Firebreaker Project

Final Capstone Project Presentation

Team #11

Team 11: #11 in Innovation

Team Lead
John (Jack) Daly

Chief Engineer
Jeffrey (JP) Mattox

Manufacturing Engineer
Christian Messner

Test Engineer
Aishwarya (Iris) Ledalla

Editor-in-Chief
William (Will) Kulus

Quality Control Manager
Saim Hasan

The Team

Figure 1: Team 11 Together

Figure 2: Prototype

Issue and Problem Statement

Societal Issue: Affordable and effective solution to contain wildfires

Problem Statement: *Design a tool/device such that firefighters can reliably and quickly clear flammable material from the ground to support creation of fire control lines in a grasslands environment and fabricate a prototype to validate the design project.*

Figure 3: Firefighters Creating Control Line via Hand Tools

1.1: Miller, C. (2019). Wildfire Academy [Digital image]. Retrieved December 4, 2020, from https://www.peterson.spaceforce.mil/News/Article/327933/local-training-teams-cheyenne-mountain

Basic Physics

Important Properties: **Soil Cohesion** and **Internal Angle of Friction**, from Coulomb-Mohr theory [1].

- These values are tabulated for various types of soil
- Used to calculate what is essentially the “ultimate strength” of the soil

Effect of grass roots calculated using a conservative approximation [2]

- Increases effective soil “ultimate strength”, by up to 150%

Can calculate force required to clear the ground using what is essentially **F = σA** with the draft force equation.

- σ is the “ultimate strength” of the ground, named the soil cohesion
- A is the cutting face area
- F is required force to displace soil and cut grass roots

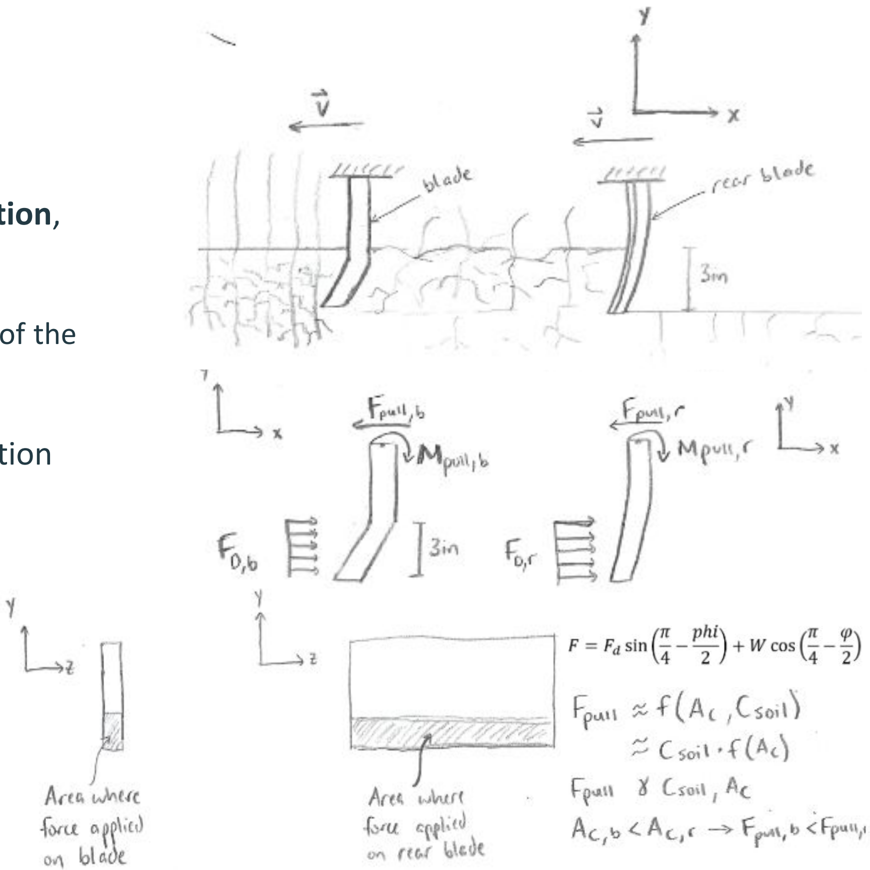


Figure 4: Simple Physics Calculations

[1] Ahmadi, 2016. Development and Evaluation of a Draft Force Calculator for Moldboard Plow Using the Laws of Classical Mechanics

[2] Wu, 1976. Investigation of Landslides on Prince of Wales Island, Alaska. P. 65-68

Production Product Requirements Validation Matrix

Table 1: Requirements and Validation Matrix

Category	Requirement	Status
Area Cleared	>6000 ft^2/hr	Validated in Testing
Width of Control Line	≥3 ft	Met by Design
Depth of Control Line	≥3 in	Validated in Testing
Adjustability	≥3 in into ground +/- 20° rotation	Met by Design
Life Cycles	Structure: 10^4 cycles	Validated by Analysis
Size of Device	≥3 ft, ≤ 10 ft long	Met by Design
Transportability	Blade can be raised >6 in from the ground	Met by Design and Validated in Testing
Factor of Safety	$F_{sy} > 1.5$	Validated by Analysis
Attach to Cat.1 Tractor 3-Point Hitch	3 Pin Connections w/ Cat. 1 dimensions	Met by Design
Number of Operators	1	Validated in Testing

QFD Analysis

After interviewing a firefighter from Walker Fire Department, these qualities were most important:

- Clearing vegetation quickly
  - Firefighters had 12+ hour days
- Ability to transport control line tool to location
  - Focus on grasslands environment

Project:	Team 11: Firebreaker
Date:	9/29/2020
Team Members:	William Kulus, John Daly, Aishwarya Ledalla, Christian Messner, Saim Hasan, Jeffrey Mattox

Relative Weight	Customer Importance	Customer Needs	Area Cleared Per Hour	Sufficient Power to Cut Shrubs and Grass	Mechanism Position and Angle Adjustable	Number of Required Operators	Number of Mechanism Life Cycles	Number of Hazard Points	Size and Weight of Device	Number of Components	Production Cost	Must be Transportable in Non-Operational State
14%	10	Clears Fuel Quickly from Ground	•	○								
13%	9	Few Operators				•						
11%	8	Operable in Differing Terrain Conditions		○	•				▽			
9%	6	Maneuverable	▽		▽				○			▽
13%	9	Durable					•					
7%	5	Ease of Operation				▽			○			▽
6%	4	Good Maintainability					○			•		
10%	7	Transportable							○			•
14%	10	User Safety				▽		•				
3%	2	Affordable							▽	▽	•	
	70	Engineering Requirements Target Values	> 6,000 ft2/hr	> 15 hp delivered to blades	+/- 10 degrees of angle, +/- 3 in	1 Required Operator	100 Miles of Operation	0 Significant Hazard Points	3 Feet Wide, Less than 10 Feet in Length	< 100	< $600	At least 12" ground clearance
		Importance Rating Sum (Importance x Relationship)	137	77	111	137	133	129	91	54	26	106
		Relative Weight	14%	8%	11%	14%	13%	13%	9%	5%	3%	11%

