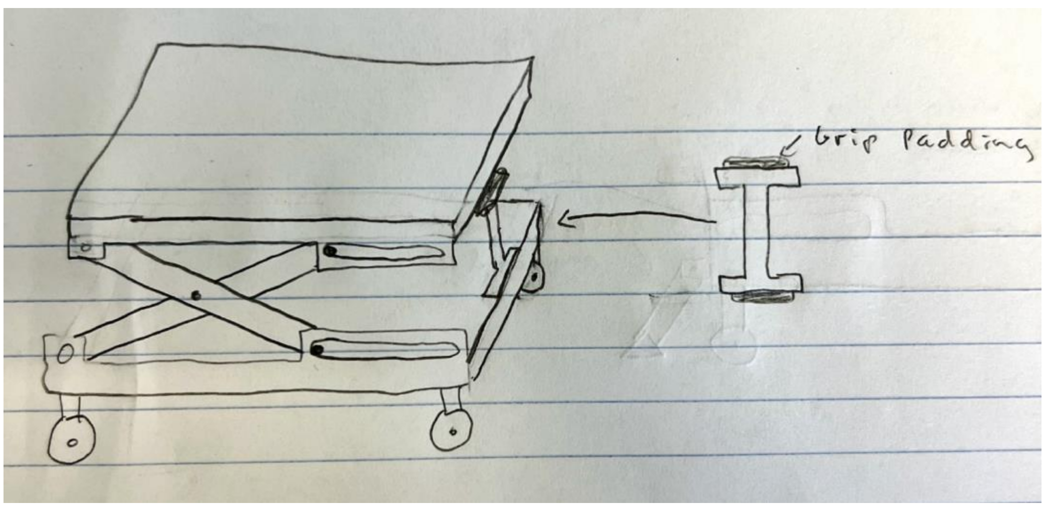

Figure 17: Metal Joints to lock in place when lift fully extended

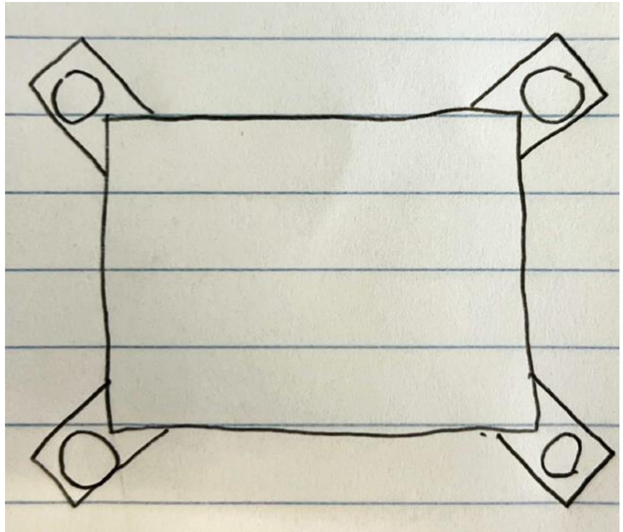

Figure 18: Diagonal supports off the base plate

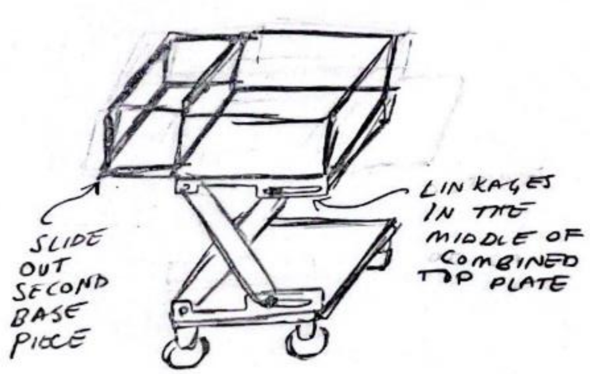

Figure 19: Slide out portion of top plate so that linkages are centered

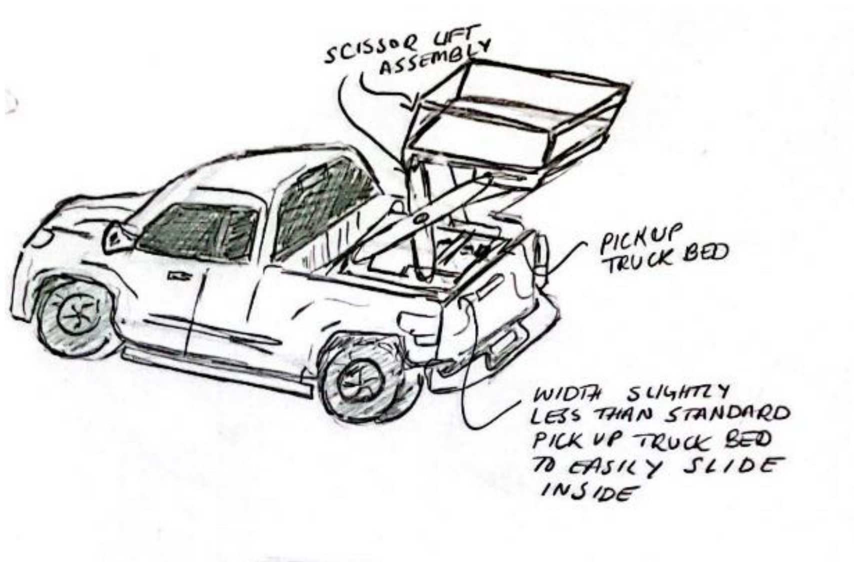

Figure 20: Attachment to put in bed of truck (would have to decrease base size)

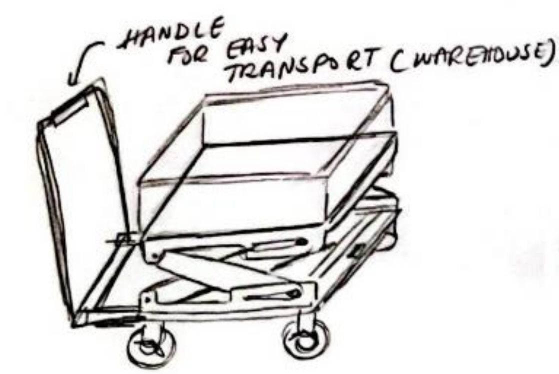

Figure 21: Make it into a cart (like pallet jack and would be used in warehouses)

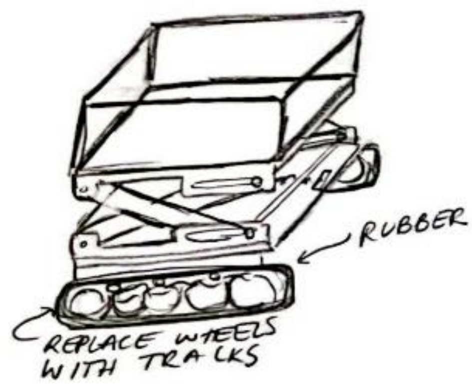

Figure 22: Use tracks instead of wheels (less pressure on ground for outside?)

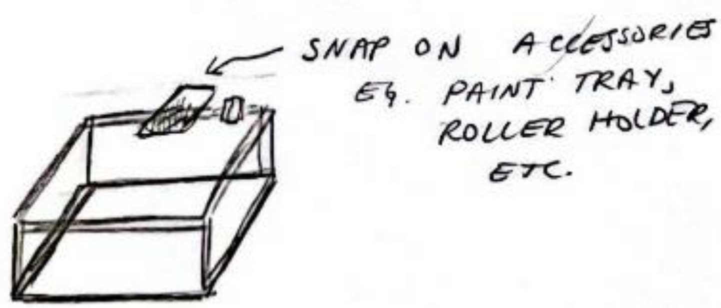

Figure 23: Snap on accessories

VII. Appendix B – Contract

Agreement for Engineering Services

Term Contract

This Agreement made this 14th day of July, 2022 between Yustianto Tjiptowidjojo hereinafter known as the OWNER and ATV Solutions hereinafter referred to as the ENGINEER:

Recitals

WHEREAS, OWNER and ENGINEER desire to establish a mutually beneficial business relationship and to develop, verify, and launch under their best efforts a high quality and competitively priced scissor jack; and

WHEREAS, ENGINEER, is in the business of developing consumer products and represents it is the owner and/or licensee of certain know-how, trade secrets and issued or pending patents including, but not limited to the scissor jack; and

WHEREAS, OWNER is in the business of distributing scissor jacks and represents it is the owner and/or licensee of certain know-how, trade secrets and issued or pending patents; and,

WHEREAS, ENGINEER desires to develop internally and with third parties, the use of, the manufacture of, and distribution of the scissor jack with OWNER.

