



PETE STEERE

“The Mega Mite”

Spring 2012 Report

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Mission Statement

The mission of Pete Steer Designs is to provide reliable and innovative solutions that reduce unassisted physical workloads, with implements that are easily attachable and adaptable to skid steers.

Problem Statement

The product will combine two common attachments for skid steer machines. The combination includes a skid steer mulcher with a skid steer grapple. This combination will allow the operator to grab brush and debris piles to be mulched. This will also give the operator a choice where to mulch the material, such as into the bed of a truck, or a remote chip pile. The product will be powered by the skid steer's auxiliary hydraulic system.

The sponsor company, Coneqtec Universal, has suggested the product idea and will be supervising the design process. Engineers at BIC have some preliminary design concepts and it is planned to spur off these current ideas. The process concept is in the preliminary stages of patenting by BIC.

Team Sponsor



Figure 1. Coneqtec Logo

Coneqtec Universal is the sponsor company. Wichita, Kansas is home to the company built on relationships developed during time spent by the engineers at Case New Holland. The company, founded by Mr. Gary Cochran, has designed and manufactures a number of skid steer after-market modifications and implements. Ranging from rock saws to rotary tillers, Coneqtec Universal strives to implement the latest technology while designing solution equipment for real world application. Super high flow kits with several auxiliary ports engineered by the company enable endless possibilities to solve issues with numerous variables. More information attached in Appendix D.

Statement of Work

The primary goal of the product is to carry debris, i.e. tree limbs, storm debris, shingles, sheetrock, etc., to a remote location and chip it into manageable form. The implement will be used on a standard skid steer, with high flow hydraulics, and auxiliary controls.

Scope of Work

- Define the finished product
- Design and Spec
- Create final design
- Build, Test, and Determine satisfactory performance

Location of Work

- The majority of the work will be performed at the OSU Stillwater campus
- Several trips to Wichita, KS will be necessary to meet at BIC with the company engineers
- Fabrication and manufacturing will be done at the OSU BAE Machine Lab
- Some fabrication may exceed the BAE Machine Lab capabilities and need to be moved to BIC or contracted out to Stillwater Steel

Period of Work

- The final design will be completed in early March
- Building and Testing will begin in March, with a final product review scheduled for April

Environmental Impacts of the Mega Mite

The Mega Mite will greatly improve the efficiency of storm debris and brush removal for cities. It will save labor with one man able to operate the job instead of the three it would take to operate a regular tree mulcher. This will be more economical by saving the owners time and fuel. It will help the environment by reducing the debris to smaller pieces allowing for faster recovery from a storm. The Mega Mite will be beneficial both economically and environmentally because of its unique ability to save labor and mulch material into a more environmentally friendly size for reprocessing.

Revised Economic Analysis

The marketing strategy for Coneqtec Universal's equipment is simple and straightforward. They want to focus on municipalities and disaster relief programs. The main reason they want to market to these two specific segments of the industry is because the customers in

these industries have an everyday use for an attachment like the Grapple-Mulcher. A recent Solid Waste Association of North America (SWANA) publication said “Yard trimmings volume has been increasing slightly since 2000, an estimated 33.2 million tons of yard trimmings were generated in MSW in 2009.” Municipalities pick up debris routinely and this implement could be used to clean up yard trimmings and aid in storm cleanup efforts. Disaster relief programs could use the Grapple-Mulcher to clean up after major storms and natural disasters. The mulching element of the Grapple-Mulcher is capable of mulching debris from trees, limbs, brush, and demolition rubble. With waste levels increasing over the last fifty years, it seems that there will always be a need for a disposal method for yard debris.

After further research there is still no other product on the market like the Mega Mite. The closest competition is a mulcher from Bradco Figure 2 and a grapple from Skid Steer Solutions Figure 3.



Figure 2



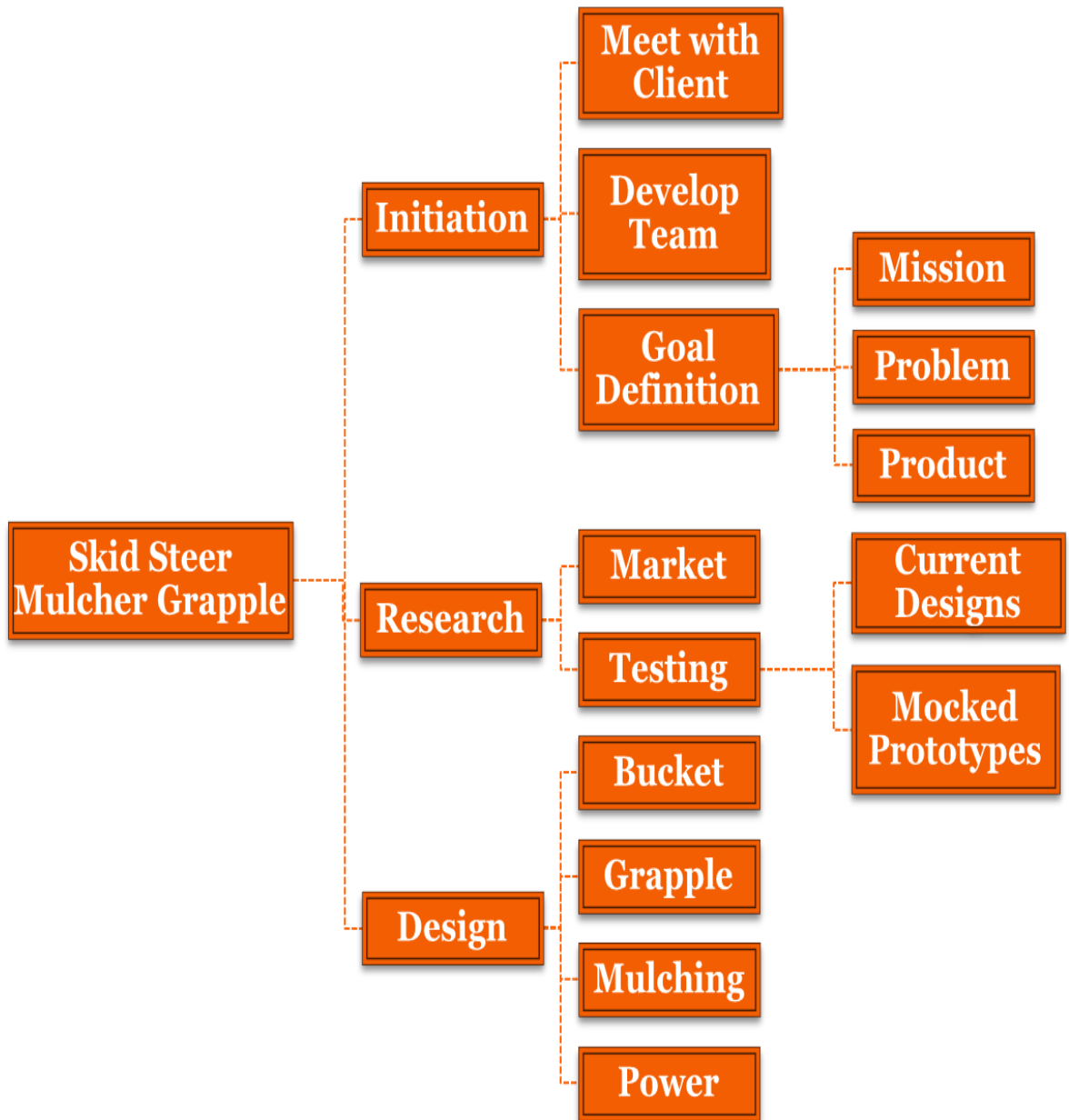
Figure 3

To perform the same function as the Mega Mite two skid steers would have to be used and it would cost \$25,000 just to buy the attachments alone. The Mega Mite will be a very economical solution to remove storm debris for cities and municipalities.

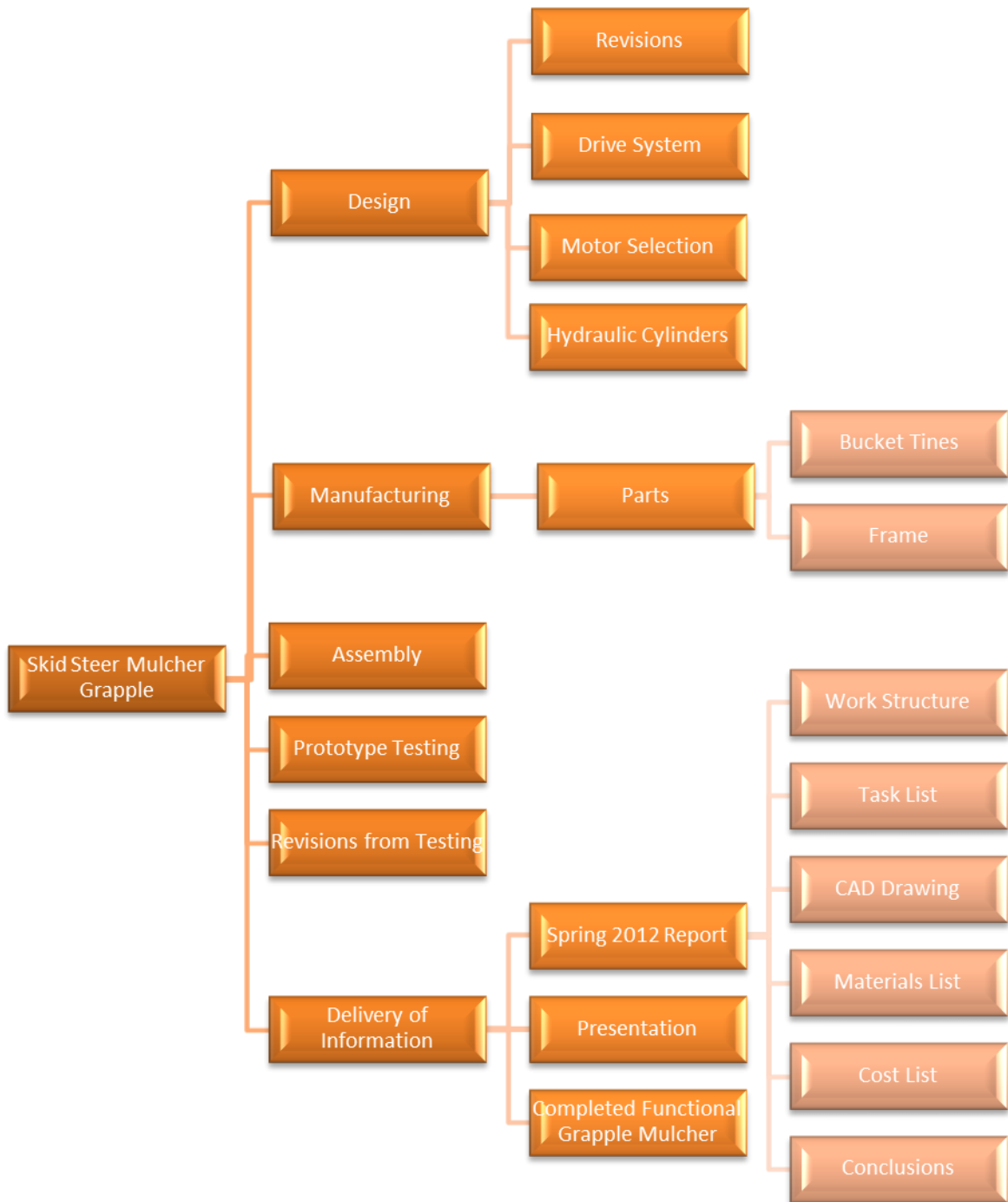
Product Definition

The completed product will be a skid steer mounted implement powered by the auxiliary hydraulics. The target vehicle will be outfitted with a super high flow kit, multiple auxiliaries and have a rated horsepower of 80 or greater. Smaller skid steers should be able to run the mulcher, but may lack sufficient power. The implement will collect a bite of material, carry to a certain location then proceed to mulch the material into a receptacle in small enough pieces. The weight of the attachment should not exceed 3000lbs out of concern for tipping over. The drums for mulching should reach around 2000 RPM's for ideal performance.

Fall Task List



Spring Task List



Deliverables Schedule

The Following things will be delivered to the client by the end of the project.

1. Formal Report including research, history, and project outline: May 4, 2012
2. Final Specifications: April 1, 2012
3. SolidWorks drawings and assemblies: March 15, 2012
4. Prototype: April 15, 2012
5. Timeline: January 15, 2012
6. Materials Breakdown: March 10, 2012
7. Cost List: March 30, 2012
8. Previous Concept Designs: Throughout project

Design Challenges

The team planned to have the design completed by the end of January. After meeting with the team sponsor more revisions needed to be made to the thumbs of the grapple. After the second meeting with the team sponsor more revisions had to be made to the design. The design was completed and sent to fabrication in March.

During the fabrication process, the team faced a number of challenges. One issue was the drum size. The BAE machine shop did not have the designed 7 inch and 0.875 inch thickness pipe. The team looked for a distributor that carried the designed pipe diameter. The search concluded when a pipe was found at Stillwater Railroad Yard that had a 7 inch diameter with a 0.375 inch thickness instead of the desired 0.875inch. The drum diameter may need to be changed in the future design for mass production due to the uncommon 7 inch diameter pipe versus the more common 8 inch diameter pipe.

Another issue was found in the connection of the cylinders to the grapple arms. A few geometries were analyzed to determine the best fitting design. The end result geometry required the addition of ball joints to the end of the cylinders in order to obtain the desired angle while maintaining hydraulic power to the grapple arms.

The main issue was determining a proper drive system. The distance between the drums and the desired drum HP proved problematic. In order to design the drive system with belts, a center distance greater than what was designed would be needed. Most of the belts found would not sustain the HP required without an unrealistic number of belts. There was talk about using a chain drive system, but due to similar space limitations and HP requirements this

design was rejected. A third option of using two independent motors was considered as well, but that option was too expensive. Finally, after deliberation and communication with a number of dealers, the team contacted John Hill at UNLAUB Company in Tulsa, OK. John and the team selected a Gates PolyBelt that would satisfy the design requirements.

Past Design

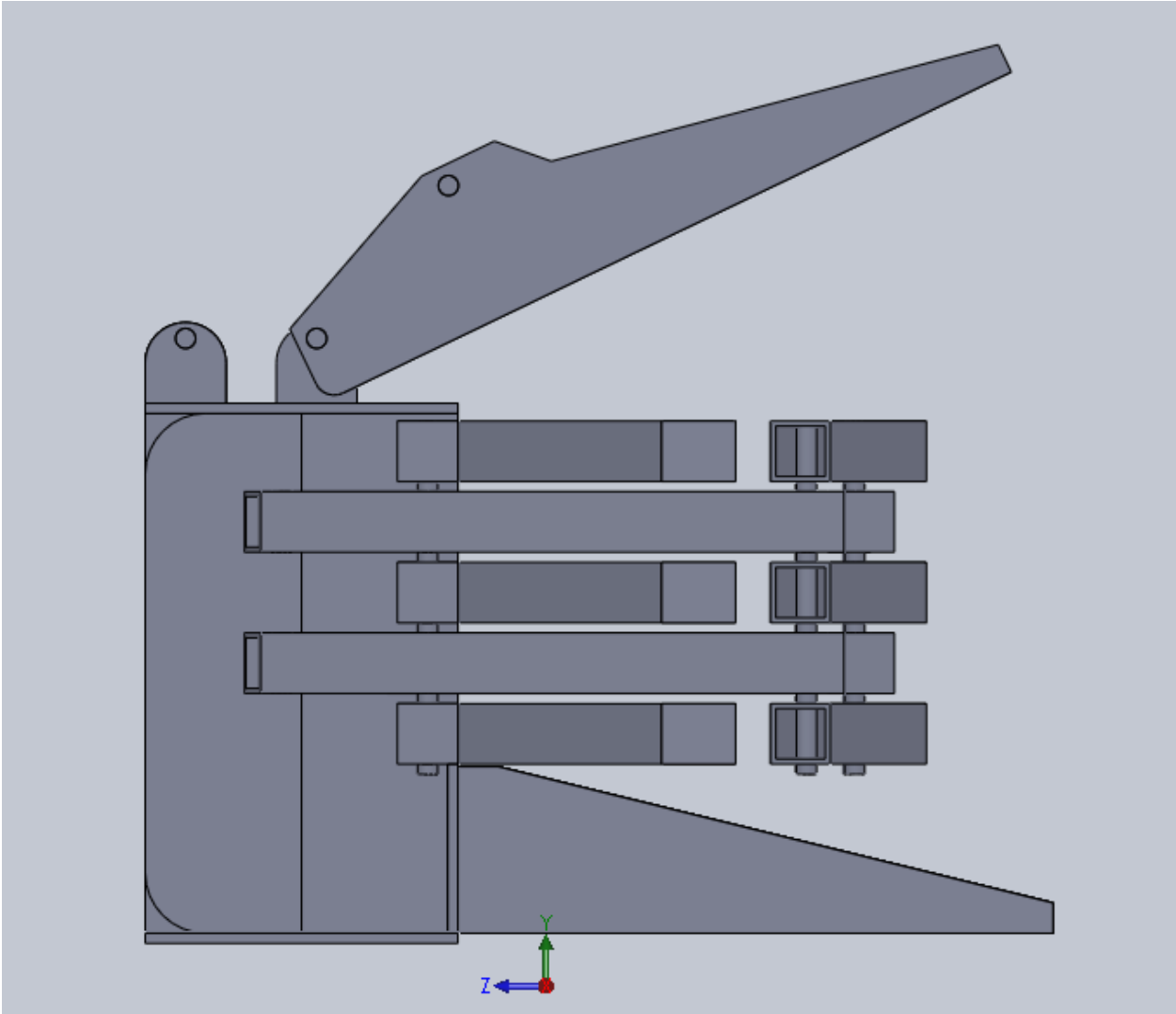


Figure 4 Right Side View. Flat top grapple design.

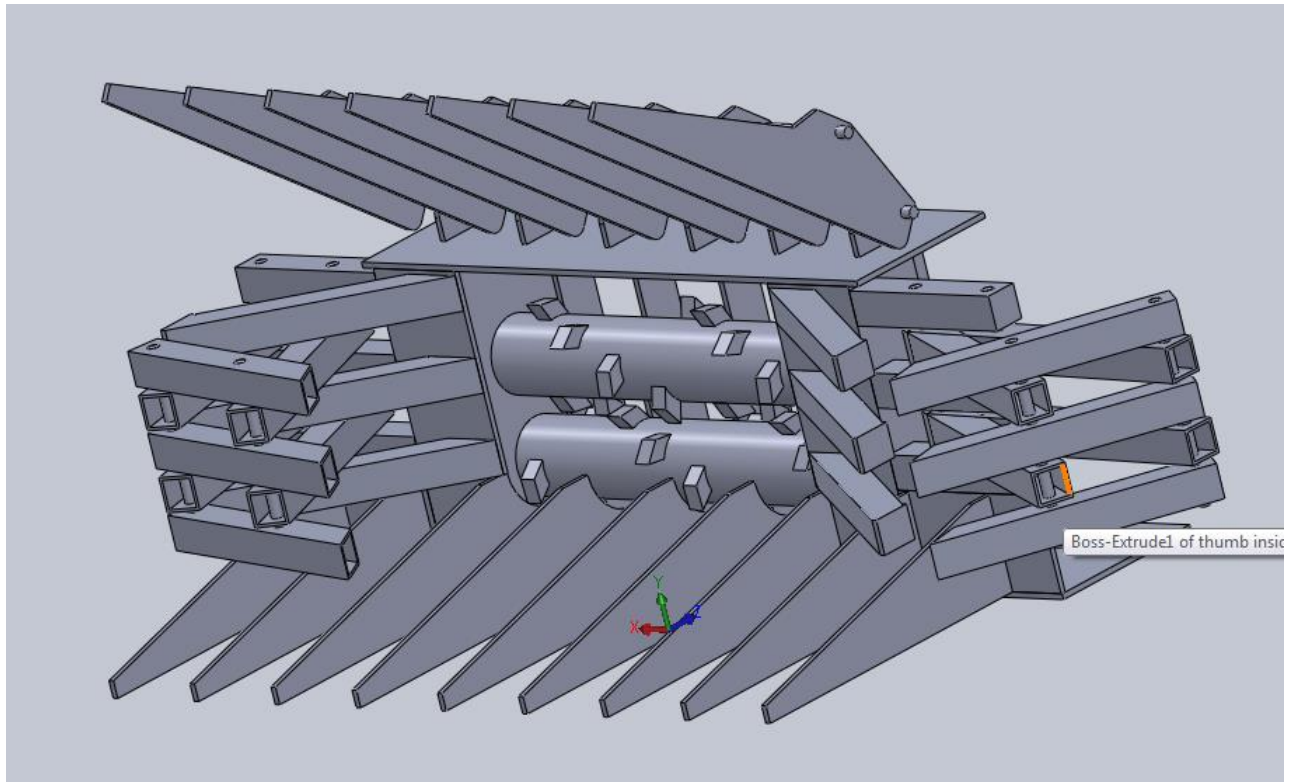


Figure 5. Isometric View. Without intermittent tines between drum teeth. Flat thumb grapple arms.

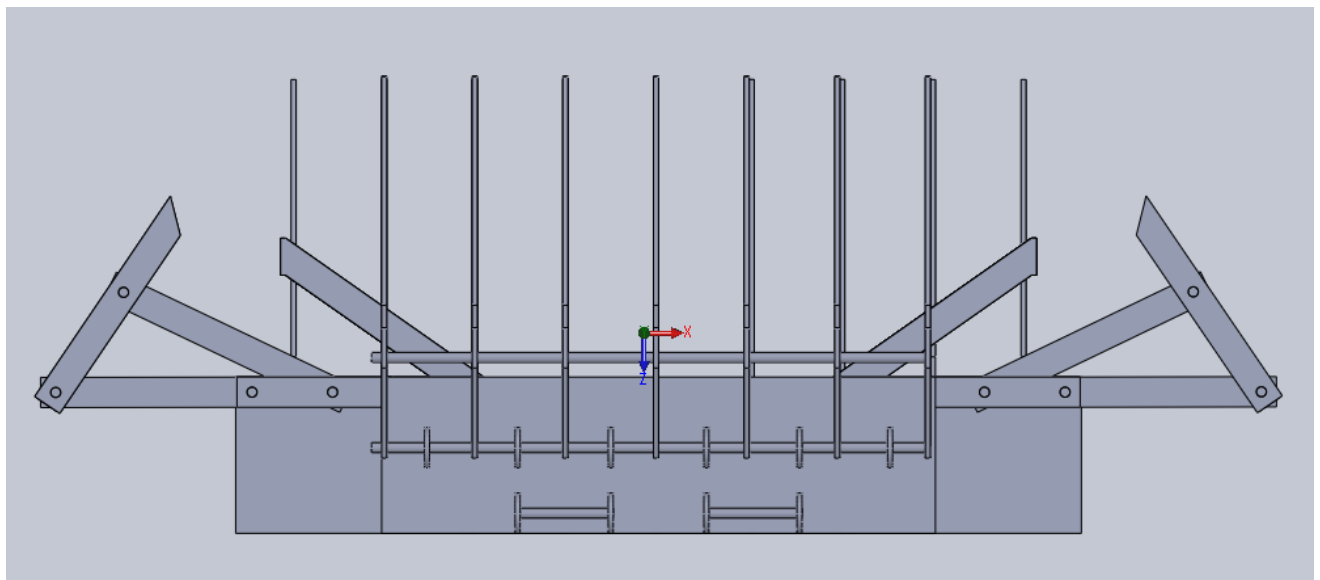


Figure 6. Top View. Thumbs are open.

Prototype Design

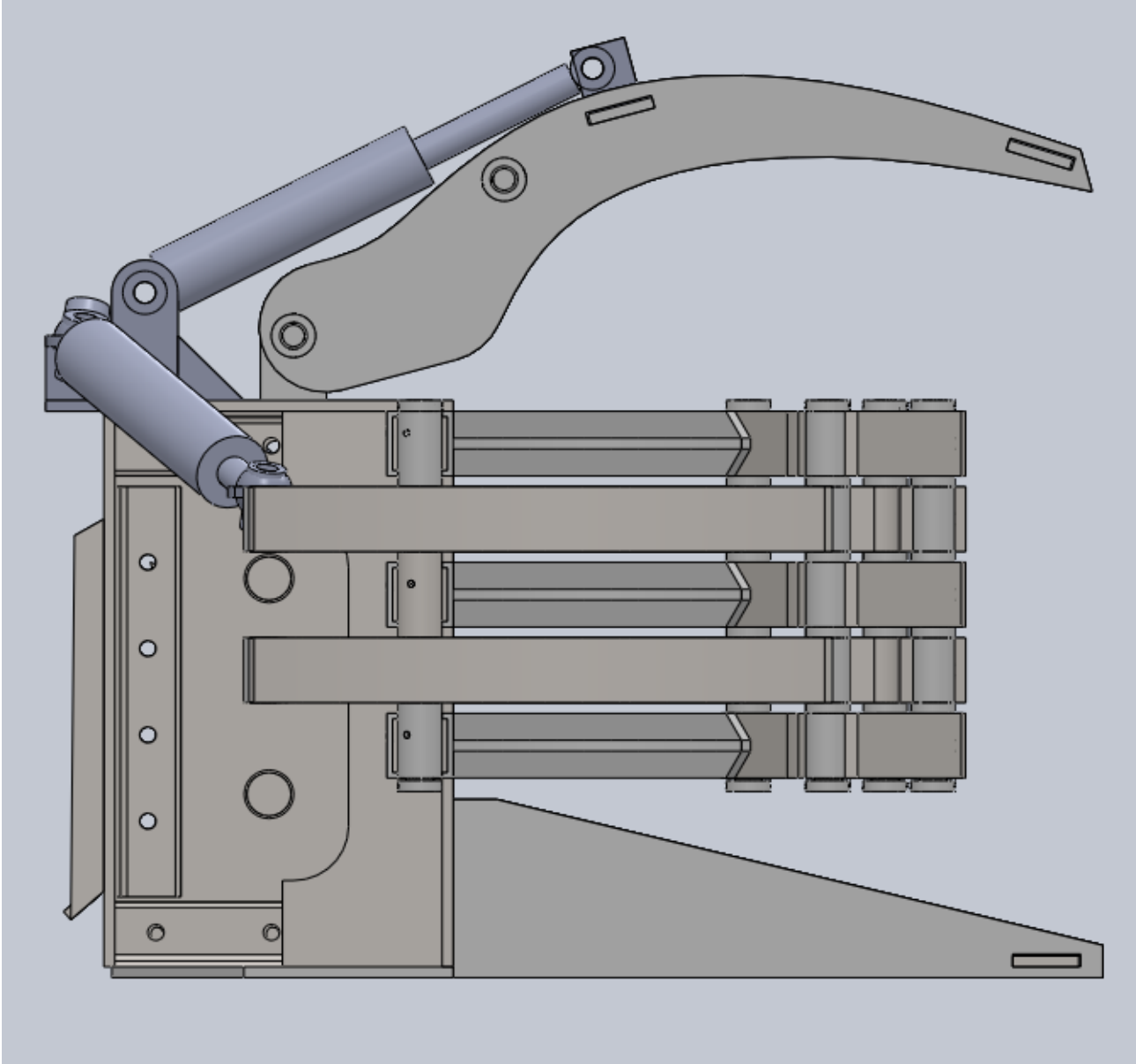


Figure 7 Side View

This is a view of the right hand of the final prototype drawing. You can see how the cylinders are attached to the side thumbs and to the top grapple. The connections for the drum cradle

are shown that allow the drums to be pulled out for maintenance. The top grapple now as a more aesthetic look.