Correlations	
Strong	+
Weak	-
No Correlation	

Relationships		Weight
Strong	•	9
Medium	○	3
Weak	▽	1

GOAL FUNCTION: MAXIMIZE AREA CLEARED PER HOUR

Figure 5: House of Quality Matrix

Phase 2 Final Conceptual Design

- Attachment for a compact tractor
- Rotary cultivators cut up ground underneath
- Rake at rear to displace and scrape away soil
- Hydraulic piston to adjust mechanism

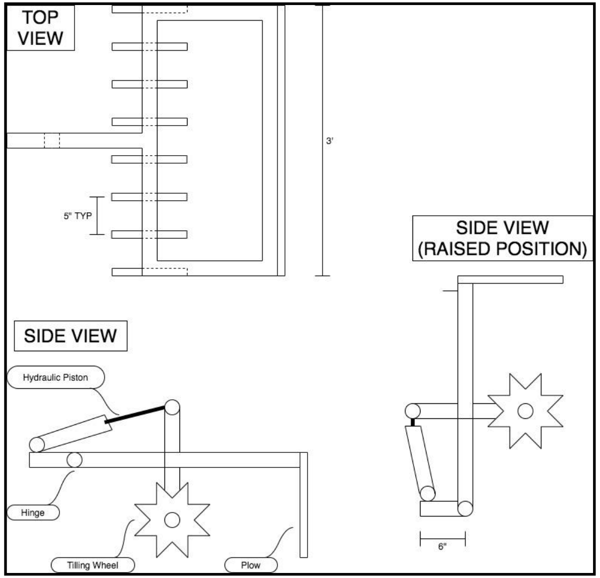


Figure 6: Schematic of Conceptual Design

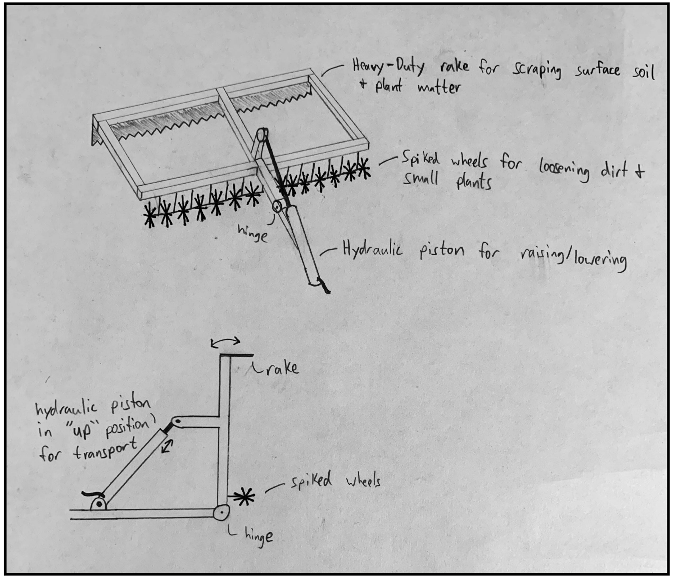


Figure 7: Sketch of Conceptual Design

Production Product CAD Model Rev 3

- RMS and FMEA (Failure Modes and Effects Analysis)

- Reliability Analysis (at 1000 Miles - 10^5 cycles)
  - Frame subsystem = 88.8%
  - With redundancies in fasteners = 99.2%
- Maintainability Analysis
  - Mean time to repair = 20 minutes
  - Mean cost to repair = $3.63/mile
  - Rear blade and ripper shanks need regular replacement cutting edges
  - System health can be monitored by a direct relationship with the performance
- Safety Analysis
  - Follows Organization for Economic Co-operation and Development (OECD) codes pertaining to tractors
  - Hazard Safety Warnings and Labels

- FMEA Analyses conducted at each interface:
  - Blade & Structure
  - Ripper Shanks & Structure
  - 3 point Hitch
  - Hydraulics

  - The high RPN items were found in the Rear Blade and Structure interface
    - Static and fatigue failure of fasteners
    - Weathering failure of rear blade

