Portable Dirt Late Model Pull Down Machine
Fixturing/Frame Section

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by

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This project was a group project between Josh Dietz, Dylan Rivers, and Tamas Bonyhati. It was sponsored by Josh Dietz and all the components were donated to him.

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ABSTRACT

This is a report on a portable dirt late model pull down machine. This machine is used to simulate and record data of a racecar during dynamic suspension travel. This allows data to be gathered about how a car accelerates, decelerates and corners when on a racetrack. This machine is capable of dynamically loading a car to accurate read world forces. Included within this report is information on what the machine does and why this problem needs addressed. It also goes into the design of the frame of the machine, which is my section of the project. Finally, the budget, schedule and testing are discussed.

PROBLEM DEFINITION AND RESEARCH

PROBLEM STATEMENT

Our problem is to create a machine capable of dynamically loading a car to accurately simulate real world forces. These forces are present when the car is entering and exiting a corner at speed. Full measurements take a highly expensive fixturing system and are not available for use when most needed; at the track. Currently, the only way to simulate this in a timely manner is by using shock travel data to predict the suspension geometry. This is not an accurate prediction due to chassis and suspension deflection under load as well as tire deformation.

BACKGROUND

In recent years, dirt racing has made tremendous technological leaps in not only how the cars are built, but also how they are setup. Setup is a term used for the generalization of how the suspension geometry, shock dampening, spring rates, wheel loads and other measurable adjustments are tuned or adjusted on the car. In years past, the setups were done at a static state. This means the car is stationary and sitting as it would as it rested. While the setup at this state can provide a good baseline, it doesn't paint the whole picture of what is happening while the car is dynamically moving on the track.

Pull down devices are used to simulate the dynamic movements of a race car when it is moving around the racetrack. These devices already exist but are very expensive and time consuming to setup and run. We are interested in this problem because we have been racing for 15 years combined and have been using trial-and-error to set up our car. This machine will diminish the amount of guess-and-check required and give you the ability to see a measurable and repeatable change dynamically without needing to do on track testing. A pull-down machine works by moving the race car into a dynamic state. This is achieved by using actuators that pull down on the chassis to simulate on track, dynamic loading of the race car. These loading conditions can include acceleration, braking, and cornering forces. During these scenarios' measurements of various aspects of the setup of the car can be taken to best optimize performance. These measurements include:

- Wheel Loads through suspension travel
- Suspension Travel
- Dynamic Camber of front wheels
- Wheelbase movement through dynamic change of the car (Rear Axle Lead)
- Spoiler Height
- Ground Clearance

Currently, to test a dynamic setup change on the go at the track you must use a machine called a "spring smasher". This machine is used to measure shock load (in pounds) at a certain ride height (in inches), but doesn't give you the whole picture of what the car is doing dynamically on the track such as dynamic camber, roll steer and the travel of each corner of the race car. On one end the shock it is fixed, while the other end travels up and down using an electric actuator. Once you move the shock to a known travel or load measurement, a load cell measures the load applied to the shock at the desired distance. While this gives you a general idea of the loading of the car, it does not read actual wheel loads and does not account for suspension and tire deformation under load.

My segment of the pull-down machine is the frame/fixturing. This part must hold every piece of the machine, while also being able to support the car and be setup and broke down easily. On past machines, timely setup and breakdown periods are needed to move them. Not only do they come in many parts, but they are also difficult to customize in order to fit the wheelbase of your car. This makes portability and at track use impossible.

RESEARCH

SCOPE OF THE PROBLEM

There are many issues with today's pull-down systems. Most of these systems are too expensive for the average user to purchase. This makes it where if the average racer wants to use one, they must find a shop that has pull down services. Other issues are due to the system being so large and immobile. Customers who can afford one, must also have the space to use it. Systems in the market today have lengthy setup time which encourages the user to keep them setup all the time. This eliminates roughly 8-foot x 20-foot section of precious shop floor space.

CURRENT STATE OF THE ART

Pull Down Systems

There are many pull down rigs on the market today, but most of them are either expensive or are time consuming to setup and use. The DRP system is a brand of pull-down rig that is sold in many different stages costing in the range of $6,000 to $46,000. (1) These systems are sold with more and more features as the price goes up. In the base system you are expected to provide your own wheel weight scales and are limited to only taking wheel weight measurements. In the higher tear machines, scales are provided as well as gauges for taking important measurements such as:

- Shock Travel Sensors
- Wheel Laser Alignment System
- Ground Plane/Chassis Ride Height Kit
- Caster Camber Gauge

The advantages the DRP system are that it comes with many different features and can measure almost any aspect of the car. The disadvantages of this pull-down machine are that it is expensive and not portable.

Another pull down rig on the market is the Mittler Brothers brand pull down system. (2) While this machine has much higher accuracy then the DRP system, it is targeted to the NASCAR market and has a steep price tag of $95,000. These two brands are by far the most popular systems on the market with few other alternatives.

Fixturing

With the pull-down machines that are on the market today, the most popular way of fixturing the system is an erected frame such as the DRP machine. (1) These frames consist of 4 raised platforms with roll off sections, along with cross beams to tie everything together. Each platform has multiple leveling screws that not only allow you to level the entirety of the system, but also each pad individually of one another. These machines can be broken down and setup in another location but must be completely disassembled to do so. This is a timely process as it normally takes around 4 hours to do.

