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CYCLONE POWER PULLERS

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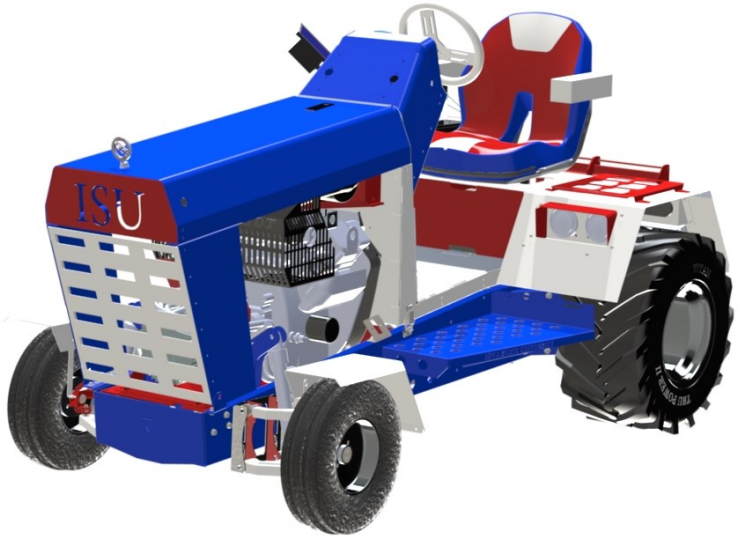

CY SPANGLED BANNER

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2024 A-TEAM DESIGN REPORT

The Cyclone Power Pullers (CPP) have had a rich history in developing an innovative tractor model each year. CPP's two wheel drive electric drive developed in 2017, *ExCyter*, opened the door for CPP to the electric drivetrain. CPP was able to advance the electric drivetrain into the four wheel drive platform with the customer favorite, 2019 *VerCYtile*. The 2023 *Cytation* did not utilize an electric drive train, but included many new innovations with *Cy-Spension* and CPP's active steering feedback system. Building on the innovations from CPP's many generations of tractors, the Cyclone Power Pullers are proud to introduce the most refined electric drive yet. *Cy Spangled Banner (CSB)* takes the best aspects and lessons learned from each of the previous models, combined with the latest technological advancements, to provide a sub-compact tractor suited for the toughest industries without sacrificing safety and operator comfort. *Cy Spangled Banner* is the most technologically advanced tractor produced by CPP to date.

2017 *ExCyter*

- Electric 2WD Transmission
- Inboard Planetary Final Drive
- Optimized Motor and Drive Speed Control

2019 *VerCYtile*

- Electric 4WD Chassis
- Articulated Steering
- Low Force Foot Print

2023 *Cytation*

- Hydro-Mechanical Transmission (*CY-Split*)
- Independent Front Suspension (*Cy-Spension)*
- In-House Active Steering Feedback

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In the beginning stages of the development of *Cy Spangled Banner* (*CSB*) the team put great importance on not only building an excellent tractor, but also making sure that *CSB* would be suited for its market. To better understand the target markets for *CSB,* the team conducted a survey of current and potential customers. The survey went out to 100 of the Cyclone Power Pullers' current and potential customers to ensure that their needs are not only met but exceeded. The results of this survey are shown in **Figure 3.1**. The survey results show that durability, serviceability, and performance were the top areas of importance to customers. The focus on serviceability led the team to develop the *Cy-Voltage Drivetrain (Cy-VD)* which required little to no service of components over the lifetime of the machine. To ensure the durability of *CSB,* the team decided to move towards cast suspension components instead of the sheet metal alternatives. Lastly the focus on performance led the team once again to the electric drivetrain that boasts a high efficiency.

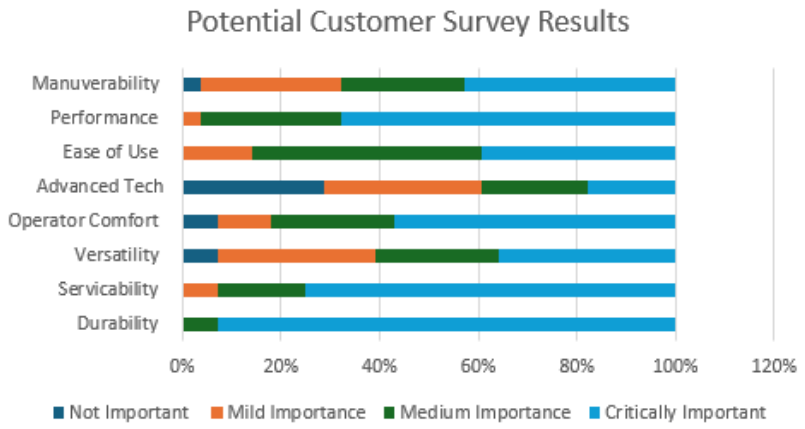


Figure 3.1: Consumer survey results

Additional market research was required to determine what industries *CSB* should be designed to work in. Through the market research shown in **Figure 3.2**, the team found that Agriculture and Manufacturing are the largest target markets for *CSB*. Within agriculture the team determined that landscaping, orchards, produce, and viticulture were the areas of highest impact. The team also learned that there is a market for the tractor in the sectors of transportation, forestry, and mining. The target market of mining led the team to create the *White* package that features a zero emissions battery instead of an internal combustion engine. Offered models can be found listed in more detail on page five.

Figure 3.2: Target Markets

Autonomy was also an area of interest in the development of *CSB* due to the target markets shown in **Figure 3.2**. The markets of agriculture, manufacturing, and mining have a heavy interest in autonomy due to a labor shortages. Due to this, *CSB* was designed with the leap to autonomy in mind.

In Dash Display

Active Steering Feedback System (ASF)

Brushless Generator

Integrated Ballast Solutions

Independent Drive motors

Cy-Spension III—Independent Front Suspension

After reviewing potential markets for sub-compact tractors, the Cyclone Power Pullers decided to move away from the *Cy-Split* hydro-mechanical transmission used in the last two production cycles. *CSB* features an electric drivetrain featuring two independent brushless drive motors and a brushless generator driven by the company standard Briggs and Stratton 31 horsepower engine. *CSB* also features a rack and pinion steering system driven by a brushless motor and controlled by an in-house designed active steering feedback (ASF) system. Great improvements were also made in making the operators station of *CSB* comfortable for any operator. These comfort improvements paired with the low maintenance electric drivetrain make *CSB* perfect for any operation.

Figure 5.1: ***Cy Spangled Banner Red***

Red

The *Cy Spangled Banner (CSB) Red* model is the entry level tractor designed for the 2024 model year. *CSB Red* offers a 31 HP Briggs & Stratton Engine coupled to a brushless generator. A single drive motor is connected to a limited slip differential, driving inboard planetaries to transfer power to the ground. This creates a more affordable tractor for the customer. Head lights are equipped on each fender, and front display is included to monitor tractor vitals. *CSB Red* comes standard with independent front suspension ensuring a soft ride for all customers. This low-cost model is designed with landscaping and entry level farming in mind. This tractor is marketed at $9,800.

Blue

The *CSB Blue* model is the mid-range model of the Cyclone Power Pullers 2024 tractor lineup. *CSB Blue* offers all of the technology of *CSB Red*, with some additional improvements. This model retains the 31 HP Briggs & Stratton engine to drive the electrical power plant, driving two brushless motors coupled to harmonic drives. Extra lights are added to *CSB Blue* model allowing work to be done on the operator's schedule. An added side display with *Cy-Bus* connectivity integrates implement monitoring as well as advanced tractor diagnostics. *CSB Blue* is the true workhorse of the CPP lineup designed to meet the majority of customers needs and comforts, without breaking the bank. This tractor is marketed at $13,700.

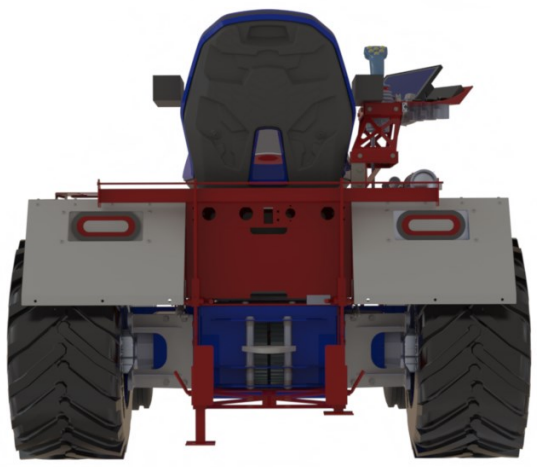
(The Cy-Spangled Banner Blue is the model CPP has built for the 2024 Prototype)

Figure 5.2: ***Cy Spangled Banner Blue***

Figure 5.3*: Cy Spangled Banner White*

White

The *CSB White* model is the flagship tractor the Cyclone Power Pullers have designed for 2024. Replacing the 31 HP Briggs & Stratton, a battery bank unleashes the full potential of *CSB*. Not limited by an Internal Combustion Engine, *CSB White* is designed to go where combustion engines are not practical or permitted. *CSB White* introduces *Cy-Track* auto guidance as standard for the smartest tractor ever produced by the Cyclone Power Pullers. Electric front wheel assist provides optimum traction in the toughest conditions, and an added electric PTO provides power for all implements. This tractor is marketed at $22,000.



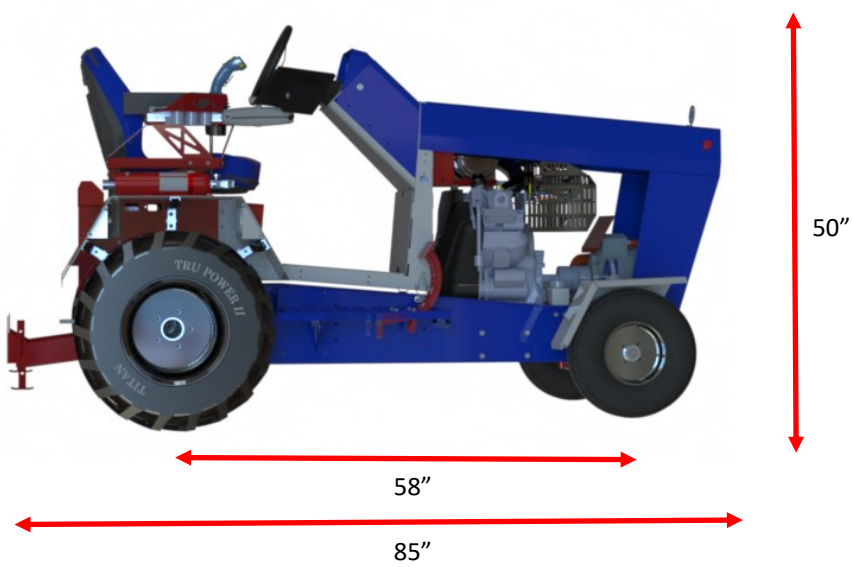


Figure 6.1: Tractor Specifications

Component		RED	BLUE	WHITE
Model ID		CPPCSB_RED24	CPPCSB_BLUE24	CPPCSB_WHITE24
Drivetrain	Type	2wd	2wd	Front Wheel Assist
	Transmission	Single Drive Motor	Dual Motor Drive	Dual Motor Drive
	Differential	Limited Slip	NA	NA
Engine	Make	Briggs & Stratton	Briggs & Stratton	NA
	Model	Vangaurd	Vangaurd	NA
	Rated Power	31 HP	31 HP	NA
	Exhaust	Briggs & Stratton	Briggs & Stratton	NA
Front Axle	Type	Solid	Independent	Independent
	Shocks	Coil Overs	Coil Overs	Pneumatic Air Bags
	Travel	3"	4"	5"
Steering	Type	Electric	Electric	Electric
	Force	275 lb	331 lb	331 lb
	Radius	56"	48”	52 “
Tires	Rear	Titan TRU Power II 26x12-12	Titan TRU Power II 26x12-12	Titan TRU Power II 26x12-12
	Front	Deestone 3-RIB 16x4.0-8	Deestone 3-RIB 16x4.0-8	Deestone AG-Tread 16x4.0-8
Select Features				
Digital Display		Single Display	Dual Display	Triple Display
Adjustable Steering Wheel		Manual Tilt/Length	Motor Driven Worm Tilt, Position Memory	Motor Driven Worm Tilt, Position Memory
Electro—Hydraulics Package		Option	Option	Standard
Rear PTO		NA	NA	Standard
Front/Rear ISO BUS		Option	Standard	Standard
Lighting Package		Option	Standard	Standard
Back-Up Camera		Option	Standard	Standard
Wheelie Bar		Option	Standard	Standard
CAT 0 3 Point Hitch		Option	Option	Standard
Ballast Package		Option	Standard	Standard
Electronic Control		Standard	Standard	Standard
Weight (lbs)				
Base Weight		765	875	1155
Maximum Operating Weight		1800	2000	2000
Maximum Pull Weight		2250	2500	2500
Fluids and Capacities (qts)				
Engine Crankcase	SAE 30	2.5	2.5	2.5
Fuel Tank	Gasoline	6	6	6
Final Drives	Grease (HFL-1)	0.1	0.1	0.1
Brake Reservoir	DOT 3	0.32	0.32	0.32
Dimensions (in)				
Width		49	51	51
Wheelbase		56	58	58
Total Length		85	85	85
Height		50	50	50

The powertrain team went to great lengths to design the best drivetrain possible. Due to supply chain issues, *Cy Spangled Banner (CSB)* will be the last tractor in the CPP lineup featuring the Briggs and Stratton 31-horsepower engine. After great deliberation, the team decided upon an electric drivetrain. This was selected based the performance of previous electric drivetrain designs in the CPP lineup and copious amounts of market research.

