ELEVATED ENGINEERING

BARRETT TRAILERS

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OSU | SENIOR DESIGN

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Background

Barrett Trailers, LLC began production in Oklahoma City, Oklahoma forty two years ago in 1973. Since then, they have moved from Oklahoma City to Purcell Oklahoma and have expanded their trailer facility substantially. Barrett Trailers are used to haul different varieties of livestock all over the United States. The high quality trailers have also been exported to countries outside the United States including: Africa, Australia, China, Europe, Mexico, Russia and South America. “Barrett livestock trailers are legendary for being the most rugged, easy pulling, and long lasting trailers that are on the market”. In today’s livestock trailer industry few competitors have designed, marketed and sold trailers that have center lifting floors. Several companies overseas have developed a center lifting floor Milson Livestock Trailers located in London and Pezzaioli Livestock Design located in Ireland. Barrett Trailer’s wants to lead the way into revolutionizing the semitrailer industry. Animal rights activists are proclaiming that the quality of meat is affected by the current way of transportation for different varieties of livestock. Currently when livestock is loaded into semitrailers, there is a ramp that leads to the top of the trailer where livestock is hauled. Activists are proclaiming that forcing livestock to climb the ramp is stressing the animal and therefore decreasing the quality of meat consumers buy. An additional convenience of having a center lifting floor is the cleaning that is necessary. By being able to completely raise the floor the operator can walk upright through the trailer and is able to clean the trailer much easier, whether that be manually or with the assistance of larger equipment.

Introduction

Elevated Engineering of Stillwater Oklahoma, will be working alongside Barrett Trailers, LLC of Purcell Oklahoma for the next year. The team is designing a livestock semi-trailer that has a center lifting floor capable of lifting a fully loaded top portion of the semitrailer to the roof of the trailer and to the bottom of the trailer. Throughout the course of the year there will be different ideas and designs that designed using SolidWorks, research upon different lifting mechanisms, Oklahoma Department of Transportation requirements reviewed as well as seeking council from both Barrett Trailers and other project engineers involved. Within this report there will be ideas that could provide the necessary requirements for our design as well as ideas that have failed to complete the requirements.

Barrett Trailer’s LLC approached Elevated Engineering with a question about designing a center lifting floor within a livestock semitrailer. The trailer has to be able to go from the bottom of the semitrailer to the roof of the semitrailer, moving approximately eight feet. The goal is to be able to lower the lifting floor, load the top of the trailer, raise the floor and then load the bottom of the trailer. The lifting floor has certain criteria that must be met such as safety of both livestock and the operator, corrosive resistant, even movement of the floor to prevent unnecessary wear and tear upon the lifting mechanism, as well as being cost efficient.

Scope of Work

Elevated Engineering will be working with Barrett Trailers, application engineers and other engineers from the state and Oklahoma State University to successfully design, build and test a solution for the task. That will include any modeling, testing, literature review, technical analysis, patent searching, safety implementation and oversight of manufacturing. The design team will be responsible for finding a way to move the gates on the first floor so that the center floor can drop down. Safety is the biggest motive in our design. The lift has to be able to raise the floor, which will weigh approximately sixty thousand pounds. Not only does it have to lift that amount of weight, but also it has to stay secure in place for long periods, while traveling long distances. A concern that Elevated Engineering has for the livestock as well as the operator, is how to keep unwanted appendages out of the side vent system. Design of safety devices will be a big part of the project for the engineering team. Barrett Trailers will review Elevated Engineering’s design, and once satisfied, will begin manufacturing the system according to the specifications provided. After manufacture of the trailer, Elevated Engineering will be taking over testing of the mechanism to ensure that all criteria is achievable.

Customer Requirements

Barrett Trailer’s presented Elevated Engineering with specific requirements that the livestock trailer design must meet. Safety of both the operator and livestock is an absolute necessity. The trailer has to have a secure locking mechanism to ensure safety of the livestock while being lifted and transported. When loaded, the livestock will be moving within the compartment so the floor must not bend or twist while in tow. The design must be efficient in the usage of floor space so hauling capacity does not decrease. The lifting mechanism must lift the floor evenly. Uneven lifting could cause wear and tear on the lifting mechanism due to binding or grinding. Livestock transportation is a crude process in relation to the environment the trailer is exposed to. Livestock produce waste and waste is very corrosive to certain materials. For this reason, the Elevated Engineering team was careful to select materials that are non-corrosive such as, stainless steel or aluminum for the majority of the design parts. Barrett Trailers also wanted the operator to have remote access of the floor in order to make the operation of the trailer more efficient. This trailer was designed with a safety factor of 1.7 for the structural components. The lifting load is approximately 35,000 pounds, but the structural components of our mechanism will be designed for 60,000 pounds. These values were applied to the project by Barrett Trailers. The lifting range the Barrett team was hoping to achieve was 72 inches. This means, the floor will need to be lifted from resting on the lower floor up to 72 inches. The desired lift time was a full lift within 70 seconds. To raise the floor there will have to be a power source, however additionally there needs to be an alternative way to unload or load the trailer if there is an unforeseeable event.

Legal Requirements

The following are the size, weight, and load requirements for the state of Oklahoma as described by the Oklahoma Size, Weight, and Load Laws, chapter 14. https://www.dps.state.ok.us/ohp/chapter14.pdf

- Size (14-103 Width, Height and Length of Vehicle and Load)
    - Width - No vehicle, with or without load, shall have a total outside width in excess of 102 inches excluding tire bulge and approved safety devices.
    - Height - No vehicle, with or without load, shall exceed a height of 13 feet and 6 inches.
    - Length – On the National Network of Highways, which includes the National System of Interstate and Defense Highways and four-lane divided Federal Aid Primary System Highways and on roads and highways not part of the National System, no semitrailer operating in a truck tractor/semitrailer combination shall have a length greater than 53 feet.
- Weight (14-109.2 Weighing as Single Draft – Axle Load Limit)

  - The overall gross vehicle weight of 80,000 pounds for vehicles operating on the Dewight D. Eisenhower System of Interstate and Defense Highways in accordance with the provisions of Section 14-118 (Movement of Over dimension Vehicles).
  - A total overall gross weight of 90,000 pounds for all other highways in the state of Oklahoma.
- Load (14-109 Single – axle Load Limit)
  - On any road or highway, no single axle weight shall exceed 20,000 pounds.

Project Research

Currently there are two companies that have started to implement similar ideas. Barrett Trailers is hoping to improve on these methods by solving the major issues that the previous designs have brought to light. A company out of Ireland named Pezzaioli has designed a trailer for hauling livestock that has potential but still does not maximize efficiency. The Pezzaioli trailer has a rear partition that raises and lowers like a ramp that is used to load livestock on different levels of the trailer. This trailer has a fully covered siding as to account for pinching safety concerns. The issue with the Pezzaioli trailer is that the siding has no ventilation. This design could not be used in a warmer climate due to the heat exhaustion the animals would be exposed to without the ventilation of the punched or slated side of a Barrett trailer.

Figure 1 shows the outside of the Pezzaioli trailer design

A demonstration of the Pezzailoi design can be seen at https://www.youtube.com/watch?v=23CY9gBCyAY

The second company who is currently working on a prototype of a center lifting livestock trailer is a company out of London named Millson Livestock Trailers. The Millson trailer is a small-scale trailer that uses hydraulics and only allows for hauling any livestock fewer than three feet tall.

Figure 2 shows the Millson trailer design from the rear

A demonstration on the Millson trailer can be seen at https://www.youtube.com/watch?v=RMUFzsnDWbY&nohtml5=False

A company called Don-Bur from the United Kingdom currently manufactures a cargo trailer with a lifting floor. This trailer incorporates a lifting and pushing mechanism to load the front half of the trailer. The back half is the lifting half while the front half acts a series of shelves or partitions.

Figure 3 shows a depiction of the Don-bur trailer

A video demonstration can be seen at, https://www.youtube.com/watch?v=Sfi_o9-qcbM.

Lifting Option

During the design process, the Elevated Engineering team looked at many different options for lifting mechanisms. A few of these options included multiple hydraulic cylinders, multiple acme/lead screws, and a rack and pinion system. Looking at the specifications provided by Barrett Trailers, it was decided that the best fit for this application would be the single hydraulic cylinder and cable system.

Hydraulic and Cable System

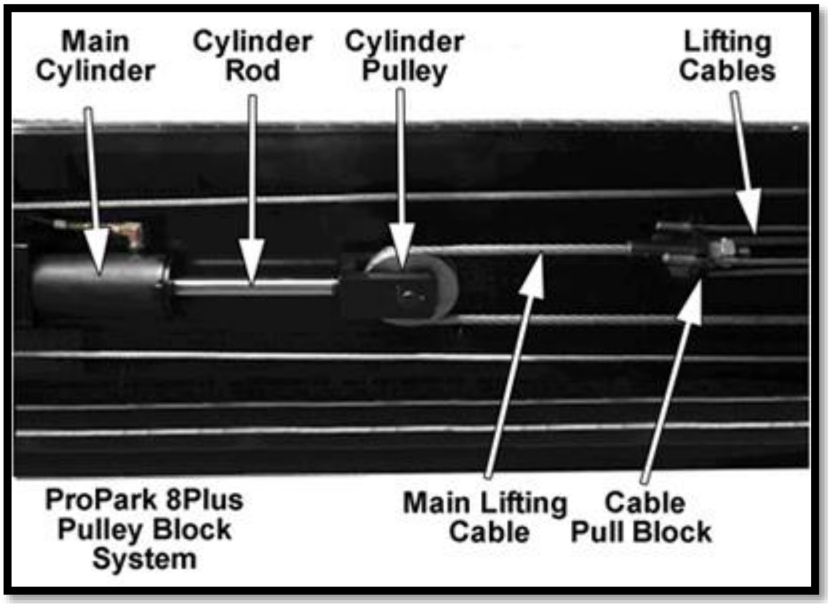


Figure 4 shows a typical cylinder and cable lift mechanism.

The concept of using a hydraulic cylinder with cables attached to the floor will provide a solution to many of our lifting problems. Since there will only be one hydraulic cylinder we will not have to worry about the floor moving unevenly. As long as we choose the correct cable lenghts, all corners of the center floor should move with the same velocity.

Engineering Specifications

To understand how viable an approach really is, we must compare it to the absolute minimum. Fundamental physics can tell us how much horsepower is required to lift the floor, under a certain load, in a definite amount of time. This will be the minimum condition without mechanical, and frictional losses.

$$Work = Force * Distance$$

$$Work = 35000lbs * \frac{72inches}{12\frac{inches}{foot}} = 210000\ lb * ft$$

$$hp = \frac{Work}{Time*550}$$

The horsepower required to lift 35000 lbs. six feet in thirty seconds is calculated below.

$$hp = \frac{210000lb*ft}{70\ seconds*550} = \boxed{5.45\ hp}$$

<u>Hydraulic Cylinder with Pulley System</u>

GPM Needed for Cylinder Speed

We have a target of 72 inches in 70 seconds.

$$\frac{72inches}{70seconds} = 1.02\ inch/sec$$

A hydraulic cylinder with a 5 inch bore, 2.5 inch rod, and 72 inch stroke has a volume of,

$$\pi r^2(L) = \pi(2.5in^2 - 1.25in^2) * (72\ in) = 1060.3\ in^3\left(\frac{1\ gal}{231\ in^3}\right) = 4.58\ gallons$$

A 4 gpm pump gives, $\frac{4.58gal}{4\ gpm} = 1.15(min)\left(60\frac{sec}{min}\right) = 68.70\ \ sec,$

$$so\ \frac{72\ inches}{68.70\ seconds} = \boxed{1.05\frac{inch}{sec}}$$

Cylinder Force

We are going to be using a welded cylinder from Bailey Hydraulics. The cylinder as mentioned before has a 5 inch bore, a 2.5 inch rod, and a stroke of 72 inches. To calculate the pulling force of this cylinder we will assume that the system is operating at 2500 psi.

$$F = P * A = 2{,}500\ \frac{lbs}{in^2} * \left(\pi(2.5\ in^2 - 1.25in^2)\right) = \boxed{36{,}816\ lbs.}$$

This exceeds our maximum operating load of 35000 lbs.

HP Requirements

$$HP = \frac{gpm*psi}{1{,}714} = \frac{4gpm*2{,}500psi}{1{,}714} = \boxed{5.83\ HP}$$

Using a cylinder to actuate the cables moving the floor is the most desirable option for our application. It ensures that the floor will be raised evenly to prevent binding, while at the same time being the most efficient option in terms of power requirement.

Lower Floor Analysis

Designing the lower floor was the most important part of this project, due to the complexity of the process and problems that occurred when designing within the given specifications. Our power unit, cylinder, and the main body of our pulley and cable design was integrated into the trailer by placing these components under the bottom floor.

Floor Strength

The floor specifications that were provided to us from Barrett was that the floor was made out of square or rectangle tubing with a corrugated floor. With a safety factor of 1.7, we were loading the floor with 60,000lbs. The stress analysis test proved that the corrugated flooring added little strength to the floor. Running a simulation with the corrugated flooring made the simulation take a very long time, and made the meshing difficult. For this reason we ran all simulations with the corrugated floor suppressed from the simulation.

The System

As shown in Figure 5, the system works by connecting the cylinder to the sub-structure where the back axles are connected. The design will use a 5 inch bore, 72-inch stroke cylinder that will be working by pulling on the cables. Attached to the cylinder are four 5/8-inch cables that go into, what we call, “the turn-around assembly”. “The turn-around assembly”, which will be explained later, is a strengthened frame that houses our four large sheaves. The 5/8-inch cables go in opposite directions toward the sides of the trailer and then turn back to the back of the trailer before transitioning into 6, ½ inch cables at the transition cable block (figure 6). “The turn-around assembly” is positioned at least 72 inches from the second post from the back of our structure to ensure a total lift height of 6 feet before the block contacts the vertical transition sheave bracket.

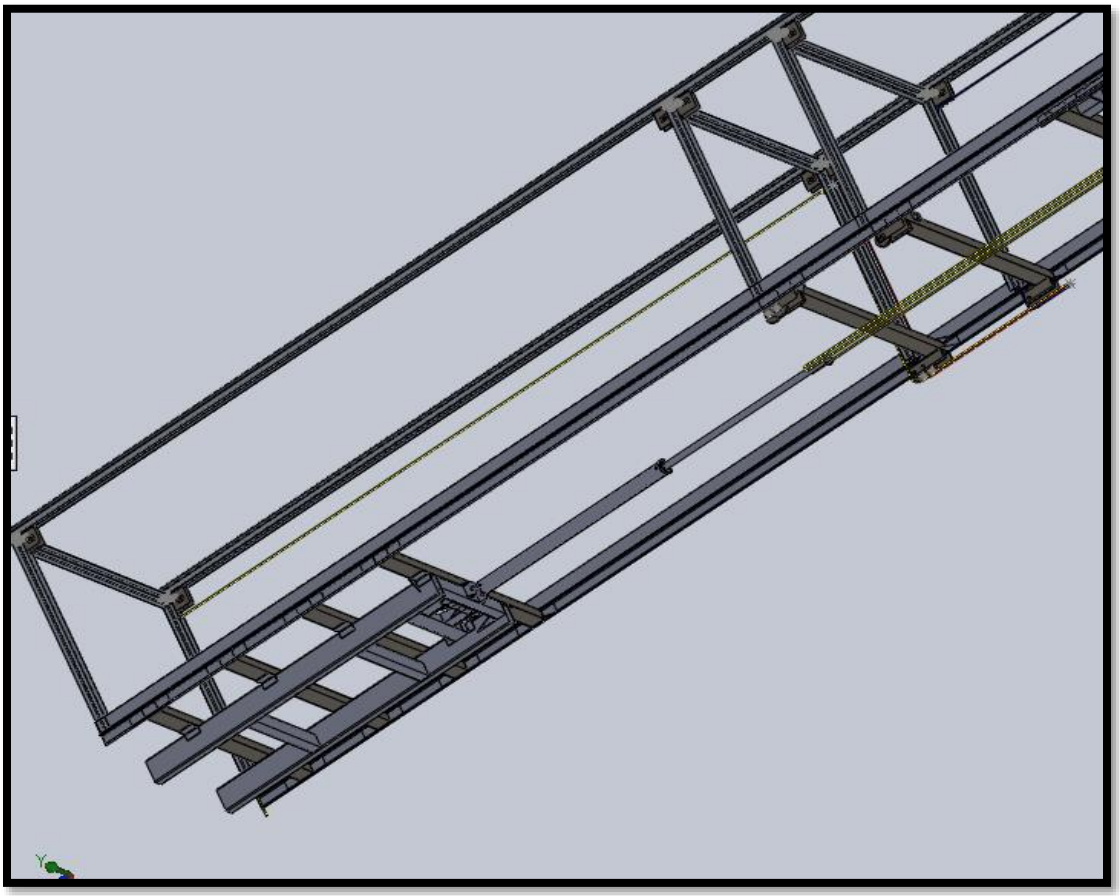


Figure 5 View of lifting mechanism

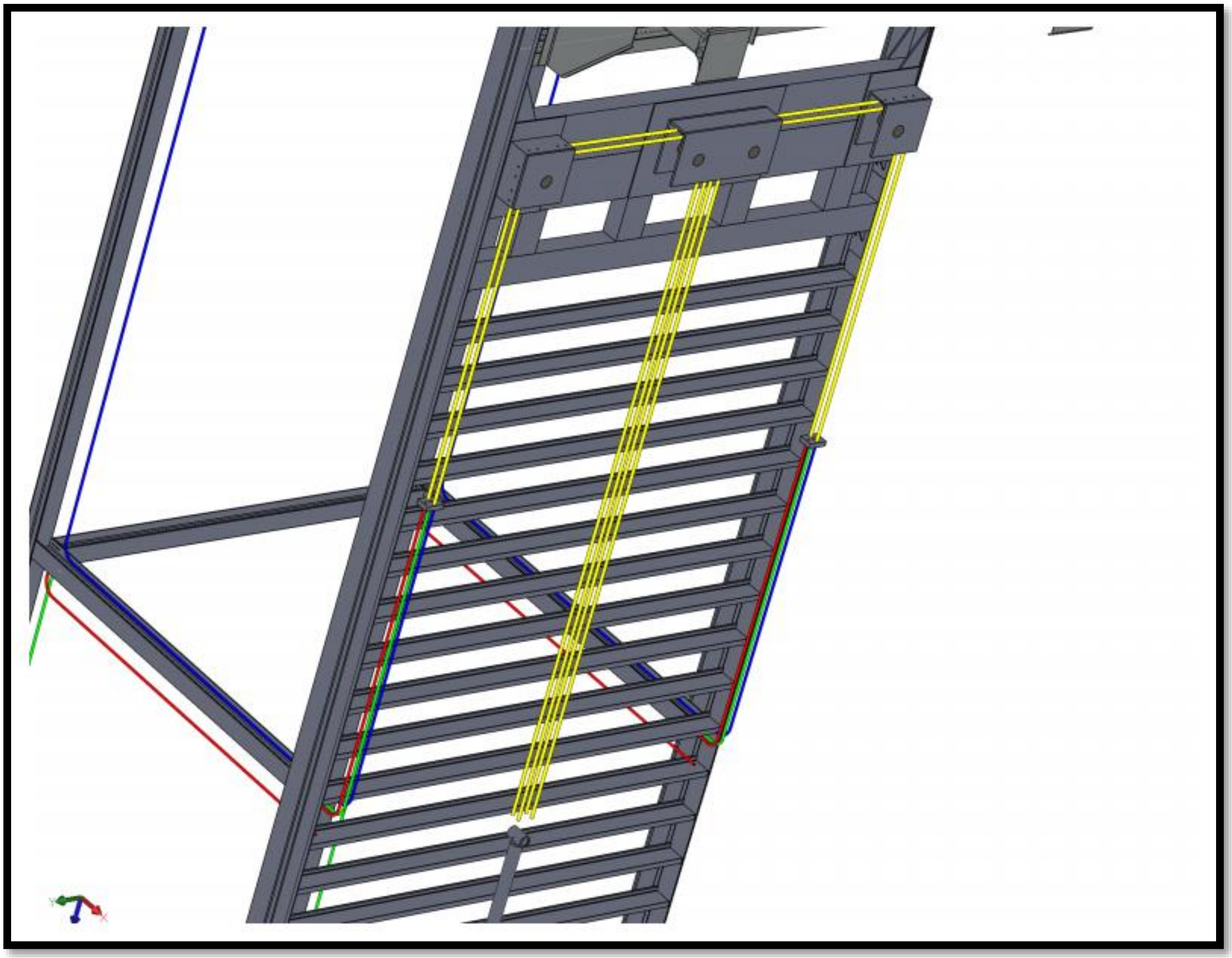


Figure 6 Cable path illustration.

Sub Frame Alterations

The hydraulic cylinder that actuates the floor will be attached to a redesigned version of the sub frame we received from Barrett. The original design, shown in Figure 7, was not strong enough to support the 35,000 lb. force that the cylinder would apply to the structure. For this reason two extra 4” x 3” x 3/16” mounting supports were added to the side rail. Some extra gussets, and supports had to be added to the front of the sub frame to strengthen the cylinder mounting point. The redesigned sub frame can be seen in Figure 8 mounted in place to the side rail.

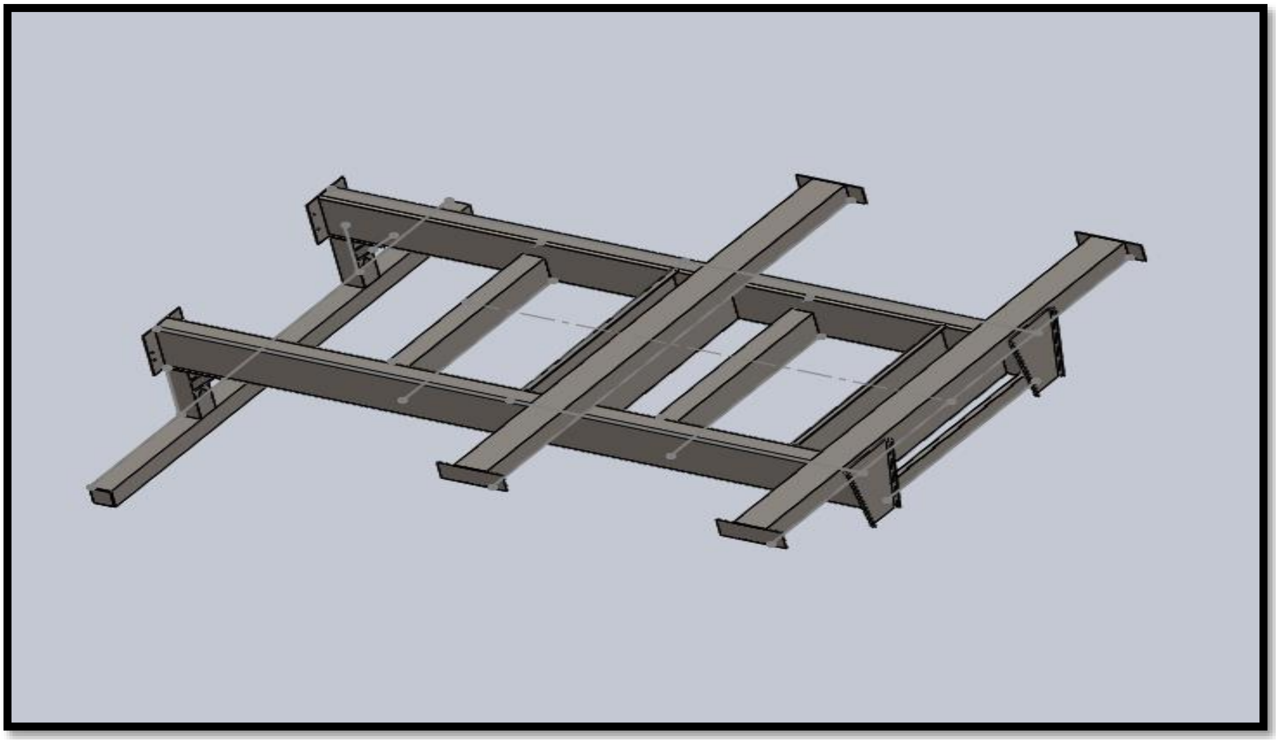


Figure 7 shows the original sub frame (top view).

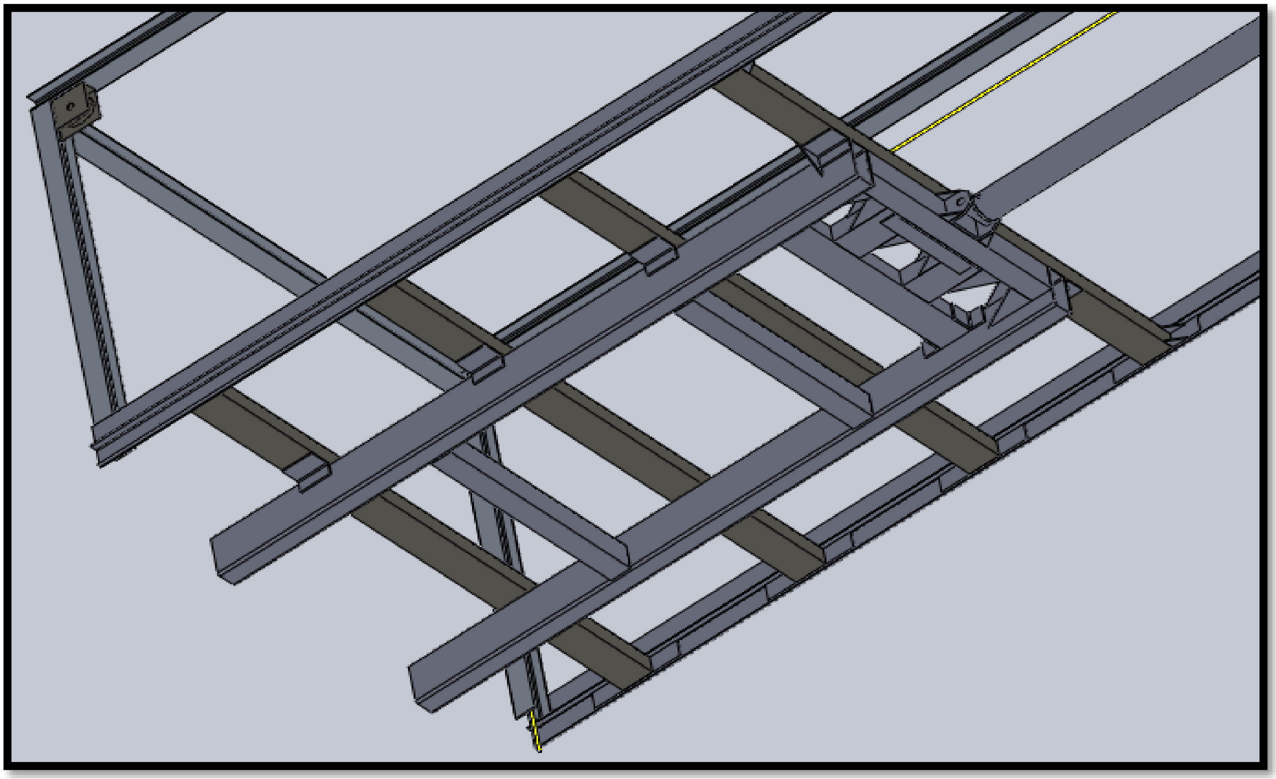


Figure 8 shows the redesigned sub frame (bottom view).

The Turn-Around Assembly

The turn-around assembly is used to transfer all forces parallel, or in line, with the cylinder so as not to place a bending moment on the cylinder rod. Bending the rod could cause the cylinder to be damaged or fail. The 6x19, 5/8-inch cables going from the cylinder to the transition cable block are made of T304 Stainless Steel, which has a breaking strength of 35,000 lbs. With two of these in parallel the breaking strength is 70,000 lbs. which satisfies the 1.7 safety factor. These cables each have 8,750 lbs. of force and place a resultant force of 24,749 lbs. on each shaft for the double pulleys (Figure 11). This resultant force is the reason for needing such a strong assembly. Each of the 8 pulleys in the turn-around assembly are 10 inches in diameter and has a 2.5 inch shaft. The assembly is made of 4 x 10 x ¼ inch and 4 x 6 x 3/16 inch rectangular tubing as seen in Figure 10. The top plate of the sheave housing will be welded onto the bottom side of the tubing and the bottom plate of the assembly will be bolted on using the angle iron connection (figure 12). These bolts have been sized to be 3/8” inch in diameter.

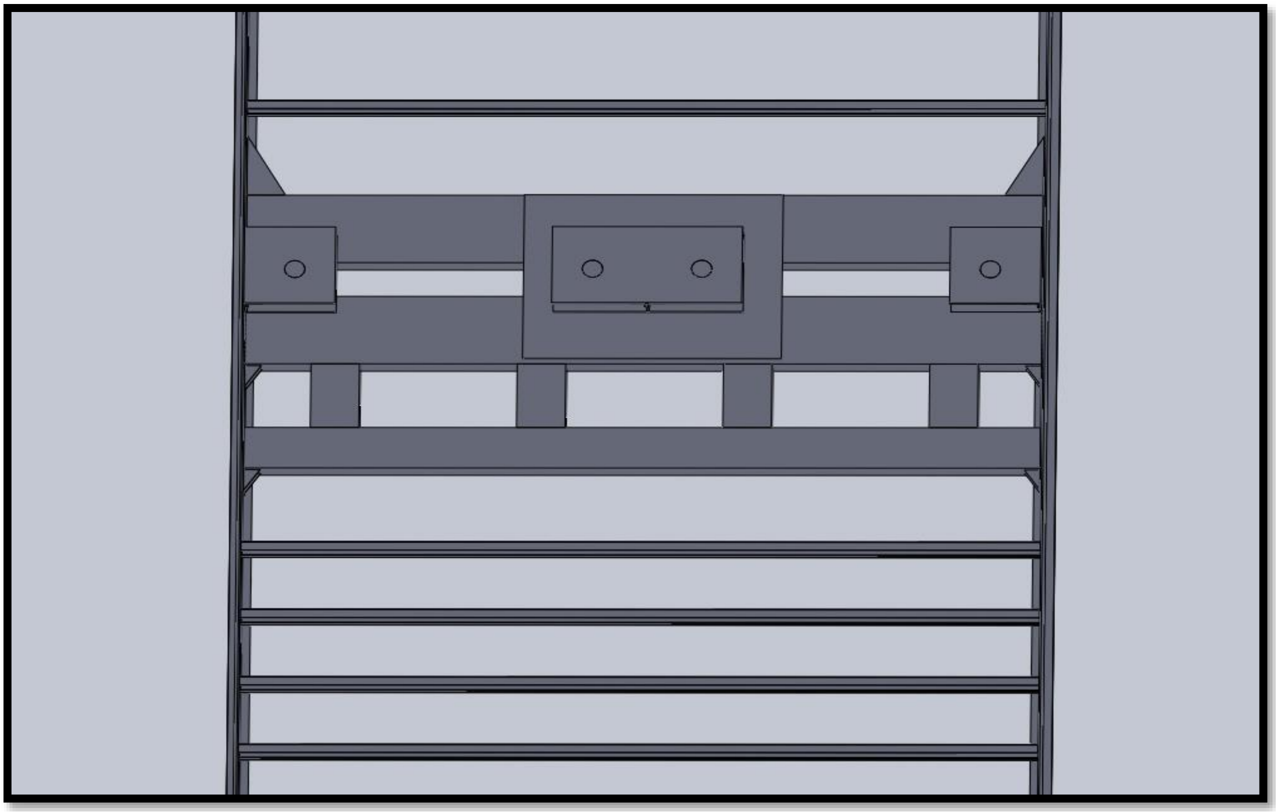


Figure 9 shows the “turn around assembly” top view looking up from underneath the trailer floor.

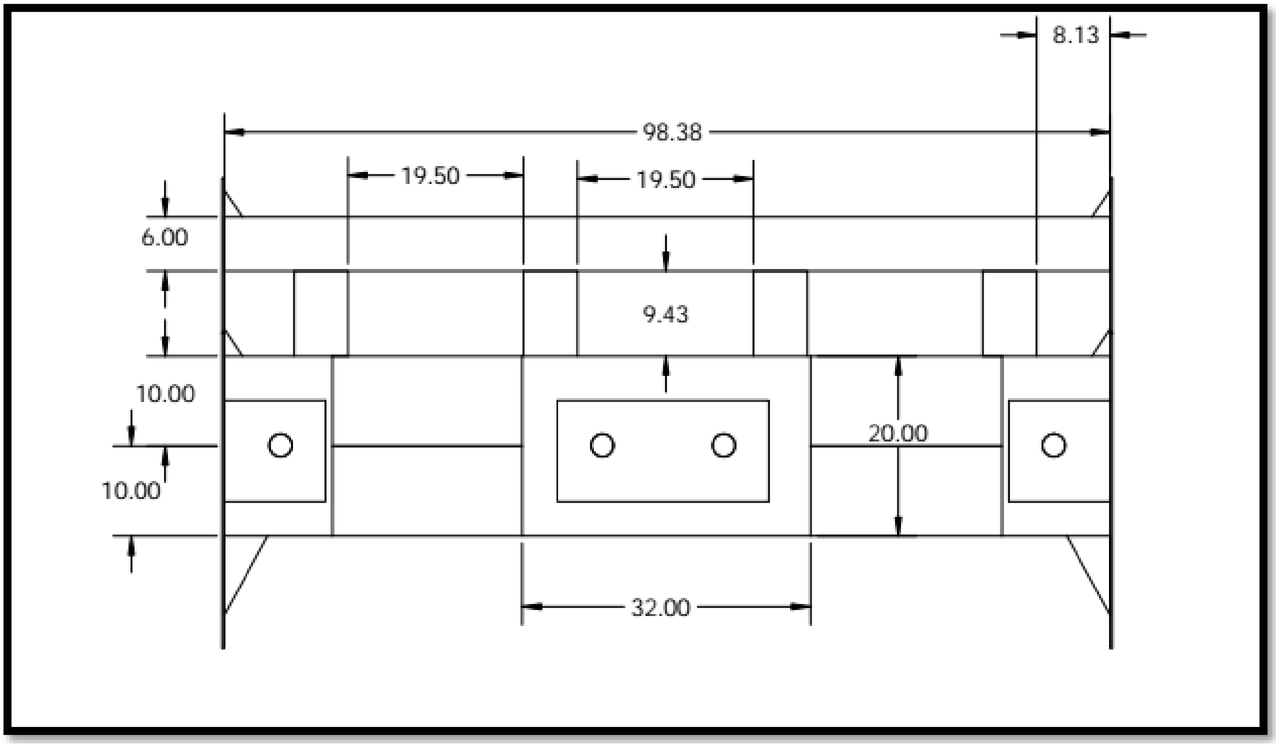


Figure 10 shows the drawing view of the turnaround assembly.

Attached to the turn-around assembly will be the main sheaves in the middle, and the outer sheaves towards the edge of the trailer. The top of the sheave brackets will be welded to the frame, which necessitated a way to allow access to the sheaves. The solution was a cap that bolts on to each sheave bracket with angle iron as the mounting bracket. Figure 11 shows the sheave assembly, and figure 12 shows how the assembly comes together. The sheave brackets on the end are of similar design concept.

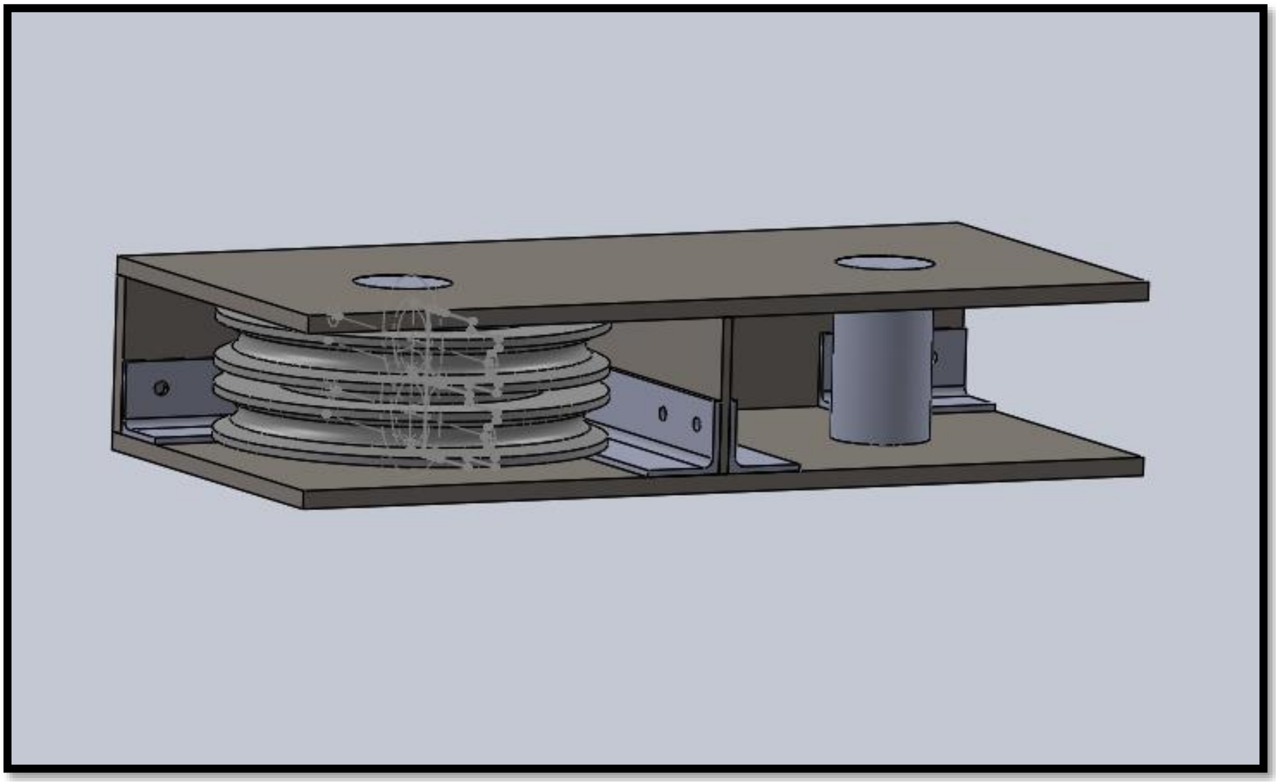


Figure 11 shows the middle sheave assembly

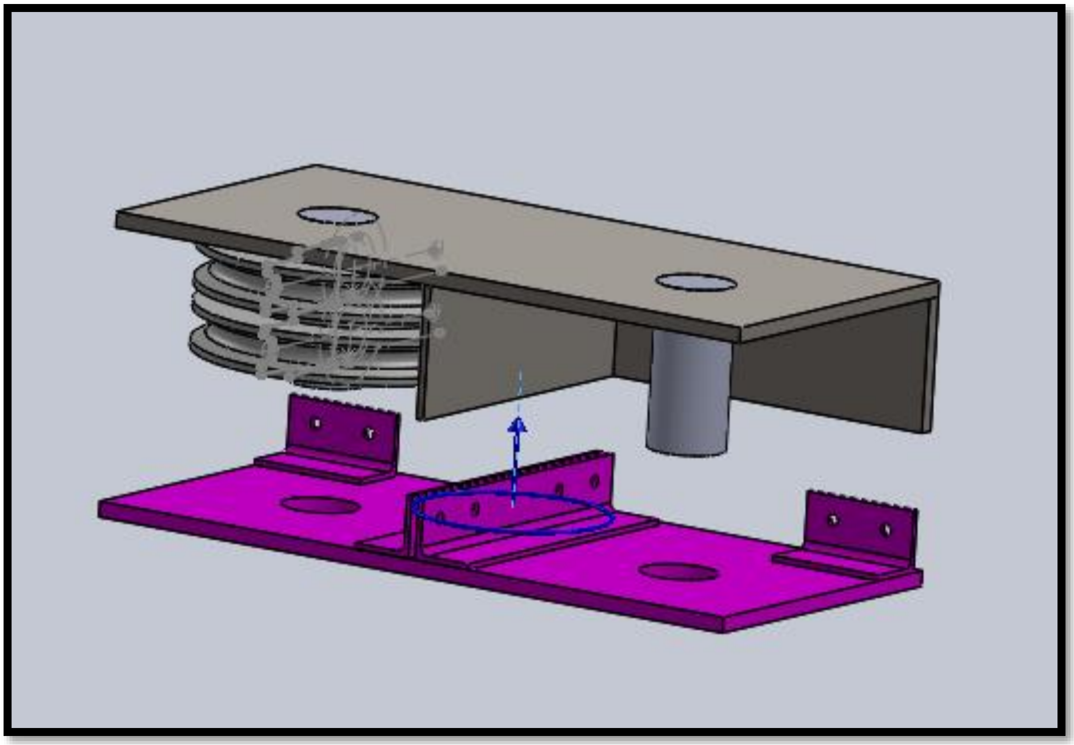


Figure 12 shows the uncapped view allowing access to the sheaves.