Other fixturing systems that are used on pull-down machines on the market today are fixed platforms that can't be dismantled such as the Mittler Brothers machine. (2) Once these machines are setup, they are extremely difficult to move. This style of machine uses a welded frame and is typically used in the higher ranks of racing such as NASCAR where they can be setup in their own room with no intent of moving them in the future. This immobility makes this style machine much less popular in the dirt late model market.

END USER

The end user of this product would be low budget and entry-level racers to provide a quick and efficient, portable calibration machine. The average racer is not able to afford currently available systems or have the time and space required to set up and use existing systems. With this system there would be little time required to set up and it will be easy to move due to simple fame design. This would allow you to quickly setup and teardown this system at any shop or even the track.

CONCLUSIONS AND SUMMARY OF RESEARCH

In summary, todays pull down machines work extremely well, but are too large and expensive for the average customer. These systems have little to no portability and can't be used at the track or moved to other shops due to the frame size and time required for setup. Our pull-down machine will have the same capability's as other machines on the market but will be more cost effective and have a frame with the portability that is sought after in the dirt late model market.

CUSTOMER FEATURES

The customer features for our project are:

- Ease of Use
- Setup time
- Portability
- Initial Investment Cost

PRODUCT OBJECTIVES

- To create a portable system on frame and wheels so that it can be moved from track to track. (Relative Weight: 18.2)
- To create a pull-down machine with a low initial investment. (Relative Weight: 16.4)
- To design and create a pull-down machine that is easy to use and setup as well as measure all the necessary and important characteristics of a dirt late model. (Relative Weight: 14.5)

QUALITY FUNCTION DEPLOYMENT

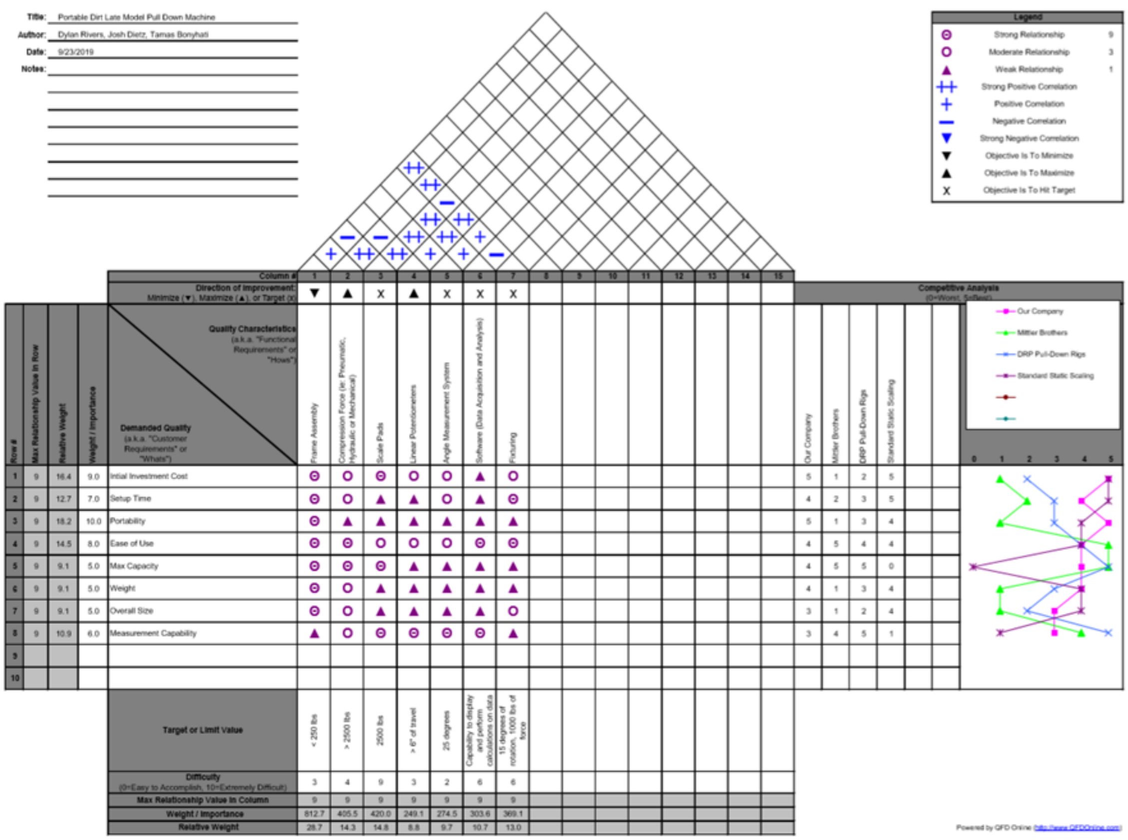


Fig. 1: House of Quality

Customer Features

The customer features for our project are:

- Ease of Use
- Setup time
- Portability
- Initial Investment Cost

Engineering Characteristics

The design features to achieve the customer needs are:

- Material and Component Choice for the system (Investment cost)
- Frame Assembly (Designing a frame that can be folded up and portable)
- Software – make all measurements and loads organized and easy to understand
- Actuation system – choose actuators that are simple to setup, inexpensive and achieve moving the car into a dynamic position

DESIGN

My section for the pull-down machine was to design and build the frame. This frame must hold every piece of the machine, while also being able to support the car while under loading conditions. This frame must also promote a quick and easy setup, while being able to be setup on a non-level surface.

