UpDog Carrier Lift

A Major Qualifying Project

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Abstract

The goal of this project was to create a device to enable a person to lift a loaded dog crate into a vehicle with minimal physical exertion. A dog owner can face difficulties trying to get an animal into a vehicle if the animal is uncooperative, or unable to enter the vehicle under its own power due to injury or old age. This is an even greater challenge if the dog is heavy, or if the owner has difficulty handling heavy loads. Many products are available on the market to assist persons to lift heavy objects, but none exist that are affordable and can be reasonably used to lift an uncooperative or infirm animal. The chosen design incorporates a scissor frame and a home-built air bladder system to lift a loaded dog crate to an intended maximum height of 30”.

Acknowledgements

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1. Introduction

Assistive devices for the elderly and persons with disabilities are extremely commonplace in modern society. Many of these devices provide excellent support in the completions of daily tasks, but often more specific tasks can still be very difficult. The area of interest is the transportation of animals, in particular, the act of lifting a dog crate into a vehicle for the transportation of a pet.

The goal of the dog carrier lift project is to create a device that is capable of lifting a loaded large-size dog crate to a height of 30 inches to assist in loading the crate into an automobile. Large size dogs typically fall within the weight range of 60-100 lbs., and the respective crates tend to weigh approximately a quarter of the weight of the animal intended for transport. The lift will be designed for a working load of 200 lbs. allowing for a variation in animal sizes and weights, potentially heavy crate designs, and expectation that the lift will be overloaded or misused by some users. A factor of safety of 3 was determined for the prototype, so a load of 600 lbs. should be possible without failure.

2. Background

2.1 Size

As described in the goal statement, this lift was designed for use with a large dog. As stated, large dogs often weigh between 60 and 100 lbs., while their crates often weigh up to about 30 lbs. Crate dimensions for this size animal were found at 42 inches x 28 inches base x 31 inches height (Midwest Pet Products, 2013). This size provides a baseline of the platform size for the lift. This will be further discussed in the functional requirements.

2.2 Devices and Solutions Currently Available

Many devices are available in the market to assist in loading animals into automobiles. These devices, however, primarily focus on aiding ease of loading an animal without a crate. The most common solutions readily available are ramps, stairs, and direct lift handles. Ramp and stair systems are very effective, simple, easy to store and transport, readily available, affordable, and do a good job of easing the vehicle entry for animals with reduced mobility. These devices however, while very useful and cost effective, require the cooperation of the animal in question, do not accommodate an animal in its crate, and do not work if the animal is very weak or fully immobile. The direct lift solution consists of a simple torso support for the animal with handles that allow the user to more easily lift the animal into the vehicle under the user's own power. Such devices are inexpensive, but require the owner to lift the full weight of the animal. Lifting a large dog using this type of device would be impractical, and could result in back or shoulder injuries. There are variants of these for larger animals that go around the animal's rear, and are used to assist the animal in getting into the vehicle instead of lifting the entire weight of the animal. These handled harnesses also cannot accommodate a crate, and would be very difficult to use with an uncooperative canine. All of these particular devices are aimed specifically at easing the loading of an animal into a vehicle, but have limitations to circumstances of use, and therefore, they do not meet our criteria.

Aside from systems intended for the sole purpose of loading animals, there are also many commercially available solutions, which are intended instead for heavy lifting and cargo applications. Since no lift devices intended specifically for dog crates were found, a broader cargo-lift category was also explored. Relevant cargo solutions found include forklifts, scissor jacks, four-bar linkages, winches, and ramps. Wheelchair lifts and pallet lifts provide a valuable source of potential design information. Examples of successful scissor-jack style operation for vehicle usage include emergency gurneys. Successful usage of both four-bar linkage and winch operation is demonstrated by the UNI-lite wheelchair lift, as well as many jetski lift designs (Ricon, 2016). These devices all provide excellent design insight, but are also prohibitively expensive as immediate solutions, as they are designed for significant working loads.

Other more general design concepts with less immediately apparent relevance have also been considered, such as inflating an air bladder under the load to provide lift, or transporting the load via trailer instead of lifting it into the core vehicle. The successful implementation of scissor lifts for cargo applications are well established. Examples of usage are shown by a number of pallet stacker and positioner products from ULINE (Uline, 2016).

2.2.1 Mechanisms of lift

2.2.1.1 Pneumatic Devices

Many powered lifts utilize some type of fluid as the working mechanism. In pneumatic systems, this working fluid is air. There is a particular air powered lift device of interest, known simply as an ‘air jack’, which is comprised primarily of a heavy duty air bladder positioned under the load. When filled from a source with sufficient pressure, the expanding bladder is capable of providing significant lifting force. Such bladder based air jacks are most common for automotive purposes, and some designs exists that will lift up to 6 tons. There is also a type available on the market primarily a for off-roading purpose that inflates using the exhaust from the vehicle being lifted (Camels, 2014). ‘Air Jack’ can also refer to pneumatic cylinder jacks, which are capable of high loads, but require an input air-line.

2.2.1.2 Winch Lift Devices

Another source of power for lifting heavy loads is the use of a winch and worm gear mechanism. Winches are capable of providing significant load lifting capabilities in an easy to operate device, but can be slow, and have difficult packaging constraints. For our purposes, a common winch powered system of interest is that of boat or jet ski lift. The lift shown below consists of a four bar mechanism and is driven by a crank and pulley system. While very effective, the system is also quite large, and would likely need to be a permanent installation.

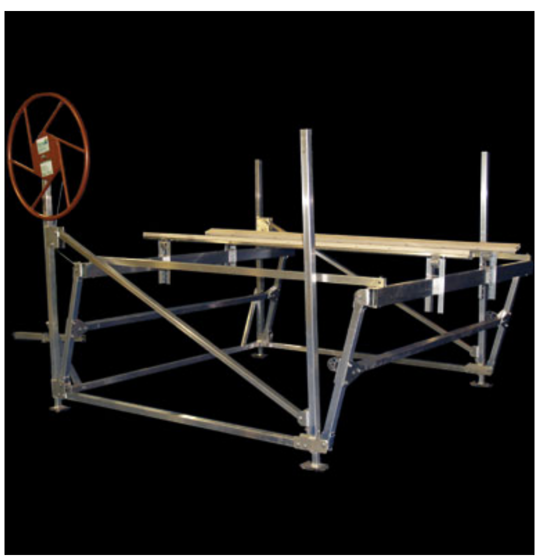

Figure 1: Ridgeline Boat Lift

These types of lifting mechanisms could be applied to this project (RidgeLine).

2.2.1.3 Hydraulic Lift Mechanisms

Another type of powered lift mechanism employs hydraulic pistons. These devices are typically used to lift and hold heavy loads and have a wide range of applications. Hydraulics can be used to assist overhead lifts as well as the power source for forklifts. Hydraulics can also be used in scissor lifts. Commercially available floor jack systems use pneumatic cylinders, can be found for reasonable costs, are capable of high load capabilities, and can be lifted by hand, but can be slow and cumbersome to operate, and are height limited.

2.2.2 Core mechanical structure and path of movement limitation

The primary concerns for the lift platform have to do with stability. It is necessary to keep the platform motion primarily in the vertical direction, to keep the platform parallel to the ground, and to minimize platform roll, rotation, and horizontal motion.

2.2.2.1 Parallel 4-bar Mechanism

The parallel 4-bar mechanism is a stable, folding platform that guarantees the lift platform stays parallel to the ground. The primary downside of the parallel 4-bar mechanism is that the platform motion is not only vertical, but also has a notable horizontal translation component. This is not inherently problematic, but may cause issues depending on the lift power method selected. This also means that the unit as a whole must be longer than a directly vertical device to remain stable under all conditions. The benefit of motion that is not solely vertical is that the lift can be powered using a force component that is also not purely vertical, which opens more options for packaging and placement the force providing member.

2.2.2.2 Supporting Guide Rails

Supporting guide rails can be used in one of the simpler solutions, and only act to keep the platform from any rotation during ascent. This method is ideal when the lift mechanism in question provides the non-back drivability required. Examples of potential usage would be with an air bladder lift method, or with a series of lines and pulleys linked to a hand winch.

2.2.2.4 Scissor Supports

The scissor lift support mechanism provides a strong lift platform that is capable of keeping the lift platform parallel to the ground, and can also provide direct vertical motion. The scissor lift system also provides some very solid points for lift actuation. Another benefit is that scissor jacks can collapse to a smaller size than the alternatives. The most immediately noticeable downside is that scissor jacks may present the highest pinch hazard. This is a valid concern for operators, and could also be a potential issue if coupled with the air bladder lift, as a closing scissor could potentially puncture the bladder if the components were to come in contact.

2.2.2.5 Straight line linkage mechanism

Straight-line linkage mechanisms are clever designs that approximate pure linear motion through the usage of linkages. However, all of these designs that have been investigated have proven to be impractically large compared to the generated motion, and many were also relatively complex. While these are versatile mechanisms, they are far from ideal for our applications.

2.3 Anthropometric data

Appropriate anthropometric data is very difficult to source, particularly for the elderly and persons with disabilities. As such, the team decided on a low input force maximum of 15lb for successful operation, and with the goal of ideally requiring negligible input force from the user. As such, externally powered systems were considered more seriously than most user-input systems.

