

# Orchard Harvesting and Pruning Platform



**Team Top Pick  
University of Idaho  
Capstone Design 2014-2015**

# Team Top Pick



Figure 1: Team Top Pick (Left to Right): Dillon Turnbull, Zachary Howard, Dhari Aldehani, Vince Schwartz

## ***Team Members:***

Dillon Turnbull: [turn1113@vandals.uidaho.edu](mailto:turn1113@vandals.uidaho.edu)

Zachary Howard: [howa7892@vandals.uidaho.edu](mailto:howa7892@vandals.uidaho.edu)

Dhari Aldehani: [alde7811@vandals.uidaho.edu](mailto:alde7811@vandals.uidaho.edu)

Vince Schwartz: [schw6383@vandals.uidaho.edu](mailto:schw6383@vandals.uidaho.edu)

Team Email: [enr-toppick@uidaho.edu](mailto:enr-toppick@uidaho.edu)

## ***Client:***

Joe Rumble of Rumble Orchards, Wenatchee Valley, Washington

## ***Advisor:***

Dr. Steve Beyerlein

## ***Mentor:***

Samuel Qualls

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## **1.0 Introduction**

### **1.1 Scope:**

The scope of Team Top Pick is to address several of the key features needed in a Fruit Picking and Pruning Platform. Team Top Pick is going to focus on making scaled models of:

1. A self-leveling frame for slopes up to 30% grade
2. 3 degree of freedom boom assembly to allow workers to access trees from ground to top, as well as the entire depth of the branches
3. Uni-Directional Bin Management to pick up, fill and leave bins full of fruit without having to go to the ends of the tree rows.
4. Fruit transport from picker to bin for continuous picking

The scope of this project was scaled down due to budget and time constraints. The team discussed the many different facets that the final machine would need to have and settled on these 3 as the most appropriate to demonstrate proof of concept. Fruit transport would only be addressed if the first three goals were adequately addressed and there was time and budget allowing.

### **1.2 Motivation:**

Joe Rumble is the owner of Rumble Orchards. He has many seasonal workers that assist in picking the fruit his trees have produced and trimming after the fruit has been harvested. The work required is labor intensive and can pose safety hazards. Alongside being labor intensive, the work is also highly inefficient. Workers need to reposition their ladders very often, climb up and down as their bags of fruit get full, often up to 60 lbs., and then walk back to the bin to unload. Mr. Rumble wants a machine that allows a worker to continuously pick fruit from any position. A machine like this would let one worker replace a team. The machine would allow for much less labor intensive work to be done, eliminating the high safety hazards presented by current methods. If one worker could safely pick as much as a team, the workplace turnover would be significantly smaller and allow each worker many more healthy seasons.

### **1.3 Goal:**

The goal of Team Top Pick is to develop a proof of concept for this machine. The machine has to be able to demonstrate full leveling functionality on a variety of slopes, access to all parts of a tree, and ability to pick up a bin, travel with it and the deposit after the bin is full of fruit.





## **2.0 Project Learning:**

To tackle such a large project, the team had to hit the ground running. Nobody grew up around orchards, so the team's first task was visiting an orchard to learn firsthand about the picking process, how trees are laid out in an orchard, common slopes to expect, and the dimensions of fruit trees. To do this the team would visit Bishops' Orchard in Garfield, Washington.

At Bishops' Orchard, the team was able to collect all of the necessary dimensions and data of the orchard and was also able to experience the current system for picking apples. It quickly became apparent that the majority of the fruit could not be reached from the ground. Ladders are commonly used in large orchards, but the team found that mechanized picking platforms are already in existence and that Bishops' Orchard was utilizing them. The team decided that this would be the most important piece to focus on. The team then interviewed the owner of the orchard and asked him questions on what it was that he liked about the machine and what he wished could be improved. This gave the team a definitive goal of what they wanted their final project to be capable of.

After returning from the orchard, the team decided that their next step would be looking at the previous year's research and analyzing it. The client, Joe Rumble, suffered from a stroke in 2014, so the team heavily researched the work of the previous team before contacting Rumble as confirmation of the team's objectives. The research and an interview with Rumble confirmed the team's goals:

Design a platform that will increase the safety and efficiency of picking and pruning fruit trees. This platform will be capable of:

-  Vertical movement of up to 10 feet
-  Lateral movement of 3 feet into tree
-  Self-leveling on uneven slopes up to 30%
-  Fruit collection and transportation

After talking with Mr. Rumble, the team decided to complete two scaled models: a 1:10 scale and a 1:4 scale. The 1:10 scale would be a complete assembly, showcasing the functionality of the boom and the chassis. The 1:4 scale would show the functionality of the bin management system. To better illustrate the 1:10 scale model, a mock orchard was also constructed. The team used the dimension that they recorded from Bishops' Orchard. The model was constructed out of wood with metal hinges to allow adjustment. It would later be fit trees and felt to increase how realistic it looked.

The team spent the next couple of months researching existing systems for picking and systems that applied to what they wanted their machine to be capable of doing. Solid models were created, improved, and sometimes exchanged for a new design concept. It took the team from September 2014 until the end of February 2015 to finalize designs and order parts. Adjustments were made constantly, updating purchase orders to reflect an over-looked feature before sending the final order to the company. This taught the team that even if you think you have planned for



everything, there will almost always be something small that was overlooked or lost in translation.

Luckily for the team, no drastic mistakes were made. The team's mistakes include:

- 🍎 An incorrect quantity of pieces
- 🍎 Forgetting to add a part to a purchase list
- 🍎 An accidental order of a steel parts list when an aluminum alternative was being produced
- 🍎 Underestimating the amount of reinforcement required to accommodate the steel mistake listed above.

After receiving the materials from the companies, the team began manufacturing. Extruded aluminum was used to eliminate the need for welding as often as possible. This allowed for immediate construction of both the 1:10 frame and the 1:4 frame. The boom assembly required heavy shop time. The team spent several consecutive days in the shop, milling the pieces to size, drilling holes, and sanding their products. No one on the team has done much work with metal, so it was a good experience for everyone. A total of approximately 100 man hours were spent in the shop to create our custom parts. Some custom parts were made out of house. The team utilized Washington State University's water-jetting to cut out joints for the 1:10 scale that would have been too complex to do by hand. This allowed the students a good opportunity to communicate with other machinists and visit WSU's engineering facilities. Finally, after machining and assembling all of their parts, the team was ready for EXPO.

At EXPO the team was able to show their design to a wide variety of people. Some of the most fun were young kids, who were eager to see how the team's system worked. The team's hard work was appreciated most by kids, but adults also were drawn in and impressed by the models. The hardest part about EXPO for the team was making the judges understand and accept that our project's scope was on the proof of concept of parts that aren't already existing in today's market. The team was constantly question about the drive train, the control system that would allow for self-leveling, and the overall weight of the real system.

Reflecting over their year's work, the biggest lesson for the team was that the team members can make or break a project. Lack of interest and effort crippled the team for the first half of the year. It improved during the second semester, but not everyone was involved still. This gave team members a look at reality and made them realize that there are always going to be people who you will work with who don't pull their own weight. They didn't get culled early and are managing to make it into the professional world.

The team is satisfied with the progress they made and hopes that their designs will be pursued. The value of learning from the Capstone project cannot be matched by any other class.

### 3.0 Conceptual Design:

#### Morphological Chart

An initial morphological was constructed to eliminate designs and give reason as to why they were eliminated. Figure 2 on the following page shows this.

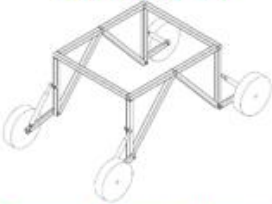

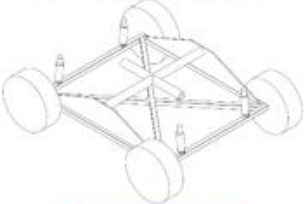


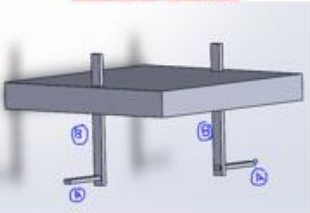
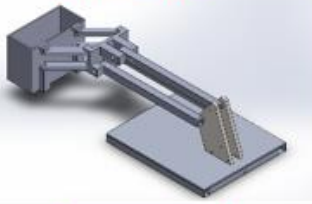








Subsystem/ Problem	Proposed Solutions		
Chassis	<b>Corner leveling</b> 	<b>Isolated leveling</b> 	<b>All-in-one leveling</b> 
Bin Management	<b>Linear Transition Tractor Fork</b> 	<b>Swinging Forks</b> 	<b>Rotating claws</b> 
Boom	<b>Double Beam</b> 	<b>Single Beam</b> 	<b>Telescopic Boom</b> 
Lateral Movement of Platform	<b>Hydraulic Joint</b> 	<b>Hydraulic Ram</b> 	<b>Winch and cable</b> 
Fruit transport	<b>Conveyor</b> 	<b>Chute</b> 	<b>Vacuum</b> 

Figure 2: Original Morphological Chart



### **3.1 Chassis:**

#### **Corner leveling**

This system divides the leveling needs among all four wheels. Each wheel is attached to a corner of the frame using a lever and a hydraulic piston. Each wheel is then free to travel up and down independently in an arc and level the frame in any direction. This design is the one we are currently using, because it divides the force among four points, it is flexible, and it can accommodate our current bin management design.