Fig. 2: Final Frame

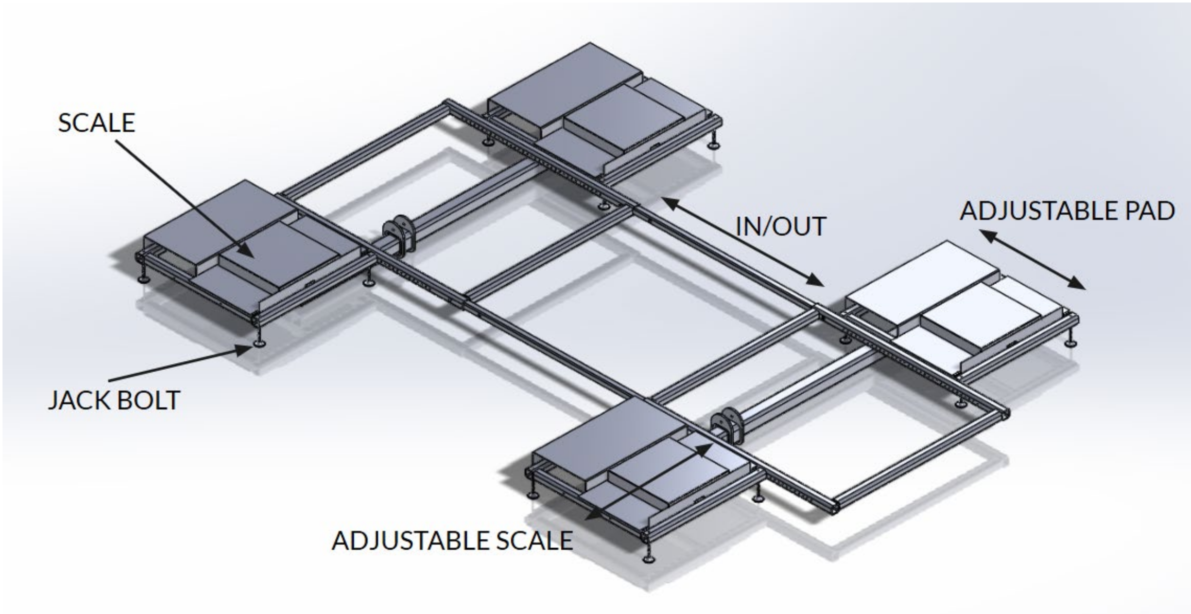


Fig. 3: Frame Model/Layout

PAD

Overview

There is a pad for each tire on the racecar. These pads must encapsulate the scale, while also allowing the frame to be leveled and bare the weight of the loaded system. Each pad has 4 adjusters. These adjusters allow the pad to not only be adjusted to level relative to itself, but also relative to each other.

Design Alternatives

Early renovations of the pad looked as they do above in fig. 3, but later a stiffener was added. This stiffener was welded to both sides of the pad and helped clean up the look of the pad as well as stiffen the raised section.