Drivetrain Selection		Cy-Split		Toroidal CVT		Electric	
Criteria	%	Rank	Score	Rank	Score	Rank	Score
Efficiency	40	6	240	4	160	9	360
Safety	20	5	100	7	140	7	140
Parts	15	7	105	2	30	7	105
Cost	15	3	45	2	30	5	75
Weight	5	5	25	7	35	6	30
Team	5	9	45	1	5	5	25
Totals	100		560		400		735

Figure 7.1: Drivetrain Selection Design Matrix

The next step in the design process was to select the target system voltage before deciding on any other components in the *Cy-Voltage* electric drivetrain. To do this, the team utilized a design matrix to weigh the positives and negatives of three different potential systems (Shown in **Figure 7.3**). After analysis, the team selected a 96-volt DC system. With this system, the team selected the ME1917 brushless motor **(Figure 7.2).**

Unlike previous electric drivetrains in the CPP lineup, the *Cy-Voltage* electric transmission will feature a brushless generator instead of the brushed alternative. This allowed CPP to cut out an expensive wear component in the system and also enabled CPP to use the ME1917 **(Figure 7.2)** as both the generator and drive motor for the system. This use of common parts allows for easy maintenance and service.

Figure 7.2: ME1917 96 VDC Motor

Voltage Selection		48 VDC		96 VDC		480 VDC	
Criteria	%	Rank	Score	Rank	Score	Rank	Score
Efficiency	40	3	120	6	240	9	360
Safety	20	9	180	9	180	6	120
Parts Availability	15	6	90	6	90	1	15
Cost	15	7	105	7	105	3	45
Weight	5	7	35	7	35	3	15
Team Knowledge	5	8	40	8	40	3	15
Totals	100		570		690		570

Figure 7.3: System Voltage Design Matrix

Figure 7.4: Emrax 480 VDC Motor

Cy Spangled Banner (CSB) features a simplified powertrain using a brushless generator with two brushless drive motors. This drivetrain will increase efficiency, serviceability, and simplicity. The electric drivetrain utilizes a 96 Volts direct current (VDC) bus. This configuration was chosen using many methods. The most important decision was the gear ratio between the drive motors and the wheels. The CPP drivetrain group developed an extensive Simscape simulation to determine the best gear ratio. **Figure 8.1** shows a selected tractor pull test with different gear ratios and motor torque ratings. This pull was conducted at a fixed power rating of 23 kilowatts (KW).

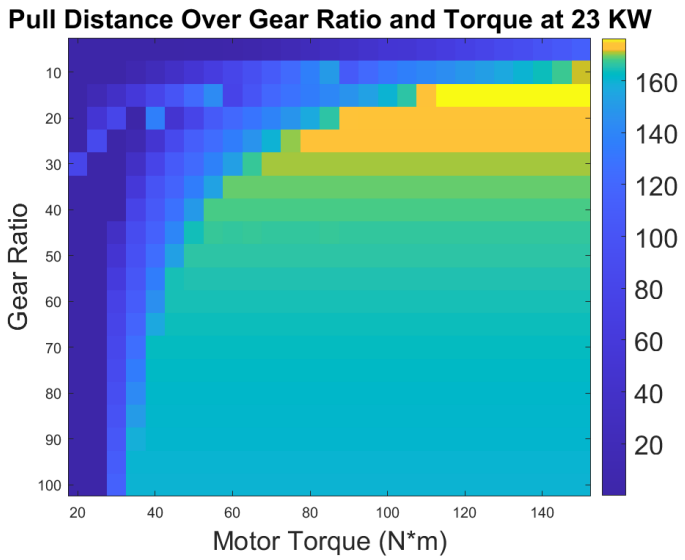


Figure 8.1: Pull Distance over Gear Ratio and Torque

With the findings from these simulations, the team had to find motors. The decision was made to go with 96 VDC because of the increased safety and serviceability, with more off-the-shelf components. The ME1917 motors were chosen because of their price, operating voltage, and availability. These motors top out at about 65 Newton meters (Nm), which means that according to the team's simulations, the ideal gear ratio would be about 35:1. This gear ratio was considered but would require custom-made harmonic gearboxes. Sticking with the theme of serviceability and off-the-shelf components, the team chose a 50:1 gear ratio. This gear ratio strikes a balance between top speed and torque. The Cy Spangled Banner has a top speed of seven mph and a maximum wheel torque of 6,400 Nm.

The powertrain layout is shown in **Figure 8.2**. This layout highlights the optional battery to enable the opportunity for plug-in hybrid or fully electric operation.

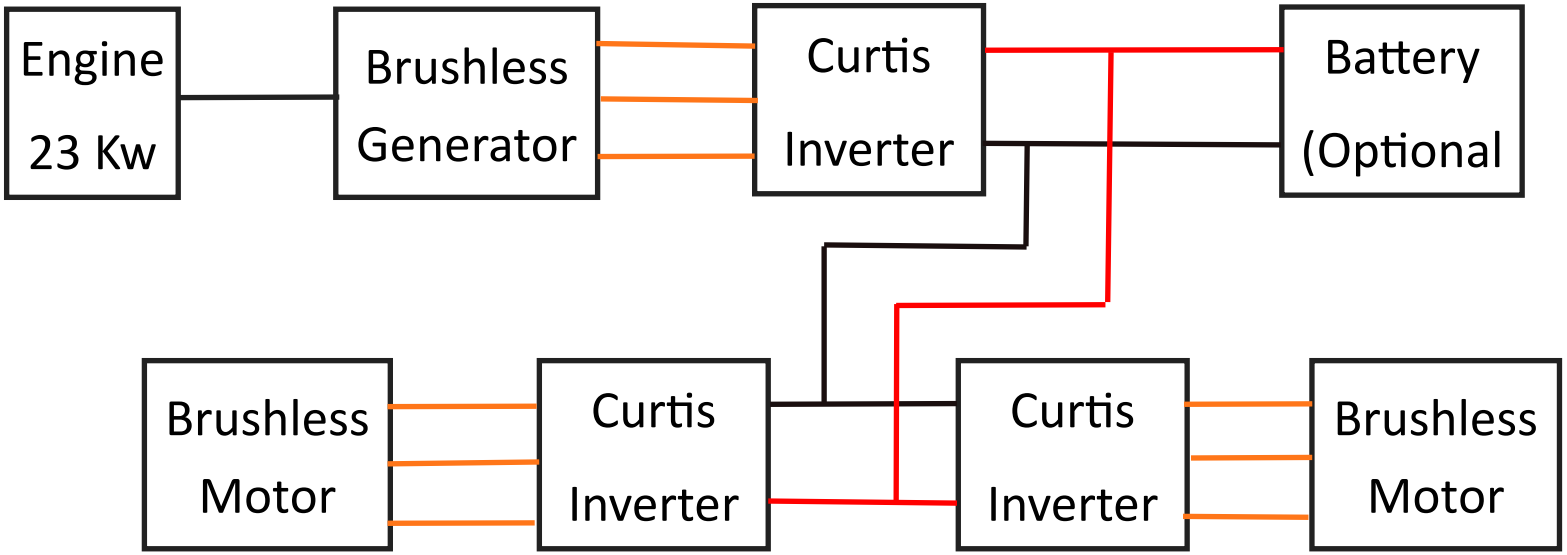


Figure 8.2: Cy-Voltage Drivetrain Layout

The powertrain of *Cy Spangled Banner (CSB)* allows a complete decoupling of the engine from the drivetrain. This means the engine has much more range to operate at any speed while the drivetrain can run at the commanded speed. This allows for efficiency matching in the powertrain, meaning the generator can always keep the motors at their most efficient point. The "floating bus" architecture means that the bus voltage can change depending on the operating point. **Figure 9.2** illustrates the efficiency point of the drive motors relative to the current running through them. By varying the voltage of the bus, the motor will always be kept at its optimal efficiency.

The engine control for *CSB* can also be integrated into the powertrain control to find the optimal match point between the engine and the generator's efficiency.