#### **Isolated leveling**

This design uses two separate systems to control the leveling. The first would level the frame and bin management system front-to-back, and the second would level the boom and power systems side-to-side on a plate mounted atop the frame.

#### **All-in-one leveling**

The first design I came up with. This design uses a central universal joint at the center of a rigid frame which the wheels are attached to. Four hydraulic pistons on each would connect to an upper frame, and would be used to level it.

### **3.2 Bin Management:**

#### **Linear Transition Tractor Fork**

The linear transition tractor fork utilizes a tried and tested design much like conventional tractor forks. The two biggest differences are the smaller size and the movement of just the forks isolated from the machine. Two big draw backs are the size required to get the linear motion we need and the amount of parts required is going to make the assembly heavy.

#### **Swinging forks**

The swinging forks are design to lower around the bin as the machine drives over it. Once over the bin, the forks will swing down. The forks will then lift the bin using hydraulic rams located on each of the forks. This design is feasible but will require several systems to allow controlled lowering of the forks, leveling on the bin, and raising the bin.

#### **Sliding claws**

The sliding claw design concept keeps the system compact, allowing the overall length to be significantly shorter than the previous examples. When the bin in position to be picked up by the claws, the claws will lower, rotate under the bin, and lift it up. The down falls to this design are the large amount of stress that would be acting on the claws, the possibility of the claws scoring the ground, accommodating the vertical movement needed by this method, and the multiple degrees of freedom required by the system.

### **3.3 Boom Design:**

#### **Double Beam**

The double beam system will have the ability to rotate about the base of the boom, rotate using a wrist at the end of the boom, and raise and lower at the base of the boom. A rod(s) would attach to a leveling plate to ensure the bucket stays levels and different heights. A hydraulic ram will be used to raise and lower the boom. A bar will have to bridge the space of the two beams so the hydraulic ram can be located between the two beams. The double beam allows for many advantages compared to a single boom. The two smaller beams will result in a decreased bending stress, more material to resist torsion, and a larger platform for fruit transport. A downside of the two beams is the space increase and the added weight.

#### **Single Beam**

The single beam would have the ability to rotate about the base of the boom, rotate using a wrist at the end of the boom, and raise and lower at the base of the boom. A rod(s) would attach to a leveling plate to ensure the bucket stays levels and different heights. The beam would have to be thick to withstand bending stresses and torsion. This is a very viable option and can be seen on many systems that are achieving a similar set of movements.

#### **Telescopic Boom**

The telescopic boom would have the ability to rotate about the base of the boom, rotate using a wrist at the end of the boom, and raise and lower at the base of the boom. A telescopic boom has a lot of appeal because it allows for a large range with a fairly compact design. However, there are several issues that also arise from a telescopic boom. The self-leveling could not be accomplished the same way unless the rod also telescoped, but controlling this would require a separate telescopic system powered by hydraulics. The smallest member would have to be sturdy enough resist any bending stress or torsion experienced by the boom. With each beam fitting inside the next, it is easy to get a massive main beam very quickly. In addition to this, a fruit transport system from the bucket down to the bin would be very tricky in conjunction with a telescopic boom and the excess cable from the control system would need a reel-in feature or risk being snagged by the branches of the tree.

### **3.4 Lateral Movement of Platform:**

#### **Hydraulic rotation at joint**

This option provides support and rotation in one system. The joint has bearing inside that allow for rotation using hydraulics. This system is compact and is implemented on man-lifts currently. This option is our choice because it is already being implemented for this purpose and is more compact than the other systems.

#### **Hydraulic ram**

The hydraulic ram would push on arms attaching the platform to the leveling plate. Extended would push the platform one direction and retracting would allow for movement in the opposite

direction. There would be 4 arms to support the weight of the picker and platform. Large systems, like tractors, use systems like this to rotate buckets. This idea would work for rotation but is more bulky than desired.

### **Cable rotation**

This system is similar to reins or turning on a sailboat. The winch will reel in line when it wishes to swing the platform one direction and will release to allow the other arm to swing. This could be achieved by wrapping the line in opposite directions on the same spool and separating them. There is a lot of possibility for error with this system and it is bulky.

## **3.5 Fruit Transport to Bin:**

### **Conveyor System**

The conveyor system would be used to transport the fruit from the platform down to the bin. The double beam boom system makes this very simple to do and the conveyor will sit between the two beams. The conveyor could have large/lipped cleats that would hold the apples safely even when the boom is at extreme angles.

### **Chute System**

The chute system would function by giving the apples a smooth surface with guide rails to slide down. The chute takes advantage of gravity and doesn't require any power systems to move the apples down. However, at extreme angles, the apples would slide fast and could bruise when they struck the bucket.

### **Vacuum System**

The vacuum system is utilized by the WHOOSHH design. They use membranes and negative pressure to move the apples quickly inward. The systems works extremely well; however, it is extremely bulky and not practical for our system.

## 4.0 Detailed Design:

### Final Designs:

An updated morphological chart was used to highlight the final design options made by the team. The team needed to address multitude of designs and parameters presented above. Figure 3 shows the designs chosen for each subsystem.






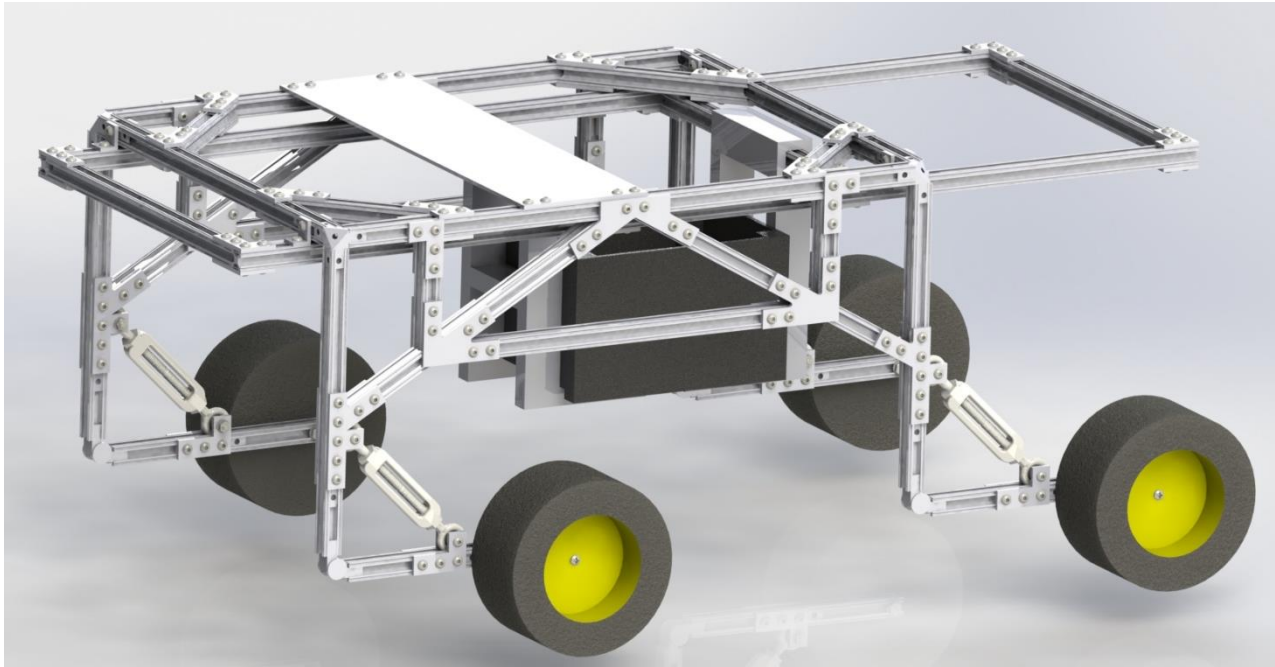
Subsystem/ Problem	Solution	
Chassis		Corner leveling
Bin Management	Linear Transition Tractor Fork	
Boom		Double Beam
Lateral Movement of Platform	Hydraulic Joint/Wrist	
Fruit Transport to Bin		Conveyor

Figure 3: Morph Chart

The choices, reasoning, and manufacturing process of the final components are explained in detail in the following literature.