Pictures

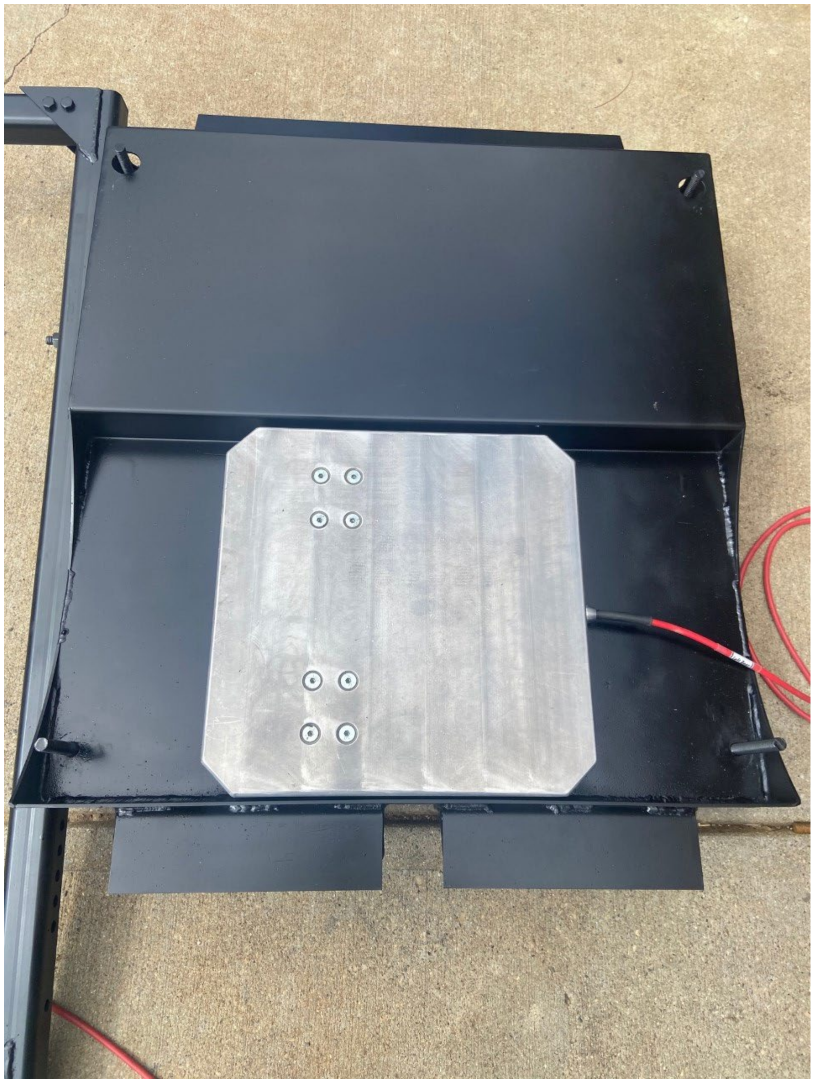


Fig. 4: Completed Pad

Loading Conditions

Each pad has one main loaded member. This loaded member holds an end of the cross bar. This cross bar is where the load is applied to the car. This can be seen in fig. 5.

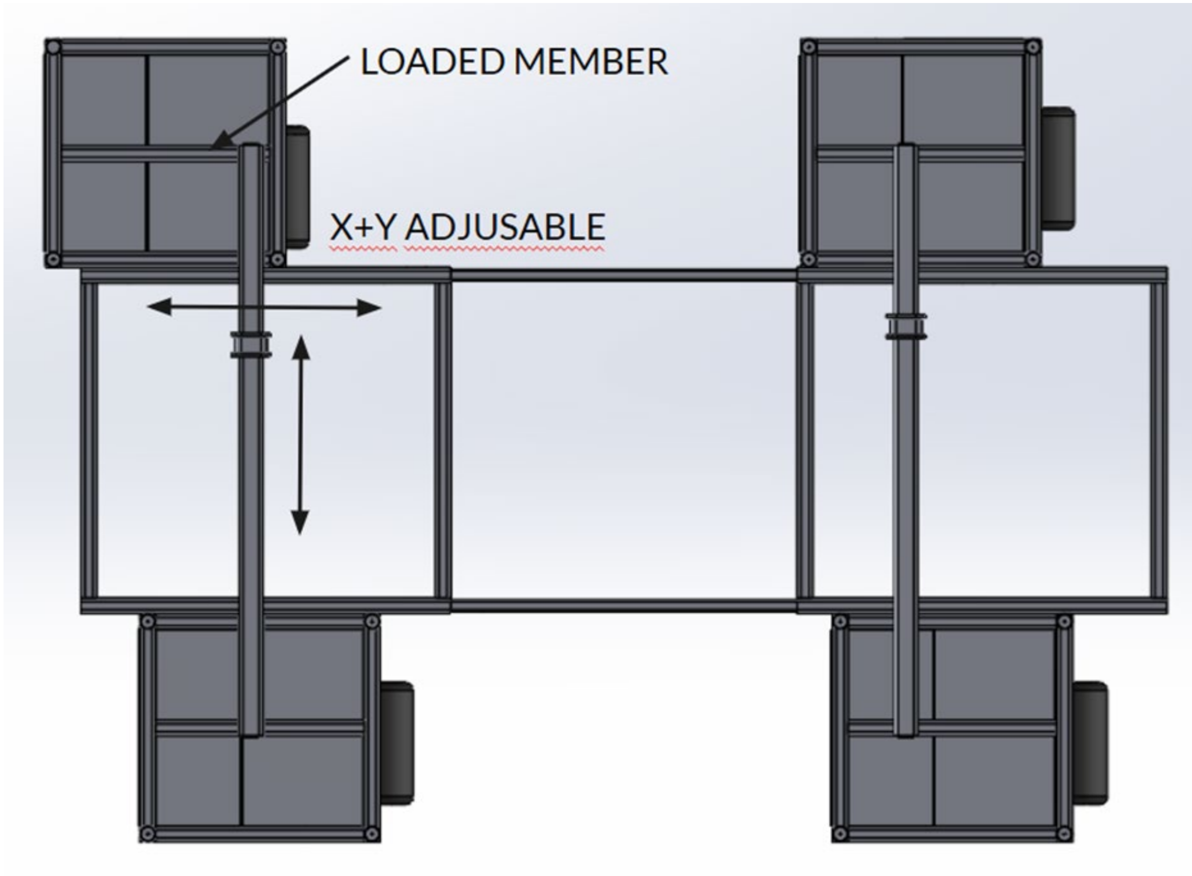


Fig. 5: Loaded Member Diagram

During worst-case scenario the loaded member would see a vertical force of 2,000lb due to the force applied from the actuation system. Other worst-case scenarios would be if the cross bar was located perfectly in the center of the loaded member as well as the tire being located on the edge of the pad. Although this is not practical in the real world, we wanted to bullet proof the pad as much as possible. Below are the worst-case scenario results.

Max Stress in Beam = 12.53 ksi
Yield Strength = 46.00 ksi
Safety Factor = 46.00ksi / 12.53 ksi = 3.67

This safety factor is fit for this application as we see the load to be represented as a sustained and constant load while being used. Although, the machine will repeatedly pull down on the car, it is not designed to be repeatedly pulling all day everyday and would be perfectly suitable for this application.