Production Product CAD Model Rev 3

- Sample FMEA

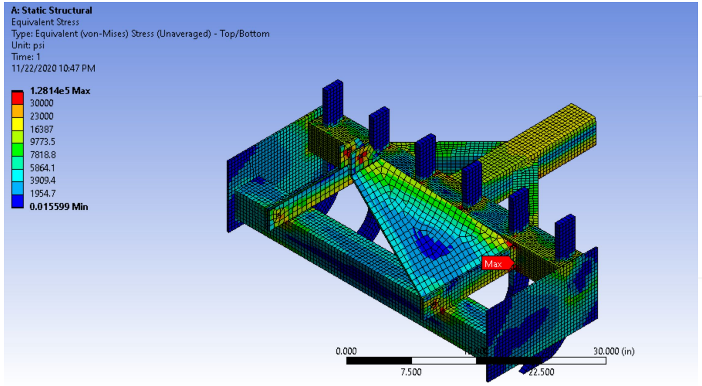


Figure 8: FEA Analysis of CAD Rev 3

Find No.	Part Name	Function	Potential Failure Mode	Potential Failure Effect	SEV	Potential Causes/Mechanisms of Failure	OCC	Current Design Controls	DET	RPN	Recommended Actions/Responsibility/Target Completion	pS	pO	pD	rpn
1	Plow Blade	Clearing separated dirt and plant matter	Static Failure	Loss of Ability to remove all plant matter	8	Insufficient design/support, tougher than expected soil, stresses caused by rocks/roots	4	Product strength analyzed, environment chosen to mitigate hazards	8	256	Specify testing plans to ensure that any defects in the plow blade will be identified and remedied. This should be completed by John Daly by 11/25/2020	8	3	3	72
2	Plow Blade	Clearing separated dirt and plant matter	Fatigue Failure	Loss of Ability to remove all plant matter	8	Insufficient design for expected fluctuating stresses	4	Static strength checked for operation in well defined environment	9	288	Complete fatigue analysis, define acceptable operating loads and ensure they do not exceed the endurance strength of the plow blade. Additionally, determine whether a COTS part is going to be used or whether we will make our own. This will define the extent of testing and designing required. This analysis should be completed before 11/25/2020.	8	3	3	72
3	Plow Blade	Clearing separated dirt and plant matter	Weathering Failure	Gradual loss of ability to remove all plant matter	6	Extended operation in conditions that are harsher than anticipated	6	Environment chosen to mitigate hazards	10	360	Gain understanding of the process of plow blade wear. If COTS blade, identify the expected life of the part and prepare appropriate documentation to ensure the customer does not attempt to exceed that life. If a designed blade, determine how to test the amount of wear with use, design accordingly, and make the customer aware of the issue.	6	4	3	72
4	Plow Blade Attachment	Interfacing plow blade with structure	Static Failure -- structure or fasteners	Immediate loss of ability to remove plant matter	8	Insufficient design/analysis, operation in exceedingly harsh conditions	5	Environment chosen to mitigate hazards	10	400	Finish design of plow blade attachment interface, analyze design to determine stress, determine appropriate testing plan during manufacture. Testing plans and static strength should be determined before 11/25/2020	8	3	3	72
5	Plow Blade Attachment	Interfacing plow blade with structure	Fatigue Failure -- structure or fasteners	Gradual loss of ability to secure blade, followed by immediate loss of functionality	7	Insufficient design/analysis, lack of redundancy, operation for longer than designed time	6	None	10	420	Finish design of plow blade attachment, select and analyze fasteners in fatigue, clearly define expected operational life, determine appropriate testing plan to confirm. Design, analysis of fasteners should be completed before 11/25/2020	7	3	1	21

Figure 9: FMEA of Rear Blade and Attachments Interface

Production Product CAD Model Rev 3

- DFMA and DTC

- DFMA Analysis
  - Focused on ensuring manufacturability of our product.
  - Multifunctional: middle beam houses ripper shanks, rear plow attachment, and the 3 point hitch (bottom of Figure)
  - Multifunctional: The 3 point hitch panels act as the implement mount, and hold both horizontal beams and vertical beam together (top of Figure)

- DTC Analysis
  - Reduce costs through material selection
  - Not cut corners with important parts and procedures like pins, fasteners, and welding.

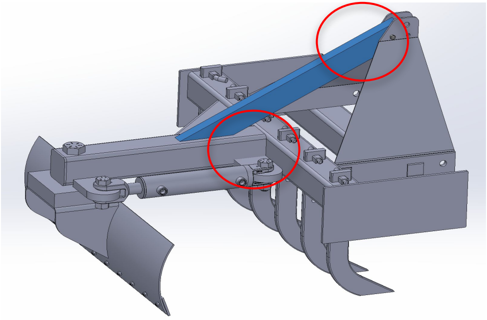


Figure 10: CAD Rev 3 DFMA Example

Table 2: Table of Design Aspect Costs

Aspect of Design	Cost
Frame (tubing, plates, three-point hitch, etc)	$1392.03
Hydraulic Cylinder	$129.99
Ripper Blades	$138.00
Pins for the Ripper Blades	$21.72
Rear Blade Mechanism	$322.99
Welding and Assembly	$200.00

Total Unit Cost: $2,204.00

Production Product CAD Model Rev 3

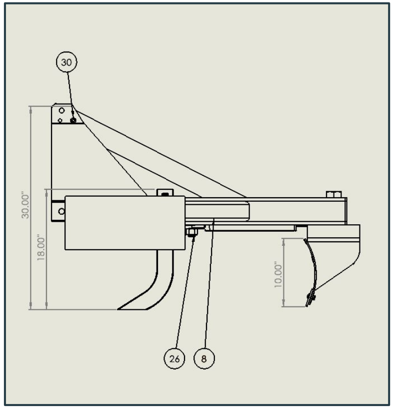


Figure 11: CAD Rev 3 Side View

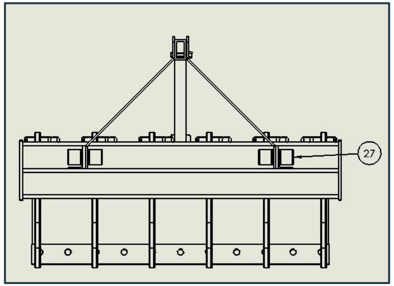


Figure 12: CAD Rev 3 Front View

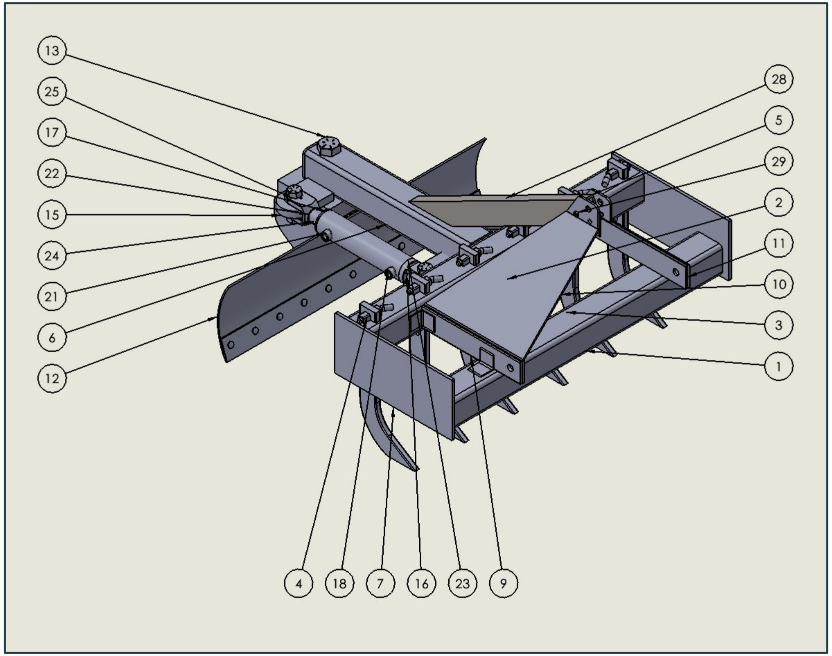


Figure 13: CAD Rev 3 Isometric View

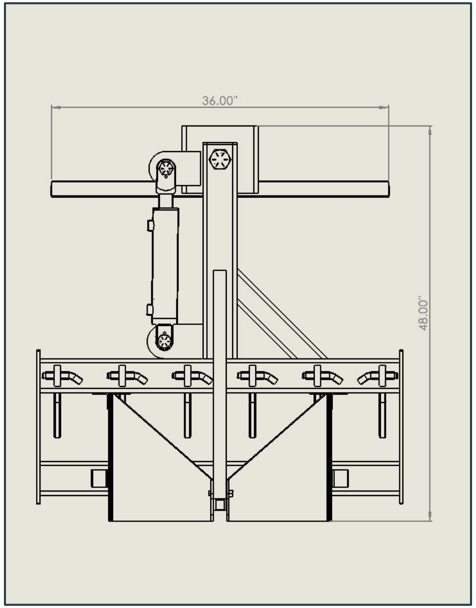


Figure 14: CAD Rev 3 Top View

Engineering Prototype Scope and Requirements

- Focus on essential functionality - removing top three inches of soil
- Use truck instead of tractor
- Scaled down to create 3 inch deep, 1 foot wide control line

