Title Page

Design Report

School Name: *Purdue University*
Team Name: *ASME Racing*
Kart Number: *27*
Date: *03/26/2025*
Written by: *Eli Frank, Bradan Welby, Aashna Johri, Austin Tuerck, Yuvi Dahiya, Andres Sendra, Mia Chapman, Yash Saxena, Pranai Vijay*
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Scope / Overview (not counted in word or page count)

Instructions: Mark an "X" in the appropriate column for each system

SYSTEM	The entire system is a new design this year	The majority of the system is a new design this year.	The majority of the system is carry-over design this year.	The entire system is carry-over design this year.
Battery & BMS	x			
Motor & Motor Controller	x			
Mechanical Systems	x			

Introduction:

The Purdue EV Grand Prix is more than just a race—it's a showcase of engineering, strategy, and collaboration. For Purdue's ASME Racing, it's an opportunity to apply real-world design principles, solve complex problems, and build a competitive electric kart from the ground up. Every component, from the drivetrain to the chassis, reflects months of iteration and teamwork. This report highlights the design decisions, technical challenges, and innovations that brought our kart to the track.

This is Purdue ASME's first year competing in the EV Grand Prix with the objective of expanding ASME's automotive presence, having only previously participated in the Purdue Grand Prix. ASME Racing's mentality for this first appearance in the EV Grand Prix was very much that of learning, taking a "walk before you run" approach to the kart's mechanical and electrical design. This is not to say that there were not engineering decisions and analyses performed, but rather that the decisions made from these analyses erred on the side of caution and simplicity. This is why you will not see any custom PCBs or Battery Packs in our design, but analyses performed on the necessary custom components like motor mounts and other mechanical systems, BMS, Battery, and motor selection.

Battery and Battery Management System:

Requirements:

The requirement for Kart 27's battery was to adhere to the EV Grand Prix guidelines and provide a reliable and cost-effective battery pack under 100V and 4320 watt-hours capacity. Additionally, we had to ensure that the battery pack was enclosed and securely attached to the kart. This being ASME's first time competing in the race, simplicity was also a goal, so the pack had to be easy to work on, safe, reliable, and inexpensive. For the BMS, we were willing to spend more for a unit capable of being adapted to a custom battery in the future but still suitable for our current battery. Additionally, a unit capable of providing a large number of the industry's available safety features was prioritized.

Research & Predictions:

Previous EV Grand Prix teams primarily ran 18650 power packs produced by Boston Power. However, the recent bankruptcy prompted many teams to construct their own custom battery packs. We found that teams either used a fully custom pack or used power from CUIC for an easier assembly process. For our first year competing in the EV Grand Prix, we had to decide whether we wanted to create a custom battery pack or buy one, accounting for several account factors such as time, experience, and most importantly budget for building a pack. After taking everything into consideration we decided our best option was to use a premade battery pack, with hopes to make a custom battery pack next year.

To decide what batteries to use for our battery pack, we tested 18650 Lithium ion cells and 21700 Lithium ion cells. and made several calculations of a pack design. We found that, when running at the highest allowable voltage of 96V the 18650s resulted in 4197.96 watt hours and the 21700s resulted in 4212 watt hours. Ultimately, we decided that were we to go the custom route, 21700s were our best bet via a combination of their lower cost and better discharge characteristics. The calculator is shown below in Figure 1.

	A	B	C	D	E	F	G	H	I	J
1		26650			18650			21700		
2	Pack	48V	72V	96V	48V	72V	96V	48V	72V	96V
3	Series (pack v/nom cell v)	20	22	30	13	20	26	13	20	26
4	Parallel	16	15	11	26	17	13	20	13	10
5	actual voltage	64	70.4	96	46.8	72	93.6	46.8	72	93.6
6	cell weight (g)	88.1	88.1	88.1	46.5	46.5	46.5	70	70	70
7	pack weight (kg)(added 15% for architecture)	32.42	33.43	33.43	18.07	18.18	18.07	20.93	20.93	20.93
8	number of cells	320	330	330	338	340	338	260	260	260
9	actual pack power (wh)	4096	4224	4224	4197.96	4222.8	4197.96	4212	4212	4212
10								0	0	0
11	COST ($$$)	6.99	6.99	6.99	9.99	9.99	9.99	4.85	4.85	4.85
12	Pack cost (added base of $200 for architecture)	2436.8	2506.7	2506.7	3576.62	3596.6	3576.62	1461	1461	1461
13										

Figure 1: Custom Battery Calculator

Design:

The BMS is designed to use 36 cell taps and 8 thermistors to monitor the battery voltages and temperatures. It was the best BMS to go with the battery pack as it can manage the correct amount of cells, voltages, and temperature of the pack.