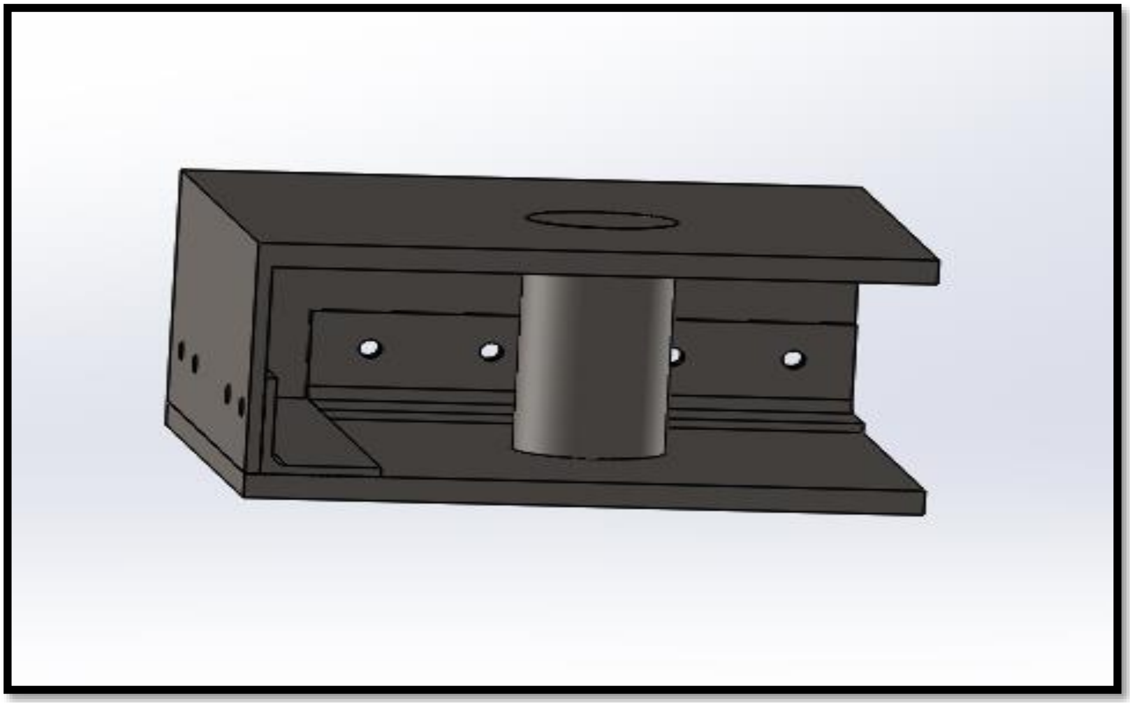


Figure 13 shows the sheave brackets on the edge of the "Turn Around Assembly".

The Transition Cable Block

The transition block is used for transitioning from 2, 5/8 inch cables to 3, ½ inch cables on each side of the trailer. By transitioning from 2 to 3 cables, the number of sheaves needed was decreased. The design team found that larger cable was less expensive than the cost of the extra 4 sheaves needed if using a three-cable system throughout. The layout of the block can be seen in figure 14. To allow for cable tension adjustment, the wire rope ends will be fitted with threaded studs like the one shown in Figure 15.

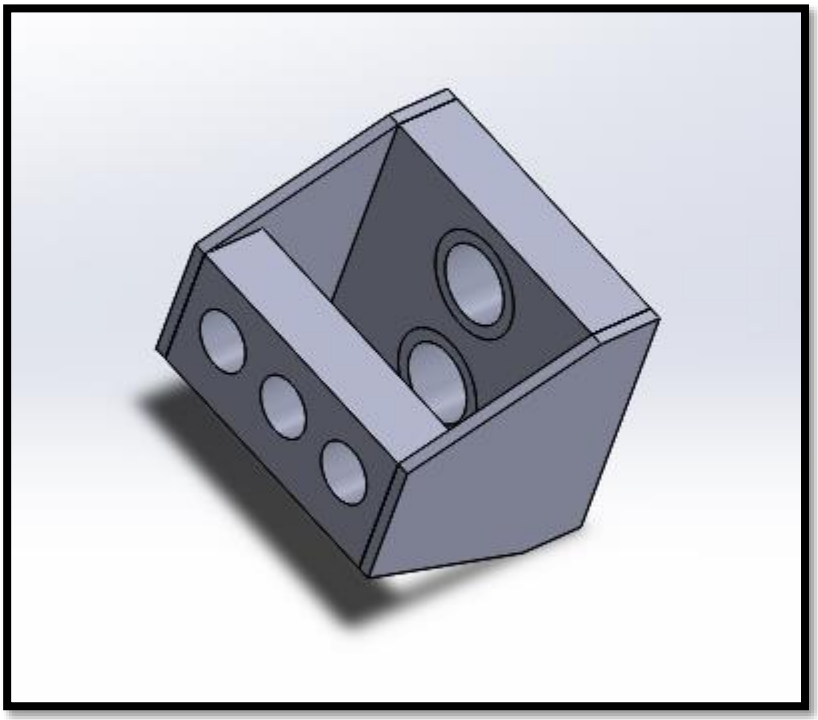


Figure 14 Cable Transition Block

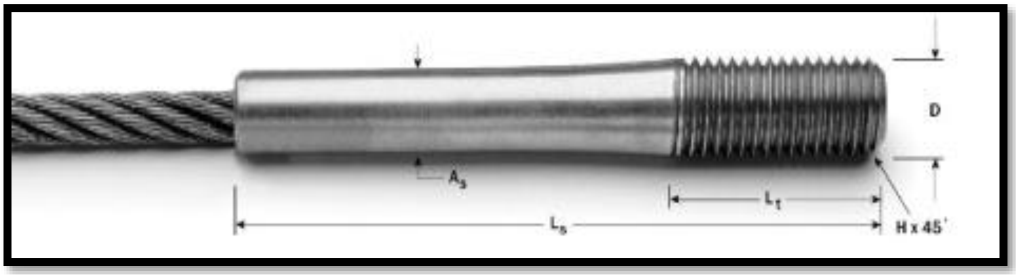
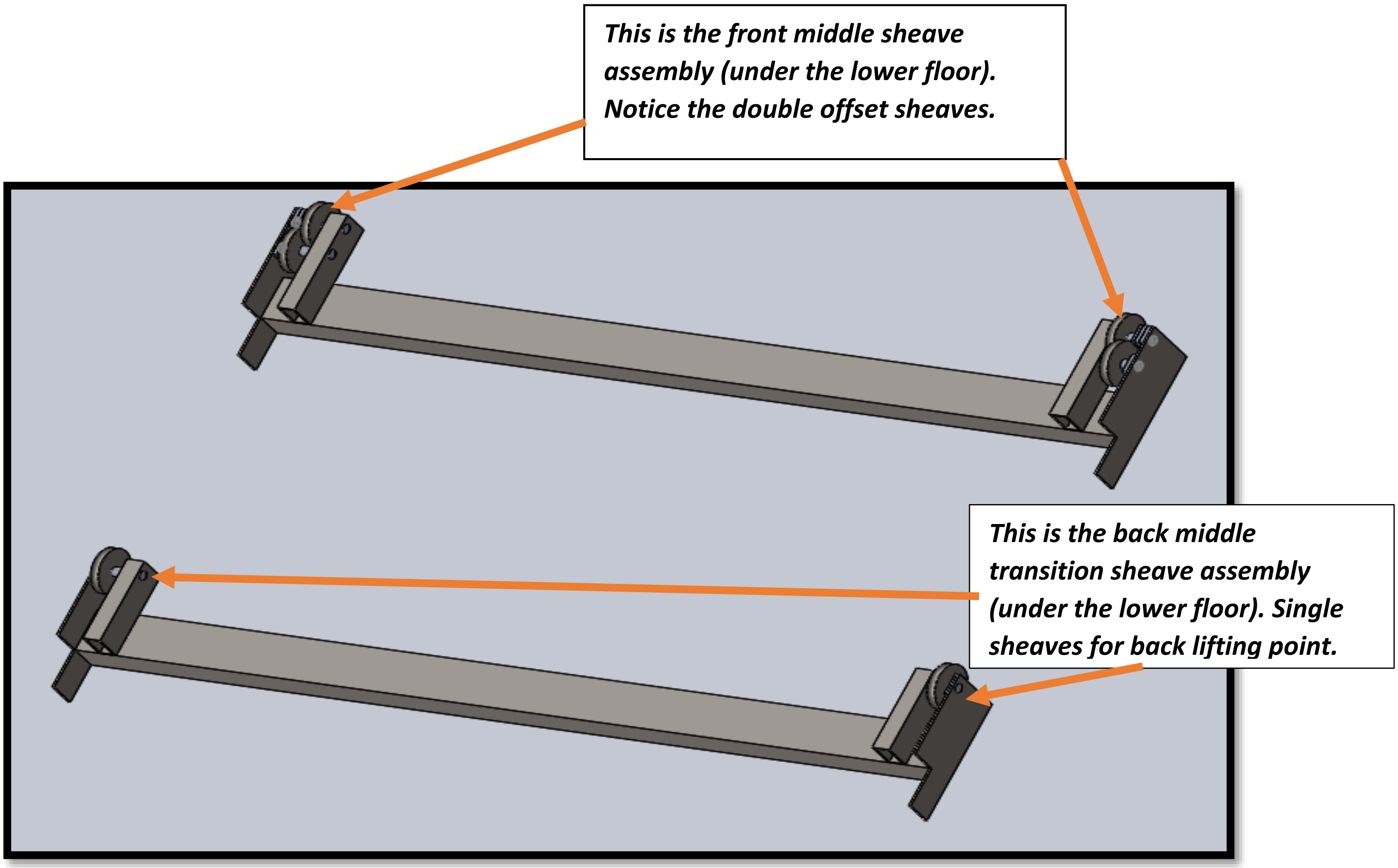


Figure 15 Threaded wire rope attachment. Source: unionrope.com

The Vertical Transition Sheaves

The vertical transition sheaves are a combination of two separate sheave/housing components (Figure 16). The reason for the split is to allow cable to travel up both sides of one of the posts, one that will go up and directly back down to connect to the floor, and another that will travel to the front of the trailer. A single sheave and housing are on the rear middle post that will send the cable to the sheaves at the top of the structure and then to the back of the trailer. The front middle vertical transition sheave assembly will have a double offset sheave design (Figure 16 and 17) that will send one cable up the backside of the vertical post and one up the front side. The cable on the backside will go up around the top pulley and back down for the middle lifting point. The cable on the front side will go through the top sheave and to the front of the trailer. This cable/sheave configuration is visible in Figure 18.



This is the front middle sheave assembly (under the lower floor). Notice the double offset sheaves.

This is the back middle transition sheave assembly (under the lower floor). Single sheaves for back lifting point.

Figure 16 shows the vertical transition sheave assembly.

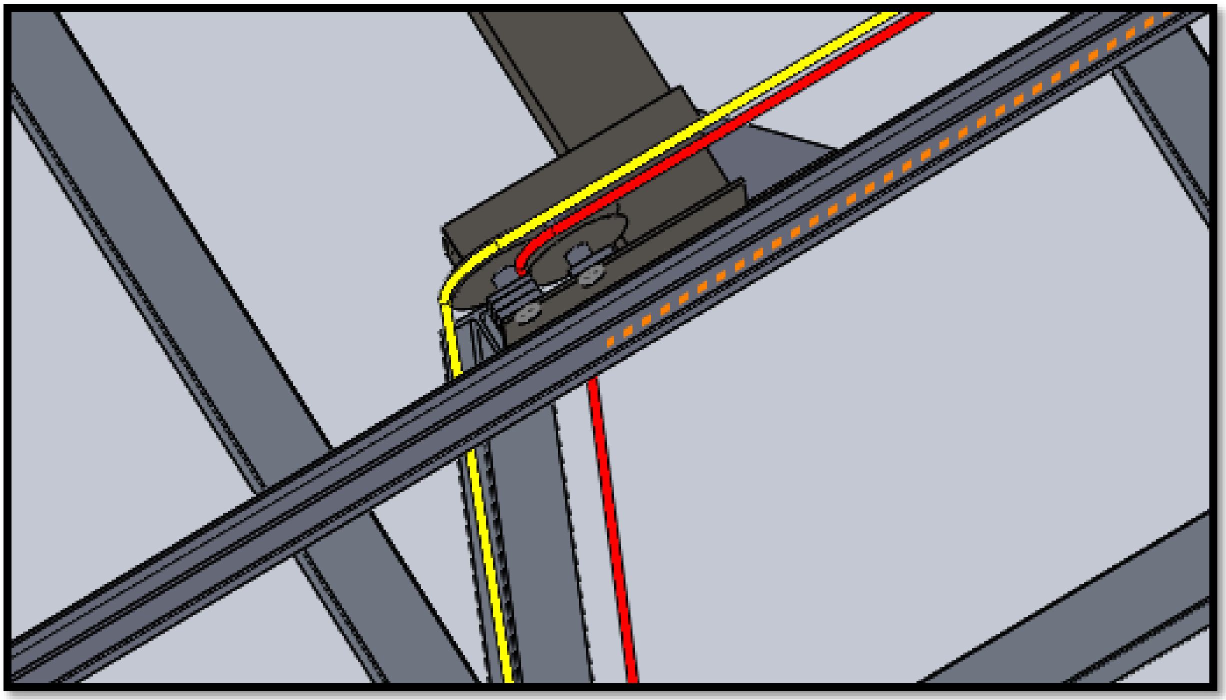


Figure 17 shows the vertical sheave bracket with the two offset sheave.

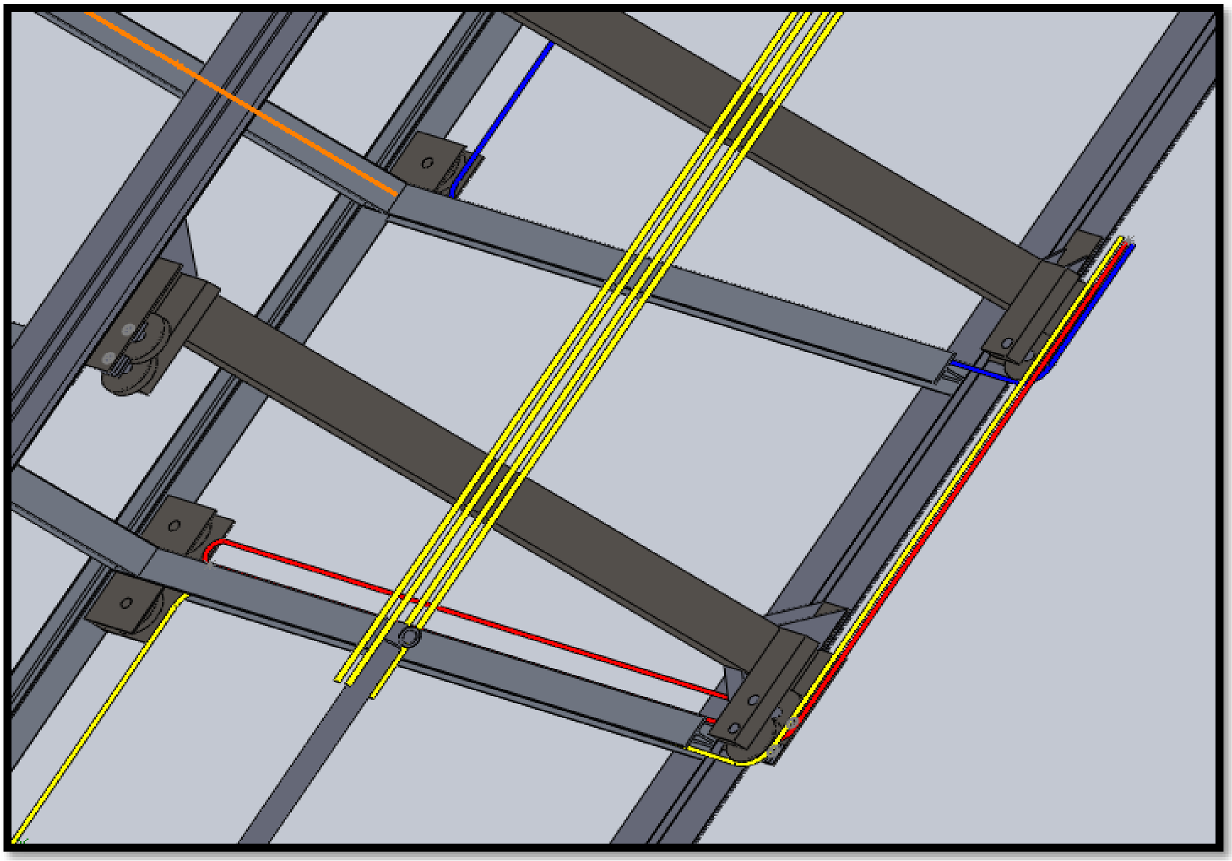


Figure 18 shows the cable paths for the vertical sheave assembly.

Top Sheave Brackets

These brackets near the top of the aluminum structure will house the last sheaves that the cables will travel through before attaching to the floor. The brackets will be constructed using 3/16” steel plate on the sides, and ¼” steel plate on the top and back. There will also be a ½” doubler on each side of the 1 ¼” pin to bring the bending stresses down to a safe level. The Top Sheave Brackets will provide us with two functions. They will house the sheaves that allow the cable to return to their respective attachment points on the floor, and they will also serve as the fasteners that tie the individual aluminum I-beams together.

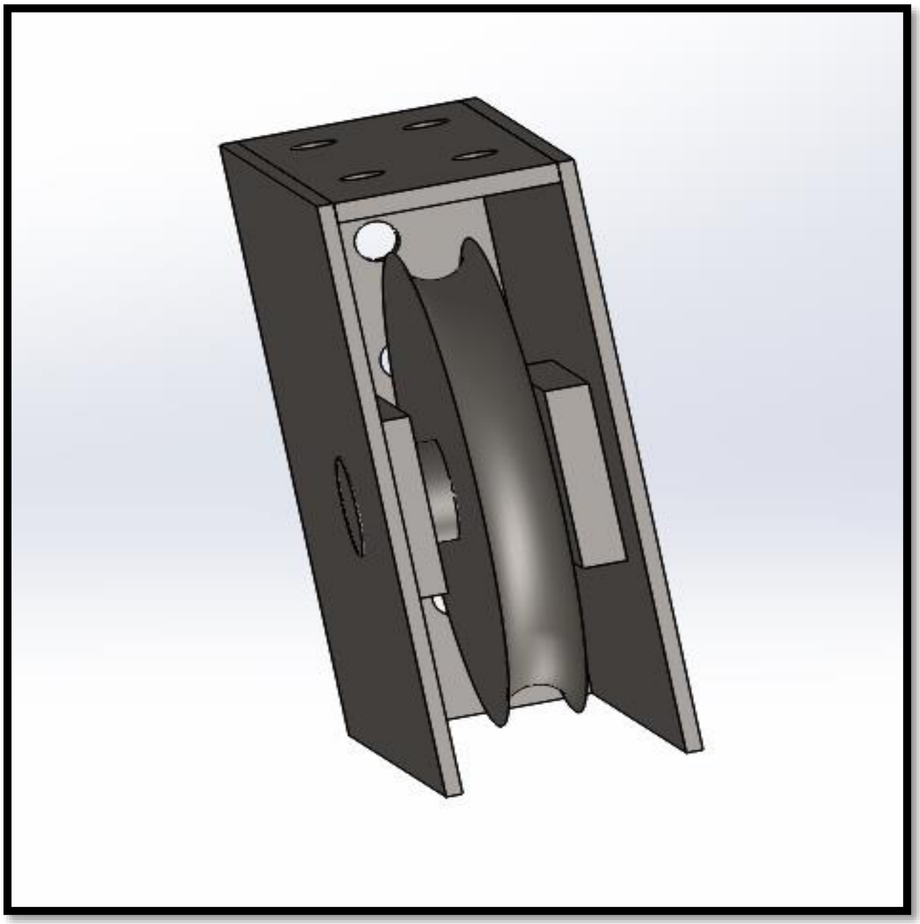


Figure 19 shows the top sheave brackets.

Structure Analysis

The structure used in the design is made up of 4 x 4 inch aluminum I-beam. The aluminum beam that we have used to build this structure is DI# 6936. This is a specific beam that Barrett Trailers has access to and can readily have delivered. Originally we had a design that consisted of three I beams along each side of the trailer, which we later upgraded to four I beams to disperse the load that is transferred from the cables to the structure as well as improve the cable and pulley design (figure 20). The brackets for the sheaves on the upper portion of the structure will serve a double purpose. These fixtures will serve as both the housing/bracket for the sheave as well as the connecting gussets that will hold the structure together. The bolts used for these gusset/sheave brackets have been sized to ½ inch bolts.

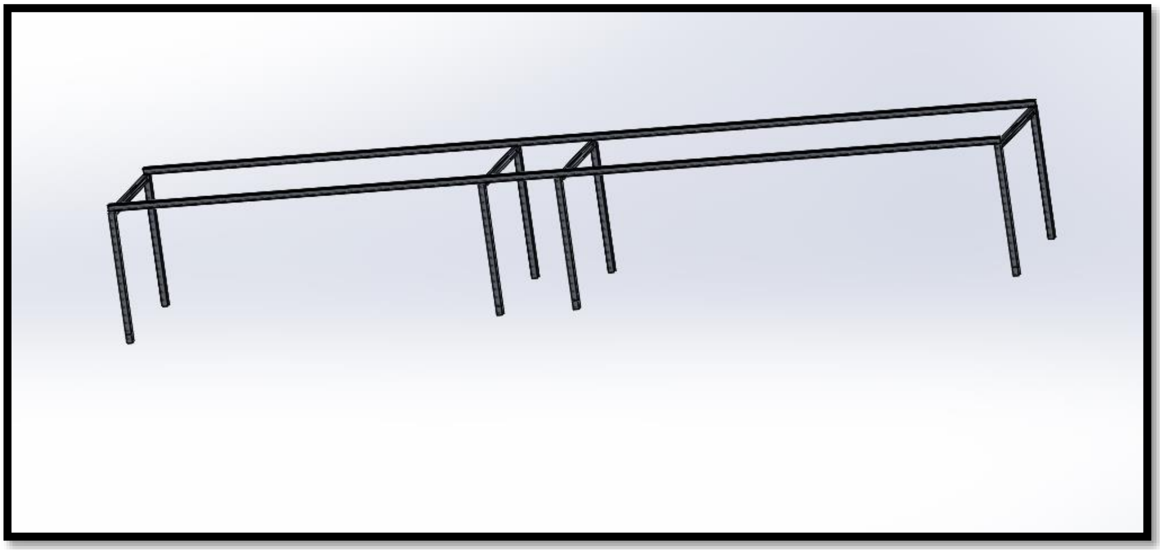
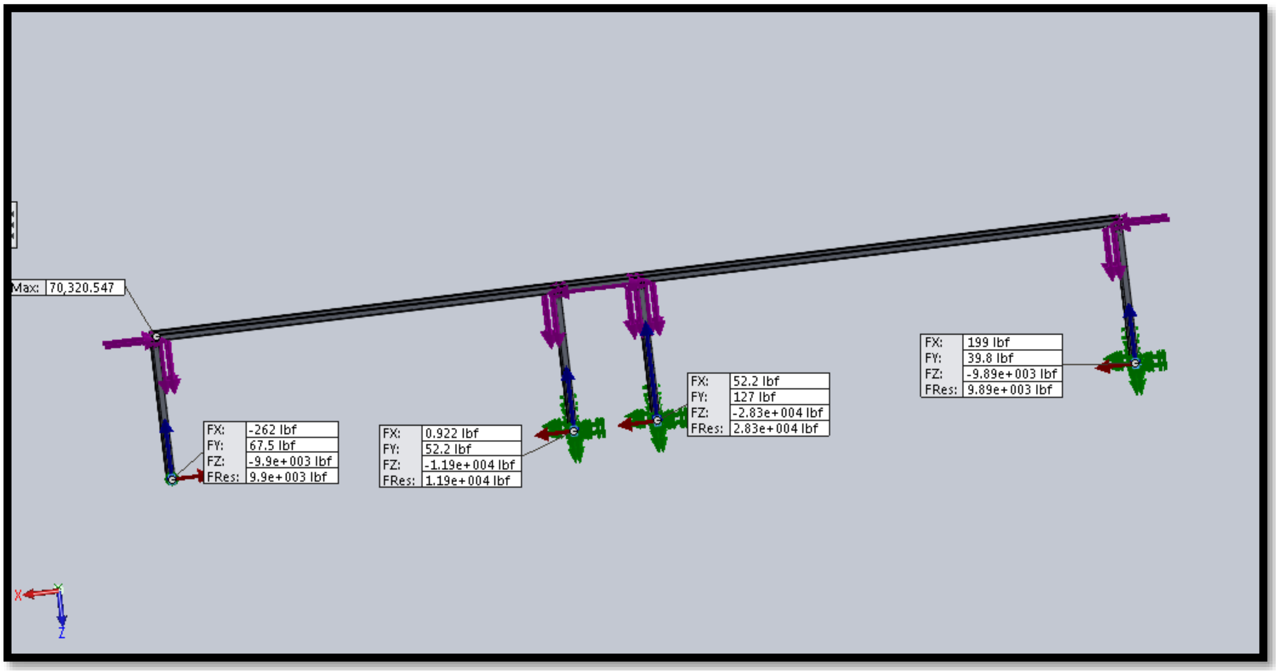


Figure 20 Structure without brackets

Stress analysis was done using loads placed at each location of a top sheave on the structure (Figure 21). The downward resultant force was highest at the middle of the structure at a value of nearly 40,000 lbs. These are the forces that forced the design team to change the structure from a 6 vertical post structure to an 8 vertical post structure. The resultant forces seen on the bottom of the structure (Figure 21) have a safety factor of 2, and will be transferred to the trailer through a side rail. The highest resultant force with 8 beams is on the middle beam at 28,000lbs. The Barrett Trailers team has taken the task of redesigning the side rail of their existing trailer to make it strong enough to withstand the forces in the downward direction. The problem is dispersing the congregated force from the structure onto the bottom floor and the side rail without interrupting the path of the cables. There are large point loads generated when lifting the floor that could cause a failure where the structure is connected to the trailer as well as under the vertical post. The force was easier dealt with after the 4th post was added to each side of the structure.



Max: 70,320.547

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FY: 67.5 lbf
FZ: -9.9e+003 lbf
FRes: 9.9e+003 lbf

FX: 0.922 lbf
FY: 52.2 lbf
FZ: -1.19e+004 lbf
FRes: 1.19e+004 lbf

FX: 52.2 lbf
FY: 127 lbf
FZ: -2.83e+004 lbf
FRes: 2.83e+004 lbf

FX: 199 lbf
FY: 39.8 lbf
FZ: -9.89e+003 lbf
FRes: 9.89e+003 lbf

Figure 21 Resultant forces with a safety factor of 2

Mid Floor Analysis

The moving or lifting floor of the trailer has a similar construction. The structure of the floor is made out of square or rectangle tubing with a corrugated floor. For analysis we ran the floor mostly without the corrugated floor since it made the analysis take too long. But, the corrugated floor does not add much strength.

We decided that we were going to use three lifting points on each side, so six lifting points in total over the whole floor. We took the existing floor that was on the trailer and did a stress analysis with the six lifting points. It failed, as we guessed it would. So, we strengthened the floor by adding a beam on the outside on top of the existing one and the stress test succeeded (Figure 22).

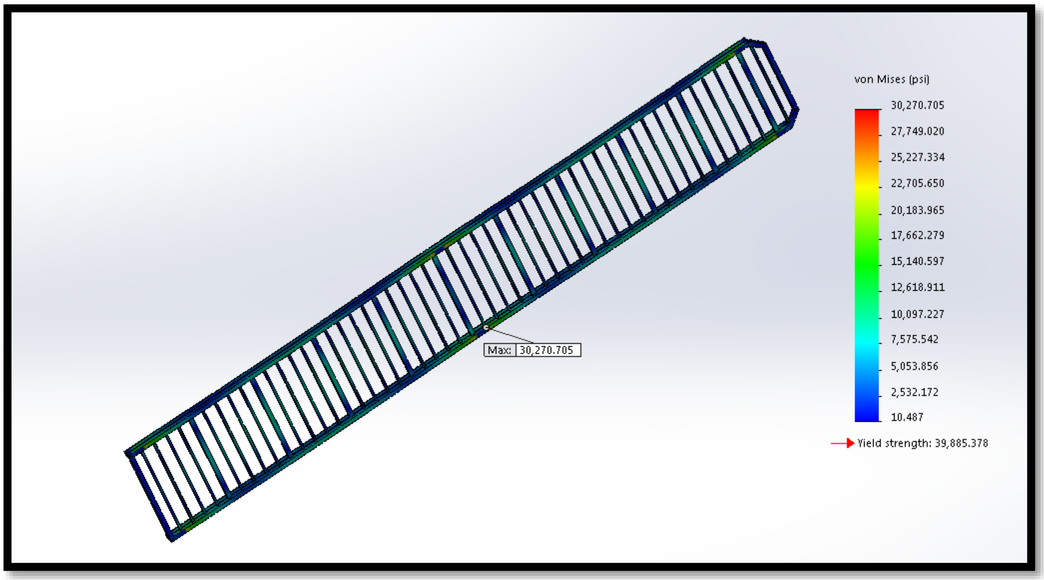


Figure 22 Mid Floor Structure Analysis 1

To minimize lost floor space this floor will need to be slotted to make room for the I-beam structure (Figure 23). The slots are 4.5in. wide and 4in. deep. These slots will serve a purpose that will allow a tracking or guide system to be integrated to ensure even lifting, as well as minimize the amount of side-to-side freedom of the lifting floor.

On the underside of the lifting floor will be the locking mechanism which will be discussed later, there are 8 locking points. There will be 6 connecting points on the floor that coincide with the cables for lifting (figure 24). The cables will be attached by sending the cables through the floor and will be fastened using Huck Bolts, more specifically their Bobtail version. The holes in the floor are ¾ inch in diameter and will be supported by a plate underneath.

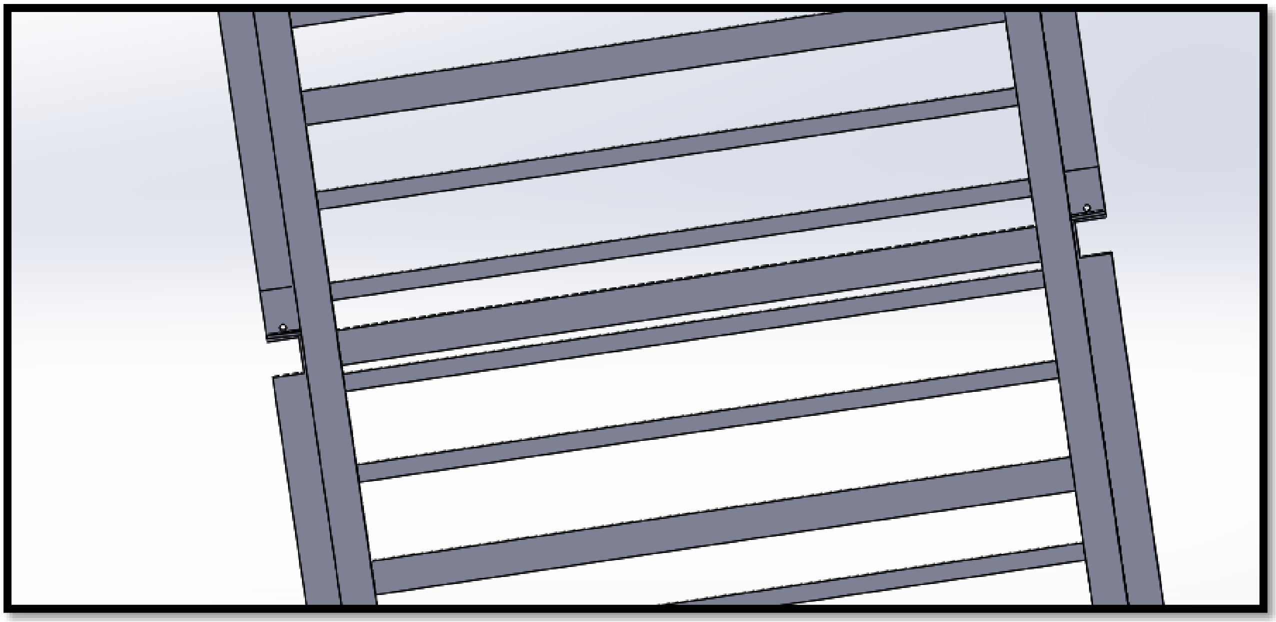


Figure 23 cutouts with holes in floor for attachment of cables

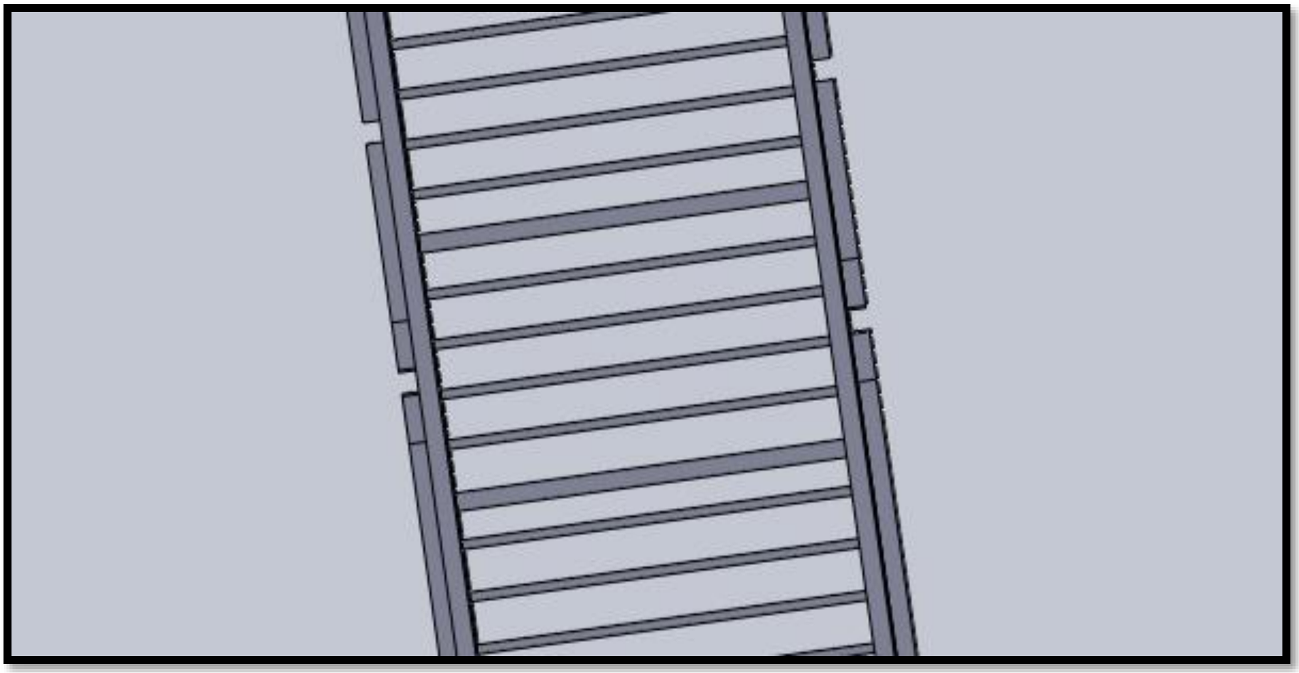


Figure 24 Cutouts needed in floor for I beam Structure

With the cutouts in the floor, we lose almost all the structure in the floor. To strengthen the floor, we have added two 4x4 square tubing beams along the inside of the floor (figure 25). These beams provide added support as well as a barrier to the cutouts in the floor. The middle lifting point has the highest amount of stress at a little less than 30,000psi (figure 26). We have placed a gusset on either side of the floor at this lifting point to transfer some of the load and reduce stress. A corrugated floor will be added on top of this assembly in the final design.

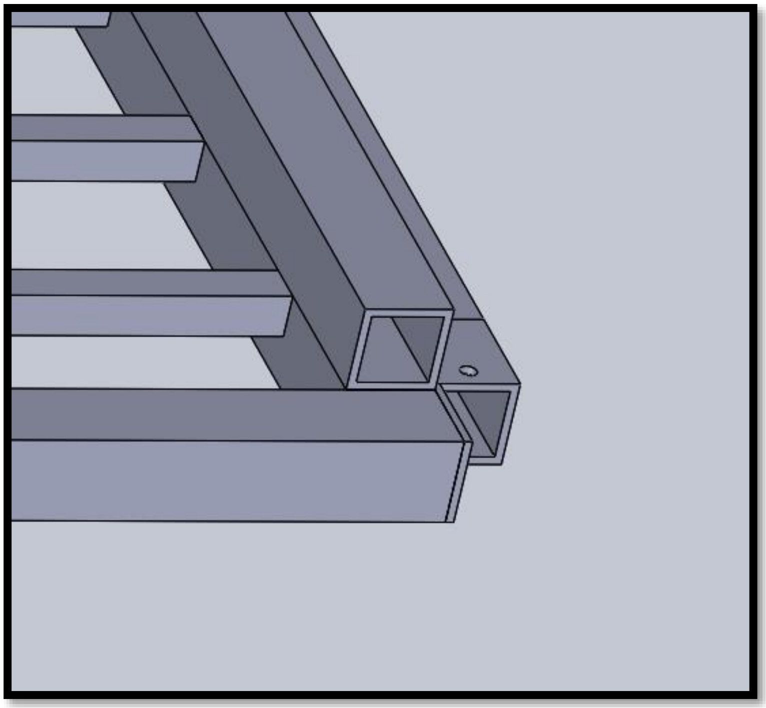


Figure 25 Beams added to strengthen the floor with the cutouts.

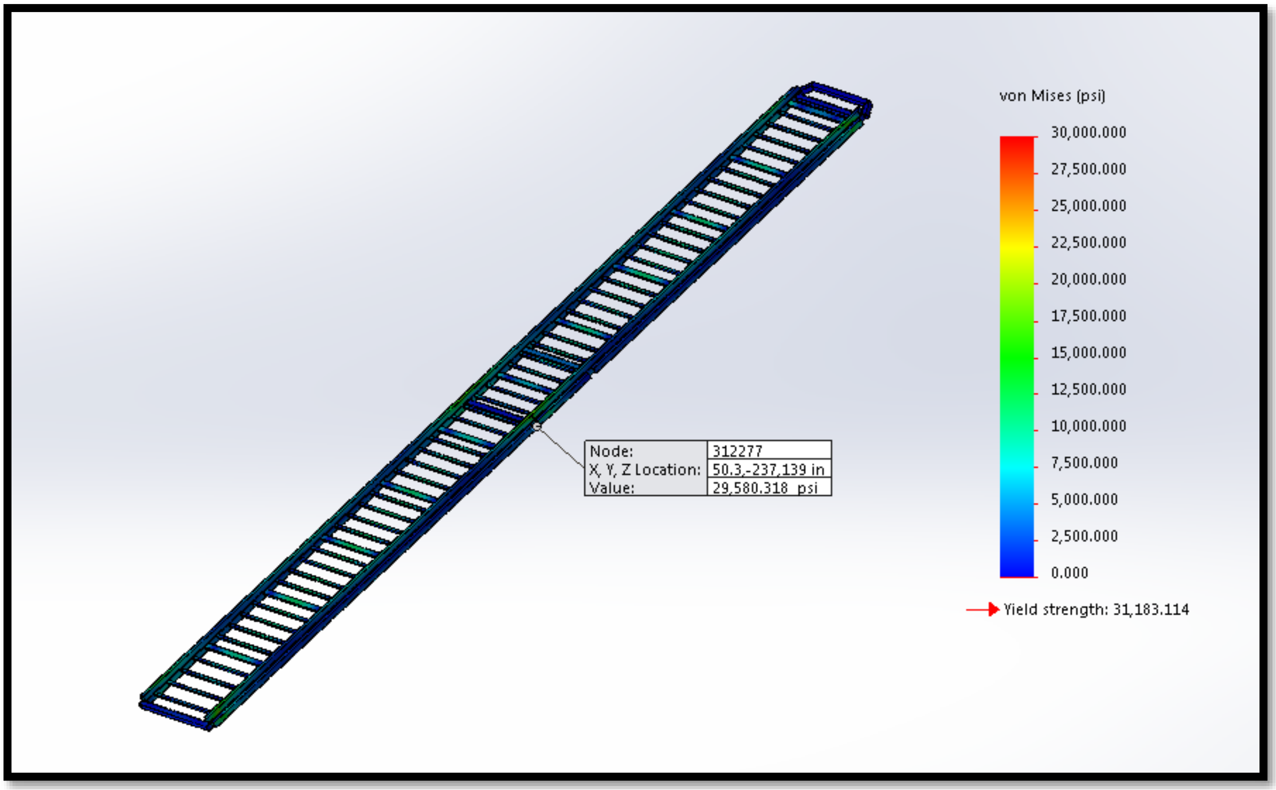


Figure 26 Stress analysis on the mid floor with cutouts

Safety Requirements

There are numerous safety concerns that result from lifting the floor from bottom to top of the trailer. The floor must go up slow enough to not stress the livestock that will be loaded on the floor. It also has to lock in place periodically (about every 6 inches or so) as it is going up and down. In the event of lifting mechanism failure, the lifting floor will only be able to fall a max of 6 inches rather than completely to the bottom floor. In addition to the lifting safety locks, transport height latches or locks must be integrated to secure the floor for transport. The design team must also take into consideration, the danger of pinch points. With punched or slatted siding, the livestock, operator, or a by-stander could be injured if an appendage were through the siding as the floor was lifted.