Table 4: Prototype Scope and Requirements

Engineering Requirement		**Validation Method**	**Status**
Area Cleared	300 ft^2/hr per HP or 3000 ft^2/hr	**Test**	Pending
Adjustability -- All Blades	Blades >=3 in. into ground	**Test**	Pending
Configurations -- Ripper Shanks	Prototype will have at least two ripper shank configurations to support testing data collection	**Design/Test**	Pending
Adjustability -- Rear Blade	Normal vector of rear blade up to 24 degrees from path direction	**Design/Test**	Pending
Control Line Width (= max width of system)	>= 1 ft wide	**Test**	Pending
Length	<= 6 ft long (Standard truck bed is 6'5" long)	Design	Demonstration
Transportability	Able to relocate prototype by hand (i.e. without truck/tractor) without blades contacting ground	**Demonstration**	Pending
Static Factor of Safety	Fsy > 1.5	Analysis	Confirmed Via Analysis
Attach to & Powered by Truck	Attach to standard hitch (likely 2" square), pulled by Truck	**Design/Test**	Pending
Number operators	1	**Test**	Pending
Budget	<= $600	Design	Demonstration

Final Prototype Solid Model

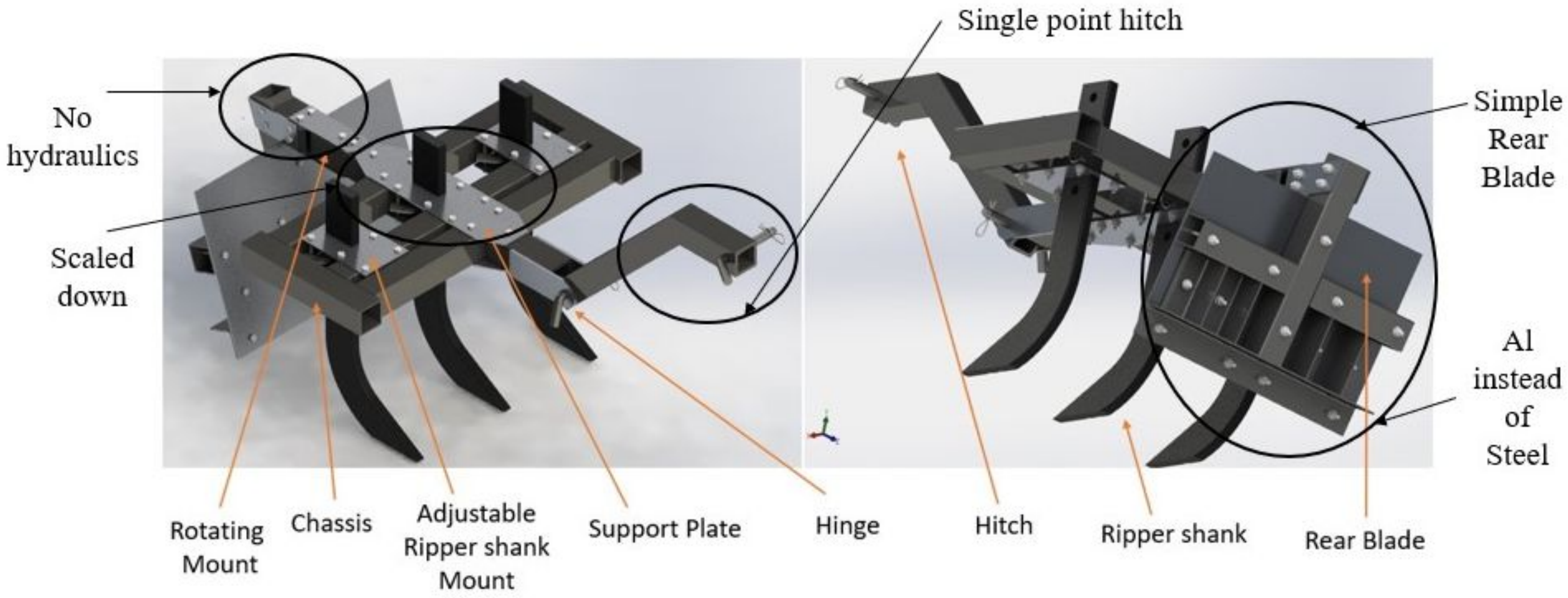


Figure 15: CAD Model of Prototype (ISO)

Figure 16: CAD Model of Prototype (Rear)