Build:

We needed a BMS that was able to group our 20 battery bricks (1 brick = 1 cell in the BMS manual) in such a way that it was able to record the temperature and voltage of each cell. We purchased the Orion BMS 2, shown below in Figure 2 with 36 cell taps and 8 thermistors. This BMS also comes with additional features such as monitoring the charging process to account for any failure before it is turned on. We were able to install the thermistors through small, insulated slots near the top corners of each brick. We put one thermistor in every other brick, 2 per row of 5 bricks, 4 per pack of 10 bricks. We also determined the order of the cell taps and decided to have two groups of 12 cells each (20, 21, 22, 23, 24 monitored as one cell as listed in the manual). We stripped the wires and connected them onto their respective nodes via screw wire connectors.

Figure 2: Orion 2 BMS

<u>Motor and Motor Controller:</u>

Requirements:

The EV Grand Prix allows for the kart's drivetrain to receive its power from one or more electric motors receiving their energy from a battery pack. Any type of electric motor and power controller is allowed. The requirements determined by our team for the controller were minimal cost, efficient operation, a lack of excess weight, and the ability to perform regenerative braking in tandem with the controller. Lastly, we wanted the motor and controller to be capable of operating on the higher end of the 100V limit due to the increased efficiency that comes with operating at a higher voltage

Research & Predictions:

Based on available sources and talking to teams with prior EV Grand Prix experience, we were able to narrow the scope of our motor selection to AC induction and brushless DC motors, as brushed DC motors had a tendency to burnout and other options were limited. Brushless DC motors seemed to be more prevalent in the series and were usually significantly lighter than their AC counterparts, requiring smaller mounts and less complicated controllers. AC induction motors, however, provided a superior efficiency and were capable of performing regenerative braking, aiding even further in efficiency.

Design:

Ultimately, we decided to use an AC9 and Curtis 1236SE combo sold to us by EVC, another team competing in the series. This decision was primarily based on budgetary concerns but the efficiency provided by this AC induction motor and customization provided by this controller made this an excellent choice for our newer team.

Build:

Figure 3: AC-09 Induction Motor Top View

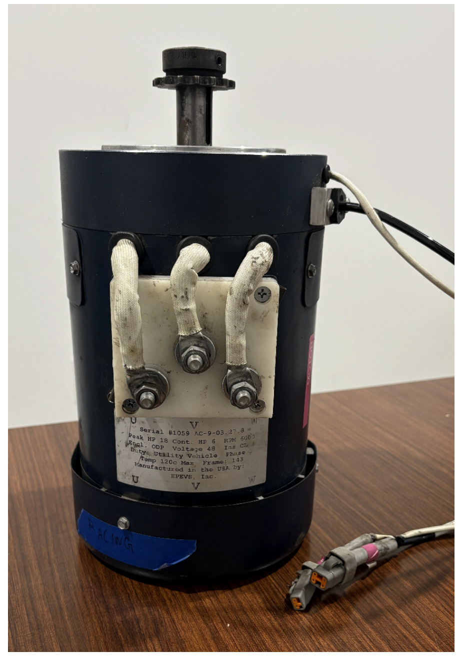


Figure 4: AC-09 Induction Motor Side View

Figure 5: Curtis 1236 SE Top View

Mechanical Systems Design:

Requirements:

The EV Grand Prix guidelines require all teams to use a commercial “sprint kart” chassis, and any additional components added must not drag on the ground. The chassis did not have mounts for the motor and battery, so our goal was to design components that would hold these additional parts securely and efficiently.

Research & Predictions:

Although we purchased a standard chassis, additional components were required to meet our performance and safety requirements. The primary additions were the battery and motor, which required custom mounting. Our primary objective was to create a lightweight, structurally sound design that integrated with the existing chassis while minimizing manufacturing and retaining familiar vehicle dynamics.

When determining how to mount the battery pack (≈70 lb) and motor (≈50 lb), we had to account for the additional weight compared to a gas kart. Initially, we considered extending the sidebars to accommodate the battery packs. However, upon further analysis, we found that this would exceed the maximum track width allowed for competition, making it an unsuitable option. Instead, we explored different placement configurations to balance weight and handling characteristics.