3. Functional Requirements

The functional requirements below were chosen to narrow the scope of the project while also making the end goal as clear as possible. A brief discussion explains the reasoning behind each requirement.

1. Device must not fall back on operator
    a. Safety is the most important consideration when designing a product for the general public. By addressing the safety aspect at the beginning of the project, the scope of the design was narrowed with safety as a first priority. One possible

method to achieve this objective is to have a device to prevent unintentional backtracking (i.e. compressed air in piston, worm gear, ratchet) from an intermediate position.

2. Device must be stable under all foreseeable conditions
    a. This requirement also addresses safety, not only for the operator but also for the dog. This ensures that the device can hold its own weight and should not shift, roll, or twist if it were to be stopped in an intermediate position.
3. Must lift 200 lbs. base load
    a. The lifting capabilities of the device are another important aspect. This lift will be designed for a large sized dog (about 85lbs) and its respective crate. The limit was set so that there could be a range of crates and dogs as well as some baseline factor of safety for the device.
4. Device must hold dog crate of 44 inches x 30 inches base x 30 inches height
    a. Typical crate dimensions of a large-size dog need to be accounted for when designing the platform of the lift device. This base size is slightly greater than the value found as typical.
5. Must fit in SUV with trunk size 60 inches long x 40 inches wide x 30 inches tall
    a. Using a collection of trunk sizes from a Subaru vehicle dimension database, the smallest dimensions for the height, width, and depth were selected from the vehicles capable of accommodating this crate size. By choosing the minimum dimensions the maximum outer dimensions of the lift are defined (Spitz, 2016).
6. Requires "low" operating force ≤ 15 lbs.
    a. This functional requirement is aimed a hand operated lifting mechanism such as a winch or ratchet. The objective for this kind of lift would be that it is easy for an elderly person to use while also providing significant lifting motion. The acceptable value was estimated, as valid anthropometric data were not found for our target audience.
7. If the device folds it must fit in a space 4 ft^3
    a. The team decided that the best way for operators to use this everyday is that if it is practical and easy to store. This was also a consideration in the design requirements.

8. Device must be stable without additional support from operator
    a. Designing the device to be stable unaided by the user is key for safety of both the operator and the animal.
9. Installation and operation must not cause any damage to the vehicle
    a. During preliminary design conceptualization, the project team explored the ideas of installing part or the entire device in the trunks of cars. However, the team did not want an operator to have any custom modifications to their vehicle that would allow them to use a proposed lift. As such, any vehicle side components would have to be installable and removable with no permanent changes to the vehicle.
10. Device must weigh less than 50 lbs. total
    a. The team decided this so that the operator could easily move the device.
11. Maintenance must be less than 20 min/year
    a. A key aspect of this device is that does not require daily or even weekly maintenance. This helps to make the device easy to use, store, and maintain. Over the course of a year, 20 minutes averages to about a minute and a half per month. This does not include setup time or setup adjustments.
12. Initial assembly time must be ≤ 30 min
    a. The usability of the device as well as simplicity of construction is a key for the success of this project
13. Operation time must be ≤ 5 min
    a. We feel that the time to load the crate into the car should not add significant time to the user’s day.
14. Set up time must be less than ≤ 5 min
    a. The setup of the device should also be short for the usability of the product.
15. Must be able to lift crate 30 inches
    a. The lifting height was determined based on the average distance from the ground to the top of the tailgate of 3 different vehicles.

Car	Hatch Height	Hatch Width	Cargo Space Width	Cargo Space Height	Floor Length Seats Up	Floor Length Seats Down	Distance from ground to top of tailgate
Subaru Crosstrek	29"	35"	42"	29" (Hybrid 28")	31"	55"	30"
Subaru Forester	35"	40" Bottom 38" Top	42"	32"	34"	60"	25"
Subaru Outback	35"	39.5"	42.5"	29"	41"	65"	29"

Table 1: Subaru Tailgate Dimensions

16. Simple maintenance will be determined by design
    a. This could include oiling linkages or gear as well as tightening nuts and bolts

4. Conceptual Designs

After design requirements were developed, four initial concepts were explored. These concepts included a four-bar mechanism, a rack and pinion mechanism (similar to an elevator), forklift variants, and a scissor lift. These concepts were modeled in SolidWorks to demonstrate the range of motion that each mechanism could experience.

4.1 Four Bar Hand Lift

The 4-Bar hand lift concept would be driven by a winch. This variant would have a line that connects at point B. Figure 2 shows the lift in the raised position. Another possible iteration of the 4 Bar lift concept could be to use a long lever reaching under the platform to a pivot near point D.

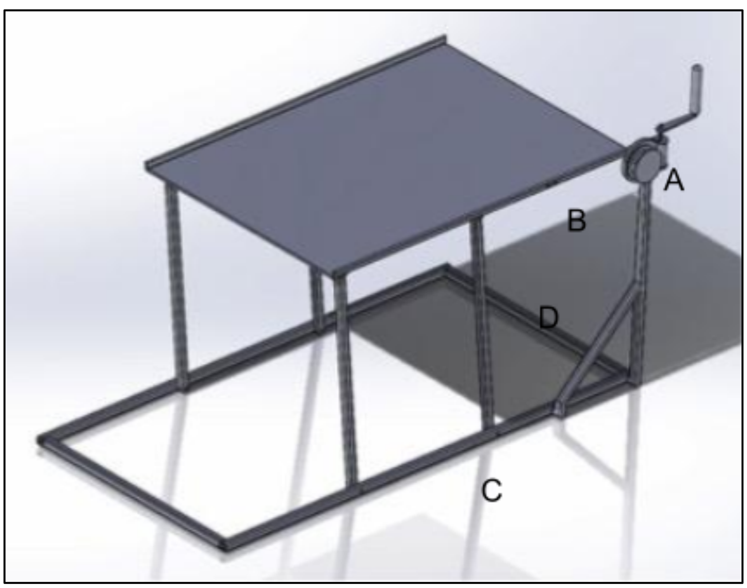

Figure 2: 4 Bar Winch Lift

4.2 Gurney/Scissor Lift

The gurney concept appeared as an initial simple design, but after further investigation turned out it was more complex than expected. The optimal designs need reasonably large mechanical advantage, while the gurney does not provide enough advantage to make it a viable option. Ambulance gurneys are collapsed when in storage, and then lifted by hand so the legs can open. This design would use either a pulley system or a powered scissor jack to lift the gurney, as these mechanisms could fit into the intended collapsed size. The top of the gurney would be designed to slide forward into the vehicle, with a lock at the rear to keep the tray in position while the lift is in motion. Figure 3 shows the collapsed gurney. While the gurney approach was not ideal, scissor lifts were still of considerable interest.

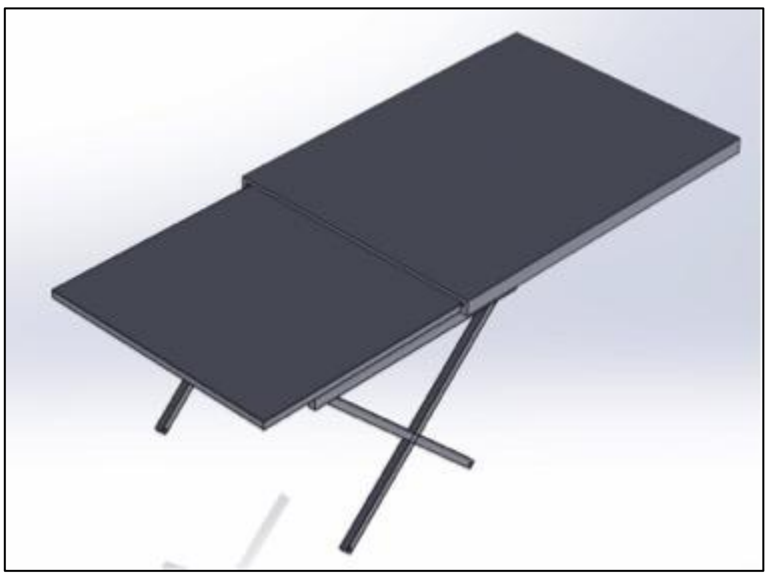

Figure 3: Expanded Gurney

4.3 Rack and Pinion Lift

Figure 4 shows the side view of the rack and pinion concept. This design uses a set of gears to pull the dog crate platform up to the desired height. At point A there will be a winch mechanism (not modeled). This winch line would feed through the pulleys at point B and attach to another pulley at point C. From here the line would feed through to the opposite side. As the operator cranks the winch the line would shorten throughout the mechanism causing the crate to be lifted to the car.