Exploded View of Prototype CAD

Figure 17: Ripper Shank Mount

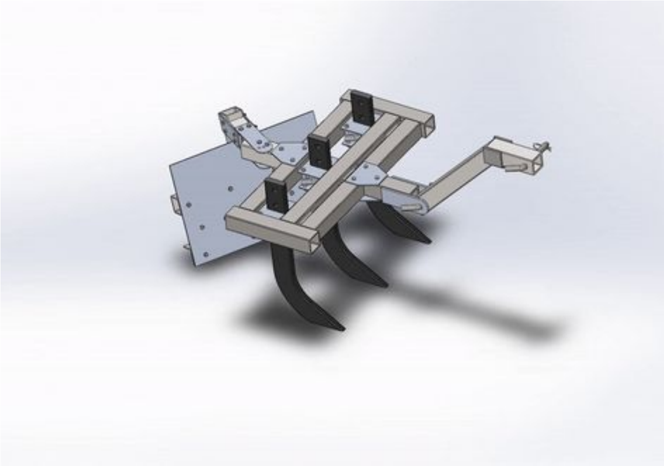


Figure 18: Total Assembly

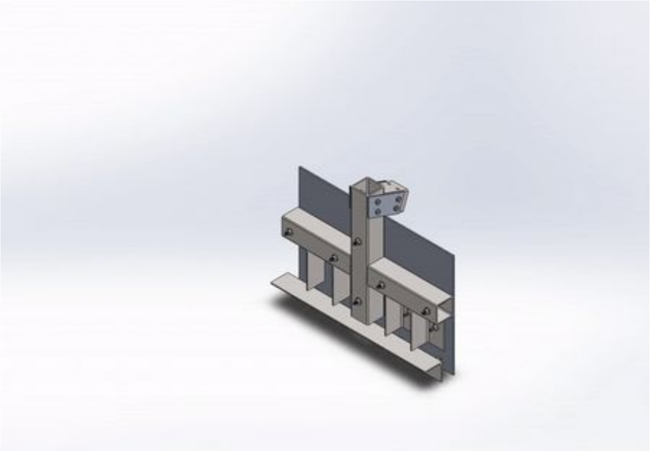


Figure 19: Rear Blade

BOM of Prototype

Table 5: Prototype Bill of Materials

Description	Material Specs	Total Price	Vendor
0.125" Aluminum Sheet	0.125" Al 6061 T6 sheet	$40.31	MetalSup
0.125” Aluminum Flat Bar	Al 6061 T6 22” x 2” Bar	$6.34	MetalSup
0.125” Aluminum Flat Bar	Al 6061 T6 55” x 4” Bar	$24.53	MetalSup
0.120” Aluminum Rectangular Tube	Al 6061 T6 3” x 1” Tube	$8.92	MetalSup
Steel Angle Stock	2" x 2" x 0.125" A36 angle stock	$13.65	MetalSup
0.120" Steel Square Tube	2" x 2" x 0.120" A500 HSS square tubing	$78.72	MetalSup
¼” - 20 x 2.75" Bolt	Grade 5 Steel	$10.50	Bolt Depot
¼” - 20 x 1” Bolt	Grade 5 Steel	$2.20	Bolt Depot
Washers	Grade 5 Steel	$3.22	Bolt Depot
Nuts	Grade 5 Steel	$2.10	Bolt Depot
0.25" Low Carbon Steel Square Tube	2" x 2" x 0.25" low carbon steel square tube	$36.56	MetalSup
0.25" Low Carbon Steel Sheet	0.25" low carbon steel sheet	$20.15	MetalSup
Hitch Pin	Hitch Pin, Steel, 1038 and 4140, Zinc, 5/8 in Pin Dia.	$8.38	McMaster
Ripper shank	Replacement 18" - 4 Hole Box Blade Shank	$122.65	Heavy Hitch
Ripper Shank Retention Pin	Ripper Shank Retention Pin	$12.00	McMaster
Welding Rods	Steel Welding Rods	$35.61	Home Depot
Bolt Spacers	Steel Spacers	$22.86	McMaster
	TOTAL (+ $19.71 Tax)	**$481.81**	

FMEA Prototype Analysis

FMEA Analyses conducted at each interface:

- Blade & Structure
- Ripper Shanks & Structure
- Single - Point Hitch

Similar to our production unit FMEA and helped us simply the various interfaces between components in our prototype

Problem Solving Example

- During testing, rear blade not in contact with the ground.
  - Caused by the force from the ground on the ripper shanks
- Prevented the topsoil from being scraped out of the way
- Added weight (200lb) to the blade to counteract the moment
- The blade contacted the ground and scraped away the topsoil

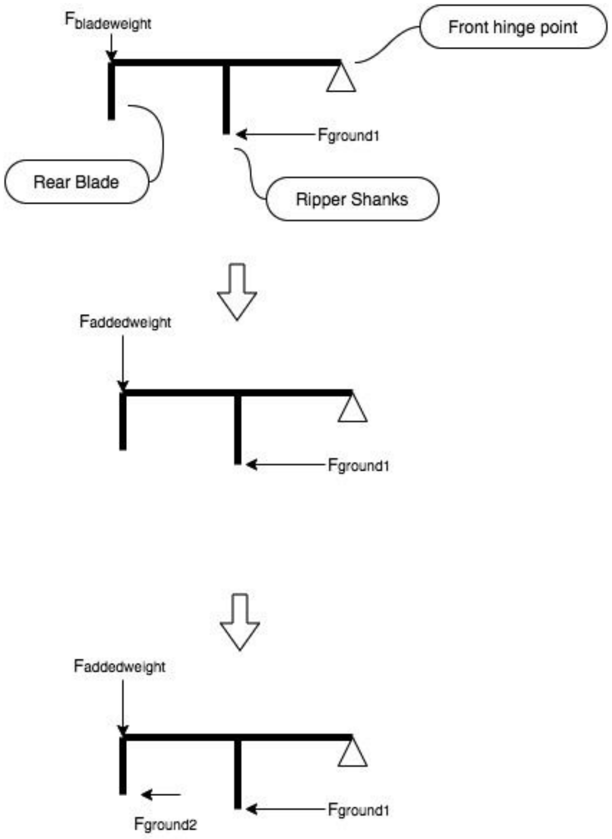


Figure 20: Simplified Force Diagram

Fabrication and Assembly

- We worked as a team to assemble our prototype, along with the ASU machine shop
- To the right, Will is preparing the steel for welding, below JP is welding the chassis

Figure 21: Welding of Chassis

Figure 22: Preparation of Material for Welding

Development

Development Tests:

- Hitch Attachment Test
- Ripper Shank Subassembly Test
- Rear Blade Rotation Test
- Transportation Test
- <u>*Configurations Test*</u>

Rework:

- Keeping prototype in ground
  - Simple, effective solution

Figure 23: Initial Ground Condition

Figure 24: Control Line Created

Figure 25: Weighted Prototype

Validation

All Requirements Validated from Development Testing

Table 6: Prototype Requirements Validation Matrix

Engineering Requirement		Validation Method	Status
Area Cleared	300 ft^2/hr per HP or 3000 ft^2/hr	**Test -- *6045 ft^2/hr***	**Validated (Test Run 11)**
Adjustability -- All Blades	Blades >=3 in. into ground avg.	**Test -- *3.25 avg***	**Validated (Test Run 11)**
Configurations -- Ripper Shanks	Prototype will have at least two ripper shank configurations to support testing data collection	**Design/Test**	**Validated (Ripper Shank Subassembly Test)**
Adjustability -- Rear Blade	Normal vector of rear blade up to 24 degrees from path direction	**Design/Test**	**Validated (Rear Blade Rotation Test)**
Control Line Width (= max width of system)	>= 1 ft wide minimum.	**Test -- *13" (1.083 ft) min.***	**Validated (Test Run 11)**
Length	<= 6 ft long (Standard truck bed is 6'5" long)	Design	Demonstration
Transportability	Able to relocate prototype by hand (i.e. without truck/tractor) without blades contacting ground	**Demonstration**	**Validated During Assembly**
Static Factor of Safety	Fsy > 1.5	Analysis	Confirmed Via Analysis
Attach to & Powered by Truck	Attach to standard hitch (likely 2" square), pulled by Truck	**Design/Test**	**Validated (Hitch Assembly Tes, Test Run 11)**
Number operators	1	**Test**	**Validated (All Test Runs)**
Budget	<= $600	Design	Demonstration