NOW, THEREFORE, in consideration of the promises and agreements set forth below and the other considerations cited herein; the parties agree as follows:

I. <u>Scope of Services</u>

The ENGINEER will design, develop, and implement the concept of the motorized catapult. This process will include the following tasks:

A. Preliminary Design

1. Examine prior art with regard to the design and integrate into preliminary design
2. Generate sketches, a mock-up, and engineering CAD of preliminary design

B. Controller Design
   1. Design simple control panel and wiring system to the motor

C. Prototyping
   1. Evaluate the system for a simple, cost-effective design
   2. Generate a list of key components

D. Testing
   1. Conduct a full tolerance analysis on components and connections where needed
   2. Perform ergonomics and human factors analysis of proposed product

E. Design Iteration
   1. Select appropriate manufacturing method for cost effectiveness with regard to quantity produced
   2. Have drawings and components quoted to build a detailed system cost
   3. Generate drawings or necessary detailed models and specify custom mechanical components
   4. Present preliminary design in a preliminary design review

F. Manufacturing Design
   1. Generate drawings or necessary detailed models and specify custom mechanical components
   2. Design and create any necessary assembly tooling

The ENGINEER is responsible for final manufacturing drawings that properly produces the given proposed design within the specifications.

II. **Schedule of Services**

The ENGINEER proposes the following schedule with receipt of a fully executed contract:

Major Milestone	Task Estimated Completions
Project Start	July 5, 2022
Presentation of Design Sketch	July 14, 2022
Component Design	August 2, 2022
Connection Design	August 15, 2022
Power Train Design	August 18, 2022

III. **Compensation & Pricing**

Service shall be billed at the following rates: $200.00 for a senior engineer and $150.00 for a junior engineer. This shall be in effect at the time of the specific project proposal. Out of pocket expenses are the responsibility of the client.

IV. **Invoiced and Payments**

This project has its own job number that will be used for billing and reference purposes. Every month an itemized invoice will be released, and payment is due within 30 days of released invoice. If OWNER fails to make payment due to ENGINEER within 30 days of invoicing, then ENGINEER shall be entitled to interest in accordance with state law.

V. Term Contract

This agreement is active for 60 days from the signed date of Agreement. The Agreement can be renewed for longer at the discretion of the OWNER, for up to two additional months.

VI. **Termination**

The obligation to provide services from this agreement may be terminated by either party with 30 days written notice due to failure by the other party in accordance with the terms hereof, though no fault of the terminating party.

VII. **Modification**

This agreement may be modified only by a written agreement signed by both parties.

VIII. **Jurisdiction**

This agreement shall be construed by the laws of the State of Massachusetts and the venue shall be in the courts of the state of Massachusetts.

VIII. Fill Agreement

This agreement is the full agreement between the parties.

Witnesses

The above contract is hereby agreed:

OWNER

Title: Professor at Northeastern University ***Date: 7/14/2022***

Signature:

Type Name: Yustianto Tjiptowidjojo

ENGINEER

Title: ATV Solutions   Date: 7/14/2022

Signature: Patrick Fries

Type Name: Patrick Fries

Signature: Emilie Hardel

Type Name: Emilie Hardel

Signature: Lauren Kreder

Type Name: Lauren Kreder

Signature: Justin Miller

Type Name: Justin Miller

References

[1] “Above All Equipment,” *https://aboveallequipmentsales.com/2020/06/18/how-long-do-scissor-lifts-last/#:~:text=As%20long%20as%20the%20scissor,should%20last%20about%2030%20years.*, 2021.

[2] “Morn Lift,” *https://www.mornlift.com/electric-scissor-lift-4/*, Jul. 2021.

[3] “Material Handling Solutions,” *https://materialhandlingsolutions.theonlinecatalog.com/products/2-man-self-propelled-scissor-lift/7/1/?gclid=CjwKCAjw_b6WBhAQEiwAp4HyINmaK1BKBWQGg9uO0y5xNuOS8iE_ByN2VbeLXTVtOUcMhtTz52qqRRoCYUAQAvD_BwE*, 2021.

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