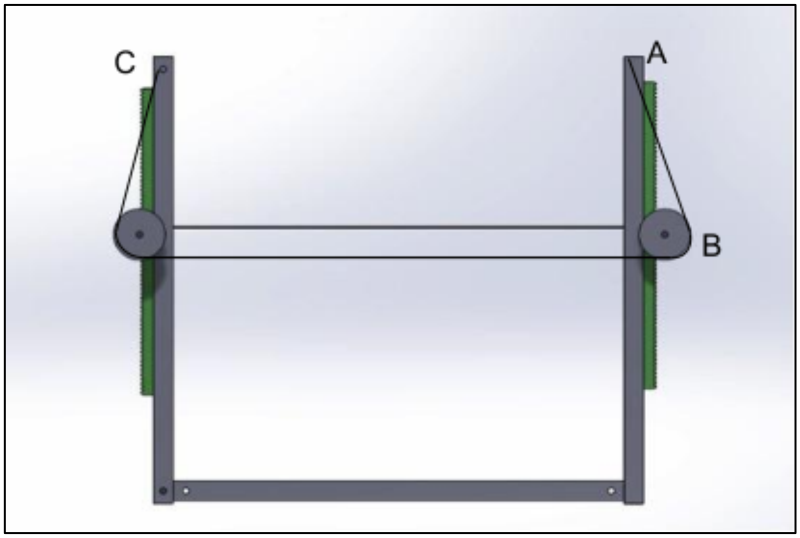

Figure 4: Rack and Pinion Concept

4.4 Forklift Style

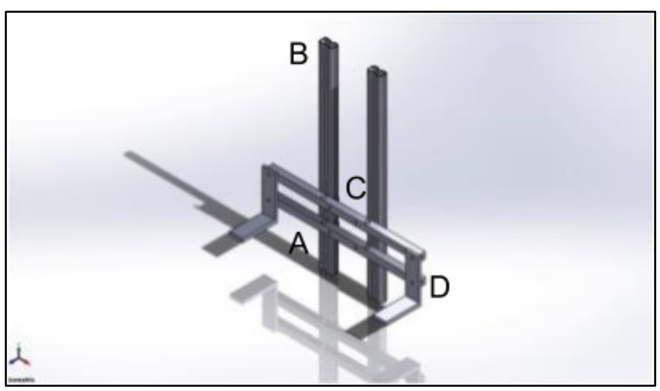

Figure 5: Forklift Style Lift

The forklift style lift shown in Figure 5 would have a pulley system to drive the lift. This model could be modified to act as a tow hitch or as a hand truck. The pulley system would require a winch that would feed from A up to the pulleys (not modeled) at location B on both sides of the guide beams. The line would then connect to a hook at point C. As the operator cranked on the winch the platform bar, D, would rise or descend depending on the direction of the motion.

4.5 Final Design Conclusions

The four above designs were used as bases for the design matrix in the next section. Each design was used as a "frame," with three separate potential forms of power or lift for each, lift by winch, air bladder, or pneumatic cylinder. This left us with twelve potential final designs. These twelve were considered and explored more in depth to allow for better understanding of each design's weaknesses and strengths.

These designs were then compared to each other to find which would be included in the design matrix (discussed below). From this comparison the top characteristics of each concept were explored further. For example, the initial gurney lift proved ineffective; however the scissor structure seemed promising. This structure was then further explored and re-categorized with the scissor lift concept. The rack and pinion design was conceptually improved to use linear sliders instead of a gear mechanism as the alignment feature. These top three designs were then considered with various lifting mechanisms in the decision matrix.

5. Decision Matrix

After initial brainstorming, we agreed on five structures to base our device on and four potential lifting mechanisms for each structure. To determine the viability of each possible combination, we used a set of criteria we felt to be the most applicable. These were ease of use, safety, cost, load capabilities, trunk space usage, storage space, durability, stability, ease of initial assembly, and general practicality.

Each criterion was assigned a in Figure 6 to determine its importance in the final design matrix. In Figure 6, rows and columns were compared to determine which criteria would carry greater weight. If the criterion in the row was determined to be of higher importance than that in the column, it was assigned a value of 1. If the two criteria were considered to be of equal value, each criterion was assigned a value of 0.5, if the row criterion was determined to be less important, the assigned value was 0. Each row of values was summed to determine the criteria weights for the decision matrix. The highest weighted value sum was 8.5, to both safety and stability, the lowest was 0 given to ease of initial assembly. These summed values were used as a basis for final weighting decisions we made. Most of the values were increased slightly. This was so the higher values would carry more weight, and so the lowest values, particularly the value of 0,would not be negligible in the design matrix output.

In the design matrix, each possible design configuration was rated from 0-5 in each criterion, with some being given half values. Each of these 0-5 values was multiplied by the corresponding previously determined weight, and then these weighted values were summed. The three designs with the highest weighted total sum, and therefore the most desirable, all used the scissor lift platform. Two design combinations were listed in the matrix but were not evaluated as they were already determined not to be viable. The combination of air-bladder and parallel 4-bar was determined to be unsatisfactory since the horizontal movement of the top in comparison to the bottom would put notable shear on the air bladder, a component we were seriously concerned would experience failure under these circumstances. Similarly, we could not think of a configuration for a 4-bar parallel setup with a pneumatic cylinder that would meet dimensional constraints and provide a sufficient vertical component to the output force. The designs have been sorted in order of highest rated to lowest rated, with the highest on the top and the lowest on the bottom. The top four selections considered in more detail are highlighted in grey. The option chosen for final design was rated highest at 222.5.

6. Concept Selection

Based on the design matrix, the scissor lift was determined to be the most viable solution. The scissor lift could potentially work through a number of different mechanisms, of which the team decided to use an air-bladder system to achieve the necessary lift height.

This design uses two parallel scissors that are each comprised of two lengths of rectangular tubing pinned together at the center. Each bar is solidly pinned towards the rear of the frame, with the other ends of the scissor members attached to sliders free to move.

6.1 Detailed Design & CAD

The final design and 3D model can be found in Appendix A. The schematics of altered parts are also located in the Appendix. Solidworks was used due to ease of use and the team's familiarity with the program.

6.2 Stress/Kinematic Analysis

Stress analysis was performed to find appropriate sizes for key components. We found that some of the highest stresses were going to occur on the pin joints and on the sliders, due primarily to the small cross sections of these components. Since these components would experience maximum loads, they were simply analyzed to determine critical dimensions. Since the smallest cross sectional area and material properties of the UHMW Polyethylene sliders, the maximum safe load for a single slider was easily found. For the steel pins, using the maximum intended load with safety factor, the smallest possible pin diameter was found assuming worst-case scenario of full weight on one pin.

6.2.1 Pin Stresses

One of the major components we needed to perform stress analysis on were the pivot pins to be used in the scissor mechanism. Based on a worst-case scenario of full weight on a single pin, we found the minimum cross sectional area allowable. For this calculation, we used a value of 900lb, which was using an older intended weight of 300lb with an applied safety factor of 3. Using steel as the pin material, the minimum pin diameter at 900lb was found to be just below ⅛ inch, making an ⅛ in pin the smallest standard-size pin we could safely use at this load. Since it

	Stability	Safety	General Practicality	Cycles to Failure	Maintenance	Cost	High Load Capabilities	Trunk Space Usage	Storage Space	Ease of Initial Assembly	Sum of Values	Chosen weight
Stability	-	0.5	1	1	1	1	1	1	1	1	8.5	10
Safety	0.5	-	1	1	1	1	1	1	1	1	8.5	10
General Practicality	0	0	-	1	0.5	1	1	0.5	1	1	6	9
Cycles to Failure	0	0	0	-	0.5	0.5	1	0	0	1	3	4
Maintanance	0	0	0.5	0.5	-	1	1	0	0	1	4	5
Cost	0	0	0	0.5	0	-	0.5	1	1	1	4	7
High Load Capabilities	0	0	0	0	0	0.5	-	1	1	1	3.5	7
Trunk Space Usage	0	0	0.5	1	1	0	0	-	1	1	4.5	4
Storage Space	0	0	0	1	1	0	0	0	-	1	3	3
Ease of Initial Assembly	0	0	0	0	0	0	0	0	0	-	0	2

Figure 6: Criteria Matrix

Design	Stability	Safety	General Practicality	Cycles to Failure	Maintenance	Cost	High Load Capabilities	Trunk Space Usage	Storage Space	Ease of Initial Assembly	Total Weighted Criteria
Weighting	10	10	9	4	5	7	7	4	3	2	
Scissor (Air Bladder)	4	3.5	4	3	2.5	3	4	4	4	5	222.5
Scissor (Winch)	3.5	2.5	3	4	3.5	4	3.5	3.5	4	4	207
Scissor (Pnuematic Cylinder)	4.5	4.5	1	3.5	2	1.5	5	3.5	4	2	198.5
Parallel 4-bar (Pnuematic Cylinder)	4	4	2	3.5	2	1.5	5	2	3	3	190.5
Parallel 4-bar (Hand Winch)	4	3.5	1.5	4	3.5	3	3.5	1.5	3	3	188.5
Linear Sliders (Air Bladder)	2.5	2.5	2.5	3	2.5	3.5	3.5	2.5	3	3	171
Scissor (Lever Arm)	3	2	1.5	2.5	4	4	1.5	2.5	3.5	4	160.5
Parallel 4-bar (Lever Arm)	3	2	1	2.5	4	3	2	2	3	3	147
Linear Sliders (Winch)	2	2	1	4	3.5	2	3	2	2.5	1.5	136
Linear Sliders (Lever Arm)	2	2	1	3	4	3.5	1	2	2.5	3	134

Figure 7: Decision Matrix

was our intention to use readily available ¼ pins, this confirmed that we would have no pin failure.

