Honda EV Conversion

Final Proposal

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DISCLAIMER

EXECUTIVE SUMMARY

The following document describes the final proposal for the Honda EV Conversion senior capstone project. The goal of the project is to provide sponsor company, Hasport Performance, Inc., with a design for an electric vehicle (EV) motor swap kit that allows for the conversion of a series of late 1990's Honda vehicles. Hasport is an automotive aftermarket part manufacturer that specializes in Honda vehicles. This project aligns with the company's current work and would appeal to their current clientele. This project would also push Hasport to the front of the electric swap community, as an electric swap kit for late 1990's Hondas has not yet been developed.

The test vehicle for the electric vehicle swap kit is a 1998 Honda Del Sol. This vehicle will be used to gather measurements and test any parts created for the swap kit. The kit's design will be made for a Tesla small drive unit (SDU) and Chrysler Pacifica hybrid batteries to be put in by the consumer, per the request of the client, Hasport's owner, Brian Gillespie. The client also specifically requested that the designed kit requires no modifications to the vehicle's frame so that parts only need to be swapped in and out with the existing mount points in the vehicle. Gillespie also requested that the design uses one of Hasport's existing mounts, in order to have a copyrighted part in the design and protect the design from competitors who may want to copy/sell a modified version of the design. After the design for the Honda Del Sol is made, the design will be simple to implement into other late 1990's Honda vehicles, as there are many similarities between the frames and mount points between the various models.

In addition to the requirements given by the client, there are other criteria that help determine the validity and quality of the generated concepts. These include sufficient battery life for an average commuter, lightweight, compatibility to similar vehicle models, allows for cooling system for batteries and electric motor, and consumer sellable product. These criteria are used in a decision matrix to decide the concept that proceeds to be the design implemented in the project. The design chosen, called "K-Flip", ranked the highest in smallest modification to the vehicle, being lightweight, customer simplicity, and number of mounts, making the concept the best choice to move forward with.

The proposed design implements directly into the existing vehicle frame and uses the existing mount points in the Honda Del Sol. On the passenger side of the vehicle, the factory mount from Tesla connects to the small drive unit, just as it did in the original Tesla the salvaged motor came from. A set of bunny ears connects to the factory mount. The bunny ears are welded to a subframe rail that connects to the mount points on the frame where the original engine from the Del Sol was mounted. On the driver's side, a bent plate is bolted to the motor, and the plate bolts to a pair of Hasport's K-Flip3 mounts, meeting the client's requirement of using a copyrighted part. The K-Flip3 mounts bolts to two sets of bunny ears, which are welded to another subframe rail on the driver's side of the vehicle. The driver's side subframe rail also bolts to the existing mount points in the vehicle. A tray that bolts to the gas tank holds six batteries and uses the existing mount points in the gas tank. A functional prototype of the design has already shown that the design is able to successfully hold the motor while the vehicle is static, however, testing must be conducted to test the possible modes of failure, such as excessive torsion placed on the set of bunny ears on the passenger side of the vehicle.

To test this design, a multi-stage testing plan will ensure the design will be functional and ready for consumers. The first stage of testing will be done at Hasport, and will ensure that the vehicle will move both forward and reverse without any concern for range. The first test will also test the batteries' ability to charge. The second test will begin testing range by driving the vehicle around a street block and will check for vibrations that indicate that the mounts are not strong enough to keep the motor and batteries static relative to the moving vehicle. The third test will have the vehicle drive on the highway to test the maximum range of the vehicle and ensure the vehicle can handle the higher velocities associated with being a commuter vehicle. The final test will see if the vehicle can drive from Phoenix to Flagstaff on one charge. This test will find how the vehicle responds to inclines, as there is a 6000-foot elevation difference between the two cities. The test will be a further test of the vehicle's range.