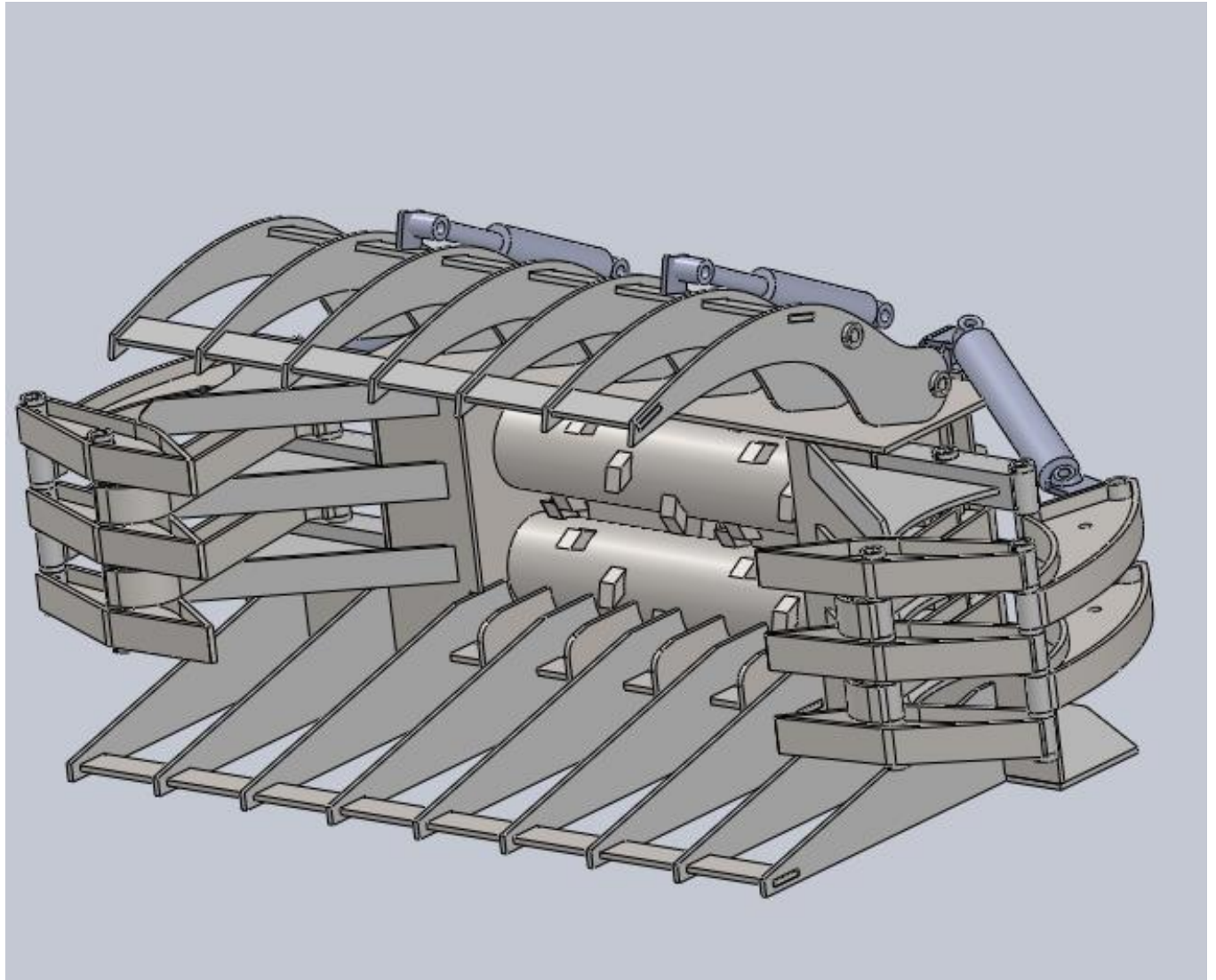


Figure 8 Isometric View

This view shows the front of the prototype. It gives a good view of the funnel arms function with the side grapple. It shows the overall view of the Mega Mite and show the functions are

working together. There are intermediate tines between the main tines for a greater mulching area. The Mega Mite now has overall better aesthetics.

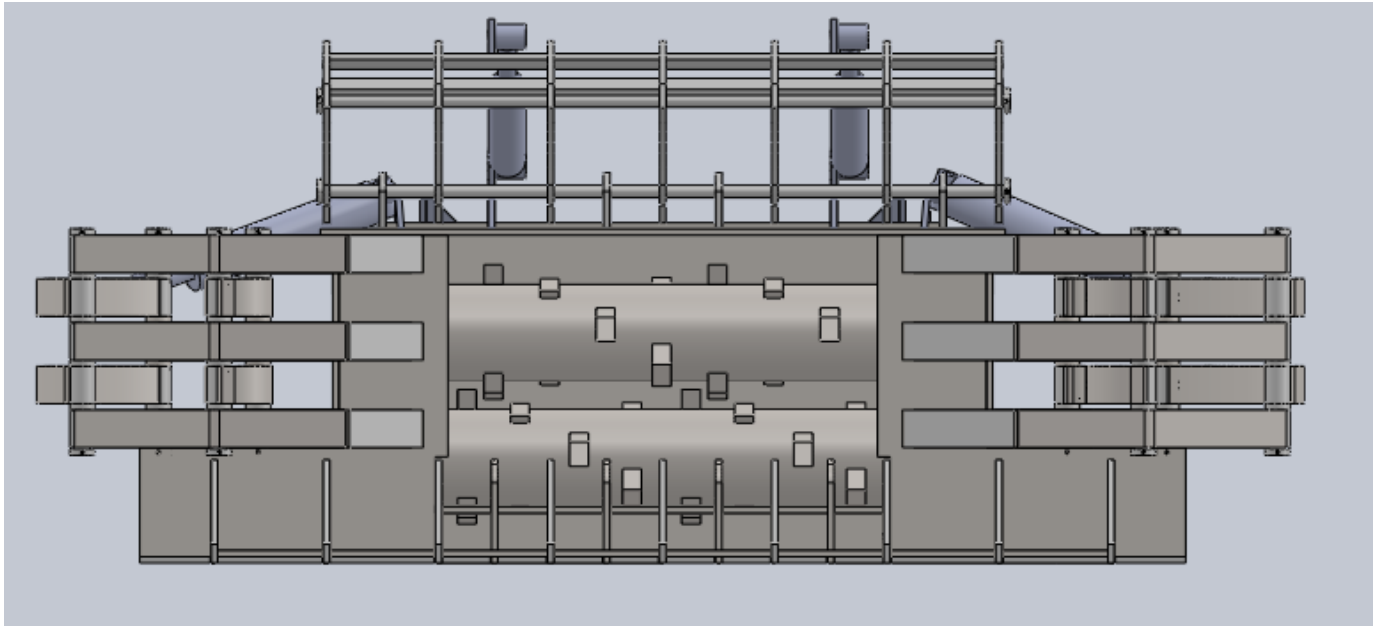


Figure 9 Front View.

This view shows the front of the prototype. The view highlights the overlapping pattern of the teeth on the drums and how the teeth overlap with the tines to provide the cutting area of the teeth. The tines bring the material to the center of the bottom drum to keep the material from being pulled under the drums and not be mulched.

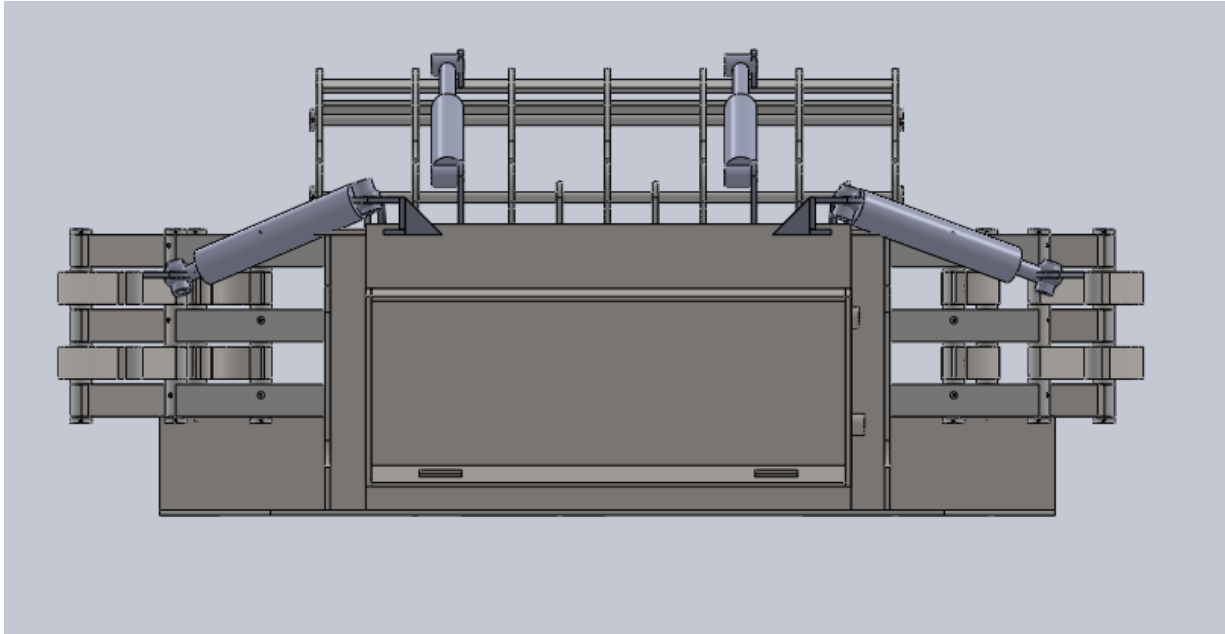


Figure 10 Back View

This view shows where the skid steer will attach to the prototype. It also shows the connections for the side grapple cylinders to the main frame and to the grapples themselves.

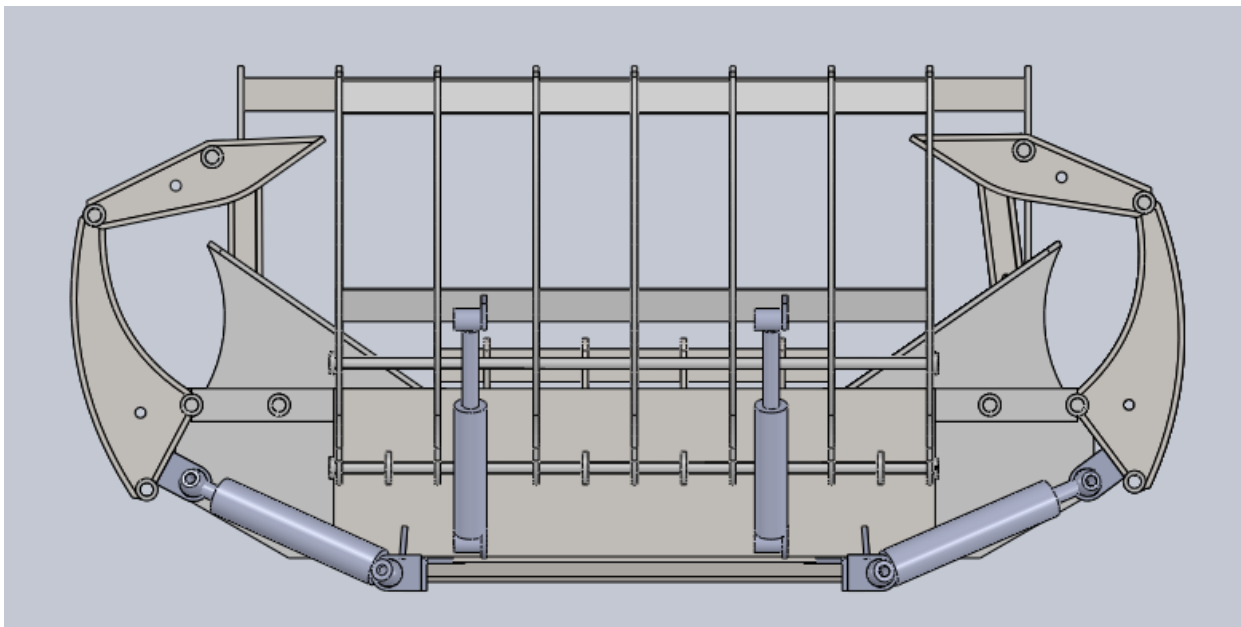


Figure 11 Top View

This is the top view of the Mega Mite, refer to Figure 12 for the closing pattern.

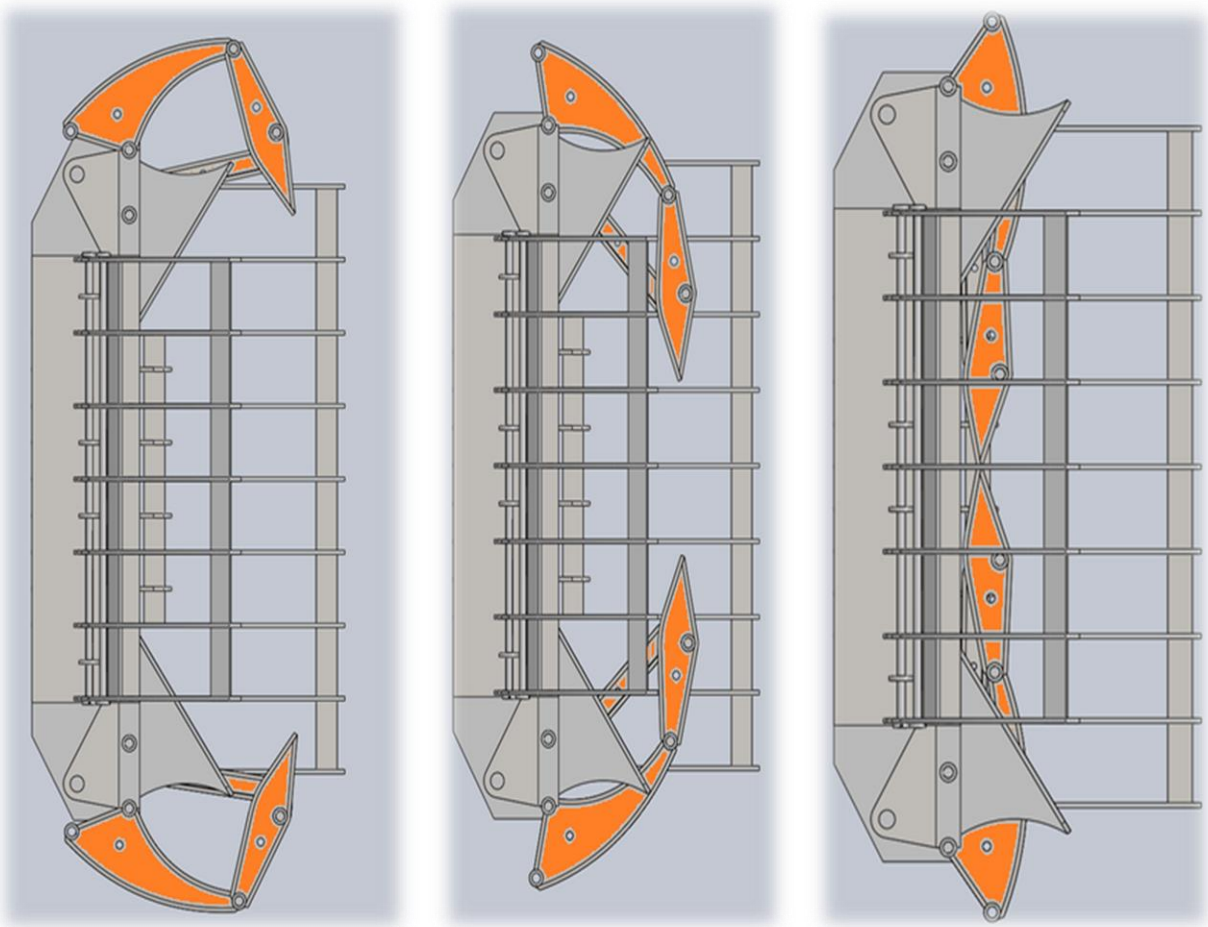


Figure 12 Grapple Closing Path

The figure clearly shows the travel path of the grapples. The diagram starts on the left showing the arms fully open. The middle show the position when the arms are halfway throuth the path of travel and the last one on the right shows the fully closed position of the grapples. As you can see from the picutres the arms gather the material and compress it into the drums to be mulched.

Prototype (Pictures)



Figure 13



Figure 14

Test Procedure

The team tested several conditions with the prototype to determine performance under probable working situations. A 192 cubic foot brush pile was conditioned by the mulcher. The team tested rolling start, with the drums already fully engaged before introducing the material. The team also tested a contact start, with some branches already contacting the drum to see if the drums would engage and mulch the brush. The brush that was tested was of a variety of conditions. There were branches less than two inches in diameter and branches up to six inches in diameter. The team tested dry and wet wood with leaves on the branches. The test also included a full dry cedar tree.

The team judged the performance based on feed performance, mulch size, if the prototype had enough power to mulch the material, and overall function. For feed performance, how well the side thumbs bring the material in and did the drums have neutral feed and not pull the material in and stop the drums was analyzed. The quality and volume reduction of the mulch was noted. The power and ability to resist bogging down was studied.

At the time of testing the team was only able to obtain a standard flow skid steer. It had an auxiliary flow of only ~15 gpm. A high flow skid steer has a flow rate of 30-35gpm, so the implement was only operating at half power. The skid steer had a lift limit of 2200lbs and could not pick up the prototype. All tests were done from stationary stands and all material had to be placed on the tines by hand. This limited some of the Mega Mites abilities. It was designed to be driven into a brush pile and use it from back pressure to help feed. It also could not be tilted back to use gravity to help it feed. These limitations are taken into account in the test results.

The first test was placing a dry full cedar tree into the mulcher (Figure 15).



Figure 15

The second test was a fuller bite that was similar to what the mulcher would grab if it were able to drive into a brush pile (Figure 16).



Figure 16

The team then proceeded to mulch the rest of the material. It included dry and wet cedar and other common Oklahoma trees. All of it was mulched and carried off in one load of the skid steer bucket.

Test Results

The Mega Mite did reduce the pile of brush from a 8'x6'x4' pile (Figure 17) to a 4'x3'x1.5' pile(Figure 18), which is a 90% reduction in size.



Figure 17



Figure 18

The first test had little results. The grapple arms did bring the tree in but it was not pulled in and mulched (Figure 15). After some repositioning the tree was mulched after several cycles of the grapple arms. It did a good job of removing the needles from the tree. The second test had better results (Figure 16). The larger bite and the dry wood worked well. With the larger bite the grapple arms had something to push against and brought the material into the drums. The drums had no trouble mulching the dry wood. It became apparent in this test with the current design that there is a dead zone between the thumb grapple and the drums. It is large enough that once the initial material is mulched the grapple cannot push the remaining material in to be mulched. After restacking the material and starting again more material was mulched in the next run. With green wood the mulcher shreds the material instead of breaking it like the dry wood. The drums do shred the wood without much problem.

The drums performed well with the rolling start and had no problems performing. With a contact start the drums would stall and not engage if the branch was larger than 2" in diameter or if a branch was wedged in between on the same plane as the drum axles. During the mulching tests the drums rarely bogged down and showed that they had adequate power, even at half power testing. The mulch that was produced was small enough to fall between the tines and land on the ground.

Test Conclusions

During testing the implement encountered two mechanical failures. The first, a broken weld, was result of a separate weld not being completed as specified. The bottom weld had a short contact surface, and low penetration. These factors, along with the missed weld, resulted in the failure illustrated in Figure 19. Figure 20 shows the second failure. The pictured shaft hub failed after about 4 hours of testing. After examining the fractures, it was determined that previous stress cracks in the part were to blame, and the failure was not a result of power exceeding rated capacity. These are the only two failures the Mega Mite experienced during initial testing.



Figure 19

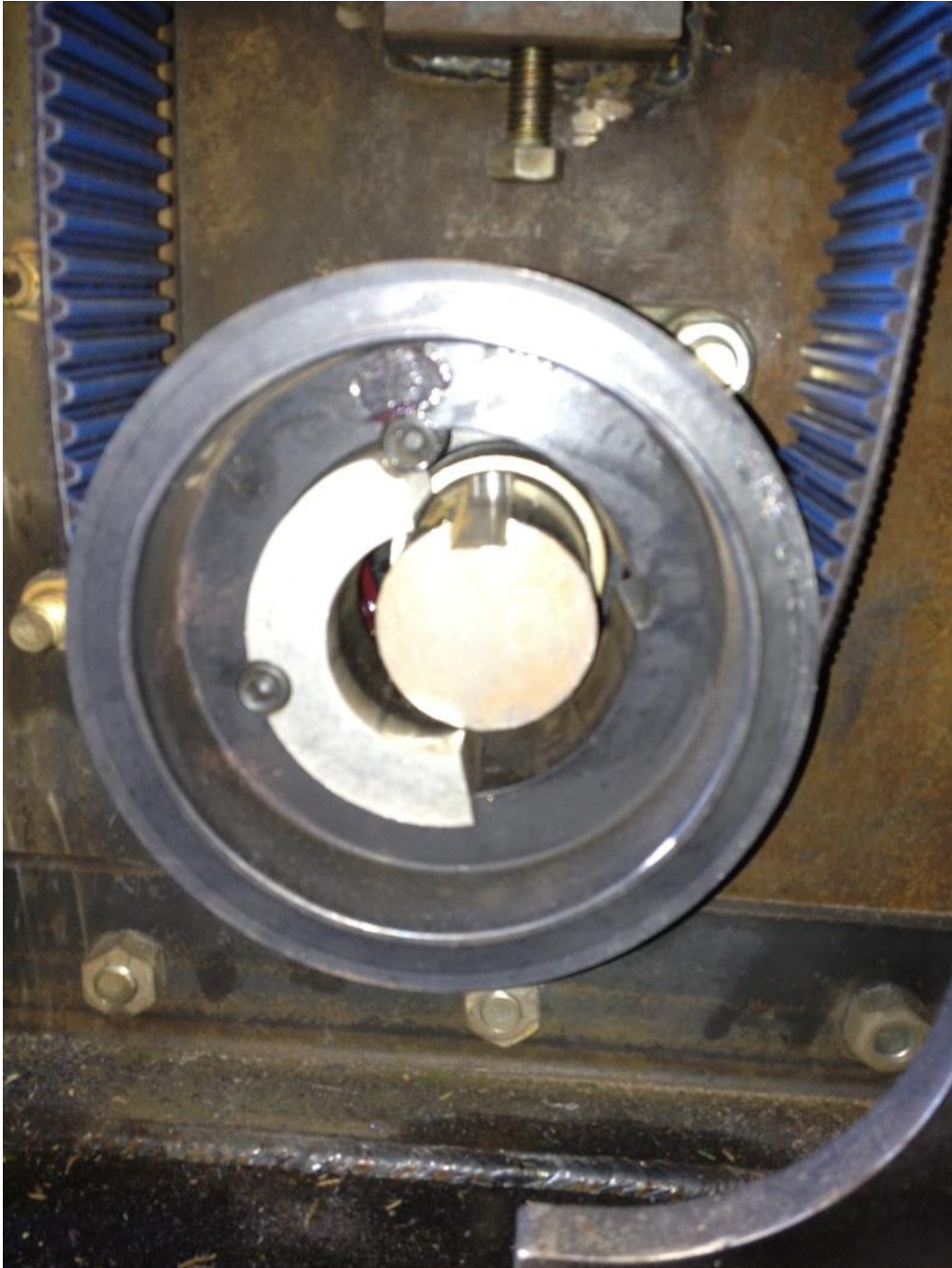


Figure 20

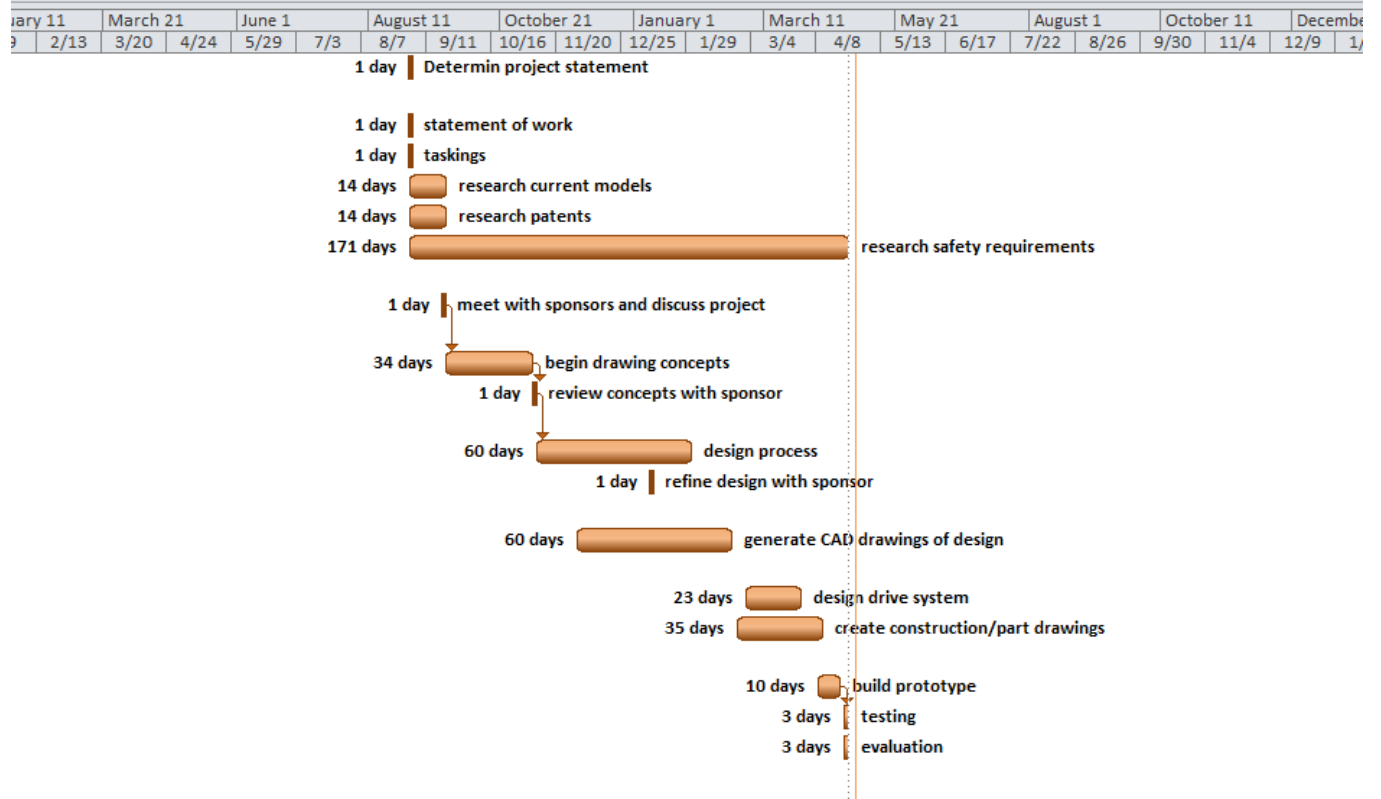
Revised Design Based on Test Results

There are several design changes that can be made to potentially improve the function of the Mega Mite.

- Bring the drums forward to reduce the dead zone between the grapple thumbs and the cutting surface
- An observation window should be installed in the back plate for the operator to see the drums
- The grapple thumbs geometry should be redesigned to increase the open position for a larger bite
- The top grapple should be redesigned and made a secondary feed device instead of just a containing device
- A solid plate should be added to the bottom tines to keep debris from falling through before reaching the drums
- The thumb cylinder mounts should be redesigned to a more even position with the new geometry of the thumbs
- Casting parts rather than hand fabricating parts to reduce cost
- Install plastic bushings to reduce the number of grease points

These changes could be made on the next prototype and tested again to assess their comparative performance.

Gantt Chart



Materials List

Prototype

part number	description	quantity	material
1000.1	base plate	1	1/2" plate
1001.1	center tine	3	1/2" plate
1002.1	mid tine	2	1/2" plate
1003.3	intermediate tine	4	1/2" plate
1004.1	outer tine	4	1/2" plate
1005.1	front plate	2	1/2" plate
1006.1	front plate support	2	1/2" plate
1007.1	intermediate tine support	1	1/2"X3 BAR
1008.1	bottom tine front support	1	1/2"X3 BAR
1009.1L	Left thumb support arm	3	3" square tubing
1009.1R	Right thumb support arm	3	3" square tubing
1010.0	thumb joints	44	2"OD x .375wall x 1.25 id 1020 dom
1010.0T	thumb support top joint	2	2"OD x .375wall x 1.25 id 1020 dom
1010.0C	thumb support center joint	2	2"OD x .375wall x 1.25 id 1020 dom
1010.0B	thumb support bottom joint	2	2"OD x .375wall x 1.25 id 1020 dom
1011.0	funnel face	6	1/2"X3 BAR
1012.0	funnel brace	6	1/2" plate
1013.4	inner thumb main	4	1/2" plate
1014.4	inner thumb skin	8	1/2"X3 BAR
1015.6	outer thumb main	4	1/2" plate
1016.7	outer thumb outer skin	4	1/2"X3 BAR
1017.7	outer thumb inner skin	4	1/2"X3 BAR
1018.7	outer thumb lower skin	4	1/2"X3 BAR
1019.3	finger main	6	1/2" plate
1020.3	finger outer skin	6	1/2"X3 BAR
1021.3	finger inner skin	6	1/2"X3 BAR
1022.0	thumb spacers	20	2"OD x .375wall x 1.25 id 1020 dom
1023.0	thumb pin end caps	24	2"OD x .375wall x 1.25 id 1020 dom
1024.0	thumb pin	8	1.25" round stock
1025.1	cylinder drive pin	2	1.25" round stock

1026.1	top main plate	1	1/2" plate
1027.1	top thumb pin	2	1.25" round stock
1028.1	top tine bracket	4	1/2" plate
1028.3	top tine	7	1/2" plate
1029.1	top tine cross support	2	1/2"X3 BAR
1030.1	drum cradle	2	1/2" plate
1031.0	drum cradle angle iron	4	3"X2"X1/4in" angle iron
1031.1	drum cradle angle upright	2	3"X2"X1/4in" angle iron
1032.1	back panel	1	1/2" plate
1033.1	quick attach bottom	1	1/2" plate
1034.1	quick attach top	1	1/2" plate
1033.1	quick attach side	2	1/2" plate
1036.0	drum	2	7" schedule xx heavy
1037.0	drum end cap	4	1/2" plate
1038.0	upper drum shaft	1	2" round stock
1040.0	lower drum shaft	1	2" round stock
1041.2	parallelogram tooth	30	1.5" square stock
1042.1	drum cradle spacers	2	1/4 in plate
	total parts	255	

Expenditures

Individual Materials Cost

Name	Date Ordered	Quantity	Price	Shipping	Sub-Total
1.) 218-828 BaileyNet.com 2X12 TR Hydraulic Cylinders 1.125" Rod	2/16/2012	2	95.00	25.41	215.41
2.) 218-827 BaileyNet.com 2X10 TR Hydraulic Cylinders 1.125" Rod	3/13/2012	2	90.00	25.41	204.03
3.) All- Hydraulic Eaton 74624DBG Hydraulic Drive Motor	3/9/2012	1	845.00	28.76	873.76
4.) Buna-N Spider for 5" Outside Diameter, Flexible Spider Shaft Coupling Hub	3/13/2012	1	28.75	3.6	32.35
5.) Flexible Spider Shaft Coupling Hub, 2" Bore, 5" Outside Diameter, with Keyway	3/13/2012	1	72.97	3.61	76.58

6.) Spider Shaft Coupling Hub, SAE B-B Splined, 2.50" Length, 5" OD	3/13/2012	1	76.56		76.56
7.) UNLAUB Two Sprockets, Two Bushings, Two 8mm Belts		1	526.92		526.92
8.) Stillwater Steel & Welding Supply 1/2 Plate 8" X 9"	2/27/2012	1	8.50		8.50
12.) SSWS 3" SQ X 1/4 Tube	2/28/2012	24	6.65		159.60
13.) SSWS 1 1/4" CR Round	2/28/2012	20	4.70		94.00
14.) SSWS 1/2" X 3 Flat	2/28/2012	40	3.50		140.00
17.) SSWS 3/8" X 3 Flat	2/28/2012	20	2.69		53.80
18.) SSWS 1 1/4" CR Round	3/1/2012	10	5.95		59.50
19.) SSWS 2" CR Round	3/1/2012	20	12.20		244.00
20.) SSWS 2" O.D. X 1 1/8" I.D. 1026 D.O.M.	3/1/2012	20	25.99		519.80
21.) SSWS 1/2" Plate 5X10	3/6/2012	1	606.30		606.30
22.) SSWS	3/6/2012	1	744.12		744.12

1/2" Plate 6X10					
23.) SSWS 16 ga Plate 4X8	3/6/2012	2	52.00		104.00
24.) SSWS Labor to Nest and Burn	3/6/2012	4 1/2 hr.			360.00
25.) SSWS Labor to Shear	3/6/2012	1/2 hr.			30.00
28.) Atwoods	4/3/2012		11.29		11.29
29.) O'Reilly Auto Parts	4/3/2012		5.59		5.59
30.) Lowe's	4/3/2012		26.08		26.08
31.) Skid Steer Rental	4/23/201 2	24 hr.	370.00		370.00
27.) Coneqtec Hydraulics	4/20/201 2	1	1043.0 0		1043.0 0

Conclusive Statements

The Mega Mite grapple mulcher is a successful proof of concept. While the implement is far from being ready for the consumer market, it has proven that there is a potential solution to the problem. The goal of mulching storm debris such as cinder blocks, shingles and other building materials will need to be further assessed, but the current model has shown that the ability to condense and mulch wood is achievable. The main design constraints of power limitation, weight limitation, mulching feed rate, and safety concerns were all adequately addressed.