Example Testing with Analysis

Configurations Test

Instrumentation and Equipment Used:

- Instrumentation: Strain gauges, Arduino amplifier circuit, smartphones
- Equipment: Truck, spray paint, wrenches, tape measure

Data Collected:

- Plant removal (100% for all weighted, 3 ripper shank configuration test runs)
- Control line shape
- Structural loading data

Table 7: Configuration Test Procedure

Step	Action	Complete?
1.	Transport test article safely to test site in bed of pickup truck.	
2.	Ensure test article shows no obvious signs of wear/structural degradation that would compromise ability to safely perform test	
3.	Ensure testing environment flat, dry, and that grasses present	
4.	Qualitatively characterize hardness of soil. Note whether the testing environment represents “best-case” or “worst-case” operating conditions	
5.	Configure the test article into the prototype configuration to be tested	
6.	Mount the test article to the test rig	
7.	SKIP IF NO INSTRUMENTATION: Ensure microcontroller, Bluetooth serial module, amplifier, and battery pack securely mounted to test article in predetermined location	
8.	SKIP IF NO INSTRUMENTATION: Inspect circuit connecting strain gauge to power supply and amplifier, and Arduino to power supply, Bluetooth serial module, and amplifier. Confirm no visible disconnects.	
9.	Determine control line path for test run. Ensure all team members know where the path lies.	
10.	SKIP IF CONFIGURATION 0: Pick three locations along control line path. Using spray paint and a cardboard sheet with a slit cut through it, spray paint three lines on the grass spanning the width of the anticipated control line.	
11.	SKIP IF CONFIGURATION 0: For each of the three spray-painted lines on the grass, count the number of small plants with spray paint on them. This is crucial to ensuring quantifiable data can be obtained. If there is a high density of plants, use all team members available to count plants at the different locations. Record observations in the datasheet.	
12.	Position two team members alongside prototype with a minimum of 8-foot distance from fire control line path, wearing appropriate eye protection, to observe test.	
13.	SKIP IF NO INSTRUMENTATION: Power on microcontroller, laptop computer for data collection. Confirm serial readings received by laptop.	
14.	Ensure slow motion video being recorded from each team member’s vantage point.	
15.	Check the Test Run Entry Checklist, confirm all necessary steps have been taken. Once confirmed, test may begin.	
16.	Team member outside car give member in front of truck the “go” command, test begins.	
17.	Prototype pulled about 20 feet at no more than 5 mph, preferably as slow as possible.	
18.	Upon completing test, immediately save recorded video, strain gauge data.	
19.	Power off truck. Confirm no damage to truck hitch.	
20.	Inspect prototype for structural damage. If structural damage identified, discuss ramifications & assess safety of continuing testing.	
21.	SKIP IF CONFIGURATION 0: Inspect control line path. Count the number of grass blades with spray paint on them remaining in the control line path. If necessary, make a distinction between uprooted and lying on path or completely unmoved by prototype.	
22.	Complete Test Run Exit Checklist, ensure all appropriate actions have been taken.	
23.	Repeat steps 7-20 for all configurations. If necessary, repeat steps for same configuration to record additional data.	

Example Testing with Analysis

Configurations Test

Data Collected:

- Control line characteristics (bottom)
- Strain gauge data (right)
  - Maximum measured draft force of *338 ± 30* lbf
  - Below what we anticipated

Table 8: Control Line Size Data

Validation Configuration -- 3 Ripper Shanks							
Test Run 11	***Location 1***	***Location 2***	***Location 3***	***Location 4***		***Mean Val.***	***+/- Conf. Int.***
Depth (in)	3.75	4.00	2.50	2.75	*(in)*	**3.25**	**0.87**
Width (in)	13.00	14.00	13.50		*(in)*	**13.50**	**0.84**
Plant Removal (%)	100.00	100.00	100.00		*(%)*	**100.00**	**0.00**
Test Alternate Configuration -- 2 Ripper Shanks							
Test Runs 12 & 13	***Location 1***	***Location 2***	***Location 3***	***Location 4***		***Mean Val.***	***+/- Conf. Int.***
Depth (in)	2.50	3.00	2.00	2.50	*(in)*	**2.50**	**0.48**
Width (in)	13.00	12.00	11.00	12.00	*(in)*	**12.00**	**0.96**
Plant Removal (%)	68.18	65.00	81.48		*(%)*	**71.55**	**14.74**

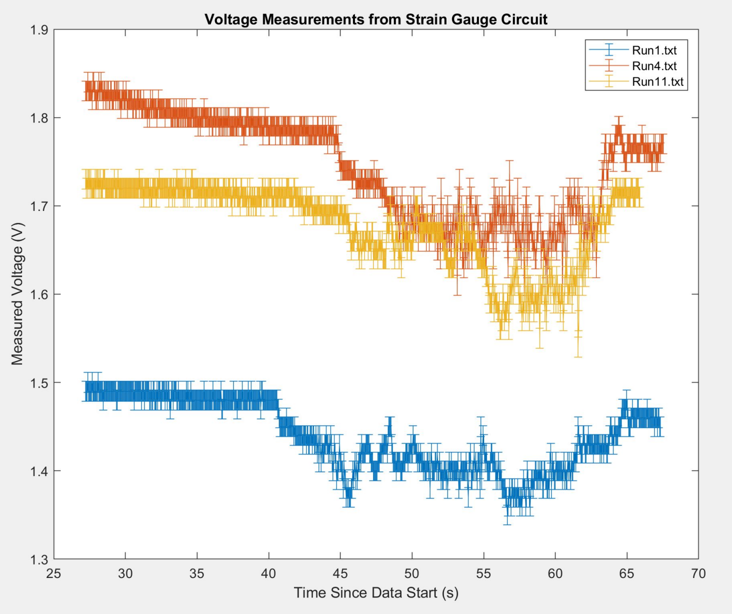


Figure 26: Voltage Data During Runs from Strain Gauges

Final Prototype Performance

Prototype Performed Well

- Effective Testbed for Different Configurations
- No structural damage
- Effectively created fire control lines