Lifting Locks

The lifting locks for this project were designed as a safety mechanism during lifting. These locks work very similar to those in an automotive car lift. Figure 27 shows a type of locking mechanism used in a car lift. In the lock pictured below, a spring loaded slack cable lock is used as the lock in case of failure. The arrow points to the slack cable lock, which would be engaged if the floor were to move downward. This is the lock that must be disengaged for lowering operations.

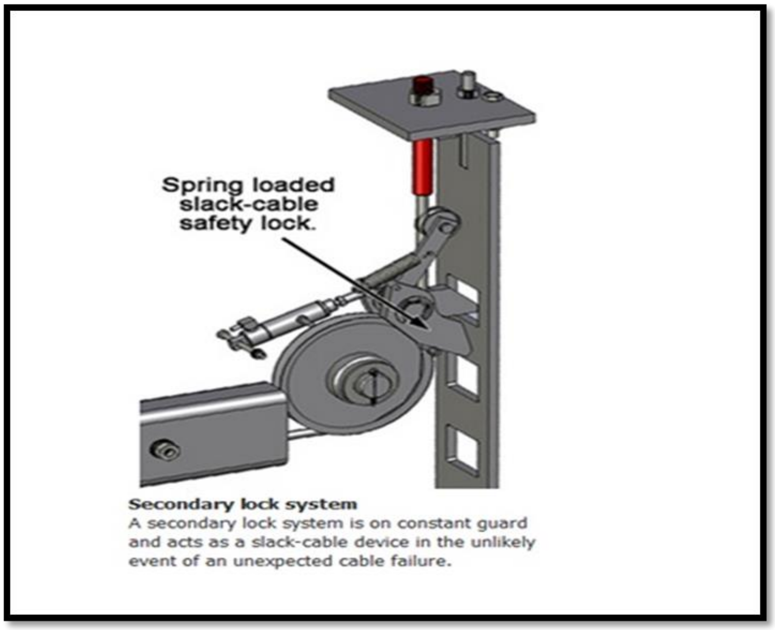
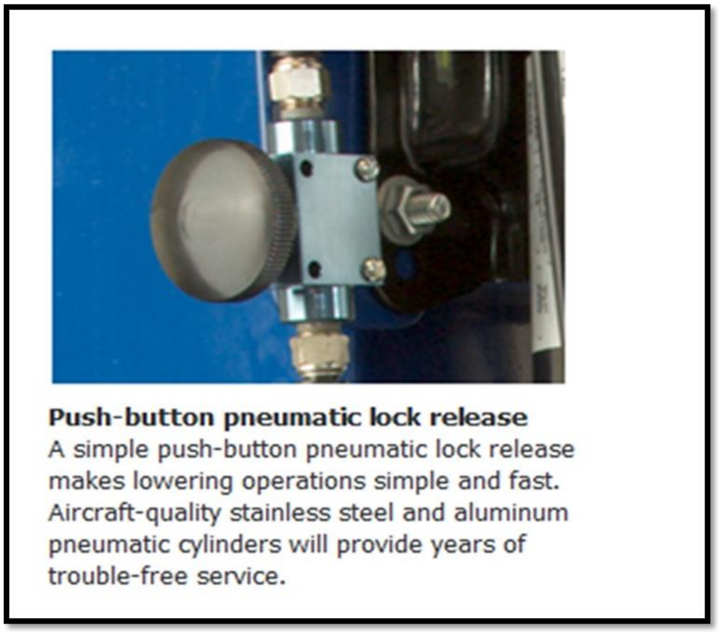


Figure 27 shows the locking mechanism in automotive lifting applications.

The multiple locking positions, which can be seen in Figure 28, provide safety the entire vertical travel distance of the floor. Should failure occur, the floor will only travel a maximum vertical distance of 6 inches before contacting a supporting locking position.

Figure 28 shows an example of incremental locking positions of a automotive lift.

This mechanism is engaged incrementally and disengaged using a lever and cable system. The lock must be disengaged during the duration of the lowering action. In most automotive lifts, a lever or button must be depressed that powers the pneumatic actuators in order to hold the lock open to maneuver past the individual locking positions. Figure 29 shows a type of pneumatic push button controller that is sometimes used in the design of lifting locks.



Push-button pneumatic lock release
A simple push-button pneumatic lock release makes lowering operations simple and fast. Aircraft-quality stainless steel and aluminum pneumatic cylinders will provide years of trouble-free service.

Figure 29 shows a pneumatic control button.

The lock designed by the Elevated Engineering team is very similar to the lock described above. This lock consists of a stainless steel lever arm on the bottom side of the floor that is attached to an aluminum bracket using a stainless steel lock arm. The bracket had to be design out of aluminum in order for the lock to be welded to the bottom side of the lifting floor, because the floor is also made of aluminum and the fact that you cannot weld steel to aluminum. Figure 30 shows the exploded and retracted views of the lock designed for this project.

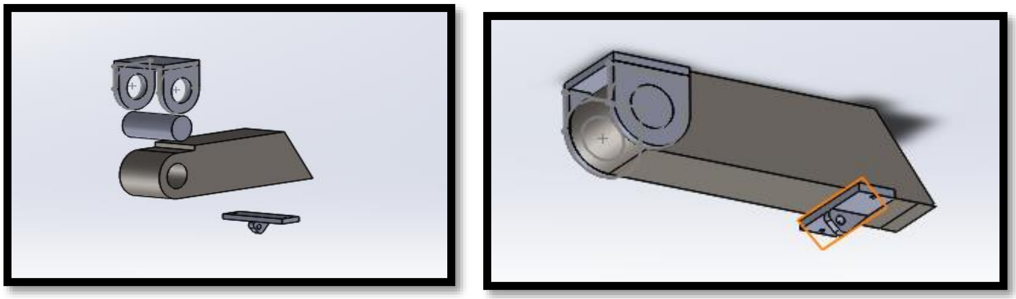


Figure 30 shows the lifting lock designed by Elevated Engineering.

The tab welded on the bottom of the pin consists of two wings that protrude past the side of the locking pin. These wings have holes in them that accommodate the springs that retract the pin after passing and incremental locking position. Tabs will be put into place in order to connect the springs to the bottom side of the lifting floor. The arm will pass tabs, which are incrementally welded onto the vertical I-beams of the structure. These tabs are placed every 6 inches in the vertical direction. As the locking pin moves past each tab, the lock will be forced down and come back to its original position by use of a spring attached to the tab on the lock. The tab also bears a vertical tab that will connect to cable. This cable will be part of the system that actuates the disengagement of the lock. One pneumatically actuating air cylinder will disengage the locks on opposite sides of the lifting floor in one motion. In the center of the bottom of the lifting floor will be a small double sheave and a pneumatic cylinder. When lowering operations a desired, air will be supplied to the cylinder causing a retraction of the rod. This action will apply force to the cables that travel to each lifting lock. When the rod retracts the cable will pull on the vertical tab forcing the lock downward. When lowering operations are concluded. The air can be disconnected returning the locks to the horizontal position. If one lock is placed on each vertical post, 4 pneumatic cylinders and cable and pulley systems will be required. Figure 31 shows the configuration of the system. The lock in green move past the incremental tabs in yellow.

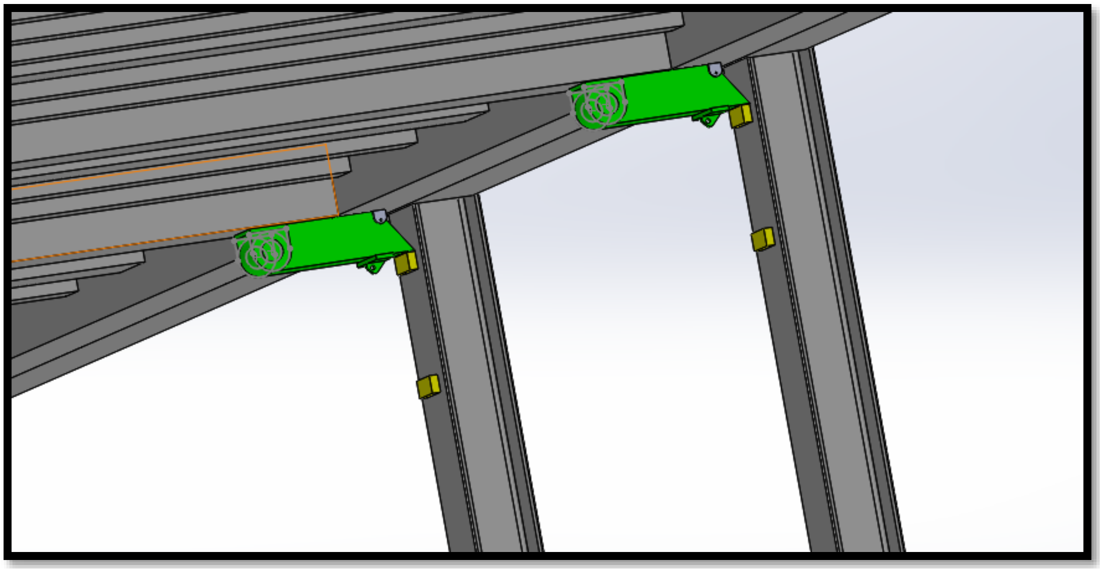


Figure 31 the configuration of the locking system on the lower floor.

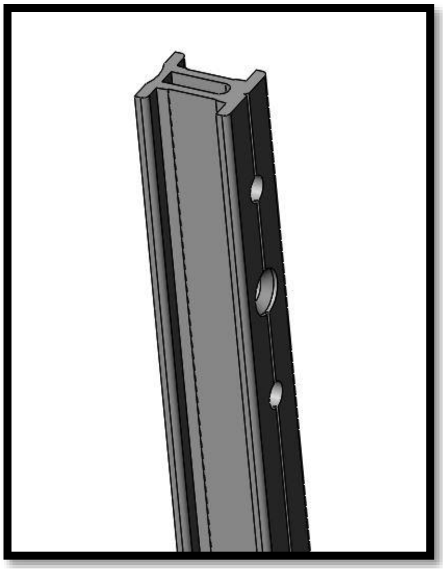
Transport Locks

The transport locks for our design will support the load while the trailer is in transport. These locks will be engaged before departure and disengaged during lifting and lowering operations. The locks need to be strong enough to withstand the forces of load shifting, impulse forces from the driver transporting down rough roads, congregation of the livestock in one area of the floor, the need to fold as close to even with the side of the trailer as possible for clearance issues, and be easily operated from the ground. Upon a site visit to Barrett Trailers facility, a thought of a triangular shaped hinged lock was brought up. Barrett had something very similar to the thought shown in Figure 32. The design shows a triangular shaped device that is hinged in two different places. These hinge points allow for the collapse of the lock during lifting. When in locking position the hypotenuse side of the triangle will set in a groove at the bottom of the triangular lock to support the lock while in transport. The lock can simply be lifted and disengaged by the operator for lowering operations. The team of engineers at Barrett have taken over the responsibility of figuring out how and where to connect these locks along the inside of the trailer.

Figure 32 shows the lock desing, provided by Barrett Trailers.

Guide and Track System

The guide and track system that is going to be used is similar to that of an industrial garage door. The track system will not bear any weight, so the system is not designed to distribute any weight force from the floor. The design is to ensure that as the floor is moved and raised that there is no pinching or twisting of the floor, and that is stays in the correct path to raise as easily and smoothly as possible. The hanger and I beam components of the guide system are made of corrosion resistant material. The guide system will be in a highly corrosive environment so this feature is an absolute must. Shown below are the components of the guide and track system that will be placed inside of the structure’s I-beam. Figure 35 shows how the guide and track system will appear looking down the structure’s I-beam. This system was believed to be the best option because it was small enough that it fit between the I-beam and the moving floor. The hanger will be welded or bolted the four by four inch square tubing that is reinforcing the moving floor.



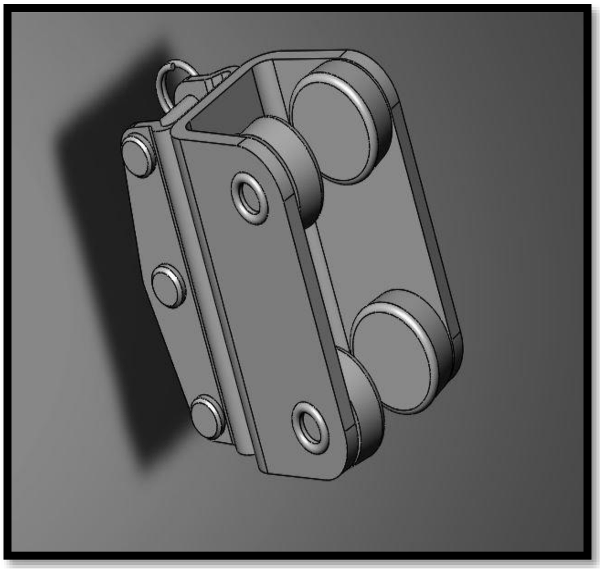


Figure 34 is the hanger that will clasp around the I-beam.

Figure 33 displayed above is the I-beam that the hanger will ride along.

A possible addition that could be made to this design is the incorporation of a brush or scraper of some kind. The environment is going to be prone to having animal waste flung and spread over all moving parts. With this problem comes the fact that the guide may not be able to slide through large amounts of waste, a brush could prove to be beneficial to provide some type of cleaning of the area before allowing the guide to raise with the floor.

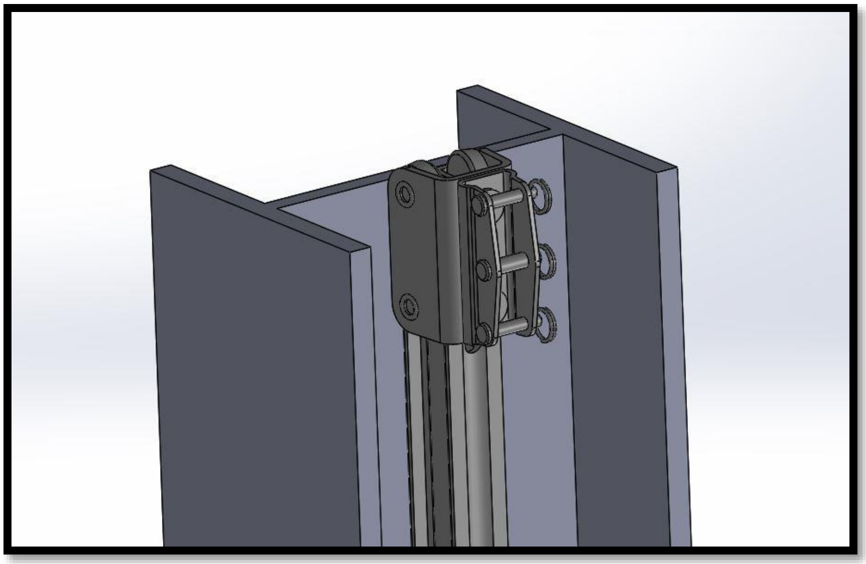
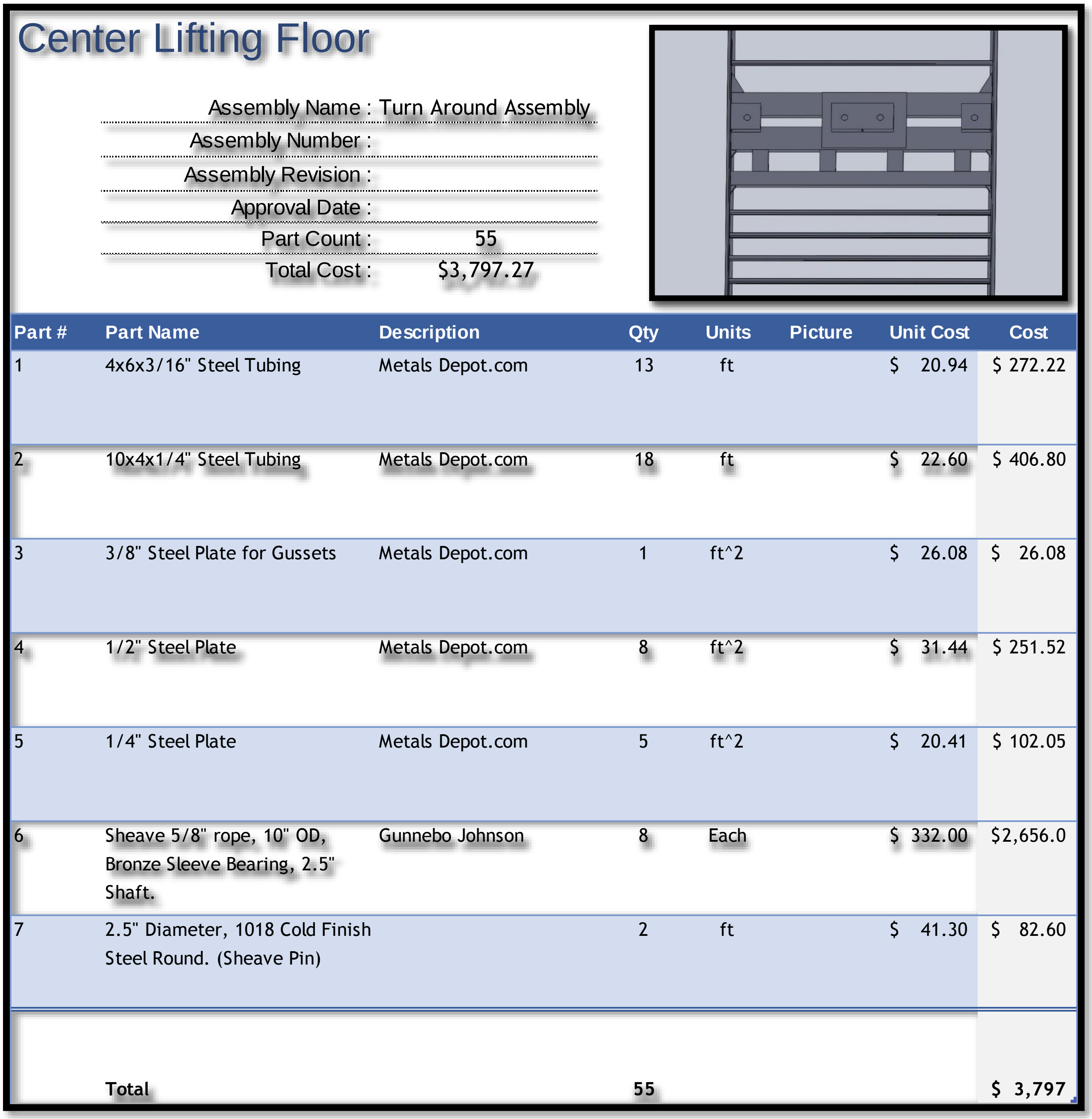


Figure 35 displays the complete guide and track system.

Bill of Materials



Center Lifting Floor

Assembly Name : Turn Around Assembly
Assembly Number :
Assembly Revision :
Approval Date :
Part Count : 55
Total Cost : $3,797.27

Part #	Part Name	Description	Qty	Units	Picture	Unit Cost	Cost
1	4x6x3/16" Steel Tubing	Metals Depot.com	13	ft		$ 20.94	$ 272.22
2	10x4x1/4" Steel Tubing	Metals Depot.com	18	ft		$ 22.60	$ 406.80
3	3/8" Steel Plate for Gussets	Metals Depot.com	1	ft^2		$ 26.08	$ 26.08
4	1/2" Steel Plate	Metals Depot.com	8	ft^2		$ 31.44	$ 251.52
5	1/4" Steel Plate	Metals Depot.com	5	ft^2		$ 20.41	$ 102.05
6	Sheave 5/8" rope, 10" OD, Bronze Sleeve Bearing, 2.5" Shaft.	Gunnebo Johnson	8	Each		$ 332.00	$2,656.0
7	2.5" Diameter, 1018 Cold Finish Steel Round. (Sheave Pin)		2	ft		$ 41.30	$ 82.60
	Total		55				$ 3,797

Center Lifting Floor

Assembly Name : Vertical Sheave Assembly

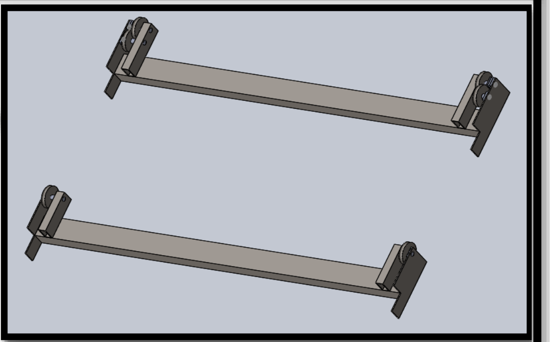
Assembly Number :

Assembly Revision :

Approval Date :

Part Count : 35.8

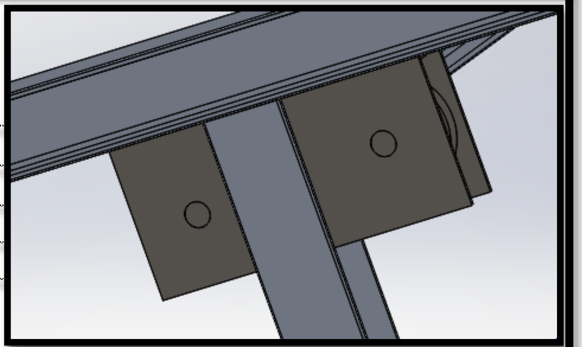
Total Cost : $1,517.45



Part #	Part Name	Description	Qty	Units	Picture	Unit Cost	Cost
1	4x6x3/16" Steel Tubing	Metals Depot.com	17	ft		$ 20.94	$ 355.98
2	4x2x1/4" Steel Tubing	Metals Depot.com	4.3	ft		$ 11.51	$ 49.49
3	2x2x1/4" Steel Square Tubing	Metals Depot.com	1	ft		$ 6.92	$ 6.92
4	1/2" Steel Plate	Metals Depot.com	0.5	ft^2		$ 31.44	$ 15.72
5	1/4" Steel Plate	Metals Depot.com	4	ft^2		$ 20.41	$ 81.64
6	Sheave 1/2" Rope, 6" OD, Bronze Sleeve Bearing, 1.5" Shaft	Gunnebo Johnson	6	Each		$ 163.00	$ 978.0
7	1.25" Diameter, 1018 Cold Finish Steel Round. (Cylinder Pin)	Metals Depot.com	3	ft		$ 9.90	$ 29.70
	Total		**35.8**				**$ 1,517**

Center Lifting Floor

Assembly Name : Top Sheave (All 10)
Assembly Number :
Assembly Revision :
Approval Date :
Part Count : 20
Total Cost : $1,206.14



Part #	Part Name	Description	Qty	Units	Picture	Unit Cost	Cost
1	3/16" Steel Plate	Metals Depot.com	11	ft^2		$ 18.04	$ 198.44
6	Sheave 1/2" Rope, 6" OD, Bronze Sleeve Bearing, 1.5" Shaft	Gunnebo Johnson	6	Each		$ 163.00	$ 978.0
7	1.25" Diameter, 1018 Cold Finish Steel Round. (Cylinder Pin)	Metals Depot.com	3	ft		$ 9.90	$ 29.70
	Total		**20**				**$ 1,206**

Center Lifting Floor

Assembly Name : Misc. Parts

Assembly Number :

Assembly Revision :

Approval Date :

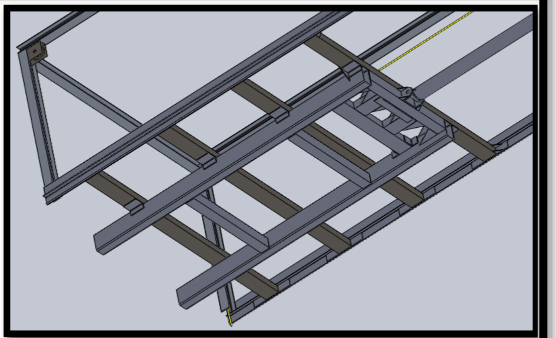
Part Count : 315.68

Total Cost : $10,085.96

[42]

Part #	Part Name	Description	Qty	Units	Picture	Unit Cost	Cost
1	5" Bore, 72" Stroke, 2.5" Rod Hydraulic Cylinder	Bailey Hydraulics	1	Each		$ 1,135.0	$1,135.0
2	5/8" 6x19 304 Stainless Steel IWRC Wire Rope	U.S. Cargo	100	ft		$ 4.99	$ 499.0
3	1/2" 6x19 304 Stainless Steel IWRC Wire Rope	U.S. Cargo	206	ft		$ 1.94	$ 399.64
4	Power Unit Containing Engine, Pump, Valves, and Resevoir.	Bailey Hydraulics	1	Each		$ 3,500.0	$3,500.0
5	4x4x1/4" Aluminum I-Beam	Metals Depot.com	7.68	25 ft		$ 592.75	$4,552.3
	Total		**315.68**				**$10,086**

Center Lifting Floor



Assembly Name : Sub-Frame Redesign
Assembly Number :
Assembly Revision :
Approval Date :
Part Count : 83
Total Cost : $1,740.82

Part #	Part Name	Description	Qty	Units	Picture	Unit Cost	Cost
1	4x6x3/16" Steel Tubing	Metals Depot.com	47	ft		$ 20.94	$ 984.18
2	10x4x1/4" Steel Tubing	Metals Depot.com	22	ft		$ 22.60	$ 497.20
3	3/8" Steel Plate for Gussets	Metals Depot.com	2	ft^2		$ 26.08	$ 52.16
4	1/2" Steel Plate	Metals Depot.com	1	ft^2		$ 31.44	$ 31.44
5	1/4" Steel Plate	Metals Depot.com	4	ft^2		$ 20.41	$ 81.64
6	3x4x3/8" Steel Angle	Metals Depot.com	6	ft^2		$ 13.25	$ 79.5
7	1.515" Diameter, 1018 Cold Finish Steel Round. (Cylinder Pin)	Metals Depot.com	1	ft		$ 14.70	$ 14.70
	Total		**83**				**$ 1,741**

Appendix

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Work Breakdown Structure

WBS 1.0 Design Center Lifting Floor

1.1– Review Requirements

Floor must raise, and lower 35000 lbs. Must be safe for the livestock, and the operator. Design must optimize the amount of space available on both floors. Trailer has to be safe for highway travel. The end product has to be aesthetically pleasing. Utilization of partition gates must be available.

1.2 – Compare and Contrast Existing Lifting Mechanisms

Weigh the benefits, and hindrances of existing lifting mechanisms as they apply to this project. Rate them based on lifting capacity, cost, power requirements, spatial requirements, and complexity.

1.3 – Design Center Lifting Floor

Design center-lifting floor based on the requirements stated in WBS 1.1. If necessary, implement ideas gathered from WBS 1.2.

WBS 2.0 Documentation

2.1 – Drafting

Complete Solidworks drawing of center floor that will be lifted. Complete Solidworks drawing of any necessary parts for manufacture.

2.2 – Modeling and Testing

Complete stress analysis on center lifting floor to determine least number of lifting points. Determine structural rigidity of entire trailer shell with center floor detached from the structure. Model lifting mechanism for proof of concept. Test design for partition gates. Test design concepts for safety mechanisms.

3.0 Engineering Review and Client Approval

3.1 – Review and Approve Engineering

Review the engineering involved in the design of the trailer in order to ensure that no errors were made.

3.2 – Seek Client Approval

Meet with client to present preliminary designs.

4.0 Manufacture of Trailer

4.1 – Assist Barrett Team with Manufacturing

Assist Barrett with any technical knowledge needed for manufacture of the lifting mechanism.

4.2 – Monitor Manufacture of Trailer

Routinely check in on progress of manufacturing in order to ensure design specifications were adhered to.

5.0 Final Testing

5.1 - Test Trailer

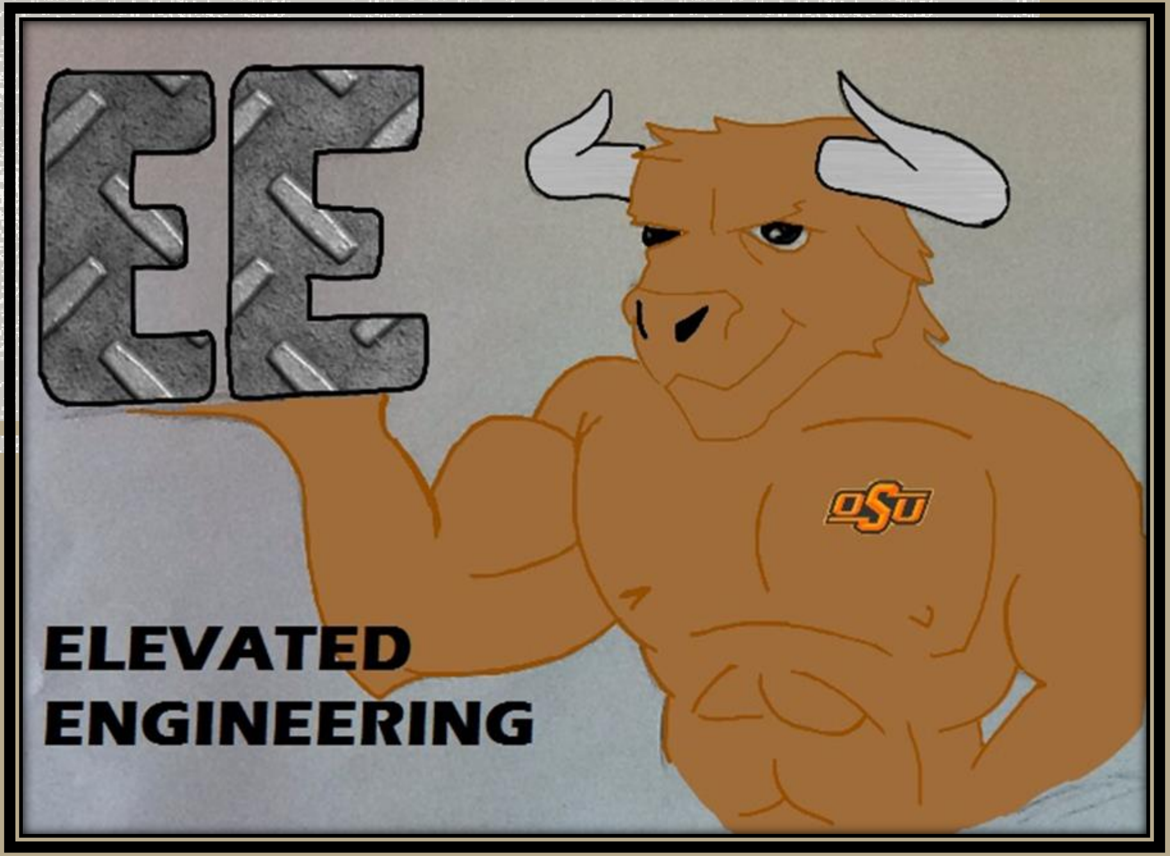
Put center floor under load, and actuate floor to maximum elevation. Determine that all safety mechanisms are functioning properly. Test gate design to determine ease of use, and functionality.

Patent Research

- Matthew M. Putze, 2000, Lock and release mechanism for vertical adjustable deck in livestock trailers, US 6058885 A
- Raymond W. Blodgett, Jr., Benjamin J. Fletes, 2003, Lift System, US 7377362 B2
- Jeffery Scott Kritzer, 2000, Safety Lock Device for Automobile Lifts, US 6382358 B1
- James J. Taylor, John DeCinque, 1984, Above-the-floor hydraulic lift, US 4457401 A

ELEVATED ENGINEERING

Barrett



Spring Presentation
April 28, 2016

TEAM MEMBERS

- ➢Gage Martin
- ➢Kade Coulter
- ➢Jodi Vinyard
- ➢Shelby Weber

BARRETT TRAILERS, LLC.

Barrett Trailers was conceived in Oklahoma City in 1973. Since then the company has grown and relocated into a 75,000 square foot facility in Purcell, Oklahoma. "Barrett Trailers LLC vision is to be the manufacturer of the finest all-aluminum livestock semi-trailers and stock gooseneck trailers". With a quality line of products, and an arsenal of motivated employees, Barrett Trailers are a leader in the livestock transportation industry.

6" Drop Double Deck Straight Floor Hog Trailer

http://www.barrett-trailers.com/semi-trailers

PROBLEM STATEMENT

- Elevated Engineering is committed to designing a safe, economical, and innovative means to raise, and lower the center floor of an aluminum hog trailer. The design must minimize floor space lost, and lift the floor evenly to reduce wear on the guides.

CUSTOMER REQUIREMENTS

- Safety for livestock and operator.
- Lifting the floor evenly to prevent unnecessary wear and tear upon the lifting mechanism.
- Corrosion resistant materials.
- Minimal floor space lost.
- Cost efficient.
- Raising the floor in a timely manner.
- Target structural capacity of 60,000 pounds.

Project Requirements	
Basic Lifting Capacity	35,000 lbs.
Safety Factor	1.7
Target structural Capacity	59,500 lbs.
Zero to Six Feet Lifting Time	70 seconds

PROJECT SCOPE

Elevated Engineering will be collaborating with Barrett Trailers, OSU Application Engineer, Oklahoma Manufacturing Alliance, New Product Development Center, and others from Oklahoma State University on the following tasks.

- ➢ Validation and design of lifting mechanisms.
- ➢ Meeting safety goals
- ➢ Prototype modeling

ENVIRONMENTAL/ECONOMIC IMPACT

There are a few possible environmental, and economic impacts associated with this project. The first will be the ease of cleaning the trailer now that the floor can be raised. Operators might not be tempted to skip the wash out process. Faster loading, and unloading times could reduce the cost of livestock transportation.

Source: https://encrypted-tbn2.gstatic.com/images?q=tbn:ANd9GcRTxhReUAip-SYo2hCF2CK0a4j4Xo5S8DiAfbrB-4CDLtsNELVtMWskvIg

DEPARTMENT OF TRANSPORTATION

- Overall gross vehicle weight for Oklahoma highways is 90,000 lbs.
- Gross vehicle weight for interstate systems is 80,000 lbs.
- No height greater than 13 feet 6 inches.
- Trailer length is limited to 53 feet.
- Width no greater than 102 inches.

SIMILAR CONCEPTS

- Pezzaioli Trailers
- Milson Livestock Trailers
- Riverside Express

PEZZAIOLI TRAILERS

- Located in Montichiari, Italy.
- Uses forced ventilation system.
- Floor is divided and each section moves independently.

Source:http://ets2.lt/wp-content/uploads/2014/08/Pezzaioli-Trailer.jpg

PEZZAIOLI TRAILERS

Source:
https://video.search.yahoo.com/video/play;_ylt=A2KLqIHD.VxWHnAAfAP7w8QF;_ylu=X3oDMTByYXI3cnIwBHNlYwNzcgRzbGsDdml
kBHZ0aWQDBGdwb3MDNA

MILSON LIVESTOCK TRAILERS

- Located in West Sussex, England.
- Front two thirds of upper floor is fixed.
- Back one third pivots down to form a ramp.

Source: http://i1.ytimg.com/vi/RMUFzsnDWbY/hqdefault.jpg

MILSON LIVESTOCK TRAILERS

Source:
https://video.search.yahoo.com/video/play;_ylt=A2KLqIKr.1xWRDwARXH7w8QF;_ylu=X3oDMTBycTlydWI1BHNlYwNzcgRzbGsDdmlkBHZ0aWQDBGdwb3MDOA

RIVERSIDE EXPRESS

- Located in Hancock, Minnesota.
- Closest in design concept.
- Issues with level floor travel.
- Floor doesn't raise all the way to the ceiling.

Source: Barrett Trailers

RIVERSIDE EXPRESS

Source: Barrett Trailers

DESIGN CONSTRAINTS

The initial steps to sifting through all of the many different types of lifting mechanisms involved rating them on a five star basis keeping the following criteria in mind.

- Lifting Capacity
- Cost
- Durability
- Safety
- Space Obligation
- Power Requirement

LIFTING MECHANISMS

Scissor Lift ★

Forklift ★★

Rack and Pinion ★★

Multiple Hydraulic Cylinders ★★★

Four Post Cable and Winch ★★★

Acme Screw ★★★★

Hydraulic Cylinder and Cable System ★★★★

ENGINEERING SPECIFICATIONS

To understand how viable an approach really is we must compare it to the absolute minimum. Fundamental physics can tell us exactly that.

- $Work = Force * Distance$
- $Work = 35{,}000 lbs * \frac{72 inches}{12 \frac{inches}{foot}} = 210{,}000 ft * lb$
- $hp = \frac{Work}{Time * 550}$
- For the floor to travel 72 inches in 70 seconds.
- $hp = \frac{210{,}000 lb * ft}{70\ seconds * 550} = \boxed{5.5 hp}$

HYDRAULIC CYLINDER WITH CABLE SYSTEM

- Now that we are looking at this option, we must find out what it takes to meet our speed requirements.
- We have a target of 72 inches in 70 seconds.

- $\frac{72 inches}{70 seconds} = 1.03\ inch/sec$

Using a cylinder with a 5 inch bore, 2.5 inch rod, and 72 inch stroke.

$$\pi r^2(L) = \pi(2.5in^2 - 1.25in^2) * (72\ in) = 1060.3\ in^3\left(\frac{1\ gal}{231\ in^3}\right) = 4.58\ gallons$$

- A 4 gpm pump gives,

$$\frac{4.58\ gal}{4\ gpm} = 1.15(min)\left(60\,\frac{sec}{min}\right) = \mathbf{68.70\ sec,} so\ \frac{72\ inches}{68.70\ seconds} = \boxed{1.05\,\frac{inch}{sec}}$$

FORCE FROM CYLINDER

- These calculations are based on a Bailey International cylinder with a 5 inch bore, 2.5 inch rod, and 72 inch stroke.

- If a 2,500 psi max pump is used, then the output force is,

$$F = P * A = 2{,}500\ \frac{lbs}{in^2} * \left(\pi(2.5\ in^2 - 1.25 in^2)\right) = \boxed{36{,}816\ lbs.}.$$

- Which exceeds the maximum operating load of 35,000 lbs.

HORSEPOWER DEMAND

- $hp = \frac{gpm * psi}{1,714} = \frac{4 gpm * 2,500 psi}{1,714} = 5.83\ hp$
- Assuming our system operates at 80% efficiency
- $hp = \frac{5.83\ hp}{0.80} = \boxed{7.29\ hp}$
- The theoretical minimum to achieve this is 5.83 hp, so this is a promising solution.

POWER SUPPLY

There are three options that stand out for supplying the hp we require.