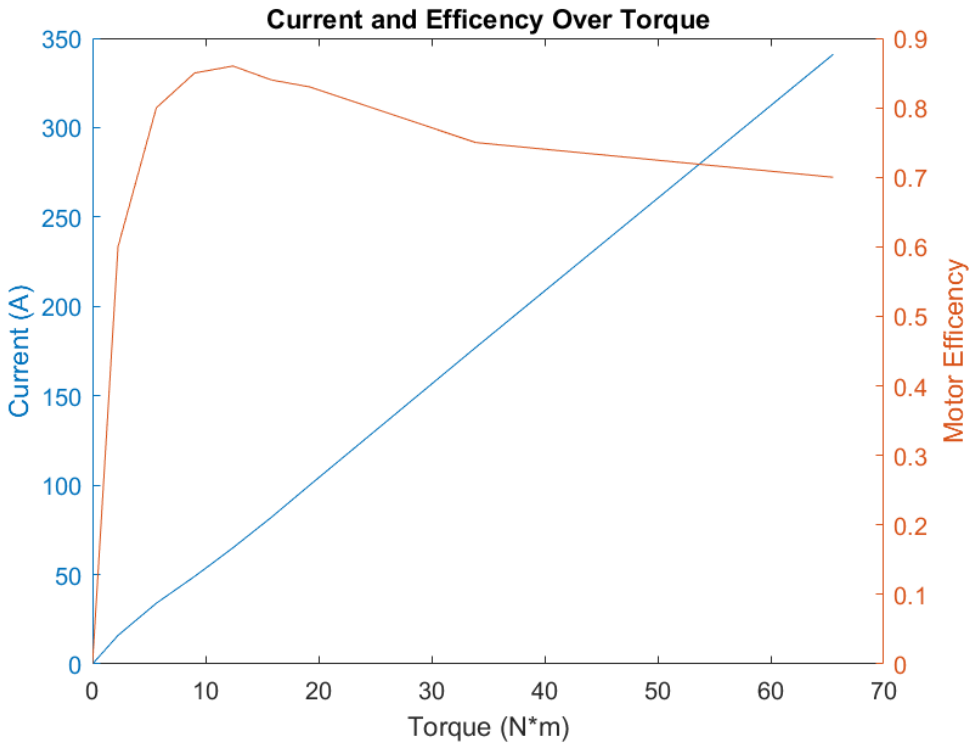


Figure 9.2: Current and Efficiency over Torque

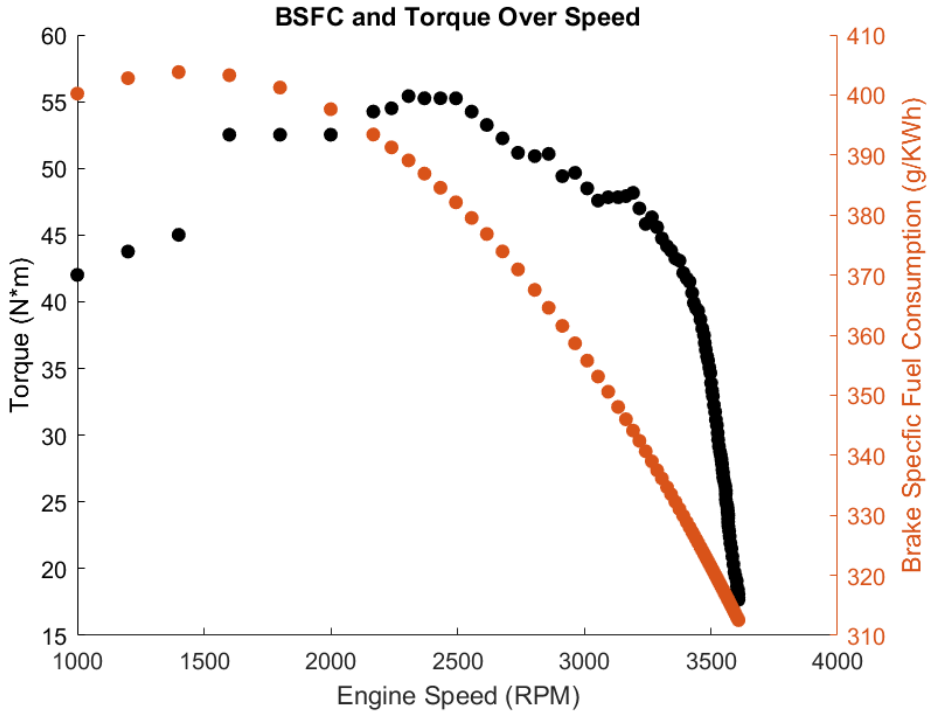


Figure 9.1: BSFC and Torque over Speed

Figure 9.3: Selected Curtis Inverters

The *Cy Spangled Banner (CSB)* design team utilized Finite Element Analysis (FEA) for many essential components to ensure that these components would hold up to extreme forces. The target components shown below are the side console and a-arms. Focusing on the side console, this multi part assembly comprises a piece of hot rolled plain steel angle iron making up the upright member and the rest being 5052 aluminum. Forces applied on this piece are 50 pounds (lbs.) directly downward on the joystick hole and 20 lbs. to the side of the joystick slot. This design aimed to minimize deformation (**Figure 10.2)** so that the operator does not feel unsafe operating the machine and reduces stress on the consol **(Figure 10.1)**. Pivoting to the a-arms, the move to cast A206-T4 aluminum was an effort to reduce production cost, increase strength, and eliminate complexities associated with previous steel weldments. Lower a-arms see up to 1000 lb. forces at the shock mounting point and spindle mount. Upper a-arms see up to a 1000 lb. force acting at the spindle mount. The 1000 lb. force was calculated based on the tractor's weight distribution fully loaded and incorporating a factor-of-safety of 2.5. Utilizing the yield point for this steal in the heat-affected zone to be 25 ksi., **Figure 10.3** and **Figure 10.4** are calculated. The cast aluminum yield point was found to be 30 ksi., represented by **Figure 10.5** and **Figure 10.6.** Based on these observations, users can have piece-of-mind in the integrity of *CSB.*

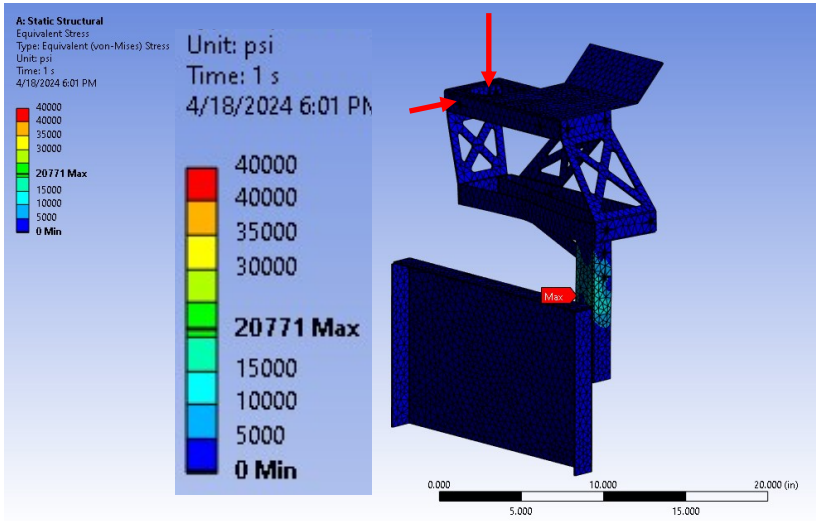


Figure 10.1: Stress Side Console

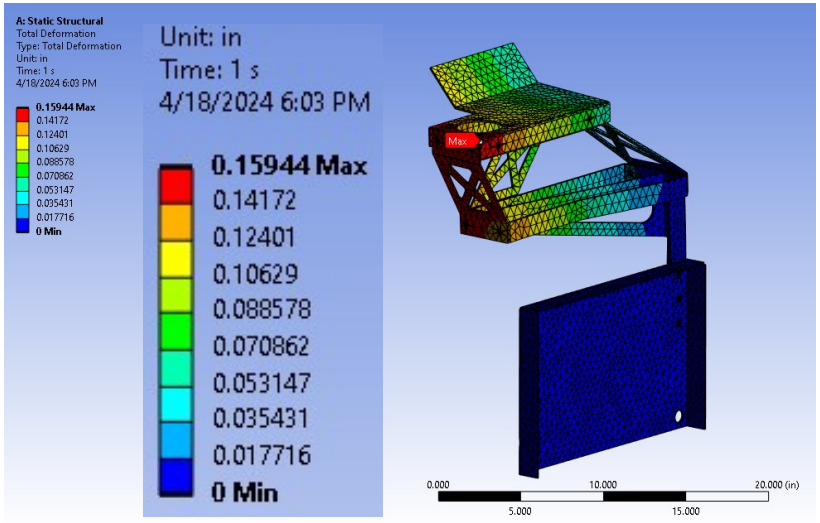


Figure 10.2: Deformation Side Console

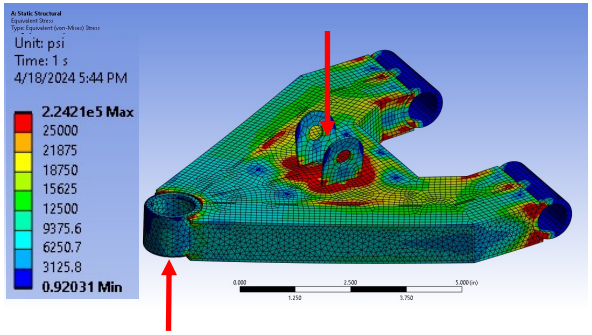


Figure 10.3: Stress Weldment Lower A-Arm

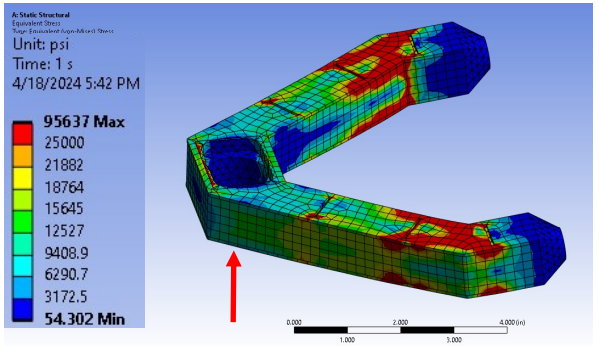


Figure 10.4: Stress Weldment Upper A-Arm

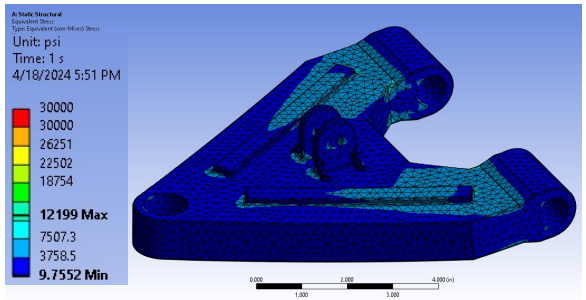


Figure 10.5: Stress Cast Lower A-Arm

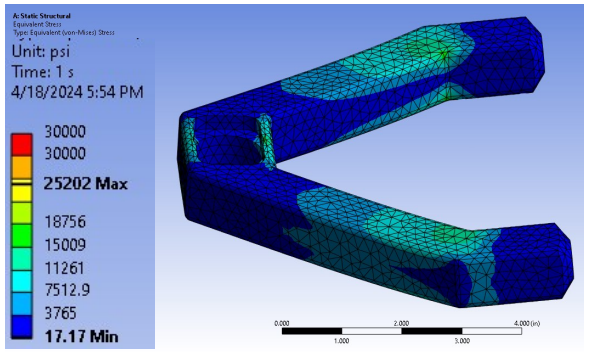
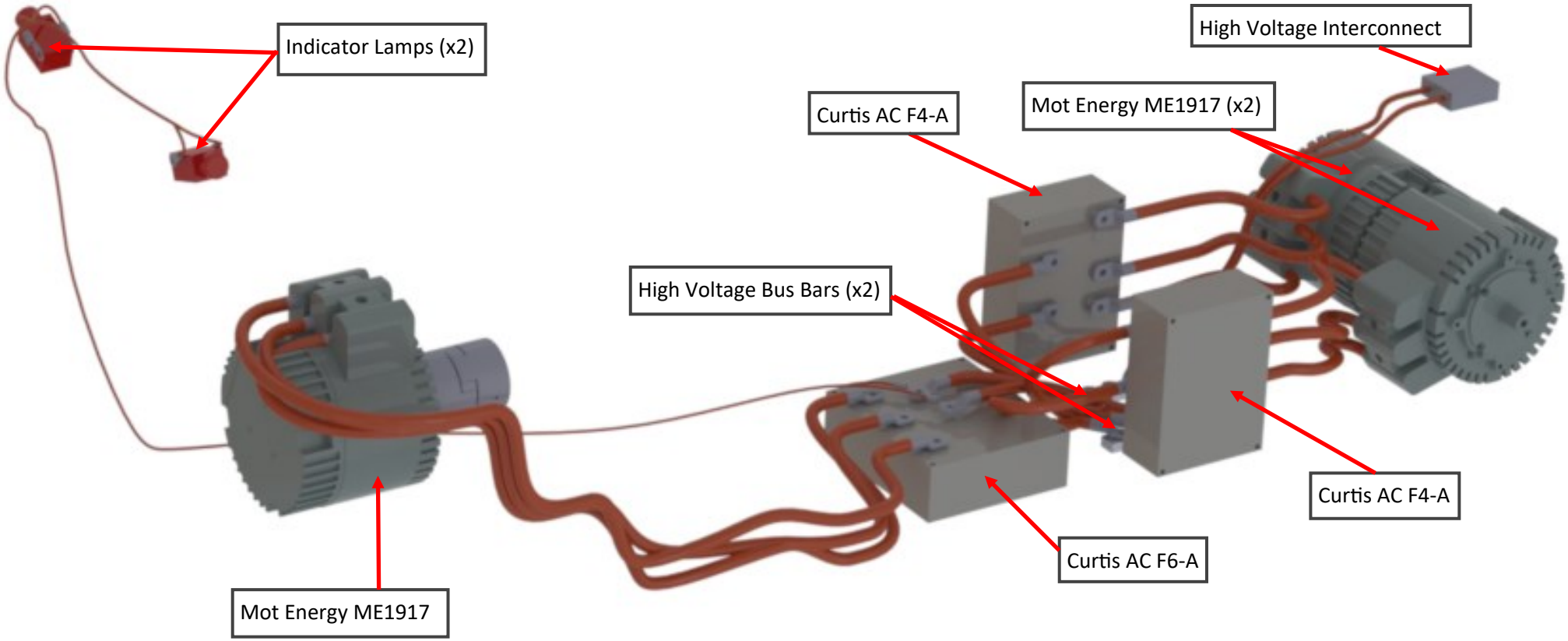
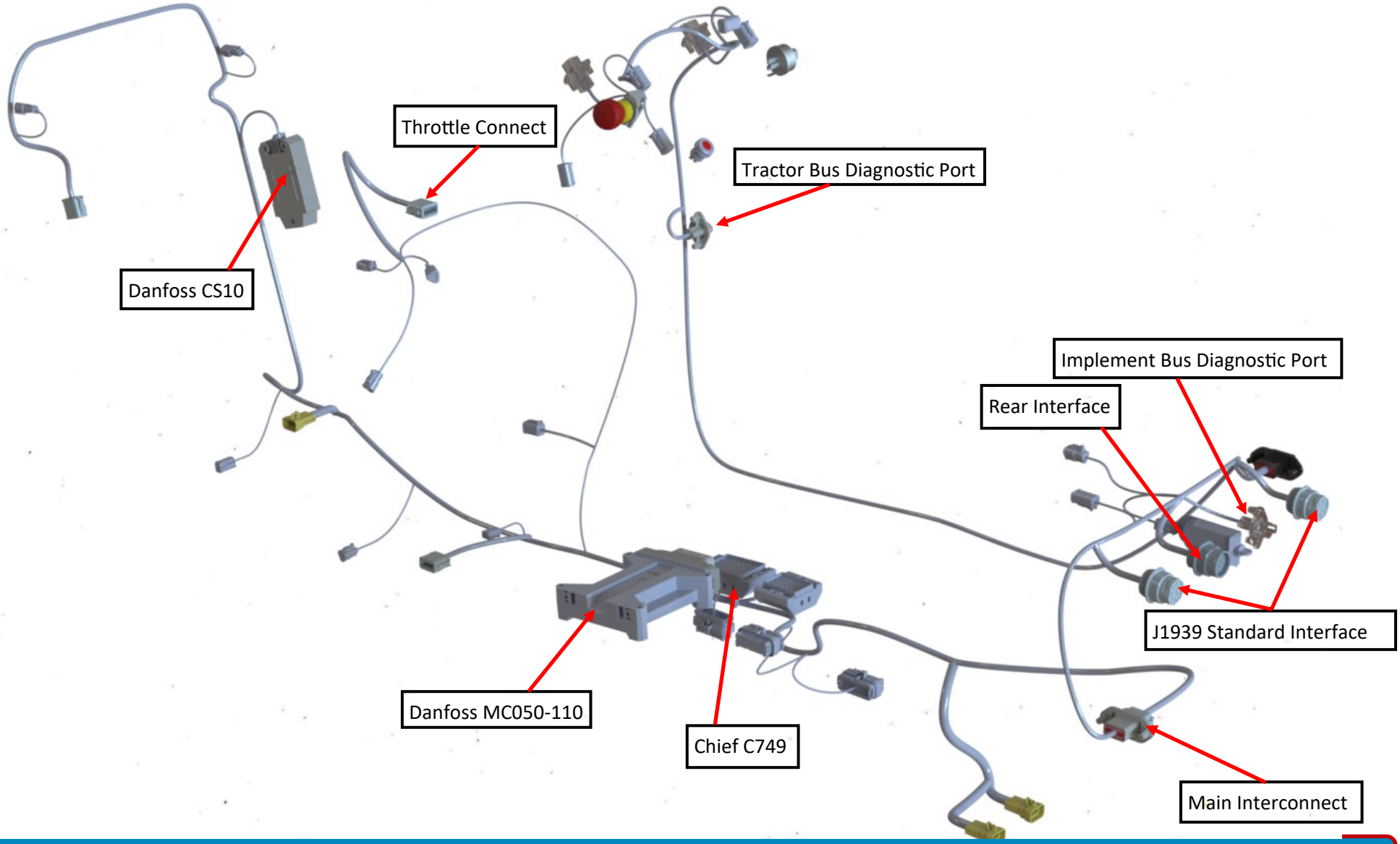