6.2.2 Slider Stresses

The next component of concern was the sliders. This was in part due to the small cross section of the part, but also due to the fact that the sliders were the only polymer part we were intending to use. The sliders used were made from Ultra High Molecular Weight Polyethylene (UHMW-PE). 80/20 Inc. provided the dimensions for the minimum cross section as 0.42664 in^2 (small cross section of S and T) and UMHW-PE has an elastic modulus of 3050 psi (TIVAR)(25-6797, 2016). The following calculation shows that the failure point is far above our expected load.

$$F = \sigma \cdot A = 3050 \cdot 0.42664 = 1289 \frac{lbs}{inch}$$

K	2.77mm
L	25.00mm
M	11.94mm
N	46.69mm
P	n/a
Q	5.33mm
R	4.06mm
S	2.79mm
T	5.08mm
U	50°
V	5.84mm
Weight lbs	0.0130

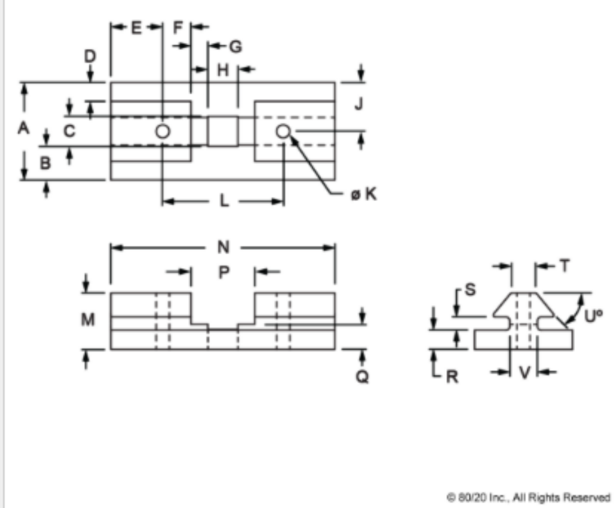

Figure 8: Critical Slider Geometry

7. Discussion

7.1 Zeroth Order Prototype

The zeroth order prototype was built to validate our scissor jack design, and to test the mechanism movement and chosen proportions. This prototype was made from cardboard and pinned with paper clips.

The frame pieces were cut from double thick cardboard in 1.5-inch width strips, approximately seventeen inches long each. The top of the prototype was a single piece of the same cardboard, dimensions 17 in by 17 in, with the left and right sides turned down 1.5 inches to allow a location for the legs to attach. All joint attachments were done using bent metal wire paper clips. The bottoms of the scissor members used more 17-inch strips of cardboard as cross members for stability. The two scissor members on each side were pinned to each other in the middle and to the top plate on one side. Being a zeroth order prototype, one side was left unpinned instead of creating a track, as the sliding motion provided by leaving the parts unpinned was sufficient. When fully collapsed, the zeroth order prototype was 17 inches long, 14 inches wide, and approximately 4 to 5 inches tall. The height value was greater than intended and expected due to the rough nature of a cardboard prototype. Fully extended, the prototype was approximately 15 inches tall.

This prototype was created only to demonstrate the movements of the scissor lift. It allowed us to see the device in motion, see where interference might occur, and check for any other potential issues.

7.2 First Order Prototype

The first order prototype was the next step after the zeroth order prototype. The intent was to create a scale model of the final design out of a stronger material than the zeroth order prototype in order to test the design's functionality at a reduced scale. Aluminum was chosen for the scale model due to its higher manufacturability in comparison to steel, which would better allow for corrections and changes as potential design flaws and better manufacturing techniques became known. Spare aluminum “L” bar stock, ½ inch by ½ inch by 3 feet long was used as the primary building material due to immediate availability.

Figure 9: First Order Prototype

In order to make the scissor members work properly, a rectangular profile was needed instead of the L shape. To fix this issue, some lengths of L bracket were welded together create square tube stock. Each scissor member was 8 inches in length. Three 3/16-inch holes were drilled in each member, one at each end ¼ inch from the end of the bar, and one in the center. Each scissor set was pinned together at the center using 2-inch long ⅛ inch diameter bolts.

In order to create the base and platform sliders, lengths of L bracket had to have slots machined into them. It was determined that when attached, the corners of the scissor members would interfere with the slotted stock. There were two possible ways to eliminate the issue, either sand the corners of the scissor member to be a rounded profile, or remove the section of interfering L bracket. We chose the second option, as it was quicker and simpler for the sake of prototyping. Four sections of 8 inch L stock were selected for the slotted members. One inch of one leg of the “L” was removed and sanded to smoothness for each piece to prevent catching and interference with the scissor member. The slots were added next. A linear series of holes, 3/16-inch diameter, were drilled along the center of the track piece on the side without material removal. These holes were drilled with the smallest spacing possible, and then the space between each successive hole was filed away to remove the excess material, leaving a rough track slightly larger than 3/8 inch wide.

The slotted pieces and scissor members were assembled together using 1-inch long ¼ inch diameter bolts. After initial assembly, the bolts were reoriented so that the nut was not on the interior of the track. After testing the opening and closing of the lift, we had found that the nut twisted with each cycle becoming increasingly loose or tight. This change in tightness of the nut would render the device unable to move or cause the nut to fall off entirely. The top sections of track were oriented such that the track section faced inward, while the bottom section had the track facing outward. This was to prevent additional interference during motion.

Once the moving sections were built, it was only necessary to attach the base and top sections. As this was an early scale prototype, we intended to simply attach two pieces each to the top and bottom in order to hold the lift together. After partial assembly, we realized that if we were to assemble it entirely in that manner the 5-inch diameter ball, used as a small-scale test air bladder to lift the prototype, would not come in sufficient contact with the top and base of the device to effectively demonstrate the mechanism. To compensate, we moved one of the crossbeams to the middle on both the top and the base. After inflating the air bladder in the initial test of the device, we found that the ball would simply move through the gaps in the top, or move partially through and inflate without lifting. To counter this, we added two additional crosspieces close together on the top. This was found to be sufficient to solve the issue.

We tested the prototype and found that with sufficient air pressure, the air bladder was able to lift a half full 2-gallon jug of coolant to slightly less than its full diameter. The height discrepancy can be attributed to a non-solid base to lift from as well as some compression of the inflated ball. From our experience with the scale model, we gained a better understanding of available manufacturing techniques. We also discovered many potential issues were able to discuss potential solution. Examples of these issues include interference, center of gravity instability, and the catching of bolts on rough edges.

7.3 Materials Selection

After completion of a representative model of the final design, suitable materials needed to be sourced. These materials not only had to allow the required movement, but also be able to withstand the given maximum load of 600lbs. Another objective for material selection was that the chosen materials needed to be relatively light in order to keep the unit under the 50lb stated in functional requirement 10. Once these goals were determined, appropriate materials for the frame were found through two different suppliers.

The first supplier used was 80/20 Inc., a company that supplies extruded aluminum beams and modular components for easy construction and industrial applications. We found that the 1-inch x 1-inch extruded aluminum was strong enough for our loads, and that 80/20 also has sliders available that are mated to the extruded aluminum track. It was decided that could be ideal for the sliding end of each scissor member provided they were of sufficient strength. Stress analysis was performed on the sliders to ensure that they would be able to withstand the maximum load, and they were found to be more than sufficient for our purposes. The connection between the lengthwise and cross members also needed to be addressed, as using interior or exterior L brackets could interfere with and limit slider movement. Using 80/20 internal anchor fasteners as shown below solved this issue.

Figure 10: 80/20 25 Series Internal Fastener

The 80/20 supplier drilled counter-bored holes for these anchors in the ends of the cross supports (Figure 9: 8020 Frame Member A).

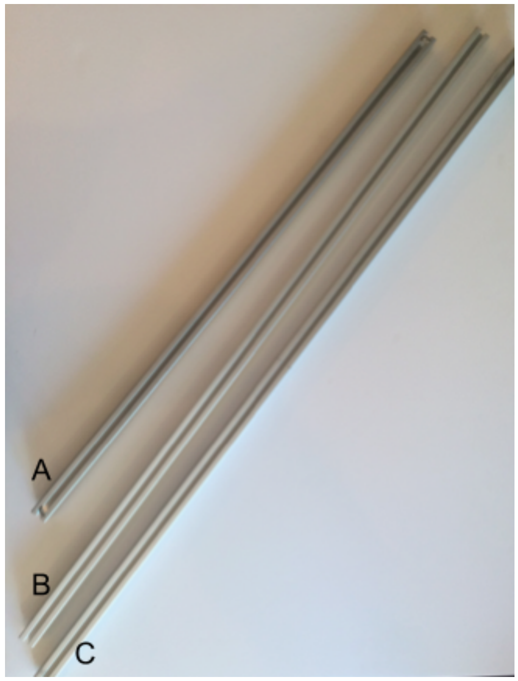

Figure 11: 8020 Frame Members

The upper and lower frames were made using this 80/20 modular aluminum system, but the scissor members were sourced from a different supplier. The scissor members would undergo the most torque and stress during operation, so to accommodate these stresses rectangular steel tube was sourced from OnlineMetals.com. This steel tube is able to withstand the load while also remaining rigid throughout operation.