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Design Presentation of the
“Mega Mite”

TEAM MEMBERS

- Benjamin Gifford (Team Leader)
- Aaron Bartel (Design, Safety)
- Dustin Hofegartner (Design, Engineering)
- Lucas Polly (Information Delivery, Cost)





SPONSOR COMPANY

- Coneqtec Corporation



- Founded and Directed by CEO Gary Cochran
- Designs and manufactures a number of hydraulic powered skid steer attachments
- Fourteen products that range from rock saws to rotary tillers
- Super high flow kits with several auxiliary ports

PROBLEM STATEMENT

- The goal is to combine a skid steer mulcher with a skid steer grapple. The combination will allow the operator to grab and mulch brush piles.
- This will give the operator a choice where to mulch the wood, such as into the bed of a truck, or a remote chip pile. The product will be powered by the skid steer's auxiliary hydraulic system.

PRODUCTS FOR COMBINATION



http://www.skidsteersolutions.com/Bradco_Skid_Steer_Forestry_Mulcher_p/br-109292.htm

http://www.skidsteersolutions.com/Skid_Steer_Skeleton_Grapple_Buckets_s/9622.htm



FALL RESEARCH

- Power analysis
 - 65-70 hydraulic HP at skid steer auxiliary
- Safety considerations
 - Guards
 - Safety Standards



<http://www.colemanequip.com/Equipment.asp?EID=46>

4

FALL RESEARCH

- Market and risk analysis*
 - Target customer: Municipalities, Disaster Relief Crews
 - Material feed issues
 - Feed drum
 - Spin up plate
 - Single vs. Dual
 - Mulching area
- *With help from Ag Econ Team

PERTINENT DESIGN CONSTRAINTS

- Safety
 - ASABE, SAE standards
 - ISO 11684 Safety Signs
- Limited Power Output
 - High flow vs. Standard Flow
- Weight
 - MAX- 3500 lbs.
- Feed rate
 - Minimize (goal is neutral)



MOTOR DESIGN

$$P (HP) = \frac{Q(gpm)*p (psi)}{1714}$$

Goals

- 2000 RPM
- 3500 PSI
- 35 GPM
- 150 FT LBS
- 72 HP

Actual

- 1500 RPM
- 3500 PSI
- 34 GPM
- 207 FT LBS
- 69 HP

Advised by Randy Nobles at Womack Machine Supply Co., Tulsa, OK

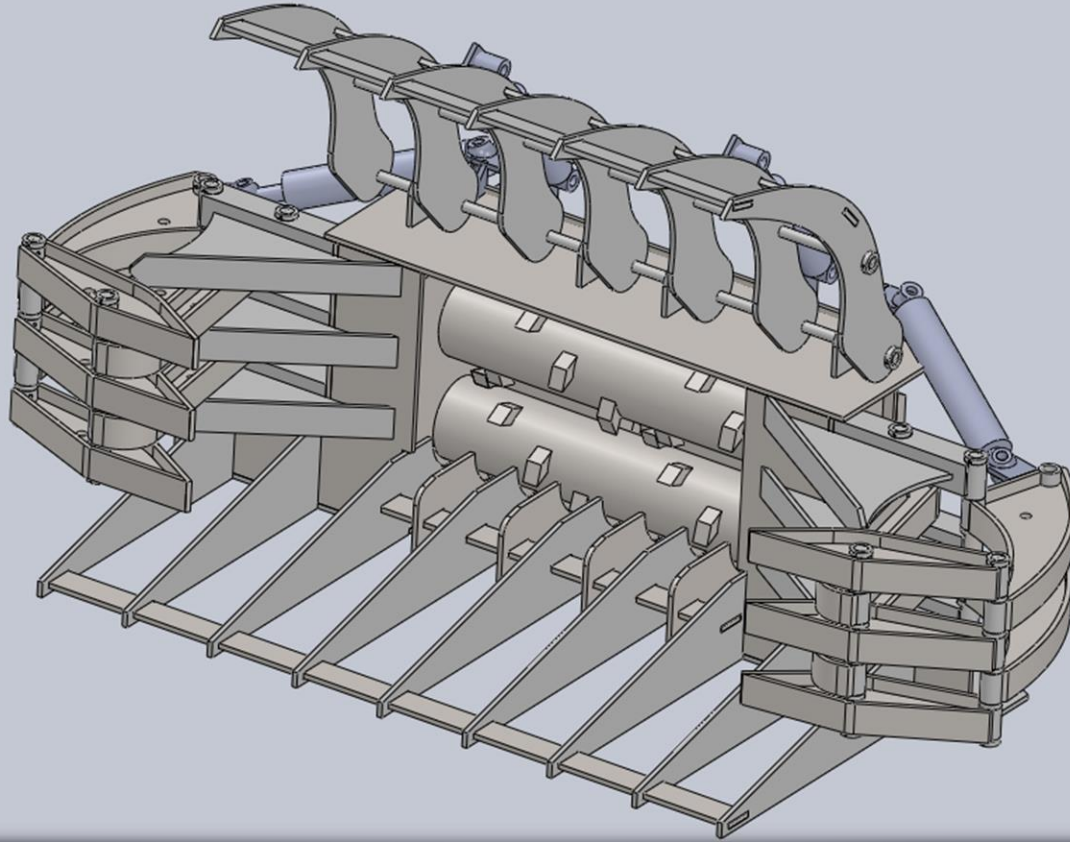
DRIVE SYSTEM

- Exceeds limitations of standard power transmission application
 - 10" center to center shaft spacing
 - 4 different drive concepts (drum to drum)
 - Simple V-Belt
 - Chain
 - Dual Motor
 - Gates PolyBelt

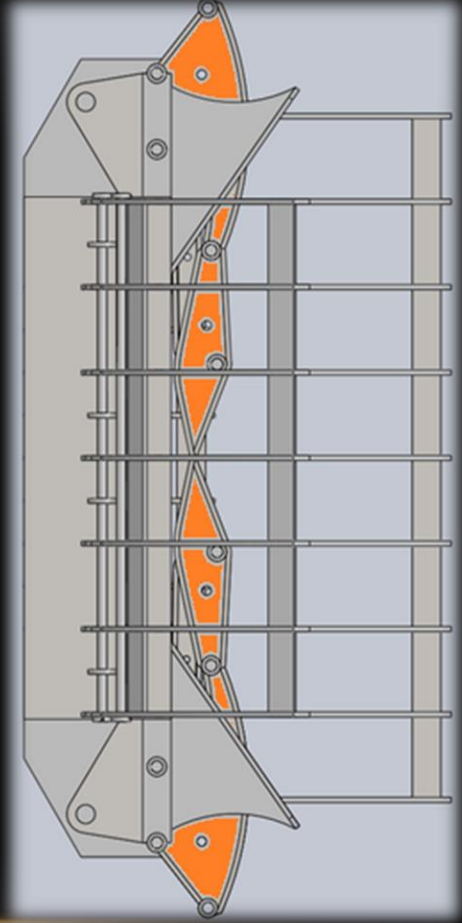
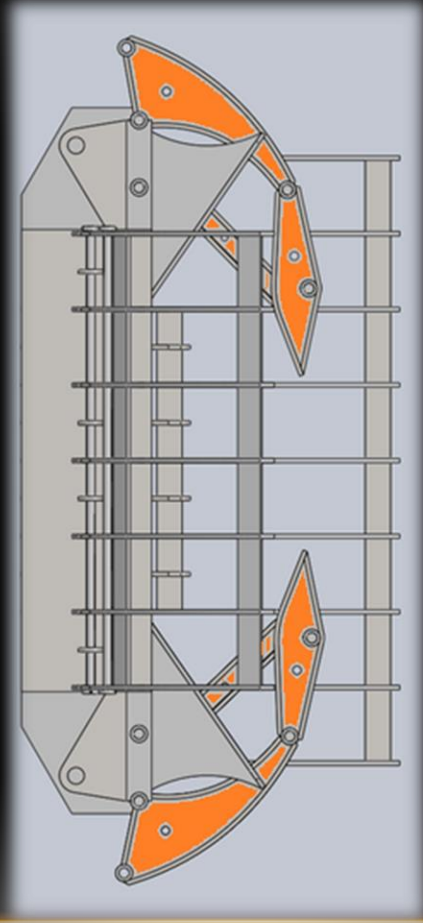
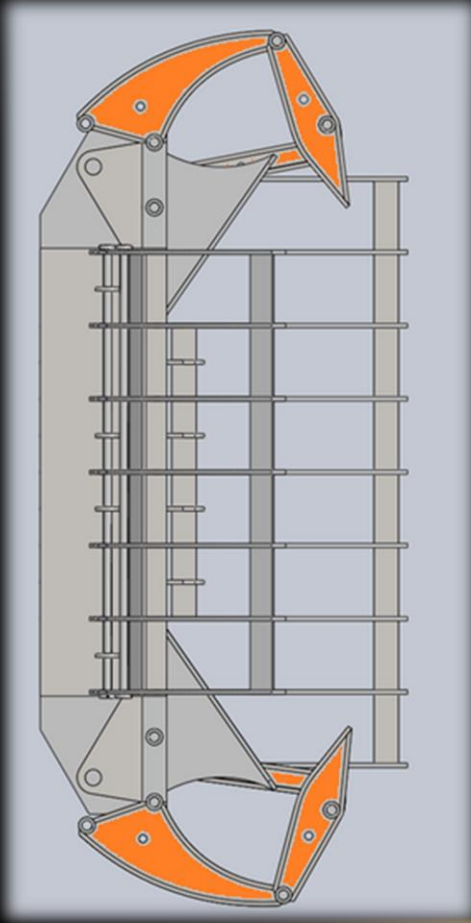


Assisted by John Hill, The UNLAUB Company, Tulsa, OK

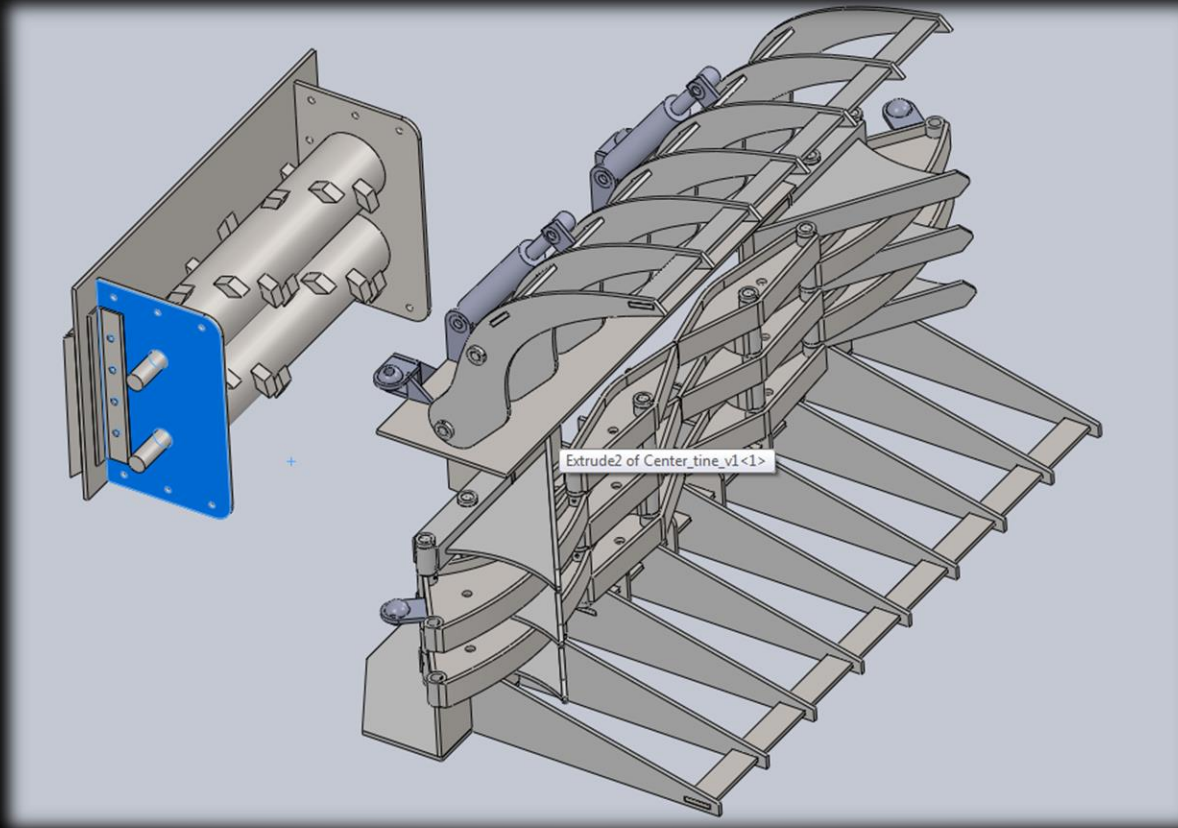
FINAL PROTOTYPE



FINAL PROTOTYPE TRAVEL



FINAL PROTOTYPE

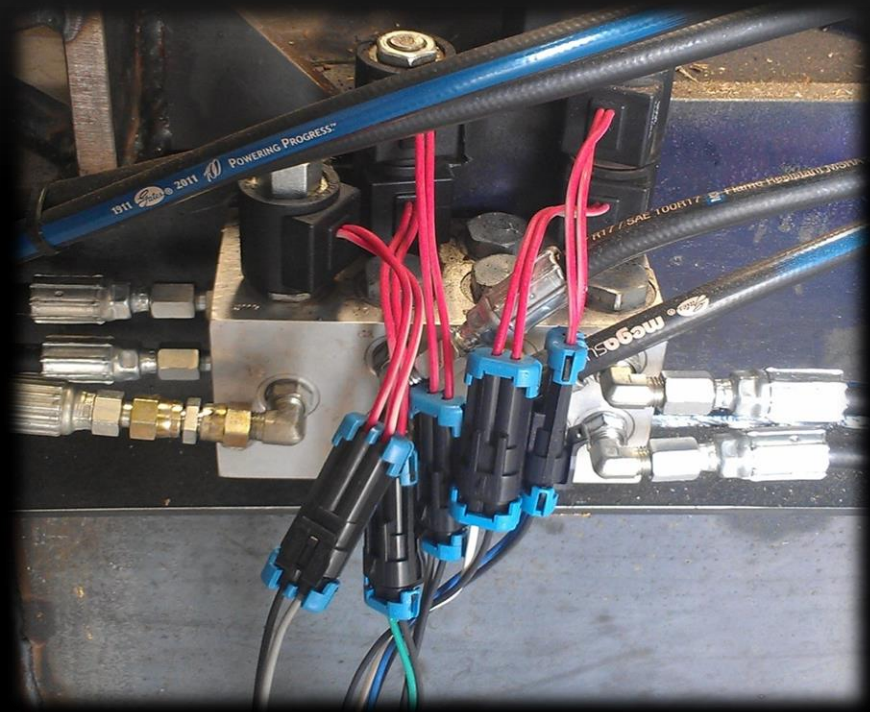
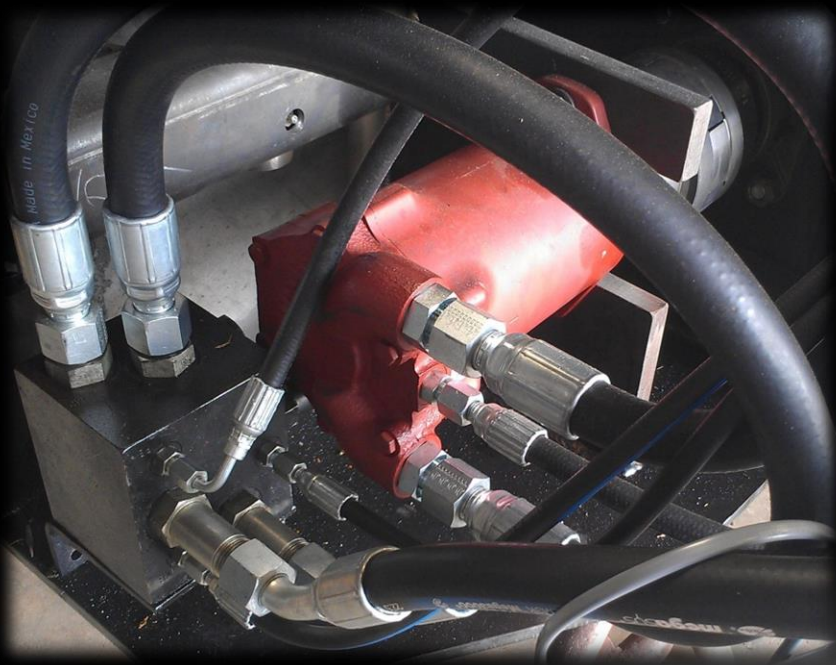


THE MEGA MITE



HYDRAULIC SYSTEM

Diverter box redirects fluid to cylinders when under power. Also allows bypass for motor protection.



A second diverter box controls feed or thumb. Controlled by pilots switch box.

CYLINDERS



Standard agricultural cylinders and connections were used for simple replacements.

GRAPPLE



Top thumb implemented for containing debris and reducing tendency to push limbs up and away from drums.

FEED



Side feed fingers grab limbs and debris and force them towards the drums to be mulched and expelled.



PARTS COST

Category	Cost
Metal Parts	3346.12
Hydraulics	1463.82
Motor and Drive	1543.04
Total	6352.98

Total
\$6400

SPRING TESTING CONCERNS

- Structural Strength of Grapple
 - Moving parts
- Drum operation
 - Speed
 - Torque
- Functionality
 - Mulching
 - Grappling
- Analysis of safety measures

TEST LIMITATIONS

- Standard flow skid steer
 - Tested at ~15 gpm
- Skid steer not rated to lift implement
 - Ran attachment while immobile
 - Could not use brush pile as backstop
 - No tilt function to allow gravity

TEST PROCEDURES

- Starting Condition
 - Rolling start
 - Contact start
- Size Differentiation
 - Branches with leaves (<2 inches diameter)
 - Stouter limbs and trunks (<6 inches diameter)
 - Treated wood, cinder blocks, shingles and other storm debris (upon consent of client)



- Non contact, rolling start
- Mid size debris

TEST RESULTS



TEST RESULTS



TEST RESULTS



TEST RESULTS

- Performed better with larger “bites”
 - Brush pile’s opposing force would help feed
- Drum rarely bogged down after start up
 - Sufficient low flow power, More available with HF skid steer
- Hard to start when in contact with branches >2”
- Mulching Ability
 - Did not over feed
 - Chipped between drums and at tine contact

ACCOMPLISHMENTS

- ~90% size reduction
- More manageable pieces

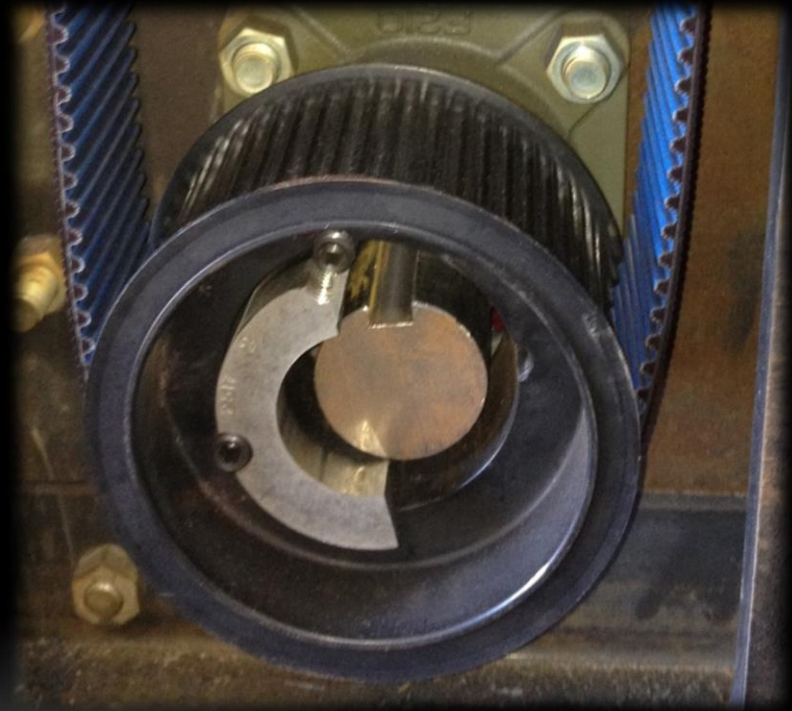


TESTING CASUALTIES

Cylinder Mount (Bad Weld)

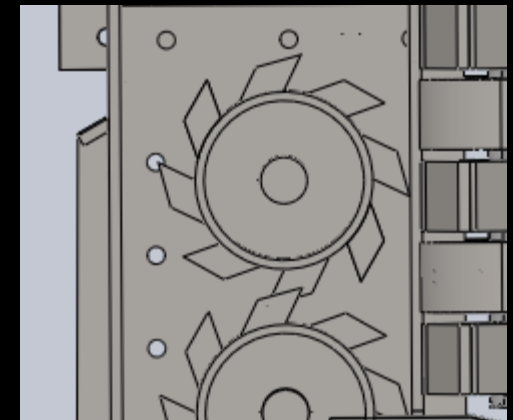
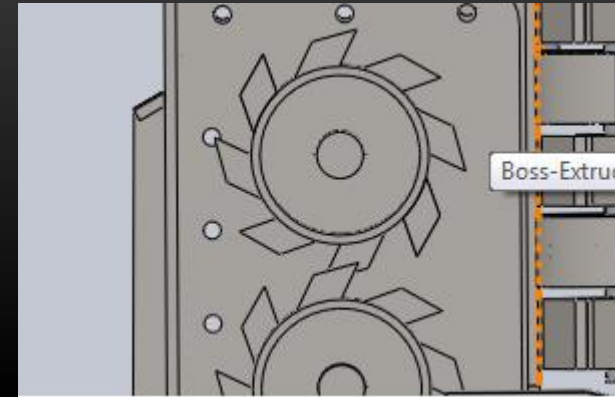


Drum Shaft Hub



DESIGN MODIFICATIONS

- Cutter head modifications
 - Drum position
 - Teeth
- Added guards and shields
 - Reduce forward flying debris
 - Pilot viewing grate
- Reduce hand fabricated, metal parts
 - Plastic spacers and bushings
 - Cast vs. mill and flame cut



DESIGN MODIFICATIONS

- Feed geometry
 - Center trunnion cylinders
- Ramp modifications
- Grapple travel angle
 - Near 180° travel (vertical up to vertical down)

ACKNOWLEDGEMENTS

- Dr. Paul Weckler
- Mr. Gary Cochran, and CONEQTEC
- Mr. Steve Youngers
- Mr. Wayne Kiner, BAE Lab Manager, and staff

ALSO...

Mr. Randy Nobles, Womack Machine Supply
Mr. John Hill, The UNLAUB Company

THE MEGA MITE





PETE STEERE

"The Mega Mite"

Fall Design Report 2011

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Meet the Design Team

Aaron Bartel

A senior in Biosystems-Mechanical Engineering, Aaron plans to farm after graduation if a suitable job opportunity does not present itself.

Benjamin Gifford

A senior in Biosystems-Mechanical Engineering, Ben plans to work in the oil field when he graduates in May of 2012.

Dustin Hofegartner

A senior in Biosystems-Mechanical Engineering, Dustin will commission as an officer in the United States Air Force upon graduation.

Lucas Polly

A senior in Biosystems-Mechanical Engineering, plans to attend graduate school after a few years in the real world.

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Mission Statement

The mission of Pete Steer Designs is to provide reliable, innovative solutions that reduce unassisted physical workload with tools and implements that are easily attached and adapted to commonplace vehicles.

Problem Statement

The product will combine a skid steer mulcher with a skid steer grapple. The combination will allow the operator to grab brush and debris piles to be mulched. This will also give the operator a choice where to mulch the material, such as into the bed of a truck, or a remote chip pile. The product will be powered by the skid steer's auxiliary hydraulic system.

The sponsor company, Coneqtec Universal, has suggested the product idea and will be supervising the design process. Engineers at BIC have some preliminary design concepts and it is planned to spur off these current ideas. The process concept is in the preliminary stages of patenting.

Sponsor Company



Figure 1. Coneqtec Logo

Coneqtec Universal is the sponsor company. Wichita, Kansas is home to the company built on relationships developed during time spent by the engineers at Case New Holland. The company, founded by Mr. Gary Cochran, has designed and manufactures a number of skid steer after-market modifications and implements. Ranging from rock saws to rotary tillers, Coneqtec Universal strives to implement the latest technology while designing solution equipment for real world application. Super high flow kits with several auxiliary ports engineered by the company enable endless

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possibilities to solve issues with numerous variables. More information attached in Appendix D.

Statement of Work

The primary goal of the product is to carry debris, i.e. wood, shingles, sheetrock, etc., to a remote location and chip it into manageable form. The implement will be used on a standard skid steer, with high flow hydraulics, and auxiliary controls.

Scope of Work

- Determine marketability and necessities
- Define the finished product
- Test related products
- Design and Spec
- Build, Test, and Determine satisfactory performance

Location of Work

- The majority of the work will be performed at the OSU Stillwater campus
- Several trips to Wichita, KS will be necessary to meet at BIC with the Sponsor Engineers

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- Most fabrication and manufacturing will be done at the OSU BAE Machine Lab
- Some fabrication may exceed the Machine Lab capabilities and need to be moved to BIC or contracted out to a local shop

Period of Work

- The final design will be completed for an early December review presentation
- Building and Testing will begin in January, with a final product review scheduled for April

Deliverables Schedule

Notable Due Dates:

Work Breakdown Structure, 7 November, 2011.

Task List, 11 November, 2011.

Engineering Specifications, 14 November, 2011.

Design Concepts, 14 November 2011.