Figure 10.6: Stress Cast Upper A-Arm

Cy Spangled Banner's (CSB) backbone is the electric drivetrain. Spinning the Mot Energy ME1917 "generator," three-phase power is delivered to a Curtis AC F6-A power inverter, converting power to direct current (DC). DC power is then routed to two bus bars, splitting power to two Cutis AC F4-A power inverters and flipping power to three-phase. These inverters send power to two Mot Energy ME1917 "motors," enabling drivetrain output. Two indicator lamps wired in series are illuminated as the Curtis F6-A inverts power to DC, ensuring a visual representation of high-voltage power. Three-phase and DC conductors are appropriately sized, wrapped in orange split loom, and ring terminals are protected utilizing insulative boots. A rear electric power-take-off and high-voltage battery interconnect is integrated into the DC bus located at the rear of the tractor. Utilizing the nominal 96-Volt system boosts efficiency in relation to lower voltage alternatives.



The *Cy Spangled Banner (CSB)* electrical team created harness prints and a schematic for the 12-volt direct current system. This system is split into two main wiring harnesses allowing the operator's station to be easily removed from the frame. An extensive Controller Area Network (CAN) system is routed through *CSB;* split into two busses. The main bus connects vital components such as the Curtis power inverters, Danfoss MC050-110, CS10, ME1917, and more. An isolated implement bus is connected to the rear interface ports. This system offers a multitude of different diagnostic ports to improve troubleshooting and serviceability.



In 2024, CPP has continued their virtual modeling journey. The continued effort allows the team to test many aspects of their tractors before they are built. The team focused this year on model validation and correlating the virtual models to their physical counterparts. CPP was gifted the unique opportunity to test their 2022 model *Cymonstrator* on a chassis dynamometer. This chassis dynamometer allowed the team the ability to test an entire tractor and collect data against a consistent model. Testing in this way allowed the team to validate the output torque calculations on the 2022 tractor. This meant that the team could use that tractor to validate their traction model, a part of virtual modeling that has always been challenging to validate.

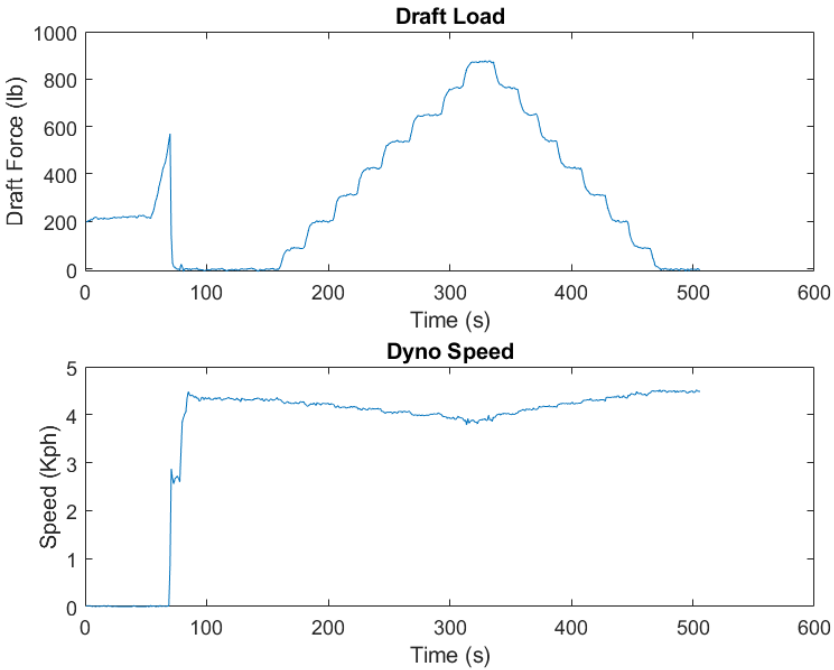


Figure 13.1: Draft Load and Dyno Speed over Time

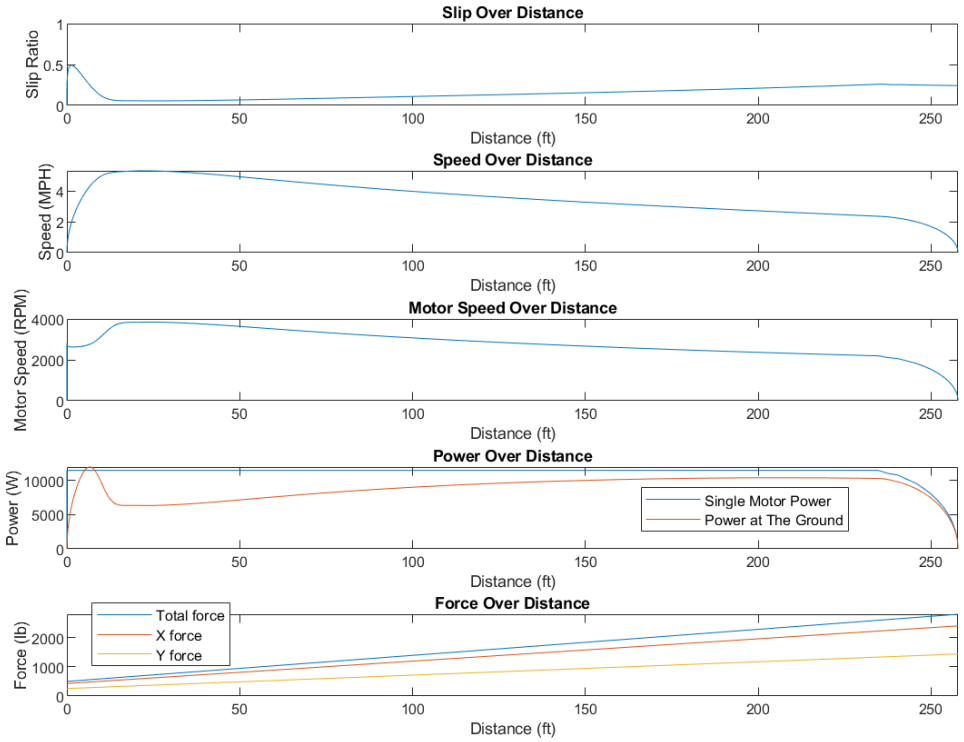


Figure 13.2: Results from Chassis Dyno

Figure 13.3: Cymonstrator on the Chassis Dyno

Durability, serviceability, and maneuverability were of utmost importance while designing the frame of *Cy Spangled Banner (CSB)*. The structural team decided to stick with the S-Style frame used in previous models due to its easy access to components within the frame rails, durability, and strength. The S-style frame also allows for components to be either slid in from the ends of the frame or dropped in from the top, unlike a C-style frame. This modular frame design, paired with the CPP standard tipping operators station, aims to make *CSB* one of the easiest tractors to service in the CPP lineup.

The frame of *CSB* boasts greater durability due to an increase in cross-member supports and an increase in their cross-sectional area due to the lack of a driveshaft. Another feature of the *CSB* frame is the CPP standard turret punch floorboards. These floorboards prevent operator slips and falls in wet and slick conditions. These floorboards are also designed to support the battery posts and the braking system for easy access. The *CSB* frame will also house the battery in a well-ventilated area at the heart of the electrical system.

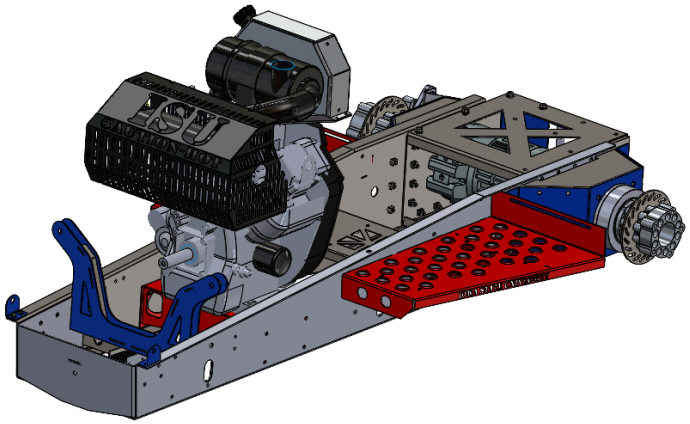


Figure 14.1: CSB Frame from the Front

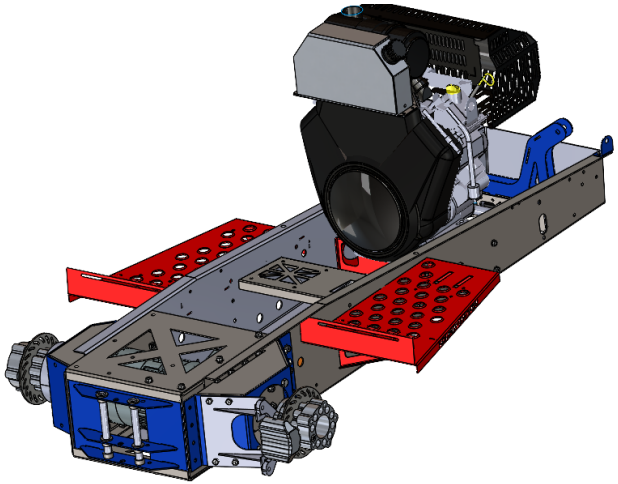


Figure 14.2: CSB Frame from the Back

To integrate the *Cy-Voltage* electric drivetrain, the frame was made wider than previous generations of CPP tractors at fifteen inches between the frame rails. To improve maneuverability, the frame design team went to great efforts to make the frame length as short as possible, at 70 inches. By doing this, the team aimed to make *CSB* better suited for tight operating conditions. This was made possible by moving the engine's output shaft to face the front of the tractor and utilizing every inch of *CSB.*