## **4.1 Chassis Design and Development:**



*Figure 4: 1:10 Scale Frame Modeled in SolidWorks*

The diverse terrain that our system would have to function on demanded that our design be accommodating to a wide variety of specifications. Our goals for the final, functional frame are as follows:

- Self-leveling on slopes up to 30%
- Large enough to house the bin management system
- Capable of being loaded with over 1,000 lbs. of fruit
- Stable, keeping the center of mass low on the frame

### **Control System:**



*Figure 5: Combine on side hill*

Current picking systems don't offer self-leveling but it isn't a new development. Large farm equipment manufacturers have taken advantage of self-leveling to increase performance on hills. This application of self-leveling can be seen around the Palouse on combines that operate on hillsides. These combines utilize a level sensitive mercury system to communicate with the rest of their system to ensure the machinery is level. This would be one option for our frame, but we could also implement an accelerometer paired with a micro-controller that would relay the data to the hydraulics.



Our system will be equipped with a hydraulic ram at each adjustable arm. The hydraulics will take readings from the control system to make the necessary corrections on any variation of terrain. Having the hydraulics individually controlled at each of the arms will allow the system to be capable of remaining level on a side hill, as well as going straight up or down an incline.

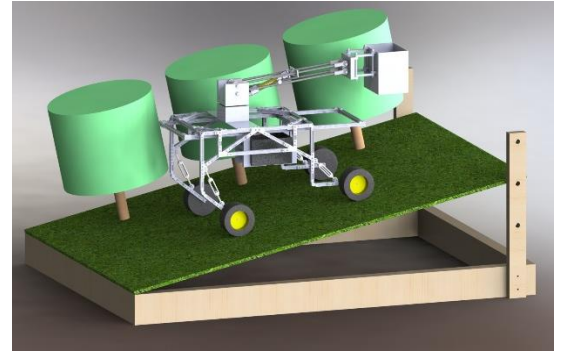


Figure 6: Scaled Model on Adjustable Orchard

**Self-Leveling:**

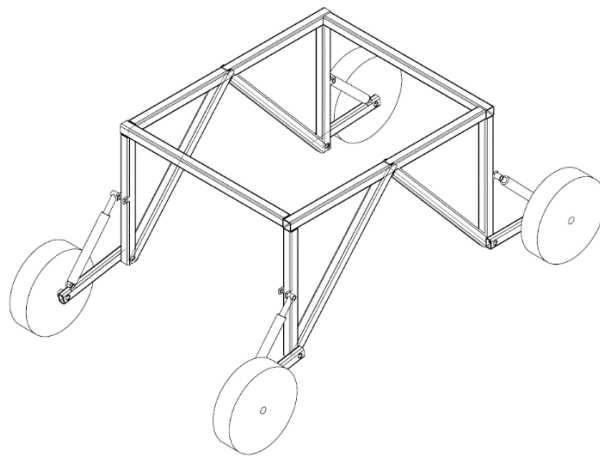


Figure 7: Initial Corner Leveling Design

Initially, we had the arms operating in opposing directions. This allowed for increased stability and easily keeping the center of mass directly between the front and back wheels. However, upon investigating the length that the arms had to be to achieve leveling on slopes of 25-30%, we realized that the frame would have to be very short to keep the distance between wheels small; however, the frame needed to be a minimum length to support the bin management system. To fix this problem, we looked at flipping one of the sets of arms around to decrease the total wheel-to-wheel distance.

Doing this meant that the distance between wheels was exactly equal to the length of the frame. Using EES, the team was able to come up with a frame size that matched their specifications.

	1	2	3
	x	y	L
	[ft]	[ft]	[ft]
Run 1	10	2.679	3.271
Run 2	10.08	2.702	3.298
Run 3	10.17	2.724	3.326
Run 4	10.25	2.746	3.353
Run 5	10.33	2.769	3.38
Run 6	10.42	2.791	3.407
Run 7	10.5	2.813	3.435
Run 8	10.58	2.836	3.462
Run 9	10.67	2.858	3.489
Run 10	10.75	2.88	3.516
Run 11	10.83	2.903	3.544
Run 12	10.92	2.925	3.571
Run 13	11	2.947	3.598

Figure 9: Parametric Study in EES of Frame Length, Vertical Adjustment, and Arm Length

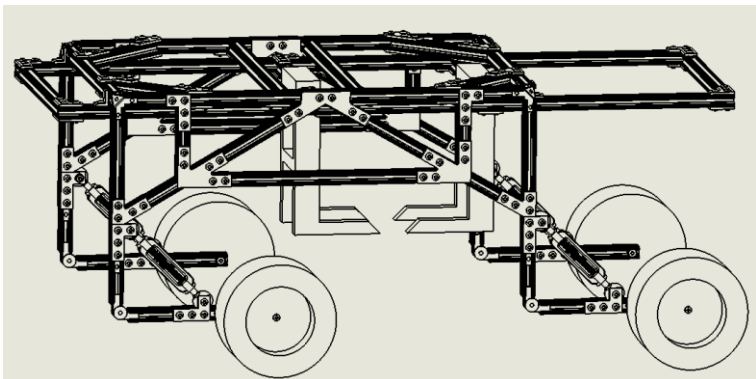


Figure 8: Final Frame with Arms Extending in the Same Direction

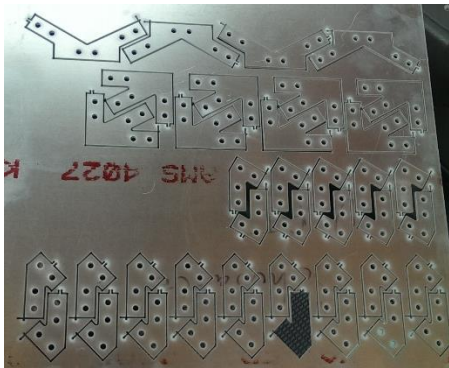
### **Structure:**

Supports were added to the frame to relieve stresses from longer beams and reduce any deformation that would occur under loading. Due to the lack of certainty on total weight, a basic truss-like support was implemented. This could be refined in the final assembly where overall weight would be known.

There would be a distance of at least 7.5 feet from outside to outside of the wheels to prevent tipping on angles up to 30%. Large, rugged tires would be desired in the full scale model to provide increased surface area and traction to reduce damage to the orchard.

### **Scaled Model:**

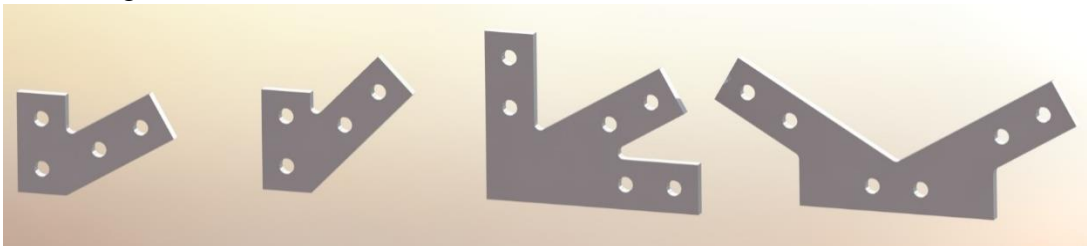
Due to cost and time constraints, the team decided to show their design's proof of concept on a 1:10 scale model. The frame was composed mainly of purchased parts. Vendors include MicroRAX, McMaster Carr, Discount Steel, RC Planet, and Tristate.



*Figure 10: Water-jetting Performed by WSU*

An extruded aluminum was purchased from MicroRAX. This extruded aluminum was used for the members of the frame to keep it light, cheap, and easy to modify. The profile of the extruded aluminum was 10mm, making it an ideal option for our 1:10 scale model. Some of the joints were also purchased from MicroRAX. These joints include the L-joints, 90 degree joints, Tri-corners, and elbow hinges. Custom joints were designed by the group to match their supports. These custom joints were water-jetted by WSU on a .008 inch aluminum plate purchased from Discount Steel. The tabs from the water-jetting were

ground off using a belt sander.