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1 BACKGROUND

1.1 Introduction

This document outlines the final proposal for the completion of the Honda Electric Vehicle (EV) conversion capstone project for the Fall of 2022 and Spring of 2023 at Northern Arizona University. The purpose of this project is to develop a kit for project sponsor, Hasport Performance, Inc., to sell to its customers that allows for the performance of a gas engine to electric motor drive conversion for a variety of late 1990's Honda vehicles. The test vehicle, provided by Hasport, is a 1998 Honda Del Sol, which has many similarities to many chassis that Hasport already manufactures parts for. The main objective for the capstone project is to make electric commuter vehicle conversions accessible to the average car enthusiast. This will help client Brian Gillespie grow his brand in the automotive aftermarket and advance the available product line for his company. The market's transition into fully electric consumer vehicles and the current pricing of electric vehicles that is out of reach to an average consumer ensures that this project's relevance will put Hasport Performance at the forefront of the electric vehicle swap kit market.

1.2 Project Description

The sponsor of this Capstone project provided baseline objectives and goals that the team should meet. The main objective of the project is to design and manufacture an electric vehicle (EV) kit that consumers use to swap out a gasoline engine for electric in a select range of Honda vehicles. Section 2.1 covers the creation of the customer requirements from the client's needs. This section covers in detail specifically how each customer requirement pertains to what the client is requesting from the project. Section 2.2 details the creation of the engineering requirements from the customer requirements. This section includes requirements used for the House of Quality. The House of Quality determines technically important requirements and is elaborated on in section 2.4.

2 REQUIREMENTS

In order to determine the most appropriate design for the conversion kit, the team had meetings with its client to understand their expectations and goals for the project. From these meetings the team has defined specific customer requirements that the design must meet, along with a set of corresponding engineering requirements, each presented in Sections 2.1 and 2.2, respectively. Taking these requirements into account, a functional decomposition was performed to create a clear picture of the broad functions that the design must carry out and each input and output that correlates to each function; this is described in detail in Sections 2.3. Next, Section 2.4 explains the project's House of Quality model, which was developed to prioritize the customer and engineering requirements and to perform a basic benchmarking against comparable existing products. Finally, all applicable standards and regulations that the team and design must abide by are presented in Section 2.5.

2.1 Customer Requirements (CRs)

The sponsor verbally communicated the project requirements to the team. The following statements introduce the requirements provided and clarify each to create the customer requirements. This kit provides electric motor and battery mounts, the wiring harness and associated electrical systems, and procedures for reversing the oil pump in the Tesla motor and installing the kit. The kit must be affordable in comparison to benchmarked products that exist on the market currently. The client stated that the range of this EV swap must cover at least the mileage expended on a typical commute to and from work. The mount design must be universal to Honda model Civic, Integra, Del Sol, and CRV. The kit must include 6 or more batteries to meet the minimum number of batteries to power the motor. No modifications to be made to the frame of the vehicle to make the kit user-friendly. The cooling system will be custom installed for this vehicle but must be transferrable to other similar models. From these verbal requirements the customer requirements are clarified and shown below.

The sponsor gave a list of requirements for the design. The customer's requirements, weighted by importance, are as follows:

1. Battery life sufficient for average commuter (15%)
2. Mount solutions for batteries and electric motor (15%)
3. Six or more batteries in vehicle (15%)
4. Consumer sellable (safe and durable) product (15%)
5. No modification to existing vehicle frame (10%)
6. Lightweight (10%)
7. Cooling system for electric motor (10%)
8. Compatibility to similar vehicle models (10%)

The first 4 CRs are weighted highest since these CRs are imperative to project success, and the lower weighted requirements are secondary requirements. Each CR contributes to the final product of this vehicle swap kit, incorporating all needs provided to the team by the sponsor.

The following requirements are class specific CRs that are incorporated into the project along with the sponsor generated CRs.

1. Cost within budget
2. Durable and Robust design
3. Reliable design
4. Safe to operate

2.2 Engineering Requirements (ERs)

The engineering requirements for the Honda EV Capstone are developed from the CRs. Each ER is justified by a corresponding CR. The CRs used to create the ERs may be reused to accommodate the sponsor's needs in the project. The following table represents how each ER is developed and the appropriate justification is provided.