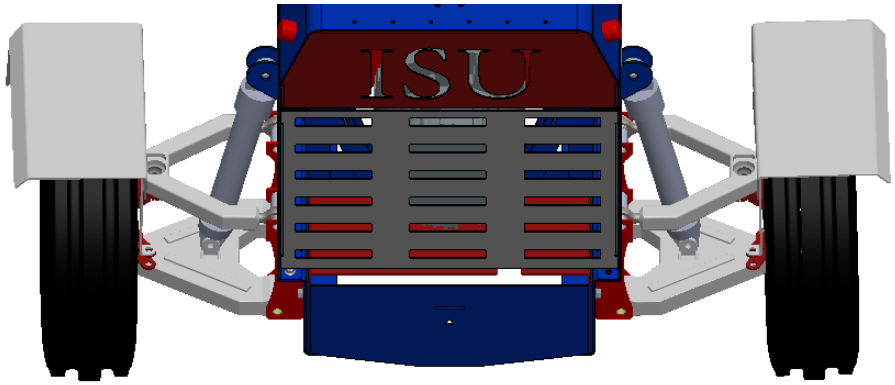


Figure 14.1: Cy-Spension III

In 2024, CPP continued to work to develop the *Cy-Spension* system. The primary focuses for the suspension design team were taking the rugged and dependable nature of *Cy-Spension* and making it lighter, more cost-effective, and easier to produce, all without compromising durability. *Cy Spangled Banner (CSB)* will feature the all-new *Cy-Spension III.* This new suspension system features new cast aluminum upper and lower a-arms, along with coil spring shock absorbers **(Figure 15.1)**. This design maintains the smooth-riding independent front suspension featured in previous model years. The cast aluminum a-arms allow for low-cost production, high levels of strength, and increased reliability. It also removes the need for a complex weldment, as seen in *Cy-Spension* and *Cy-Spension+.* The coil spring shock absorbers provide an off-the-shelf option, meaning they have low cost and high availability, all without compromising performance.

The *Cy-Spension III* cast aluminum suspension components were designed with several different features in mind. CPP is known to build durable and reliable tractors, and *CSB* is no exception. By keeping the same overall geometry as seen in the previous renditions **(Figure 15.2)**, *CSB* maintained a phenomenal turning radius and suspension travel. The upper aluminum a-arm features a bearing cup and adjustable rod ends with steel thread inserts for an easily adjustable camber angle and increased strength in the casting **(Figure 15.3)**. The new cast aluminum lower a-arm design presented a few more challenges as it needed to hold up to the spindle bearing, the shock mount, and tractor pivot. This meant there were three individual areas where this part would see stress and experience impact forces. To combat this, the suspension design team chose to increase wall thicknesses around machined holes, as well as design cast-in gussets to help support potential impacts and increase part longevity. Large sweeping fillets were used in areas to help increase overall strength. The overall design change has increased the strength of the suspension components while maintaining a low cost and high reliability.

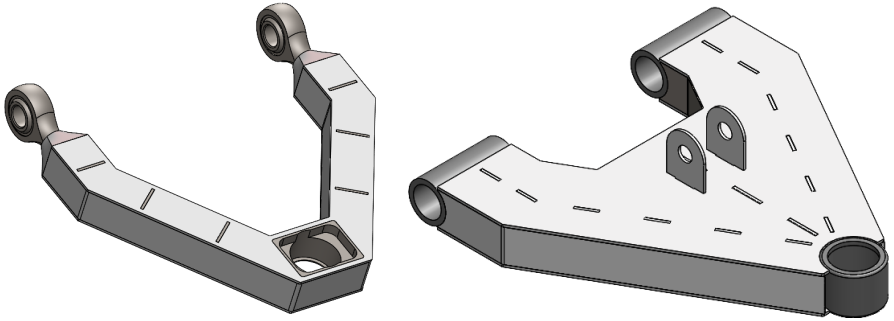


Figure 14.2: Cy-Spension+ Welded Components

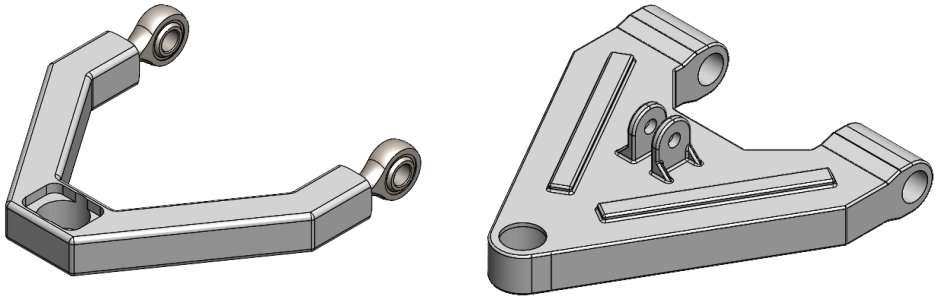


Figure 14.3: Cy-Spension III Cast Components

Cy Spangled Banner (CSB) utilizes a fully steer-by-wire control system. The steering of this tractor can be broken down into two significant sub-components. The first principal component is the steering mechanism in the front of the tractor, and the second is the active steering feedback system that the operator interfaces with. The mechanical steering mechanism features a mechanical gear-driven rack and pinion system with Heim joint rod ends. This gear rack is coupled to a brushless electric motor with a modular 100:1 gear reduction for increased torque. With three and a half turns from end to end, maximum left or right steering angle can be achieved quickly, with high efficiency and accuracy. The case-hardened gears in the mechanical steering set ensures that it can withstand impact from any operating conditions. This allows the tractor to steer while sitting stationary and in any soil conditions that might otherwise bog down any other system. The brushless motor is coupled to a CAN-based motor controller, which allows it to integrate seamlessly with the rest of the tractor control system. Lastly, the off-the-shelf selection of these components ensure that supply chain issues in an ever-flexible and volatile world will not drastically affect the production ability of this machine.

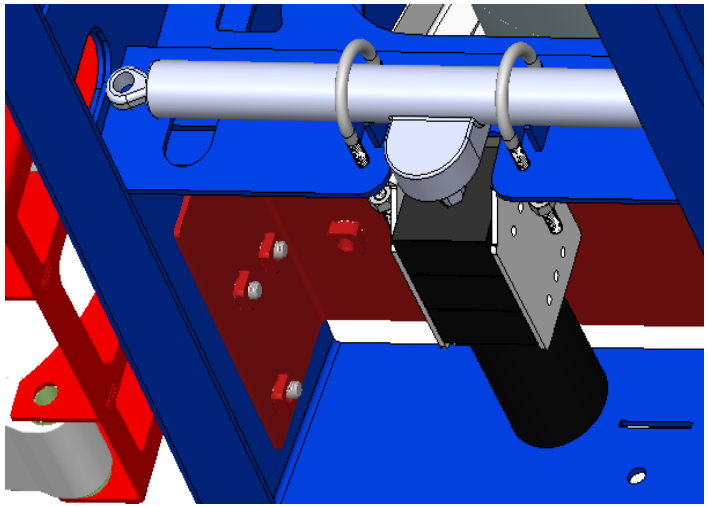


Figure 16.1: Electric Motor and Gear Rack

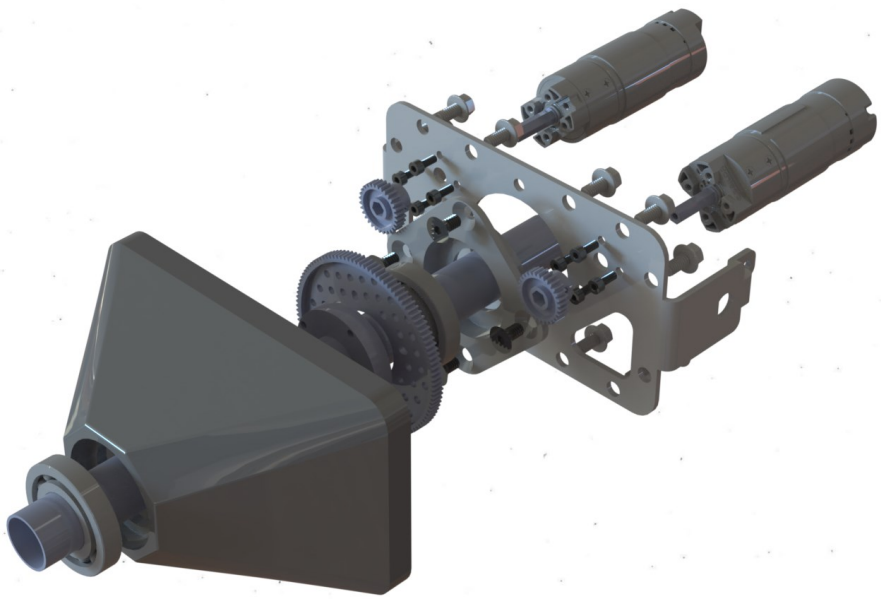


Figure 16.2: Cy-Steer

The operation of *CSB* is greatly enhanced for the user by providing a mechanical feel to a drive-by-wire system. *Cy-Steer*, (**Figure 16.2**) integrates an active steering feedback system (ASF) by monitoring the steering linkage at the front of the tractor. Force feedback can be given to the operator by utilizing effort monitoring on the motor actuating the steering rack. This gives the operator the feel of mechanical steering. The resistance does not overpower the operator but does alert the driver if the front end experiences any change in trajectory. During turning operation, the ASF is lessened, allowing for seamless control of *CSB*. Transitioning back into ASF is automatic; however, the user can enable and disable the system through the user interface on the side display. If disabled, *Cy-Steer* will only record positional data of the steering shaft through the ASF motors' encoder, which is relayed up to the front of the tractor to the steering motor. Once ASF is enabled, users are encouraged to select an appropriate gain value to determine how much feedback they want to experience during operation. By equipping the user with ASF, the operation of *CSB* will be similar to other vehicles with a mechanical linkage, reducing the learning curve of new users.

Cy Spangled Banner (CSB) offers maximum versatility and ergonomics integrated into its operator station platform. Startup functions are located at the front of the platform. The choke switch and key switch are located on the front and right-hand side, respectively, following previous CPP designs. User functionality is enhanced during the operation of *CSB* by incorporating major control components near the natural lay of human geometry. These components include the joystick, side console rotary dials, the keypad, and the side console display. Functionality of side console components is configurable through the side console display. However, preset values are determined by the manufacturer. This offers custom functionality to the rotary dials and keypad to be configured based on *CSB* application needs. Safety is specifically highlighted on the left side of the front of the operator station by an easily visible and open emergency stop button, with an easily accessible fire extinguisher to the operator's right.