*Figure 11: Custom Joints Modeled in SolidWorks*

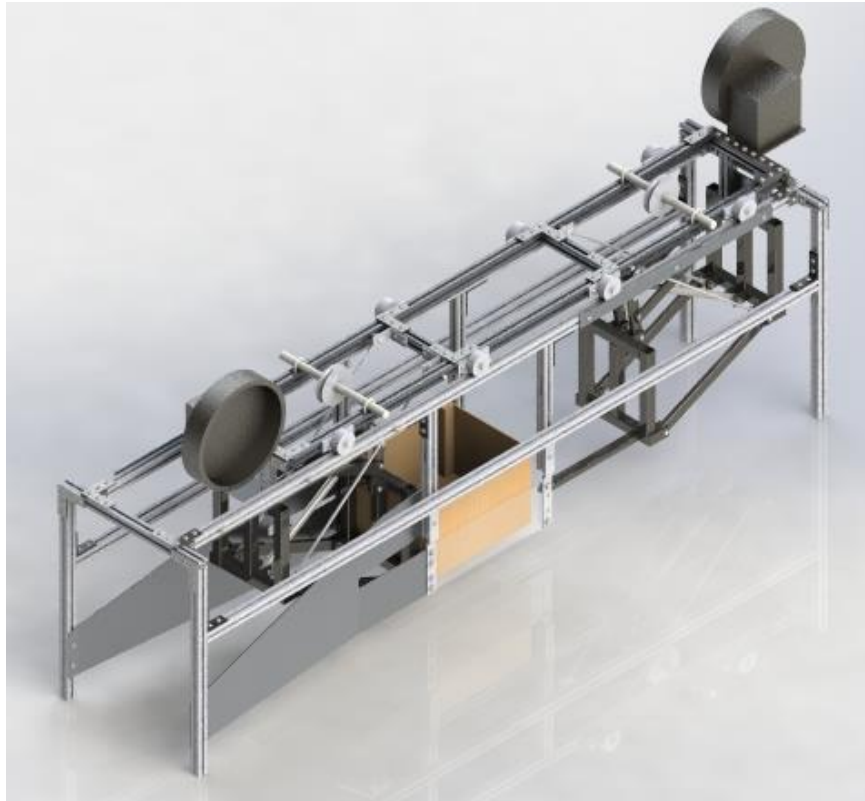
Turnbuckles were used on the scaled model to simulate hydraulics. Spacers were put in place to reduce the turnbuckles' movement, making it more closely resemble the sturdiness of the full scale. Plastic tractor forks were 3D printed to show where the bin management system would be locate on the 1:10 scale model.

**Next Steps in Development:**

The team's project was able to show the proof of concept of the team's design. However, there is a lot of work yet to be done. Most of this involves properly sizing components to make the system work. A complete list is as follows:

- Designate a self-leveling method for the frame (accelerometer, mercury leveling, or other).
- Size the frame with appropriate hydraulics, drive train, and engine(s).
- Design or implement an existing fruit distribution system that will gently place fruit into the bin.
- Conduct a new stress analysis on the entire system, including the weight from all components, and assign material type and size to meet these requirements.

## **4.2 Bin Management Detailed Design:**



*Figure 12: 1:4 Scale Bin Management Model*

### **Introduction:**

Due to constraints found within the orchard layout, a special system of managing the bins was needed. A current tractor with a boom can only pick an object up and drop it off after changing directions. The Linear Transition Forks design allows a narrow profile to fit between the tree rows as well as being able to pick a bin up, transport it while being filled with fruit, and then lower the bin without changing directions. The machine is able to do this using a pair of forks that work in conjunction with a sliding chassis that moves within the actual frame that the rest of the machine is attached to. Underneath the sliding chassis are a pair of standard sized tractor forks that handle the bins. In order to illustrate this assembly a  $\frac{1}{4}$  scale model was built.  $\frac{1}{4}$  scale was chosen because it would be small enough that our budget would accommodate the cost of parts, but big enough the intricate details of the mechanics would be easily shown.

### **Design Process:**

Many designs were introduced. The two with the most promising were the Swinging Forks and the Linear Transition Forks. The swinging forks are two sets of forks that would swing in from above the bin, grabbing onto the edges of the bin and then lift vertically. This design was decided against due to the low range of grasp the forks would be able to provide. Rotation and linear movement limits the length of the forks because the ground would interfere. The forks would also be very inconsistent in their ability to grab on uneven terrain. Thus, the Linear Transition Forks were decided to be the best option to pursue.

**Features:**

Mentioned above are the sliding chassis and tractor forks. There are two transition forks opposing each other as shown in Figure 13. Figure 13 shows the two main sub-assemblies in the main assembly.

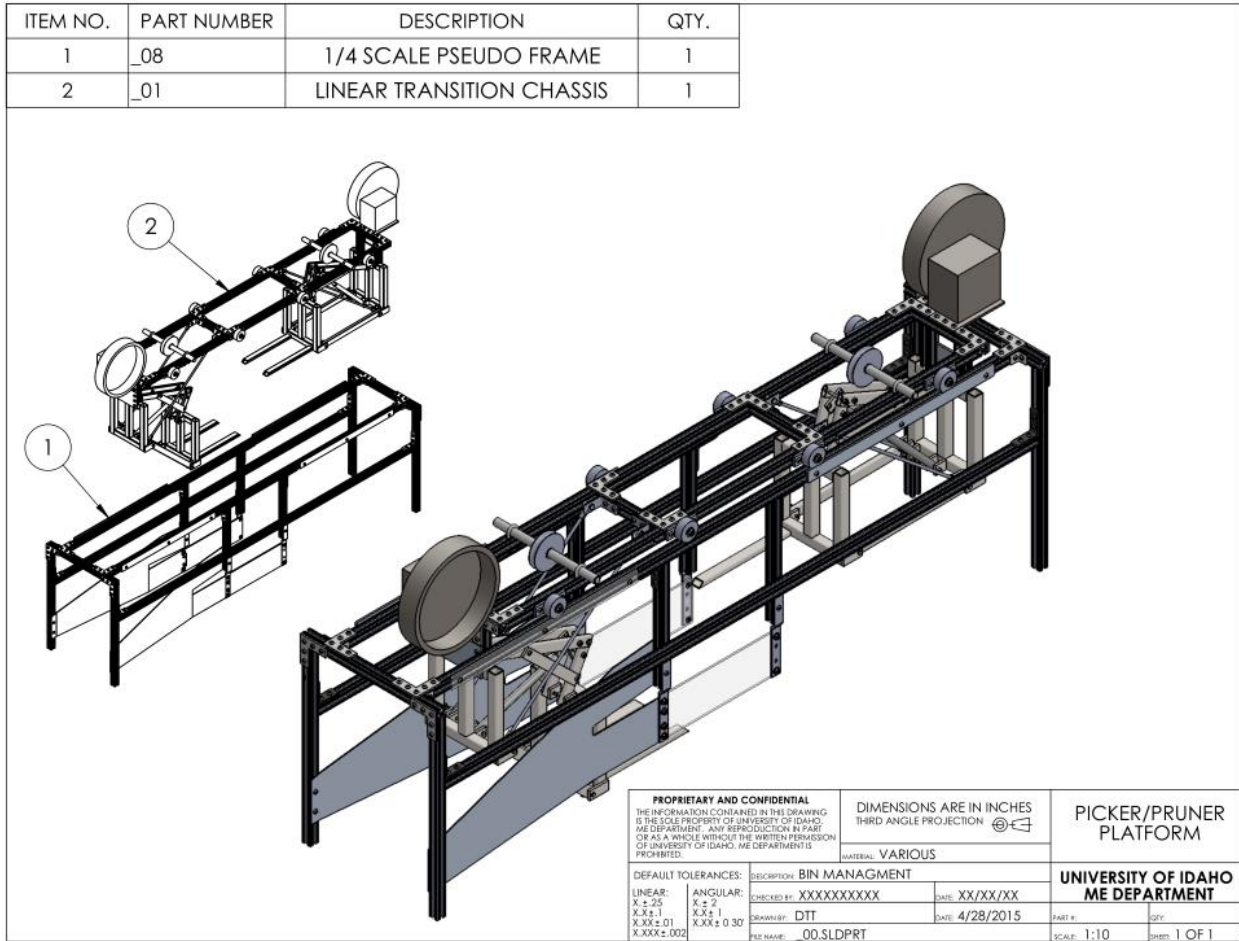


Figure 13: Main Assembly Drawing

Item 1 shows the pseudo frame for the 1/4 scale display. The sliding frame that includes the tractor forks as mentioned above is labeled by Item 2.



**1/4 Scale Pseudo Frame Features:**

Many things were taken into consideration when designing the Pseudo Frame. The most important task of the frame is getting the bin orientated correctly so the forks can easily pick it up. Secondly, the frame has to keep the sliding chassis in the correct position so the wheels don't fall off the tracks. Figure 14 is a detailed drawing of the Pseudo Frame highlighting all pertinent features.