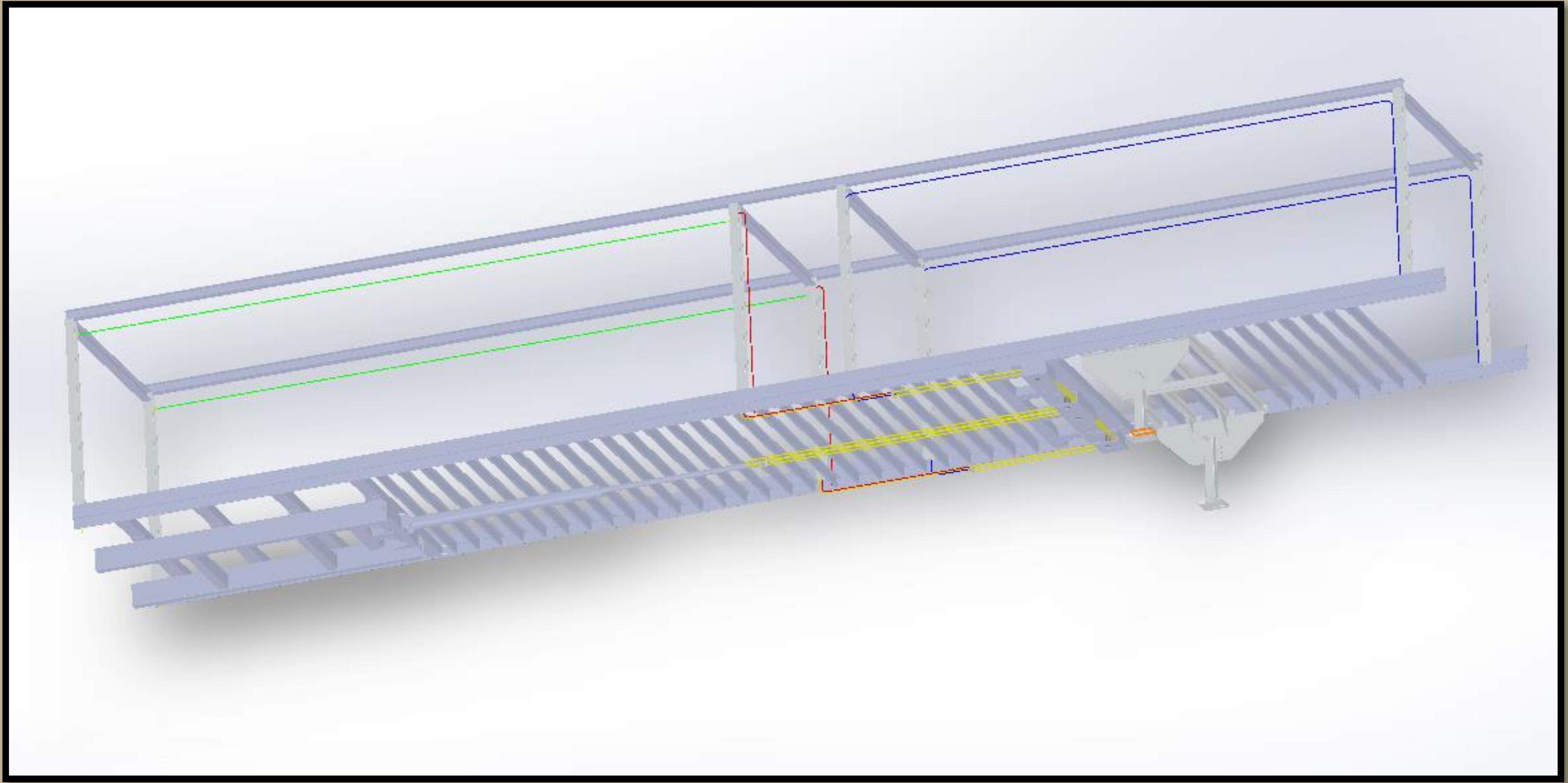
- Engine mounted clutch pump
- Transmission mounted PTO (Power Take Off)
- Stand alone power unit

CABLES

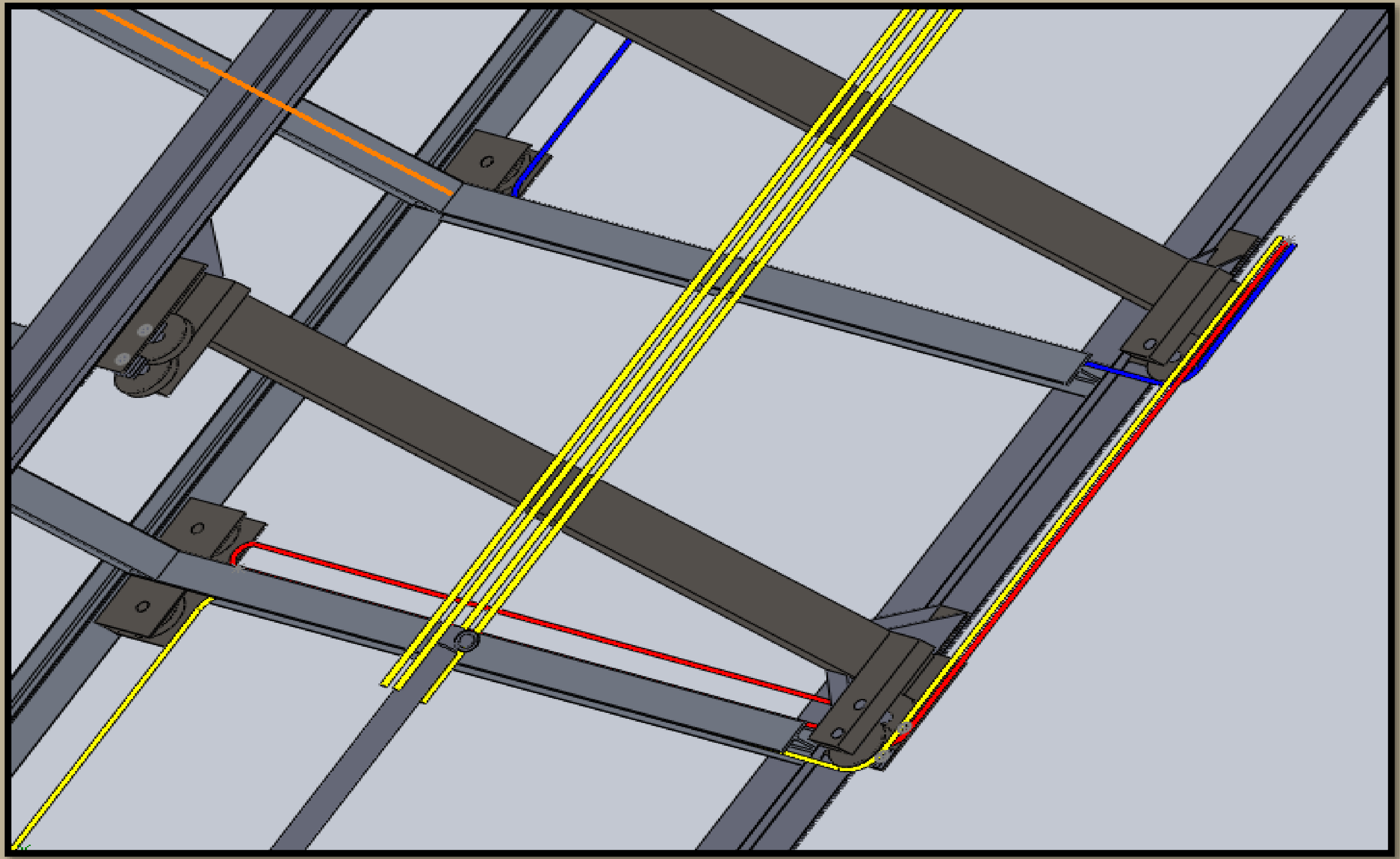
- 5/8-inch cables-
  - ✓Used between the cylinder and the transition block.
  - ✓35,000 lb. breaking strength.
  - ✓4 cables total.
  - ✓6x19 IWRC construction

- ½ -inch cables-
  - ✓Used between the transition block and the lifting points.
  - ✓22,800 lb. breaking strength.
  - ✓6 cables total.
  - ✓6x19 IWRC construction

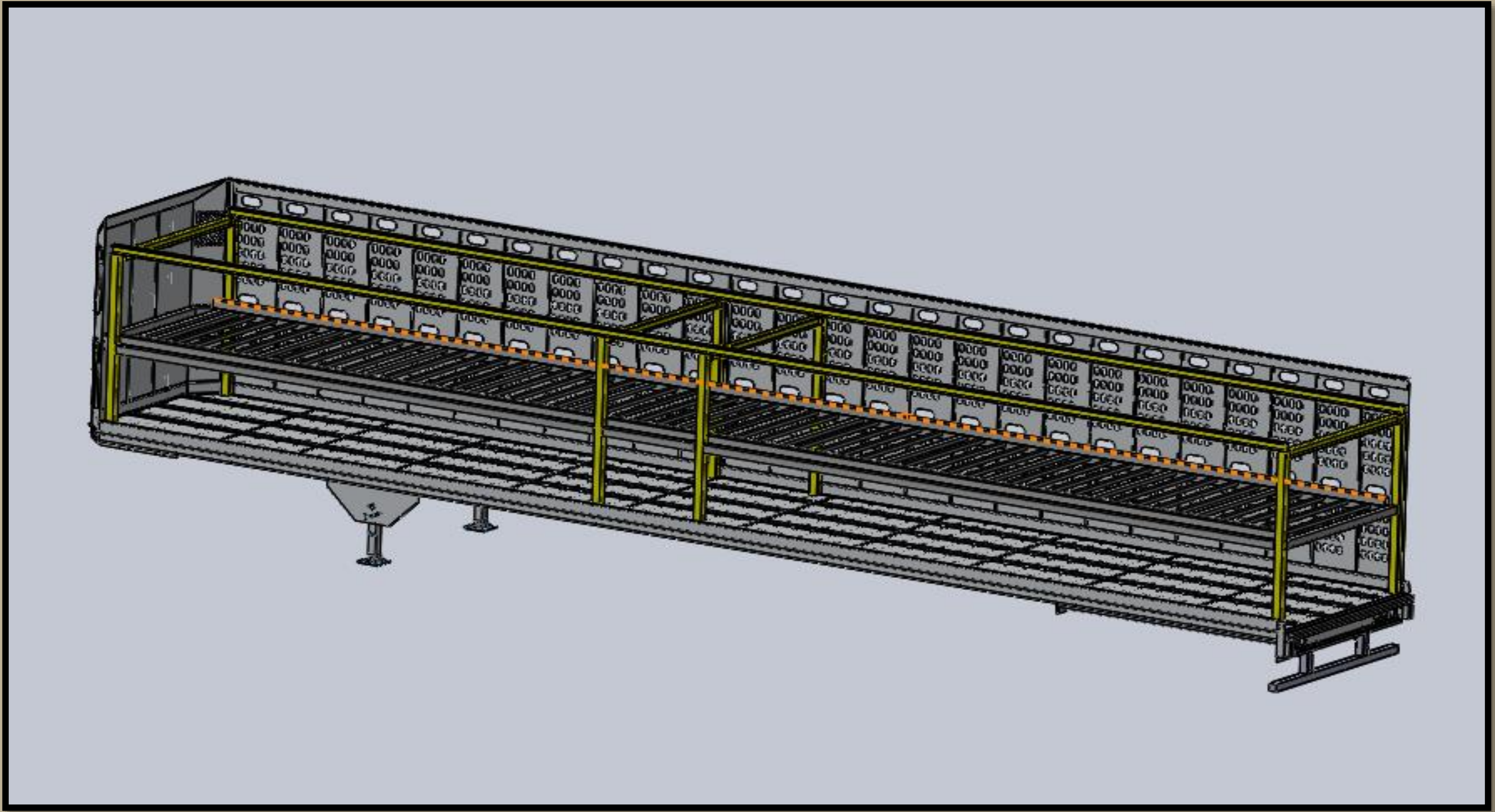
CABLE PATH ILLUSTRATION



CABLE PATH ILLUSTRATION

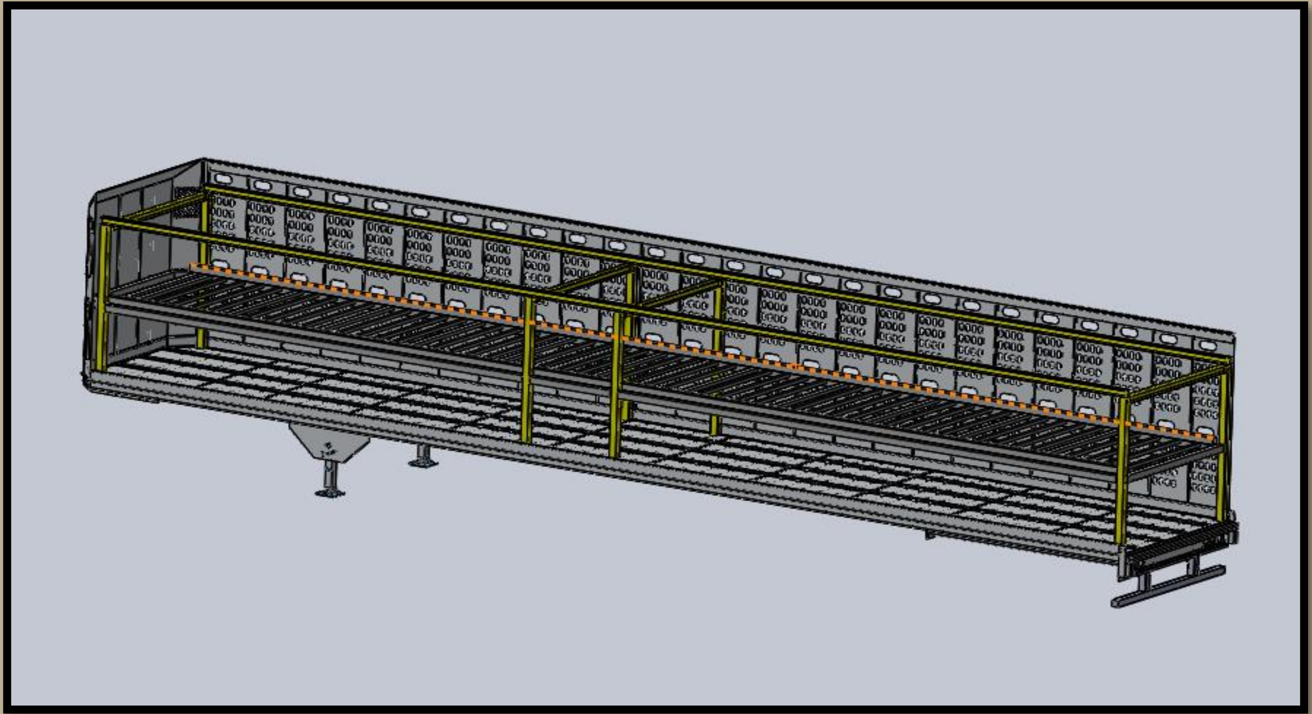


TRAILER STRUCTURE



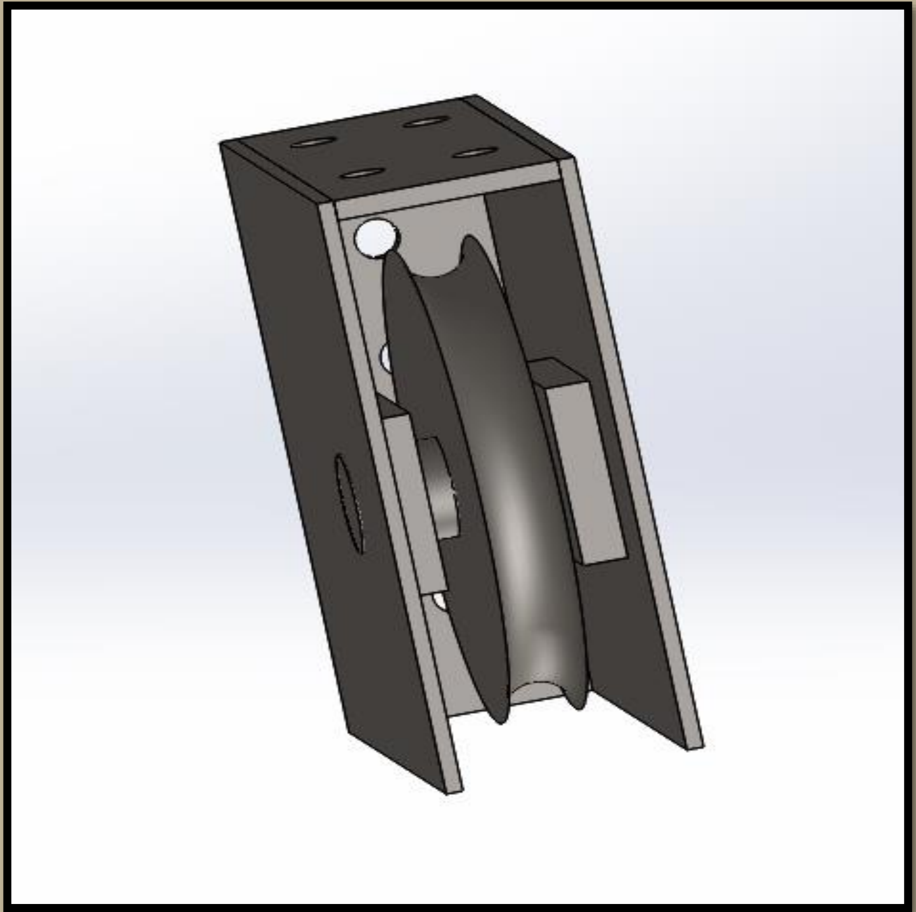
TRAILER STRUCTURE

- Made up of 4 x 4 inch DI# 6936 aluminum I-beam
- The structure is constructed with 8 vertical weight bearing posts.



UPPER BRACKETS

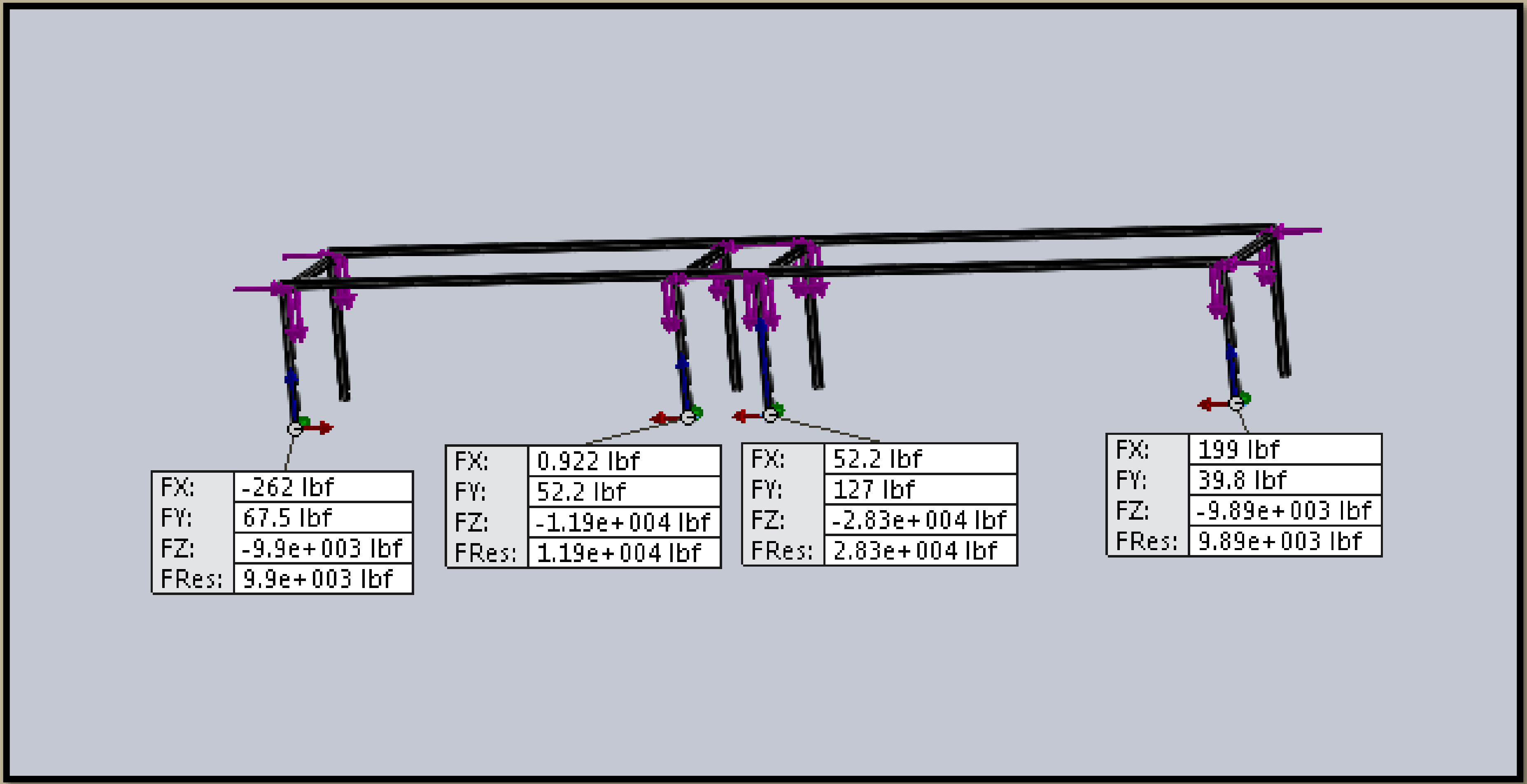
- Dual purpose.
- Provides a housing for upper sheaves.
- Acts as supporting gussets for I-beam.



STRUCTURE

- 4 point loads per side equaling 8 total.
- The structure is connected to the trailer’s side rail.
- The maximum force was 28,000 lbs. with a safety factor of 2.

STRUCTURE RESULTANT FORCES



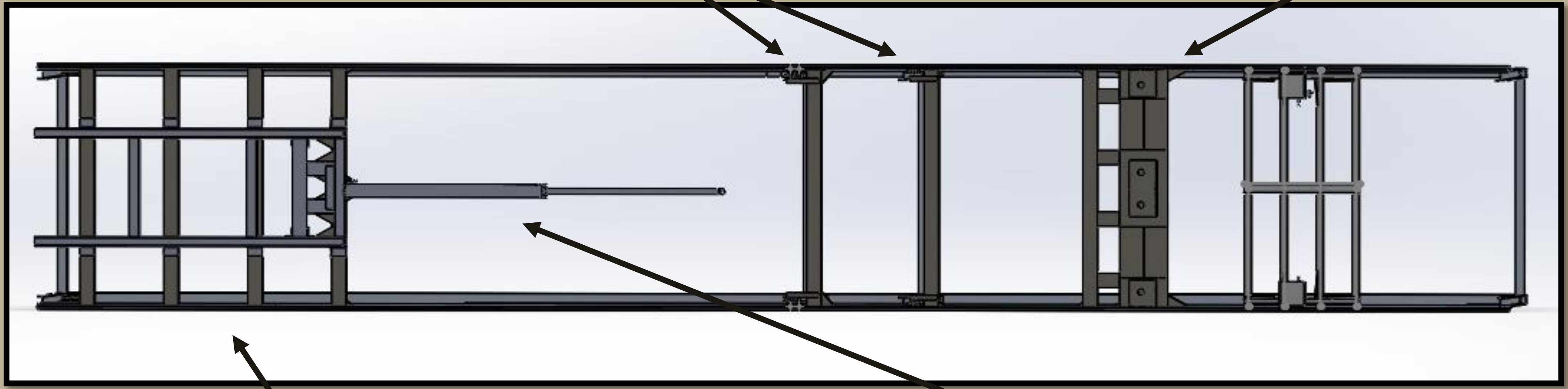
FX:	-262 lbf
FY:	67.5 lbf
FZ:	-9.9e+003 lbf
FRes:	9.9e+003 lbf

FX:	0.922 lbf
FY:	52.2 lbf
FZ:	-1.19e+004 lbf
FRes:	1.19e+004 lbf

FX:	52.2 lbf
FY:	127 lbf
FZ:	-2.83e+004 lbf
FRes:	2.83e+004 lbf

FX:	199 lbf
FY:	39.8 lbf
FZ:	-9.89e+003 lbf
FRes:	9.89e+003 lbf

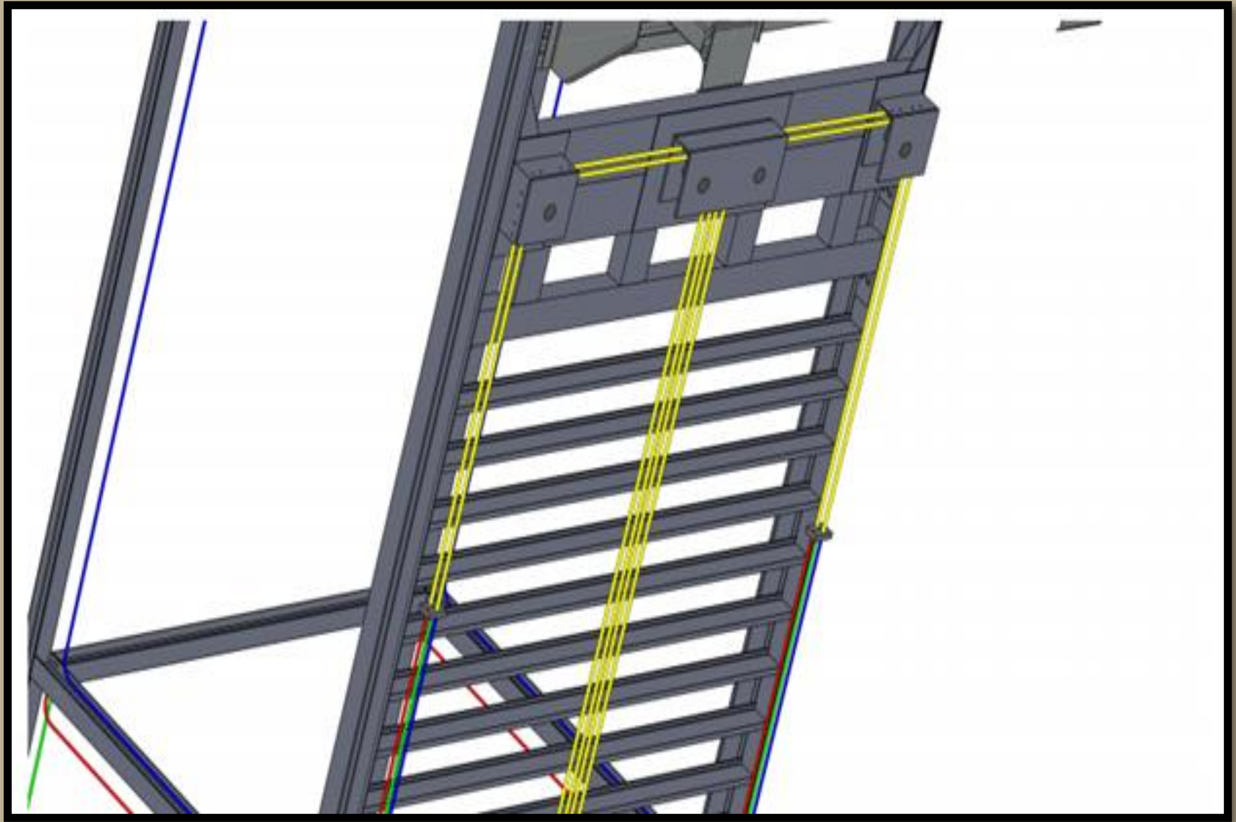
LOWER FLOOR



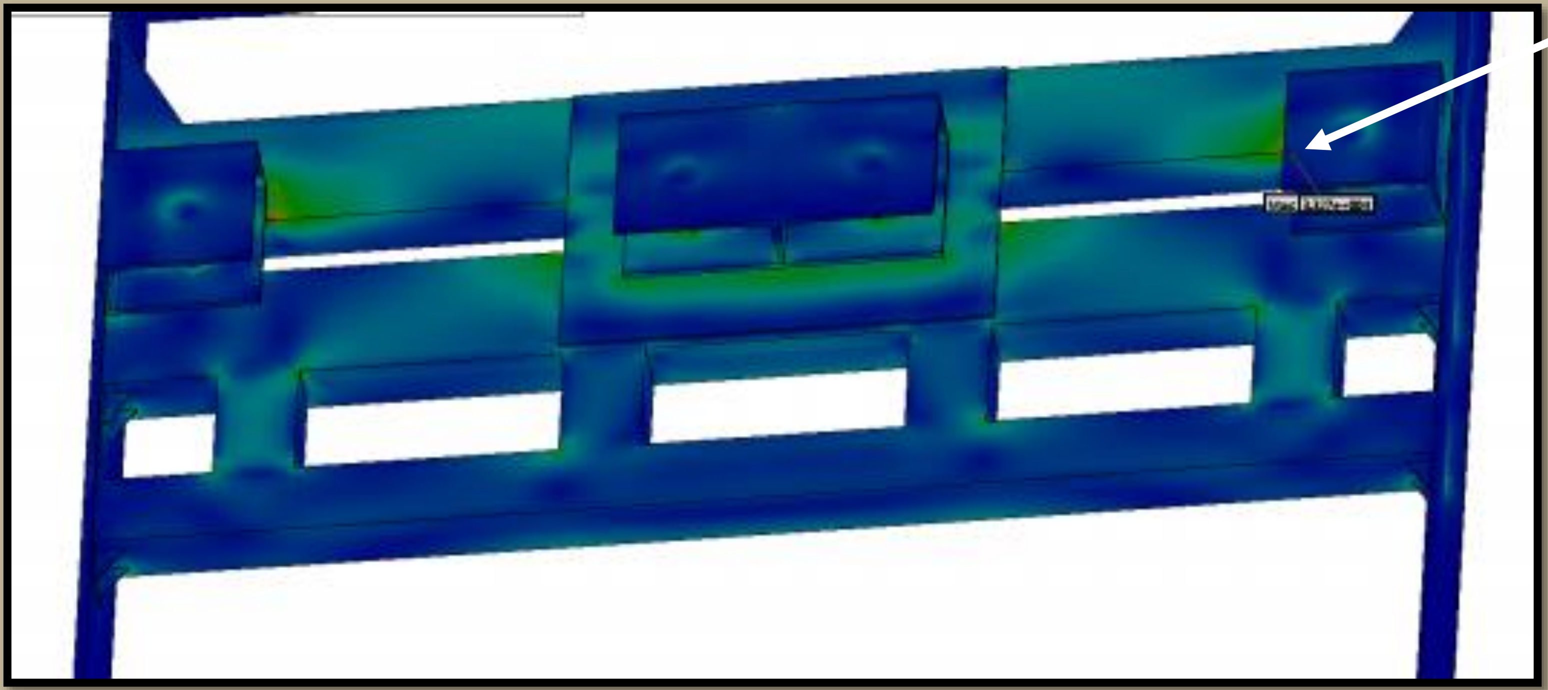
- Vertical transition sheaves
- Turn Around Assembly
- Sub Frame
- Hydraulic Cylinder

TURN AROUND ASSEMBLY

- Transfers all forces parallel with cylinder.
- Consists of 8, 10 inch diameter sheaves with 2.5 inch shafts.
- Four 5/8" diameter stainless steel cables enter the assembly and reverse direction



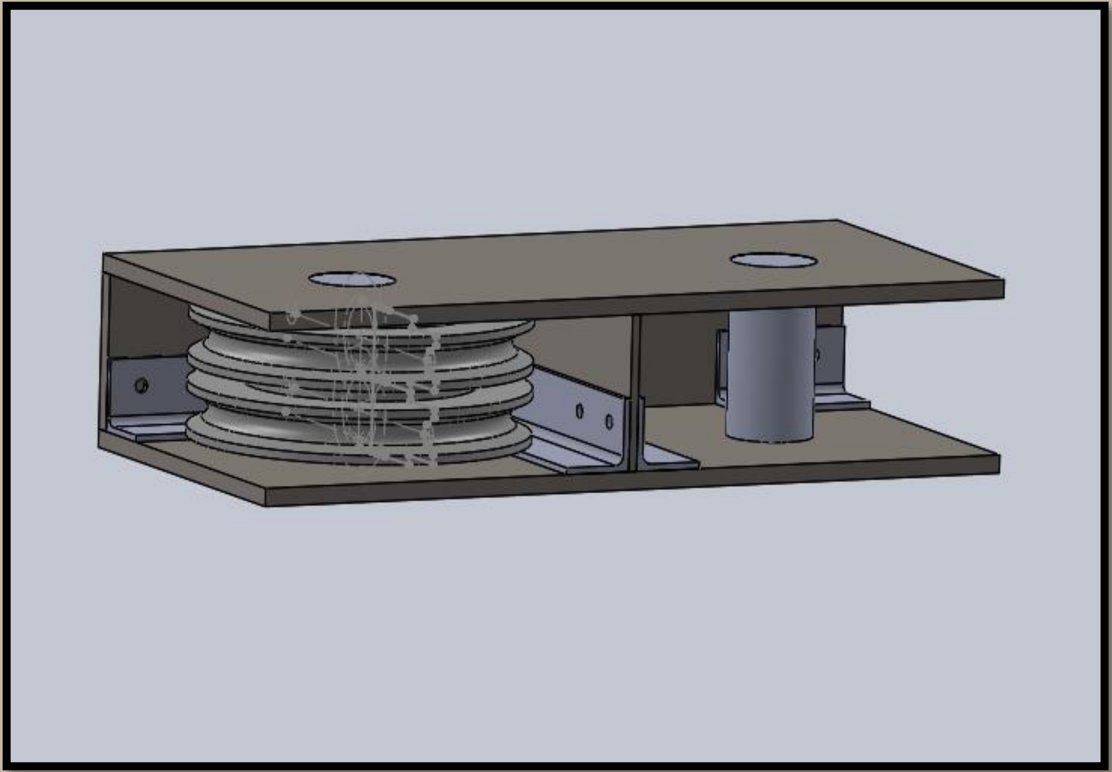
TURN AROUND ASSEMBLY



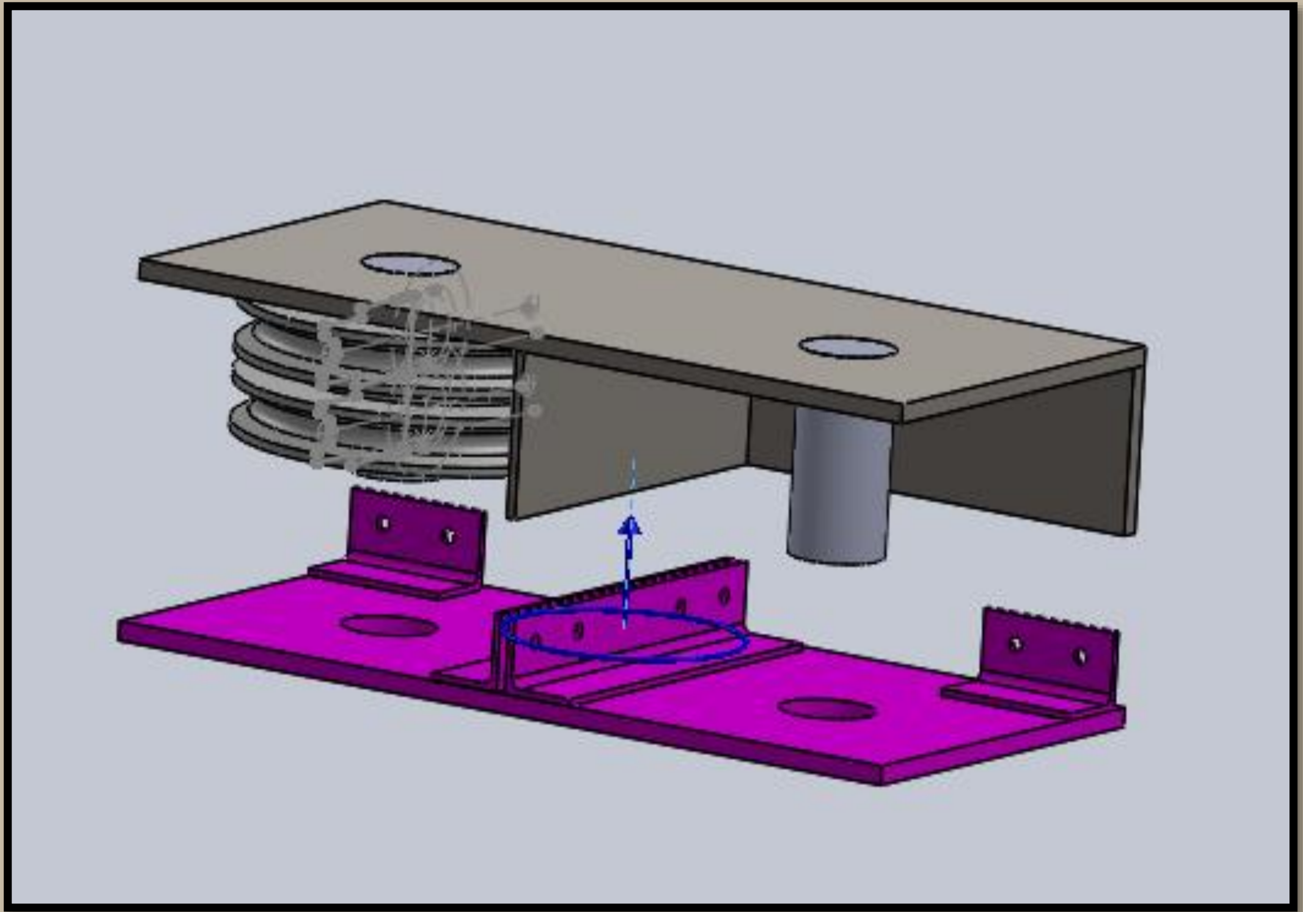
Max Stress: 35000 psi

TURN AROUND ASSEMBLY SHEAVE BRACKET

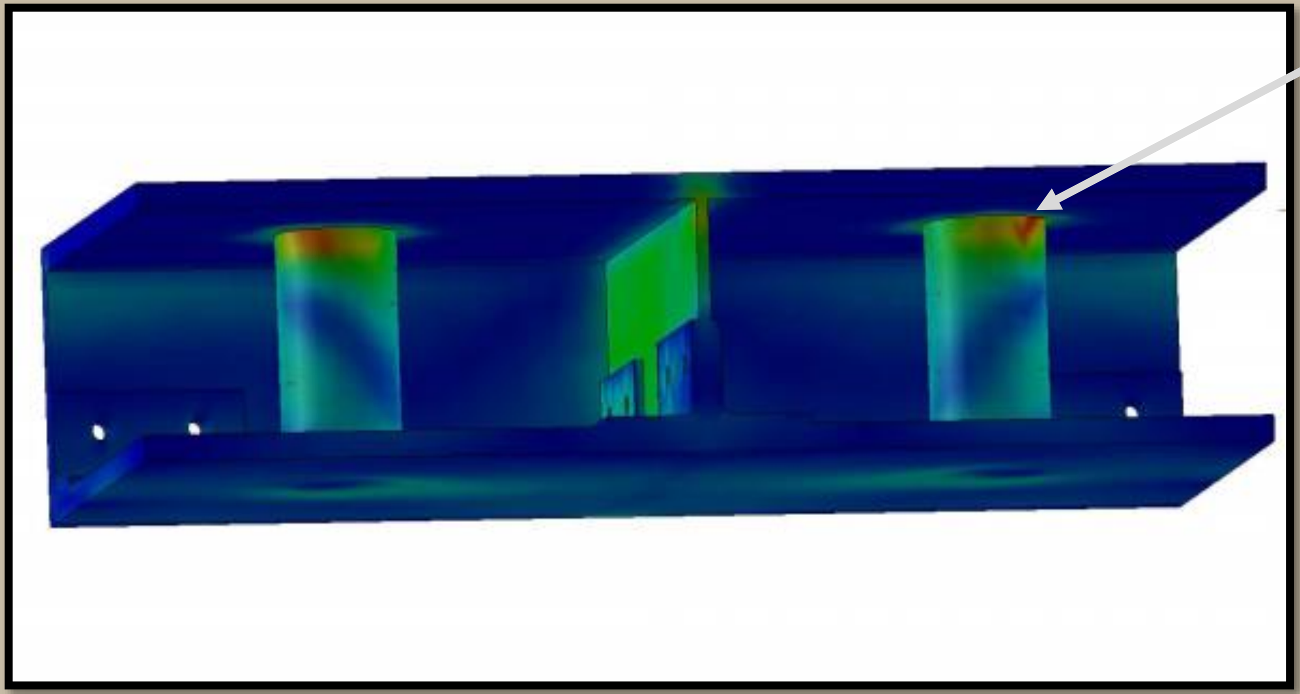
- Welded to the turn around assembly.
- Strong construction minimizes stresses and deflection.
- Bottom of bracket unbolts to allow access to the sheaves.