Table 1: ERs developed from CRs

Customer Requirement	Developed Engineering Requirement
Battery life sufficient for average commuter	Increase range greater than 100 miles
Six or more batteries in vehicle	Increase battery capacity greater than 40 kWh
Consumer sellable (safe and durable) product	Reduce cost of production ($)
Consumer sellable (safe and durable) product	Maximize power output 300 hp
Consumer sellable (safe and durable) product	Maximize torque output 250 ft-lb
Lightweight	Decrease weight less than 3000 lbs.
Cooling system for electric motor	Cool components to less than 200°F
Compatibility with similar vehicle models	Reduce number of mounts, 5 or less

Each ER has a measurable target value specified by the sponsor or assigned by the team. The team researched the average distance of a typical commuter car which is around 27.6 minutes [2]. Most drivers (85%) travel less than 75 miles per day [3]. The first ER parameter is 100 miles to include enough mileage for the commute to and from work and extra to account for the ever-increasing commute distance in America [2]. A typical Chrysler Pacifica hybrid battery holds roughly 16 kWh, the target value of 40 kWh accounts for less batteries in this project but is a reasonable capacity to achieve [4]. The project should stay in a reasonable budget of $4000 or less, incorporating the cost of donated items, such as the materials and vehicle. To keep this kit appealing to a consumer market, the motor needs to be able to output maximum torque and horsepower when under optimal battery capacity conditions. The weight of the vehicle needs to stay under 3000 pounds to achieve the other ERs such as maximizing power and torque output and increasing the range of the motor. The cooling system for the electric motor need to stay under 185°F according to Tesla cooling requirements [5]. With respect to the batteries, there is no longer a need to consider incorporating them into the cooling system; the team has opted to make use of Chrysler Pacifica hybrid batteries which are only passively air-cooled and not tied into any heat exchanger circuit. To keep the motor cooled properly, temperatures will ideally stay below 200°F. To keep the kit compatible with other vehicles, the number of mounts is minimized to 5 or less. The anticipated number of mounts is for battery placement in the engine bay, fuel tank, and trunk of the vehicle. Each ER is verifiable with standard measurement tools. The range of the electric motor will be determined empirically.

2.3 Functional Decomposition

The final steps of researching electric vehicle conversions and developing the primary features of the conversion kit features involve creating the design's black box model, which gives an overview of the general function the kit must perform along with various inputs and outputs to the design. With this model the team then performs a functional decomposition; a thorough analysis of each material, energy, and signal input and the step-by-step function that each one contributes to the design in conducting its defined main function. Breaking the design down to each step of its functional process gives a strong perspective to the team of what tasks must be performed, so that in the concept generation process each member creates their variants with the necessary functions at the front of mind.

2.3.1 Black Box Model

A black box model is meant to provide a macroscopic view of the main function that the design must perform and descriptions of its accompanying materials, energies, and signals that are both input to and output from the design when it conducts that function. The primary purpose of the design that has been defined is that it must position the Tesla SDU and at least 6 total batteries correctly within the design vehicle, and that it must securely constrain it to that position under normal city and highway automotive operating conditions. With the broad overall description of the design's main function established, the team must identify the materials, the types of energies, and the different signals that are considered as inputs into the design performing its function, followed by characterizing a similar set of outputs for each of the corresponding inputs.

The materials are the broadest set of inputs, including the Tesla SDU, the batteries, and all the fasteners that are required to be input into the design vehicle and the design itself, though the only output in this regard is that each material remains constrained in their respective locations. Next, the energy input into the design's main function comes solely from the array of batteries that are fastened into the vehicle, however the energy outputs are a bit more complex in the torques and bending moments that will be placed upon the design during vehicle operation. Both sets of materials and energies are particularly important to the team in performing its concept generation and help create a clear picture of what must be focused on in developing different variants. The last set of inputs and outputs considered are the signals, and although it should still be considered in the design process it is the least influential set on the design; the input is simply drive signals sent to the Tesla SDU with the corresponding outputs being visual confirmation that the design is correctly locating and constraining each part in its location.