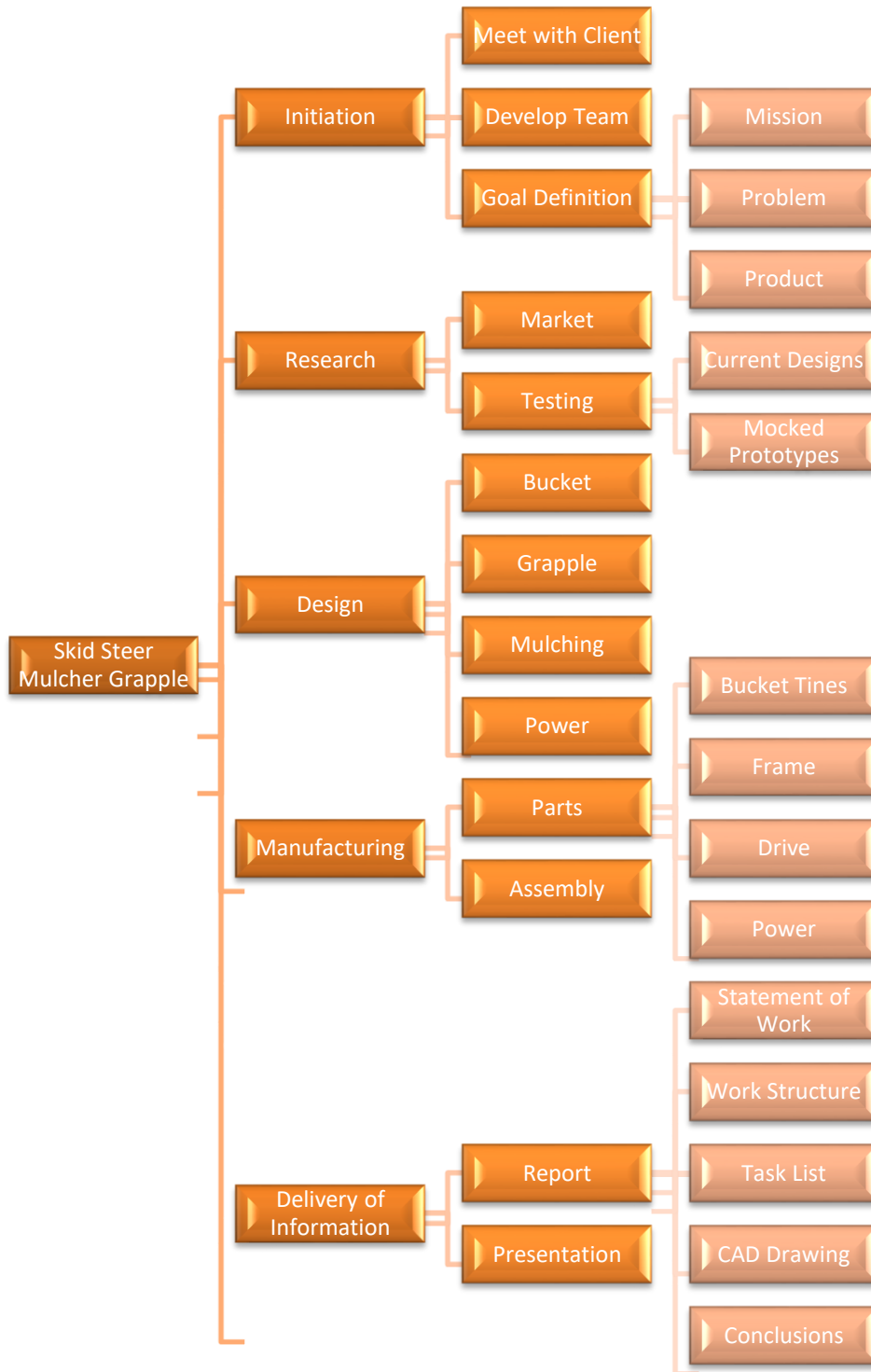
First Draft Report, 18 November, 2011.

Final Presentation and Report for Fall, 16 December, 2011.

Product Definition

The completed product will be a skid steer mounted implement powered by the auxiliary hydraulics. The target vehicle will be outfitted with a super high flow kit, multiple auxiliaries and have a rated horsepower of greater than 80. Smaller skid steers should be able to run the mulcher, but may lack sufficient power. The implement will collect a bite of material, carry to a certain location then proceed to mulch the material into a receptacle in small enough pieces.

Task List



Research

Technical Research

Several applicable patents were found, but none directly associated with the intended process. It is apparent that the idea has not been patented, if even previously attempted. Research showed industry standards across the board, ranging from similar drum RPM, to similar overall design. The overwhelming majority of available products have similar design basics and tendencies. Applicable patents follow in Appendix A.

Skid steer horsepower ratings are provided at motor horsepower. This is generally reported as the brake horsepower, or power at the flywheel of the motor. As the implement will be run from hydraulics, this number given is not necessarily applicable for specifications of the implement. The general relationship between the hydraulic horsepower provided and the reported horsepower of the vehicle was studied to help give an idea of what levels of horsepower were really available.

	Case (SR200)	New Holland(L180)	Bobcat (S630)	Cat (242B Series 3)	Deere (320D)
GPM	23.8	21	23	22	20
GPM(HF)	33.2	35.8	30.5	31	31
PSI	3050	3050	3500	3335	3100
HP	42.4	37.4	47.0	42.8	36.2
HP(HF)	59.1	63.7	62.3	60.3	56.1
AVG STDFLOW=	41.1	AVGHIFLOW=	60.3		*for 70 HP models

Table 1. Skid Steer Hydraulic Horsepower

Cutter head speed and force at the tooth are pertinent to the design of the implement. With insufficient speeds or incorrect forces at the tooth, material may not be cut to standards. While research on the specific dual drum cutter head is impossible due to lack of available products, tables of angular velocities, linear velocity at the tooth, and force available at the tooth will ease testing and theoretically expedite the revision process. While it is impossible to know which speeds and forces are most practical for the dual drum system, the team will implement and relate researched information on common torques and speeds for current models. The table below lists tooth velocities with respective drum sizes and speeds. It is followed by a torque analysis for the proposed drum sizes for 3 possible motors.

Radius (center to tooth, in)		$v=R*\omega(1000\text{rpm})$	$v=R*\omega(2000\text{rpm})$
5		6.9	13.9
6		8.3	16.7
7		9.7	19.4
8		11.1	22.2
9		12.5	25.0
10		13.9	27.8
11		15.3	30.6
12		16.7	33.3
13		18.1	36.1
14		19.4	38.9
15		20.8	41.7

Table 2. Cutter Tooth Velocities

Force at the Tooth			$T=F*D$	
Torque (lb-in)		Radius (in)		Force
16370		5.09		3216.11
20730				4072.69
25440				4998.04

Table 3. Force at Tooth

Market Analysis

A complete market analysis was performed by the corresponding business team.

Their work proceeds:

The marketing strategy for Coneqtec Universal's equipment is simple and straight forward. They want to focus on municipalities and disaster relief programs. The main reason they want to market to these two specific segments of the industry is because the customers in these industries have an everyday use for an attachment like the Grapple-Mulcher. A recent Solid Waste Association of North America (SWANA) publication said "Yard trimmings volume has been increasing slightly since 2000, an estimated 33.2 million tons of yard trimmings were generated in MSW in 2009." Municipalities pick up debris routinely and this implement could be used to clean up yard trimmings and aid in storm cleanup efforts. Disaster relief programs could use the

Grapple-Mulcher to clean up after major storms and natural disasters. The mulching element of the Grapple-Mulcher is capable of mulching debris from trees, limbs, brush, and demolition rubble. With waste levels increasing over the last fifty years, it seems that there will always be a need for a disposal method for yard debris.

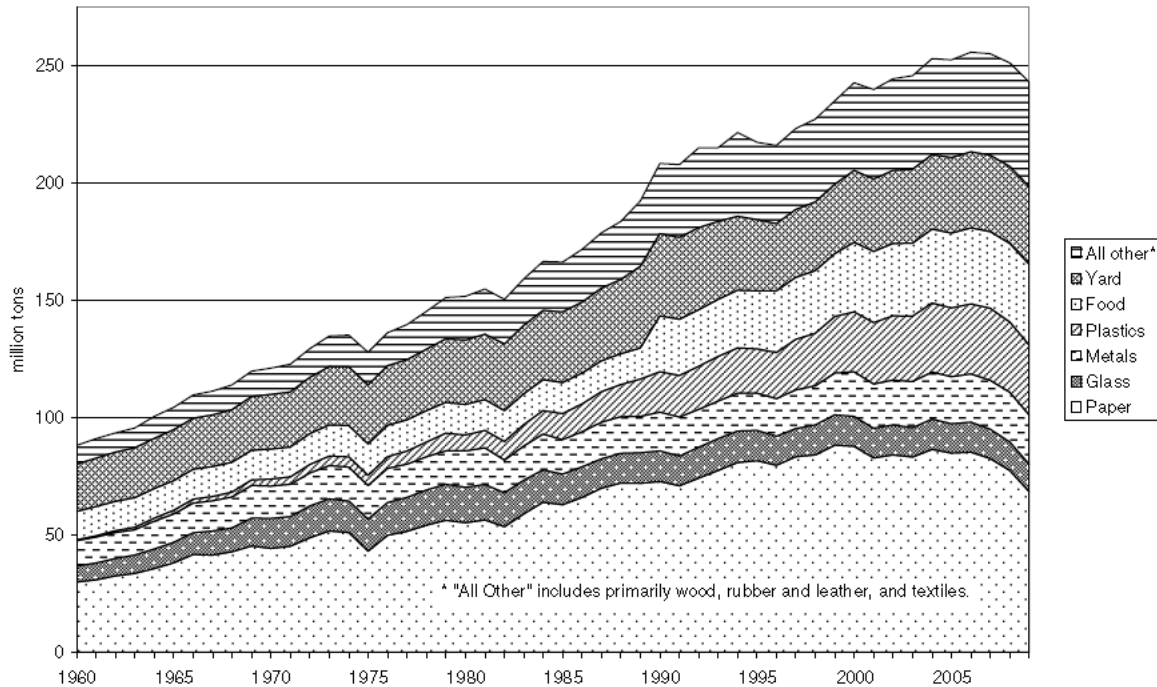
- Recovery (as a percentage of generation) of most materials in MSW has increased dramatically over the last 39 years. Some examples:

	1970	1980	1990	2000	2009
Paper and paperboard	15%	21%	28%	43%	62%
Glass	1%	5%	20%	23%	26%
Metals	4%	8%	24%	35%	35%
Plastics	Neg.	<1%	2%	6%	7%
Yard trimmings	Neg.	Neg.	12%	52%	60%
Selected Consumer Electronics				10%	19%
Lead-acid batteries	76%	70%	97%	93%	96%

Neg. = less than 5,000 tons or 0.05 percent.

Source: Environmental Protection Agency. Municipal Solid Waste in the United States. 2009 Facts and Figures.

Figure 10. Generation of materials in MSW, 1960 to 2009



Municipal Solid Waste (MSW) statistics from 1960-2009

Source: Environmental Protection Agency. Municipal Solid Waste in the United States. 2009 Facts and Figures.

Target Market

The intended target markets include rural, city, county and state municipalities that are looking to increase efficiency and lower the costs of operation during disaster relief and annual cleanup procedures. Disaster relief programs will be a viable target market as they would greatly benefit from having a piece of machinery that only requires one operator. We will also target Coneqtec Universal's active distributors. Secondary target

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market would include pursuing the following industries: forestry conservation, pasture restoration, and demolition services.

Competitive Comparison

At this time there is no similar competition to Coneqtec Universal's Grapple-Mulcher available on the market. This means that the Grapple-Mulcher will not be competing with another skid steer attachment but rather the current systems used for debris removal. When meeting with David Higgins from the City of Stillwater he informed us that the most common method for brush removal is a multi-person crew using a hand fed chipper and collecting debris by hand or by some type of grapple. A Vermeer BC600XL chipper cost \$15,800 dollars. This chipper is pulled behind a truck and the debris is hand loaded into the chipper as it is then mulched and blown into the truck bed. This system involves a trailer attached to a truck which means that you are not capable of putting the chipper right next to the pile of debris that needs to be mulched. If workers have to walk every piece of debris to the chipper you are losing valuable time. Then you also have small twenty seven horse power gas engine that runs this chipper. Equipment with small gas engines are typically more prone to have problems because they are all carbureted. The Vermeer chipper also has to be completely unhooked in order to dump your load of mulch.

Risk Assessment

Potential risks for the Grapple-Mulcher include:

1. Future competitors that will be designed after the Grapple-Mulcher is introduced to the market.
2. Meeting strict Society of Automobile Engineers (SAE) safety regulations will play a vital role in the final design and usability of this project.
3. With a depressed economy some smaller business will not be able to justify a \$24,920.20 purchase for a piece of machinery that will have limited functions, instead they may opt to spend that money on additional labor to operate cheaper equipment.

Testing

A significant amount of testing was performed on different machines and also using scaled down constructed models. The main areas of interest were testing competitive mulcher ability, brush feed rate and grapple area and volume. These are all applicable concepts that will require consideration when building and designing a product with the intended purpose.

Competitive Mulcher

A machine made by Seppi was available for testing. It was run on a Case Skid steer with a super high flow kit. The team observed the machine mulching different brush, such as standing trees, grounded limbs, stumps, and small twigs. The main

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deficiencies discovered were keeping momentum while grinding a large trunk or limb (6 inches or better), and maintaining a solid cutting surface. Limbs and branches would simply shoot out of the cutting area and be thrown into the skid steer or underneath it. Safety and efficiency necessitate a solid cutting surface. A two speed motor with a high torque low gear will be applied to ensure cutting speed is maintained.



Figure 2. Seppi MidiForest.

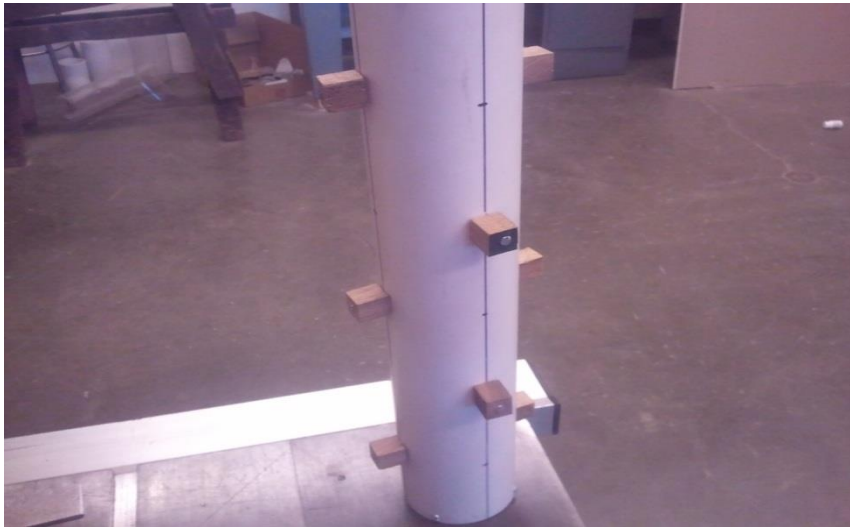
<http://www.seppi.it/en/mulchers/hydraulic-drive-mulchers/midiforst-skid-steer.html>

Brush Feed Rate

A main concern for the product is that the feed rate of the material will exceed the maximum cutting rate of the drums. Several ideas to slow feed were examined, and one main test was performed. A dual drum system with similar rotation on both drums,

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directly driven together, was built utilizing PVC. The goal was to create a neutral feed rate. While a neutral feed rate was not completely accomplished, the idea significantly increased cutting area and slowed the rate per area. The two drums were stacked vertically as shown below.



Mock up drums were constructed from PVC pipe and wood stock. The intent was not to actually cut up the material, but judge the path of the material through the "implement".

Figure 3. Test Drum

Power was supplied by a handheld drill. The transmission is shown, tape was used. It was extremely effective, contrary to expectation of the team.



Figure 4. Test Setup

Grapple Area

The bite capacity of the grapple is a major concern. A larger volume of material per bite will significantly reduce work time. With the goal being to get a load, move to a different location, then mulch, greater capacity per bite will result in less travel time, causing the reduction in overall work time. Several models of grapple were built using scaled down tinkering objects (Legos), and different linkages were studied to increase volume. The optimal linkage proportions were determined and implemented into the design of the full scale model.

Design

Design Constraints

The main problems with the design process are few in number, but will have big negative effect on the final outcome of the project if not properly assessed. These three topics will require a vast majority of our time, and are the most important. Applicable limiting factors are power output, weight capacity, and safety.

The average power output of a skid steer is limited, and the design must be capable of mulching the debris that it picks up. With the intended goal of reducing storm debris, the implement may have to power through materials such as wood, sheet rock, shingles, and carpet fiber, with wood being the most common.

The rated weight capacity for a skid steer loader mechanism is generally defined as half of the tipping weight. 3500 pounds is the average determined for an applicably sized skid steer. Inability to meet this requirement has obvious and immediate repercussions. Tipping of the vehicle would cause liability for injury and property damage, and cannot be a subject taken lightly.

Safety of operator and bystanders is a third issue that must be addressed. Mulchers and grapples alone have inherent safety concerns, and with a plan to match

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the two, safety measures must be taken. Pinch points, exiting projectiles, and mechanical suction into the machine are all dangers that will be apparent.

Power output, weight capacity, and safety are all factors that could be the difference between a successful product and a waste of company time and money. These have been active determinants in the design process and are the basis for the end product shape.

Current Designs for Integration



Figure 5. Mulcher Design Commonly Used for a Skid Steer

http://www.skidsteersolutions.com/Bradco_Skid_Steer_Forestry_Mulcher_p/br-109292.htm



Figure 6. Common Grapple Design for a Skid Steer

http://www.skidsteersolutions.com/Skid_Steer_Skeleton_Grapple_Buckets_s/9622.htm

Rejected Designs

First Concept Design

The original design incorporated a single mulcher drum with a single motion grapple. Along the side walls of the grapple bucket, indicated in pink in Figure 7, is a bolted on shear surface that would ideally cut the excess branches hanging outside of the bucket. The sheared edge walls were designed to prevent excess un-mulched material out of the desired mulch location, i.e. truck bed. Another major component of this design was a solid plate shown in blue in Figure 8. This plate was designed to protect the user from flying debris, and allow the mulcher drum to spin up to the desired speed of 2000 RPM before being introduced to the mulching material. A high speed flywheel was originally considered in the original design. The high speed flywheel was designed in order to keep the drum spinning without much loss of speed when "caught" on a material that would potential slow down the drum speed, thereby decreasing the force applied by the drum. This design was rejected by the team and it was decided to go about designing something much more radical.

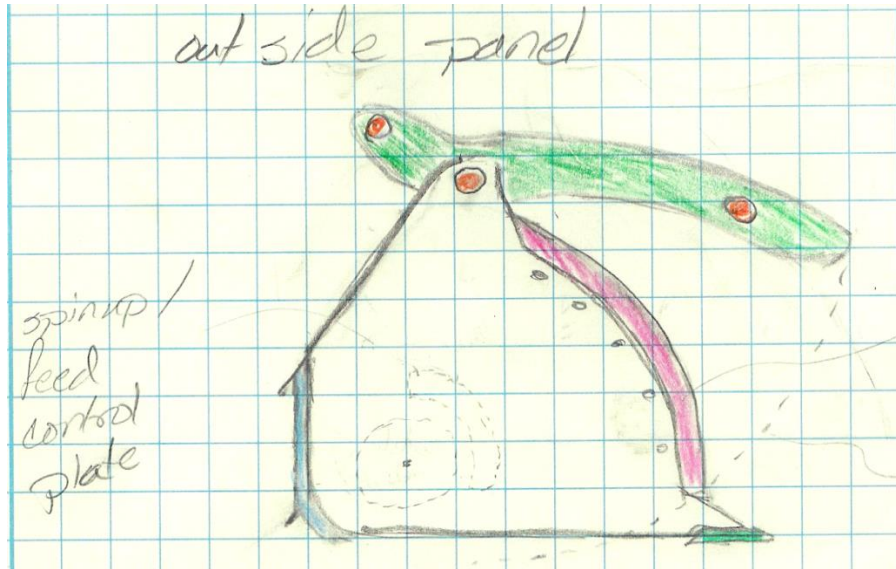


Figure 7. First design of outside bucket

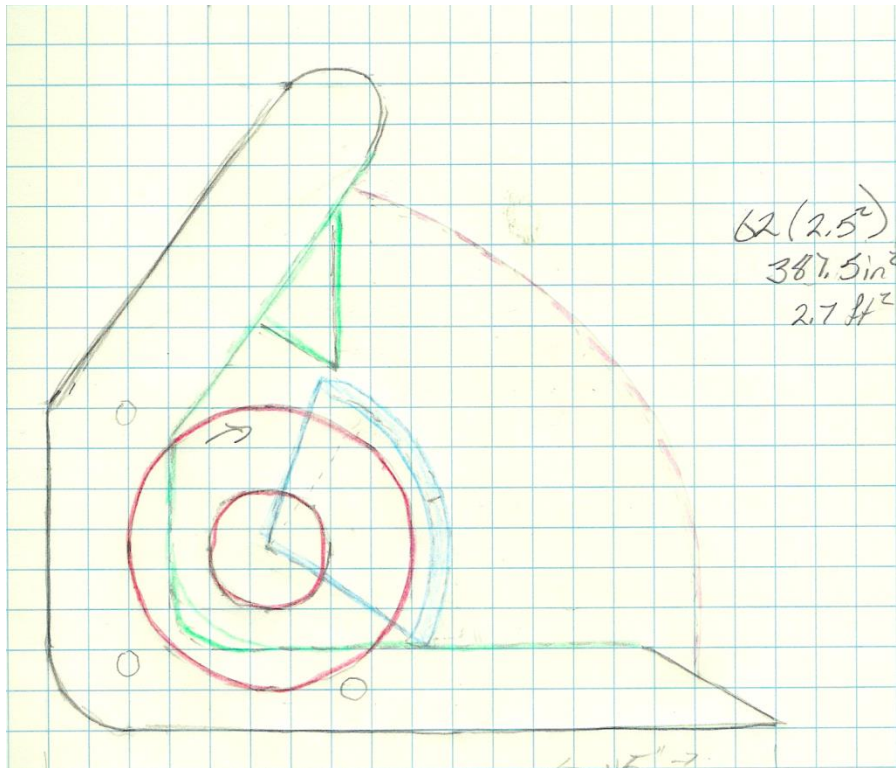


Figure 8. First design of internal

Final Concept Design

After meeting with the client about the first design, the team created a second design that included the new specifications desired by the client. Coneqtec suggested they use two drums instead of a single drum mulcher, and the entire group brainstormed ideas for a more radical grapple design. The new design concepts implemented a horizontal motion for the grapple. The grapple will now open and close outside to center. The motion of the grapple is controlled by two hydraulic cylinders, with the extension actuation closing the arms for greater crushing power. The new design for the grapple will assist the grapples ability to grab a larger quantity of brush, and compact the brush towards the mulcher drum. It was also mentioned that the bucket should be angled so that when in use with the skid steer, the bucket will tip upwards allowing the remaining debris to be gravity fed into the mulcher drum. The second design was accepted better than the original design with the only change to make is the addition of a top grapple that will close off the grapple bucket. A drum design was adopted from several other mulchers. The similar rotating drums will chip against one another. The implement was aptly nicknamed "the Mega Mite", due to the resemblance to termite jaws and its ability to destroy wood.

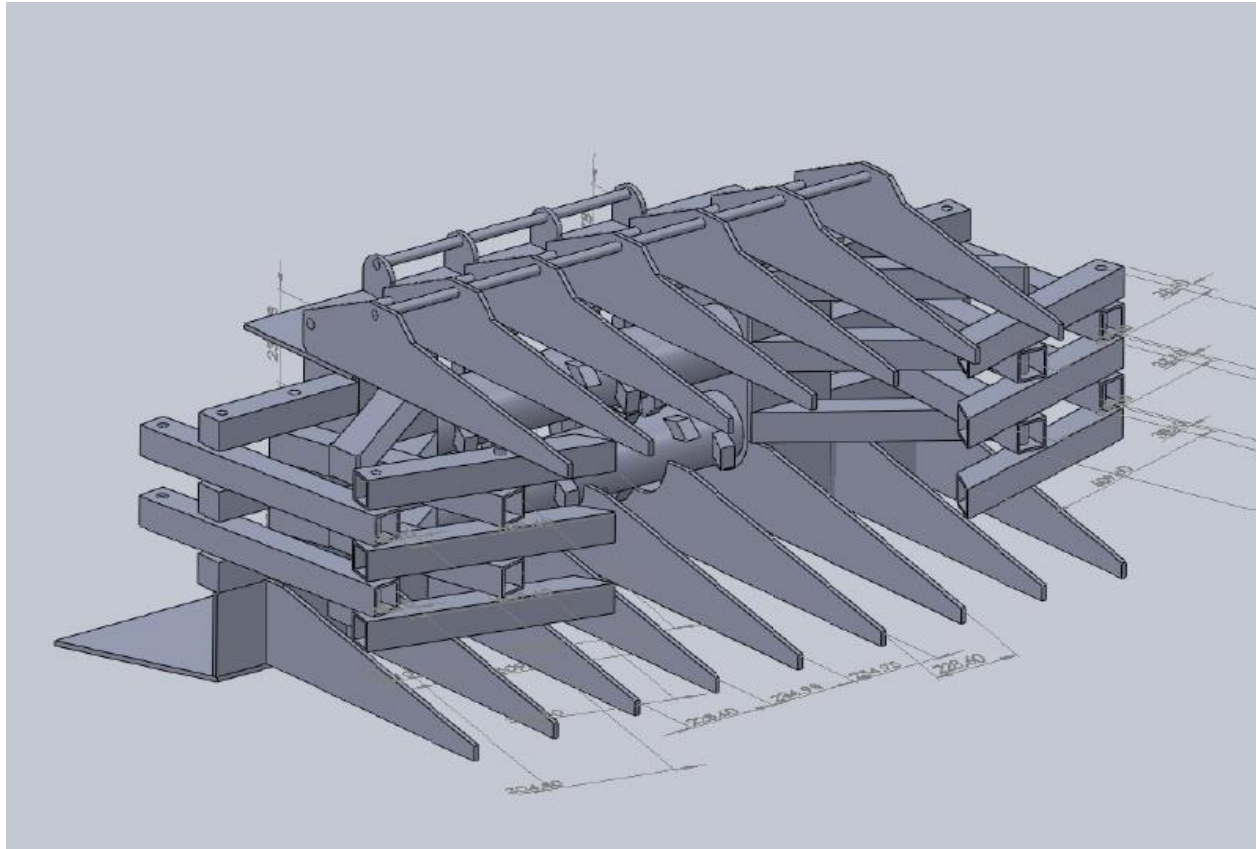


Figure 9. Full View of Current Design (December 2011)

The above figure shows the current design produced in SolidWorks. The top is actuated by hydraulics cylinders. Material to be destroyed will be swept into the drums by the side thumbs shown below.

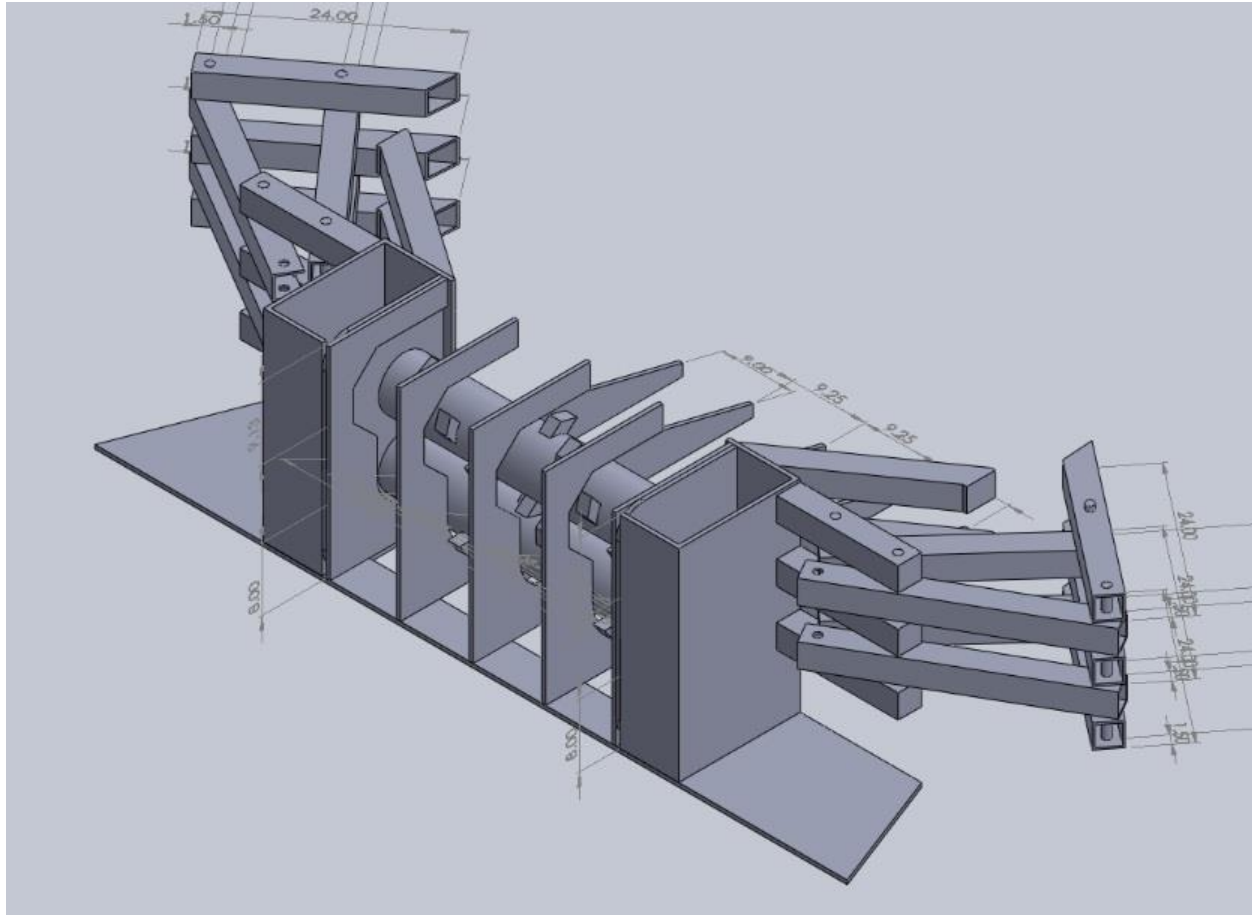


Figure 10. Back Top Angled View

A back view shows more clearly the protection and housing for the drive system. A motor, tentatively an Eaton Series 45 VIS 991 cm³ hydraulic motor, will power the lowest drum and the top drum will be driven by the bottom. The drums will be connected via chain drive, while the motor to drum transmission will be v-belt.