TURN AROUND ASSEMBLY SHEAVE BRACKET



TURN AROUND ASSEMBLY SHEAVE BRACKET

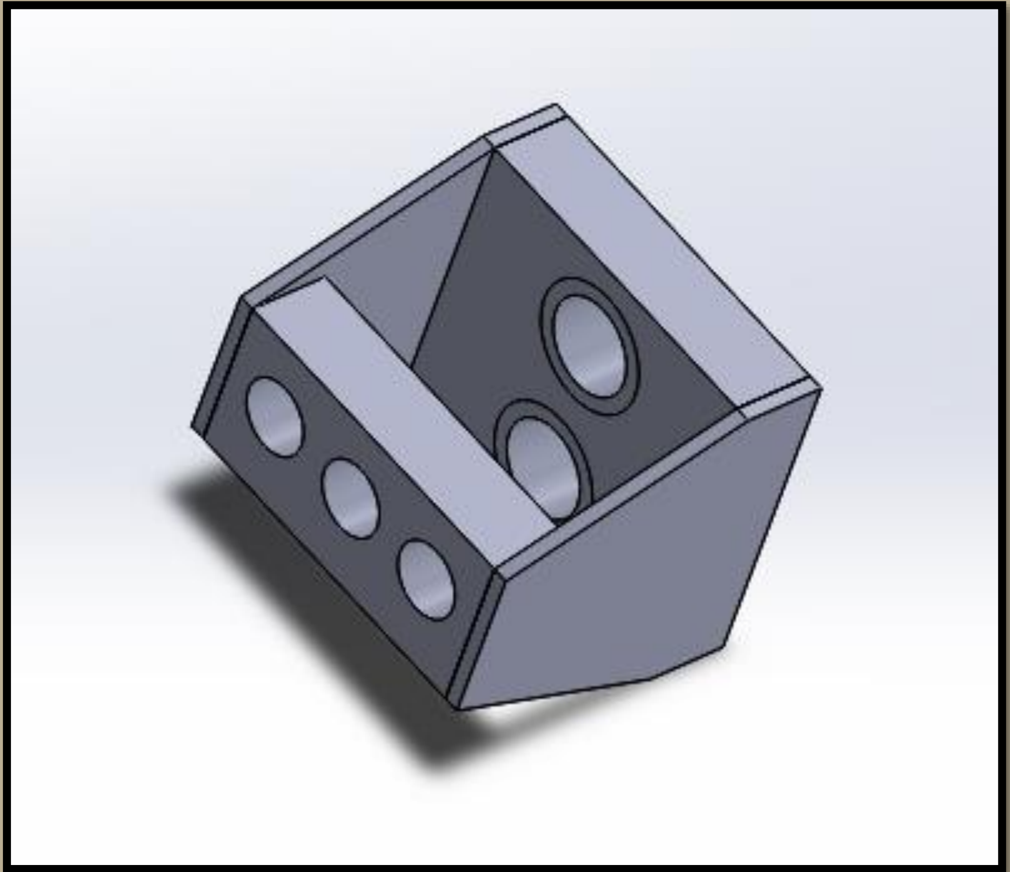


Max Stress: 13000 psi

TRANSITION CABLE BLOCK

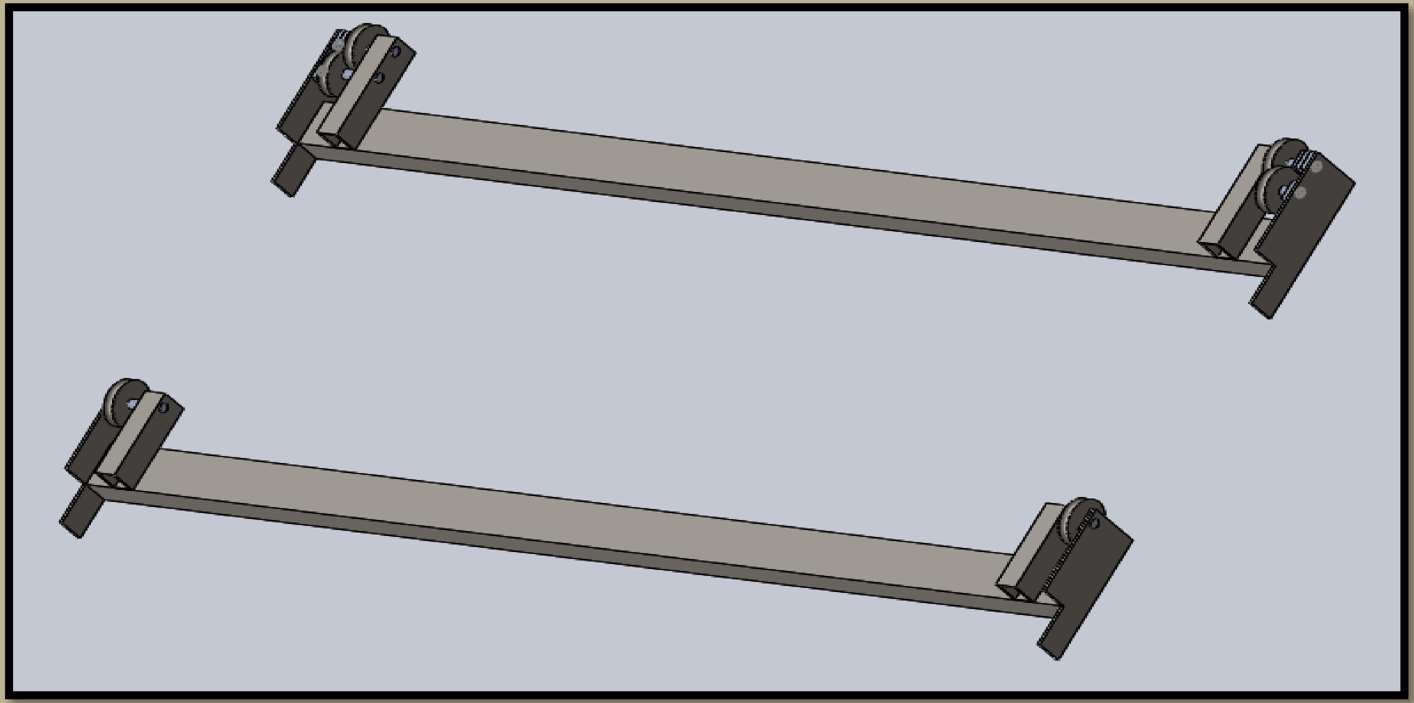
- One on each side of the trailer.

- Transitions from 5/8-inch cables to ½ -inch cables.



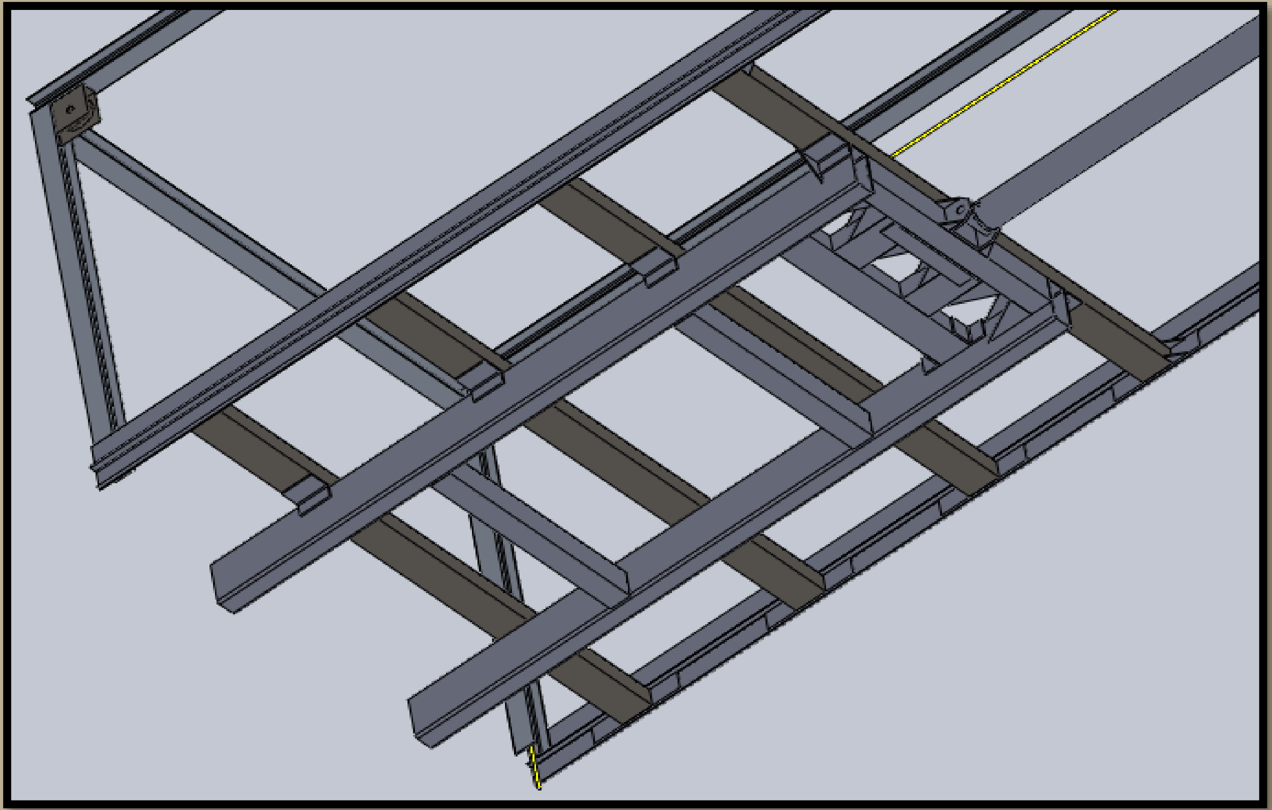
VERTICAL TRANSITION SHEAVES

- Serve as the transition from horizontal to vertical running cables.
- Front sheaves are offset to allow cable to travel up each side of the I-beam.

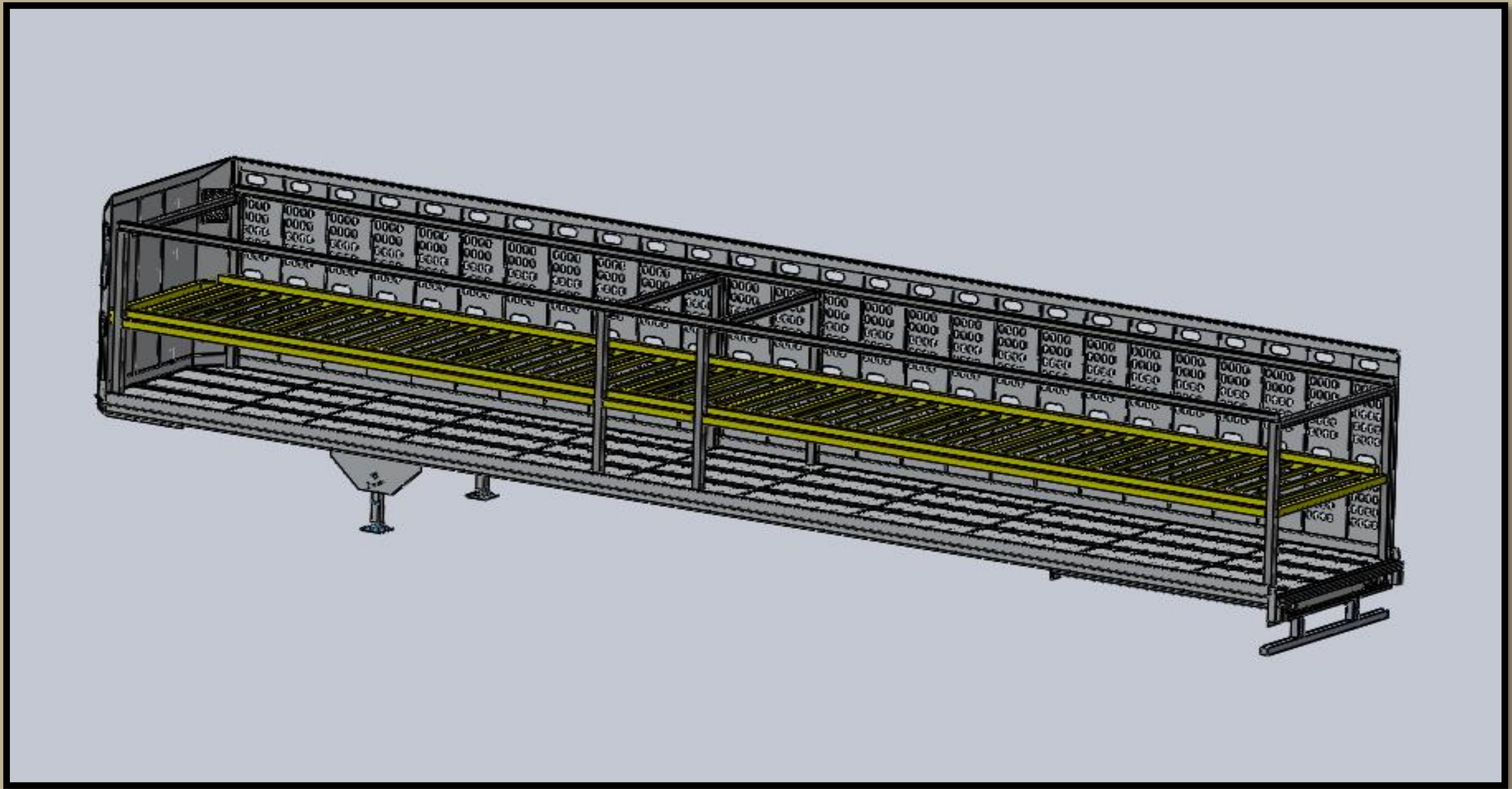


SUB-FRAME AND CYLINDER

- The sub-frame is used on all trailers to connect and support the axles.
- Similar to existing one, but this one has been redesigned to withstand the reaction forces from the cylinder.

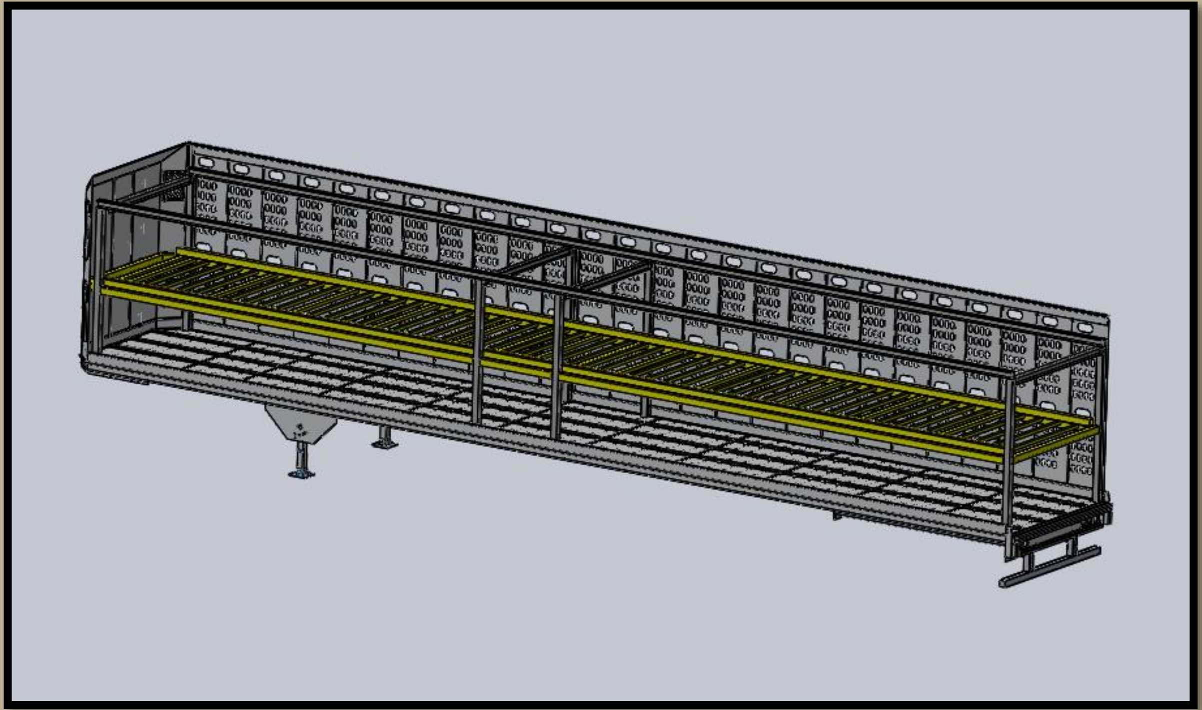


LIFTING FLOOR

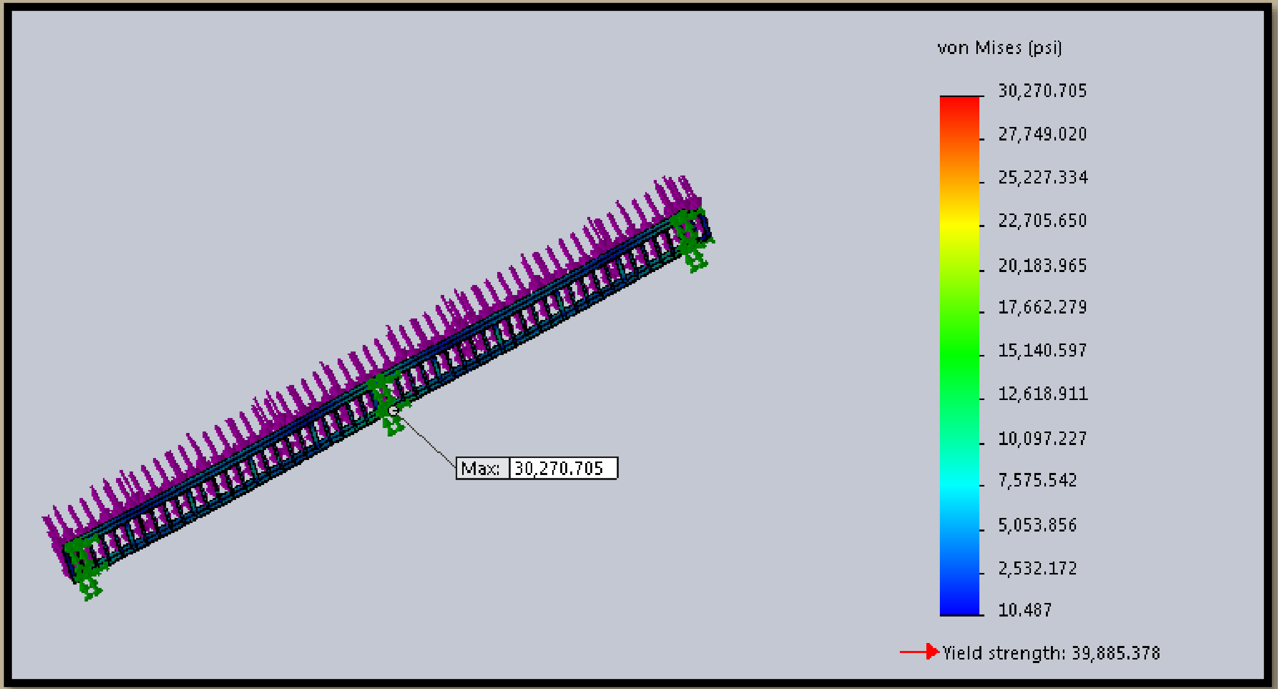


LIFTING FLOOR

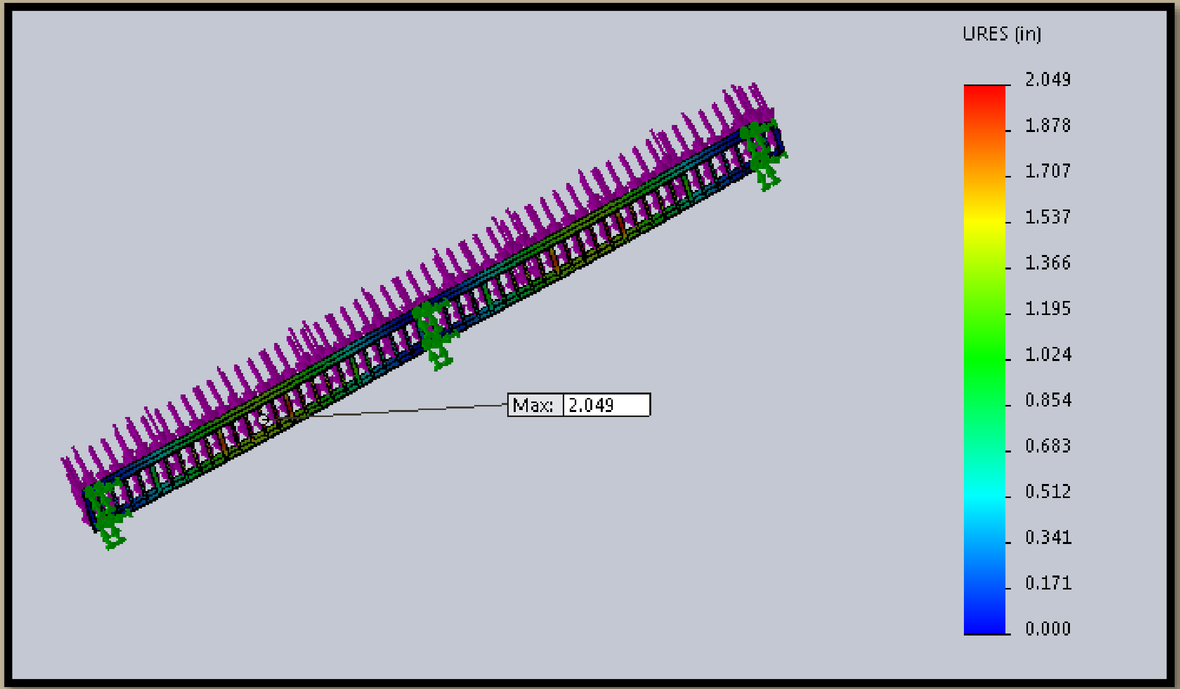
- ➢Trolley design for lifting stability.
- ➢Lifting safety locks.
- ➢Lifting points.
- ➢Cutouts in floor
- ➢Extra support



LIFTING FLOOR STRESS ANALYSIS



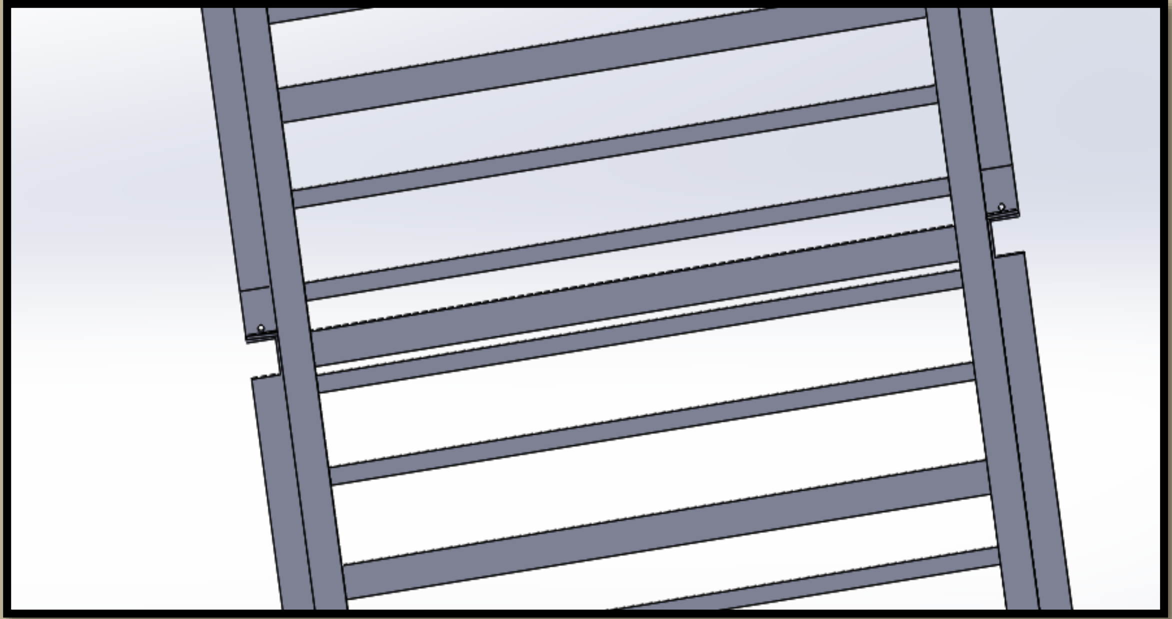
- ➢ Stress plot of center lifting floor
- ➢ 6 fixed points on the floor
- ➢ 60,000 pound load force
- ➢ Max stress is 30,271 psi



- ➢ Displacement plot of center lifting floor
- ➢ 6 fixed points on the floor
- ➢ 60,000 pound load force
- ➢ Max displacement is 2.049 in

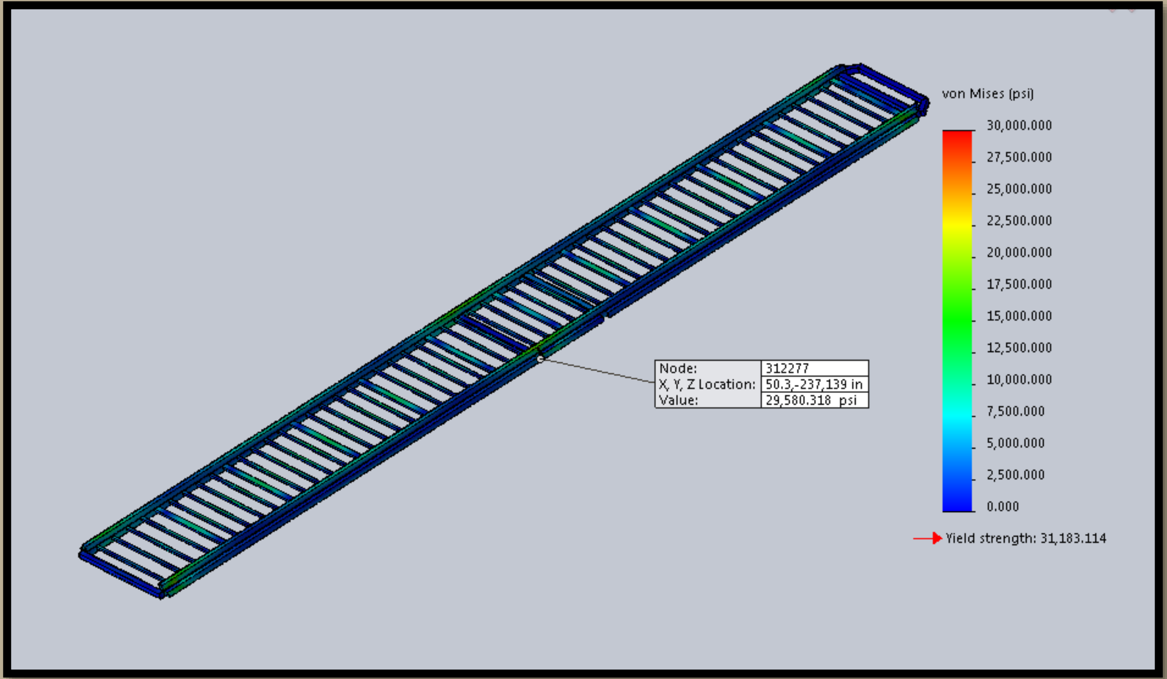
LIFTING FLOOR WITH CUTOUTS

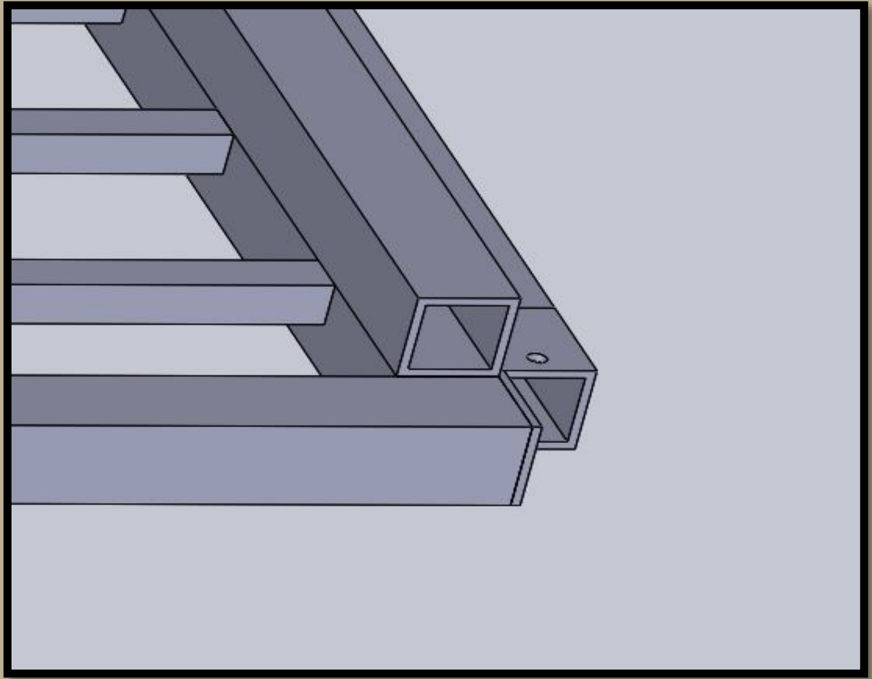
- To minimize space lost on the floor due to the structure, we made cutouts in the floor for the structure’s I-beams to go through.
- Cutouts are 4in. deep by 4.5 in. wide.
- With these cutouts we lose almost all the floor strength.



LIFTING FLOOR WITH CUTOUTS ANALYSIS

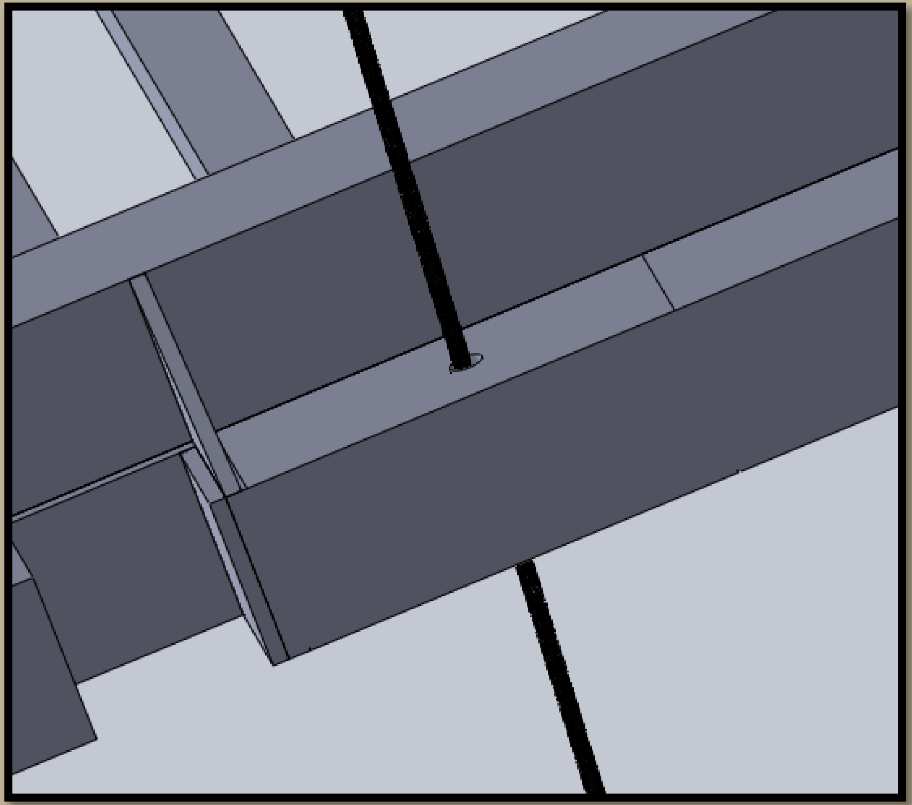
- To strengthen, 4X4 beams were added on the inside of the floor length
- The open end of the middle lifting point is caped, and a gusset was added to disperse the load at that point.


Node: 312277
X, Y, Z Location: 50.3,-237,139 in
Value: 29,580.318 psi



LIFTING POINTS

- There are 6 lifting points in total
- Cable goes through the 4X4 and is fastened underneath
- The two end lifting points are 1 inch from the edge
- The middle lifting point is 6 inches from the edge



SAFETY LOCKS CONCEPT

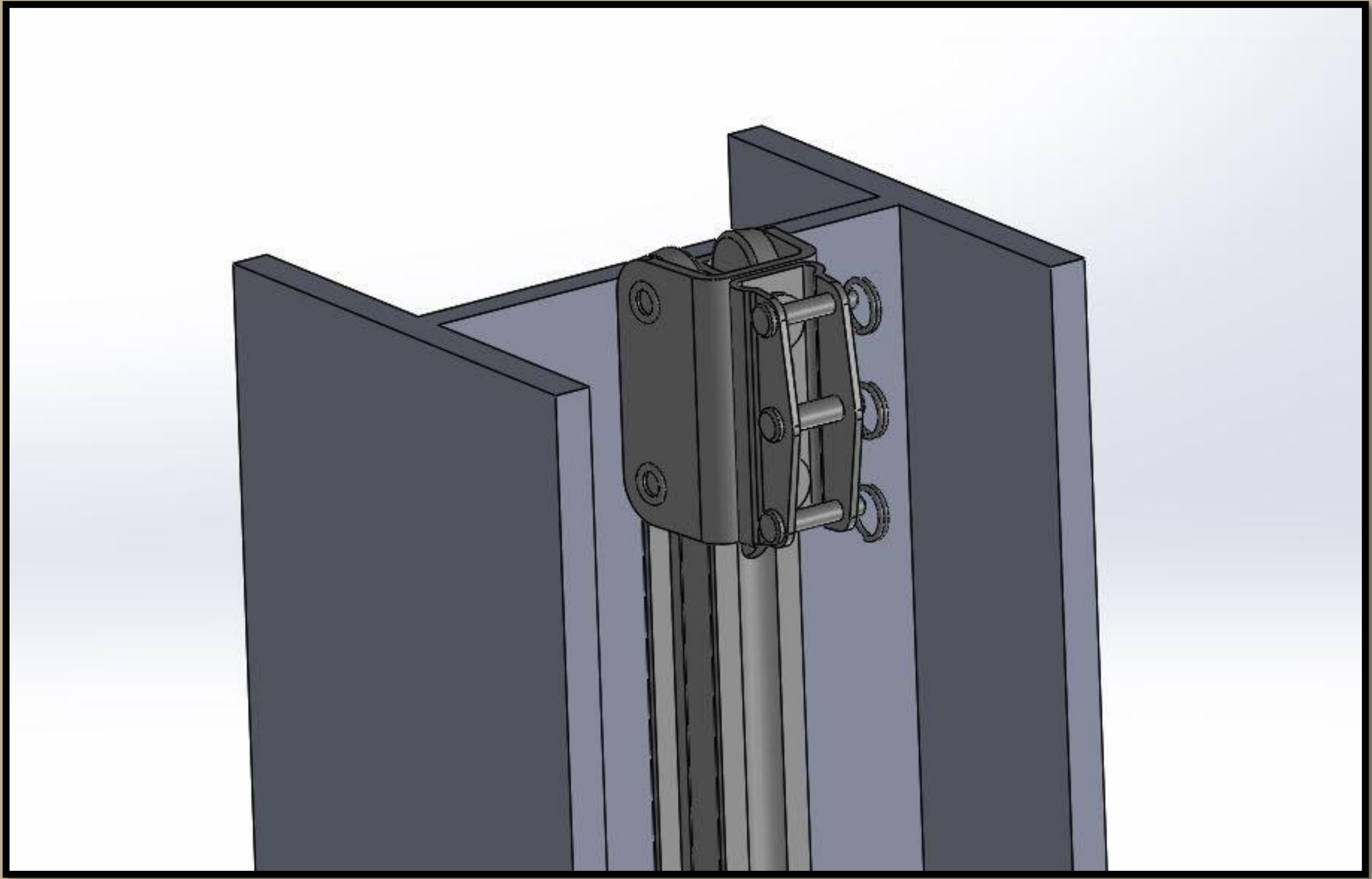
- Housing made of aluminum.
- Pin and shaft made of steel.
- Engaged incrementally.
- Disengaged pneumatically.

RIDE HEIGHT LOCKS CONCEPT

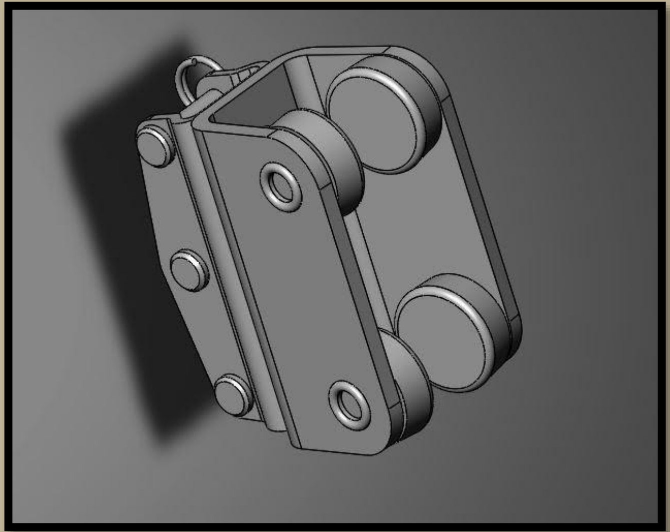
SAFETY LOCKS FOR LIFTING FLOOR

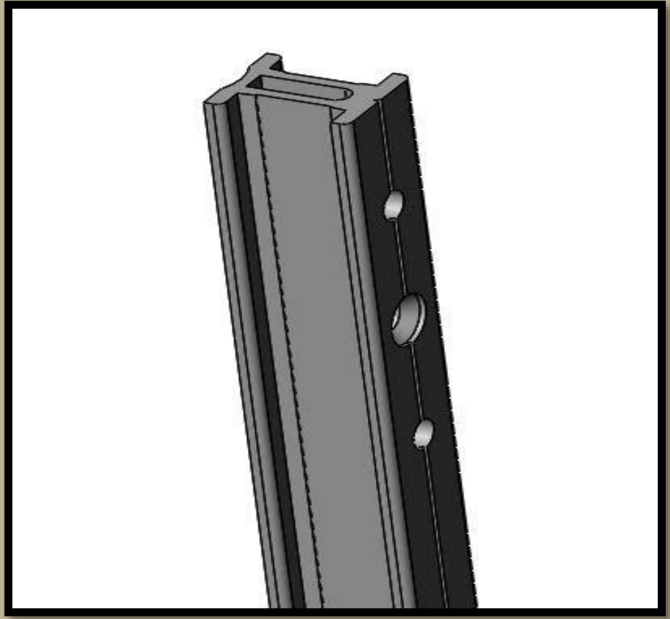
- Lock system in case of cable failure
- Can be pneumatically engaged and disengaged
- Locks at multiple elevations so cable failure at any level will secure the floor

FLOOR GUIDE SYSTEM



FLOOR GUIDE SYSTEM





- Simple guide system designed to help the floor lift smoothly.
- Constructed of corrosion resistant material.
- Rail bolts onto aluminum I-beam.
- Brushes, or scrapers may need to be attached to prevent build up of debris.

IN CONCLUSION

- The Elevated Engineering team has weighed all options and done numerous calculations in order to believe the hydraulic cylinder and cable system to be the best option to complete the fore mentioned tasks. This method reduces lost floor space and is capable of lifting the required 35,000 lbs. Combined with the safety mechanisms mentioned, the hydraulic cylinder and cable system can propel Barrett Trailers into a new market for a different type of product.

QUESTIONS?

ELEVATED ENGINEERING

BARRETT TRAILERS

Jodi Vinyard, Shelby Weber, Gage Martin, Kade Coulter
OSU | SENIOR DESIGN

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Background

Barrett Trailers, LLC began production in Oklahoma City, Oklahoma forty two years ago in 1973. Since then, they have moved from Oklahoma City to Purcell Oklahoma and have expanded their trailer facility substantially. Barrett Trailers are used to haul different varieties of livestock all over the United States. The high quality trailers have also been exported to countries outside the United States including: Africa, Australia, China, Europe, Mexico, Russia and South America. “Barrett livestock trailers are legendary for being the most rugged, easy pulling, and long lasting trailers that are on the market”. In today’s livestock trailer industry few competitors have designed, marketed and sold trailers that have center lifting floors. Several companies overseas have developed a center lifting floor Milson Livestock Trailers located in London and Pezzaioli Livestock Design located in Ireland. Barrett Trailer’s wants to lead the way into revolutionizing the semitrailer industry. Animal rights activists are proclaiming that the quality of meat is affected by the current way of transportation for different varieties of livestock. Currently when livestock is loaded into semitrailers, there is a ramp that leads to the top of the trailer where livestock is hauled. Activists are proclaiming that forcing livestock to climb the ramp is stressing the animal and therefore decreasing the quality of meat consumers buy. An additional convenience of having a center lifting floor is the cleaning that is necessary. By being able to completely raise the floor the operator can walk upright through the trailer and is able to clean the trailer much easier, whether that be manually or with the assistance of larger equipment.