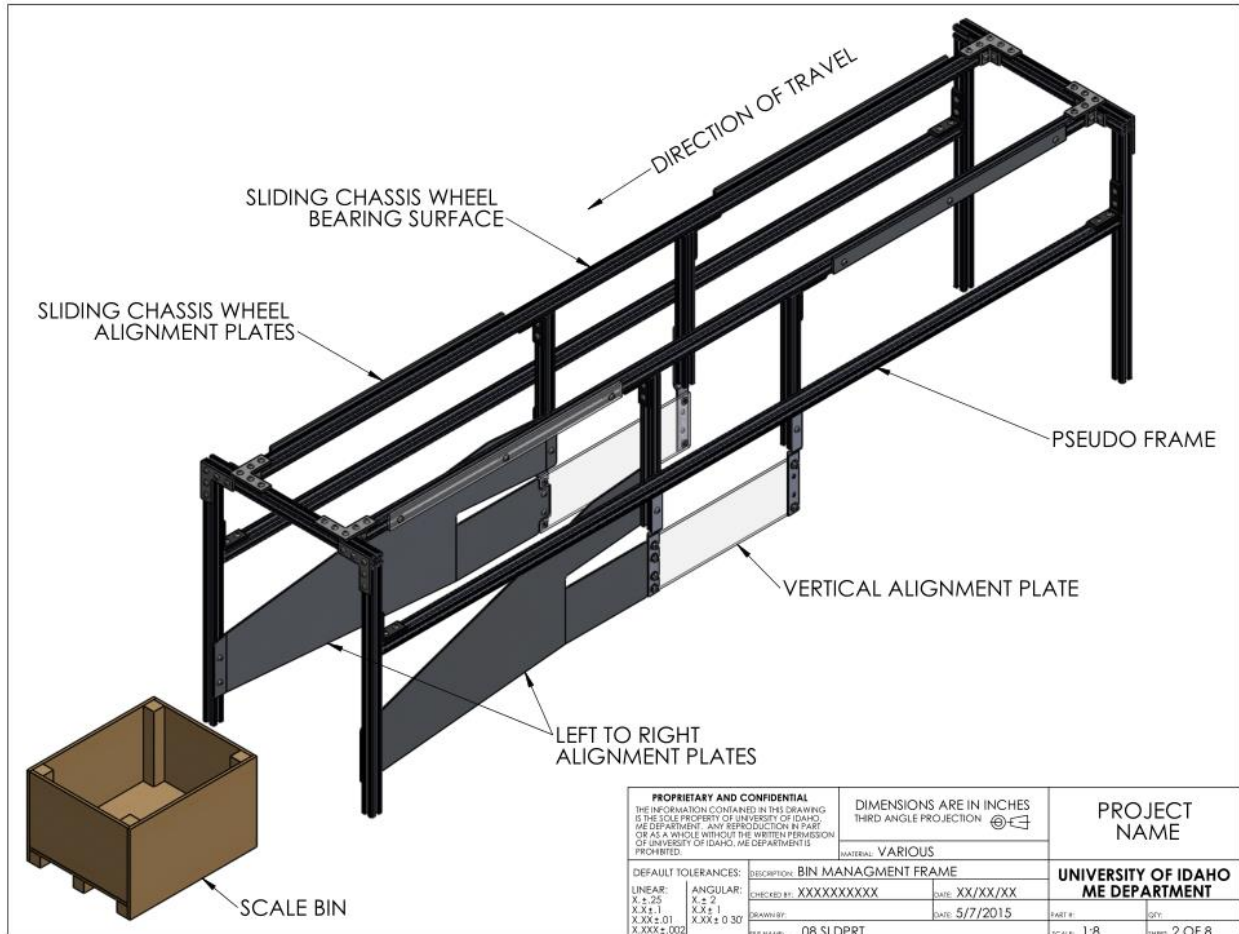


Figure 14: Pseudo Frame

From the drawing one can see the orientation of the frame with respect to travel direction as well as the bin location. The left to right alignment plates physically move the empty bin into the center of the frame. Once the bin has come to the appropriate position left to right, the machine keeps moving in the direction of travel until it has been centered front to back. Once centered in the middle of the frame the vertical alignment plates then keep the bin in that center position as the forks lift it off the ground. The sliding chassis alignment plates keep the wheels of the Linear Transition Chassis centered on the sliding chassis wheel bearing surface. These 4 plates make sure that the Linear Transition Chassis can only move forward and backward.

**Linear Transition Chassis Features:**

The Linear Transition Chassis is the machinery that allow a one direction pickup and drop off. Two opposing forks allow one fork assembly to pick the empty bin up, transition over to the second fork assembly to load the fruit and lower to the ground when full. Figure 15 gives a visual representation of the described assembly.

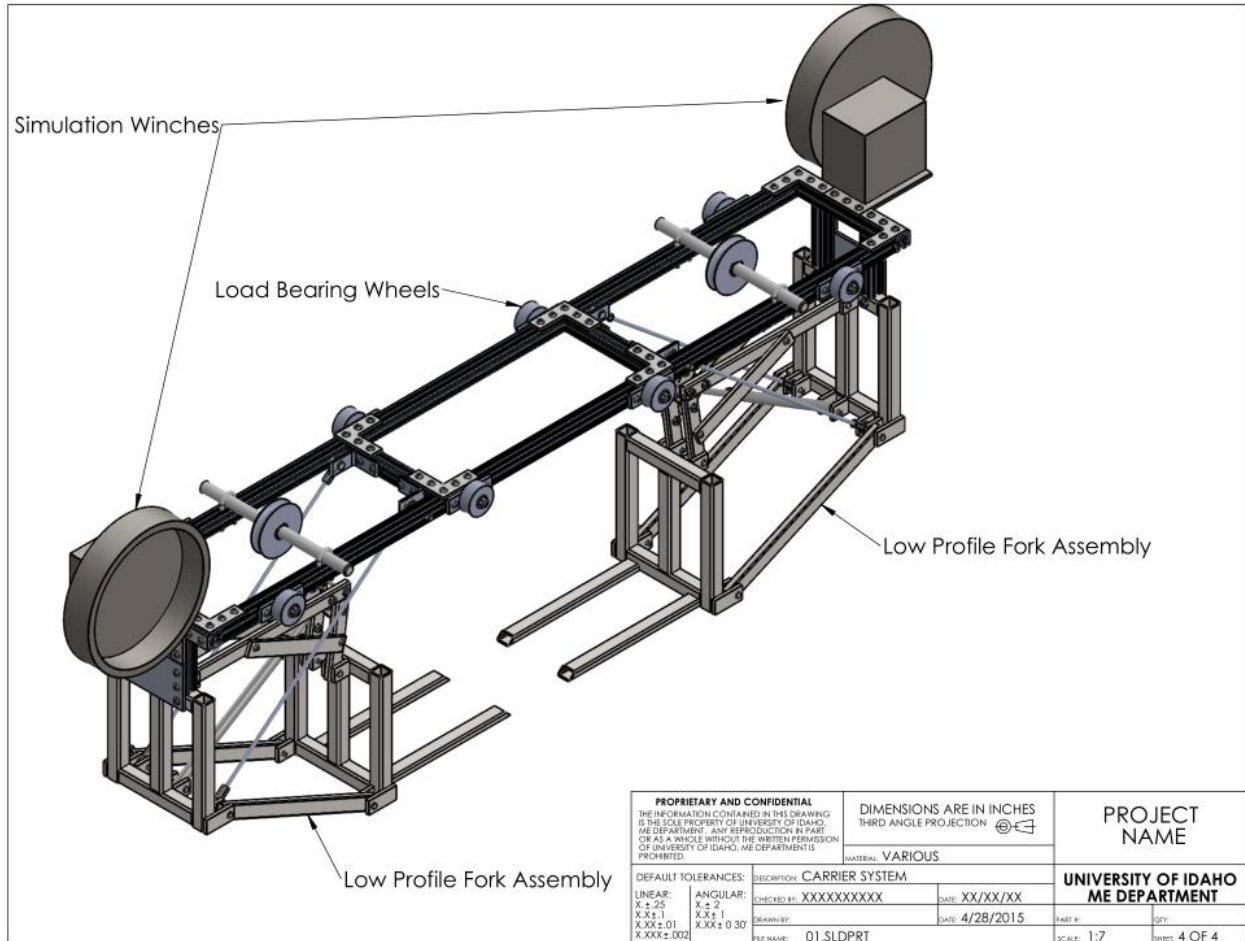


Figure 15: Linear Transition Chassis

Figure 15 shows the mechanisms in the Linear Transition Chassis. The low profile fork assemblies fit underneath the chassis, allowing full range of motion without any physical interferences. One set of forks will pick the bin up and the second will move via the load bearing wheels thus transitioning the bin to the second set of forks.

### Low Profile Forks Features:

With the design we have, a lower profile fork system was needed. The forks had to be able to fit underneath the Linear Transition Chassis. The general shape of the fork assembly is very similar to a traditional boom/hydraulic combination. A design challenge that was overcome was there was no room underneath the linkages to attach cylinder. Modeling these forks after a 3 point hitch allowed the cylinder to be mounted inside the connection linkages. This is explained further in Figure 16.