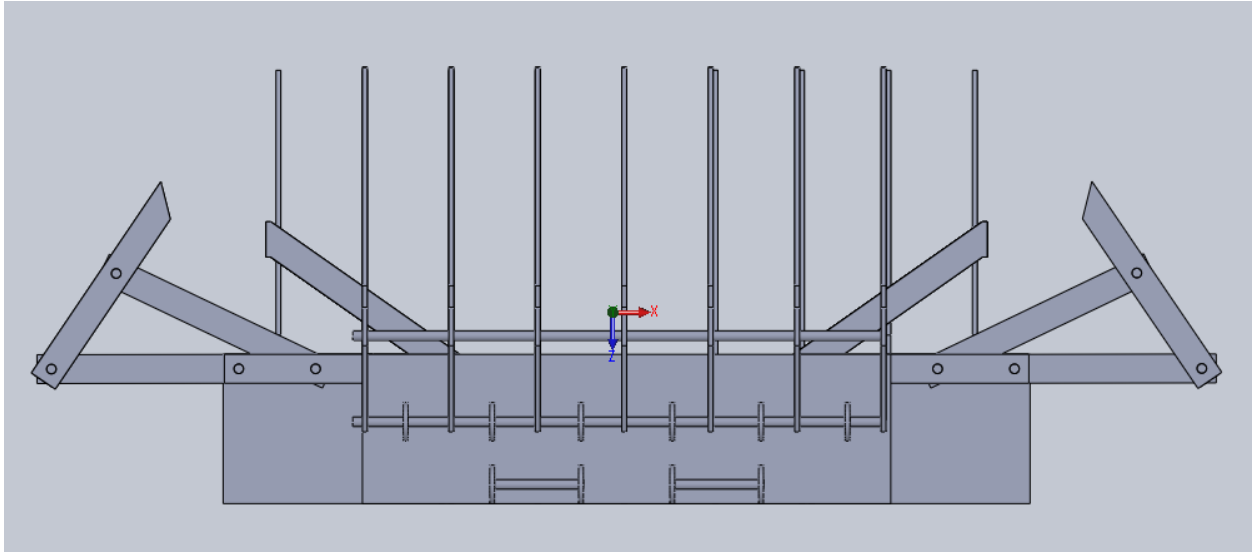


Figure 11. Top View of Grapple Area Open

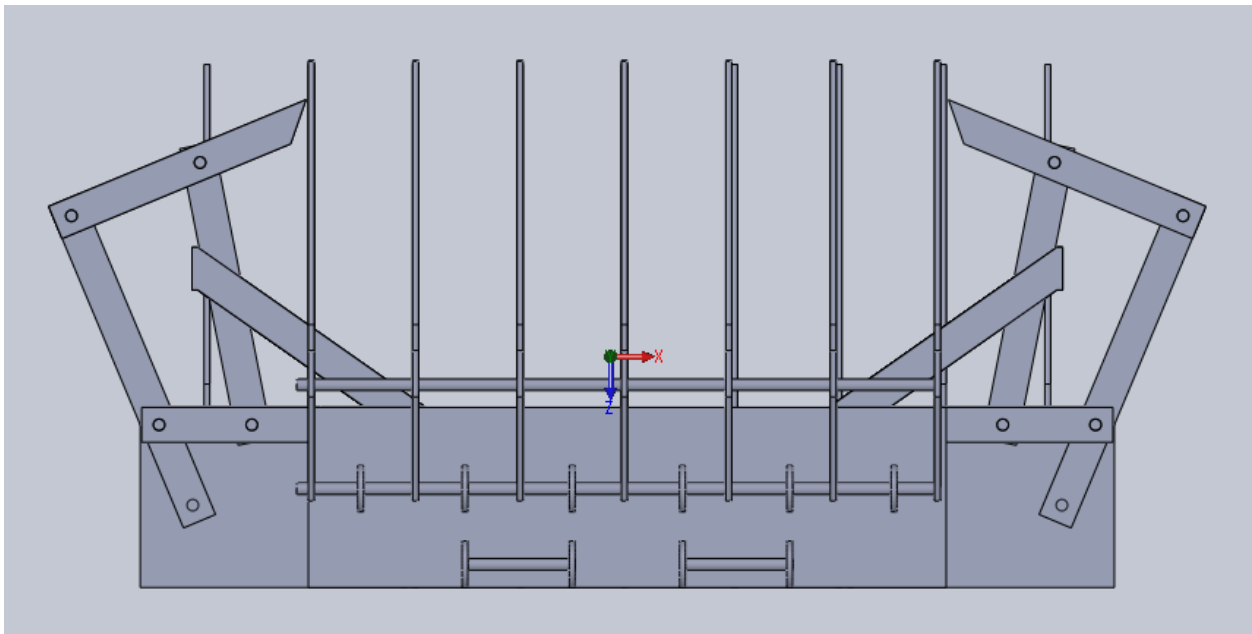


Figure 12. Top View of Grapple Area Partially Open

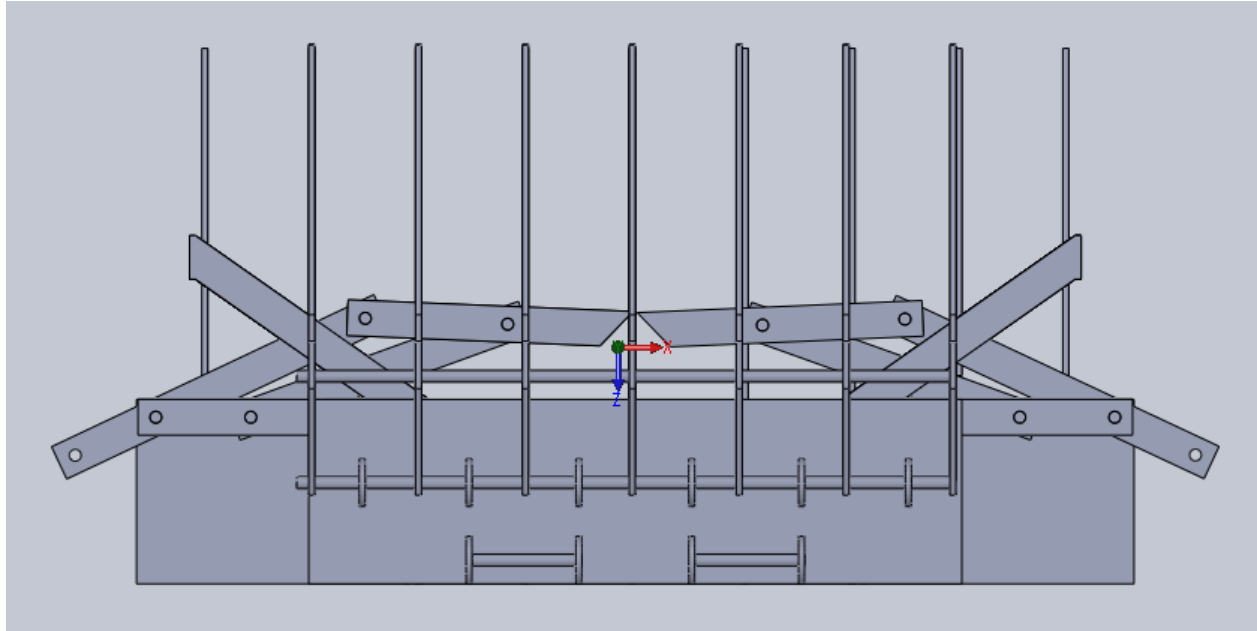


Figure 13. Top View of Grapple Area Closed

The previous three pictures show the grappling area of the implement design. This was a main concern of the design process to increase efficiency. A larger capacity per run of the mulching apparatus will decrease time and fuel consumption by reducing travel time.

In the series of design pictures following, one can view the overall appearance of the implement and get a better feel for how the Mega Mite may work.

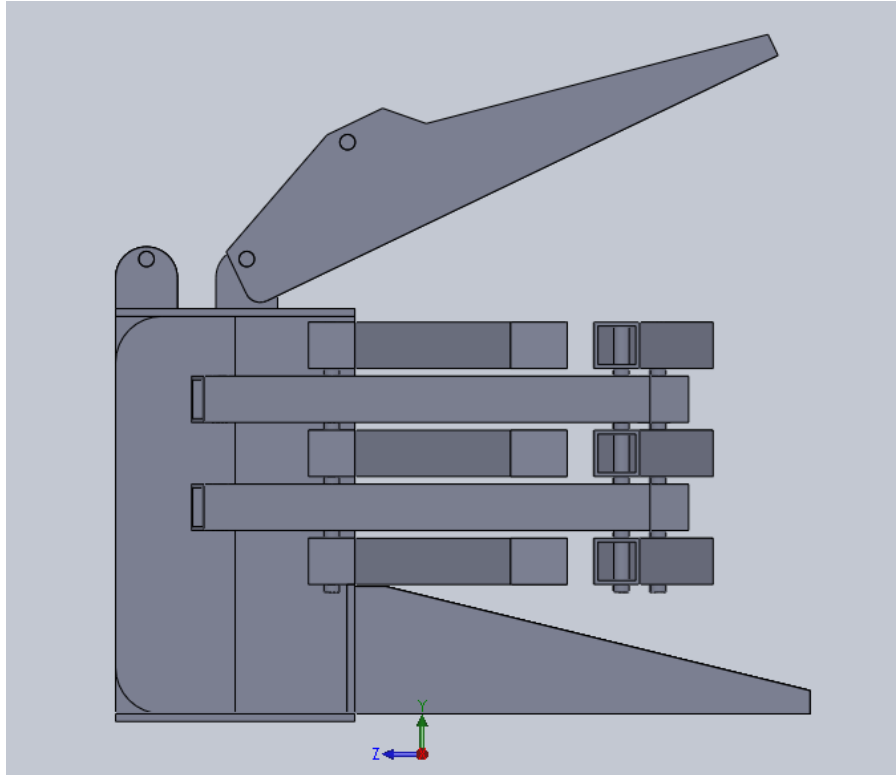


Figure 14. Right View Top and Thumbs Partially Open

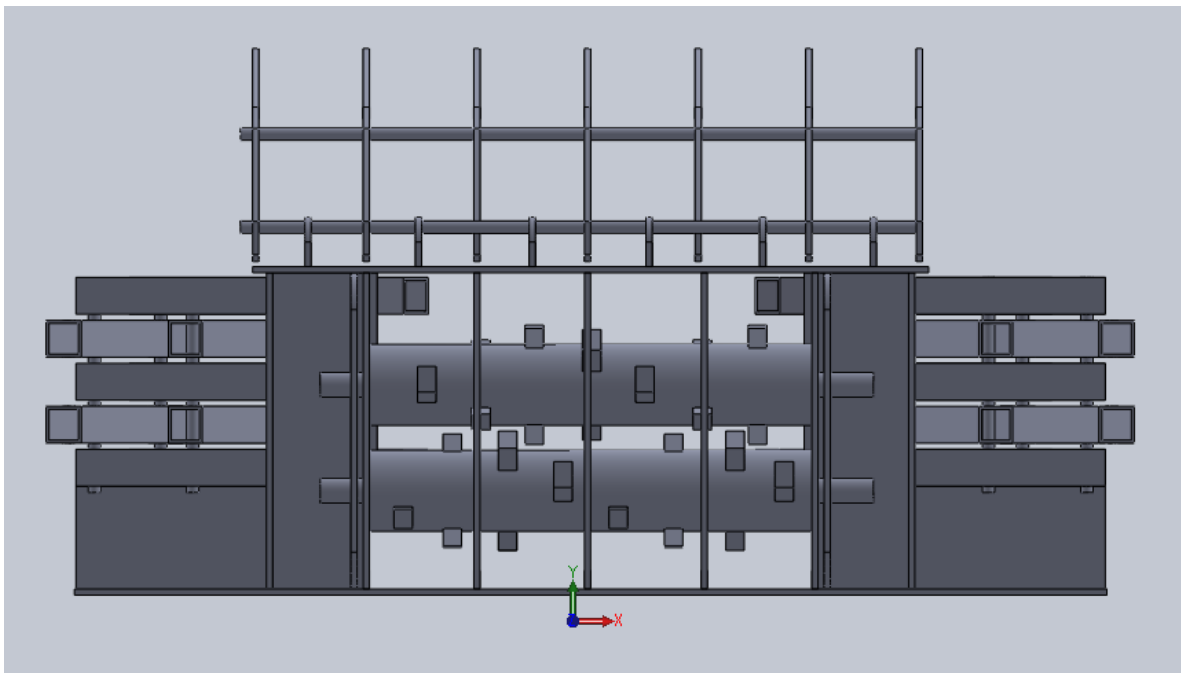


Figure 15. Back View Top Partially Open

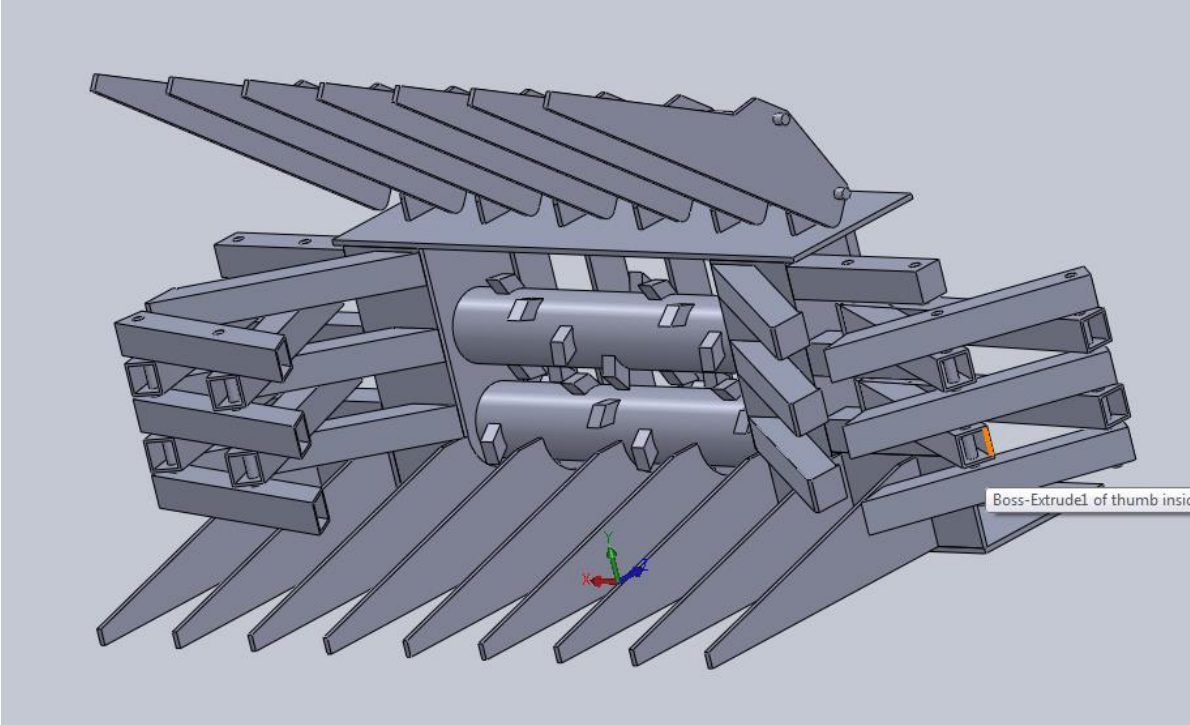


Figure 16. Front Angle Inside

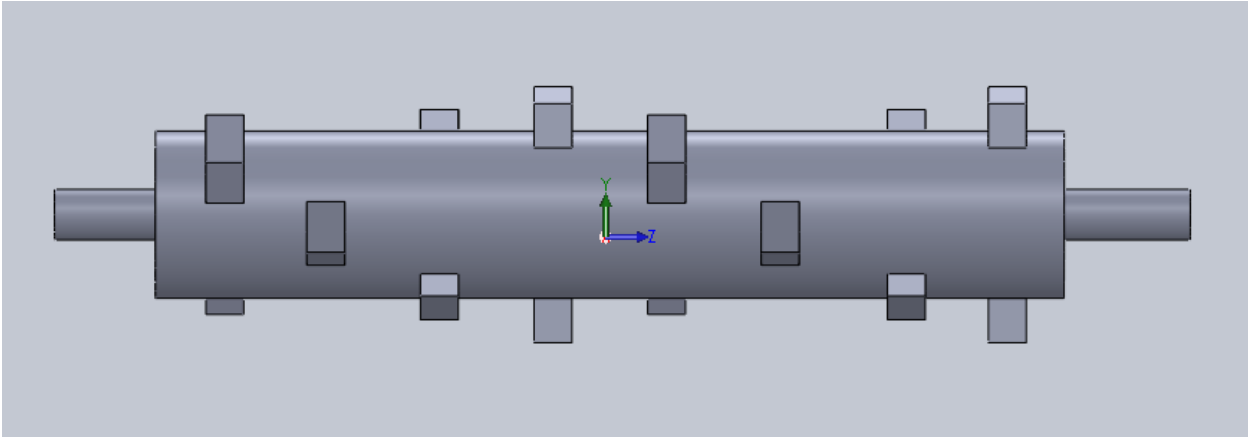


Figure 17. Long View of Drum

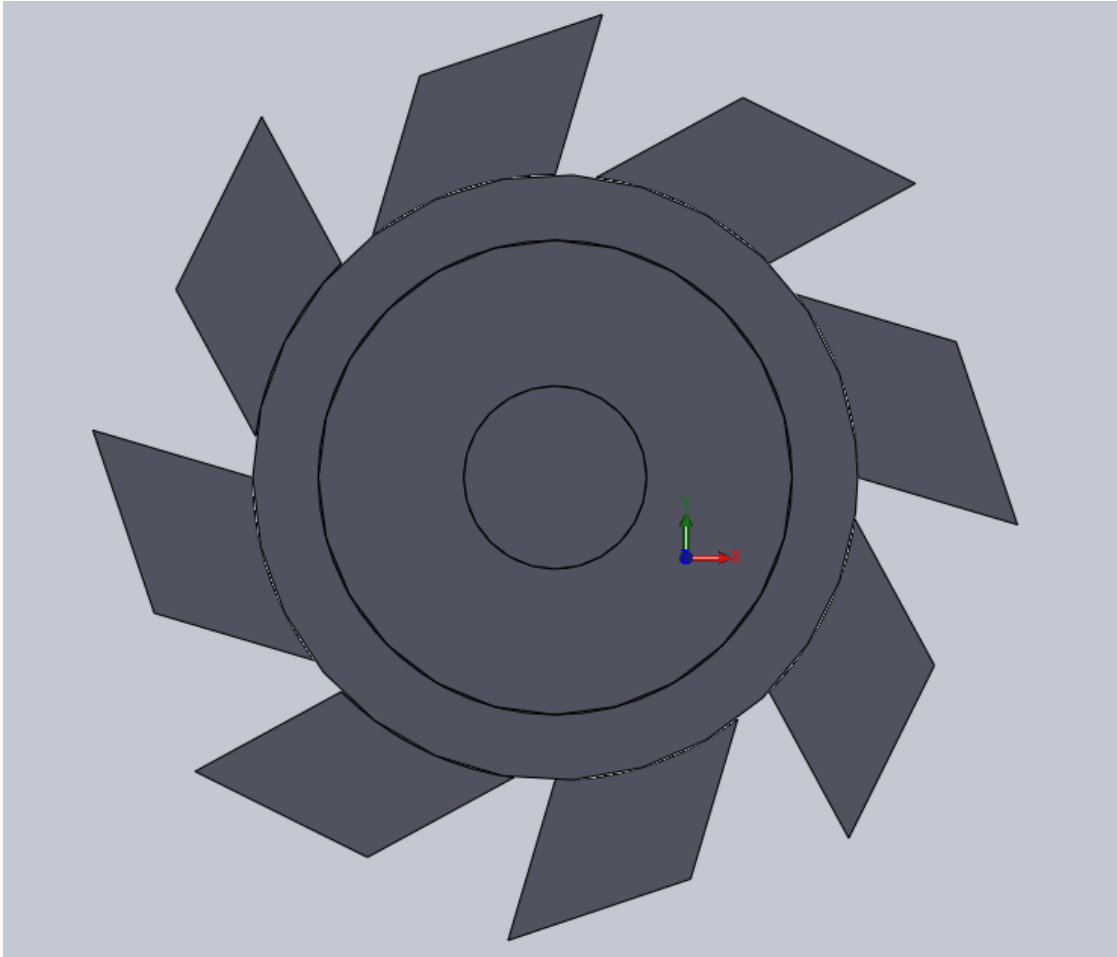


Figure 18. Expanded Side View (Note Tooth Shape)

While many large scale chippers are equipped with carbide cutting teeth, the prototype will initially be built with square stock angled blocks for teeth. They are designed so that the drum can be retrofitted with knife blade tooth attachments if a cleaner chip is desired. The initial design will save a substantial amount of money.

As with any new product, design specifications are tough to determine. The Mega Mite will be the first of its kind and this has proved both helpful and detrimental to the design process. Specifications for weight and power were determinable by skid

steer requirements and power limitations. The most difficult area to spec the machine was in the drive system; there we endless possibilities and virtually no precedents. Through examining other models and testing their capabilities, an initial drum angular velocity was determined of 2000 rpm. When the dual drum system was adopted, the speed was cut in half due to counter rotating cutting surfaces. The relative velocities of cutting surface remain similar to previous values. The force at the cutter head will be greater because of the gearing, so the benefits are two-fold. Following are the calculations to spec the drive system:

▶ ***Goal 1000–1200 rpm***

▶ $R = \omega_1 / \omega_2 = N_2 / N_1$

▶ $R = T_2 / T_1$

$$R = 2:1 * 5:1 = 10:1 * 110 \text{ rpm}_{\text{motor}} = \mathbf{1100 \text{ rpm}}$$

$$R = 2 = 2160 \text{ ft*lbs} / T_2$$

$$T_2 = 1060 \text{ ft*lbs}$$

$$F_{5 \text{ inch pulley}} = T / D = 2540 \text{ lbs}$$

$$T_{\text{small pulley}} = F * D = 425 \text{ ft*lbs}$$

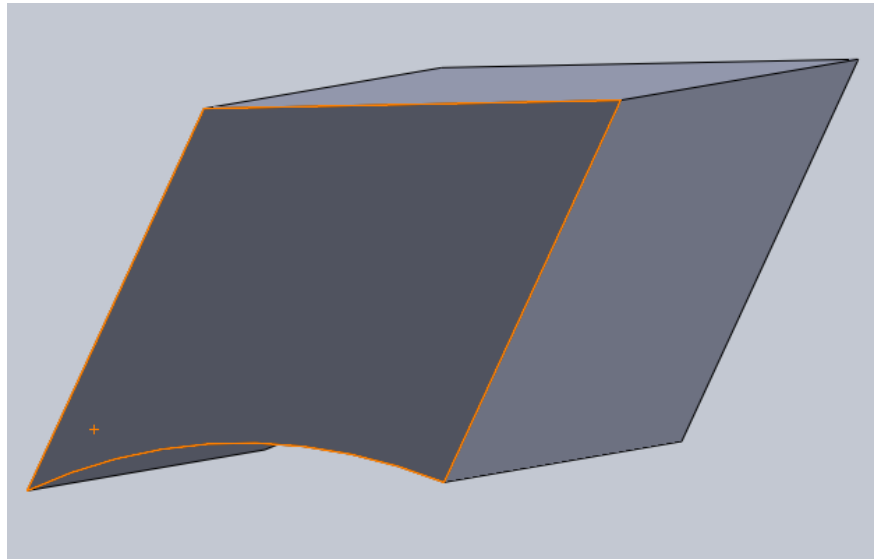
$$F_{\text{tooth}} = T / D = \mathbf{850 \text{ lb}_f}$$

▶ $v = 6 \text{ in} * 1100 \text{ rpm} * \frac{1 \text{ ft}}{12 \text{ in}} * \frac{1 \text{ min}}{60 \text{ sec}} = \mathbf{9.2 \text{ ft/sec}}$

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The most pressured part of the implement will be the teeth, and with any engineering project, the likely point of fracture will be in the pressured connections. Due to this fact, the weldment of the teeth to the drum will need serious care in design. Calculations for the dimension of the welds follow.



$$x = (b - 2h) * (d - 2h)^3$$

$$y = (b - 2h) * (d - 2h)^1$$

$$\sigma_b = \frac{6 * P * A * d}{b * d^3 - x}$$

The above calculations yielded sufficient stress values for the height of the weld to be safe at 1/4 inch. A safety factor of 10 was observed to ensure that the teeth will not fly off.

	part description	quantity	Material			area (in ²)
			type	length (in)	width (in)	
frame	bottom plate	1	1 1/2" plate	96	15.5	1488
	drive housing (left)	1	1 1/2" plate	16.5	25.75	424.875
	drive housing (right)	1	1 1/2" plate	16.5	25.75	424.875
	drum case	2	1 1/2" plate	15	25.75	772.5
	drum cradle	5	1 1/2" plate	45	25.75	5793.75
	mid tine	4	1 1/2" plate	29.5	8.25	602.24
	funnel arm	6	3"x3" square tubing	24	0.25	144
	side extension plate	2	1 1/2" plate	8.5	15.5	263.5
	thumb main support	6	3"x3" square tubing	15.5	0.25	93
	thumb inside support	4	3"x3" square tubing	26	0.25	104
side finger assemblies	thumb outside support	4	3"x3" square tubing	30	0.25	120
	finger	6	3"x3" square tubing	24	0.25	144
	pins	8	1" rod	17.5	1	140
	drums	2	6.5" pipe	36	Sched 80	
drums	shafts	2	2" rod	45	2	90
	teeth	30	2" square stock	2		60
main drive m	eaton 991 VIS*	1				
Cylinders	unknown	3	2" bore	14		3.14

Table 3. Materials Analysis

A materials list was added to show the base materials that will be used. This list is useful for performing a cost analysis and totaling the weight.

Weight Totals:				
	Plate (in ²)=	11170	Weight=	1582
	3"x3" (in)=	237		174
	2"square (in)	60		68
	2" rod (in)=	90		80
	1" rod (in)=	140		31
*sched 80	Drum=	2		172
	Motor=	1		150
	Cylinders=	3		60
	3x3 alum=	368		110
				2428

Table 4. Weight Total

By this analysis, the implement should weigh in well below the specified maximum weight of 3000 pounds. Several design aspects were incorporated to reduce weight. These reductions come from the skeletal bucket design, select aluminum components, and elimination of unnecessary bracing. Testing of the prototype will determine where extra bracing is necessary, but with 500 pounds of play before the limit is reached there should be plentiful ability to support all parts.

Expenditures

Logistics

Travel will be a necessary expenditure, as the heart of the design will likely need periodic review from the sponsor engineers at BIC. In the spring, more travel will be probable due to manufacturing needs, and hydraulics planning.

Costs

Materials and construction will be a significant expenditure for the project. Although the hard parts will likely be fairly generic, there will be a significant amount of welding and cutting of thick plate metal. Capabilities of the Biosystems Engineering machine shop may be limited, so building may require some outside machine shop work. Materials necessary will range from hydraulic components, to metal prefabricated parts, blank metal and other small parts. While some parts can be bought, predominantly designed parts for the implement will be necessary, which will increase the overall machining cost. A cost analysis based on rough estimates of what may be needed is attached.

	price/unit	Total Price	
Plate (in ²)=	0.109	1582.8	
3"x3" (in)=	0.701	216.0	
2"square (in)=	1.09	85.0	
2" rod (in)=	0.854	99.9	
1" rod (in)=	0.199	36.2	
Drum=	20	52.0	
Motor=	1000	1000.0	
Cylinders=	139.99	420.0	
3x3 alum=	1.26	463.7	
plasma cuts	0.1	122.94	
welds	0.15	143.52	
all=	\$	4222.0	*30% Slack

The total cost for production will be significantly higher than the above number, as this number is hard materials only. While these numbers are an estimate based on current prices, the total materials price will be far different from this due to certain availabilities and then-current market prices. A production over run of 30% slack was utilized to account for the amount of extra material that will be wasted due to cutting pattern necessities. A significant cost will be incurred for machine shop time and weld time. A \$40.00 per hour labor cost was suggested, and 20 hours of labor time is expected. The goal cost is roughly \$12,000 total, to fit a markup of 40% suggested by the sponsor.