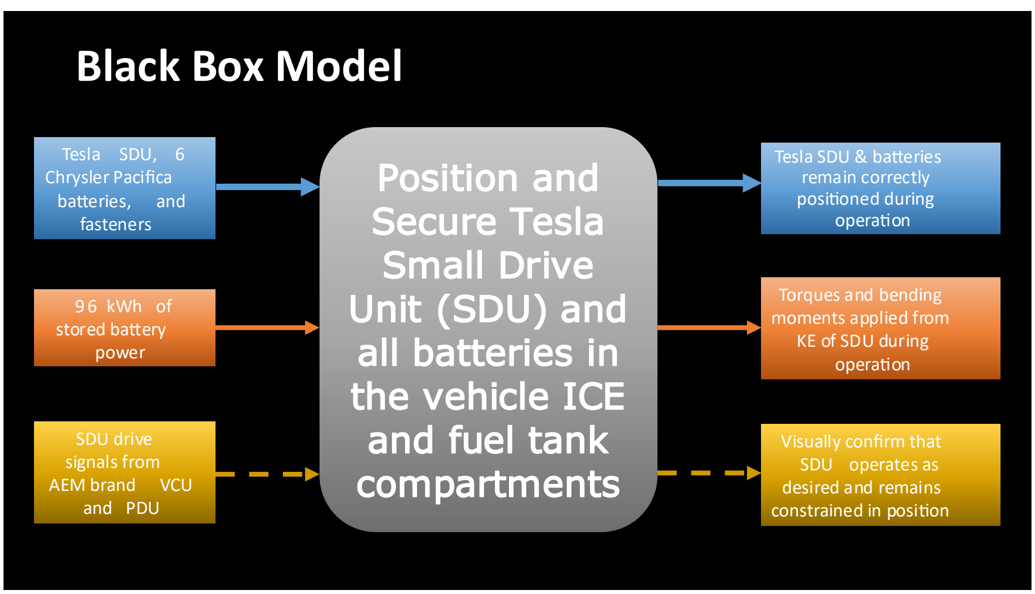

Figure X: Updated Black Box Model

2.3.2 Functional Model/Work-Process Diagram/Hierarchical Task Analysis

Upon completion of its black box model the team moved onto performing a functional decomposition of each individual input into the main function of the design, which is a step-by-step analysis of the flow of all the separate inputs and how they contribute to the design's functional performance. Given the nature of the design and its primary function, the most expansive functional flows correspond to the material inputs. Beginning with the fasteners, these are critical materials that will locate and mount the design to the design vehicle, and also provide a means to fasten other input materials (the Tesla SDU and batteries) to their locations on the design. The next material inputs are the Tesla SDU and the batteries; they must be properly captured by the design thus aligning the drive unit to the design vehicle's drive wheels and positioning the batteries such that there will not be any interference with the body of the vehicle, the surroundings of the vehicle, and the drive unit and axles; and they must be constrained to their capture points by the fasteners already discussed.

This leads to the sole energy input of the batteries and the input signals from the drive control modules; the battery type that has been purchased follow the functional flow by storing chemicals to create a voltage potential that can be used for 16 kWh per battery, and the signals from the drive unit control module are input to and interpreted by the drive control module to dictate how the Tesla SDU should operate. The combination of these inputs leads to the design correctly positioning and constraining the Tesla SDU and all the batteries into the design vehicle over a range of operating conditions. Just like the black box model, having the functional decomposition at its disposal helps the team in its concept generation and evaluation. With respect to the functional decomposition, understanding the flow process for each input makes the group members consider all the individual inputs, ensuring that concept variants are efficiently created by bearing in mind each function that must be met and performed.