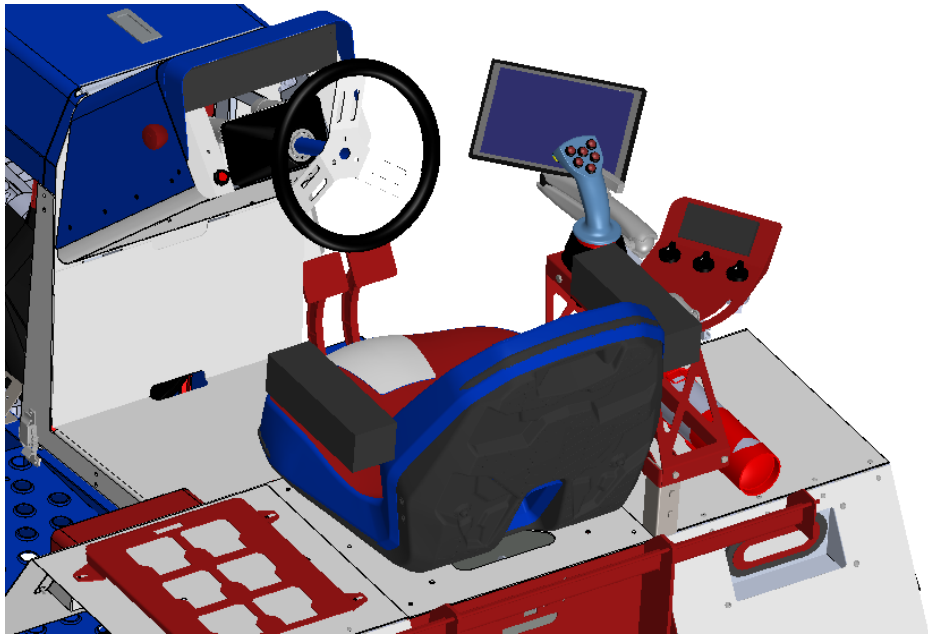


Figure 17.1: CSB Platform

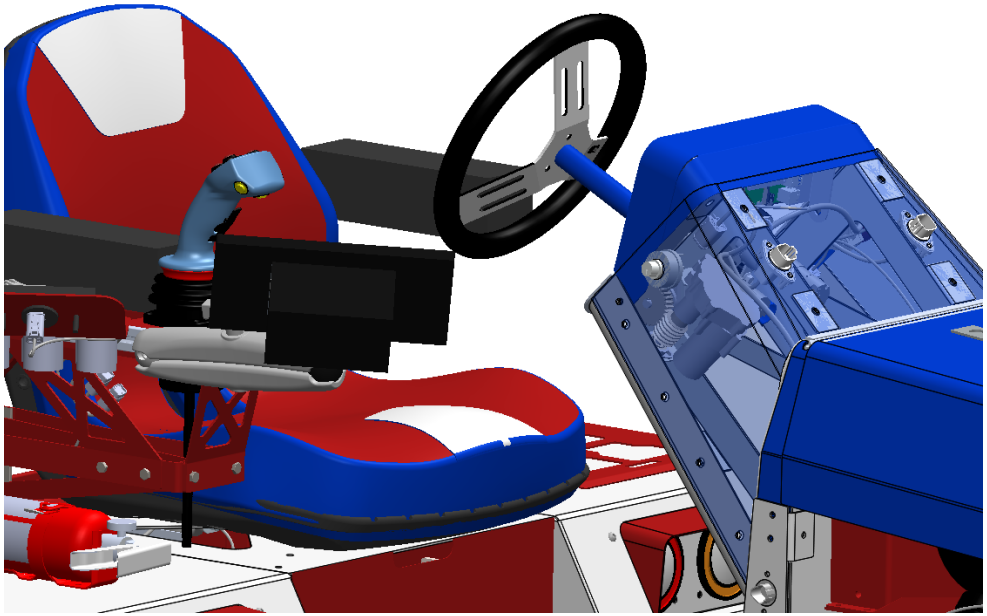


Figure 17.2: Operation

Sitting in the seat, operators have full adjustability to maximize functionality. Sliding rails mount the seat to the operator station base to allow forward and backward movement of the seat to ensure proper placement of the joystick based on the operator. The side console rotary dials and keypad rotate in and out to be set based on operator preference. *CSB's* side display incorporates adjustable mounts to allow three dimensional movement of this display to enable the operator to move this vital piece to any place best suited for the operator. T-slotted rails are also located on the side console and at the base of the front of the operator station to allow for further attachment options. These rails are paired with interconnection points that come default with power, ground, and CAN; integrating electronics into *CSB*. The operator also defines adjustment of the steering column by rotating one of the side console rotary dials. By rotating this dial, the column is rotated up and down, ensuring proper alignment of this vital component.

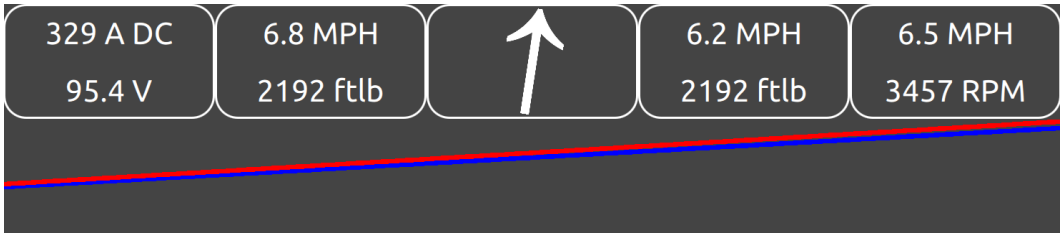


Figure 18.1: Front Display Option A

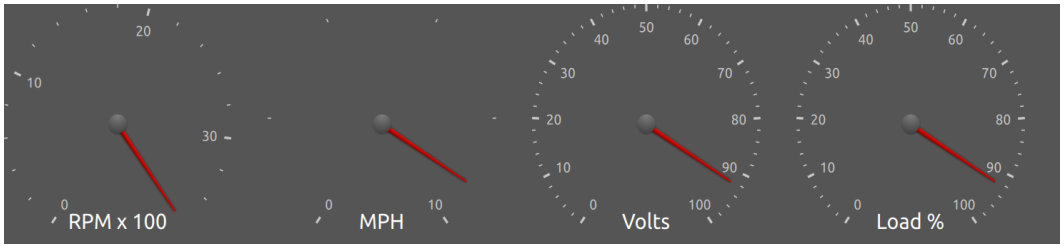


Figure 18.2: Front Display Option B

Keeping with CPP's focus on ease of operation and simplicity by design, the team focused effort on the display system on this tractor. *Cy Spangled Banner (CSB)* includes the CPP standard dual display package. The front display offers accessible information for the operator to view easily. The side display is the hub for user interaction. The side display shows diagnostic information and more in-depth operating parameters and exposes tractor settings. After many years of making tractor displays, CPP decided to make the most customizable display yet. The side display offers the user page, allowing operators to select a user profile change their steering settings through Active Steering Feedback and column tilt position. The operator profiles can also change the display itself. The operator has the option to change the entire color palate that the display offers. Operators also have the option to choose from a multitude of front display options. **Figure 18.1** and **Figure 18.2** show different options for the front display, from a classic gauge cluster to a sleek and modern digital readout with graphs to expose more vehicle information if desired.

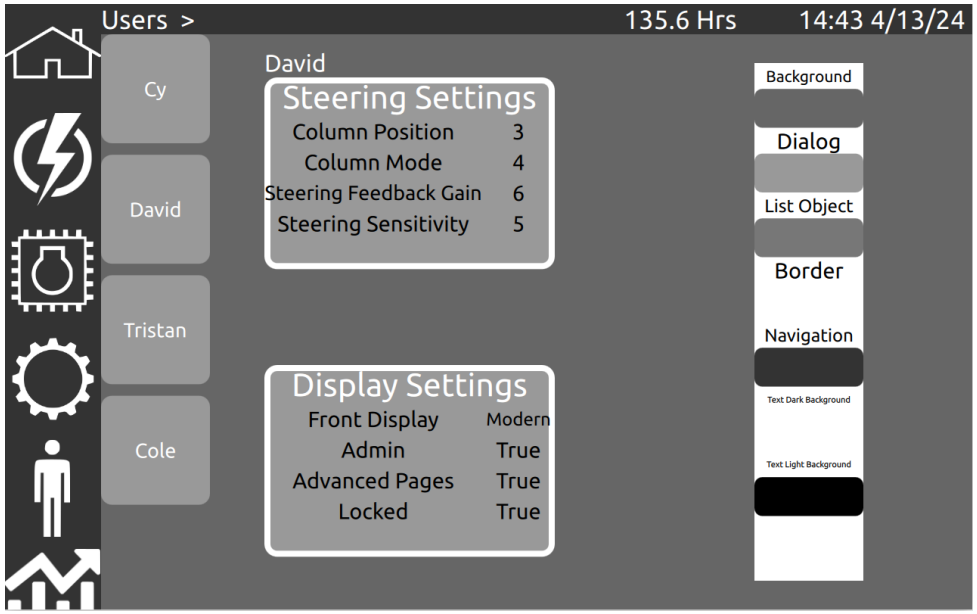


Figure 18.3: Side Display Setting Page

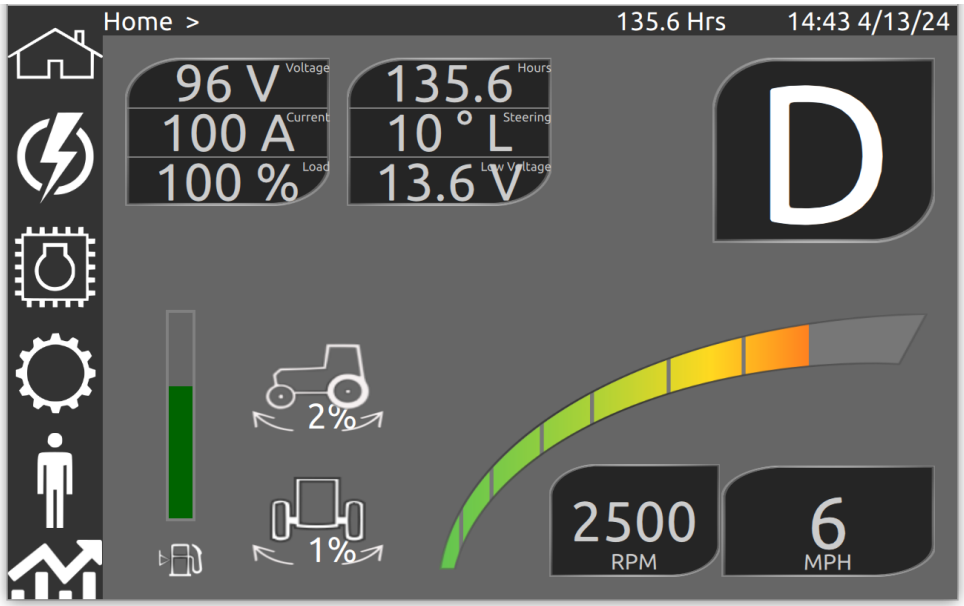


Figure 18.4: Side Display Home Page

CPP has a continued focus on serviceability and ease of operation. This focus extends throughout the entire tractor. The team decided to add operator manual information to the display, allowing the operator to have a secondary source for the information located in the owner's manual.

Cy Spangled Banner (CSB) has brought service intervals into the display with an interactive menu to see all service intervals, track the history of when they were completed, and be notified through a fault when the item is overdue.

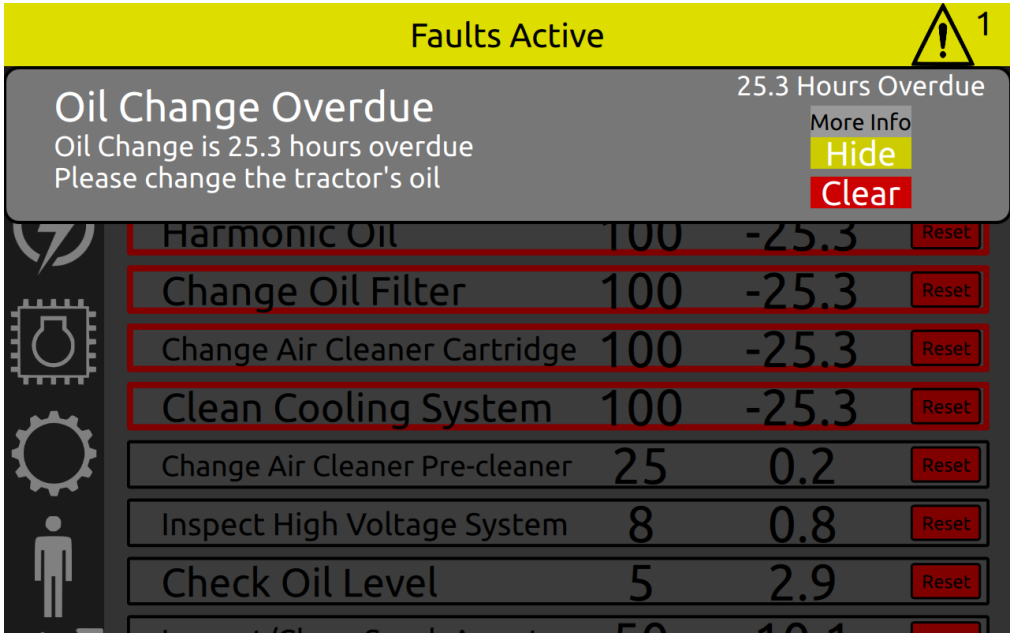


Figure 19.2: Side Display Fault Active

This service system also allows the operator to jump straight from a service interval or a fault into instructions on resolving that issue. On top of this, *CSB* will maintain a log of every maintenance operation performed; this log can be used for diagnosing issues down the line or assessing the overall health of the tractor.