Introduction

Elevated Engineering of Stillwater Oklahoma, will be working alongside Barrett Trailers, LLC of Purcell Oklahoma for the next year. The team is designing a livestock semi-trailer that has a center lifting floor capable of lifting a fully loaded top portion of the semitrailer to the roof of the trailer and to the bottom of the trailer. Throughout the course of the year there will be different ideas and designs that are built and constructed using SolidWorks, research upon different lifting mechanisms, Oklahoma Department of Transportation literacy reviewed as well as seeking council from both Barrett Trailers and other project engineers involved. Within this report there will be ideas that could provide the necessary requirements for our design as well as ideas that have failed to complete the requirements.

Barrett Trailer's LLC approached Elevated Engineering with a question about designing a center lifting floor within a livestock semitrailer. The trailer has to be able to go from the bottom of the semitrailer to the roof of the semitrailer, moving approximately eight feet. The goal is to be able to lower the lifting floor, load the top of the trailer, raise the floor and then load the bottom of the trailer. The lifting floor has certain criteria that must be met such as safety of both livestock and the operator, corrosive resistant, even movement of the floor to prevent unnecessary wear and tear upon the lifting mechanism, as well as being cost efficient.

Scope of Work

Elevated Engineering will be working with Barrett Trailers, application engineers and other engineers from the state and Oklahoma State University to successfully design, build and test a solution for the task. That will include any modeling, testing, literature review, technical analysis, patent searching, safety implementation and oversight of manufacturing. The design team will be responsible for finding a way to move the gates on the first floor so that the center floor can drop down. Safety is the biggest motive in our design. The lift has to be able to raise the floor, which will weigh approximately sixty thousand pounds. Not only does it have to lift that amount of weight, but also it has to stay secure in place for long periods, while traveling long distances. A concern that Elevated Engineering has for the livestock as well as the operator, is how to keep unwanted appendages out of the side vent system. Design of safety devices will be a big part of the project for the engineering team. Barrett Trailers will review Elevated Engineering's design, and once satisfied, will begin manufacturing the system according to the specifications provided. After manufacture of the trailer, Elevated Engineering will be taking over testing of the mechanism to ensure that all criteria is achievable.

Work Breakdown Structure

WBS 1.0 Design Center Lifting Floor

1.1– Review Requirements

Floor must raise, and lower 60000 lbs. Must be safe for the livestock, and the operator. Design must optimize the amount of space available on both floors. Trailer has to be safe for highway travel. The end product has to be aesthetically pleasing. Utilization of partition gates must be available.

1.2 – Compare and Contrast Existing Lifting Mechanisms

Weigh the benefits, and hindrances of existing lifting mechanisms as they apply to this project. Rate them based on lifting capacity, cost, power requirements, spatial requirements, and complexity.

1.3 – Design Center Lifting Floor

Design center-lifting floor based on the requirements stated in WBS 1.1. If necessary, implement ideas gathered from WBS 1.2.

WBS 2.0 Documentation

2.1 – Drafting

Complete Solidworks drawing of center floor that will be lifted. Complete Solidworks drawing of any necessary parts for manufacture.

2.2 – Modeling and Testing

Complete stress analysis on center lifting floor to determine least number of lifting points. Determine structural rigidity of entire trailer shell with center floor detached from the structure. Model lifting mechanism for proof of concept. Test design for partition gates. Test design concepts for safety mechanisms.

3.0 Engineering Review and Client Approval

3.1 – Review and Approve Engineering

Review the engineering involved in the design of the trailer in order to ensure that no errors were made.

3.2 – Seek Client Approval

Meet with client to present preliminary designs.

4.0 Manufacture of Trailer

4.1 – Assist Barrett Team with Manufacturing

Assist Barrett with any technical knowledge needed for manufacture of the lifting mechanism.

4.2 – Monitor Manufacture of Trailer

Routinely check in on progress of manufacturing in order to ensure design specifications were adhered to.

5.0 Final Testing

5.1 - Test Trailer

Put center floor under load, and actuate floor to maximum elevation. Determine that all safety mechanisms are functioning properly. Test gate design to determine ease of use, and functionality.

Customer Requirements

Barrett Trailer's presented Elevated Engineering with specific requirements that the livestock trailer design must meet. Safety of both the operator and livestock is an absolute necessity. The trailer has to have a secure locking mechanism to ensure safety of the livestock while being transported. When loaded the livestock will be moving within the compartments, the floor must not bend or twist while in tow. The design must be efficient in using floor space so that the hauling capacity does not decrease. The lifting mechanism must also lift evenly, if it does not lift evenly it can cause additional wear and tear that does not have to happen. The material that is used to build the floor must be corrosion resistant to prevent the floor from failing and causing major problems. Due to the quantity of livestock that is being transported the amount of waste that is produced is substantial and can corrode metals easily. Barrett Trailers also wanted the operator to have remote access of the floor, so that when they're trying to load the trailer they can operate it as needed. When the livestock trailer is fully loaded, they are at ODOT standard weight limit. The safety factor that is applied to this trailer is 1.7, the amount of weight that is to be lifting is approximately sixty thousand pounds. To help make the floor stronger, the floor could be made thicker. Barrett wants the floor to go from the bottom of the trailer to within eighteen inches of the ceiling, within a ninety second time window. To raise the floor there will have to be a power source, however additionally there needs to be a tactic to unload or load the trailer if there is no power available if the truck dies or some other unpredictable event occurs. Currently, a standard stamping mechanism is used to produce the sidewalls of the trailer. These are a necessary requirement because the livestock needs proper ventilation while traveling.

Legal Requirements

The following are the size, weight, and load requirements for the state of Oklahoma as described by the Oklahoma Size, Weight, and Load Laws, chapter 14. https://www.dps.state.ok.us/ohp/chapter14.pdf

- Size (14-103 Width, Height and Length of Vehicle and Load)
    - Width - No vehicle, with or without load, shall have a total outside width in excess of 102 inches excluding tire bulge and approved safety devices.
    - Height - No vehicle, with or without load, shall exceed a height of 13 feet and 6 inches.
    - Length – On the National Network of Highways, which includes the National System of Interstate and Defense Highways and four-lane divided Federal Aid Primary System Highways and on roads and highways not part of the National System, no semitrailer operating in a truck tractor/semitrailer combination shall have a length greater than 53 feet.
- Weight (14-109.2 Weighing as Single Draft – Axle Load Limit)
    - The overall gross vehicle weight of 80,000 pounds for vehicles operating on the Dewight D. Eisenhower System of Interstate and Defense Highways in accordance with the provisions of Section 14-118 (Movement of Over dimension Vehicles).
    - A total overall gross weight of 90,000 pounds for all other highways in the state of Oklahoma.
- Load (14-109 Single – axle Load Limit)
    - On any road or highway, no single axle weight shall exceed 20,000 pounds.

Project Research

Currently there are two companies that have started to implement similar ideas. Barrett Trailers is hoping to improve on these methods by solving the major issues that the previous designs have brought to light. A company out of Ireland named Pezzaioli has designed a trailer for hauling livestock that has potential but still does not maximize efficiency. The Pezzaioli trailer has a rear partition that raises and lowers like a ramp that is used to load livestock on different levels of the trailer. This trailer has a fully covered siding as to account for pinching safety concerns. The issue with the Pezzaioli trailer is that the siding has no ventilation. This design could not be used in a warmer climate due to the heat exhaustion the animals would be exposed to without the ventilation of the punched or slated side of a Barrett trailer.

Figure 1 shows the outside of the Pezzaioli trailer design.

The second company who is currently working on a prototype of a center lifting livestock trailer is a company out of London named Millson Livestock Trailers. The Millson trailer is a small-scale trailer that uses hydraulics and only allows for hauling any livestock fewer than three feet tall.

Figure 2 shows the Milson trailer design from the rear.

Design Options

In order to compare the many possible lifting mechanisms we will use a zero to five star system based on the following criteria. Each method will be scrutinized based upon its lifting capacity, cost, durability, safety, space requirements, and power requirement.

The Rack and Pinion ★★

Since the floor will be moving vertically, we looked at ways to convert the horsepower of a motor (radial motion) into linear motion. The first method considered was using a rack and pinion method (figure 1). This method is normally considered an older technology that has been passed by or outdated. However, there have been advances made in this technology to improve the system. Previously, the rack and pinion was seen to have poor accuracy. The new advancements now offer high dynamic performance and unlimited travel distance. Another assumption made is that the rack and pinion is unreliable in dirty environments. This is also false today. Usually the mechanism is open to the environment, now there are bellows or covers that can be used to minimize buildup of foreign matter. Rack and pinion mechanisms are now offered in corrosion resistant material such as stainless steel as well (2011, Entwistle). The pros with using the rack and pinion are such that the parts to this system are available in aluminum and stainless steel. The parts can be purchased in many different sizes, hardness treatments, with or without mounting bolts, and there are options to the type of gears available (straight or helical). The cons are that depending on the stress analysis of the trailer itself, we could possible need 4 to 6 different systems for stabilization and each system is costly. For a rack and pinion system that is only 6 feet in height, and made of C45E bright steel, the cost could be upward of $5,000. Keeping in mind that this is not the noncorrosive material we are looking for. Stainless steel or aluminum could end up being even more costly. This method may not meet the low cost requirements depending on the quality and length of rack we may need to raise the center floor to the top of the trailer. Another problem that may come into play with this method is the weight of the rack and pinion systems since a 72-inch rack section weighs almost 200 pounds. Adding 4 to 6 of these systems at 105 inches long, could cause weight problems within the structure and lifting mechanism in the trailer. A heavy weight mechanism may reduce the amount of livestock that is legally within ODOT weight restrictions. For A 10000 lb load it will take a motor with a torque rating of almost 500 lb-ft. Considering the fact that the motor has to travel with the floor, brings the overall rating of a rack and pinion system down.

Figure 3 shows a helical type rack and pinion system

Acme Screw ★★★

The acme screw, or the lead screw as it is sometimes called is a plausible means to lift the floor. A mechanism like this turns the rotational motion of a motor into linear motion.

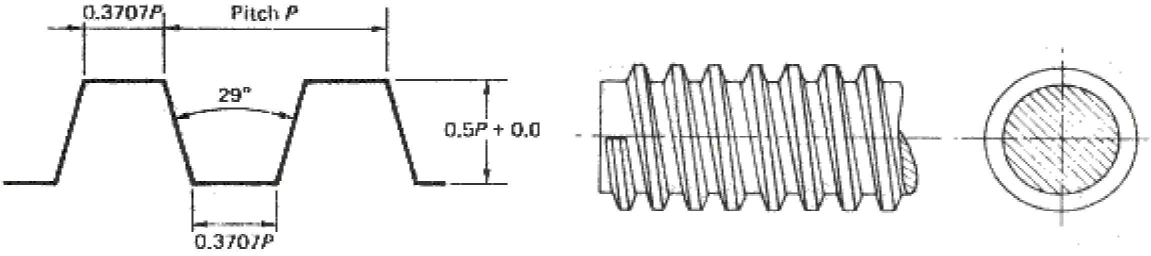


Figure 4 shows a side view, and cross section of typical acme screw.

Unlike a normal fastening screw that has sharp threads, an acme screw has trapezoidal shaped threads. These screws vary greatly in diameter, and pitch, depending on the application. Attached to the screw will be a nut similar to the one in Figure 2 below. When it comes to lifting the floor, we will have the acme screw attached to a motor, and the nut will be fastened to our moving floor.

The acme screw method has its limitations that must be considered. Backlash is one of the main faults, and is the result of space between the threads on the screw, and the threads on the nut. What this does is allows some play in the nut. Since our application will have constant downward vertical force, backlash will not be an issue. Friction is also a problem with lead screw designs. Coefficients vary depending on the materials used for the nut, and the screw. A major benefit to using this method is the low cost. Typical prices for an acme screw suitable to our application are around $31.00 per foot, and go as high as $134.00 per foot for stainless steel. Acme screws also save a ton of space. With our application, the only floor space that will be lost is the diameter of the screw. The power requirements for acme screws are acceptable for our application. A 1.5 in lead screw requires 180 lb-ft of torque to raise 10000 lbs.

Figure 5 shows an example of an acme screw nut.

Multiple Hydraulic Cylinder Systems ★★★

By getting away from radial motion of a motor and moving into positive displacement pumps we minimize the cost of multiple parts to a mechanism. When people think about lifting heavy objects they instantly revert to a hydraulic system. Yes, hydraulic systems are very reliable for their strength, but they have some down falls as well. Most companies that have explored a center lifting floor have used hydraulics to lift the floor. Using hydraulics would be good because it has been tried before so it would be easy to expand on existing ideas. The dilemma with hydraulic cylinders would be that the floor would more than likely bind. That could cause problems with wear on the guides, or the hogs being tossed to one side. The trailer Barrett explained had to continue running the hydraulic pump once it reached the top in order to level the floor (Figure 7). The competitor’s trailer also has roughly half of the hydraulic cylinder hanging below the trailer. It is not a clean look, and looks very unprofessional. Also, the hydraulics took around 45 seconds to complete a full lift. We are looking to do a little better than that. We know we can’t raise the floor too fast for the safety of the hogs, but the Barrett team would like it to move faster than the one they had seen. For a 2-inch rod diameter, 60-inch stroke hydraulic cylinder Bailey International quoted us a price of $529 dollars per cylinder. A 3000-psi hydraulic pump costs around $350. Because of the aesthetics, and the uneven lifting wear issues this system receives three stars.

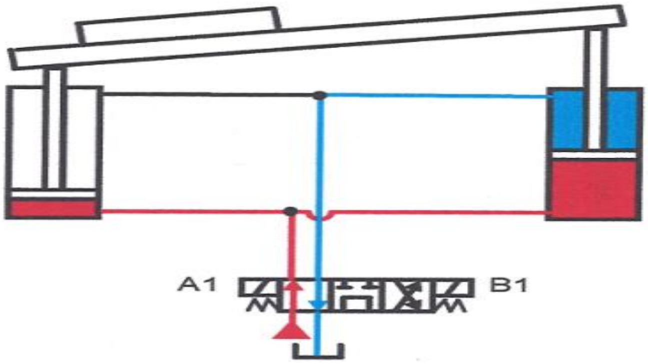


Figure 6 Shows how uneven weight distribution can be problematic in multiple cylinder systems.

Hydraulic and Cable System ★★★★

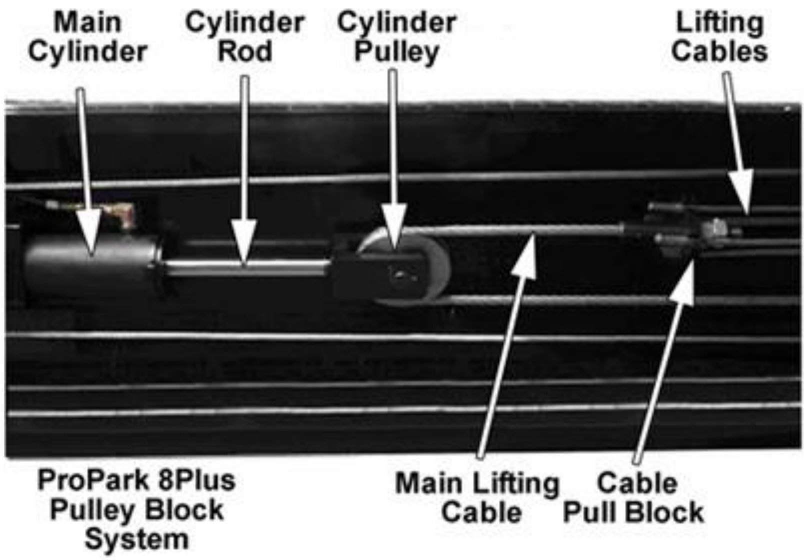


Figure 7 shows a typical cylinder and cable lift mechanism.

The idea of using a single hydraulic cylinder with cables attached to the floor is being categorized as a four star lifting mechanism. Since there will only be one hydraulic cylinder we wont have to worry about the floor moving unevenly. As long as we choose the correct cable lenghts then all corners of the center floor shoud move with the same velocity. This option also saves about the same amount of space as the acme screw option will. A company called Don-Bur from the United Kingdom currently manufactures a cargo trailer with a lifting floor. A video demonstration can be seen at, https://www.youtube.com/watch?v=Sfi_o9-qcbM.

PFlow Industries Lift ★ ★

The lift in the figure below is the F series lift from PFlow Industries. This is an interesting concept that has a heavy duty roller chain attached to a gear reducer. The concern with this method is that it is only capable of lifting 50000 lbs. That is 10000 lbs short of our target capacity. The other concern is not the space requirements along the walls, but the ceiling room required for a set up like this. For those faults this has to be a two star option.

Figure 8 PFlow Industries cargo lift.

Forklift Mechanism ★★

Forklift mechanisms are a good concept for this application. There are a few different types of lifting methods used on forklifts. Lifting the center floor with a device like this is possible, but we run into the same issues as with the multiple hydraulic cylinder set up. If the load gets shifted, the floor will not raise evenly. The mechanism in Figure 9 would also take up a lot more room than the acme screw, or the cylinder/cable combo.

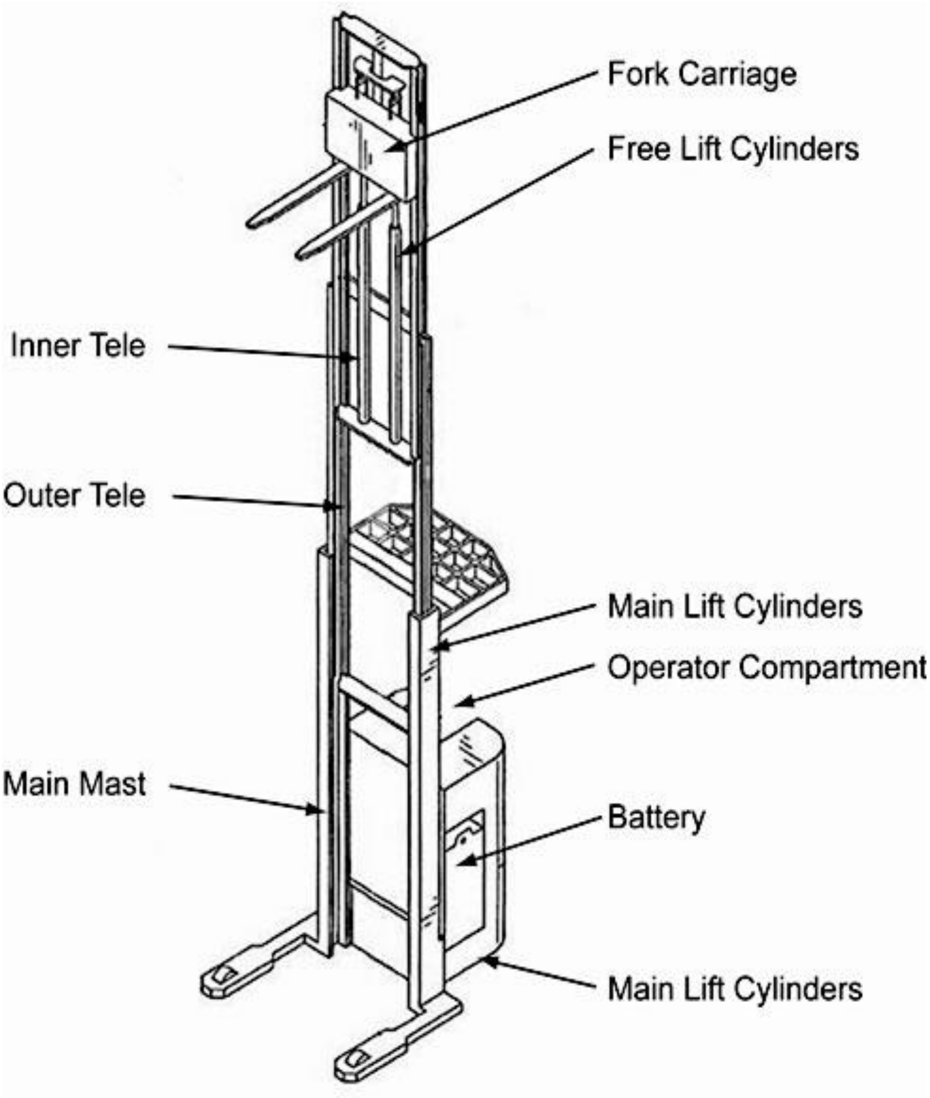


Figure 9 shows a multiple mast forklift.

The lifting method in Figure 10 does present an advantage over the multiple cylinders lifting method. Where with the design of the Riverside Express VerLift using the multiple hydraulic cylinders set up you have roughly a third of the cylinder sticking out of the bottom of the trailer. With the design below, the cylinder would be allowed to sit flush with the bottom deck. Both of these options would be more expensive, because cylinders, chains, and mast assemblies must be purchased. The need for multiple lifting points also multiplies this cost. The power requirements will be consistent with the multiple cylinder lift system. For these reasons, the forklift mechanism receives three stars.

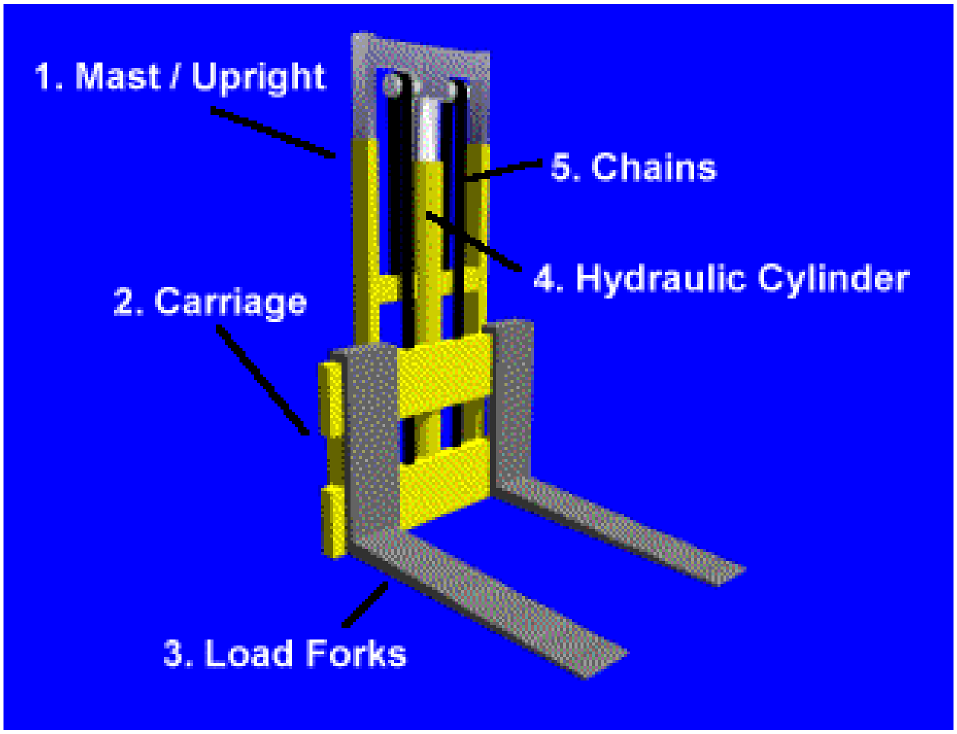


Figure 10 shows a more applicable forklift design.

Scissor Lift ★

Scissor Lifts like the one on the figure below are a common tool for lifting a variety of things. The scissor lift has one major downfall. When the device is in the lifted position there is way too much room taken up in the space below. For our application that gives it an immediate one star because we have to be able to utilize as much floor space as possible.

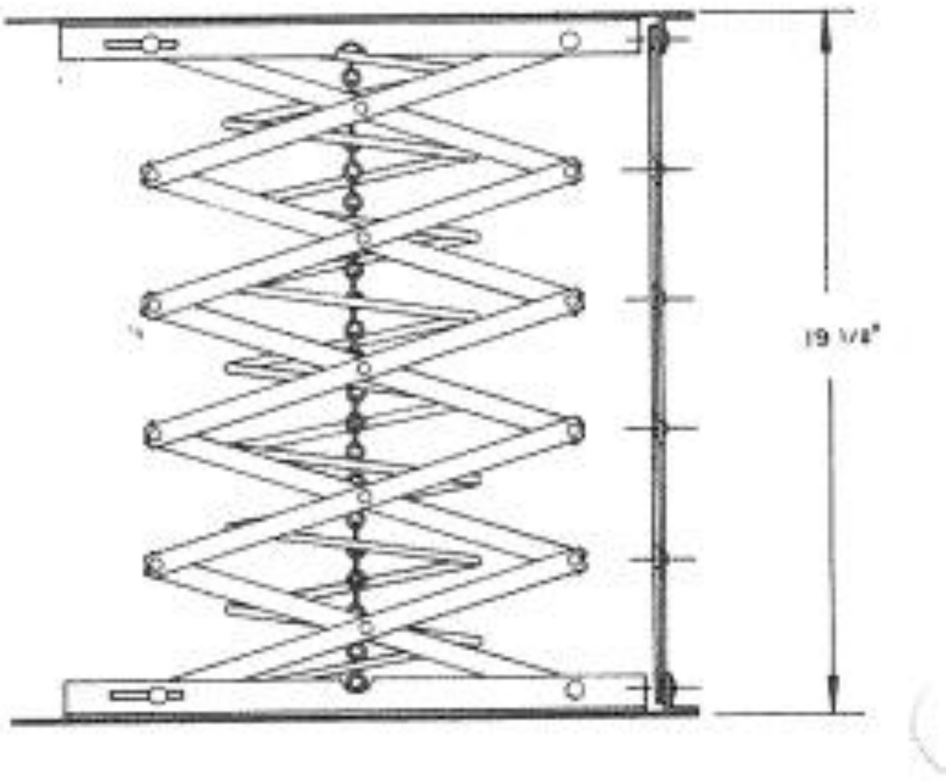


Figure 11 shows an example of a scissor lift.

Four Post Cable and Winch ★★★★

This is a device similar to the hydraulic and cable system. The only real difference is that instead of a hydraulic cylinder actuating the floor, a winch is used. The main concern with this option is compromising between a winch powerful enough to lift the floor, and lifting speed. This method also possesses the space saving capabilities as the acme screw and the cylinder/cable combo. This mechanism receives four stars because it has the potential to be a good solution.

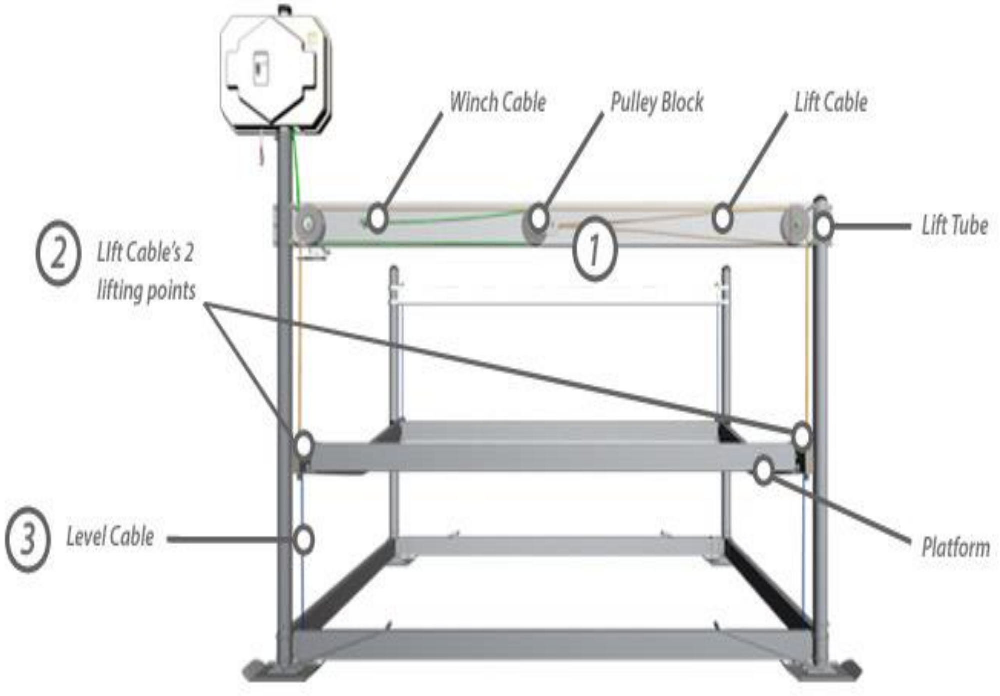


Figure 12 shows a cable winch system.

Patent Research

- Matthew M. Putze, 2000, Lock and release mechanism for vertical adjustable deck in livestock trailers, US 6058885 A
- Raymond W. Blodgett, Jr., Benjamin J. Fletes, 2003, Lift System, US 7377362 B2
- Jeffery Scott Kritzer, 2000, Safety Lock Device for Automobile Lifts, US 6382358 B1
- James J. Taylor, John DeCinque, 1984, Above-the-floor hydraulic lift, US 4457401 A

Environmental Impact

There are a few possible environmental, and economic impacts associated with this project. The first will be the ease of cleaning the trailer now that the floor can be raised. Operators might not be tempted to skip the wash out process. Faster loading, and unloading times could reduce the cost of livestock transportation.

Customer Requirements

Barrett Trailer's presented Elevated Engineering with specific requirements that the livestock trailer design must meet. Safety of both the operator and livestock is an absolute necessity. The trailer has to have a secure locking mechanism to ensure safety of the livestock while being transported. When loaded the livestock will be moving within the compartments, the floor must not bend or twist while in tow. The design must be efficient in using floor space so that the hauling capacity does not decrease. The lifting mechanism must also lift evenly, if it does not lift evenly it can cause additional wear and tear that does not have to happen. The material that is used to build the floor must be corrosion resistant to prevent the floor from failing and causing major problems. Due to the quantity of livestock that is being transported the amount of waste that is produced is substantial and can corrode metals easily. Barrett Trailers also wanted the operator to have remote access of the floor, so that when they're trying to load the trailer they can operate it as needed. When the livestock trailer is fully loaded, they are at ODOT standard weight limit. The safety factor that is applied to this trailer is 1.7, the amount of weight that is to be lifting is approximately sixty thousand pounds. To help make the floor stronger, the floor could be made thicker. Barrett wants the floor to go from the bottom of the trailer to within eighteen inches of the ceiling, within a ninety second time window. To raise the floor there will have to be a power source, however additionally there needs to be a tactic to unload or load the trailer if there is no power available if the truck dies or some other unpredictable event occurs. Currently, a standard stamping mechanism is used to produce the sidewalls of the trailer. These are a necessary requirement because the livestock needs proper ventilation while traveling.

Engineering Specifications

To understand how viable an approach really is, we must compare it to the absolute minimum. Fundamental physics can tell us how much horsepower is required to lift the floor, under a certain load, in a definite amount of time. This will be the minimum condition without mechanical, and frictional losses.

$$Work = Force * Distance$$

$$Work = 60000lbs * \frac{105inches}{12\frac{inches}{foot}} = 525000lb * ft$$

$$hp = \frac{Work}{Time*550}$$

For the floor to travel six feet in 45 seconds, it will travel 105 inches in 66 seconds.

$$hp = \frac{525000lb*ft}{66\ seconds*550} = \boxed{14.5\ hp}$$

By looking at the different options for solving the problem stated above, the Elevated Engineering team looked, in depth, at two mechanisms.

The acme screw is an idea that can fit into this project without violating many constraints. They are small as to save space, efficient, a system of them can be designed to lift simultaneously, and easily made safe. However, as can be seen by the following calculations, require a high-powered motor to operate them at the desired speed. These motors are available but may be costly.

Acme Screw Specifications

Maximum Column Load -

$$P = F(14.03 * 10^6)\left(\frac{d^4}{L^2}\right)$$

F= 4.0 (both ends fixed)

d= root diameter (inches)

L= Maximum distance between support, and acme nut. (Inches)

For six lifting points, each screw must support 10000 lbs.

$$P = 4.0(14.03 * 10^6)\left(\frac{1.196^4}{105^2}\right) = \boxed{10415\ lbs = 5\ \text{Tons}}$$

Critical Rotational Speed -

$$C_s = F(4.76 * 10^6)\left(\frac{d}{L^2}\right)$$

F= 2.23 (both ends fixed)

d= root diameter (inches)

L= Length between supports

$$C_s = 2.23(4.76 * 10^6)\left(\frac{1.196}{105^2}\right) = 1151\ rpm$$

Speed Requirements -

In order to achieve a full lift in 90 seconds

$$\frac{105\ inches}{90\ seconds} = 1.16\ \frac{inches}{second}\left(\frac{1}{0.250\ \frac{inches}{revolution}}\right) = 4.64\frac{rev}{second}\left(\frac{60seconds}{minute}\right) = \boxed{280\ rpm}$$

Torque to Raise Floor (1 of 6 lifting points) -

$$T_R = \frac{Fd_m}{2}\left(\frac{l + \pi f d_m}{\pi d_m - fl}\right) + \frac{F f_c d_c}{2}$$

$F =\ Load\ (lbs)$

$d_m =\ mean\ diameter = \frac{1.5-1.196}{2} = 1.348\ in.$

$l = lead = 0.250\frac{in}{rev}$

$f_c = thrust\ bearing\ friction\ coefficient = 0.0018$

$f = screw\ friction\ on\ nut = 0.16$ (Budynas, and Nisbett. Table 8-5)

$d_c = collar\ diameter = 1.5\ in.$

$$T_R = \frac{10000lbs(1.348\ in.)}{2}\left(\frac{\left(0.250\frac{in}{rev}+(\pi*0.16*1.348in.)\right)}{\left(\pi*1.348in.-0.16*0.250\frac{in.}{rev.}\right)}\right)+\frac{(10000lbs*0.0018*1.5\ in.)}{2}$$

$$T_R = 6740*\left(\frac{0.9276}{4.195}\right)+13.5=\boxed{1504\ lbf*in}$$

Torque to Lower Load -

$$T_{\boldsymbol{L}} = \frac{Fd_m}{2}\left(\frac{\pi f d_m - l}{\pi d_m + fl}\right)+\frac{Ff_cd_c}{2}$$

$$T_L = \frac{10000lbs(1.348\ in)}{2}\left(\frac{\left((\pi*0.16*1.348in.)-0.250\frac{in.}{rev}\right)}{\left((\pi*1.348in.)+\left(0.16*0.250\frac{in}{rev}\right)\right)}\right)+\frac{(10000\ lbs*0.0018*1.5)}{2}$$

$$T_L = 6740\left(\frac{0.4276}{4.2749}\right)+13.5=\boxed{688\ lbf*in.}$$

Gear System and Motor Selection (Turning two screws) -

A 15 hp motor running at 2000 rpm produces 473 lb_f*in of torque.

A 7:1 gear reduction gives 3311 lbf*in of torque @ 285 rpm.

This translates to 276 lb_f*ft. of torque.

Using three 15 hp motors is simply too inefficient, when the theoretical minimum is only 14.5 hp for the entire floor.

The cylinder with pulley system poses as a great solution to this problem. It utilizes very little area, and by placing the operating cylinder under the floor of the trailer, it is almost invisible.

<u>Hydraulic Cylinder with Pulley System</u>

GPM Needed for Cylinder Speed

We have a target of 72 inches in 45 seconds.

$$\frac{72 inches}{45 seconds} = 1.6\ inch/sec$$

A 3 stage telescoping cylinder with a 103.75 inch stroke has a volume of 9.1 gallons.

A 10 gpm pump gives, $\frac{9.1 gal}{10\ gpm} = 0.91(min)\left(60\frac{sec}{min}\right) = 54.6\ sec, so\ \frac{103.75\ inches}{54.6\ seconds} = \boxed{1.9\frac{inch}{sec}}$

Cylinder Force

The first stage has a six inch bore. If a 3000 psi max pump is used, then the force output for the first stage is, $F = 3000psi * (\pi * 3inch^2) = \boxed{84823\ lbs}$.

The second stage of the telescoping cylinder uses a five inch bore. The force generated by this stage is, $F = 3000psi * (\pi * 2.5inch^2) = \boxed{58905\ lbs}$.

The third, and final stage of the cylinder has a four inch bore. The force output from this stage is, $F = 3000psi * (\pi * 2inch^2) = \boxed{37699\ lbs}$.

This final stage is below the minimum lifting requirements for the system. Since it is the last stage, the floor will be high enough that the floor should not be loaded.

HP Requirements

$$HP = \frac{gpm*psi}{1714} = \frac{10gpm*3000psi}{1714} = \boxed{17.5\ HP}$$

Using a telescoping cylinder with a pulley system looks to be a promising solution. 17.5 hp is very close to the theoretical minimum, especially when compared with the acme screw application.

After considering both options, it is clear that using a single telescoping cylinder with a pulley system is the most efficient lifting mechanism. There are three different options for powering our system. The first is using a clutch activated hydraulic pump that is mounted on the motor of the truck. The pump will be tied in with the existing serpentine belt system. The next option is using a power take off mated to the transmission. This PTO will drive a gear pump that supplies the necessary flow rate. The third uses a stand-alone power unit that includes the reservoir, hydraulic pump, and gas/diesel fueled motor.

Floor Strength

The floor specifications that were provided to us from Barrett was that the floor was made out of square or rectangle tubing with a corrugated floor. With a safety factor of 1.7 we were loading the floor with 60,000lbs. The stress analysis test proved that the corrugated flooring didn't add much strength to the floor. Running a simulation with the corrugated flooring made the simulation take a very long time, and made the meshing difficult. So, since the floor didn't add much strength to the assembly we ran all simulations without the corrugated floor.

We first wanted to only load the floor with four points to lift the floor, but after running the stress analysis quickly found it would not work. We moved onto 6 points. With just the existing floor, it was not strong enough. We added a 4x4 square tubing beam along both the sides of the trailer floor. With this addition the floor succeeded the stress analysis. The floor displaced a little over 2 in. and had a max stress of about 9,000psi under yield strength for aluminum 6061 as show in figure 10 and 11.

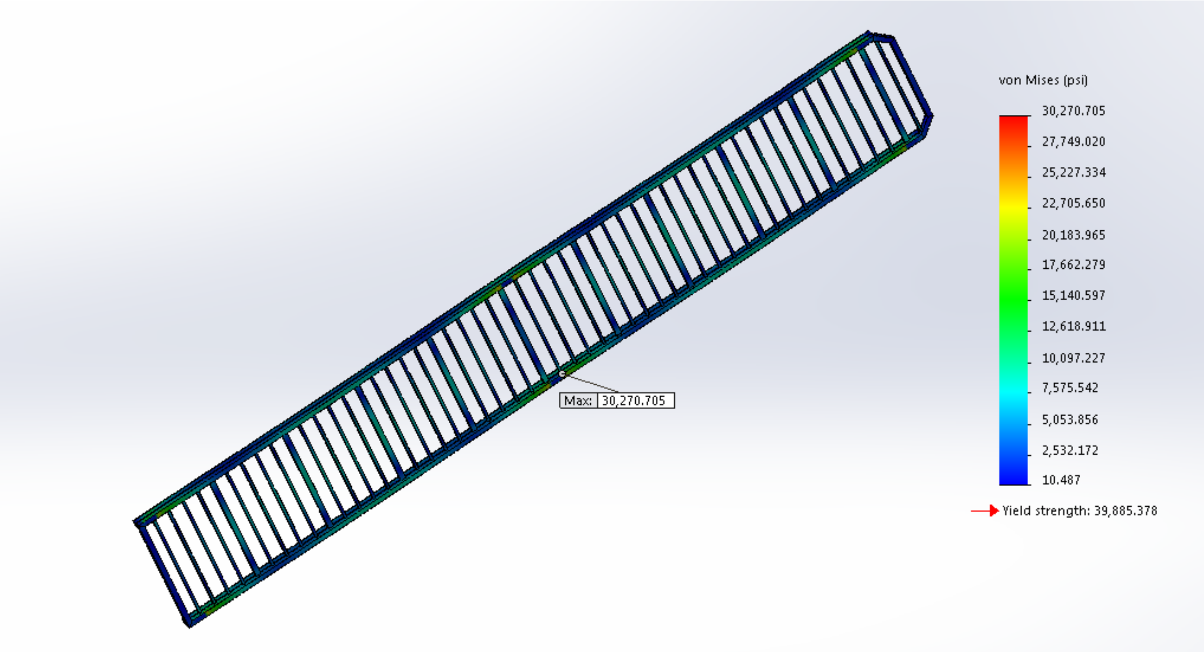


Figure 13 Stress analysis of the floor with a max stress of 30,270 psi.