We determined that distributing the battery weight across three primary locations: one full pack opposite the motor, half a pack between the driver’s legs, and the remaining half on the motor side, resulting in similar forces and understeer characteristics to a gas-powered kart, which our driver is already experienced with (Anaya et al. 2019). However, we ultimately decided to stack the battery packs vertically on the sidebar due to their reduced complexity, intact battery casing, and fewer required mounting parts.

This raised concerns about an increased center of gravity (CoG), which will impact vehicle dynamics. To validate the concerns about the impact of the raised CoG, we plan to conduct testing on kart stability and weight distribution once final assembly is complete.

Another critical factor was weight reduction while ensuring structural integrity and manufacturability. We evaluated steel, aluminum, and composite materials for the mounts:

- Aluminum: Lightweight but with lower strength, requiring thicker sections.

- Steel: Highest strength but heavier.
- Composites: Lightweight but pose manufacturing challenges.

Ultimately, we selected steel for its superior strength and ease of welding/manufacturability. This choice resulted in an increase in structural strength over aluminum while reducing welding difficulty and assembly time.

Design:

We replaced the current side bars with a new design with extra bracing in the middle, made from 0.875-inch OD steel tubing with a 0.125-inch wall thickness, to ensure our battery packs had a strong platform. This also gave us more points to attach our mounting brackets, as shown in Figure 6.

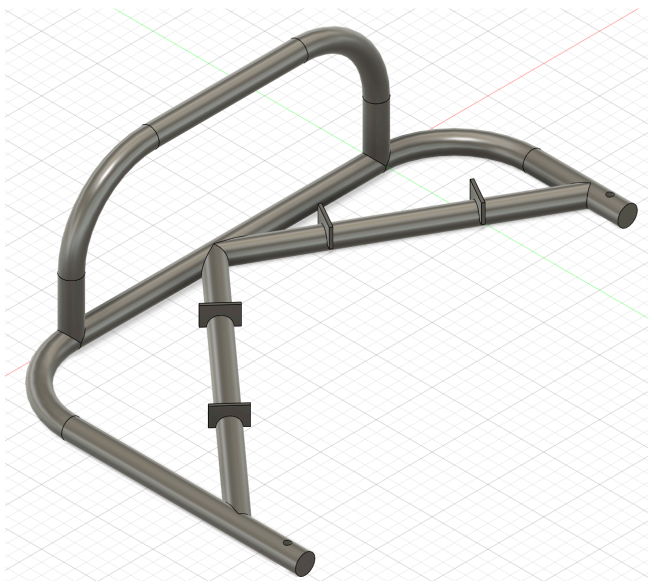
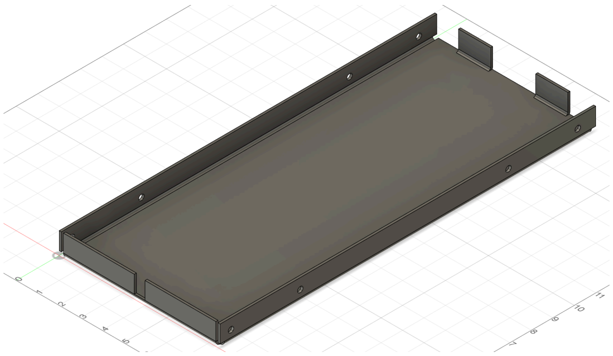


Figure 6: Improved sidebar for battery mounting

We also made mounting trays to house our battery packs, motor controllers, and other miscellaneous items. We wanted to contain everything neatly and found that bending sheet metal into trays was the most efficient and effective option. The battery mount and motor controller mount are shown in Figures 7 and 8 below.