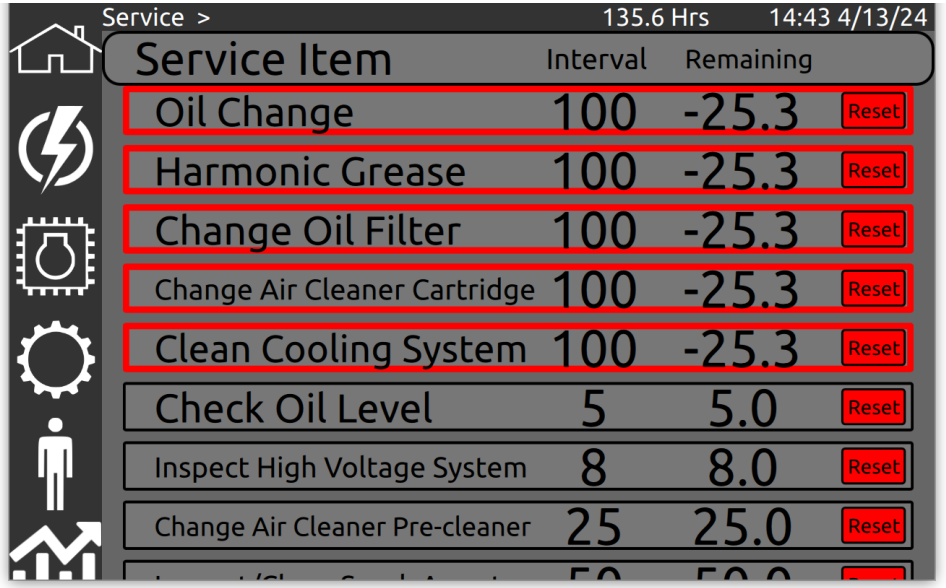


Figure 19.1: Side Display Service Page

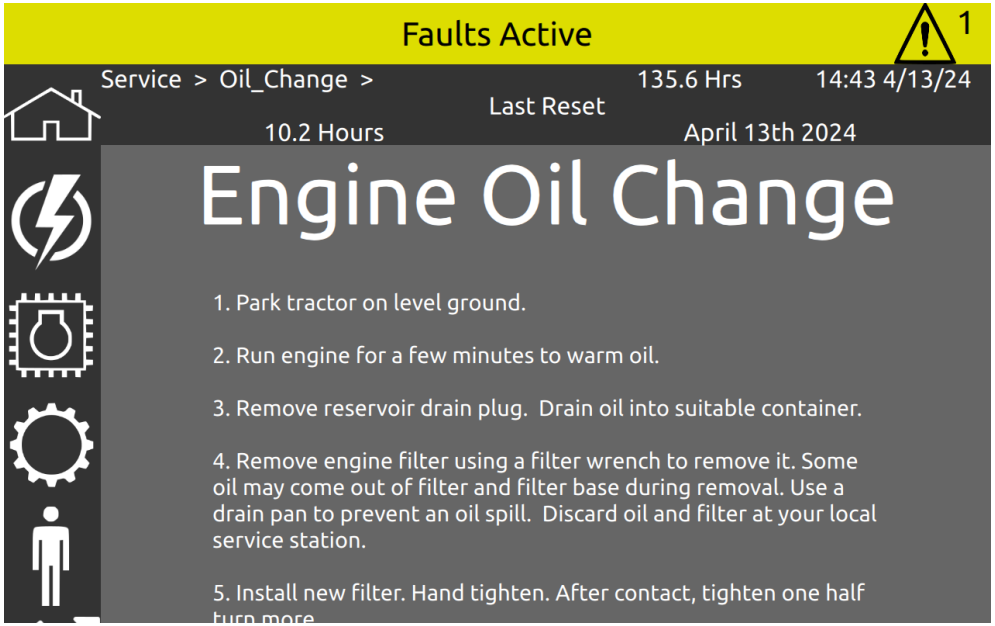


Figure 19.3: Side Display Fault Page

With serviceability as a focus, the sub-components of the chassis are designed in a modular fashion to bolt together and take apart shown in **Figure 20.1**. This modular design makes serviceability easier and more efficient, as only a small part of the tractor needs to be disassembled for servicing. The CPP tilt-up operator station and hood concept from previous models were applied to Cy Spangled Banner (*CSB)* **(Figure 20.2)**. This feature provides excellent accessibility to all core components of the tractor such as mechanical and electrical components to the power train system.

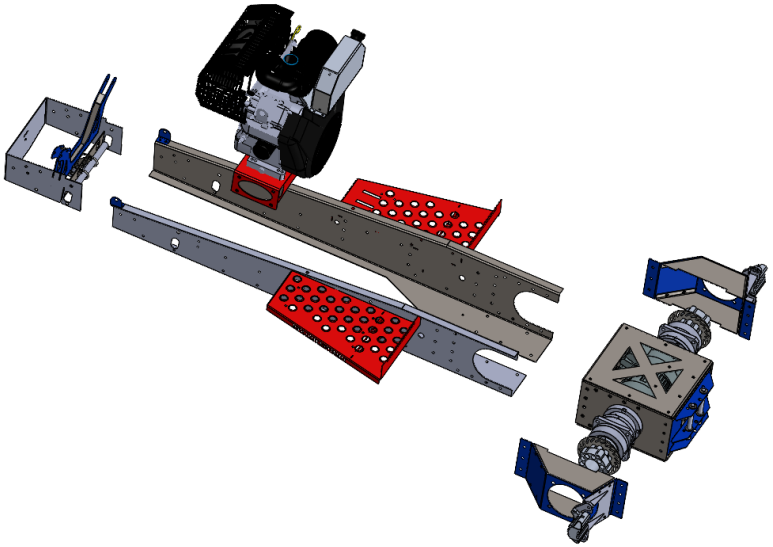


Figure 20.1: Modular Design

Figure 20.2: Cy Spangled Banner Accessibility

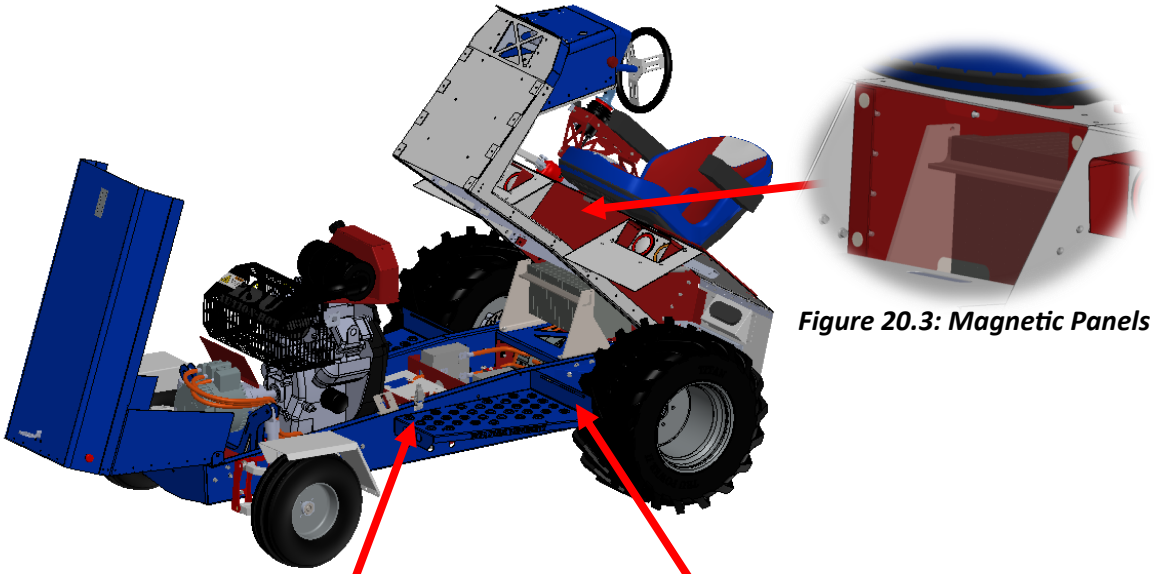


Figure 20.3: Magnetic Panels

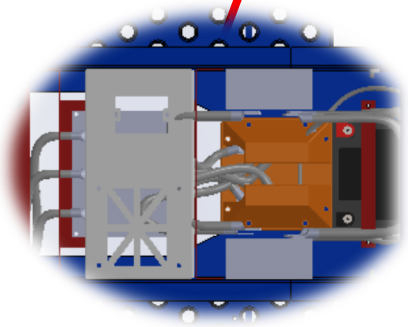


Figure 20.4 Organized Electrical System

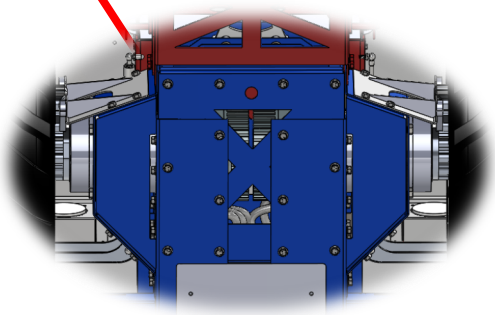


Figure 20.5: Modular Motor Box

The operator station features magnetic cover panels for quick access **(Figure 20.3)** to areas such as the controller, fuse panel, electric drivetrain inverters, and the low-voltage battery can be accessed for quick servicing or inspection. These designs give the operator peace of mind about keeping their machine in optimal working conditions. Given the advanced electrical system of the tractor, including the presence of high-voltage wires, it is crucial that wires and terminals stay sheathed for consumer safety. For this reason, high-voltage wires have sturdy high visibility orange sheathing to protect the system and operators, all connected to bus bars from the motors or inverters in a central and serviceable location. By locating electrical components in easy-to-access locations, centered in the frame **(Figure 20.4),** and using a modular rear motor box (**Figure 20.5)**, the maintenance of *CSB* is as easy as ever. The operator can also find serviceability pages on the side display for more in-depth service intervals and specifics. This information can also be found in the service section of the owner's manual mounted to *CSB.*

Operator safety is of great importance to the Cyclone Power Pullers. Making this a critical design criterion, the design team implemented many safety features of previous models to ensure the highest level of safety for the customer was achieved with *Cy Spangled Banner*. Some key features integrated into the *CSB* platform are the safety interlocks, orange sheaths on high voltage wires, and alerts for tipping potential when the tractor exceeds 15 degrees of rotation in any direction. CSB utilizes many ISO informative, warning, and danger decals which are posted on the tractor in the necessary places. Another essential item that the design team considered is that safety also includes the operators comfort. All within arms reach is the emergency stop kill switch on the left dash, the joystick on the operator console complimented by rotary dials and a keypad, and a fire extinguisher to the right of the operator. The tilt-up operator station utilizes locking gas struts that are simple to use and make sure that the operator station will not collapse or close unless the operator wishes to do so.