Table 9: Prototype Performance

Requirement	Minimum Acceptable Value	Actual Value	Req. Met?
Area Cleared (ft^2/hr)	3000	5940	Yes
Control Line Min. Width (in)	12	13	Yes
Control Line Avg. Depth (in)	3	3.25	Yes
Plant Removal (%)	85	100	Yes

Final Production Firebreaker Model

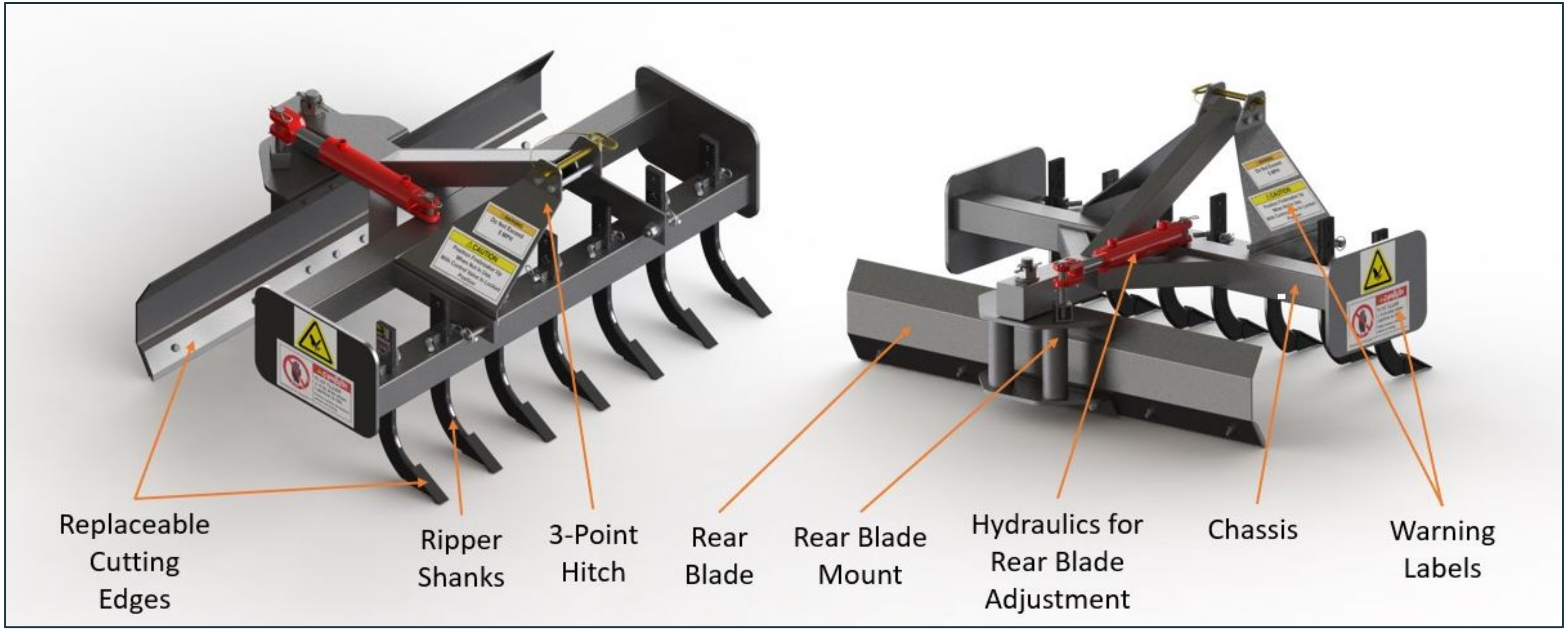


Figure 27: Final Labeled Firebreaker

Compact Tractor 3-Point Hitch

Figure 28: 3-Point Tractor Hitch

Commercialization (Goldsmith Model)

- Unit Price: $3499.99
- Contract with Fire agency for 200 production units
- Production fabrication and facility acquisition

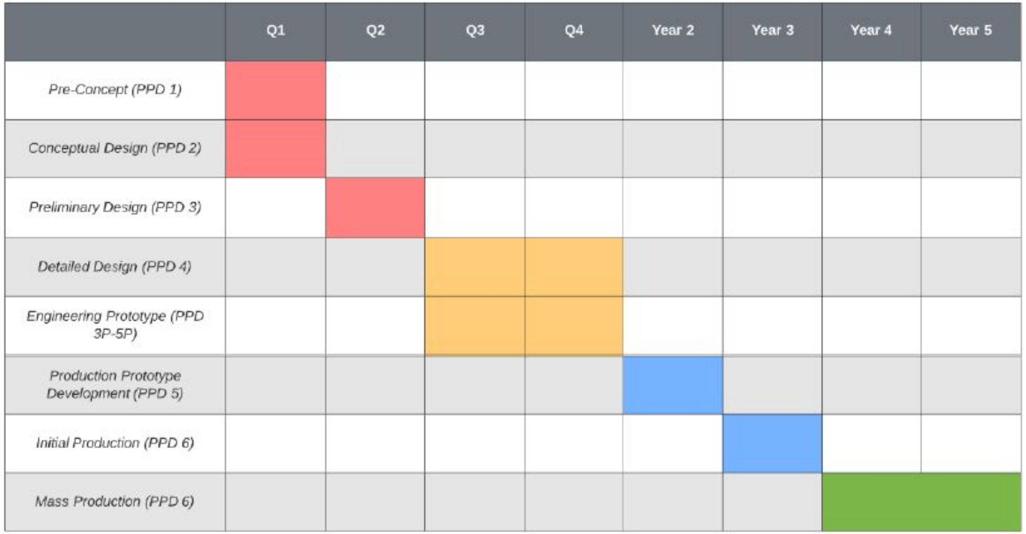
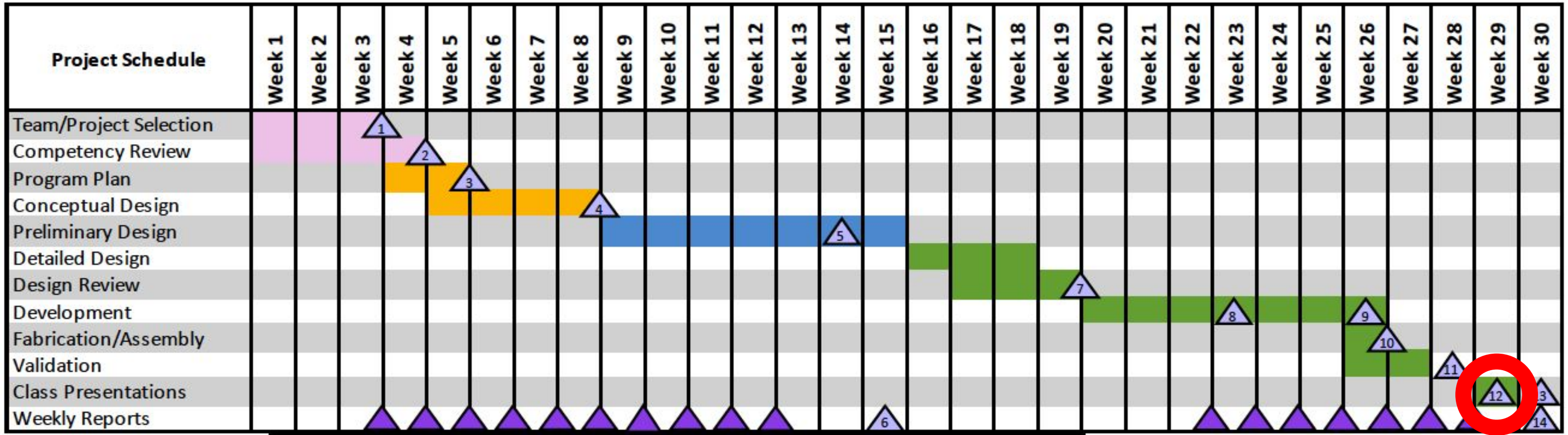