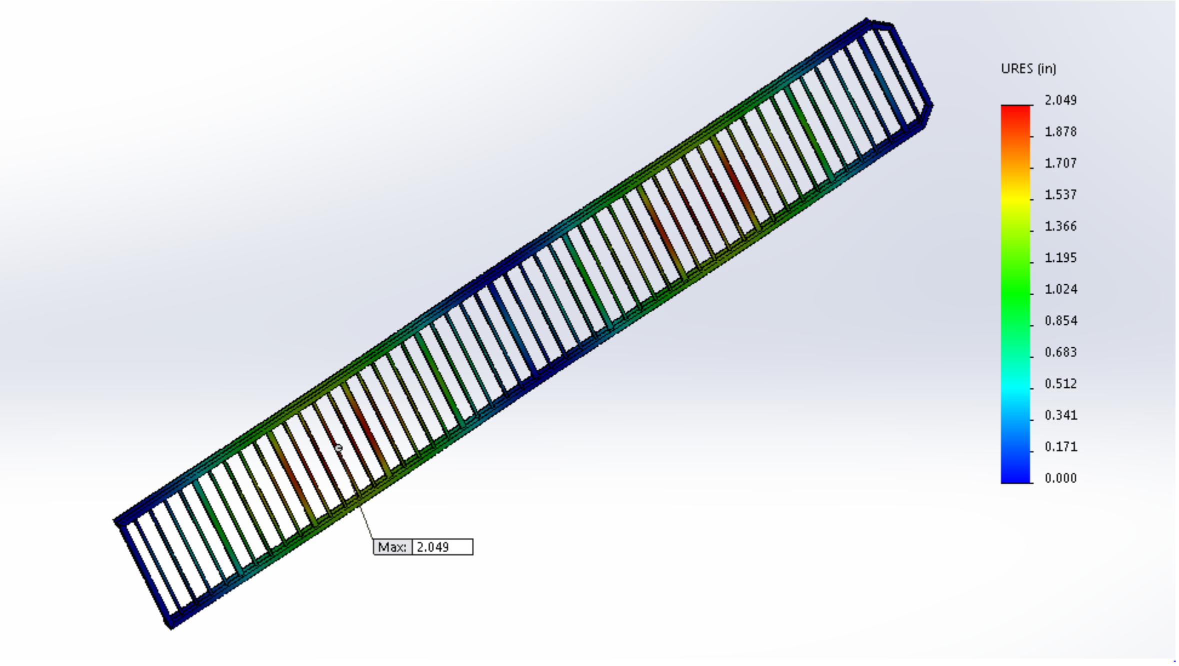
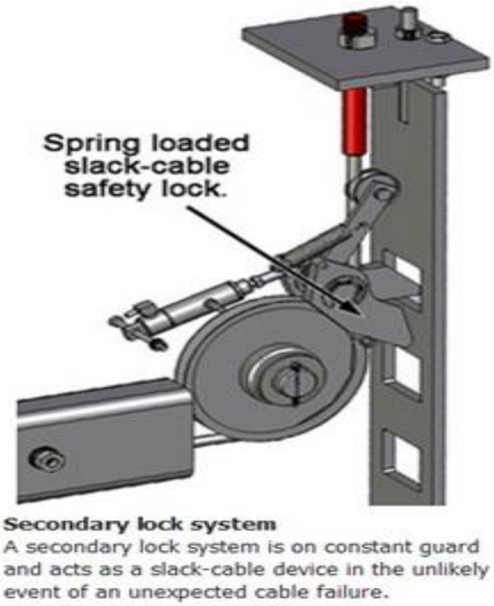


Figure 14 Displacement plot of the floor with a max displacement of 2.049 in

With this information from the stress analysis we can know exactly where the best points to support the floor would be. We will be adding a truss like support on the floor to add more strength and provide a wall around the floor. With the extra support being added, the floor will by far be strong enough to hold up the 60,000 lb load.

Safety Requirements

There are quite a few safety concerns that come along with lifting the floor from bottom to top of the trailer. With whatever option we think is the best to lift the floor, there must be a lot of safety measures taken. The floor has to go up slow enough to not stress out the hogs that will be loaded on the floor. It also has to lock in place as it is going up and down, so it does not come crashing down if the system fails. Another concern is as it is going up or down hogs could stick their nose or legs out of the siding and get it caught. The operator or anyone around the trailer could stick their arm through the side and get it caught as the floor is going up or down.



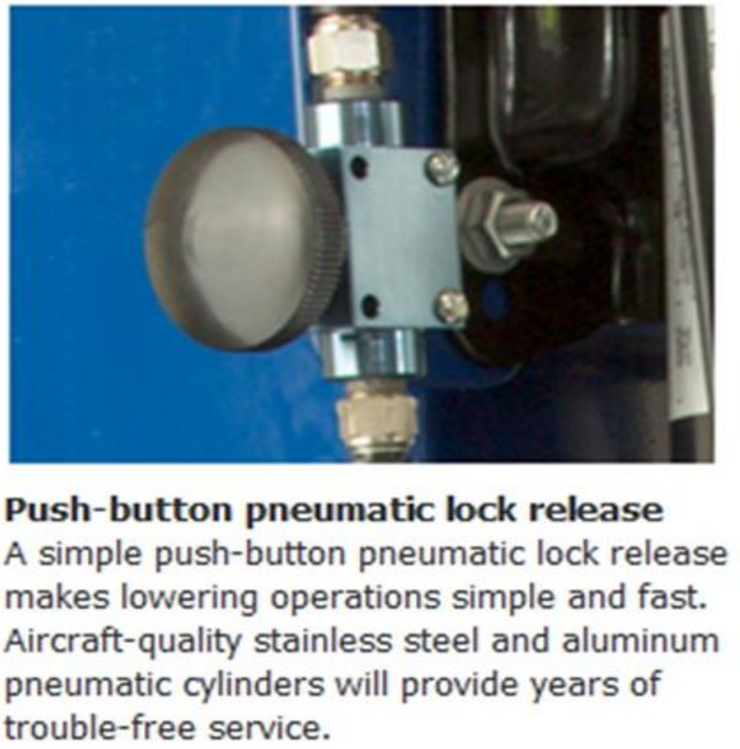
Secondary lock system
A secondary lock system is on constant guard and acts as a slack-cable device in the unlikely event of an unexpected cable failure.

Figure 15 Safety system for cable mechanism

Adjustable height locking positions

Each column features multiple adjustable height locking positions for variable-height parking and infinite leveling. 12" x 10" base plates provide a solid foundation.

Figure 16 Safety system for cable mechanism



Push-button pneumatic lock release

A simple push-button pneumatic lock release makes lowering operations simple and fast. Aircraft-quality stainless steel and aluminum pneumatic cylinders will provide years of trouble-free service.

Figure 17 Safety system using pneumatics

Timeline

Table 1. Timeline of our activities throughout the year.

Task #	Task	Status	Date
1	Patent Research and Analysis	Completed	15 Sept. 15
2	Technical Analysis Report	Completed	2 Oct. 15
3	Statement of Work	Completed	23 Oct.15
4	SolidWorks Drawings and Simulations	In Progress	
5	Design Report	In Progress	
6	Present to Barrett Trailers, LLC		1 Dec. 15
7	Finalize All Design Material		TBD
8	Begin Building at Barrett's Facility		TBD
9	Test and Evaluate Final Product		TBD
10	Present all Data and Information to Barrett Trailers, LLC.		TBD

Prototype Budget

Table 2 Clutch Pump Budget

Part	Manufacturer	Price
Telescoping Hydraulic Cylinder	Custom Hoist	$1,550
Clutch Pump Mounting Kit	CW Mounting Kits	$450
Hydraulic Pump	Northern Tool	$569
Pulleys X 20	Grainger	$384.00
Cable (200 ft)	E-Rigging	$313.50
Materials (Floor guides, and Cylinder mount)	N/A	$1,800
Control Valve	Brand Hydraulics	$150
	Total	$5,217

Table 3 PTO driven option.

Part	Manufacturer	Price
Telescoping Hydraulic Cylinder	Custom Hoist	$1,550
PTO Attachment	Muncie	$950
PTO Hydraulic Pump	Muncie	$435
Pulleys X 20	Grainger	$384.00
Cable (200 ft)	E-Rigging	$313.50
Materials (Floor guides, and Cylinder mount)	N/A	$1,800
Control Valve	Brand Hydraulics	$150
High Pressure Hydraulic Hoses (70 ft.)	Eaton	$560
	Total	$6,143

Table 4 Stand-Alone Power Unit

Part	Manufacturer	Price
Telescoping Hydraulic Cylinder	Custom Hoist	$1,550
Power Unit	Bailey	$950
Pulleys X 20	Grainger	$384.00
Cable (200 ft)	E-Rigging	$313.50
Materials (Floor guides, and Cylinder mount)	N/A	$1,800
Control Valve	Brand Hydraulics	$150
High Pressure Hydraulic Hoses (70 ft.)	Eaton	$560
	Total	$5,708

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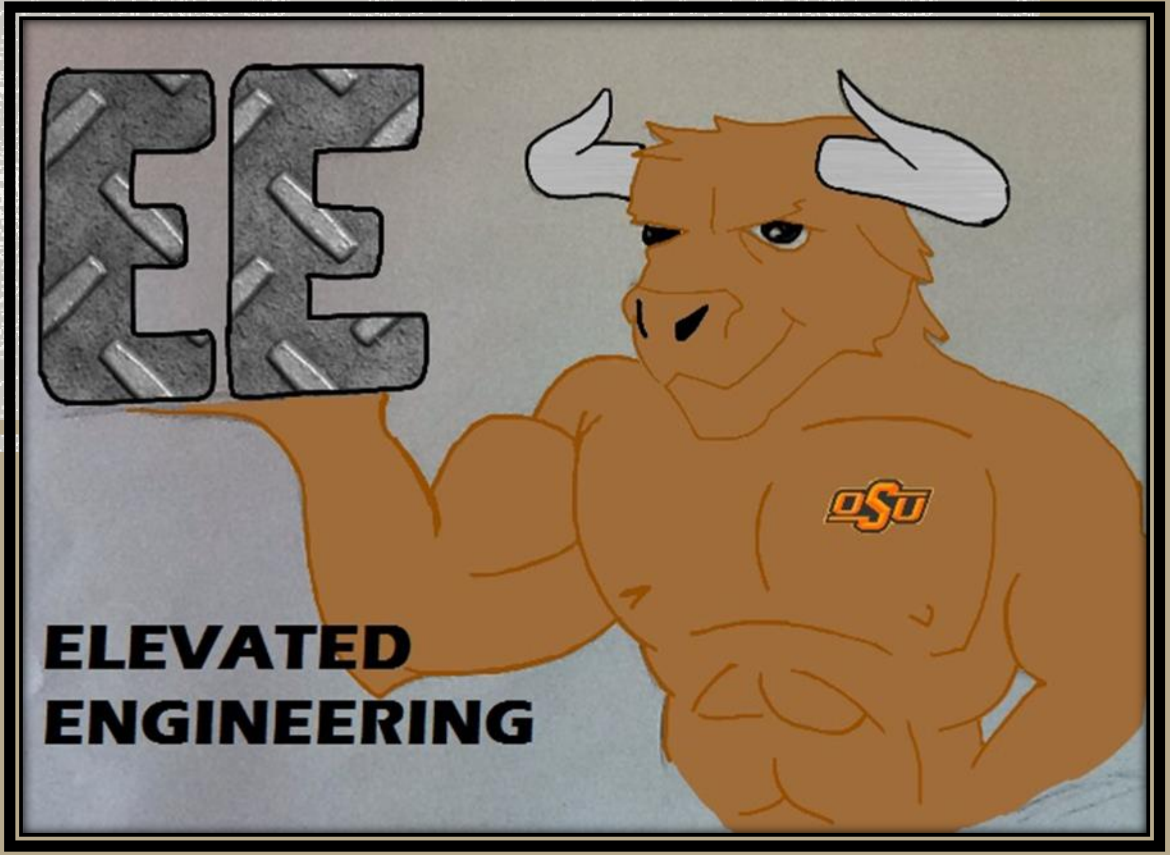
ELEVATED ENGINEERING

Barrett

Fall Presentation
December 1, 2015

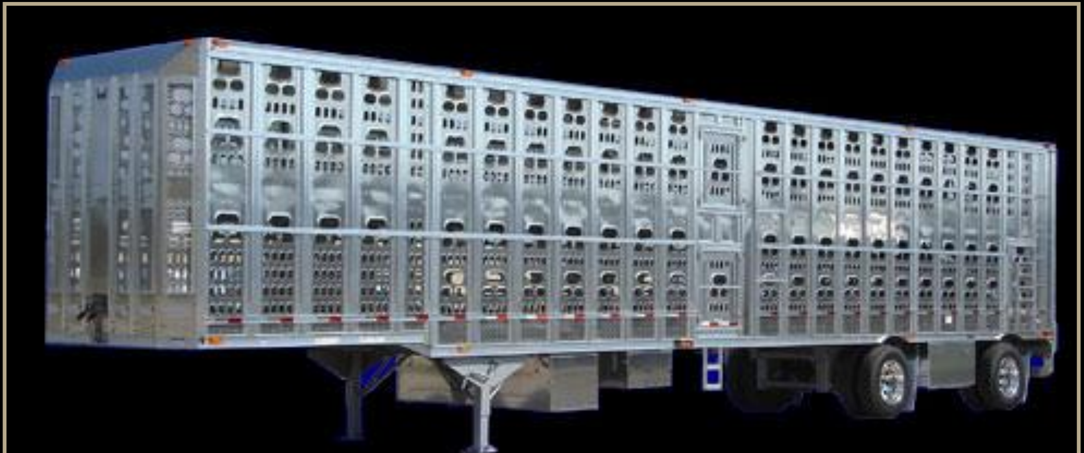


TEAM MEMBERS

- Gage Martin
- Kade Coulter
- Jodi Vinyard
- Shelby Weber

BARRETT TRAILERS, LLC.

Barrett Trailers was conceived in Oklahoma City in 1973. Since then the company has grown and relocated into a 75,000 square foot facility in Purcell, Oklahoma. “Barrett Trailers LLC vision is to be the manufacturer of the finest all-aluminum livestock semi-trailers and stock gooseneck trailers”. With a quality line of products, and an arsenal of motivated employees, Barrett Trailers are a leader in the livestock transportation industry.



6” Drop Double Deck Straight Floor Hog Trailer

http://www.barrett-trailers.com/semi-trailers

PROBLEM STATEMENT

- Elevated Engineering is committed to designing a safe, economical, and innovative means to raise, and lower the center floor of an aluminum livestock pod. The design must minimize floor space lost, and lift the floor evenly to reduce wear on the guides.

CUSTOMER REQUIREMENTS

- Safety for livestock and operator.
- Lifting the floor evenly to prevent unnecessary wear and tear upon the lifting mechanism.
- Corrosion resistant materials.
- Minimal floor space lost.
- Cost efficient.
- Raising the floor in a timely manner.
- Lifting capacity of 60,000 pounds.

Project Requirements	
Basic Lifting Capacity	35,000 lbs.
Safety Factor	1.7
Target Lifting Capacity	59,500 lbs.
Zero to Six Feet Lifting Time	45 seconds
Zero to 8.75 Feet Lifting Time	66 seconds

PROJECT SCOPE

Elevated Engineering will be collaborating with Barrett Trailers, OSU Application Engineer, Oklahoma Manufacturing Alliance, and others from Oklahoma State University on the following tasks.

- ➢ Validation and design of lifting mechanisms.
- ➢ Meeting safety goals
- ➢ Prototype Manufacture
- ➢ Testing

ENVIRONMENTAL/ECONOMIC IMPACT

There are a few possible environmental, and economic impacts associated with this project. The first will be the ease of cleaning the trailer now that the floor can be raised. Operators might not be tempted to skip the wash out process. Faster loading, and unloading times could reduce the cost of livestock transportation.

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DEPARTMENT OF TRANSPORTATION

- Overall gross vehicle weight for Oklahoma highways is 90,000 lbs.
- Gross vehicle weight for interstate systems is 80,000 lbs.
- No height greater than 13 feet 6 inches.
- Trailer length is limited to 53 feet.
- Width no greater than 102 inches.

SIMILAR CONCEPTS

- Pezzaioli Trailers
- Milson Livestock Trailers
- Riverside Express

PEZZAIOLI TRAILERS

- Located in Montichiari, Italy.
- Uses forced ventilation system.
- Floor is divided and each section moves independently.

Source:http://ets2.lt/wp-content/uploads/2014/08/Pezzaioli-Trailer.jpg

PEZZAIOLI TRAILERS

Source:
https://video.search.yahoo.com/video/play;_ylt=A2KLqIHD.VxWHnAAfAP7w8QF;_ylu=X3oDMTByYXI3cnIwBHNlYwNzcgRzbGsDdml
kBHZ0aWQDBGdwb3MDNA

MILSON LIVESTOCK TRAILERS

- Located in West Sussex, England.
- Front two thirds of upper floor is fixed.
- Back one third pivots down to form a ramp.

Source: http://i1.ytimg.com/vi/RMUFzsnDWbY/hqdefault.jpg

MILSON LIVESTOCK TRAILERS

Source:
https://video.search.yahoo.com/video/play;_ylt=A2KLqIKr.1xWRDwARXH7w8QF;_ylu=X3oDMTBycTlydWI1BHNlYwNzcgRzbGsDdmlkBHZ0aWQDBGdw
b3MDOA

RIVERSIDE EXPRESS

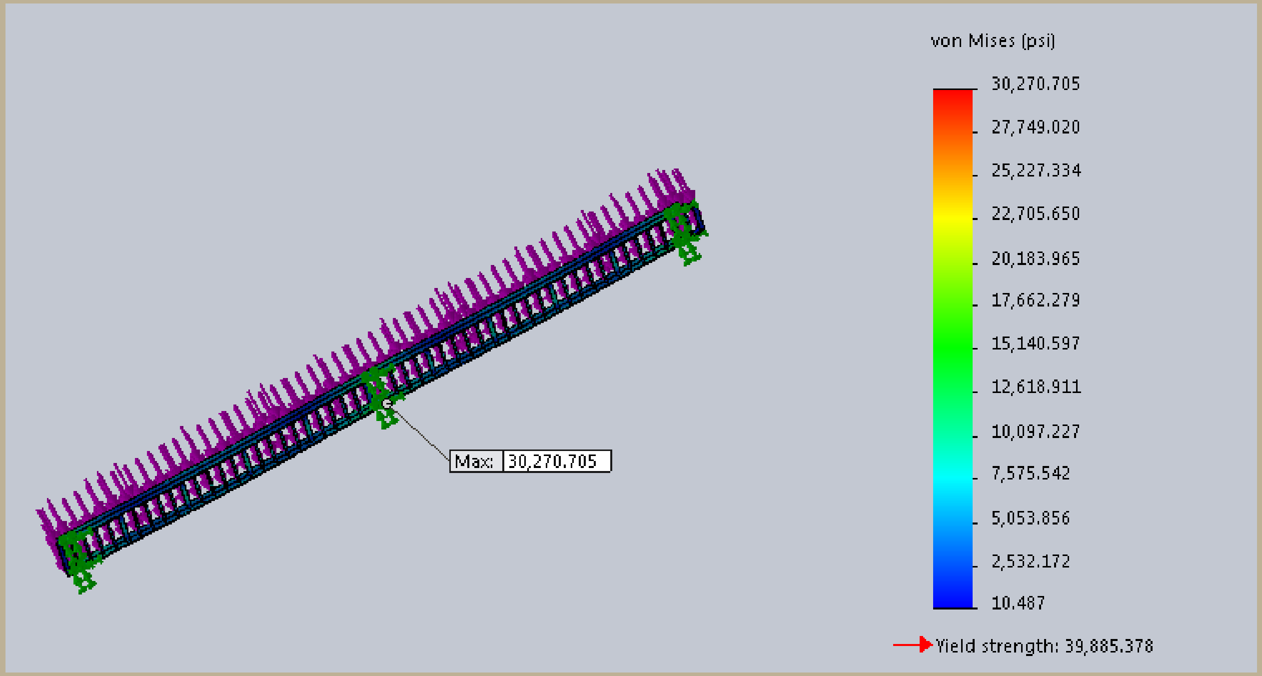
- Located in Hancock, Minnesota.
- Closest in design concept.
- Issues with level floor travel.
- Floor doesn’t raise all the way to the ceiling.

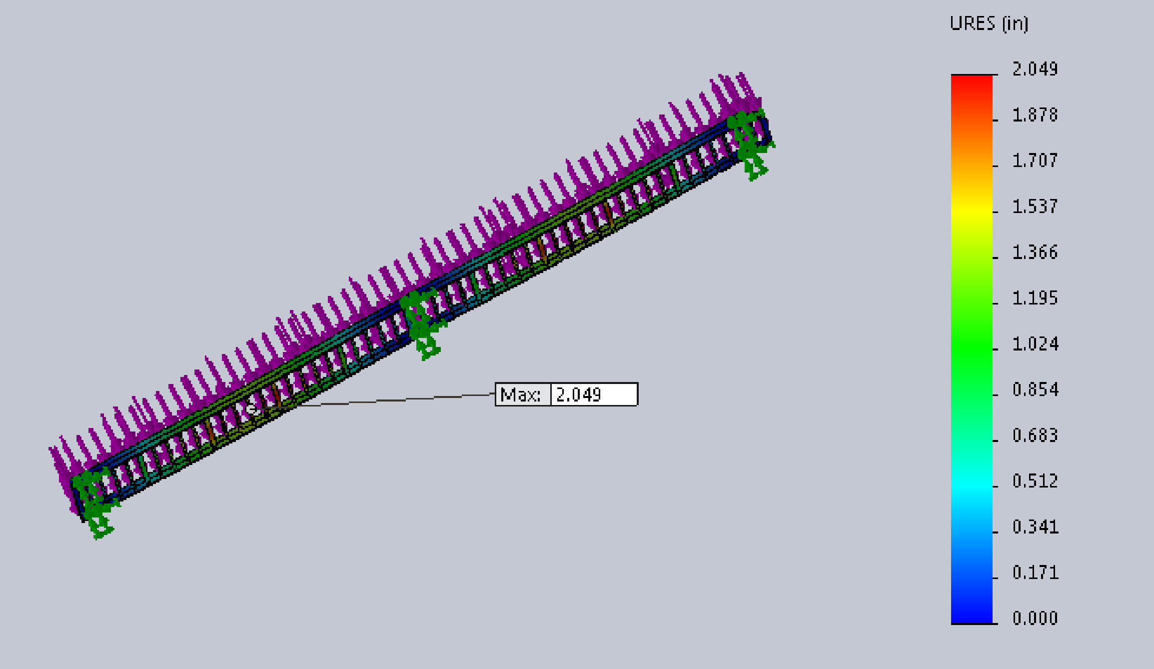
Source: Barrett Trailers

RIVERSIDE EXPRESS

Source: Barrett Trailers

STRESS ANALYSIS





- Stress plot of center lifting floor
- 6 fixed points on the floor
- 60,000 pound load force
- Max stress is 30,271 psi

- Displacement plot of center lifting floor
- 6 fixed points on the floor
- 60,000 pound load force
- Max displacement is 2.049 in

DESIGN OPTIONS

The initial steps to sifting through all of the many different types of lifting mechanisms involved rating them on a five star basis keeping the following criteria in mind.

- Lifting Capacity
- Cost
- Durability
- Safety
- Space Obligation
- Power Requirement

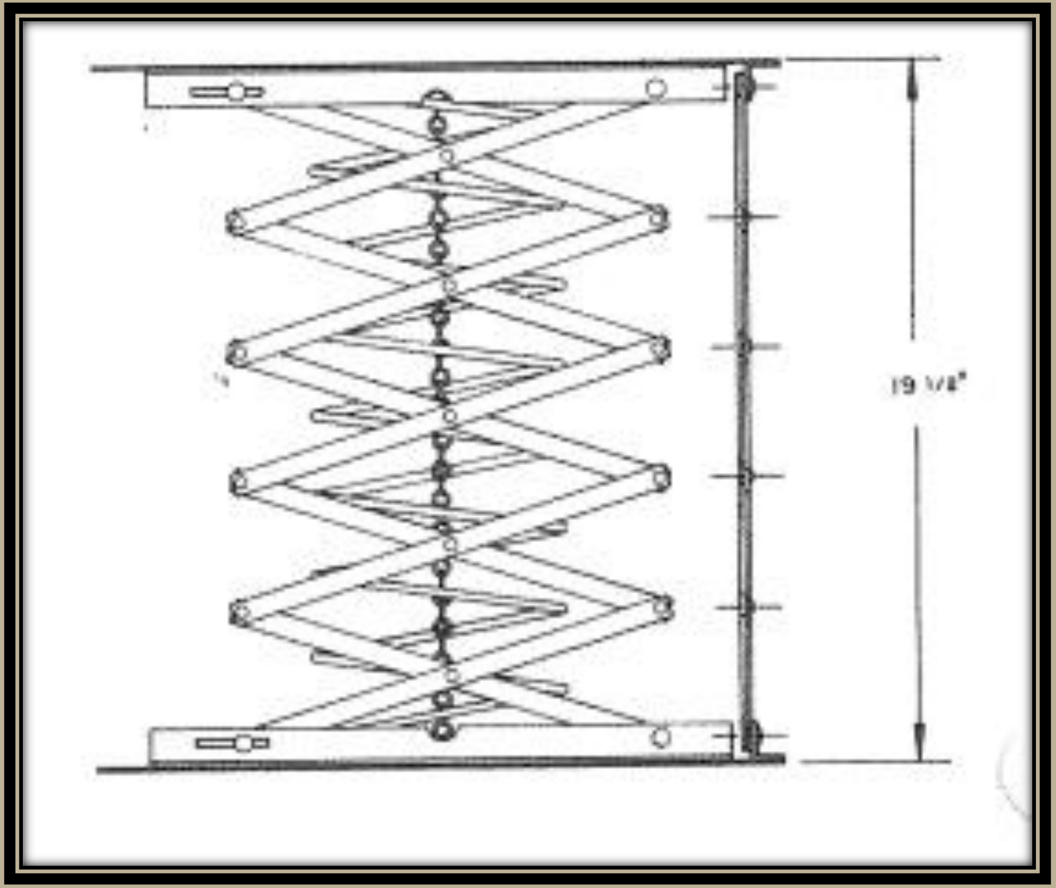
SCISSOR LIFT ★

Pros

- ➢High lifting capacity
- ➢Fast travel time

Cons

- ➢Heavy construction
- ➢Takes up more room than any other option



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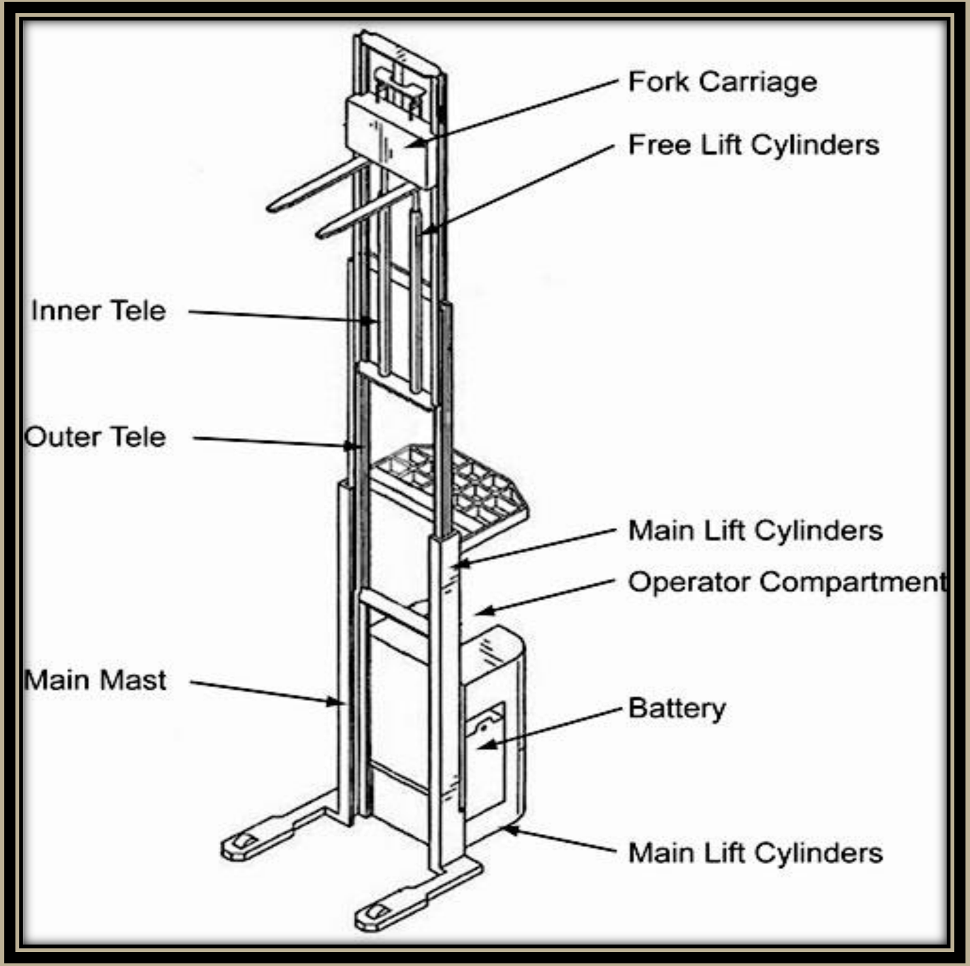
FORKLIFT MECHANISM ☆☆

Pros

- Simple
- High lifting capacity
- Allows cylinder to sit flush with lower floor.

Cons

- Multiple masts require extra materials
- Takes up more space than other mechanisms
- Uneven force distribution



Source: https://sp.yimg.com/xj/th?id

RACK AND PINION ★★

Pros

- Simple
- Non corrosive material available
- Range of travel

Cons

- High Cost
- Heavy
- Foreign debris clogging teeth
- Motor travels with the floor

Source: https://sp.yimg.com/

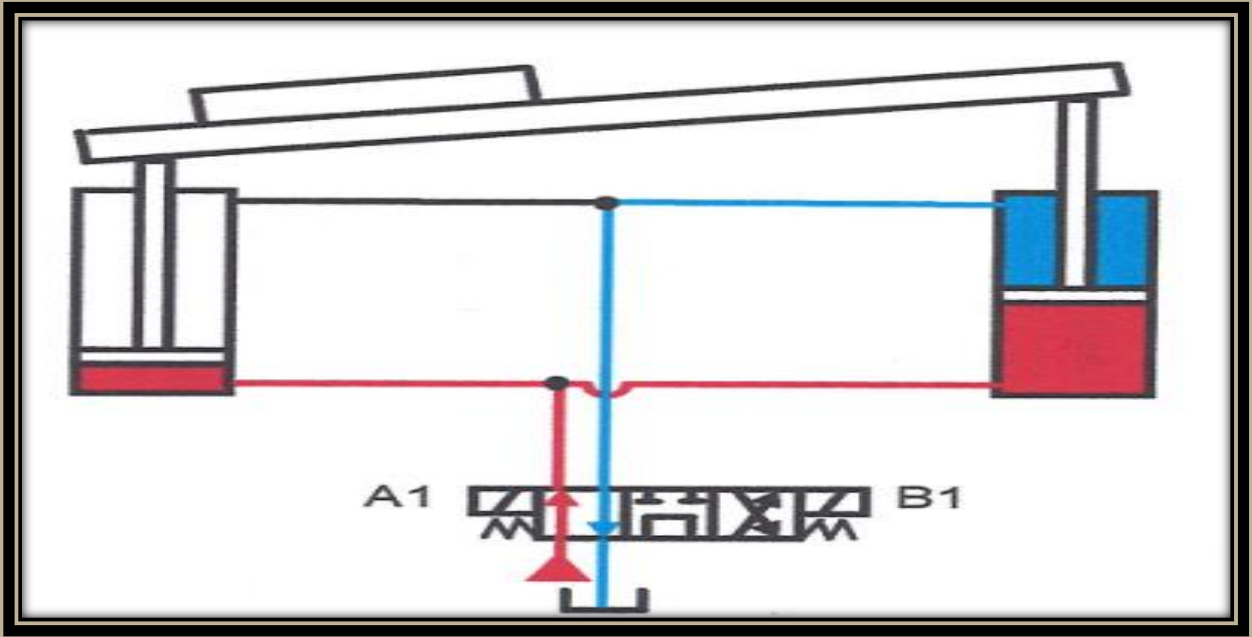
MULTIPLE HYDRAULIC CYLINDERS ☆☆☆

Pros

- Fast lifting
- High load capacity
- Simple design

Cons

- Uneven load distribution
- Smaller lifting range
- Cost of six cylinders



Source: http://insidepenton.com/images/Fig-22-2.jpg

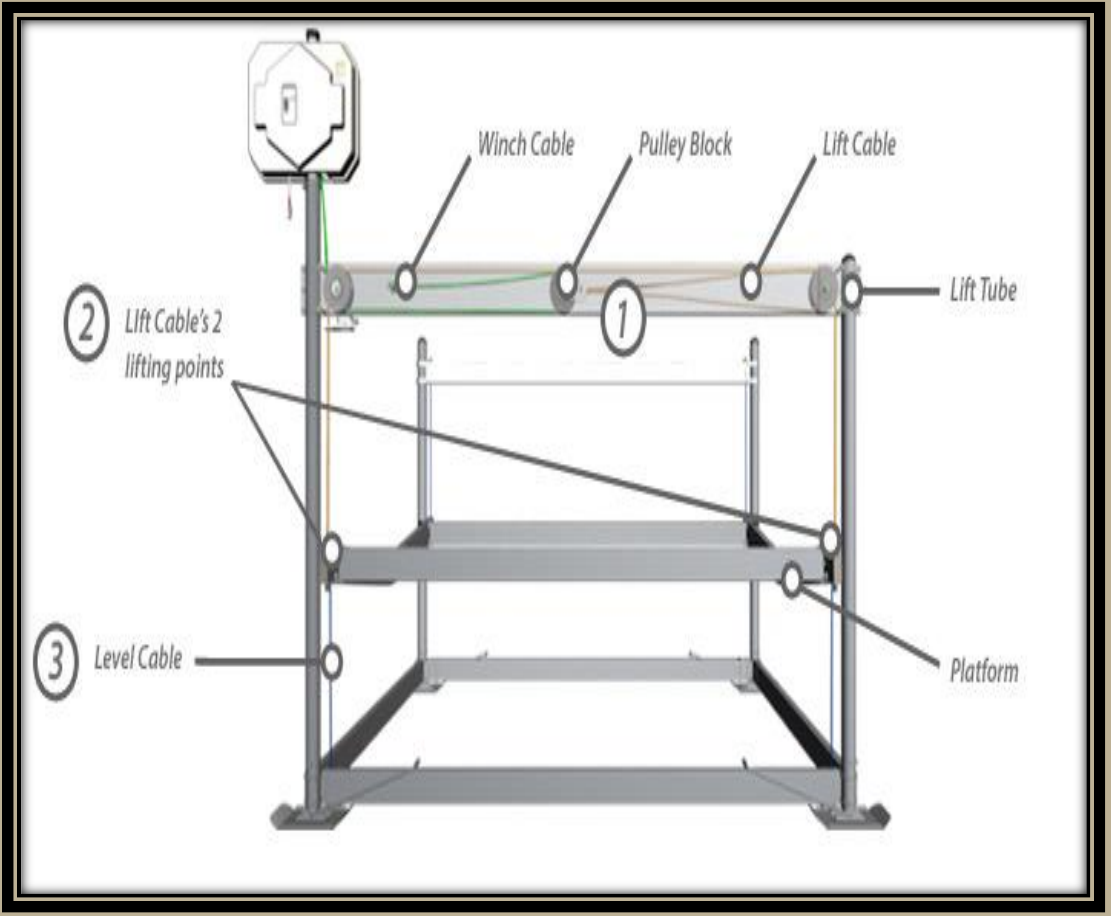
FOUR POST CABLE AND WINCH ★★★

Pros

- ➢Level floor travel
- ➢Low cost
- ➢Safe guide system

Cons

- ➢Powering a winch with the required power at the desired speed.
- ➢Cable life span compared to other mechanisms



Source:
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ACME SCREW ★★★★

Pros

- Level lifting of upper floor
- Requires torque to lower load
- Utilizes little space

Cons

- Friction and wear
- Power requirement

Source: http://www.dnsales.com.au/Product/Resources/imageaspx3.jpeg

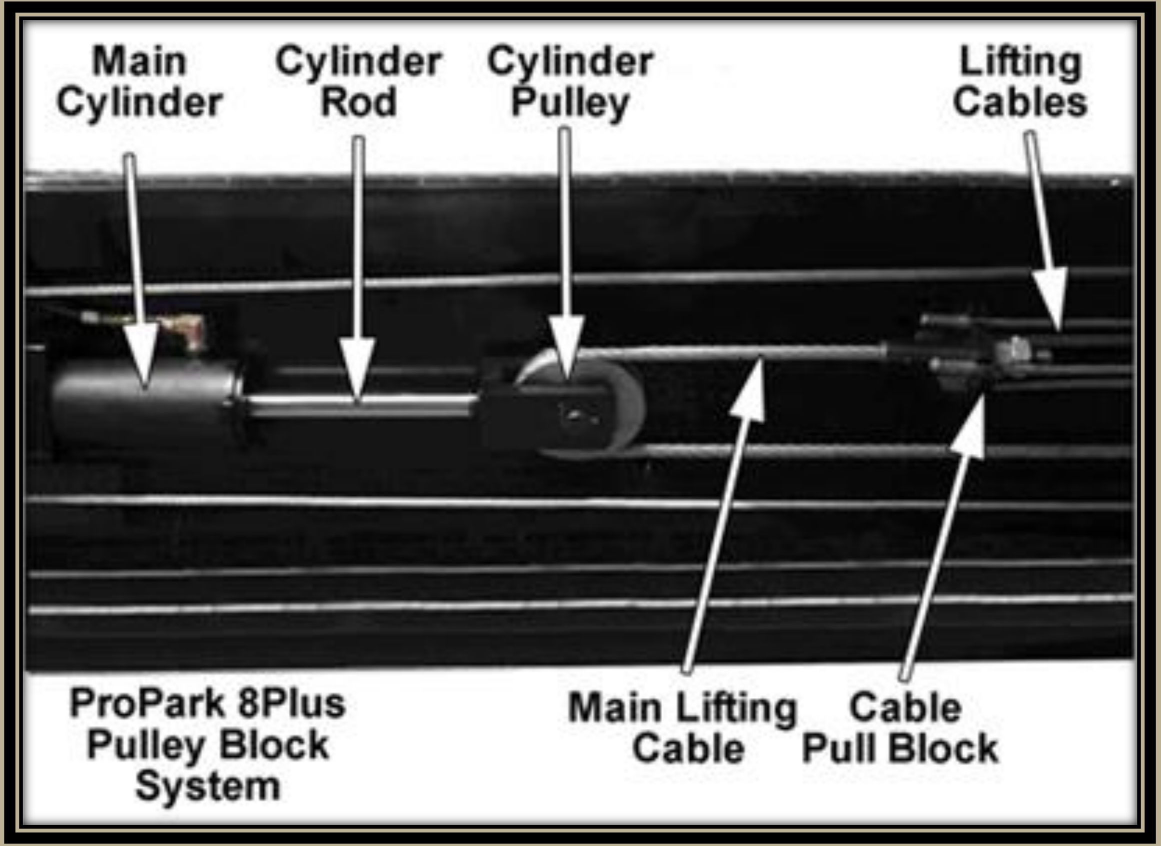
HYDRAULIC AND CABLE SYSTEM ★★★★

Pros

- ➢Single cylinder ensures even lifting
- ➢Low cost
- ➢Much faster lifting times.