7.4 Construction

7.4.1 Description of Materials

Before construction of the final prototype could begin, sourcing out core building materials was necessary. All 80/20 aluminum and 80/20 internals anchors were ordered from the 80/20 company. Ordered parts included four pieces at 45 inches in length with one flat side and no additional modifications, and four pieces at 35 inches in length with counter-bored holes for fastening purposes. Eight 80/20 3395 Anchor Fasteners were also ordered. These have a cylindrical end which fits in the counter-bored holes on the cross members which connects at a 90 degree angle to a slider designed to fit into the predesigned slots of 80/20 stock material, and a small internal bolt to hold both together. When placed and tightened, the anchor holds the two pieces together solidly at a 90° angle. Four 25-6797 sliders composed of white UHMW were ordered as well.

For the scissor members, ½ inch by 1 inch rectangular steel tubing was used. ¼ in diameter threaded rod, washers, polyurethane tube spacers, and nuts were used as pivots in the centers of the steel piping, were used as pivot connections where the steel piping was pinned to the sliders, and ¼ in clevis pins were used as pivots where the steel piping was pinned directly to the top and bottom frames. Washers were used on the clevis pins to gap the steel tube out from the frame approximately the same distance as was done by the sliders to prevent misalignment.

Two sheets of Masonite were used for the top and bottom panels. The top panel was additionally supported by two 43 inches long 80/20 cross members that were supported by L bracket connections to the top cross beams shown in Figure 10.

Figure 12: Top Panel Support Structure

The air bladder used to lift the device was built using eight 10-inch diameter by 2.5-inch tall tire lawn mower tire inner tubes. These tires stacked together to create a cylindrical makeshift air bladder, and were plumbed together using ¼ inch vacuum tubing and eight T connectors. A release ¼ NPT (National Pipe Thread) pull ring release valve and ¼ NPT Schrader valves were also used. To connect the ⅜ inch vacuum tubing to the tires, the Schrader valve cores on each tire were removed, and the vacuum tube screwed directly onto the now unrestricted Schrader fitting. Since the ¼ NPT threading would not screw into the same size vacuum tubing, a tube size converter, three 1-inch lengths of larger vacuum tubing, and a larger T connector were also used.

Several cut lengths of ½ inch Polyvinyl Chloride pipe were used as spacers for various bolts and rods.

7.4.2 Frame Manufacturing

Assembly and manufacturing of the frame began with the shaping of the rectangular steel piping for use as the scissor members. The tubing was cut from 48 inch to 42 inches and three ¼ inch diameter holes were drilled, one in the middle of the member 21.5 inches from either end, and two 21 inches out from the center hole in both directions, or approximately ½ inch from each end of the beam. For measurement, the first hole was measured from the end, then the next two measured from the first hole for increased accuracy.

In order to keep the corners of the tubing from interfering with the top or bottom platforms when rotating, the ends of the tubing were roughly cut and then ground to create approximately rounded ends with ½ inch radii.

The 80/20 aluminum was pre cut to our desired lengths from the supplier, and minimal work was required to form these pieces. One additional hole needed to be added to each 45 inch sections for the clevis pins to connect the scissor members to the solidly to the frame (80/20 Inc., 2016). The eight pieces of aluminum, four 45 inch members and four 35 inch counter-bored members, were fastened to each other using 3395 anchor fasteners to create two 45 x 37 rectangular frames for the base and platform.

Each of the plastic sliders had a 3/16-inch hole drilled in the center for the shoulder screws to screw into (See Appendix A for 25-6797 drilled schematic). It was decided to not tap the holes as the sliders were made of fairly soft material and would provide a tighter fit untapped.

Steel sheeting or grate was initially intended for the top and bottom panels, and would have been preferable for strength and rigidity, but Masonite was used instead due to cost concerns. The two sheets of Masonite used were cut to 45 inch by 35 inch, and were held in place using 16 sets of nuts, bolts, and washers. Since metal plate was not an option, strength and structural rigidity on the top plate was provided by two extra 80/20 lengthwise members which were purchased and installed with the Masonite. The top panel of Masonite, requiring greater strength, was attached using 12 short bolts, 3 on each lengthwise support member, while the bottom panel used only 4, one at each corner. The washer and nut connected to each bolt were placed into the holes of the Masonite, then fed into the slot of the 80/20 to avoid the necessity of drilling holes through the 80/20 aluminum beams before tightened.

7.4.3 Frame Assembly

With all components fully cut, shaped, and drilled, assembly could commence. For simplicity, the lengthwise members were assembled with their respective scissor members, and then the two scissor members were connected via the cross members. The extra lengthwise supports and Masonite paneling was the final added frame component. For the lengthwise 80/20 members, the flat side of the extrusion profile was initially intended to face down and up towards the ground and platform, respectively, as it was initially believed having a flat mounting surface may be beneficial, but as possible Masonite panel attachment methods were considered, it was determined that the slots should instead face the panels. This was so that a washer nut set could be placed in the slot for each screw instead of having to drill a large number of new holes in the material. Due to the nut thicknesses that were readily available, a washer was needed with each nut, as the nut on its own was slightly too short and would rotate in the slot instead of properly tightening. Because of this, the nut, washer, and screw needed to be inserted into the slot already fastened to each other, which made panel assembly significantly more difficult than if the nut could have been placed in the slot on its own.

The first step in assembly was to connect the shoulder screws to the sliders through an end hole on each scissor member. Plastic spacers were added between washers at the end of the shoulder screws and the steel bars to reduce unwanted movement as shown in Figure 13. Ideally shorter shoulder screws would have been used, but were not readily available in the desired length. Two 80/20 beams were placed on top of each other, smooth sides in with the end and drilled holes aligned. One scissor member and plastic slider was then inserted into a slot on each 80/20 member, and were made sure to be inserted on opposite sides of the stack. Each scissor member was then lined up so the hole at the far end of the member would line up with the drilled hole on the lengthwise member with which it was not already mated via slider.

Figure 13: Slider Assembly

Clevis pins were then used to connect the scissor bars and the 80/20 members. Washers were used as spacers to match the offset created by the sliders on the other end of each scissor member. At this point in assembly, the scissor could move in roughly the correct motion, but with nothing holding the scissors together, the sliders tended to fall out, and parallel motion was not guaranteed. This was corrected when the central pin was added shown in Figure 14.

Figure 14: Scissor Alignment Pin

A ¼ inch diameter, 3.5 inch long rod with each end threaded for ~¾ inch was inserted through the center holes of both scissor members. As the two scissor bars are on opposite sides of the 80/20 stack, the spacing between the two scissor bars is maintained by a 1-inch plastic spacer and washers. Washers and nuts were screwed onto both ends of the rod to keep the central pin in place. Assembly of the second scissor was nearly identical, but was mirrored to maintain symmetry and improve stability in the design.

Once both scissor assemblies were complete, work began on the rest of the assembly. The 80/20 cross beams were attached first to provide stability to the frame while the top and bottom panels were attached. Since the top panel would have the full weight distributed across it, the lifting force is located in the center of the panel, and Masonite is of less than ideal strength, it was supported from below by two additional 80/20 crossbeams placed as close to the air bladder as possible without major interference as shown in Figure 12 above. Twelve holes were drilled into the Masonite for the top plate; four rows of 3 lengthwise down the board. The two outer lines were evenly spaced at 21.5 inches between holes and 1 inch from the edges of the hardboard. The two inner lines were spaced one inch shorter apart due to the shorter support member length, and with the lines being spaced approximately 12 inches apart from each other to leave room for the air bladder in between. The short bolts were pushed through the three outer holes on the each side, and then a washer and nut were loosely screwed onto the end.

Figure 15: Masonite Drilling\ Layout

At this point in time, the lift frame was brought back into a partially assembled state lacking the extra length supports, and one cross member on the top. The partially assembled lift was rested vertically so that the top panel could be lined up so the sets of nuts would align with the slot, and be slid into place. Once in place, the bolts were tightened. At this point, the six center bolts were inserted, and the center supports slid down over them. Once the center supports were firmly attached to the top plate and the L brackets (provided by 80/20) that would fasten them in place inserted into the respective tracks, the missing cross crossbeam was attached. With both cross beams in place, the support beams were then affixed to both cross members using L brackets, completing the top of the lift.

The base would require less strength to resist movement, as the main function of the bottom plate was only to help keep the unit steady instead of to bear load, therefore, only four bolts were used to hold it in place. The bottom panel was primarily necessary to give the air bladder a local frame of reference to provide lift from, without the panel the unit could slide around during operation. Small holes were drilled into the bottom Masonite panel, one on each corner ½ inch from each edge. The panel was slotted into place similar to the top panel.

7.4.5 Pneumatic Manufacturing and Assembly

The pneumatic system uses a combination of a series of riding mower tire inner tubes stacked and affixed in a cylindrical stack, and a small portable air compressor to provide lift power. The valve cores were removed from each of the eight inner tubes so they could be more easily plumbed together. The tubes were stacked on each other and were plumbed using T joints and automotive vacuum hosing as shown below. There were 8 T joints used in the plumbing, 7 for the tires, as the last two tires shared a T, and one to connect the bleed and Schrader connections for filling and draining the system. For simplicity, the side junction lines were fed into the inner tubes, with the in line connectors connecting to the previous and following T junctions. The final T supplied both the 7th and 8th tube in the stack.