Figure 29: PPD Gantt Chart

Project Schedule with Key Milestones



Phase 1
Phase 2
Phase 3
Phase 4

Milestones:

1: Team Project Checklist
2: Competency Exam
3: Program Plan
4: Conceputal Design Review
5: Preliminary Design Review
6: Notebook and Final Report Chapters
7: Detailed Design Review
8: Progress Check 1
9: Progress Check 2
10: First Article Inspection
11: Phase 5 Exit Review
12: Final Report Due
13: ABET Assessment Fair
14: Project Notebooks Due

Figure 30: Project Schedule

Labor Chart Budget Line

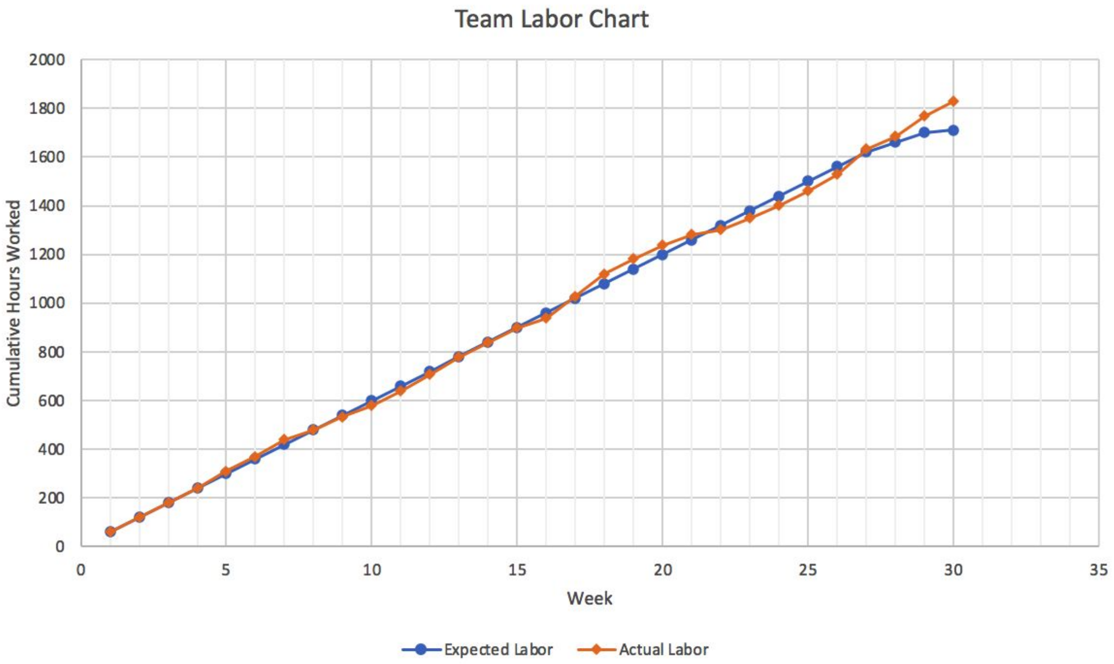


Figure 31: Labor Budget Chart

Team Performance

- Got behind schedule for prototype, then caught back up quickly
- Well under financial budget
- Slightly over labor budget
- Team worked well together

ABET Outcomes

Table 10: ABET Criteria Outcomes

ABET Criterion Outcome	Target Level of Mastery	Example from Report
1) An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.	Analysis	6.6 - Analyses
2) An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.	Analysis	3.1 - PPD Process (include IPDS process graphic)
3) An ability to communicate effectively with a range of audiences.	Application	3.2.5 - Lessons Learned
4) An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.	Comprehension, Application	1 - Introduction, 1.5 - Societal Impact, 1.6 - Applicable Contemporary Engineering Issues
5) An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.	Application	14.2 - Project Performance
6) An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.	Analysis	12.2 - Test Results
7) An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.	Application	9.5 - Example of Test Rig Drawing

Top Lessons Learned

- Proper time management throughout the engineering design process
- Benefits of creating a prototype that can be easily modified when issues arise
- Importance of data acquisition/ calibration/ processing
- Using engineering assumptions to make the testing process more efficient
- Consulting manufacturers and our sponsor for guidance

Summary

- Collaborated as an engineering team to solve a major societal need
- Analyzed and created a conceptual CAD design
- Successfully engineered a prototype to validate our production unit
- Arrived at a final production unit design
- Completed our Capstone project meeting all ABET requirements

Figure 32: Final Prototype

Acknowledgements

- **Dr. Shuaib** and **Dr. Trimble** helped us throughout Capstone
- TAs **Sibo Sithole, Osei Dua, Koushik Paul**, and **Cameron Starostecki**
- **Roger** from Walker Fire Department provided great insight into how firefighters operate in the wild lands
- **Lenny** and **Andre** for fabricating quality parts
- We would like to acknowledge all these vendors:
    - **Stotz Equipment**
    - **Heavy Hitch**
    - **Metal Supermarkets**
    - **Tractor supply**
    - **McMaster Carr**
    - **Bolt Depot**
- **The Mattox family** for providing us with a workshop for fabrication and assembly
- **Jesus Acuna**, provided us with a truck for testing.

Any Questions?