Conclusive Statements

Several conclusions have been attained through rigorous research and evaluation of testing. Market analysis showed no current models available similar to the product. The implement will fill a brush removal niche of the market well since it allows one operator to move and destroy material with no assistance. The testing simulation shows that the two drum design will achieve near neutral feed, allowing the grapples to control the feed rate to keep from overloading the drum. A single drum mulcher cannot control the feed rate without assistance of a separate feed mechanism. The design for the frame is skeleton style to reduce weight to enable the product to meet the weight requirements. The grapple is designed so that the arms allow them to take a large bite and bring material into the drum. Pete Steere engineers will thoroughly test the product in the spring semester to ensure that the design meets the goal specifications set by the team and client. The product will be complete and ready for production by the end of the spring semester.

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Refer To:

Connolly, C., Daily, T., Henry, J., Moore, E., 2011. Grapple-Mulcher Attachment Business Plan. 2011., Stillwater, Okla. Oklahoma State University.

http://www.skidsteersolutions.com/Skid_Steer_Skeleton_Grapple_Buckets_s/9622.htm

http://www.skidsteersolutions.com/Bradco_Skid_Steer_Forestry_Mulcher_p/br-109292.htm

<http://hydraulics.eaton.com/products/pdfs/E-MOLO-MC001-E6.pdf>

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Appendix A

Patents Utilized

United States Patent [19]
Brown

[11] **Patent Number:** **4,706,721**
[45] **Date of Patent:** **Nov. 17, 1987**

[54] **DOUBLE-DRUM WOOD CHIPPER APPARATUS**

[76] **Inventor:** **Kenton J. Brown**, 5613 Regency Oaks Dr. North, Mobile, Ala. 36609

[21] **Appl. No.:** **802,495**

[22] **Filed:** **Nov. 27, 1985**

[51] **Int. Cl.⁴** **B27C 1/00; B02C 18/18**

[52] **U.S. Cl.** **144/174; 241/190; 241/236**

[58] **Field of Search** **241/190, 236, 28; 144/167 R, 173, 174**

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,209,801 10/1965 Little et al. 144/172
3,314,459 4/1967 Beaubien 144/172
3,929,294 12/1975 Cox 241/236

3,991,944 11/1976 Baikoff 241/236
4,399,946 8/1983 Stevenson 241/236

FOREIGN PATENT DOCUMENTS

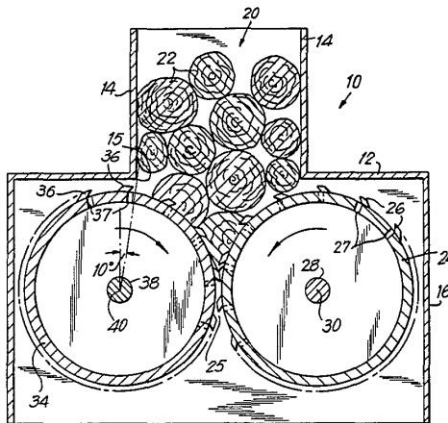
2065350 5/1973 Fed. Rep. of Germany 144/174

Primary Examiner—W. D. Bray

[57] **ABSTRACT**

A double-drum wood chipper for obtaining wood chips of uniform thickness from logs. Each one of a pair of oppositely rotating, hollow, open ended drums is provided with cutting knives. An aperture through the drum walls is located near each knife for reception of the wood chips. Two knife patterns on the drums are disclosed. The parallel-cutting edge of each knife makes an angle of about 150° with the cutting edge of each of two laterally positioned, integral cross cutting knives.

7 Claims, 11 Drawing Figures



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Appendix B

Business Plan (formulated by Business Team)

Business Plan

1.0 Executive Summary

Coneqtec Corporation, Inc. is an engineering and manufacturing company that develops heavy duty attachments and hydraulic kits for skid steer, backhoe, compact and utility loaders. Coneqtec is going to enter an unsaturated market as there are currently no other Grapple-Mulchers available at this time. They will meet sales goals by attending various trade shows and by advertising in industry related publications.

1.1 Mission

Coneqtec aims to offer this high-quality Grapple-Mulcher skid steer attachment to city, county, and state municipalities, tree service businesses, and disaster relief clean-up programs at a price which is competitive in comparison to other products on the market.

1.2 Keys to Success

Coneqtec Corporation's keys to success will include:

1. A high level of quality and functionality of this product.
2. Maintaining and growing its distribution networks in order to generate new and repeat sales.

1.3 Objectives

The objectives of Coneqtec Universal are:

1. To enter an unsaturated market in debris cleanup industry.
2. Sell a minimum of twenty Grapple-Mulchers the first year they are on the market
3. Attend various trade shows to showcase our product to prospective customers

2.0 Company Summary

Coneqtec Corporation, Inc., headquartered in Wichita, KS, is an engineering and manufacturing company that has developed heavy duty attachments and hydraulic kits for skid steer, backhoe, compact and utility loaders since 1990. Coneqtec owns Universal Construction Products, Inc., Universal Bingham, Inc., TerraQuip Construction Products, Inc. and the majority interest in Burlington Installation Corporation, Inc. (BIC). Coneqtec has facilities located in Iowa, Indiana, Kansas, West Virginia and England. The Coneqtec group has an international network of dealers to provide products and services worldwide.

TerraQuip Construction Products acquired the assets and the rights to manufacture and distribute the product lines of The Terramite Company, Inc. in December of 2008. Terramite was formed in 1965 and designed the first compact tractor loader

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backhoe in the early 70s. The Terramite line includes CTLBs, street sweepers and paving screeds and is sold both domestically and internationally.

BIC was established in 1992 and is located adjacent to the CASE plant in Burlington, IA. This facility provides safety and productivity equipment and installation for CASE backhoes. To provide this service for skid steers, there is a BIC facility in Wichita, KS and is located directly across the street from the CASE skid steer plant. BIC works exclusively with CASE and approximately 85% of all backhoes and skid steers are customized by BIC before they are shipped to the dealers. The list of products and services from BIC is exhaustive and include items such as hydraulic kits, GPS monitoring systems, cabs, fenders, guards, tires, radios, thumbs, lights, mirrors, chroming and pre-delivery inspections to name a few. BIC services are available for most of CASE construction equipment lines including forklifts and utility loaders.

Universal Construction Products is Coneqtec's sales and marketing arm that makes available heavy duty hydraulic attachments including: cold planers, slot cutters, manhole saws, rock saws, stripe removers, pattern mills, berm grinders, brooms, compaction plates, stump grinders, tillers, brush cutters and hydraulic kits. Cold planers, featuring the patented open drum, are Coneqtec's most popular line of attachments. Since 1995 these products have been branded as Coneqtec/Universal and are recognized as the industry's most productive attachments available. Universal Bingham provides a channel for the European market.

Source: Steve Youngers, Coneqtec consultant.

2.1 Company Ownership

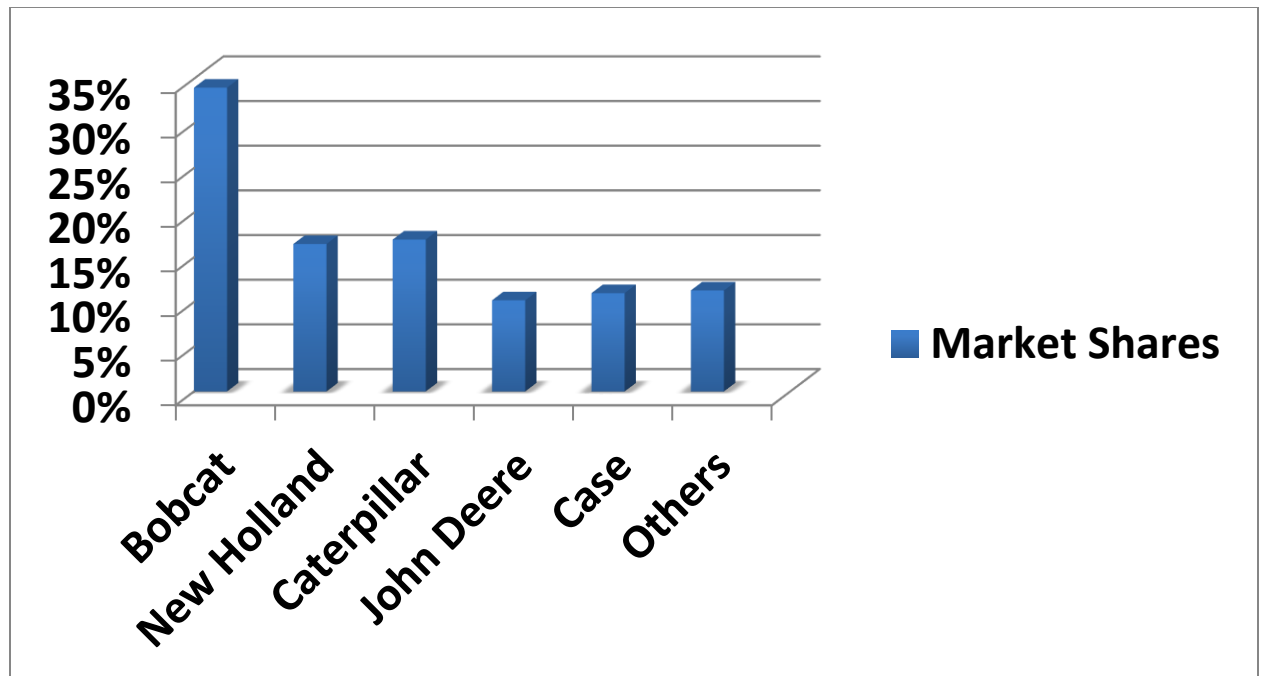
The Coneqtec group is directed by Gary Cochran, founder and President. Before he formed Coneqtec, Gary was head of engineering at CASE. During that time, he and his team designed CASE's first in-house manufactured skid steer. Before unveiling Gary's 1845 series, CASE sold the Uni-Loader line from Universal Industries. Gary has brought a number of long time CASE engineers over to join the Coneqtec family.

Source: Steve Youngers, Coneqtec consultant.

2.2 Industry Analysis and Trends

Bobcat, New Holland, Caterpillar, John Deere, Case IH, GEHL, Mustang, Thomas, ASV and Takeuchi. Together the ten manufacturers combine to own 99 percent of the skid steer market.

Table 1



Source: www.groundstradesexchange.com

3.0 Products and Services

Coneqtec Universal manufactures fifteen various skid steer attachments. Coneqtec's product line includes: ax planers, slot cutters, and berm grinders that grind and cuts pavement up. They also manufacture a pattern mill that cuts rumble strips along highways, a surface prep that removes road paint, a manhole drill, and a pick up broom all for road work. Their dirt working line includes: compaction plate, rotary tiller, water kits, and backhoes. They also have started a tree cleanup line stump grinder and the Grapple-Mulcher. The Grapple-Mulcher will allow you to pick up debris from one location and mulch it in another without having to loading the debris up or handling it with your hands. The Grapple Mulcher is a grapple skid steer

attachment with a mulcher in the mouth of the grapple. This will allow you to scoop up debris with the grapple and then mulch the debris inside the grapple.

4.0 Market Analysis Summary

The marketing strategy for Coneqtec Universal's equipment is simple and straight forward. They want to focus on municipalities and disaster relief programs.

The main reason they want to market to these two specific segments of the industry is because the customers in these industries have an **everyday** use for an attachment like the Grapple-Mulcher. A recent Solid Waste Association of North America (SWANA) publication said "Yard trimmings volume has been increasing slightly since 2000, an estimated 33.2 million tons of yard trimmings were generated in MSW in 2009." Municipalities pick up debris routinely and this implement could be used to clean up yard trimmings and aid in storm cleanup efforts. Disaster relief programs could use the Grapple-Mulcher to clean up after major storms and natural disasters. The mulching element of the Grapple-Mulcher is capable of mulching debris from trees, limbs, brush, and demolition rubble. With waste levels increasing over the last fifty years, it seems that there will always be a need for a disposal method for yard debris.

Table 2

- Recovery (as a percentage of generation) of most materials in MSW has increased dramatically over the last 39 years. Some examples:

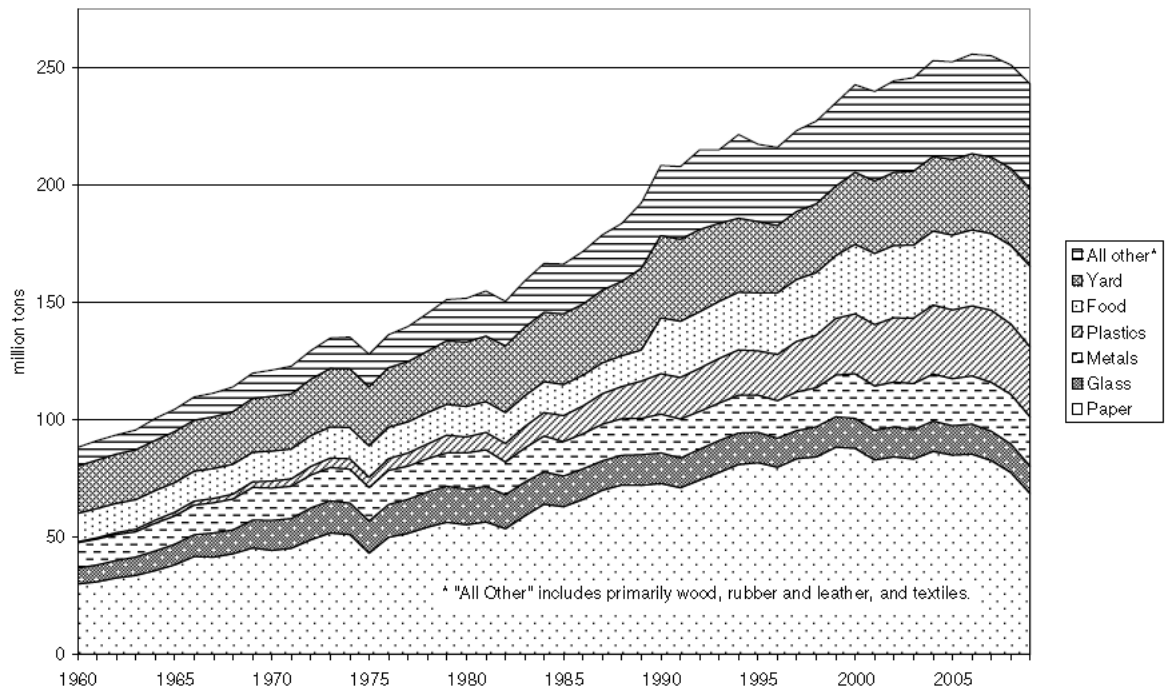
	1970	1980	1990	2000	2009
Paper and paperboard	15%	21%	28%	43%	62%
Glass	1%	5%	20%	23%	26%
Metals	4%	8%	24%	35%	35%
Plastics	Neg.	<1%	2%	6%	7%
Yard trimmings	Neg.	Neg.	12%	52%	60%
Selected Consumer Electronics				10%	19%
Lead-acid batteries	76%	70%	97%	93%	96%

Neg. = less than 5,000 tons or 0.05 percent.

Source: Environmental Protection Agency. Municipal Solid Waste in the United States. 2009 Facts and Figures.

Table 3

Figure 10. Generation of materials in MSW, 1960 to 2009



Municipal Solid Waste (MSW) statistics from 1960-2009

Source: Environmental Protection Agency. Municipal Solid Waste in the United States. 2009 Facts and Figures.

4.1 Target Market

The intended target markets include rural, city, county and state municipalities that are looking to increase efficiency and lower the costs of operation during disaster relief and annual cleanup procedures. Disaster relief programs will be a viable target market as they would greatly benefit from having a piece of machinery that only requires one

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operator. We will also target Coneqtec Universal's active distributors. Secondary target market would include pursuing the following industries: forestry conservation, pasture restoration, and demolition services.

4.2 Competitive Comparison

At this time there is no similar competition to Coneqtec Universal's Grapple-Mulcher available on the market. This means that the Grapple-Mulcher will not be competing with another skid steer attachment but rather the current systems used for debris removal. When meeting with David Higgins from the City of Stillwater he informed us that the most common method for brush removal is a multi-person crew using a hand fed chipper and collecting debris by hand or by some type of grapple. A Vermeer BC600XL chipper cost \$15,800 dollars. This chipper is pulled behind a truck and the debris is hand loaded into the chipper as it is then mulched and blown into the truck bed. This system involves a trailer attached to a truck which means that you are not capable of putting the chipper right next to the pile of debris that needs to be mulched. If workers have to walk every piece of debris to the chipper you are losing valuable time. Then you also have small twenty seven horse power gas engine that runs this chipper. Equipment with small gas engines are typically more prone to have problems because they are all carbureted. The Vermeer chipper also has to be completely unhooked in order to dump your load of mulch.

4.3 Risk Assessment

Potential risks for the Grapple-Mulcher include:

4. Future competitors that will be designed after the Grapple-Mulcher is introduced to the market.
5. Meeting strict Society of Automobile Engineers (SAE) safety regulations will play a vital role in the final design and usability of this project.
6. With a depressed economy some smaller business will not be able to justify a \$24,920.20 purchase for a piece of machinery that will have limited functions, instead they may opt to spend that money on additional labor to operate cheaper equipment.

5.0 Management Summary

Gary Cochran; President and founder, He started the company in 1990 and now employs over one hundred-twenty people. As the company has grown over the years Gary now spends more and more of his time in Europe and China negotiating future business ventures.

Andy Campbell; Sales Manager, has been with Coneqtec since 2007. He works with all of the companies 763 distributors and supports the manufacturing facility in Carbon, IN.

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Steve Youngers; Consultant, works contractually with Mr. Cochran on design projects.

6.0 Financial Plan

Due to the lack of a final engineering design for the Grapple-Mulcher all financials were prepared with part price estimates from John Deere, New Holland, or Wheeler Metal Supply. The parts list was composed from the closest competing product on the market. The estimated total cost of goods for the Grapple-Mulcher will be \$17,800.14. If we used a typical mark-up percentage of 40% the retail price would be approximately \$24,920.20.

-See attached appendices

Table 4

Parts	Price/Unit	# units	Cost
Bearings	\$137.00	4	\$548.00
Pulleys	\$110.00	4	\$440.00
Belts	\$442.00	2	\$884.00
Teeth	\$75.00	50	\$3,750.00
Drum	\$5,650.00	1	\$5,650.00
Fly wheel	\$379.00	1	\$379.00
1/2 in Plate	\$11.21	32	\$358.72
1/4 in Plate	\$5.61	32	\$179.52
12 Gauge metal	\$2.41	32	\$77.12
Hyd. Cylinders	\$165.00	2	\$330.00
Hyd. Motor	\$1,520.00	2	\$3,040.00
1/2 Hyd. Hose	\$5.40	50	\$270.00
Hyd. Connector	\$9.00	20	\$180.00
3in Tubing	\$7.60	15	\$114.00
Belt tensioner	\$87.39	2	\$174.78
Bolts	\$1.00	100	\$100.00
Nuts	\$0.75	100	\$75.00
Washers	\$0.50	100	\$50.00
Labor/fabrication costs (hours)	\$40.00	20	\$800.00
Destination/shipping cost	400	1	\$400.00
Total Inputs, Labor, & Delivery Costs per Unit			17,800.14

6.1 Sales Forecast

Coneqtec sales manager Andy Campbell predicts that they should be able to sell twenty Grapple-Mulchers with a sales growth of ten percent annually based off of

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implements they have produced in the past. Projected revenue in the first year is \$ 498,403.92. The total cost of goods sold in the first year one is \$361,003with a \$137,400.92 profit margin. These estimate only included variable costs because company fixed cost were not disclosed and were deemed confidential by the Coneqtec Corporation.

-See attached appendices

7.0 Strategy and Implementation Summary

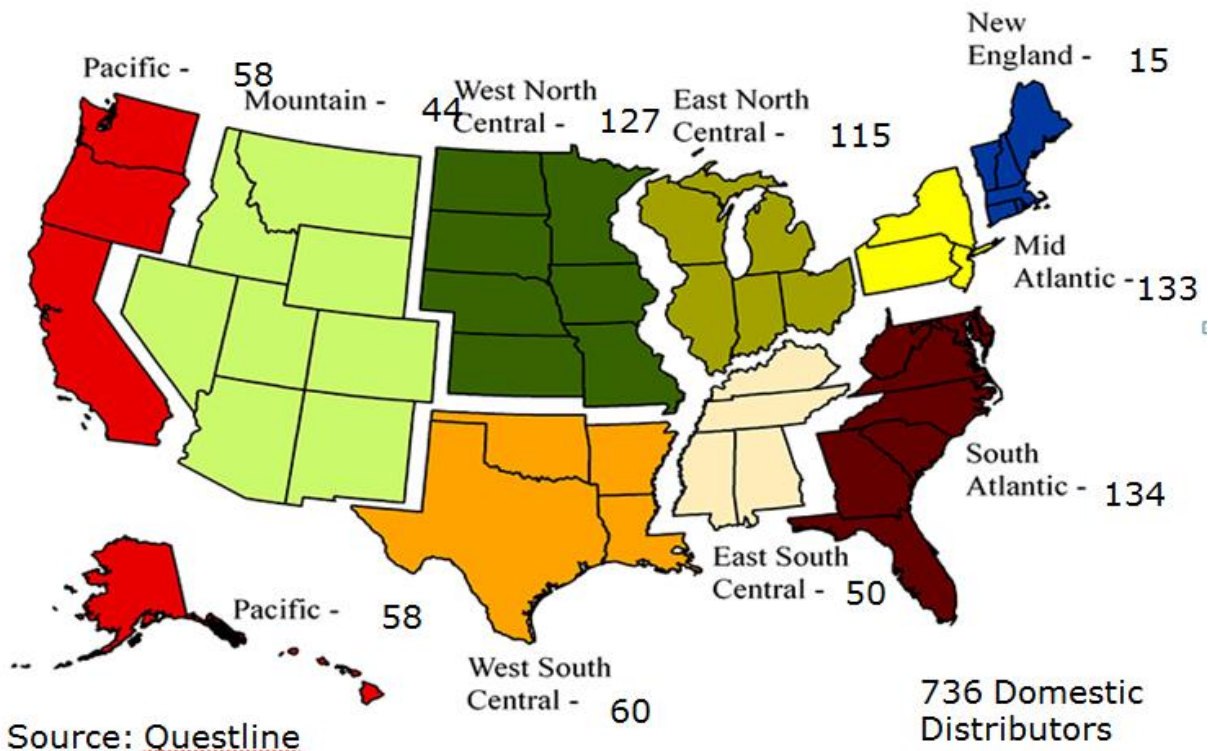
Coneqtec will succeed by manufacturing this high quality, durable attachment that has significant number of product features and options which are extremely precise in control of movement. It will focus on a very narrow segment of the market and attempt to achieve the best reputation in that segment.

7.1 Competitive Edge

Coneqtec Corporation's competitive edge is its level of quality, product features and options, and the company's relationships with numerous major dealerships nationwide.

Table 5

Coneqtec Dealer by Region



7.2 Sales Strategy

The reason the Grapple-Mulcher will be successful is because customers are always looking for ways to cut the cost of operations. Companies will benefit from a piece of equipment that could allow them to replace a team of two or more people with one person. The Grapple-Mulcher would also replace bulky unnecessary pieces of equipment that have to be stored and maintained. The Grapple-Mulcher will allow you to eliminate the need for a worker that picks up debris by hand and loads it into a chipperr. The mulchine element of the Grapple-Mulcher will allow you to mulch

debris in the same location you grapple it, meaning a worker never touches any debris by hand, reducing the risk of injury.

7.3 Marketing and Advertisement

Ways to advertise our product will be to use the Solid Waste Association of North America (SWANA) and American Public Work Association (AWPA) organizations as marketing tools. Showcasing the Grappler-Mulcher through these respected organizations will increase the scope of potential customers and or dealers. Displaying the new product line through trade shows will increase the awareness and knowledge regarding the unique capabilities of the only Grappler-Mulcher commercially available. A few of these trade shows include; Waste Expo, May 1-3, 2012; The Road to Zero Waste (SWANA), February 8, 2012. Also, advertising Coneqtec Universal's new product through respectable and credible magazines like Waste Handling Equipment News magazine will be a good stepping stone to introduce the grappling mulcher to the debris cleanup industry. This publication is for contractors involved in wood waste, recycling concrete, asphalt recycling, construction demolition and scrap metal recycling.

8.0 SWOT Analysis

Strengths:

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- Product quality and capacity
- Product diversification
- Innovation and technology
- Engineering capabilities
- Strong network of established dealers

Weaknesses:

- Website
- Familiarity of the Coneqtec brand name with end customers

Opportunities:

- Emerging markets
- Market segment (domestic and foreign)

Threats:

- Increasing competition from other manufactures
- Safety regulations
- Depressed economy

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Appendix C

Materials Analysis

	part description	quantity	type	Material			area (in ²)	perimeter	weld lengths
				length (in)	width (in)				
frame	bottom plate	1	1/2" plate	96	15.5	1488	220		
	drive housing (left)	1	1/2" plate	16.5	25.75	424.875	120	23.4	
	drive housing (right)	1	1/2" plate	16.5	25.75	424.875	120	23.4	
	drum case	2	1/2" plate	15	25.75	772.5	100		
	drum cradle	5	1/2" plate	45	25.75	5793.75	147	96	
	mid tine	4	1/2" plate	29.5	8.25	602.24	76	72	
	funnel arm	6	3"x3" square tubing	24	0.25	144		72	
	side extension plate	2	1/2" plate	8.5	15.5	263.5	47	94	
	outer tine support	1	1/2" plate	73	3	219	152	126	
	top tine	7	1/2" plate	37	8	183	89		
top assembly	top plate	1	1/2" plate	55	15.5	852.5	141	90	
	brackets	10	1/2" plate	4	4	13.5	17.4		
	short pin	2	1" rod	9.75					
side finger assemblies	long pin	2	1" rod	55					
	thumb main support	6	3"x3" square tubing	15.5	0.25	93		72	
	thumb inside support	4	3"x3" square tubing	26	0.25	104			
	thumb outside support	4	3"x3" square tubing	30	0.25	120			
	finger	6	3"x3" square tubing	24	0.25	144			
	pins	8	1" rod	17.5	1	140			
drums	drums	2	6.5" pipe	36	Sched 80				
	shafts	2	2" rod	45	2	90			
	teeth	30	2" square stock	2		60		288	
	main drive meaton 991 VIS*	1							
Cylinders	unknown	3	2" bore	14		3.14			
			Weight Totals:						
						11170	Weight=	1582	
				Plate (in^2)=		237		174	
				3"x3" (in)=		60		68	
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				1" rod (in)=		2		172	
				Drum=		1		150	
				Motor=		3		60	
				Cylinders=		368		110	
				3x3 alum=				2428	

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Appendix D

Company Background



Coneqtec Corporation, Inc., headquartered in Wichita, KS, is an engineering and manufacturing company that has developed heavy duty attachments and hydraulic kits for skid steer, backhoe, compact and utility loaders since 1990. Coneqtec owns **Universal Construction Products, Inc.**, **Universal Bingham, Inc.**, **TerraQuip Construction Products, Inc.** and the majority interest in **Burlington Installation Corporation, Inc. (BIC)**. Coneqtec has facilities located in Iowa, Indiana, Kansas, West Virginia and England. The Coneqtec group has an international network of dealers to provide products and services worldwide.

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Coneqtec.com ConeqtecUniversal.com BurlingtonInstallation.com

Terramite.com



PETE STEERE

Design Presentation of the
“Mega Mite”

Team Members

- ▶ Benjamin Gifford (Team Leader)
- ▶ Aaron Bartel (Design, Safety)
- ▶ Dustin Hofegartner (Design, Engineering)
- ▶ Lucas Polly (Information Delivery Design)



Mission Statement

- ▶ The mission of Pete Steer Designs is to provide reliable and innovative solutions that reduce unassisted physical workloads, with implements that are easily attachable and adaptable to all skid steers.

Sponsor Company



▶ Coneqtec Corporation



- Founded and Directed by CEO Gary Cochran
- Designs and manufactures a number of hydraulic powered skid steer attachments
- Fourteen products that range from rock saws to rotary tillers
- Super high flow kits with several auxiliary ports

Problem Statement

- ▶ The goal is to combine a skid steer mulcher with a skid steer grapple. The combination will allow the operator to grab and mulch brush piles.
- ▶ This will give the operator a choice where to mulch the wood, such as into the bed of a truck, or a remote chip pile. The product will be powered by the skid steer's auxiliary hydraulic system.