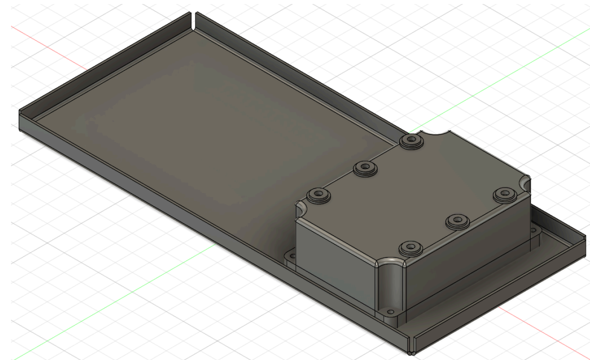
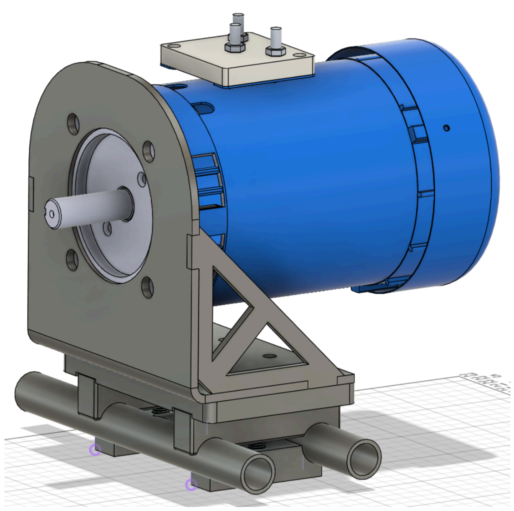


Figure 7: Battery Tray CAD

Figure 8: Motor Controller Tray CAD

We designed a motor mount that mounts to existing points on the chassis while providing us with adjustable chain tension. The CAD models are shown in Figures 9, 10, and 11, and the finished mounting plate is shown in Figure 12.



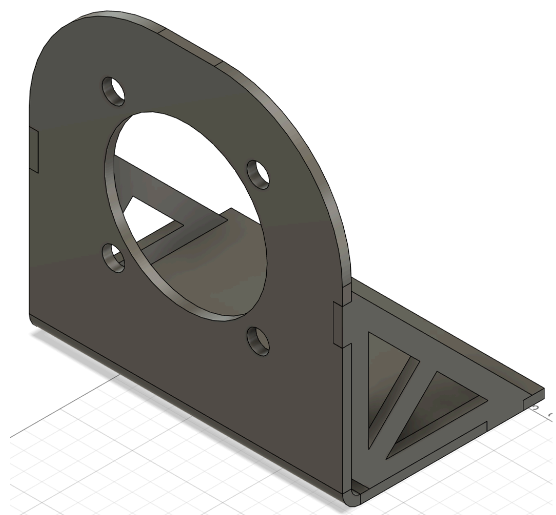
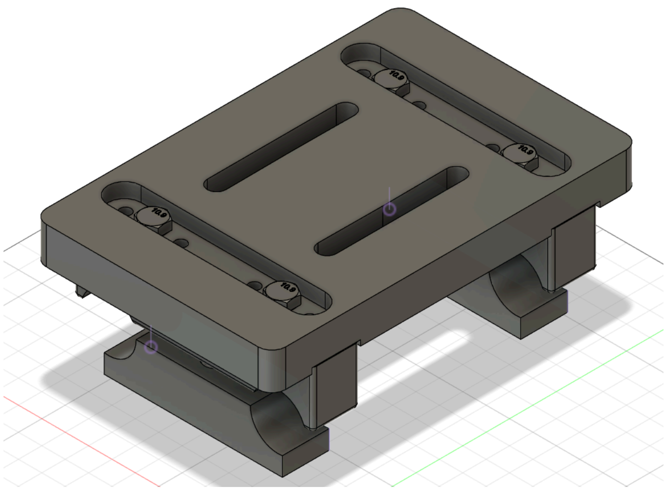