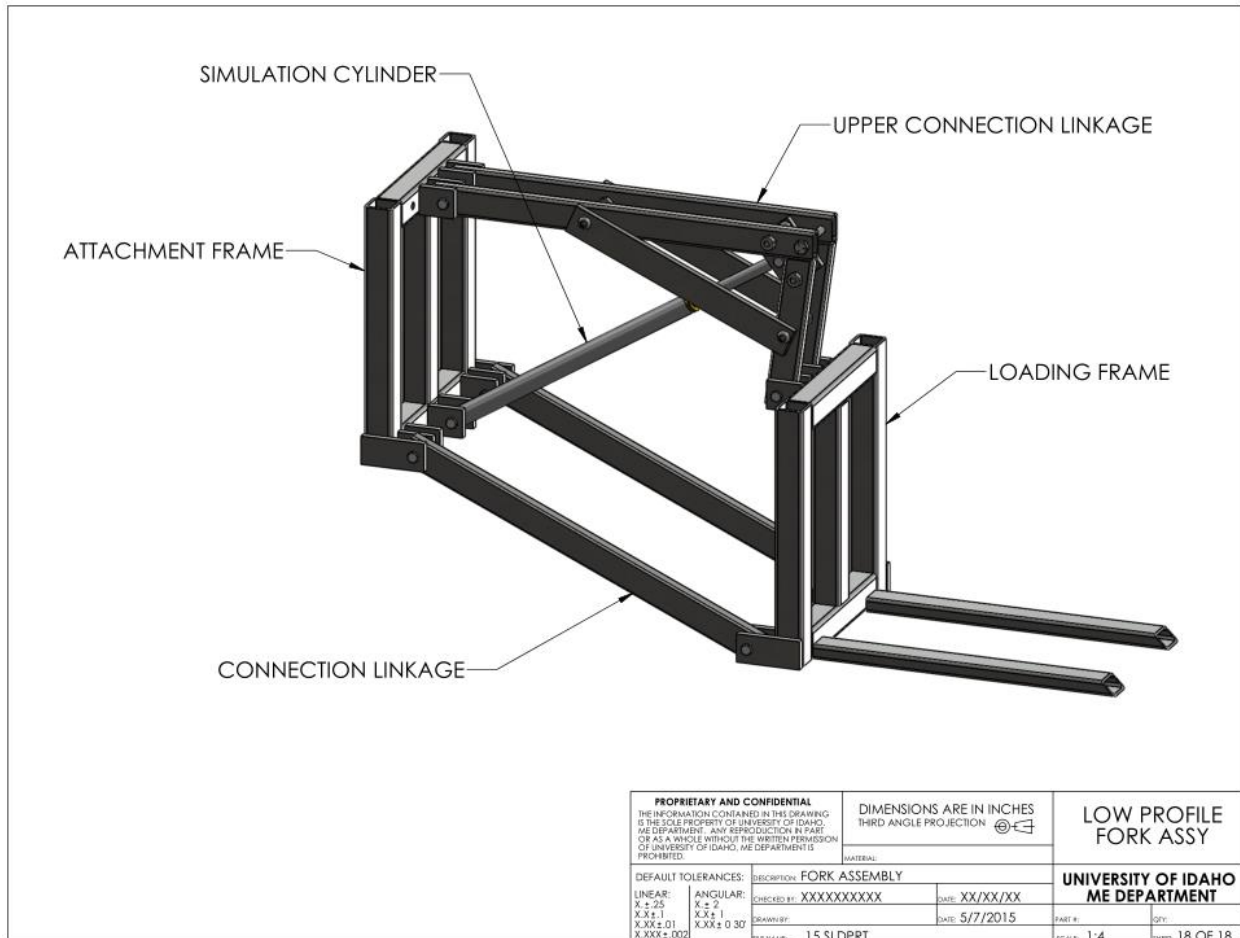
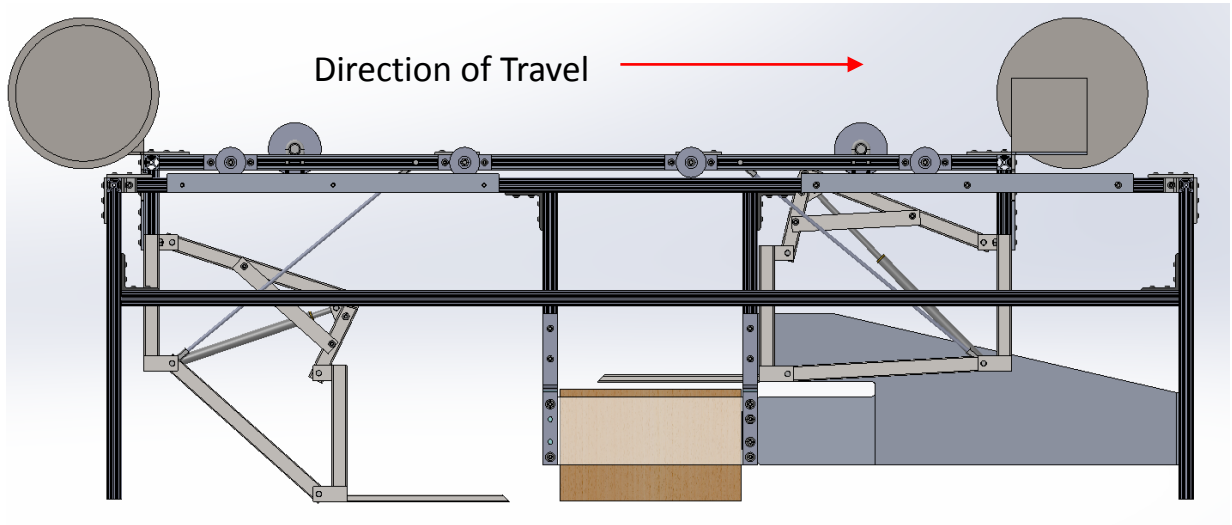


Figure 16: Low Profile Fork Assembly

Due to size constraints the linkages had to be exceptionally long. The travel for the cylinder was relatively large compared to the size of the assembly. Finding a cylinder to fit inside the linkages at a 1/4 scale was very challenging. A comprehensive linear algebra code was made in order to optimize the geometry and find a cylinder that could work. Once the design was complete, there wasn't room the budget to accommodate the cylinder (McMasterCarr Part Number 6509K86, 11" retracted length, 17" extended length). At \$300 apiece, a more cost effective solution had to be found. This constraint led the team to decide on making a simulation cylinder. The cylinder had all the same geometry as the actual cylinder and was made with two pieces of pipe and a bronze bushing to reduce friction from the sliding.

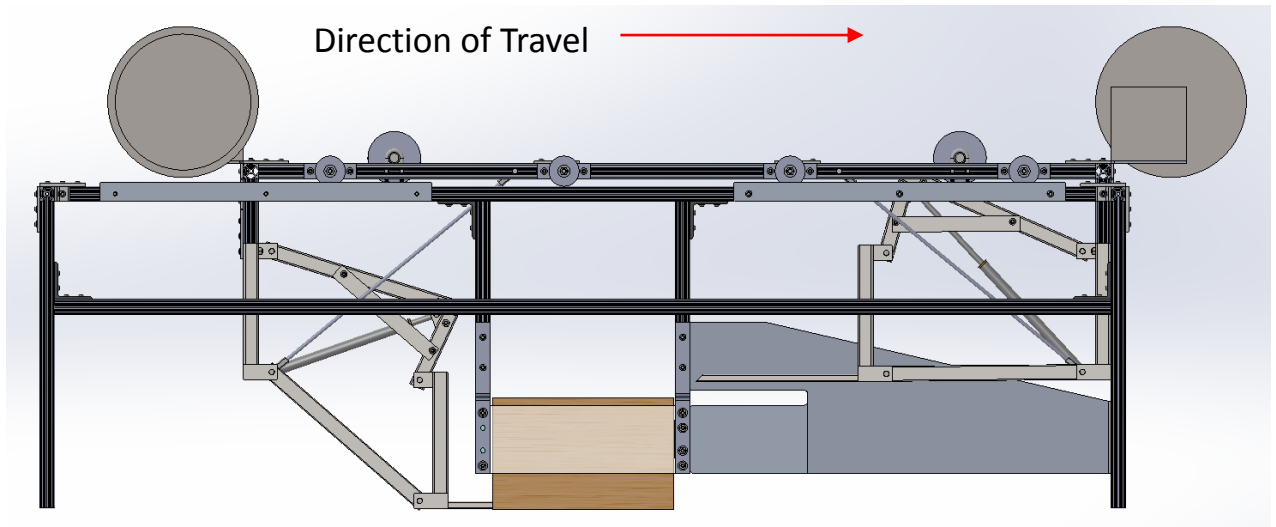
### Assembly Operation Steps:

1. As the machine approaches the bin, the non-load bearing forks extend down to the ground. The load bearing forks are lifted up, allowing the bin to pass underneath, as shown in Figure 17. All of the alignment plates have gotten the bin correctly positioned underneath the frame.