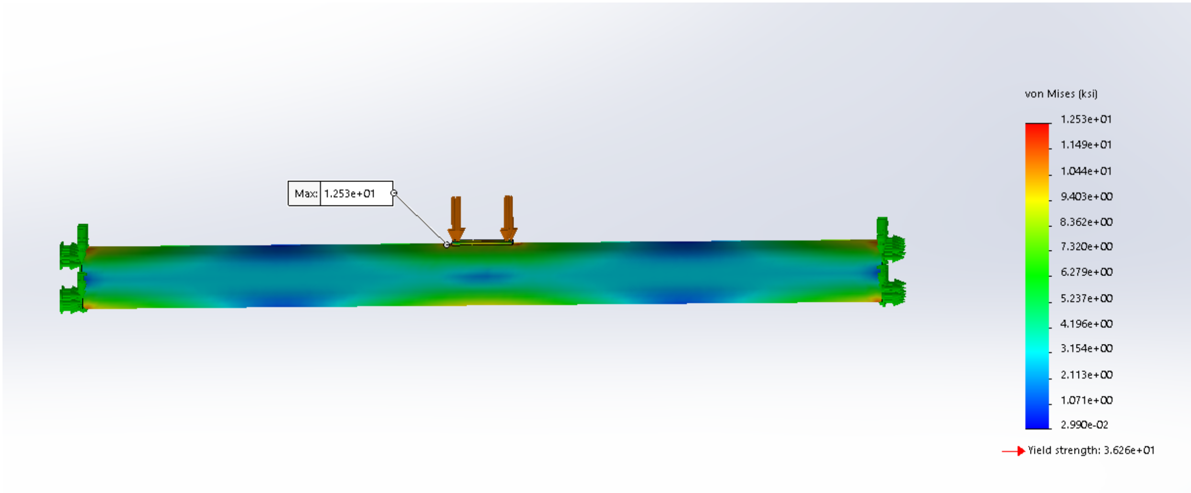


Fig. 6: Loaded Member Analysis

Material Selection

TUBE: A500 GRB TUBE 2X2X1/4

SHEET: 10GA A1008 CR

ADJUSTERS: ½-13 grade 8 bolt

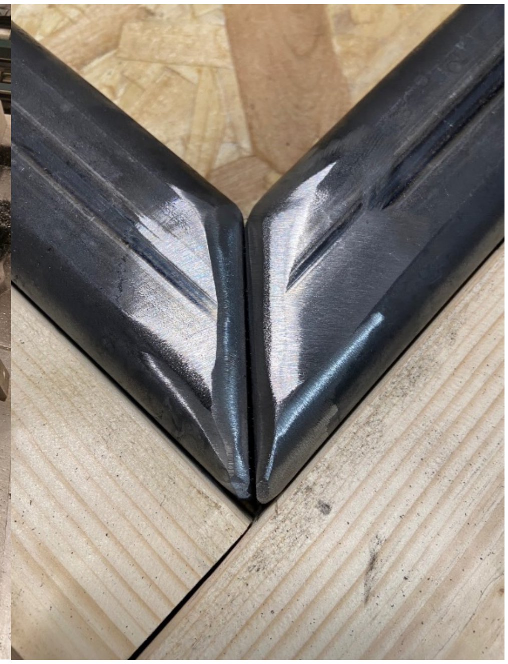
Manufacturing

Below are the steps taken in manufacturing of the pads:

1. Saw and miter the 2x2 tube
2. Weld prep tubing
    - 60deg weld prep for 100% penetration welding
3. Tack up tubing
    - Use fixture to ensure square and flat
4. Mig weld tube frame
    - 2 passes
5. Waterjet sheeting
6. Bend sheeting
    - Minimum radius bends
7. Fit and tack sheet to tube frame
    - Ensure flatness of sheeting as this will hold the scale pad
8. Tig sheet to frame
9. Drill all holes
    - Adjuster rod holes
    - Pin holes for center section
10. Paint prep
    - Wire wheel and sand smooth
11. Paint

12. Install adjusters


(Fig. 7: Build Step 1)


(Fig. 8: Build Step 2)


(Fig. 9: Build Step 3)


(Fig. 10: Build Step 4)

(Fig. 11: Build Step 7)

(Fig. 12: Build Step 7)

CENTER SECTION

Overview

There are two center sections on the frame. One front section and one back section. The rear center section is solely used to locate the rear pads whereas the front section would be responsible for holding the pads as well as the hydraulic controls and pump. Due to the complex geometry of these racecars, a system with high adjustability was required. During research, it was found that the cars wheels are not located square from one another. This means the system had to allow for offsets from one side to the other.

Design Alternatives

Early renovations of the center section had it as a loaded member. The pull points would be located on the frame itself rather than on the cross bar. This was changed due to the moments this would cause within the system. The system used, involved having a cross bar that was independent of the frame and attached at the center of the pad (directly under the contact patch of the tire). This would reduce the moments of the system as much as possible.