Figure 16: T-Joint connected to vacuum hosing

The first T-junction in the stack was connected to a feed line of significantly longer length. This line feeds into a larger diameter T junction which splits into a Schrader valve connection and a pull ring pressure release valve. A pull ring valve was chosen to easily control the speed of descent, and avoid any chance of the valve being left partially open. This junction is shown in Figure 17. Since the pull ring and Schrader valves used a different sized connection than the inner tubes, 1/8NPT as opposed to Schrader, it was necessary to use a line converter and a larger 3/16-inch T Joint and ¼ inch vacuum tubing. The release valve (A) and Schrader valve (C) are linked into the smaller feed line through the 3/16-inch T Joint (B) and a ¼ inch to ⅛ inch converter (D).

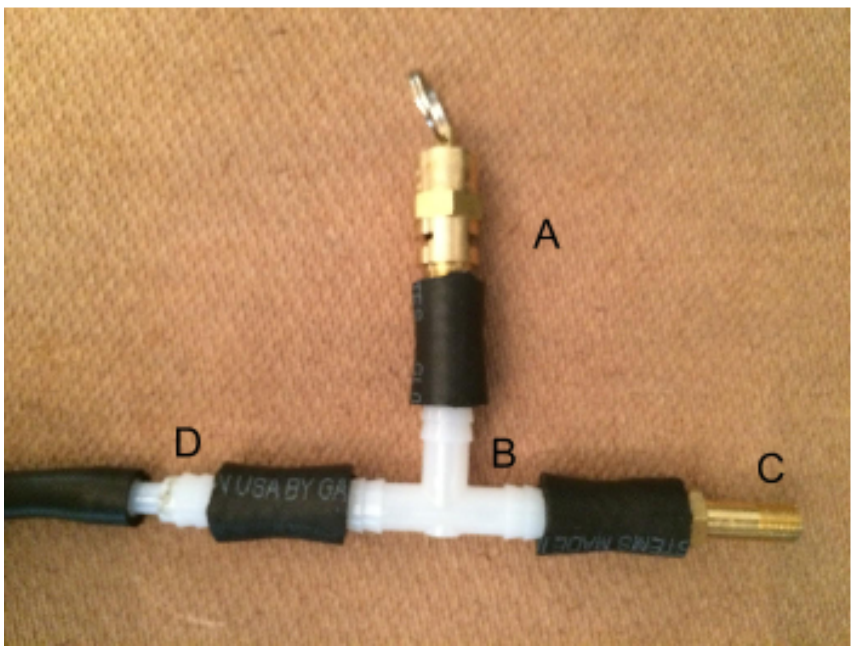

Figure 17: Input, Bleed Connection, and Feed Line Assembly

The objective was to use eight 10-inch tires to achieve the intended height. These tires were glued together after inflated in order to create a cylindrical stack as shown below. To allow for the lowest compressed height the curved valves were angularly offset in a spiral pattern so the plumbing would coil inside as the system deflated. Once completed, this stack only allowed for a height of 17 inches. The height deficit is believed to be due to a misunderstanding in the dimension of the tire inner tubes. Each tube was listed as 3.5-4 inches, but in reality was found to be closer to 2.5 inches on average, and is labeled as such on the actual tire inner tubes. It is now the team's belief that the 3.5-4 inch width designation on the box was not for the inner tube itself, but instead was a width range for tires the inner tube could be successfully paired with. The completed stack is shown in Figure 18.

Figure 18: Tire Stack Air Bladder

7.4.6 Final Assembly

After the completion of the mechanical and pneumatic portions of the build, the final assembly was fairly straightforward. For maintenance purposes as well as convenience, we elected to not permanently attach the air bladder to the inside of the lift. It was necessary to be able to repair the air bladder plumbing in case of damage, but if it were permanently attached then access to the air bladder plumbing would be severely limited. The air bladder was instead simply placed in the center of the lift and adjusted as necessary to provide stability. Stability was less than desired due to the relatively loose manufacturing tolerances the team was able to achieve.

A small 12V DC tire inflator that plugs into an automotive 12V cigarette lighter actuated the lift mechanism. As the lift is supposed to be portable, a large AC converter was not used. This small compressor can be seen in Figure 19. This compressor was also used during the testing of the device.

Figure 19: Completed Lift

7.5 Experiments and Testing

When testing the carrier lift, three weight sets were used, no weight, 35 lbs., and 70 lbs. The lift was designed with the intention of a maximum listed weight capacity of 200 lbs. with a safety factor of three, but testing was limited to 70lb due to concerns about the stability of the lift and load as well as the integrity of the inner tubes. The lift was first tested with no test load in order to get a baseline of the lift's capabilities. A timer was started when the compressor was turned on, then stopped when it was determined that there would be no additional meaningful height gain, and the compressor was shut off. After the compressor was shut off, the lift platform height was measured and recorded. A timer was then started again as the unit began to be deflated, and was stopped when decompression of the inner tubes was deemed to be complete. For the no-load test, some additional pressure was applied to the top plate during the last ten seconds, as the lift weight alone did not weigh to completely deflate the bladder. The same procedure was followed for 35 lbs. and 70 lbs. tests. It was necessary at some points for one of the testers to move the top platform to ensure it stayed level and lifted smoothly. If the platform was not kept level then there would be risk of the load coming off or the sliders binding. Please note that the 35lb and 70lb values are estimated, as automobile wheels with tire were used as the testing weights. Each wheel and tire were estimated to weigh approximately 35 lbs, and the lift was tested unloaded, with one wheel, and with two wheels.

8. Conclusions & Results

8.1 Lift Capabilities

The device was tested with a few different load values, and the maximum attainable lift height, lift time, and deflation time was measured for each load value. This data is summarized below.

	Lift Time	Lift Height	Deflation Time
Unloaded	3 minutes	17 inches	37 seconds
Loaded (35 lbs)	3 minutes 40 seconds	15 inches	25 seconds
Max Load (70 lbs)	4 minutes	14 inches	23 seconds

Table 2: Lift Results

Unfortunately we were unable to meet some of our functional requirements with the initial proof of concept. These include functional requirement 2 and 15, namely that the device must be stable under all conditions (FR.2.) and that the device must lift the crate to a height 30 inches (FR.15.).

The stability of the prototype was limited primarily by the tolerances in the frame manufacturing being of lower quality than would be ideal. In a full scale automated manufacturing environment, these tolerances could be considerably improved. Since the scissor stability was not ideal, the prototype's overall stability was heavily dependent on the air bladder and load placement. The prototype lift height was limited to 17 inches due to the air bladder size. As previously mentioned, this sizing error was due to misinterpretation of inner tube dimensioning. The device frame is capable of safely rising to a height of 40 inches when lifted by hand, which does exceed our functional requirement, meaning that the requirement could be met with an improvement in air bladder height. These functional requirements will be further discussed in the recommendations.

8.2 Recommendations

The built proof of concept lift was a generally successful prototype, but had many areas that can be improved upon in terms of functionality and safety in future iterations. These recommendations are discussed in the following sections.

8.2.1 Support Structure

During initial testing it was noticed that if the applied lifting force was not properly centered, then the two scissor members would lift at different rates, pitching the platform and binding the sliders. This could often cause the lift to stop both in opening and closing, but could be easily fixed by nudging the platform to level it. We believe that adding a cross support between the aligned scissor members with solid 90° brackets at the connections would significantly improve parallel scissor movement. This could potentially also be improved by putting a cross support between the sliders, which would make sure the scissors opened at the same rate. If added, the crossbar between the sliders could also provide a push point for a horizontal air bladder or actuation setup. The addition of the of either of these options would also increase overall stability and hopefully be enough to fulfill functional requirement 2.

8.2.2 Lift Mechanism & Air Bladder

Another area that would need improvement was the air bladder setup. Our bladder was created using stack of 10 inch inner tubes connected through a series of T connections and vacuum hosing. Since premade air bladders are not available in the required dimensions, other potential bladder ideas were considered such as a yoga ball or truck suspension. The yoga ball idea was scrapped since the required lift height was very similar to the lift width, and being spherical, interference between the ball and scissors was a concern. Truck air suspension members were also scrapped as they are extremely costly, have a minimum psi value, and did not meet our lift and compressed height requirements. The use of a homemade air bladder was cost effective and proved the functionality of the system, but would not be reasonable solution for production device. The main issues with the homemade stack are as discussed below.

As previously mentioned, there was some misunderstanding about the dimensioning scheme used for the inner tubes. These tubes were listed as "tire size 4.10/3.5-4" which we understood to mean that the maximum outer diameter of the inner tube was between 3.5 inches and 4 inches. Through simple calculation we had determined that we would need 8 tires to achieve the intended height of 30 inches. Unfortunately, the inner tubes were only about 2.5 inches each, and experienced lateral expansion under load, further lowering their effective height to an average of 2.125 inches. If the device were to go into production, a single cylindrical air bladder of a more resilient material such as rubberized canvas or 1000-denier polyester would be used as this would reduce necessary plumbing, increase stability, and decrease deflection of the bladder.