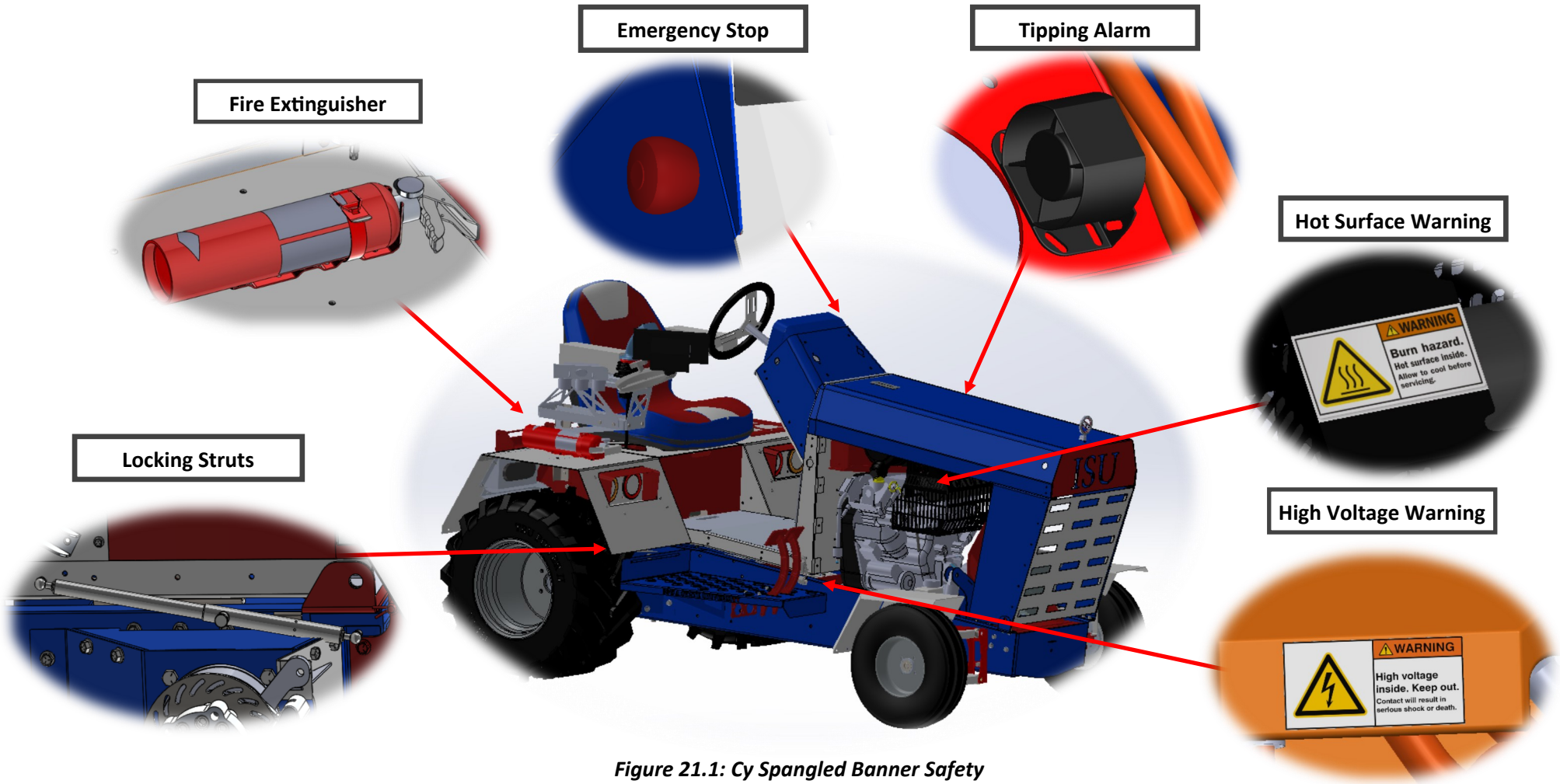


Figure 21.1: Cy Spangled Banner Safety

Cy Spangled Banner (CSB) was designed with the idea of limiting failure points and maximizing the customers safety, as well as the safety of the machine. This meant that evaluating components such as the frame, and its subsystems was necessary to ensure all quality standards were met and risk items were mitigated.

Item	Potential Failure Mode	Potential Effect(s) of Failure	Se-verity	Potential Cause(s)/ Mechanism(s) of Failure	Oc-curren	Current Design Controls	De-tectability	RPN	Recommended Action (s)	Responsibility and Target Completion Date	Action Results				
Function											Actions Taken	Sev	Occ	Det	RPN
Shock Tower	Welds	Suspension and steering fail, front of tractor could collapse	9	Weld quality control	3	CPP Manufactur-ing, CPP Design Standards	5	135	Ensuring all welders are certified and quali-ty standards are en-	Manufacturing and Quality Control	Increased hiring standards and quality control	9	1	3	27
	Hardware	Suspension and steering fail, frame rail separation, front of tractor may col-	8	Hardware Failure, Torque spec not met	2	Supplier Quality, CPP Assembly	3	48							
	Structural	Suspension and steering fail, frame rail separation, front of tractor may col-	9	Bending and/or Crack-ing	1	CPP Design Stand-ards	2	18							
Frame Rails	Welds	Floor Boards of tractor may detach from frame rails	7	Weld quality control	3	CPP Manufacturing Standards	5	105	Welders are certified and quality standards	Manufacturing and Quality Control	Increased hiring and quality con-	7	1	3	21
	Hardware	Sub assemblies of the frame may detach such as: suspension, generator sled, engine mount, motor box, and hitch	8	Hardware Failure, Torque spec not met	4	Supplier Quality, CPP Assembly	3	96							
	Structural	Tractor completely inoper-	10	Bending and/or Crack-	1	CPP Design Stand-	2	20							
Harness Brack-ets	Harness Management	Unsecure high voltage wires	9	Harness Clamp, Torque not met	6	Supplier Quality, CPP Assembly	2	108	Ensure toque specs of clamps are met and	Assembly and Quality Control	Increased hiring and quality con-	9	2	2	36
Motor Box	Hardware	Rear drivetrain may detach from tractor	9	Hardware Failure, Torque spec not met, Prolonged motor	4	Supplier Quality, CPP Assembly	3	108	Ensure toque specs motor box hardware are met	Assembly and Quality Control	Quality control practices with customer safety	9	2	3	54
	Structural	Frame may flex, Failure of	9	Bending and/or Crack-	2	CPP Design Stand-	2	36							

In 2023, Cyclone Power Pullers (CPP) saw immense growth of the production team. CPP has finally outgrown the confines of their previous production facility and will be saying goodbye to the old factory. CPP was able to purchase a 20-acre lot on Riverside Drive in Ames, Iowa near the Ames Airport. While leaving the former production facility may be a sad closing of a chapter for CPP, the new production facility allows for the optimization of production with a new facility. While remaining in Ames, the production team is able to keep a dedicated workforce while giving them a state-of-the-art production facility to rival any Fortune 500 manufacturer. *Cy Spangled Banner* will be the first production tractor produced from the new facility, while a new factory service and rebuild shop allows CPP to remain committed to their customers' needs.

While designing the new shop, the team wanted to maintain lean manufacturing practices by designing the machining, welding, and bending to run in parallel with the assembly line to ensure a low dependence on a warehouse of stock manufactured parts. For CPP's newly developed factory service and rebuild, the older tools from the machining department will be transferred to the service machinist while new CNC mills, lathes, and line boring machines are purchased for the production machining department. The focus of production is a one-way directional flow of material to a finished product. The work in progress (WIP) will follow this direction as the work feeds the production line. WIP storage will be place along the assembly line to lessen the distance a part travels before being used. Service and repair parts will be factored into the production line, and may move against the desired production flow, but that is something CPP does to ensure the best customer factory support possible.

To keep the office team deeply involved with the production team, the new offices are placed right along the production floor. This builds a relationship between the office team members and production members. An additional loading dock is included close to the warehouse for incoming shipments as well at the end of production an out going shipping dock at the end of the production line. Before a CPP tractor can be shipped to the customer, it must pass through the extensive quality control process to make sure the tractor is built to the highest quality. All tractors that don't meet the CPP standard will be reworked, while the team improves future production models.

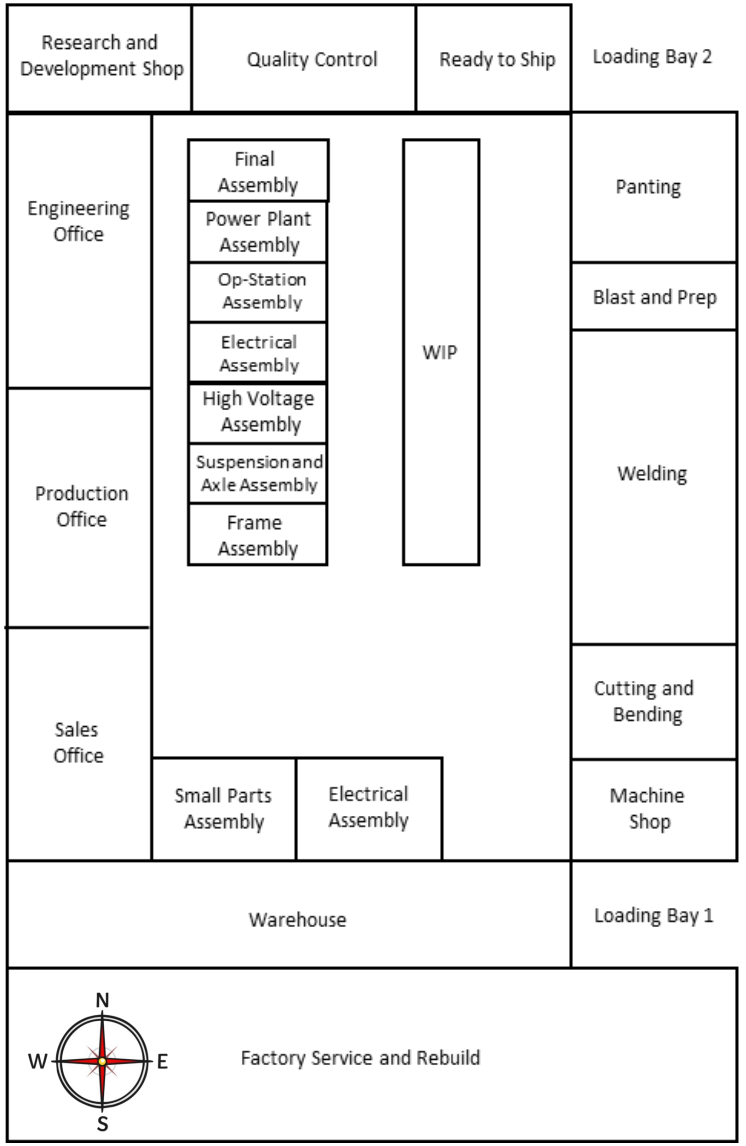


Figure 23.1: Plant layout

The 2024 production facility is designed to reign in a new era of CPP excellence while keeping the promise to customers of a quality product, even if it was purchased many years ago. The team is as dedicated as ever to build a quality product they are proud to say they had a part in producing while ensuring customer needs are met.

Red Model Options	Cost
Lighting Package	$ 83.47
Backup camera	$ 47.00
Ballast Package	$ 93.68
ISOBUS	$ 74.92
Wheelie bar	$ 67.73
Total Red Options	**$ 366.80**

Figure 24.1: Red Package Costs

During the development of *Cy Spangled Banner*, the team put great importance on making it affordable to customers. The team did this by pricing the three packages of *CSB* competitively to the market. To do this the team aims to have a gross profit margin of 20%, calculated using the variable manufacturing cost shown in **Figure 24.2**. (More information on this can be found in the Cost Analysis Report).

Blue Model Cost Analysis			
Category	Purchased	Fabricated	Cost/Unit
Engine System	$ 1,551.97	$ 83.27	$ 1,635.24
Drivetrain	$ 2,967.90	$ 112.44	$ 3,080.34
Tires and Wheels	$ 390.92	$ -	$ 390.92
Steering	$ 401.69	$ 605.57	$ 1,007.26
Frame	$ -	$ 428.44	$ 428.44
Body		$ 863.06	$ 863.06
Brake System	$ 333.94	$ 257.68	$ 591.62
Electical System	$ 1,274.70	$ 64.86	$ 1,339.56
Fasteners	$ 673.74	$ -	$ 673.74
Safety Equipment	$ 9.48	$ 143.84	$ 153.32
Misc	$ -	$ 148.83	$ 148.83
Trim		$ 64.38	$ 64.38
Assembly	$ -	$ 630.00	$ 630.00
Total	$ 7,604.34	$ 3,402.37	$ 11,006.71

Figure 24.2: Blue Model Cost Analysis

White Model Options	Cost
Battery Package	$ 4,500.00
PTO	$ 475.00
3 Point Hitch	$ 198.00
Front Wheel Assist	$ 2,800.00
Auxiliary Displays	$ 147.00
Total White Options	**$ 8,120.00**

Figure 24.3: White Model Cost Breakdown

Despite building a new facility the team has selected a period manufacturing cost of 17% because CPP was able to re-use many manufacturing fixtures from previous electric drive models. Another result of working off knowledge from previous electric drive models was selecting a Research and Development cost of 4%.

	Production Per Year	Variable MFG Cost	MSRP	Total Revenue	Net Income	Gross Profit Margin	Profit Per Unit
Red Model	600	$ 7,830	$ 9,800	$ 5,880,000	$ 1,182,228	20%	$ 1,970
Blue Model	1700	$ 11,007	$ 13,700	$ 23,290,000	$ 4,578,593	20%	$ 2,693
White Model	700	$ 17,641	$ 22,000	$ 15,400,000	$ 3,051,587	20%	$ 4,359
Total Per Year	3000			$ 44,570,000	$ 8,812,408		

Figure 24.4: Production Costs for Cy Spangled Banner Blue

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* Hyvee, Fareway Meat Market, Timpte, Interstate Batteries, Kwik Trip, Chief Enterprises, Snap-On

Acknowledgements

The Cyclone Power Pullers would like to say thank you to those who have helped us accomplish the task of building *Cy Spangled Banner.* The team's faculty advisor Dr. Stuart Birrell, for always extending his knowledge. The Iowa State University Department of Agricultural and Biosystems Engineering, for giving us the resources and tools needed to bring our design to real life. CPP's generous sponsors for their donations and guidance to support the tractor build.

Citations

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