Pictures

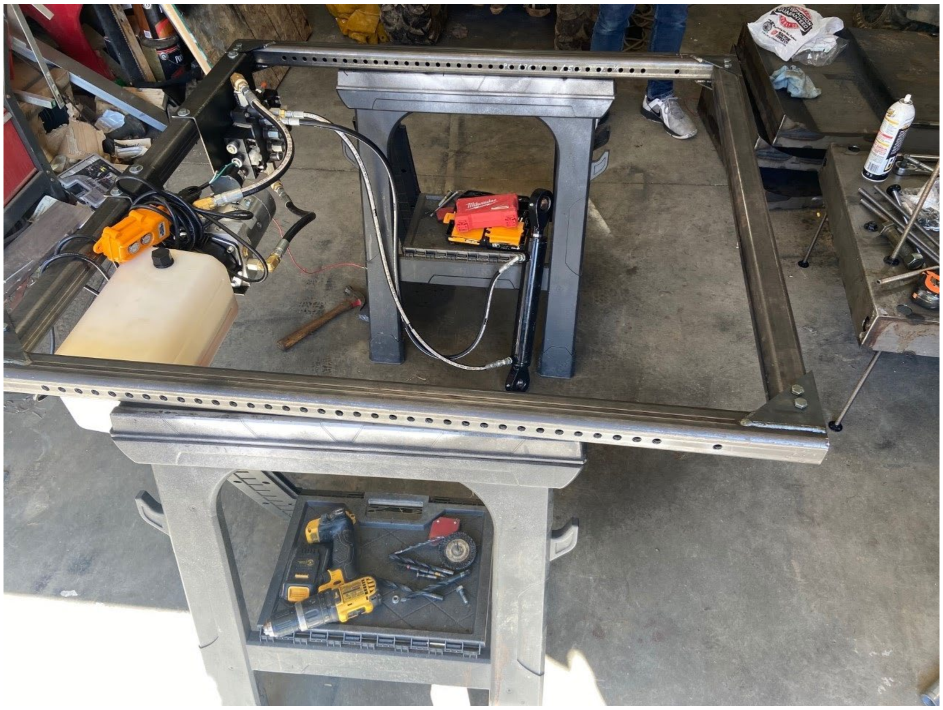


Fig. 13: Center Section

Loading Conditions

Due to the updated design, the new system would only have loading due to the weight of itself as well as the pump and hydraulic system. This was deemed as negligible.

Material Selection

TUBE: A500 GRB TUBE 2X2X1/4

GUSSETS: 10GA A1008 CR

Manufacturing

Below are the steps taken in manufacturing of the center section:

1. Saw the 2x2 tube
2. Waterjet gussets and bracketry for hydraulics
3. Bend bracketry
    - Minimum radius bends
4. Mig weld gussets to tube
    - Welding before drilling the holes will ensure the holes are as square as possible.
5. Drill all holes
    - Adjuster holes for pad

- Bolt holes for gussets
6. Paint prep
   - Wire wheel and sand smooth
7. Paint
8. Assemble

PROJECT MANAGEMENT

BUDGET, PROPOSED/ACTUAL

During the project we did go over budget. This was largely due to the actuation system. During preliminary design we did not account for the high price of fittings that were needed for the hydraulics.

Table 1: Preliminary Budget

Preliminary Budget	
Component	**Cost**
Frame/Fixturing	$400
Actuation System	$800
Measuring System	$500
Total:	$1,700

Table 2: Proposed Budget

Proposed Budget	
Component	Cost
Frame/Fixturing	$500
Actuation System	$1,300
Measuring System	$700
Total:	$2,500

Table 3: Final Budget

Actual/Final Budget	
Component	Cost
Frame/Fixturing	$800
Actuation System	$1,600
Measuring System	$700
Total:	$3,100

SCHEDULE, PROPOSED /ACTUAL

We stayed on schedule up until the manufacturing. Once the COVID-19 pandemic hit, it made it difficult to make progress. This was a major setback, but we still were able to complete it before the end of the semester.

Table 4: Proposed Schedule

Proposed Schedule	
Milestone	**Date**
Choose Design Concept	10/18/2019
Complete Calculations	11/15/2019
Finalize Design	12/6/2019
Order Materials	1/17/2020
Complete Manufacturing	3/20/2020
Test	3/27/2020
Revisions	4/3/2020
Tech Expo	4/9/2020

Table 5: Actual/Final Schedule

Actual Schedule	
Milestone	**Date**
Choose Design Concept	10/18/2019
Complete Calculations	11/15/2019
Finalize Design	12/6/2019
Order Materials	1/17/2020
Complete Manufacturing	4/11/2020
Test	4/18/2020
Tech Expo	Cancelled

TESTING

We were able to complete our project, which allowed us to complete testing as well. Our testing composed of two different categories. These categories were setup time and repeatability testing.

Fig. 14: Testing

Setup Time

Initial testing included setup procedure and time. Our overall goal was to be able to have a car capable of being pulled down on the machine after 30 minutes of setup time. Once a procedure was put together, a three-man team was able to complete this in 28 minutes. We only had time to complete this test once timed but believe with more practice we would be able to make this time even better. Below is an overview of the steps to setup:

1. Mark wheel positions of the car on the ground and roll car out of the way.
2. Slide pads in the center section of the frame where they correlate to the wheel position marked.
3. Level pads
4. Position cylinders and brackets roughly where they will be on the frame.
5. Setup boards for rolling onto the pads.
6. Push/winch the car on.
7. Hookup brackets.