Figure 9: Motor Mount Assembly CAD model

Figure 10: Motor Mount CAD model



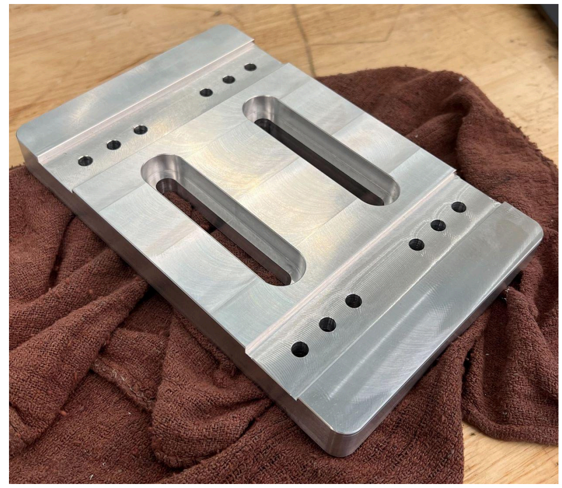


Figure 11: Motor Mounting Plate CAD mode

Figure 12: Machined Motor Mounting Plate

In determining the gear ratio that would be used on the kart, we started by building a MATLAB calculator to give us approximate values based on speed and RPM ranges. The MATLAB script can be found below:

```
motorRPM = 7000; %final drive RPM
vehicleSpeed = 50; %desired top speed
motorTeeth = 15; %sprocket size on motor shaft
tireDiameter = 10.5; %diameter of drive axle tires

wheelRPM = (vehicleSpeed * 1056) / (pi * tireDiameter); %converting units
gearRatio = motorRPM / wheelRPM;
axleTeeth = motorTeeth * gearRatio;
axleTeethRounded = round(axleTeeth);

fprintf('\nTo achieve %.1f mph at %d RPM:\n', vehicleSpeed, motorRPM);
fprintf('You need approximately %d teeth on the axle sprocket.\n',
axleTeethRounded);
```

Based on the inputs seen above, a sample output is shown below:

To achieve 50.0 mph at 7000 RPM:
You need approximately 66 teeth on the axle sprocket.

From the range of values generated by the calculator, we bought a range of rear sprockets ranging from 40 to 70 teeth. We aim to test the different sprockets on track to see which performs the best, seeing as we have not had on-track EV experience and do not know how the track performs with an electric drivetrain.

Build:

As shown in Figure 13, we will mount the battery packs to the battery tray and the sidebar. We plan to use custom brackets to secure the top battery to the bottom battery and the existing threaded rods used in the pack's construction to secure them to the bent sheet metal tray.

Figure 13: Battery Pack Assembly

As shown in Figure 14, we will use the other sidebar to mount the motor controller and miscellaneous items, like fuses, shunts, and precharge circuitry, on the other tray. Components will be directly bolted to the tray.

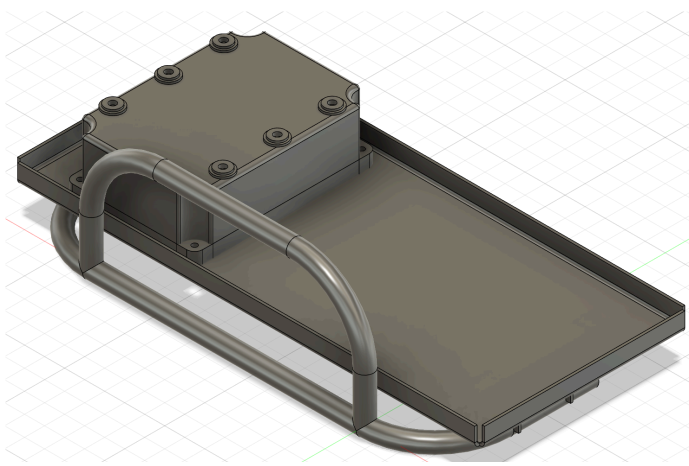


Figure 14: Motor Controller Assembly

Test:

We were not able to test the kart before submitting this report. However, we will test the following in the upcoming track tests.

- Test different sprockets on the kart to select the best one based on the range provided by the MATLAB calculator.
- Determine whether vibrations loosen components mounted on trays.
- Evaluate the effectiveness of different vibration dampeners in reducing loosening effects.

Correlation/Iteration/Optimization:

For our first iteration, we 3D-printed the motor mount to test whether it would fit properly on the chassis and see if any other changes needed to be made. We decided to increase the degrees of freedom to the motor mount to allow for sprocket alignment and allow for chain tensioning.

Conclusion:

ASME Racing's kart is the culmination of many hours spent researching, learning, designing, testing, iterating, building, and assembling. The initial goal of the 2025 race was an expeditionary adventure for ASME into the EV Grand Prix, seen as an opportunity to test our knowledge and conceptual understanding of EVs without producing a kart on the top level of competition. Hours in CAD and CAM softwares, the Bechtel machine shop, and our ME Klondike workspace have paid off in the physical manifestation of our hard work that is kart number 27. We are more than excited to see how our first foray into the EV Grand Prix goes and how we can improve upon each of our design choices and engineer an even better kart for the 2026 race.

References

Anaya, J. M., Calderon, S. C., Bradley, A., & Gonzalez-Mancera, A. (2019). Multibody Simulation of an Electric Go-Kart: Influence of Power-Train's Weight Distribution on Dynamic Performance. *Volume 3: 21st International Conference on Advanced Vehicle Technologies; 16th International Conference on Design Education*. https://doi.org/10.1115/DETC2019-98112