While the air bladder system provided sufficient vertical lift for the proof of concept, we also feel that the inclusion of a winch mechanism could fulfill multiple requirements. The use of a winch lift mechanism could change the outcome of initial testing. A winch mechanism has different advantages compared to the pneumatic system. The primary advantage would be that the steel cable would always provide movement in a single direction. Another advantage of a winch system would be that winches are by design unable to back drive unless intended by the user. This could allow the user to stop the motion mid cycle, adjust the crate, and continue lifting without any hazards. However, integration of a winch into the system would also bring a different set of mechanism, packaging, and ease of use challenges.

In conclusion, further development of the primary lift system would prove beneficial to the overall safety and functionality of the device. Our device incorporates two safety features, a Schrader valve and pull ring bleed valve, which only allow air flow in one direction and require user input to lower the lift.

8.2.3 Car mounting

Functional requirements 5 and 9 address the installation of the device in a vehicle. The device did not include any mounting features as it was thought that keeping the device outside of the car would allow for a more universal design. Many sport utility vehicles (SUVs), wagons, and hatchback vehicles have mounting points in the trunk and on the backside of the rear row of seats. Future iterations of the carrier lift could make use of these mounting points to reduce the need to store the device outside of the car, or to affix a non-permanent auxiliary system to assist in getting the crate from the lift into the cargo space. FR.9. required that any installation within the user's vehicle not cause any permanent damage. As such, modification to create non-stock permanent mounting points was never considered.

8.2.4 Crate Loading and Unloading Features

As acknowledged in the background research, elderly persons or persons with disabilities often have trouble moving large and heavy objects. During the construction of the top platform we felt that including a loading system, such as drawer slides or the previously mentioned car-side auxiliary, would enhance the usability of the carrier lift. This aspect of the project would require further research and analysis.

Another consideration for the top platform was to use rollers in conjunction with the drawer slides. This would allow the crate to be pushed off on the platform so the user would not have to lift the crate from the raised lift and into their trunk. This would reduce possible back strain, but would need to be approached carefully to avoid the rollers causing the crate to slide while the lift was in motion.

8.2.5 Safety Mechanisms

The last recommendation for future project iterations addresses safety for both the user and the dog as stated in functional requirement 1. The device currently depends on the air bladder mechanism to resist back driving. While the air bladder system is designed to resist back driving without user input, there is no redundant backup system in case of pneumatic system failure. This poses a risk should the bladders, piping, or any connections within the stack failed, as this could cause a rapid collapse of the lift. The inclusion of a ratcheting mechanism on the scissor members would be a potential solution to this issue, but would be difficult to incorporate while the lift is lowering.

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Appendix A: Components Drawings

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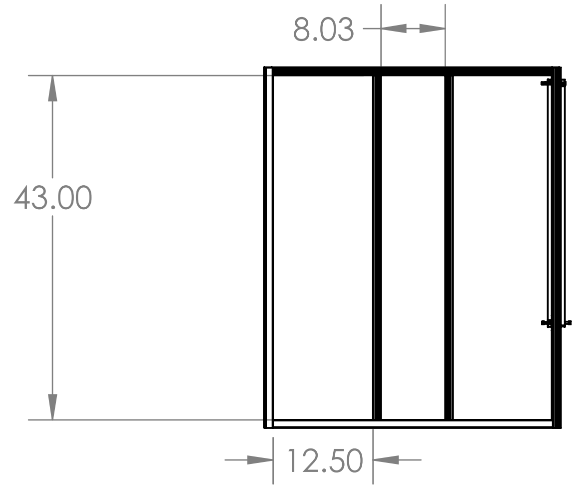

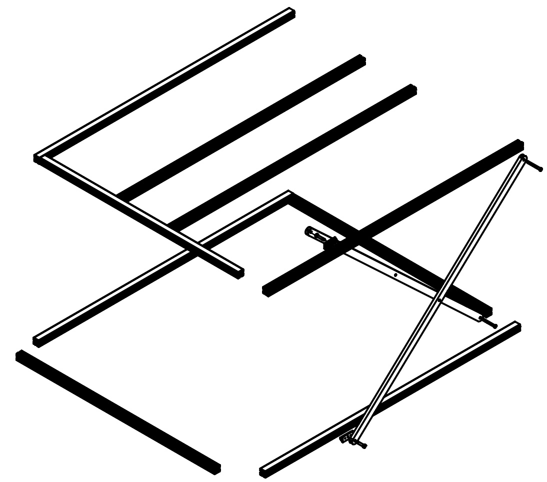

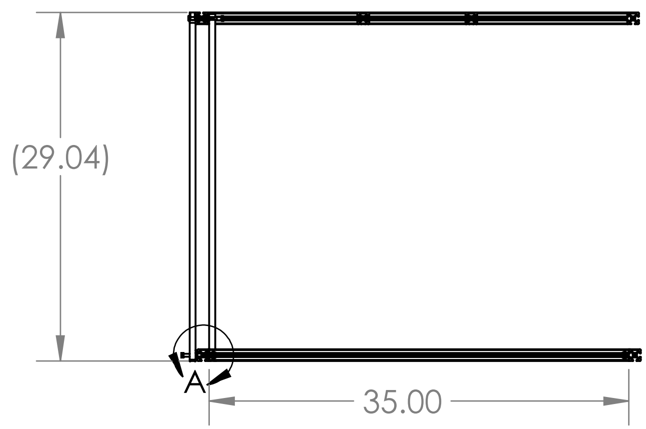

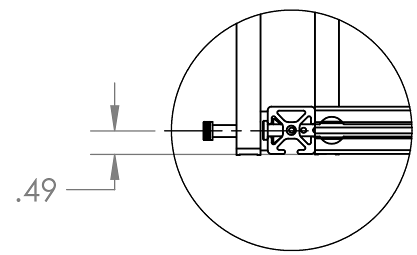

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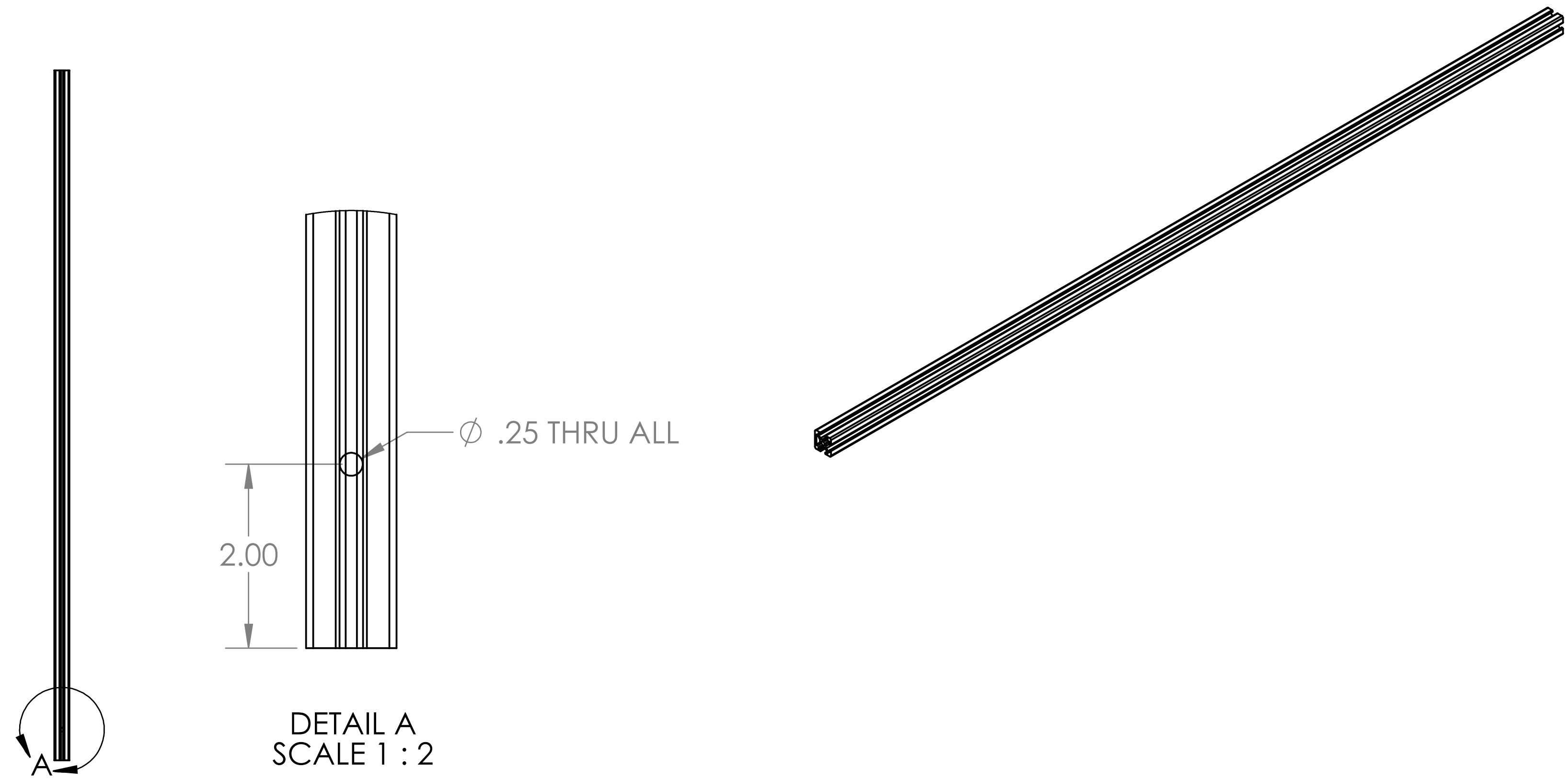