Repeatability

We performed a CPK analysis on the data. The CPK values where all greater than 1.33 therefore our process capability was high enough to be acceptable.

1. Car will be set with the standard chassis manufacturer recommended settings.
2. The machine will pull each corner down until a desired shock distance is reached. (±1/16”)
3. Test will be ran 30 times with the wheel loads recorded
4. Wheel Load Error = ± 2% of Expected Wheel Load (± 15 lbf)
5. RF spring is shimmed by ⅛” and test is run 3 times to see if wheel weight is affected on the right front.

Table 6: Test 1 - Recorded Values

Wheel Weights (lb.)					Measured Distances (in.)		
Test	Right Front	Left Front	Left Rear	Right Rear	Right Front	Torque Arm	Right Rear
1	1103	704	633	562	14.45	16.24	22.86
2	1109	702	630	559	14.45	16.25	22.76
3	1095	704	632	564	14.45	16.19	22.8
4	1090	710	625	557	14.45	16.21	22.8
5	1108	690	631	559	14.45	16.25	22.8
6	1116	698	644	553	14.43	16.3	22.89
7	1098	698	647	553	14.47	16.25	22.82
8	1100	692	646	551	14.45	16.24	22.83
9	1086	695	643	550	14.51	16.22	22.8
10	1096	681	645	551	14.48	16.21	22.81
11	1095	687	652	545	14.45	16.24	22.85
12	1106	701	642	546	14.45	16.25	22.86
13	1101	697	639	548	14.45	16.19	22.76
14	1097	696	649	550	14.45	16.21	22.8
15	1093	700	650	552	14.45	16.25	22.8
16	1104	703	642	559	14.43	16.3	22.8
17	1106	697	644	555	14.47	16.25	22.89
18	1108	695	651	547	14.51	16.24	22.82
19	1099	705	640	542	14.48	16.22	22.83
20	1091	699	645	555	14.45	16.21	22.8
21	1105	703	642	556	14.45	16.25	22.81
22	1103	697	651	543	14.45	16.24	22.85
23	1095	695	641	549	14.47	16.25	22.8
24	1089	685	642	554	14.45	16.19	22.8
25	1100	687	646	558	14.45	16.21	22.89

26	1105	704	649	557	14.43	16.25	22.82
27	1108	693	652	552	14.47	16.3	22.83
28	1098	700	655	545	14.45	16.25	22.89
29	1100	701	643	548	14.51	16.24	22.82
30	1101	698	651	551	14.48	16.22	22.83
AVG	1100	697	643	552	14.46	16.237	22.824
STDEV	6.803	6.526	7.308	5.586	0.021	0.029	0.035
LSL	1070	667	613	522	14.335	16.112	22.699
USL	1130	727	673	582	14.585	16.362	22.949
CPK	1.469	1.532	1.368	1.790	1.931	1.425	1.183

After completing the first 30 tests, a 1/8" shim was added to the RF shock bump stop, there was a weight increase on the rf. This change would ramp up the spring rate earlier in travel causing a greater load at the final travel distance. This proves that we can make a change to the car and see a wheel weight change on the machine.

Table 7: Test 2 – Recorded Values

Setup Change: Adding 1/8" Packer Shim to RF shock							
Prediction of change: should increase wheel weight on the RF							
Wheel Weights (lb.)					Measured Distances (in.)		
Test	Right Front	Left Front	Left Rear	Right Rear	Right Front	Torque Arm	Right Rear
1	1170	677	660	531	14.51	16.2	22.7
2	1160	680	658	540	14.52	16.3	22.76
3	1165	686	654	542	14.52	16.25	22.81

SUSTAINABILITY AND MATERIAL USAGE

Future Recommendations:

1. Aluminum Construction
    - This would add cost but create a lighter final project.
    - This would allow for a formed frame construction rather than tubular.
2. Electric Actuation System
    - This would eliminate the need for the hydraulic lines and pump.

WORKS CITED

1. **DRP Pull Down Systems & Pakcages.** ***DRP Performance Products.*** **[Online] [Cited: September 11, 2019.] https://www.drpperformance.net/copy-of-pull-down-systems-1.**
2. Ultimate Pull Down Rig. ***Mittler Brothers.*** **[Online] [Cited: September 11, 2019.] https://www.mittlerbros.com/econo-pull-down-rig.html.**

APPENDIX A

DRP Pull Down Machine:

Mittler Brother's Pull-Down Machine

APPENDIX B

Below is a picture of the survey that we used to collect information on which features are important to the end user. The customer features that had the highest average ranking of importance where investment cost, setup time, portability, and ease of use.

Portable Dirt Late Model Pull-Down Machine Survey

This survey will be used to prioritize various features to maximize customer satisfaction. The system in question will address issues for setting up dirt late models. This system will measure various aspects of a car through dynamic on track travel to aid in setup ability.

How important is each feature to you?

Please circle the appropriate answer. 1=low importance 5=high importance

Initial Investment Cost	**1**	**2**	**3**	**4**	**5**	**N/A**
Setup Time	**1**	**2**	**3**	**4**	**5**	**N/A**
Portability	**1**	**2**	**3**	**4**	**5**	**N/A**
Ease of Use	**1**	**2**	**3**	**4**	**5**	**N/A**
Max Capacity	**1**	**2**	**3**	**4**	**5**	**N/A**
Weight	**1**	**2**	**3**	**4**	**5**	**N/A**
Overall Size	**1**	**2**	**3**	**4**	**5**	**N/A**
Measurement Capability	**1**	**2**	**3**	**4**	**5**	**N/A**

How satisfied are you with current setup technology?