Products for Combination



http://www.skidsteersolutions.com/Bradco_Skid_Steer_Forestry_Mulcher_p/br-109292.htm

http://www.skidsteersolutions.com/Skid_Steer_Skeleton_Grapple_Buckets_s/9622.htm



Current Production Equipment

Seppi MidiForest



Bradco Magnum Mulcher



- 72" swath
- Carbide Teeth
- No grapple ability
- Requires 30 gpm
- Retail about \$30k

<http://www.everythingattachments.com/PhotoGallery.asp?ProductCode=BR-SS-Magnum-Mulcher-72Double>

Grapple



<http://www.nodillroc.com/grapplespecs.html>

Responsibilities

- ▶ Determine Marketability and Necessities
- ▶ Define the Finished Product
- ▶ Test Related Products
- ▶ Design
 - Develop Concepts
 - Finalize Design
- ▶ Build, Test, and Determine Satisfactory Performance

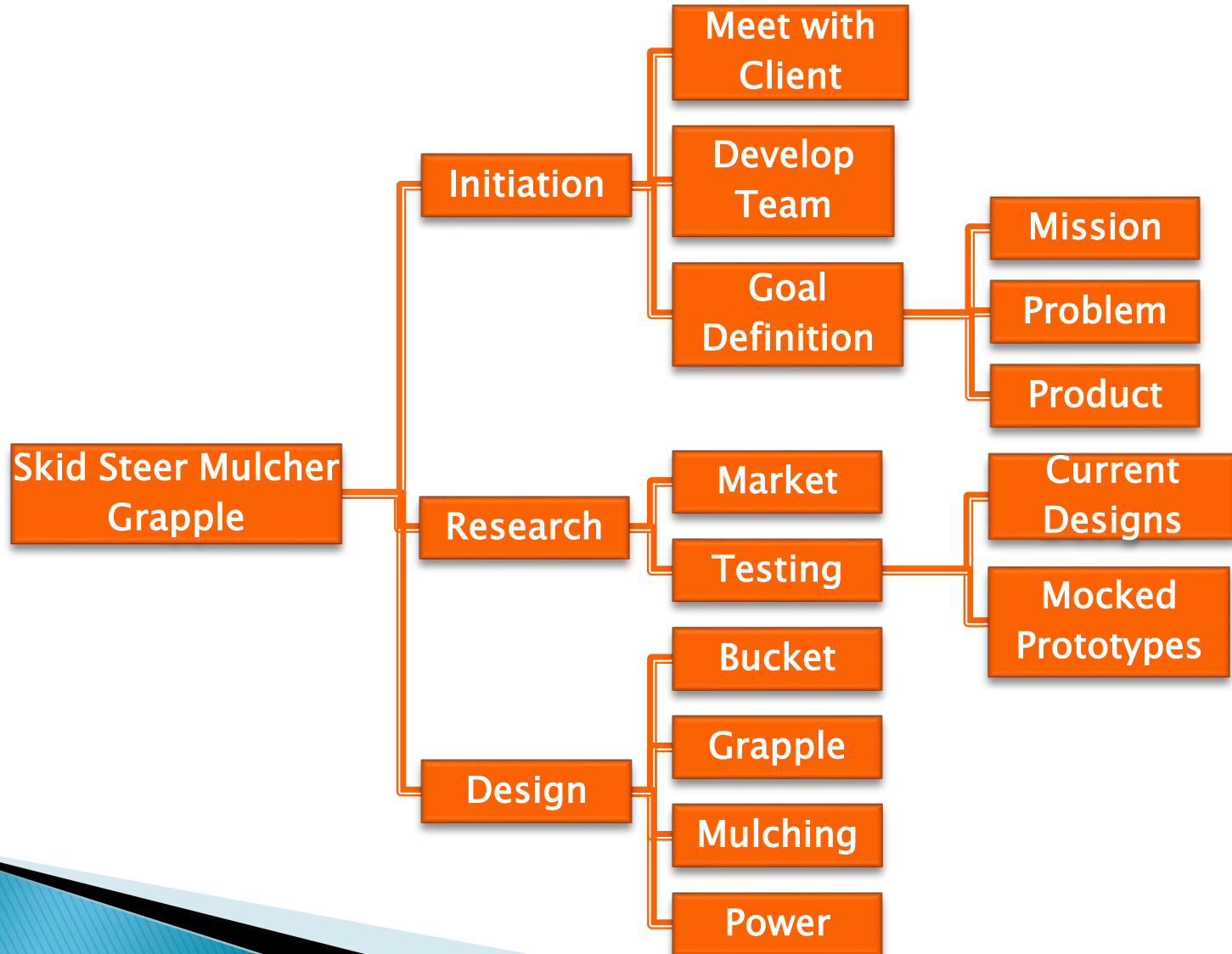
Location of Work

- ▶ Design work– OSU Stillwater campus
- ▶ Design Reviews– Wichita Kansas, Coneqtec Universal.
- ▶ Fabrication and Manufacturing– OSU BAE Machine Lab.
 - Some limitations of the BAE Lab may necessitate outside machine shop work

Period of Work

- ▶ Design– September '11 – March '12
 - Several Design Meetings (Throughout)
 - Research (September – October)
 - Determine Goal Specifications (October)
- ▶ Building and Testing– March – April '12
- ▶ Final Product review scheduled for April '12

Fall Task List



Market Analysis

- ▶ Aimed at cities and disaster relief programs
- ▶ Product is not intended to be a low cost attachment
- ▶ “Yard trimmings volume has been increasing slightly since 2000, an estimated 32.2 million tons of yard trimmings were generated in 2009” – Solid Waste Association of North America (SWANA)

Risk Assessment

- ▶ Future competitors implements that will be designed after the Mega Mite is introduced to the market.
 - Importance for patent
- ▶ Meeting the safety standards
 - SAE

Technical Research

- ▶ Several Patents are applicable but none directly associate with the desired product.
- ▶ Specific components can be analyzed for the design process to determine standard ratings
 - Drum RPM
 - Grapple size
 - Implement weight
 - Available hydraulic horsepower

Available Power

	Case (SR200)	New Holland(L180)	Bobcat (S630)	Cat (242B Series 3)	Deere (320D)
GPM	23.8	21	23	22	20
GPM(HF)	33.2	35.8	30.5	31	31
PSI	3050	3050	3500	3335	3100
HP	42.4	37.4	47.0	42.8	36.2
HP(HF)	59.1	63.7	62.3	60.3	56.1
AVG STDFLOW=	41.1	AVGHIFLOW=	60.3		*for 70 HP models

$$P (HP) = \frac{Q(gpm)*p (psi)}{1714}$$

Avg. Power Hi Flow = 60 HP

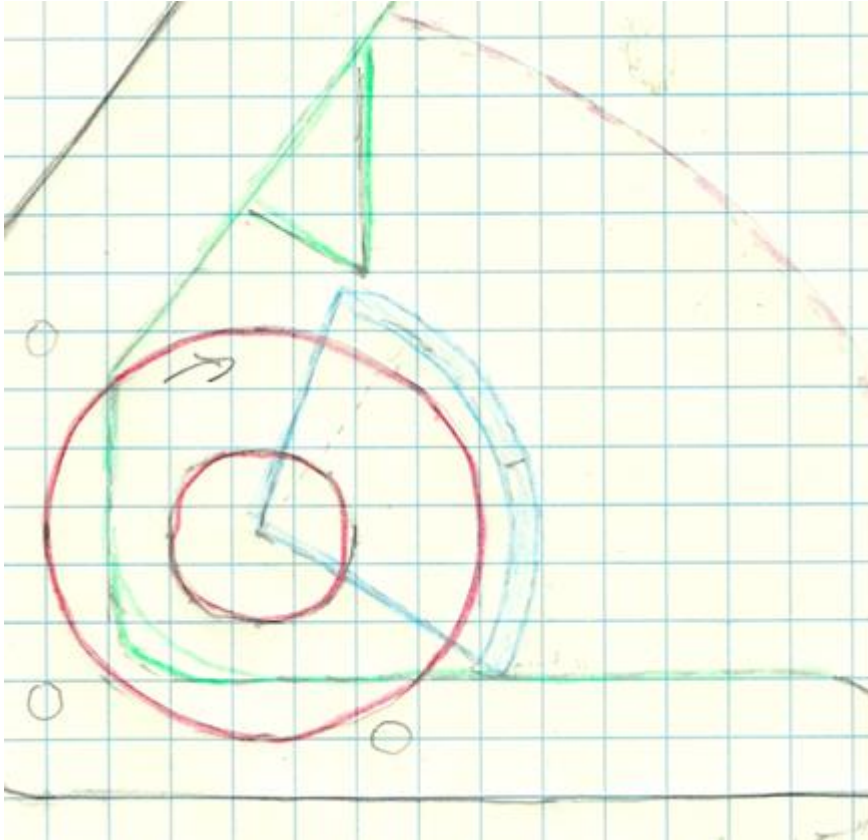
Conceptual Ideas

- ▶ Main concern for the implement is the feed rate of the material in comparison to the cutting rate of the drums
- ▶ Feeding too fast will reduce inertia or prevent drums from recovering inertia

Conceptual Ideas

- ▶ Various ideas to slow feed rate were examined
 1. Spin Up Guard Plate
 2. Feed drum
 3. Two drums
 - Opposite or similar rotation
- ▶ Prototype of the dual drum system was created with both drums rotating in the same rotational direction

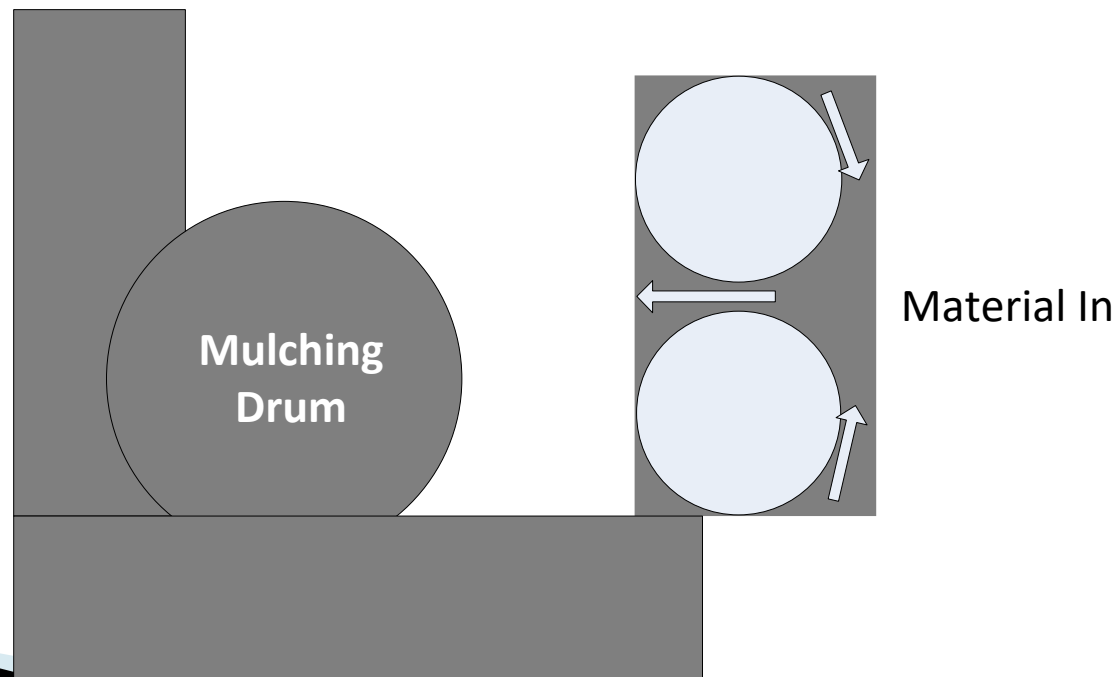
Spin Up Plate



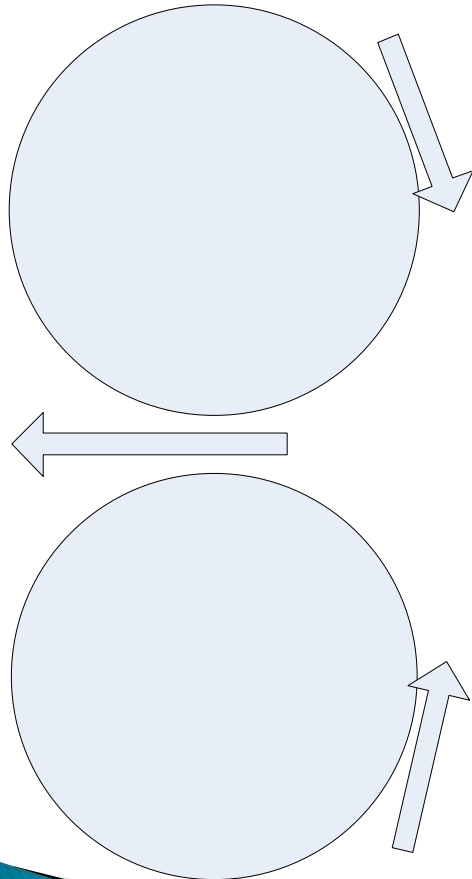
- The picture at left shows a round spin up plate
- Also considered flat spin up

Feed Drum

- ▶ Similar designs on stationary and trailer mounted chippers
- ▶ Discounted due to weight requirements

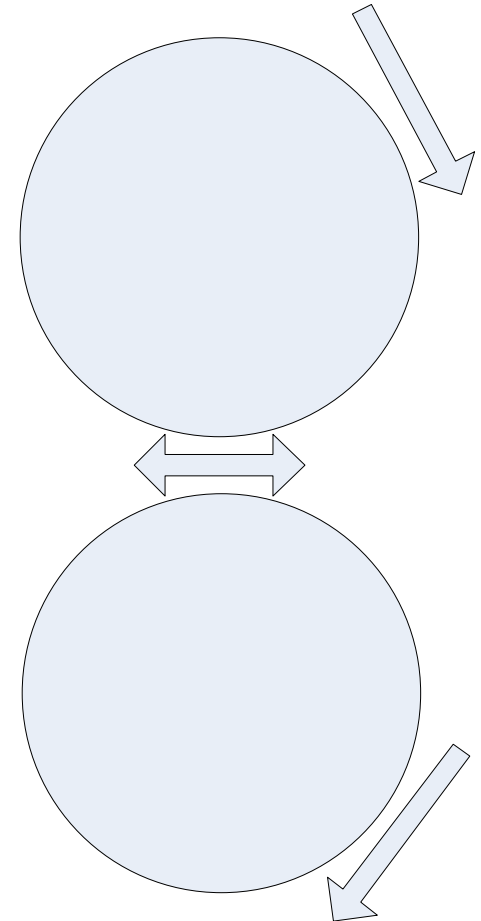


Drums (2 Rotations)

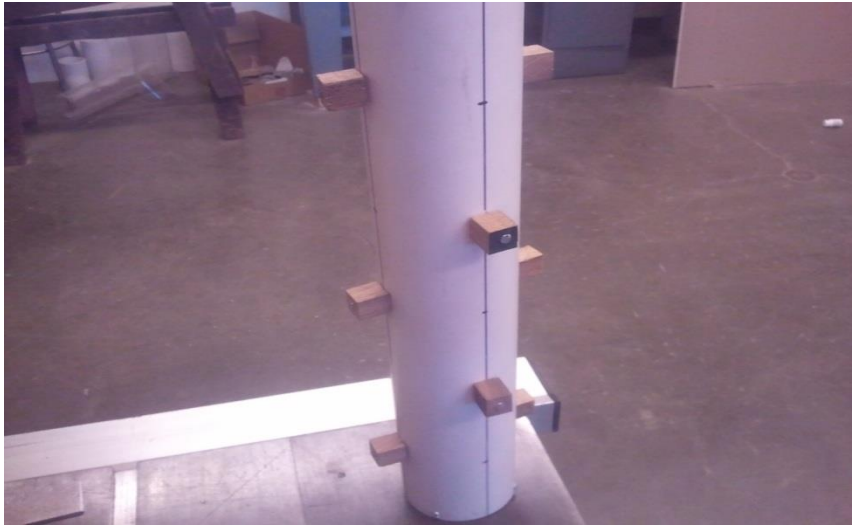


Opposite rotating drums will produce a fast feed rate as both drums grab material and thrust through. (Left)

Similar rotation on the drums will encourage a more neutral feed and produce a greater chipping area.



Testing



Power was supplied to the top drum by the hand drill.

The intent of the test was to judge the path of the material through the “implement.” Mock up drums were constructed from PVC pipe and wood stock.



Feed Test



Test Conclusion

- ▶ Feed rate was significantly reduced
 - Top drum pushes material to bottom drum
 - Increases cutting area even with narrower drum
- ▶ Grapple will force feed in backed up situations
 - Ideal situation
 - Gives most control to operator

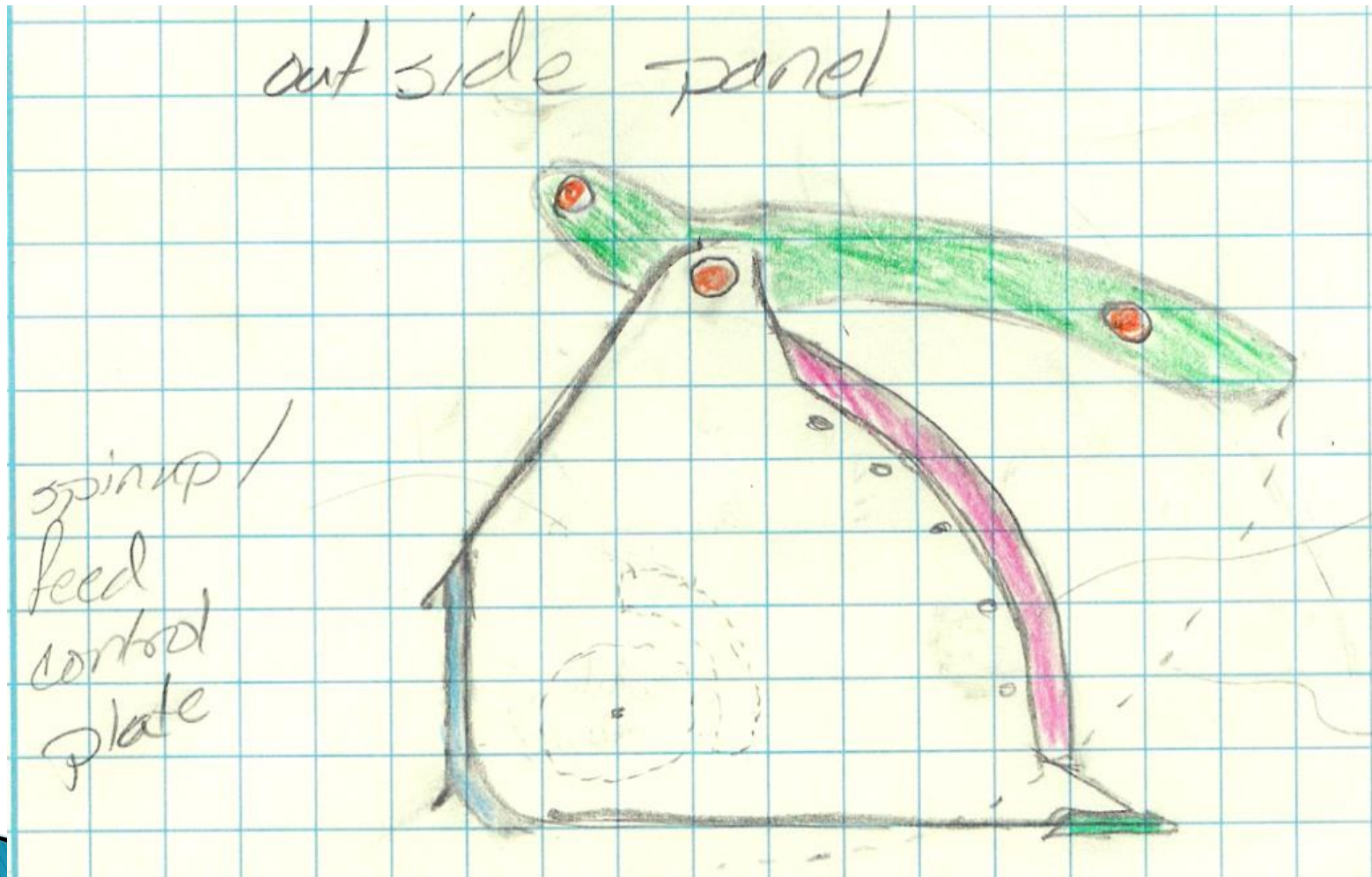
Design Meetings With Sponsor

- ▶ September 20th 2011
 - First meeting with Coneqtec about Design Project
 - Determine scope and problem
- ▶ November 1st 2011
 - 2nd Meeting with Coneqtec about original design concept
 - Sponsors and team brainstormed and decided new ideas to pursue
- ▶ November 15th 2011
 - 3rd Meeting with Coneqtec
 - Approved Design concept and encouraged CAD work commencement

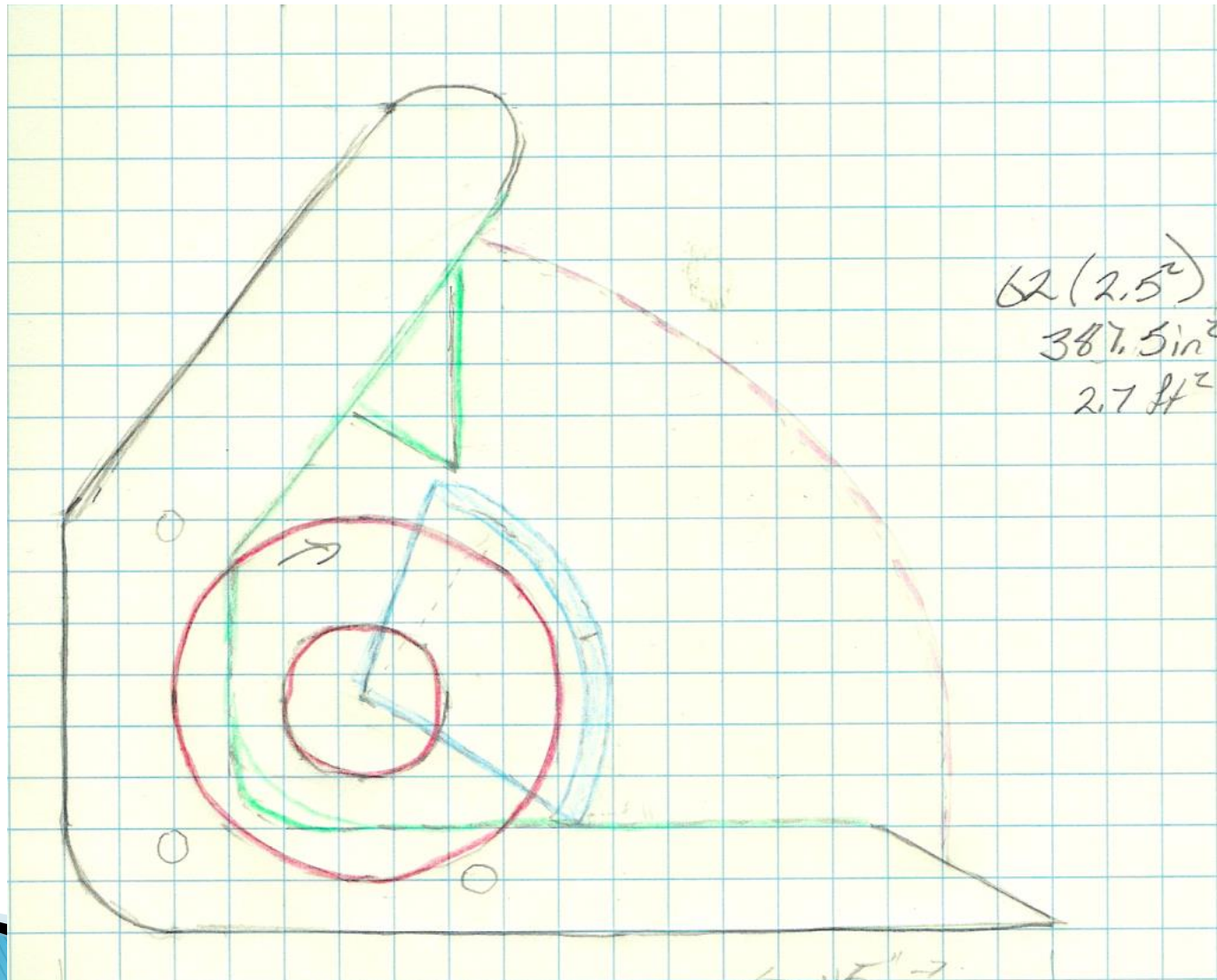
Pertinent Design Constraints

- ▶ Safety
 - SAE standards
- ▶ Limited Power Output
 - High flow vs. Standard Flow
- ▶ Weight
 - MAX– 3000 lbs.
- ▶ Feed rate