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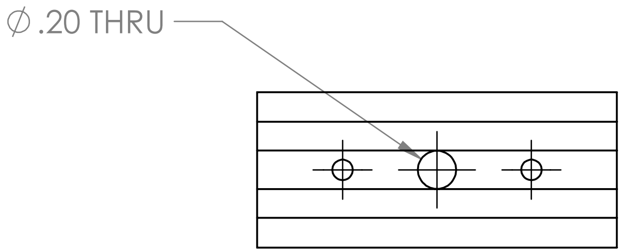
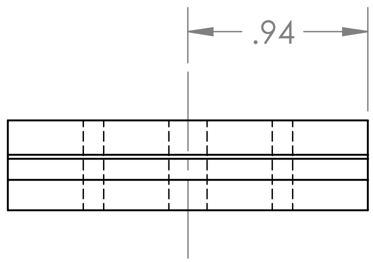
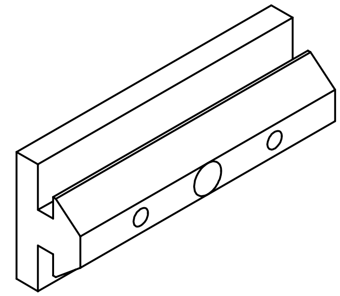
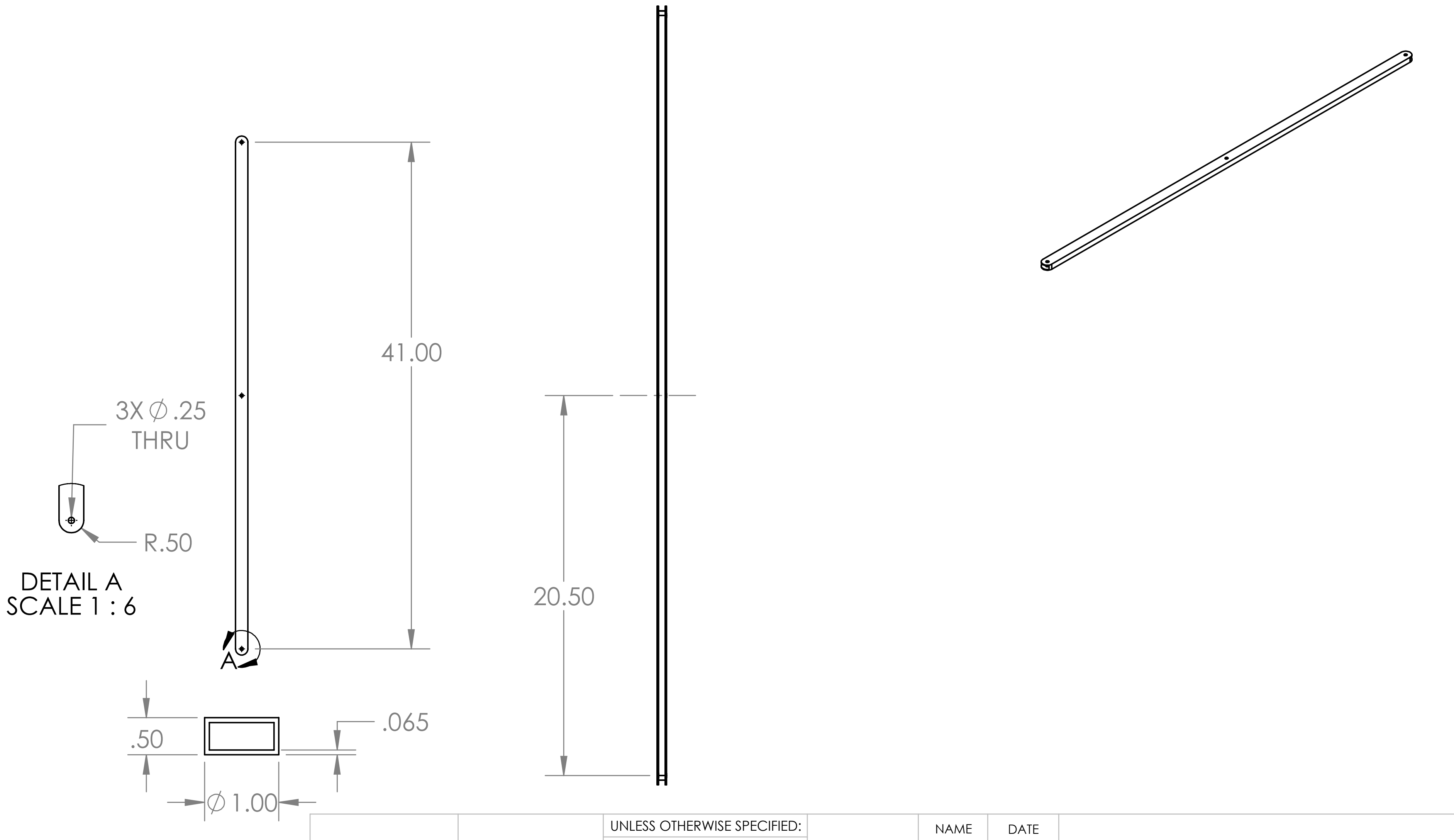






UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN			
	CHECKED			TITLE:
	ENG APPR.			
	MFG APPR.			
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
MATERIAL UHMW Polyethylene	COMMENTS: Other dimensions are standard from 80/20 Inc.			SIZE A · DWG. NO. 25-6797 Drilled · REV
FINISH				
DO NOT SCALE DRAWING				SCALE: 1:1 · WEIGHT: · SHEET 1 OF 1

NEXT ASSY	USED ON
APPLICATION	



2 1

B B

A A

NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE:

SIZE	DWG. NO.	REV
A	SteelBeam	

SCALE: 1:12 WEIGHT: SHEET 1 OF 1

2 1

Appendix B: Bill of Materials & User Assembly Guide

Hardware and Components List		
QTY	**Description**	**Use**
23	8-32 Nuts	Masonite/Top Platform
21	8-32 ½" Socket Cap Screws	Masonite/Top Platform
18	8-32 Washer	Masonite/Top Platform
8	¼ - 20 Nuts	Scissor Pins
16	¼ - 20 Screws	Top Platform - 80/20
16	¼ - 20 T Nuts	Top Platform - 80/20
4	8-32 1.5 inch Shoulder Screws	Scissor Member
4	¼ inch D 2 inch Long Clevis Pins	Scissor Member
4	Clevis Keys	Scissor Members
28	¼ inch Washer	Scissor Members
8	80/20 25-3392 (Internal Fastener)	Frame
4	80/20 25-6797 (Linear Bearings)	Scissor Member
4	25-2503 35 inch Countersunk	Frame
4	25-2503 45 inch	Frame
2	25-2525 43 inch	Top Platform Frame
4	42 inch ½ inch X 1 inch Rectangular steel tube	Scissor Member
2	1.125 inch half inch spacers	Scissor Member
4	.625 inch half inch spacers	Scissor Member
6	⅛ inch NPT T Joints	Tire Stack
8	10 Inch Inner Tube	Tire Stack
1	¼ inch Schrader Valve	Tire Stack
1	¼ inch pull ring valve	Tire Stack
1	¼ inch T joint	Tire Stack
1	¼ to ⅛ converter	Tire Stack

NOTE: This assembly guide is meant to supplement the construction section as a user guide.

Relevant components to end user assembly:

Top panel
Bottom panel
Scissor bars (2)
Half-inch spacers (2)
Shoulder screws (2)
Washers (10)
Sliders (2)
Air bladder assembly
Air compressor/Air Pump

Top and bottom panels provided assembled

Sliders are pre attached to two of the fours scissor members.

Two (2) sliders on interior of outer beams of top panel

Place the sliders of the scissor members with sliders into exterior slot of bottom panel (longer 80/20 beam).

Connect two remaining scissor members to the bottom panels by pinning the two remaining scissor members on the inside of the frame using a clevis pin. Use the holes drilled in the 80/20 members and the holes drilled at the end of the scissor members. Use two washers between the 80/20 and scissor for spacing.

Connect each set of scissors by pinning them together through the holes in the center of each member using a 3.5-inch double threaded rod, 1-inch spacer, and four washers each.

*Bottom Masonite removed for clarity purposes.

Connect the free ends of the of each inside scissor bar to the interior sliders on the top panel using a shoulder screw, half inch spacer, and one washer each.

Lastly, connect the loose ends of the other scissor members to the top plate using another set of clevis pins and washers. Once again, use the holes pre-drilled into the 80/20.

The lift mechanism assembly is now complete.

Raise the lift approximately one-foot and place air bladder assembly inside lift. Center the bladder using the top and bottom panels as reference. Ensure that the hosing is in such a position that it will not be pinched by the lift operation.

Full assembly is now complete.

Connect the air compressor to the exterior Schrader valve for operation.