Please circle the appropriate answer. 1=very <u>uns</u>atisfied 5=very satisfied

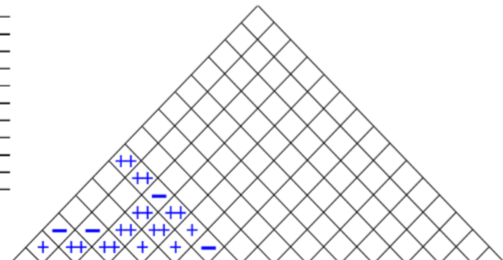
Initial Investment Cost	**1**	**2**	**3**	**4**	**5**	**N/A**
Setup Time	**1**	**2**	**3**	**4**	**5**	**N/A**
Portability	**1**	**2**	**3**	**4**	**5**	**N/A**
Ease of Use	**1**	**2**	**3**	**4**	**5**	**N/A**
Max Capacity	**1**	**2**	**3**	**4**	**5**	**N/A**
Weight	**1**	**2**	**3**	**4**	**5**	**N/A**
Overall Size	**1**	**2**	**3**	**4**	**5**	**N/A**
Measurement Capability	**1**	**2**	**3**	**4**	**5**	**N/A**

How much would you be willing to invest in this setup tool?

\$500 - \$1000, \$1000 - \$3000, \$3000 - \$10000, \$10000+

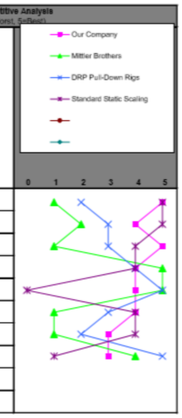
APPENDIX C

Title: Portable Dirt Late Model Pull Down Machine
Author: Dylan Rivers, Josh Dietz, Tamas Bonyhati
Date: 9/23/2019
Notes:



Legend		
Θ	Strong Relationship	9
O	Moderate Relationship	3
▲	Weak Relationship	1
++	Strong Positive Correlation	
+	Positive Correlation	
−	Negative Correlation	
▼	Strong Negative Correlation	
▼	Objective Is To Minimize	
▲	Objective Is To Maximize	
X	Objective Is To Hit Target	

				Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Competitive Analysis (0=Worst, 5=Best)					
				Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x)	▼	▲	X	▲	X	X	X														
Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Quality Characteristics (a.k.a. "Functional Requirements" or "Hows") / Demanded Quality (a.k.a. "Customer Requirements" or "Whats")	Frame Assembly	Compression Force (ie: Pneumatic, Hydraulic or Mechanical)	Scale Pads	Linear Potentiometers	Angle Measurement System	Software (Data Acquisition and Analysis)	Fixturing									Our Company	Mittler Brothers	DRP Pull-Down Rigs	Standard Static Scaling		
1	9	16.4	9.0	Intial Investment Cost	Θ	O	Θ	O	O	▲	O									5	1	2	5		
2	9	12.7	7.0	Setup Time	Θ	O	▲	▲	O	▲	Θ									4	2	3	5		
3	9	18.2	10.0	Portability	Θ	▲	▲	▲	▲	▲	▲									5	1	3	4		
4	9	14.5	8.0	Ease of Use	Θ	Θ	O	O	O	Θ	Θ									4	5	4	4		
5	9	9.1	5.0	Max Capacity	Θ	Θ	Θ	▲	▲	▲	▲									4	5	5	0		
6	9	9.1	5.0	Weight	Θ	O	▲	▲	▲	▲	▲									4	1	3	4		
7	9	9.1	5.0	Overall Size	Θ	O	▲	▲	▲	▲	O									3	1	2	4		
8	9	10.9	6.0	Measurement Capability	▲	O	Θ	Θ	Θ	Θ	▲									3	4	5	1		
9																									
10																									



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Target or Limit Value	< 250 lbs	> 2500 lbs	2500 lbs	> 6" of travel	25 degrees	Capability to display and perform calculations on data	15 degrees of rotation, 1000 lbs of force								
Difficulty (0=Easy to Accomplish, 10=Extremely Difficult)	3	4	9	3	2	6	6								
Max Relationship Value in Column	9	9	9	9	9	9	9								
Weight / Importance	812.7	405.5	420.0	249.1	274.5	303.6	369.1								
Relative Weight	28.7	14.3	14.8	8.8	9.7	10.7	13.0								

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APPENDIX D

Product Objectives

- To create a portable system on frame and wheels so that it can be moved from track to track. (Relative Weight: 18.2)
- To create a pull-down machine with a low initial investment. (Relative Weight: 16.4)
- To design and create a pull-down machine that is easy to use and setup as well as measure all the necessary and important characteristics of a dirt late model. (Relative Weight: 14.5)

SPECIAL THANKS

Machintek: Donated machine time

Jim Couch, CTEK: Donated machine time

Brian Gray, BGR: Donated scale pads

Peter Bonyhati: Controls knowledge, Donated PLC

Mike Nuchols, Warrior Race Cars: Setup knowledge