*Figure 17: Step 1*

2. There will be some sensing equipment on the frame, either a mechanical switch or an electronic eye, to know exactly when the machine needs to stop and the forks have properly engaged with the bin.



*Figure 18: Step 2*

3. The non-load bearing forks then lift the bin up, leveling the bottom with the load bearing forks. As shown in Figure 19, there will be members hanging down off the Frame. These members keep the bin from sliding back and forth out of center.

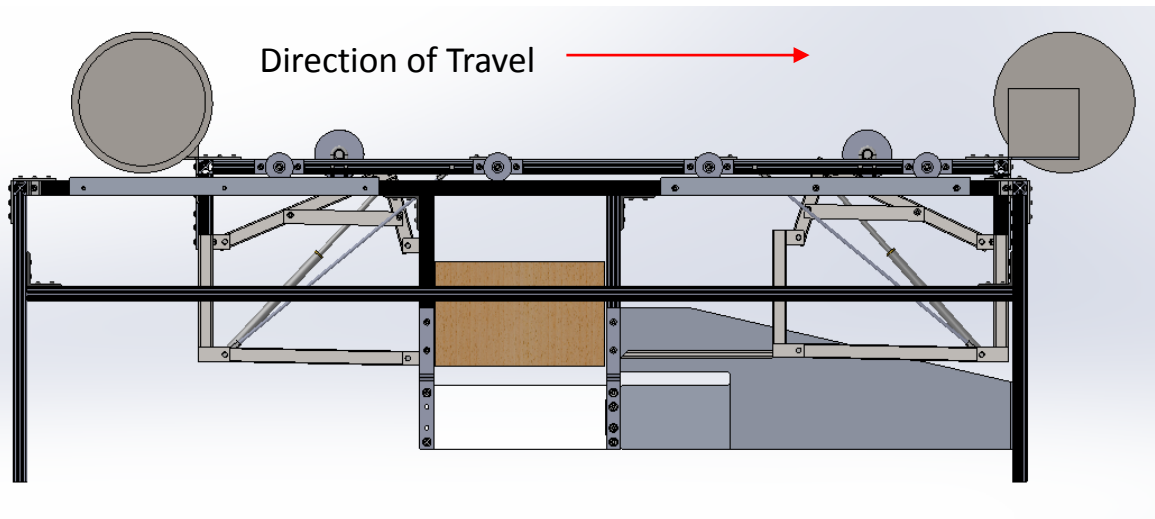


Figure 19: Step 3

4. Once the bin has been lifted to the correct height a transition will happen with the forks. The Linear Transition Frame rolls towards the rear of the machine, thus transitioning the bin to the Load Bearing forks as shown in Figure 20.

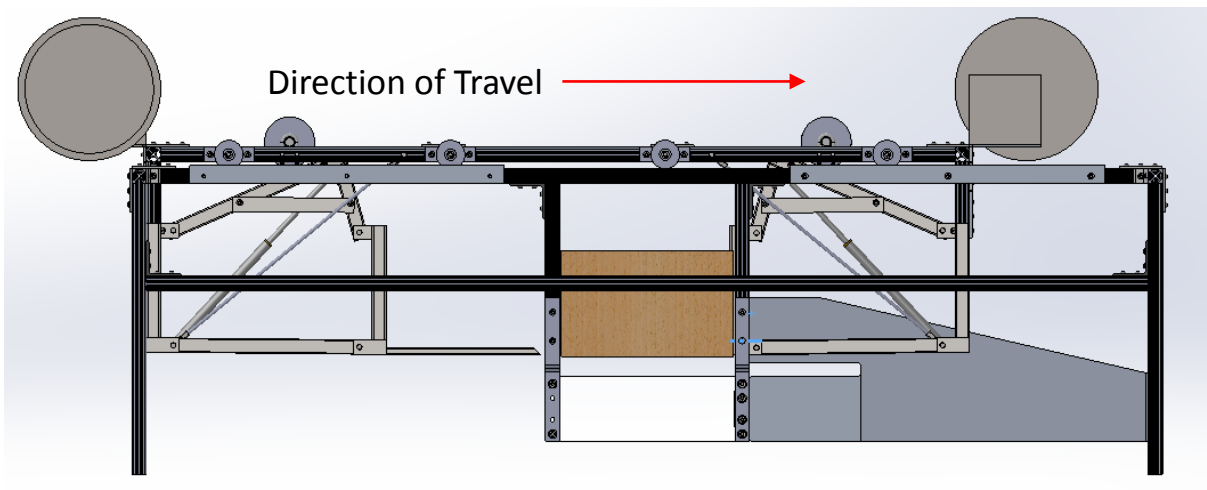


Figure 20: Step 4



5. After the bin has been moved onto the load bearing forks the machine can start moving forward. The worker then starts picking the fruit from the bucket. Fruit is transported down the boom, into the bin via a system similar to the vacuum tubes in the Whoosh system. Once the bin is full, it can be lowered, seen in Figure 21.

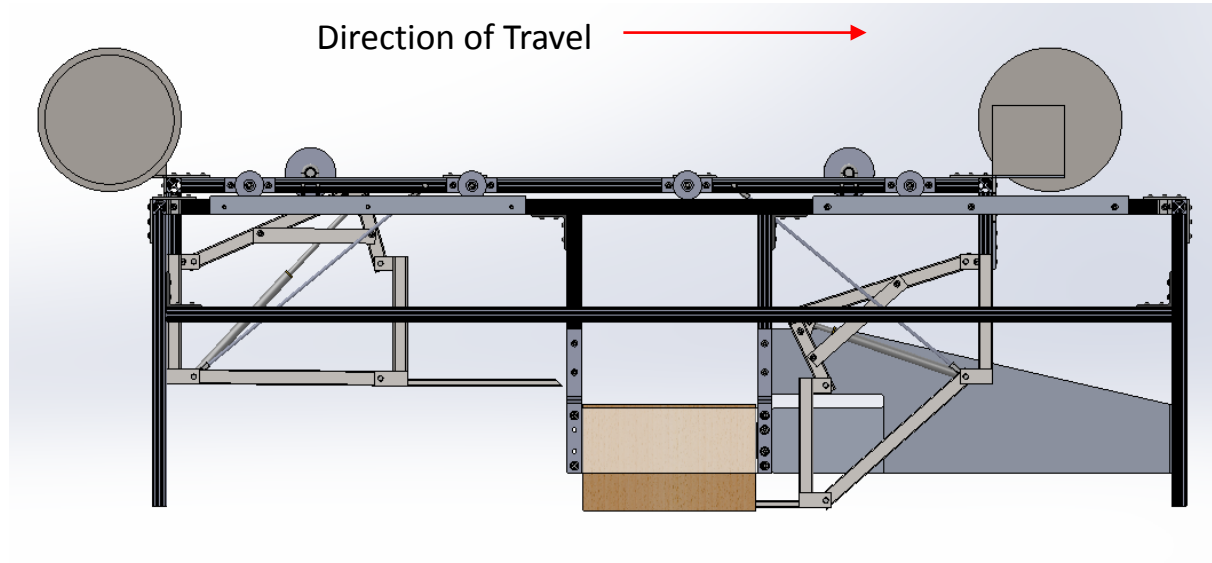


Figure 21: Step 5

6. Once the bin is full of fruit, the machine can then lower the bin and drive away without changing direction.

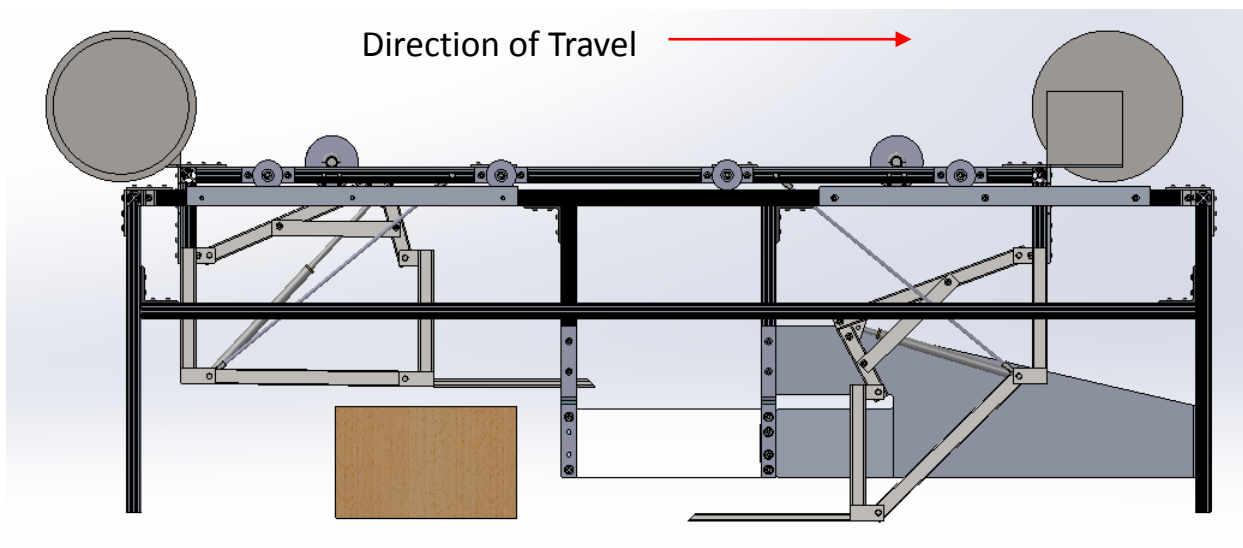


Figure 22: Step 6

**Next Steps in Manufacturing:**

The next steps needed to make this a more robust model are:

- Motorizing the Linear Transition Chassis
- Installing a controlled cylinder to lift and lower the bins
- Develop a code to let the Linear Transition Chassis and the forks work together without running into each other
- Putting the Simulation Chassis on wheels to more accurately simulate the full scale model
- Reducing the size of the fork assembly which would shorten the Linear Transition Chassis

**Pro's/Cons of the Bin Management System:****Pros:**

- Simplicity
- Known and existing Technology
- Proven ability to work via scaled model

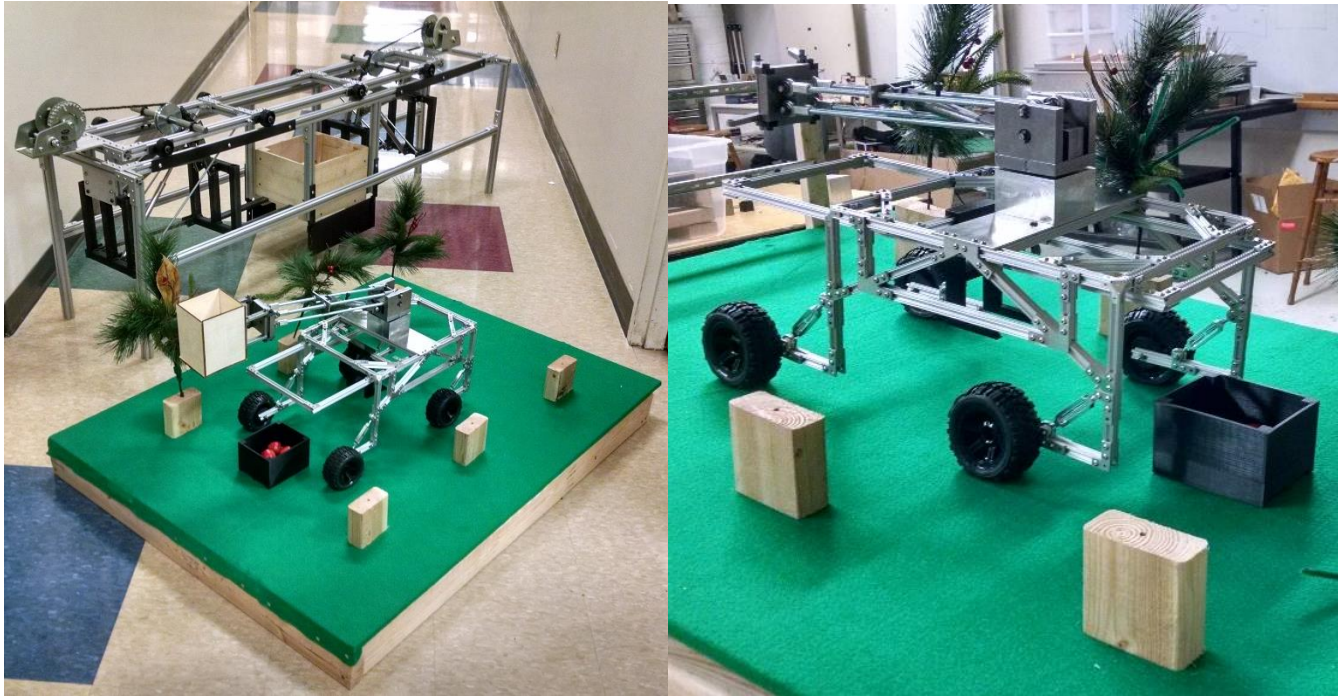
**Cons:**

- Cannot pick up another bin without depositing the last one
- Large frame size
- Large hydraulics needed to lift fully loaded bins

**Conclusion:**

Using existing technology, a solution to unidirectional bin management can be built. Some refining will be needed for the assembly that was designed. The biggest goal for future design would be to condense the frame, making it have a smaller overall footprint as well as shorter height. Once the full sized machine is designed and built, some research will need to be done to determine the bin spacing in the rows so that the worker can efficiently use the machine and use as little time as possible to change bins.

### **4.3 Boom Design and Development:**



*Figure 23: Finished product: scaled model of boom system*

In order to create a proof-of-concept model for our machine, a boom system needed to be built which would adequately show the degrees of freedom that we included in the design. Since this model was only meant to show the ranges of motion we intended for the machine, it was not necessary for it to be powered.

#### **Initial Design:**



*Figure 24: Orchard Ape Picker Platform*

Several design options were considered before arriving at the final conclusion. Our first idea was something similar to a scissor lift, in which the platform housing the worker would rise up and

down vertically. The downside for this design is that it is bulky and heavy, and must be repositioned frequently. After we visited Bishop Orchards we saw a machine called an Orchard Ape (shown above) which the orchard owner highly recommended. We decided at this point that the system for elevating the workers to the fruit was to be similar to a cherry picker; that is, a one-man bucket on the end of a long arm.

### **Freedom of Movement:**

To allow a worker maximum mobility from the end of the boom, we decided to have the boom system provide three degrees of freedom:

1. Vertical movement, up to 15 feet
2. Side-to-side rotation at the base (limited to a  $15^\circ$  arc in front of the machine for safety)
3. Horizontal travel of the bucket independent of boom

The first degree of freedom was taken through several design iterations. Firstly, we considered a single main boom with one or two stabilizing rods, similar to the Orchard Ape. A telescoping boom was also considered. However, we realized that a single boom gave no room for a fruit transport system, unless the beam was unreasonably large. We decided to have multiple parallel beams; first three, then four. These would distribute the load resulting from the weight of the bucket and operator, as well as provide a place for the fruit conveyor to fit. The beams would keep the bucket level as it rose and fell.

The second degree of freedom was solved with a large spindle around which the entire boom mounting point would rotate. Although a motive system was not designed, it is assumed this would use a hydraulic motor in conjunction with a worm gear.

The third degree of freedom was again taken through several design iterations. The possibility of even having this third degree of freedom was not guaranteed, but it eventually found a place in the final design. One of the first suggested designs was to simply have an articulated boom, where the upper segment would be able to swivel and elevate independently of the main boom. However, this was deemed too complicated in terms of fruit transport and construction, and so we settled on a system of parallel bars, similar to the elevation system but oriented horizontally. The above picture shows an early sketch of the proposed mechanism.

### **Design and Manufacturing:**

Once we knew the rough form of the boom system, we set out to design a scale model which could be easily manufactured. The final product is shown below, on its own and mounted to the 1/10 scale frame we built to demonstrate the self-leveling system.



Figure 26: Final 1:10 Scale Boom Design



Figure 25: Final 1:10 Scale Assembly

The model was never meant to be a perfectly scaled model fit for a diorama; as stated above, it was only meant to show degrees of freedom. Therefore some portions, especially the rotating mount, came out to appear oversized. The boom length and bucket size, however, were carefully scaled with the intent of placing a 1/10 scale human model in it. Unfortunately a model of the correct scale could not be obtained.

A piston analog was made to show the movement of a real hydraulic piston powering the vertical boom movement. This piston was built using two sections of pipe which slid over each other, and a set screw was threaded into the larger section so that the model could be locked into an elevated position.

### **Next Steps in Manufacturing:**

To continue design work on the boom system, several elements need to be considered. Firstly, the boom needs to be designed (and possibly constructed) with a full-scale product in mind. That entails stress and material analysis, as well as powertrain and hydraulic piston design. The design work will also encompass the mounting point, including a system that can reliably turn the boom to either side while also handling the stresses produced by the long boom. A mechanism to transport the fruit will need to be designed as well, and although it is partly contained within the boom it may require its own subsystem.



## **5.0 Conclusion:**

The system presented above will serve as a jumping-off point for future design efforts. Using the resources at our disposal, we were able to construct two prototype systems that function as proofs-of-concept for our design decisions. The boom, frame, and bin handling systems designed and constructed by our team will provide solutions for the problems presented by our client and within the constraints that we discovered. These systems were designed and built so that any future design projects can pick up from where we let off and continue our work into a fully-fledged product. Fruit transport wasn't involved in our prototypes due to time, manpower, and budget constraints.