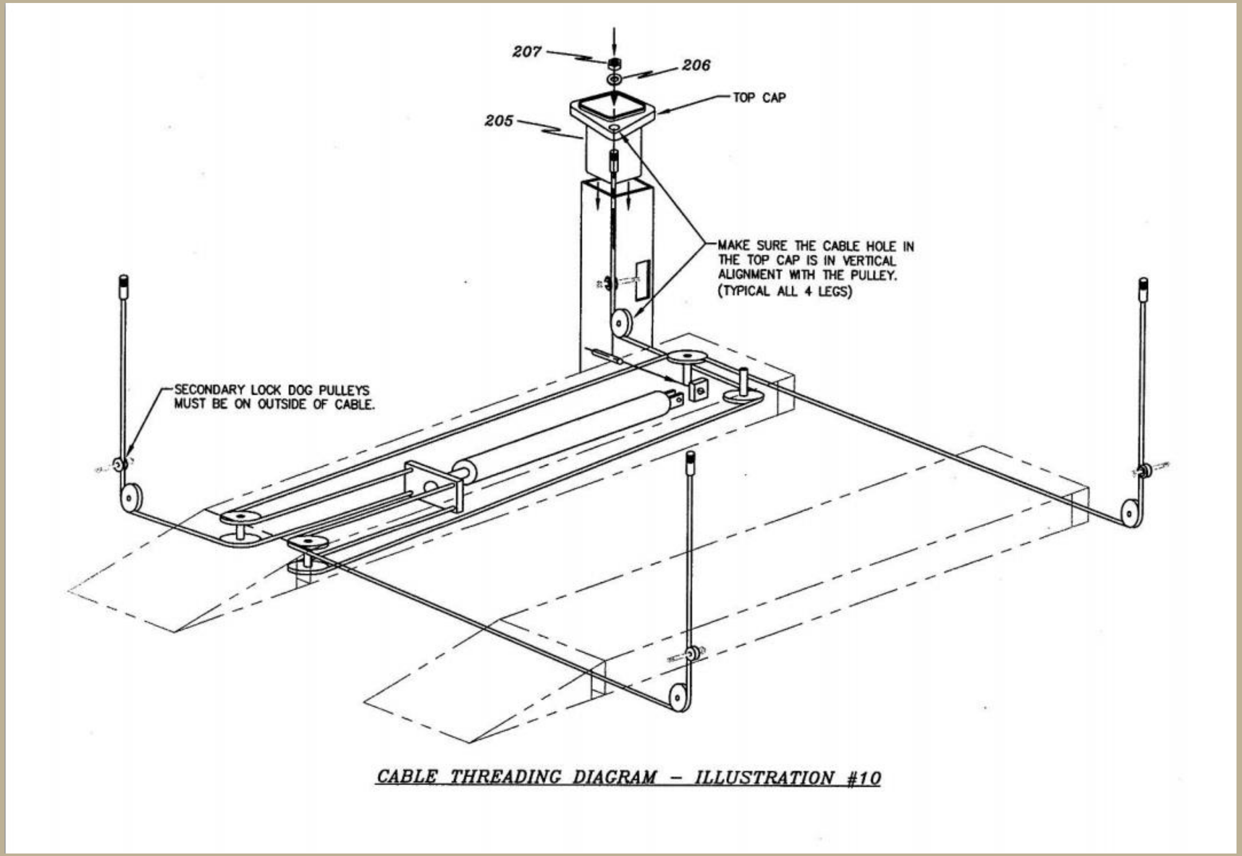
Cons

- ➢More moving parts
- ➢Cable life span



Source: http://www.bendpak.com

HYDRAULIC AND CABLE SYSTEM



Source: http://i292.photobucket.com/albums/mm11/Belgiquebasterd/Screen%20Shot%202015-06-14%20at%2006.33.57_zpsgw9jiwbi.png

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POTENTIAL SOLUTIONS

- After ranking the possible mechanisms based on the before mentioned criteria, we decided to investigate, in depth, two mechanisms.

- **Hydraulic and Cable System** ★★★★
- **Acme Screw** ★★★★

ENGINEERING SPECIFICATIONS

To understand how viable an approach really is we must compare it to the absolute minimum. Fundamental physics can tell us exactly that.

- $Work = Force * Distance$
- $Work = 60{,}000lbs * \frac{105inches}{12\frac{inches}{foot}} = 525{,}000ft * lb$
- $hp = \frac{Work}{Time*550}$
- For the floor to travel 72 inches in 45 seconds, it will travel 105 inches in 66 seconds.
- $hp = \frac{525{,}000lb*ft}{66\,seconds*550} = \boxed{14.5\ hp}$

ACME SCREW COLUMN LOAD

- **Maximum Column Load (1.5 inch diameter screw)**
- $P = F(14.03 * 10^6)\left(\frac{d^4}{L^2}\right)$
- F= 4.0 (both ends fixed)
- d= root diameter (inches)=1.196
- L= Maximum distance between support, and acme nut. (Inches)
- For six lifting points, each screw must support 10,000 lbs.
- $P = 4.0(14.03 * 10^6)\left(\frac{1.196^4}{105^2}\right) = \boxed{10{,}415\ lbs = 5\text{ Tons}}$

ACME SCREW SPEED REQUIREMENTS

- *In order to achieve a full lift in 90 seconds*

- $\frac{105\ inches}{90\ seconds} = 1.16\ \frac{inches}{second}\left(\frac{1}{0.250\ \frac{inches}{revolution}}\right) = 4.64\,\frac{rev}{second}\left(\frac{60seconds}{minute}\right) =$ $\boxed{280\ rpm}$

TORQUE TO RAISE FLOOR (1 OF 6 LIFTING POINTS)

- $T_R = \frac{F d_m}{2}\left(\frac{l+\pi f d_m}{\pi d_m - f l}\right) + \frac{F f_c d_c}{2}$

- $F = \ Load\ (lbs)$
- $d_m = \ mean\ diameter = \frac{1.5-1.196}{2} = 1.348\ in.$
- $l = lead = 0.250 \frac{in}{rev}$
- $f_c = thrust\ bearing\ friction\ coefficient = 0.0018$
- $f = screw\ friction\ on\ nut = 0.16$ (Budynas, and Nisbett. Table 8-5)
- $d_c = collar\ diameter = 1.5\ in.$

TORQUE TO RAISE FLOOR (CONTINUED)

- $T_R = \frac{10{,}000 lbs(1.348\ in.)}{2}\left(\frac{\left(0.250\frac{in}{rev}+(\pi*0.16*1.348 in.)\right)}{\left(\pi*1.348 in.-0.16*0.250\frac{in.}{rev.}\right)}\right)+\frac{(10{,}000 lbs*0.0018*1.5\ in.)}{2}$

- $T_R = 6{,}740*\left(\frac{0.9276}{4.195}\right)+13.5 = \boxed{1{,}504\ lbf*in}$ or $\boxed{125\ ft*lbf}$

TORQUE TO LOWER FLOOR

- This is significant because, if there is a torque required to lower the floor then, when in a lifted position the floor will not move unless acted on by the motor.
- $T_{\boldsymbol{L}} = \frac{Fd_m}{2}\left(\frac{\pi f d_m - l}{\pi d_m + fl}\right) + \frac{Ff_c d_c}{2}$
- $T_L = 6740\left(\frac{0.4276}{4.2749}\right) + 13.5 = \boxed{688\ lbf * in.}$ or $\boxed{57\ ft * lbf}$

MOTOR/GEAR REDUCER SELECTION

- A 15 hp motor running at 2,000 rpm produces 39.5 ft.*lb_f of torque.
- A 7:1 gear reduction gives 276 ft.*lb_f of torque @ 285 rpm.
- One screw requires 125 ft.*lb_f.
- Turning two screws with one motor demands $3{,}008 lbf * in\left(\frac{1ft}{12\ in}\right) =$

  $\boxed{251\ ft * lbf}$.

REQUIRED POWER

- 3 motors running at 15 horsepower each will be needed.

- $3\ motors * \frac{15\ hp}{motor} = 45\ hp$

- Converting to kilowatts for generator selection

- $45\ hp * \frac{746\ W}{hp} * \frac{1kW}{1000\ W} = 33.57\ kW$

ACME SCREW CONCLUSION

- When looking at the acme screw option during the preliminary selection process it look to be a good solution to our problem. When doing the calculations we found that it actually takes a great deal of power to achieve the lifting capacity required in the set time frame. Using six lifting point it would take three 15 hp DC motors all running simultaneously that must be supplied by an onboard generator. All of these things together result in a very high initial cost.

- For the reasons above, we turn to the hydraulic cylinder and cable assembly for a solution

HYDRAULIC CYLINDER WITH CABLE SYSTEM

- Now that we are looking at this option, we must find out what it takes to meet our speed requirements.
- We have a target of 105 inches in 66 seconds.
- $\frac{105 inches}{66 seconds} = 1.6\ inch/sec$
- A 3 stage telescoping cylinder with a 103.75 inch stroke has a volume of 9.1 gallons.
- A 10 gpm pump gives, $\frac{9.1 gal}{10\ gpm} = 0.91(min)\left(60\frac{sec}{min}\right) = \mathit{54.6\ sec}$

$$54.6\ sec, so\ \frac{103.75\ inches}{54.6\ seconds} = \boxed{1.9\frac{inch}{sec}}$$

FORCE FROM A TELESCOPIC CYLINDER

- These calculations are based on a Bailey International three stage telescoping cylinder.
- The first stage has a six inch bore, the second is five inches, and the third is four inches.
- If a 3000 psi max pump is used, then the force output for the first stage is, $F = 3000psi * (\pi * 3inch^2) = \boxed{84{,}823\ lbs}$.
- The force generated by the second stage is, $F = 3000psi * (\pi *$

HORSEPOWER DEMAND

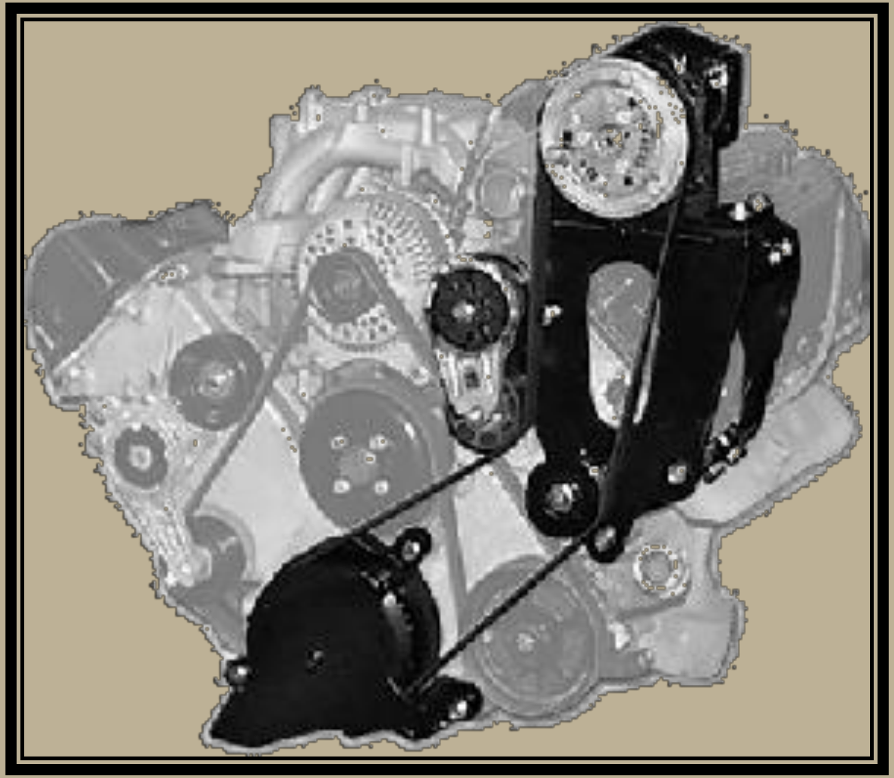
- $hp = \frac{gpm*psi}{1,714} = \frac{10gpm*3000psi}{1,714} = 17.5\ hp$
- Assuming our system operates at 80% efficiency
- $hp = \frac{17.5\ hp}{0.80} = \boxed{21.9\ hp}$
- The theoretical minimum to achieve this is 14.5 hp, so this is a promising solution.

POWER SUPPLY

There are three options that stand out for supplying the hp we require.

- Engine mounted clutch pump
- Transmission mounted PTO (Power Take Off)
- Stand alone power unit

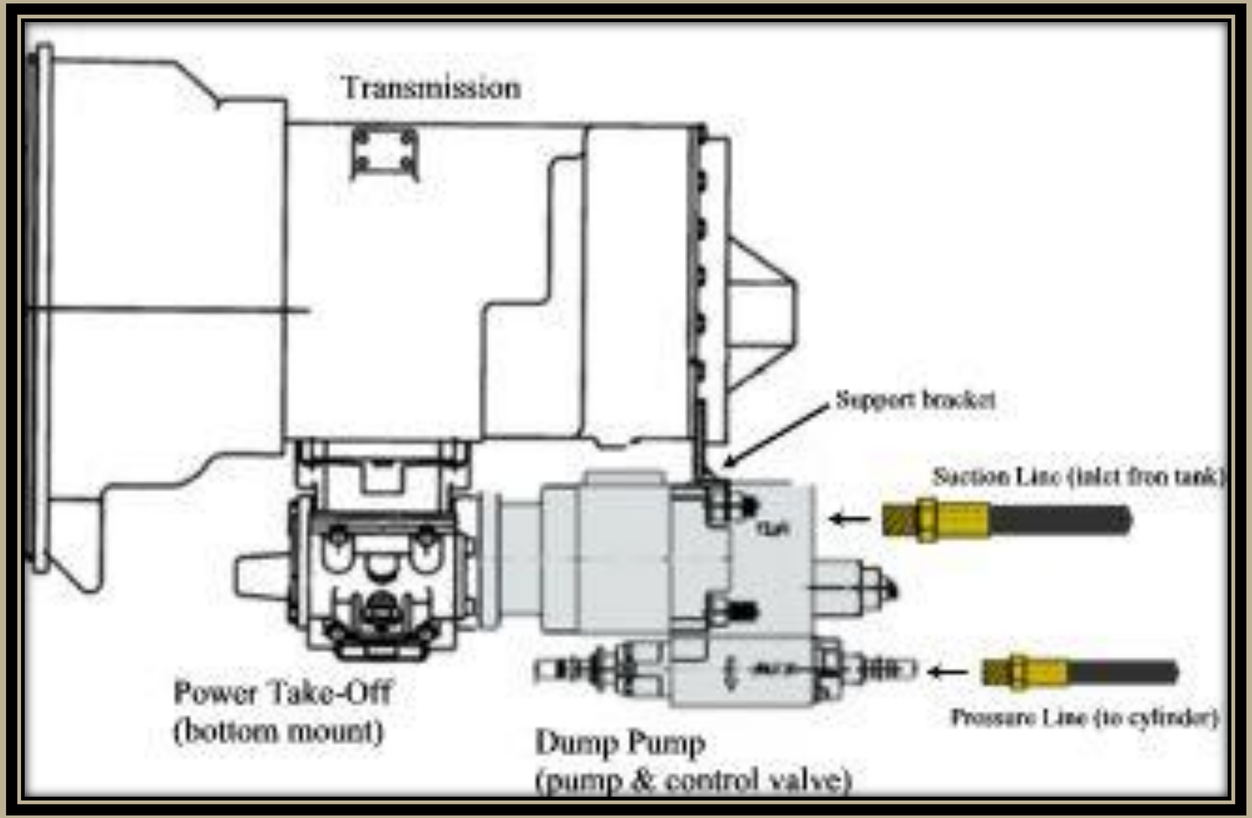
CLUTCH PUMP



Source: http://www.adifp.com/images/cwkit.gif

- Easy Installation
- Clutch allows pump to be engaged when needed.
- Utilizes engine power to run pump
- Direct crank shaft mount offers better power transmission.

TRANSMISSION MOUNTED PTO



Source: http://www.adifp.com/images/transptopump4sm.jpg

- Slightly more expensive option.
- More reliable
- Allows for greater power transmission
- Remote activation
- Most semi trucks have pto port on transmission

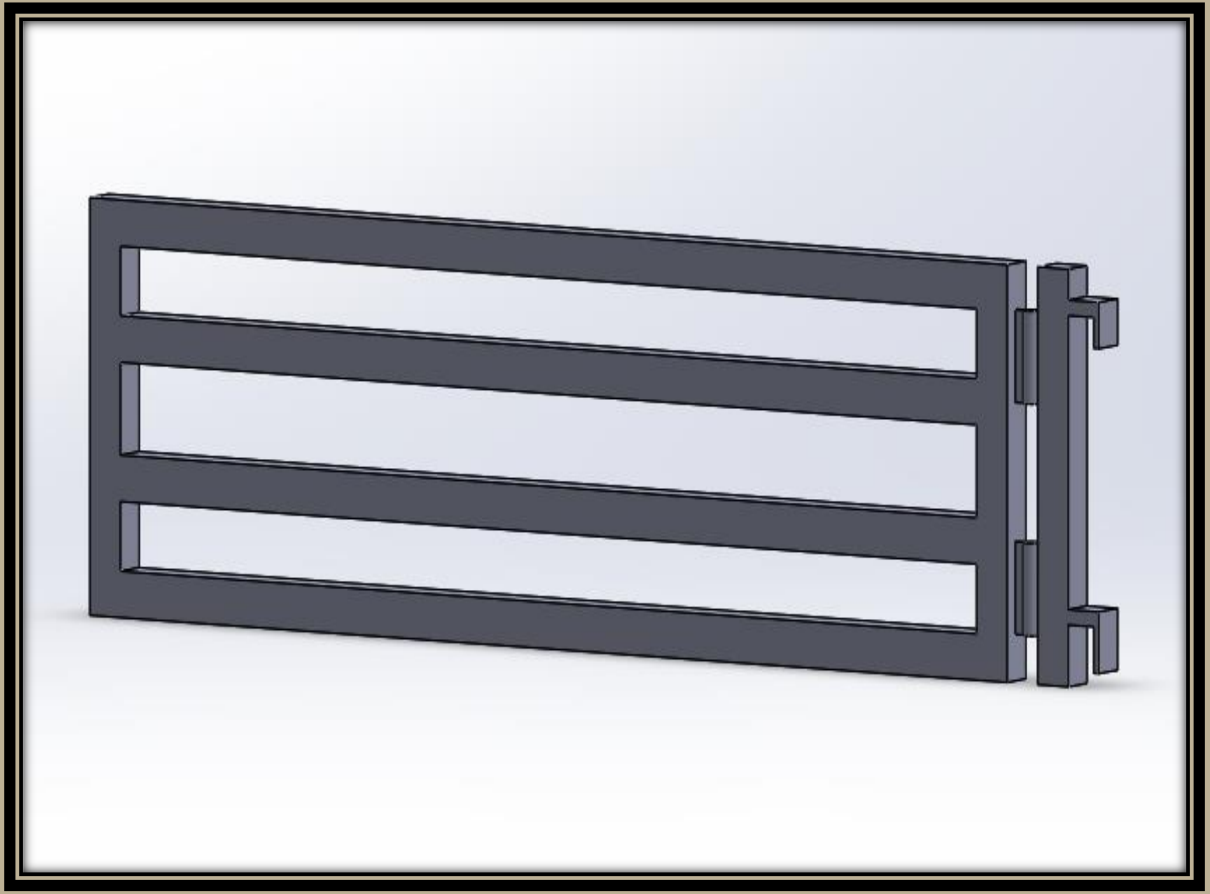
STAND ALONE POWER UNIT

- Allows floor to be actuated without the truck being attached
- Includes gas motor, pump, and reservoir.
- Can run out of gas

Source: https://sp.yimg.com/xj/th?id=OIP.M0976bcb51a792055b72baac57272d34fo0&pid=15.1&P=0&w=230&h=163

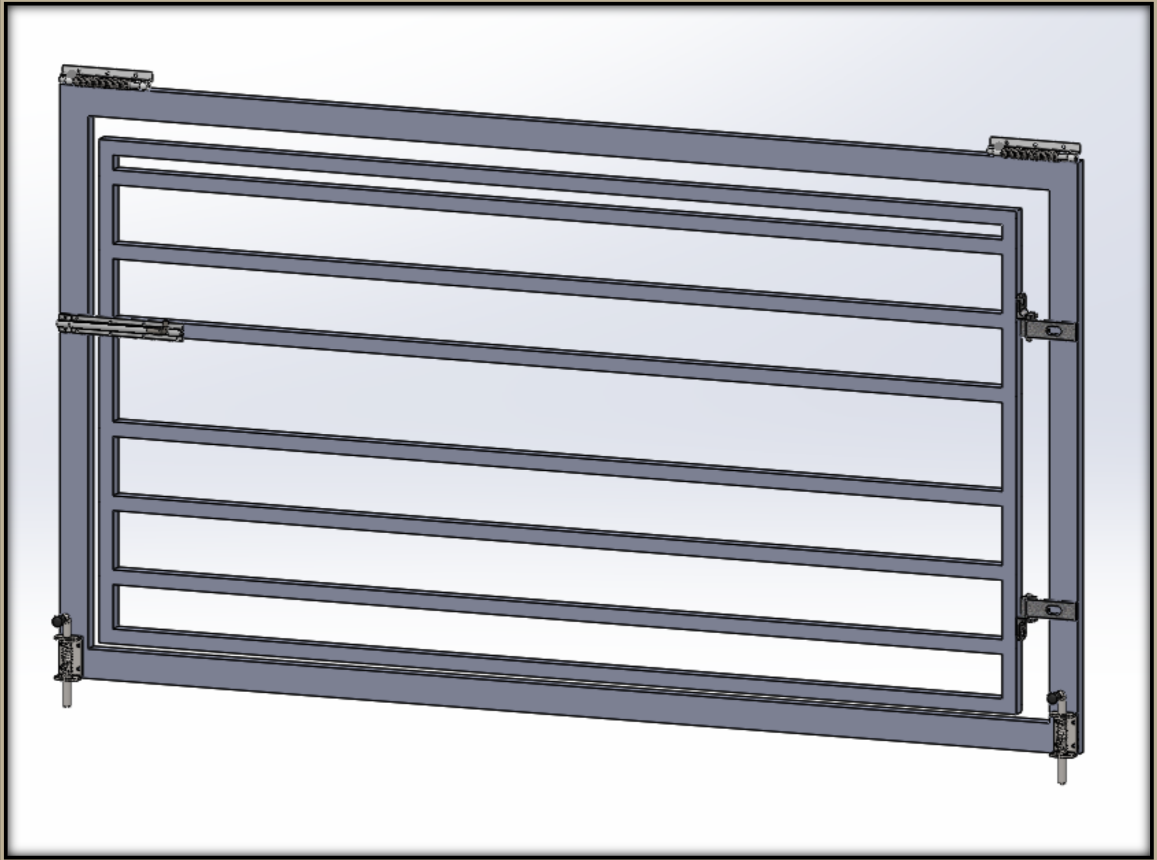
BOTTOM FLOOR GATE (FRESHMEN)

- Removable gate
- Saves Space
- Lightweight aluminum construction
- Could be hard to remove, and install gate.



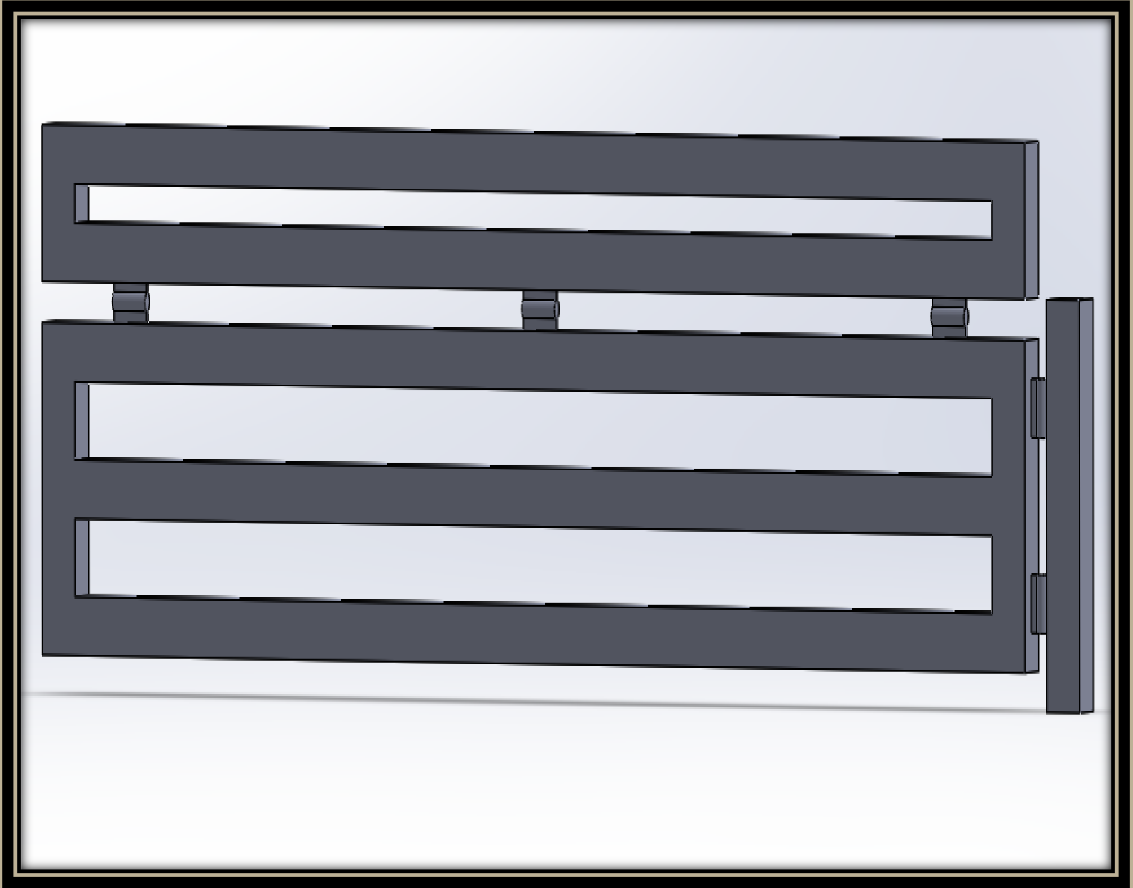
BOTTOM FLOOR GATE

- Attached to bottom side of moving floor
- Swings down and locks with a pin to the floor
- Inner gate opens to allow passage
- Must be made as thin as possible



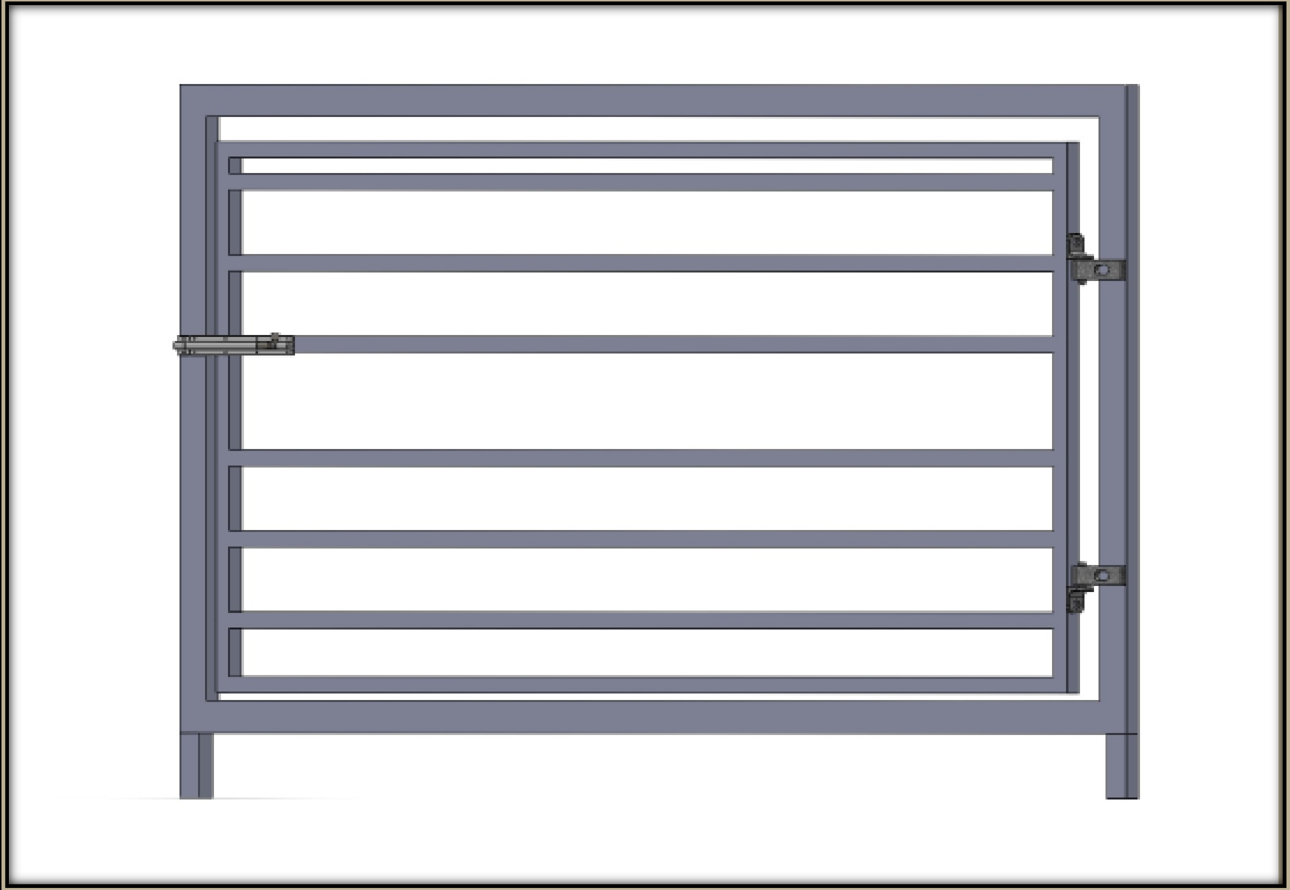
TOP FLOOR GATE (FRESHMEN)

- Hinge folds upper third of gate down to raise floor
- Post connecting gate is welded to floor
- Restricts lifting range



TOP FLOOR GATE

- Removable Gate
- Slides into supported opening in floor
- Inner gate opens to allow passage
- Just remove to raise floor to highest point



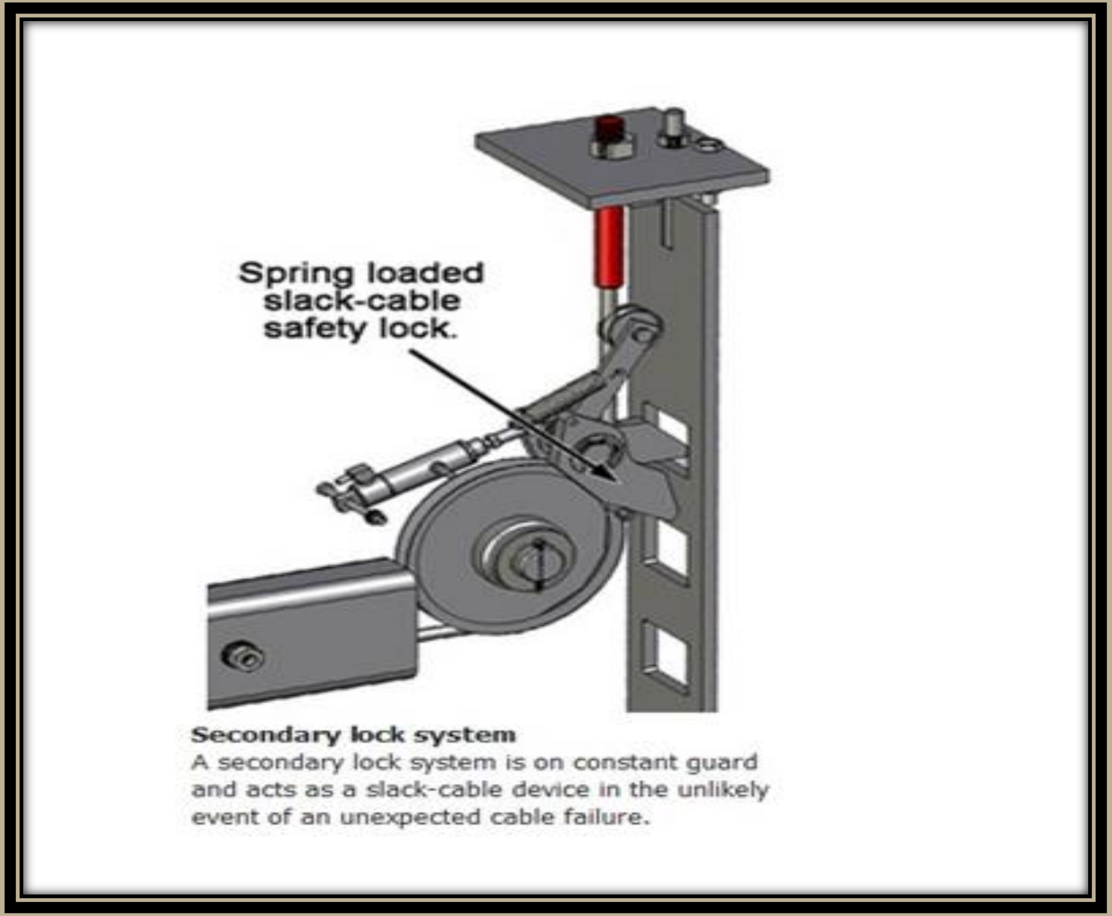
PUNCH SIDING PINCH POINTS

Fiberglass Mesh:

- Excellent corrosion resistance
- High tensile strength and impact resistance
- Resistance to aging
- Applied to first four feet of siding, which is eight feet from the ground.

SAFETY LOCKS FOR LIFTING FLOOR

- Lock system in case of cable failure
- Can be pneumatically engaged and disengaged
- Locks at multiple elevations so cable failure at any level will secure the floor



Secondary lock system

A secondary lock system is on constant guard and acts as a slack-cable device in the unlikely event of an unexpected cable failure.

PROTOTYPE BUDGETS

Clutch Pump Budget est.

Part	Manufacturer	Price
Telescoping Hydraulic Cylinder	Custom Hoist	$1,550
Clutch Pump Mounting Kit	CW Mounting Kits	$450
Hydraulic Pump	Northern Tool	$569
Pulleys X 20	Grainger	$384.00
Cable (200 ft.)	E-Rigging	$313.50
Materials (Floor guides, and Cylinder mount)	N/A	$1,800
Control Valve	Brand Hydraulics	$150
High Pressure Hydraulic Hoses (70 ft.)	Eaton	$560
	Total	$5,217

PROTOTYPE BUDGETS

PTO Driven Budget est.

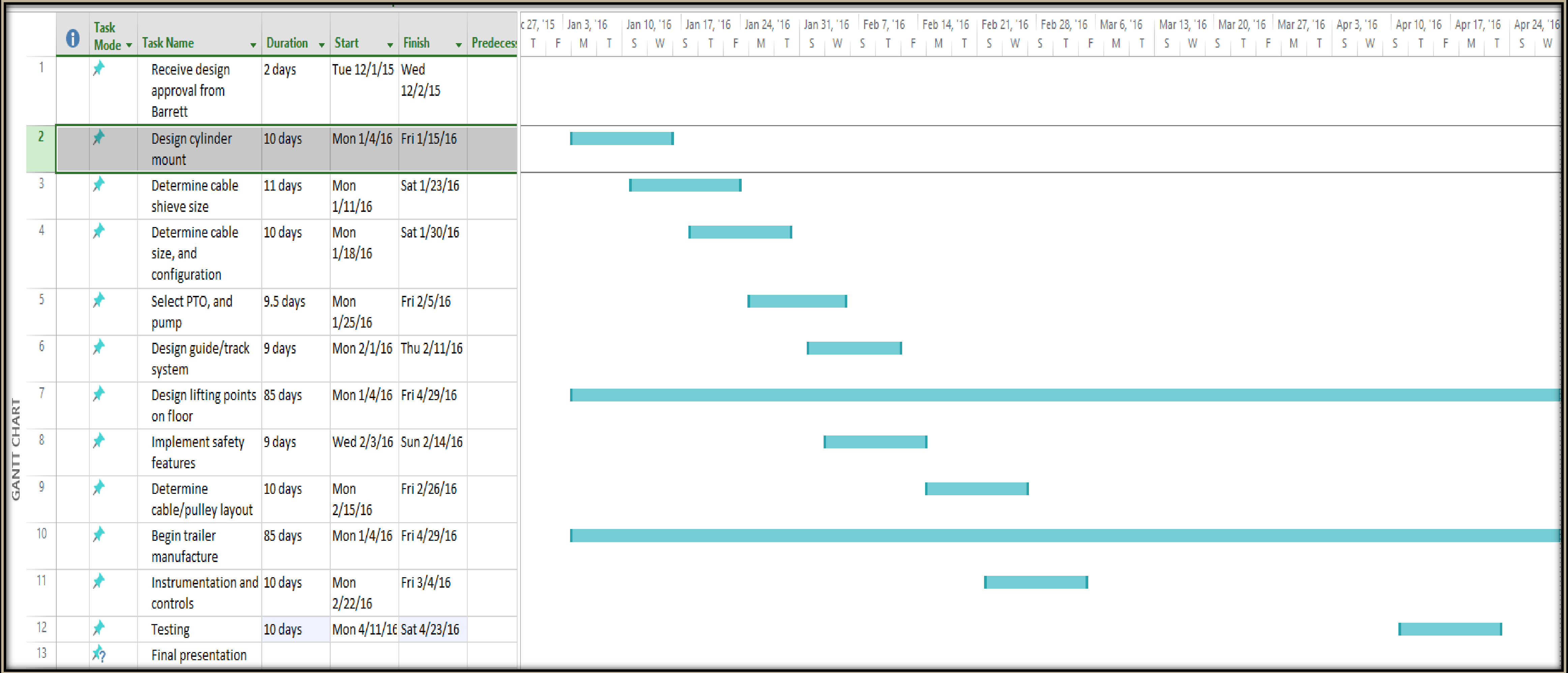
Part	Manufacturer	Price
Telescoping Hydraulic Cylinder	Custom Hoist	$1,550
PTO Attachment	Muncie	$950
PTO Hydraulic Pump	Muncie	$435
Pulleys X 20	Grainger	$384.00
Cable (200 ft.)	E-Rigging	$313.50
Materials (Floor guides, and Cylinder mount)	N/A	$1,800
Control Valve	Brand Hydraulics	$150
High Pressure Hydraulic Hoses (70 ft.)	Eaton	$560
	Total	$6,143

PROTOTYPE BUDGETS

Stand Alone Power Unit Budget est.

Part	Manufacturer	Price
Telescoping Hydraulic Cylinder	Custom Hoist	$1,550
Power Unit	Bailey	$3000
Pulleys X 20	Grainger	$384.00
Cable (200 ft.)	E-Rigging	$313.50
Materials (Floor guides, and Cylinder mount)	N/A	$1,800
Control Valve	Brand Hydraulics	$150
High Pressure Hydraulic Hoses (70 ft.)	Eaton	$560
	Total	$7757.5

SPRING SEMESTER TIMELINE



	ℹ	Task Mode	Task Name	Duration	Start	Finish	Predeces
1		📌	Receive design approval from Barrett	2 days	Tue 12/1/15	Wed 12/2/15	
2		📌	Design cylinder mount	10 days	Mon 1/4/16	Fri 1/15/16	
3		📌	Determine cable shieve size	11 days	Mon 1/11/16	Sat 1/23/16	
4		📌	Determine cable size, and configuration	10 days	Mon 1/18/16	Sat 1/30/16	
5		📌	Select PTO, and pump	9.5 days	Mon 1/25/16	Fri 2/5/16	
6		📌	Design guide/track system	9 days	Mon 2/1/16	Thu 2/11/16	
7		📌	Design lifting points on floor	85 days	Mon 1/4/16	Fri 4/29/16	
8		📌	Implement safety features	9 days	Wed 2/3/16	Sun 2/14/16	
9		📌	Determine cable/pulley layout	10 days	Mon 2/15/16	Fri 2/26/16	
10		📌	Begin trailer manufacture	85 days	Mon 1/4/16	Fri 4/29/16	
11		📌	Instrumentation and controls	10 days	Mon 2/22/16	Fri 3/4/16	
12		📌	Testing	10 days	Mon 4/11/16	Sat 4/23/16	
13		📌?	Final presentation				

IN CONCLUSION

- The Elevated Engineering team has weighed all options and done numerous calculations in order to believe the hydraulic cylinder and cable system to be the best option to complete the for mentioned tasks. This method reduces lost floor space and is capable of lifting the required 60,000 lbs. Combined with the safety mechanisms mentioned, the hydraulic cylinder and cable system can propel Barrett Trailers into a new market for a different type of product.

QUESTIONS?