Initial Design Concept



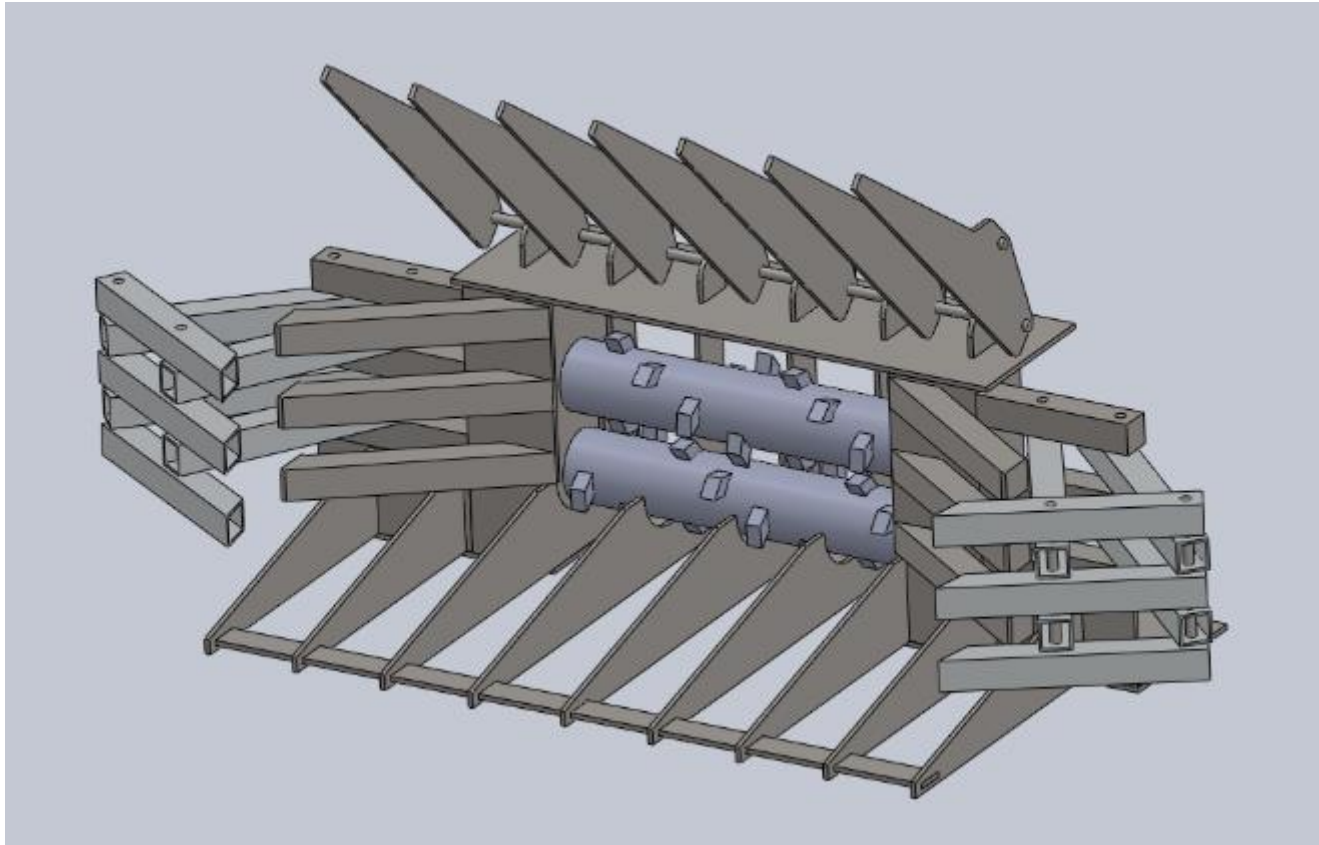
Initial Design Concept



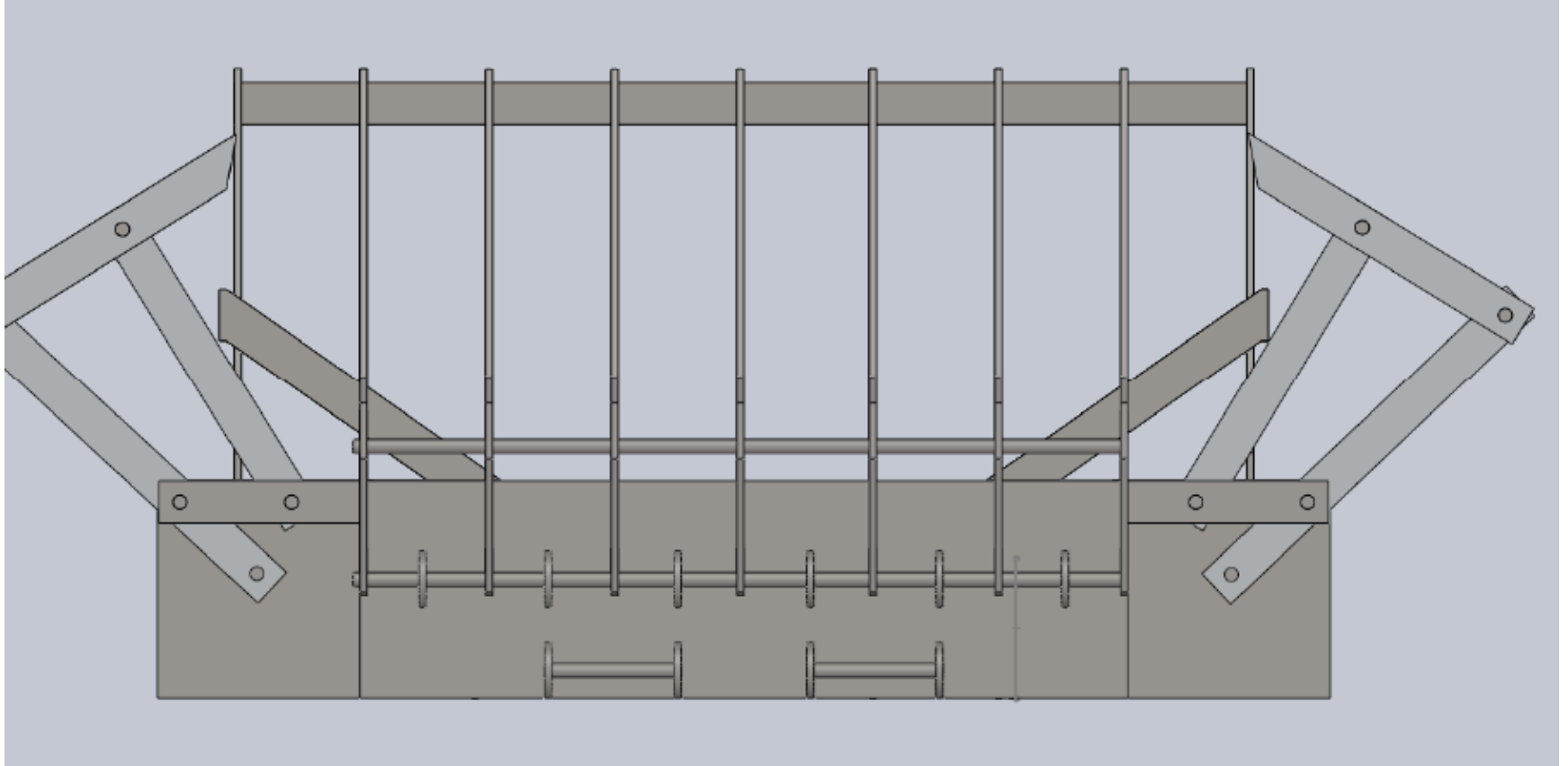
Grapple Concept



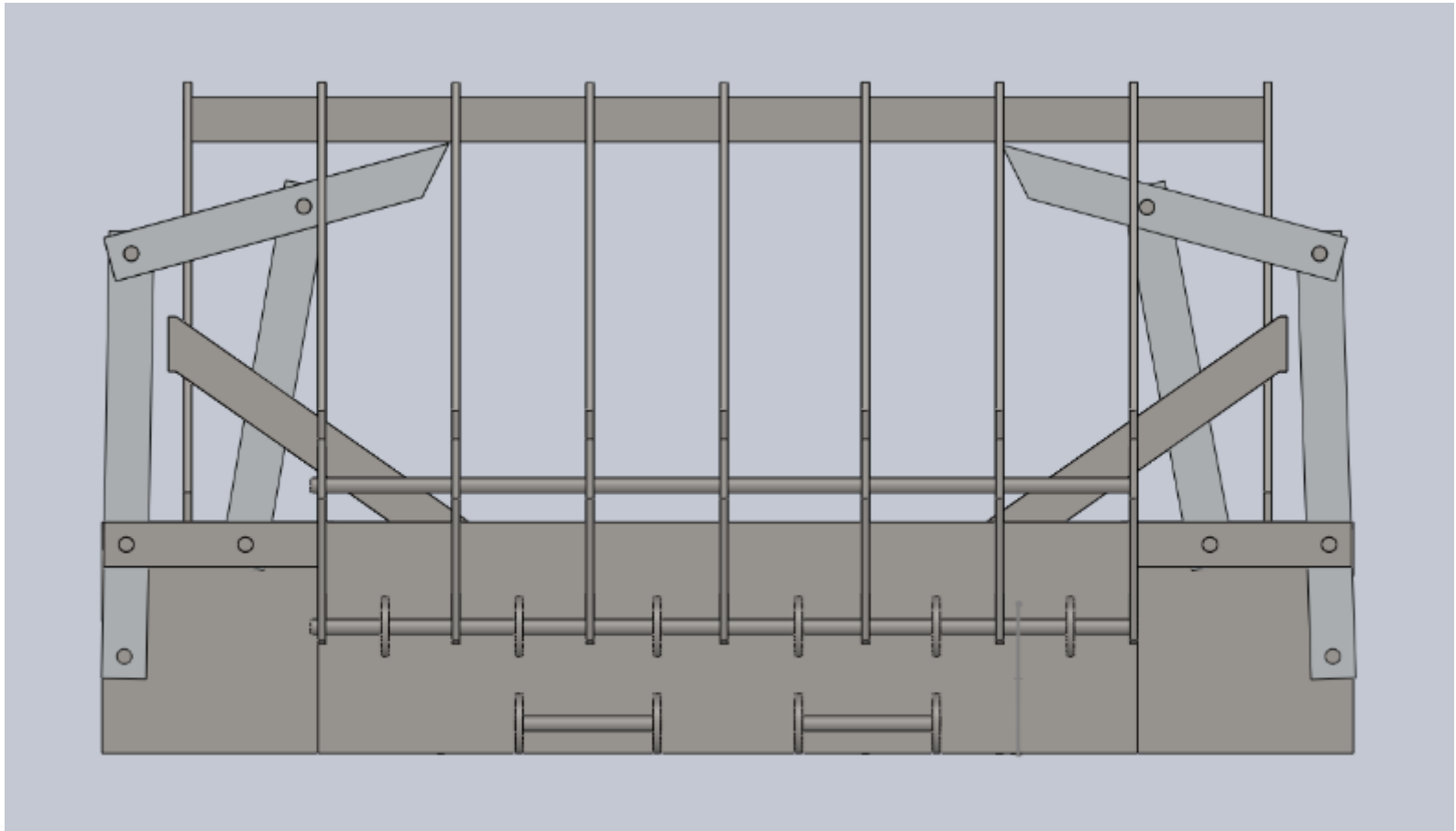
Current Design



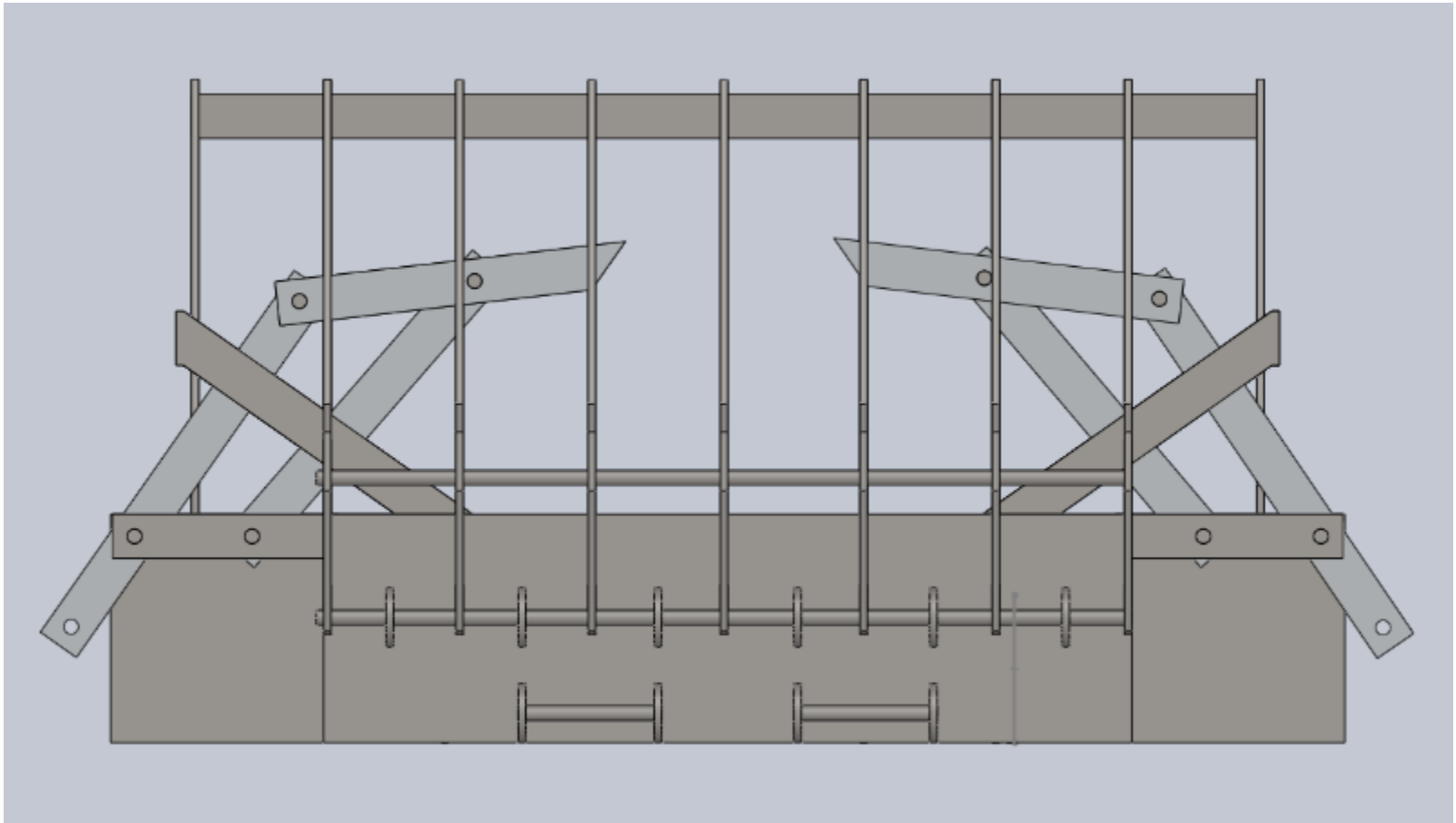
Top Open



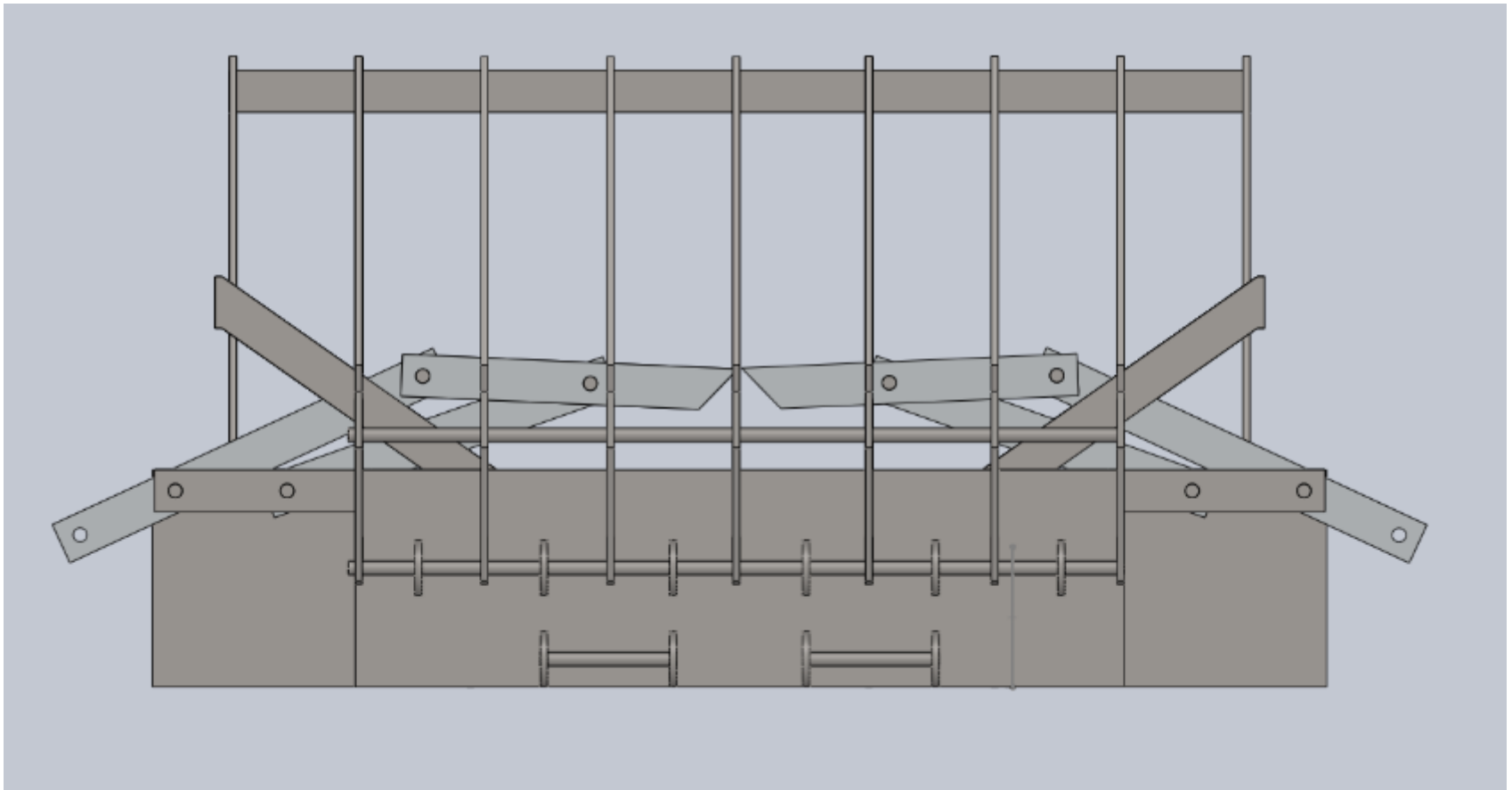
Top Partial Open



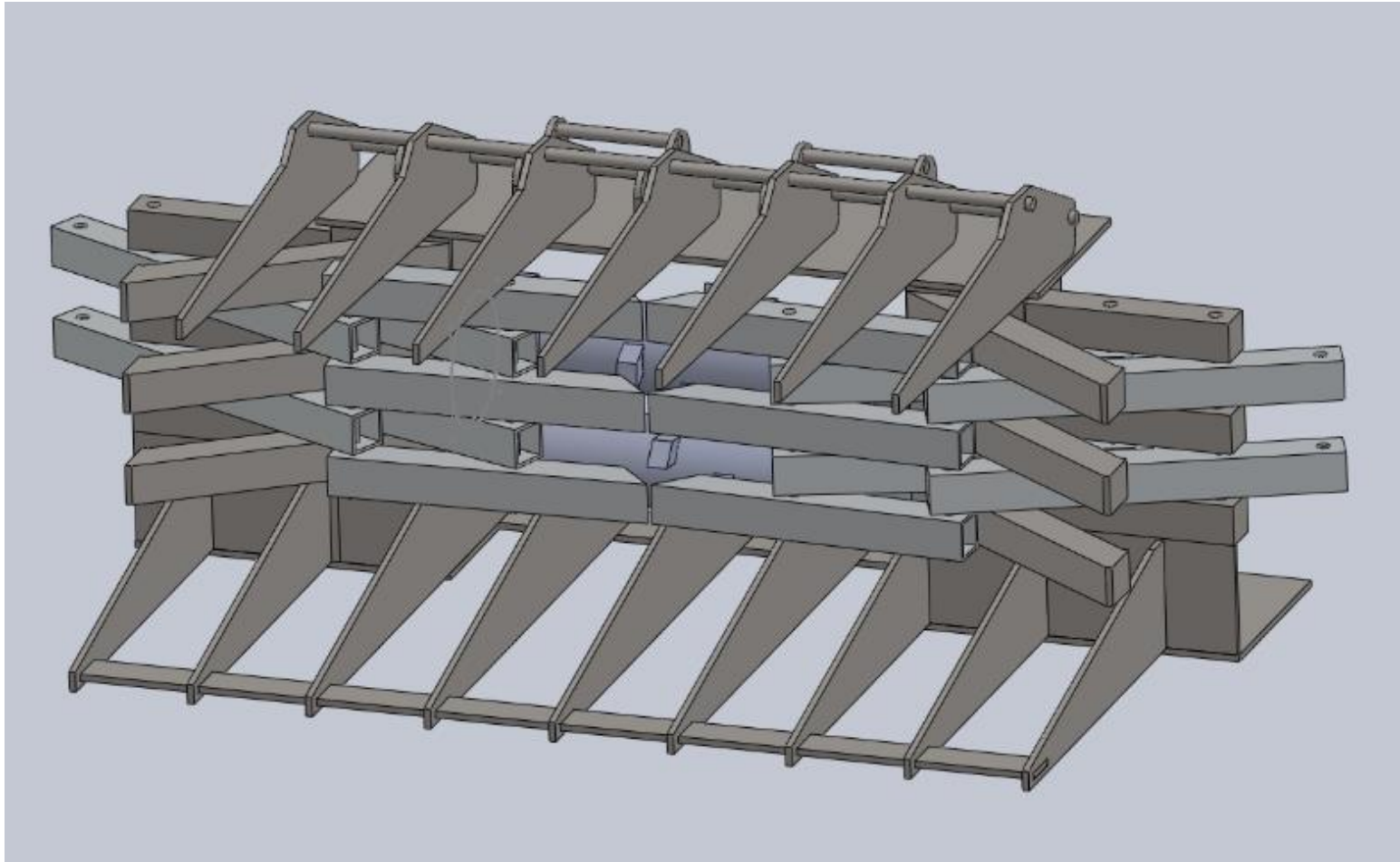
Top Partial Closed



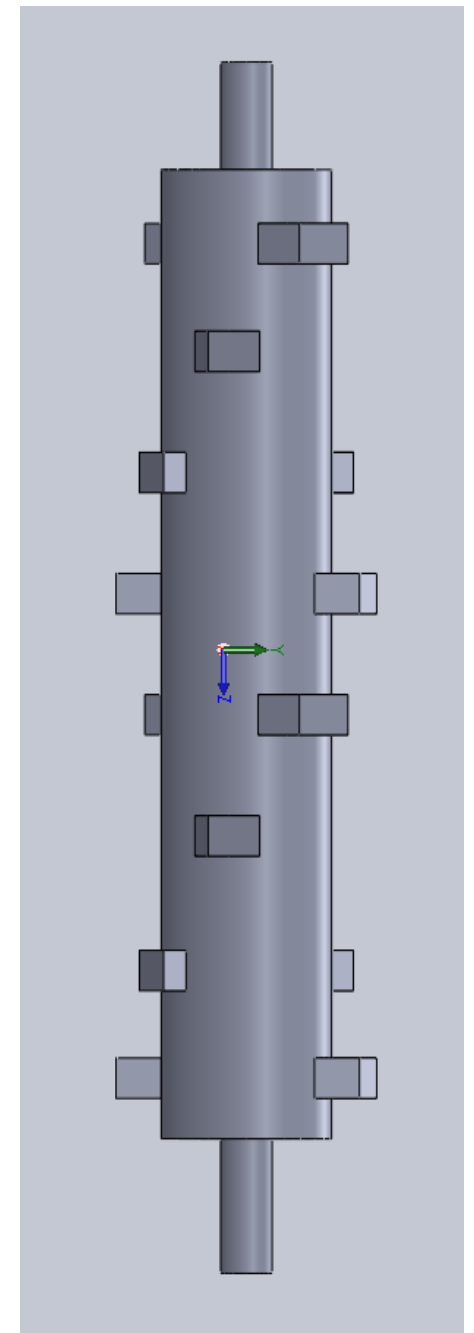
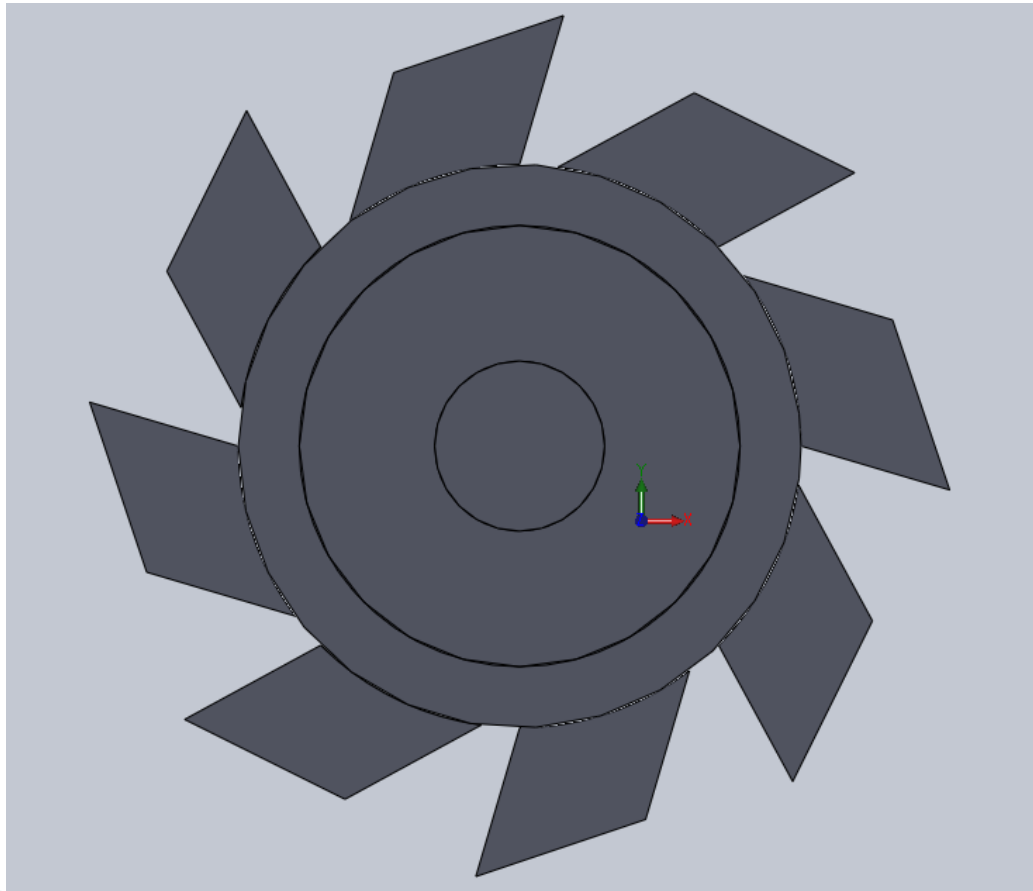
Top Closed



Angled-In Closed



Drums



Retrofit Cutterhead Blades



The drum and teeth are designed to be compatible with a retrofit of cutter blades similar to the ones shown here. The drum is designed without replaceable cutter blades initially to save cost.

Tubing vs. Plate in Thumb

piece	total length	adjusted length	length a	length b
finger	24	22.5	12	11.5
outside thumb	30	27	19.5	7.5
inside thumb	26	23		

(top profile matches top profile of respective tubing components)

half inch plate steel

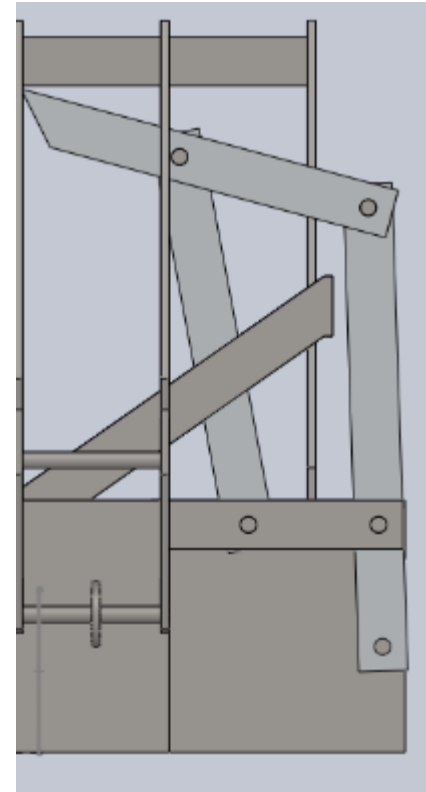
lx value 0.03125

ly value 1.125

piece	total length	adjusted length	length a	length b
finger	24	22.5	12	11.5
outside thumb	30	27	19.5	7.5
inside thumb	26	23		

Deflection Calculations

- ▶ Square tubing
 1. $I = 1/12(b_o h_o - b_i h_i^3)$
- ▶ Plate
 1. $I_x = 1/12(bh^3)$
 2. $I_y = 1/12(b^3h)$
- ▶ $V = (-Pba)(L^2 - b^2 - a^2) / 6EIL$



*Calculations based on worst scenario geometry

square tubing

2 in cylider		2.5 in cylider	
deflection (in)		deflection (in)	
steel	aluminum	steel	aluminum
0.041	0.077	0.064	0.182
0.034	0.097	0.053	0.151

plate steel

deflection (in)		deflection (in)	
x	y	x	y
2.445	0.068	3.820	0.106
2.746	0.076	4.291	0.119

- The risk of bending plate is approximately one and a half times higher than the tubing in the plane of motion
 - There is also a significant added risk of bending in the plane normal to the plane of motion

Weight Total

Weight Totals:				
	Plate (in ²)=	12438	Weight=	1762
	3"x3" (in)=	237		174
	2"square (in)	60		68
	2" rod (in)=	90		80
	1" rod (in)=	140		31
*sched 80	Drum=	2		172
	Motor=	1		150
	Cylinders=	3		60
	3x3 alum=	368		110
				2607

*pounds

Materials Cost

	price/unit	Total Price	
Plate (in ²)=	0.109	1762.4	
3"x3" (in)=	0.701	216.0	
2"square (in)=	1.09	85.0	
2" rod (in)=	0.854	99.9	
1" rod (in)=	0.199	36.2	
Drum=	20	52.0	
Motor=	1000	1000.0	
Cylinders=	139.99	420.0	
3x3 alum=	1.26	463.7	
plasma cuts	0.1	122.94	
welds	0.15	143.52	
all=	\$	4401.7	*30% Waste

Drive Equations

▶ *Goal 1000–1200 rpm*

▶ $R = \omega_1 / \omega_2 = N_2 / N_1$

▶ $R = T_2 / T_1$

$$R = 2:1 * 5:1 = 10:1 * 110 \text{ rpm}_{\text{motor}} = \mathbf{1100 \text{ rpm}}$$

$$R = 2 = 2120 \text{ ft*lbs} / T_2$$

$$T_2 = 1060 \text{ ft*lbs}$$

$$F_{5 \text{ inch pulley}} = T / D = 2540 \text{ lbs}$$

$$T_{\text{small pulley}} = F * D = 425 \text{ ft*lbs}$$

$$F_{\text{tooth}} = T / D = \mathbf{850 \text{ lb}_f}$$

*assuming 100% efficient,
will be fairly close

Cutter Head Speed

▶ $v = r * \omega$

▶ $r = 6 \text{ in}$

▶ $\omega = 1100 \text{ rpm}$

▶ $v = 6 \text{ in} * 1100 \text{ rpm} * \frac{1 \text{ ft}}{12 \text{ in}} * \frac{1 \text{ min}}{60 \text{ sec}}$

▶ $= 9.2 \text{ ft/sec}$

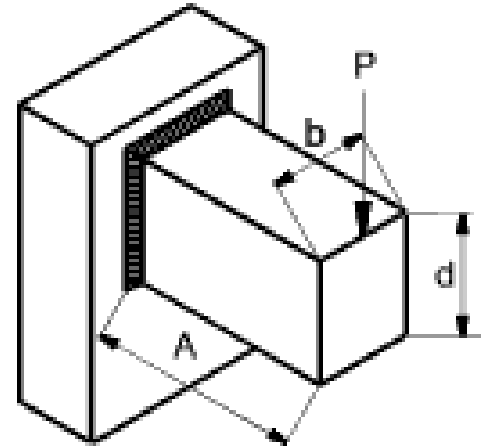
Weld Dimensioning

$$x = (b - 2h) * (d - 2h)^3$$

$$y = (b - 2h) * (d - 2h)$$

$$\sigma_b = \frac{6 * P * A * d}{b * d^3 - x}$$

$$\tau_s = \frac{P}{(b * d - y)}$$



- ▶ $\sigma_{\max} = 1700 \text{ psi}$ for $\frac{1}{4}$ inch weld
- ▶ $\tau_{\max} = 400 \text{ psi}$ for $\frac{1}{4}$ inch weld
- ▶ Tooth weld will be $\frac{1}{4}$ inch

Spring Testing Concerns

- ▶ Structural Strength of Grapple
 - Moving parts
- ▶ Operating RPM of the Drums
 - Speed
 - Torque
- ▶ Functionality
 - Mulching
 - Grappling
- ▶ Analysis of safety measures

Spring Task List



Future Plans

- ▶ Build Prototype
- ▶ Test Prototype
- ▶ Re-engineer Prototype
- ▶ Overall Cost Analysis