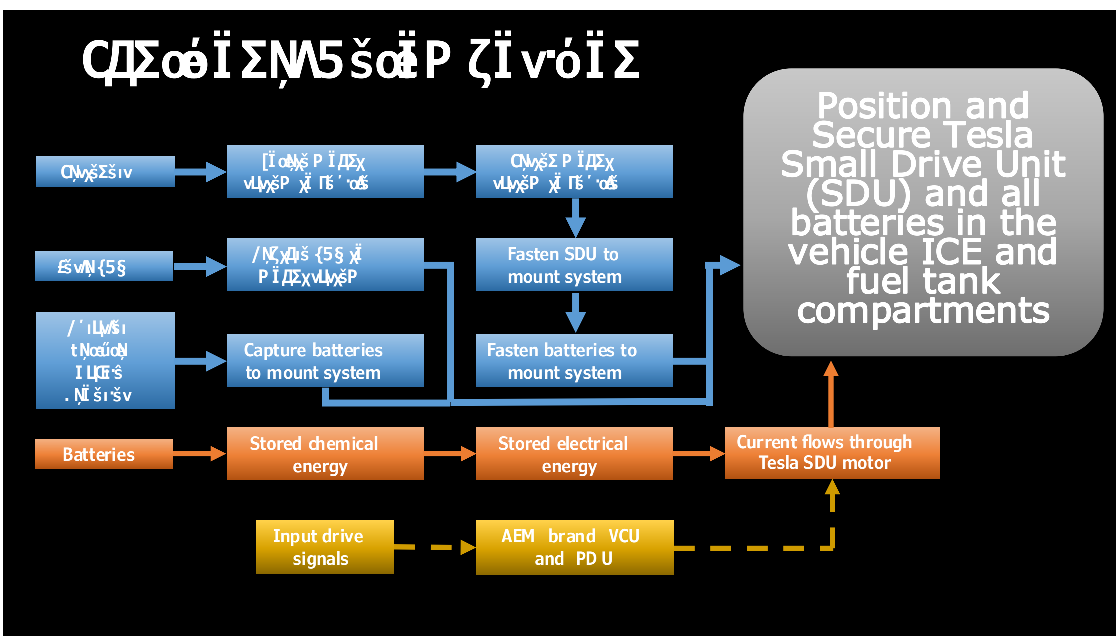

Figure X: Updated Functional Decomposition Model

2.4 House of Quality (HoQ)

The House of Quality uses the CRs and ERs to rank each ER. These rankings are based on the weighted values assigned to each CR. The HoQ has 4 main sections: comparing ERs to CRs, ERs to other ERs, benchmarking, and technical requirements. The main section where the CRs are related to the ERs is based on a 1, 3 and 9 scale. These values indicate the correlation from low to high, 1 to 9, between how well the engineering requirement meets the customer requirement. Where there are blanks in this section, there is no correlation. For example, increased range is highly correlated to making the battery life sufficient for the average commuter. The top section uses pluses minuses to correlate ERs to other ERs. For example, increased range is close to increased battery capacity. This section helps the HoQ user determine the similarity between ERs; this section fulfills multiple requirements at once, such as reducing the number of motor mounts, which in turn reduces the cost of production. The HoQ compares benchmarked products to existing electric vehicles swap kits on the market. The benchmarked products are EV West air-cooled VW kit, Legacy EV, and the Ford crate motor [7]. The customer opinion survey states that all benchmarked products are poor at determining mounting solutions for the electric motor and batteries, also poor compatibility to other models. These needs are a direct requirement to be fulfilled by this Capstone project. The HoQ helped the team determine the technical importance of each ER. The absolute technical importance section multiplies the weighted values by each column number to determine that the most technically important ER is to reduce the number of mounts in the system. This top ER is a reasonable ER to accomplish and from the system QFD (HoQ) this will hit other target requirements. The least technically important ER is to maximize power output. This ER is not as relevant to project success since the motor will output constant power if the number of batteries allows for this. The HoQ is illustrated in the figure below:

System QFD

Project: **Honda EV Conversion**
Date: 9/20/2022

		1	2	3	4	5	6	7
1	Decrease Weight							
2	Increase Battery Capacity							
3	Increase Range	-	++					
4	Reduce cost of production	+	-	-				
5	Reduce # of mounts	++			++			
6	Component cooling		-	-				
7	Maximize power output		++	-			+	
8	Maximize torque		++	-			+	--

Key
A EV West Aircooled VW Kit
B Legacy EV
C Ford Crate Motor

	Customer Needs	Customer Weights	Decrease Weight	Increase Battery Capacity	Increase Range	Reduce cost of production	Reduce # of mounts	Component cooling	Maximize power output	Maximize torque	1 Poor	2	3 Acceptable	4	5 Excellent
1	Battery life sufficient for average commuter	15	3	9	9	3			9	3			C	B	A
2	No modification of existing vehicle frame	5				3	3						BC		A
3	Lightweight	10	9	1		9	9						B		AC
4	Mount solutions for batteries and electric motor	15	1	9		9	3	1		1	ABC				
5	Cooling system for electric motor and batteries	10				1		9	9	3	C	B	A		
6	Compatibility to similar vehicle models	10				1	9				ABC				
7	6 or more batteries in vehicle	15	9	9	9	1	9	1	3	9			ABC		
8	Consumer sellable product	15			1	3	9	3	1					C	AB

	Decrease Weight	Increase Battery Capacity	Increase Range	Reduce cost of production	Reduce # of mounts	Component cooling	Maximize power output	Maximize torque
Technical Requirement Units	lbs	kWh	Miles	Dollars	# of items	Degrees Farenheit	HP	Ft-lbs
Technical Requirement Targets	3000	40	100	4000	3	150	300	250
Absolute Technical Importance	285	415	285	365	510	165	150	225
Relative Technical Importance	5	2	4	3	1	7	8	6

Figure X: Quality Functional Deployment

2.5 Standards, Codes, and Regulations

This project is an entirely new design that is meant to be manufactured for general consumer use on public roadways. Any engineering project must adhere to applicable standards and regulations and given the nature of this EV conversion kit it is no exception; this team must ensure that its design meets the standards put forth by a number of entities that relate to the scope of this project. While there are many different organizations with defined standards that could be related to this design, there are very specific groups with corresponding standards and regulations that the team has identified as critical to ensuring the design is safe and appropriate for wide-scale use on public roads and highways; these include Arizona Department of Transportation (ADOT) [37], International Organization for Standardization (ISO) [38], American Welding Society (AWS) [39], and Society of Automotive Engineers (SAE) [40], [41].

Table X: Standards of Practice as Applied to this Project

Standard Number or Code	**Title of Standard**	**How it applies to Project**
Title 49 Part 396	Inspection, Repair, and Maintenance	Provides the team with Arizona specific and Federal regulations that define the process of vehicle inspection and the requirements that must be met
Title 49 Part 393	Parts and Accessories Necessary for Safe Operation	Comprehensive list of all required automotive parts and additional accessories required for an automobile to be considered road legal in the state of Arizona
ISO/DIS 5474	Electrically propelled road vehicles – Functional requirements and safety requirements for power transfer	ISO documents still under development that provide the base-level requirements for all electric vehicles that are to be operated on public roads, including DC, AC, and conductive power transfer as well as energy storage and charging systems
AWS D8.4:1961	Recommended Safe Practices for Automotive Welding Design	Clear guidelines that dictate the types of welds suitable for automotive applications along with quality and inspection standards
SAE J1634_202104	Battery Electric Vehicle Energy Consumption and Range Test Procedure	Gives the team a set of established uniform procedures by which to conduct its design's performance, range, and battery consumption testing
SAE J-2344	Guidelines for Electric Vehicle Safety	A set of clearly defined safety standards that applies to on-road electric vehicles, meant to ensure the safety of the vehicle operator and those performing service on the vehicle, as well as emergency response protocols in automotive accidents or hazardous situations like battery fires

3 Testing Procedures (TPs)

The testing procedure designed by the team will be utilized to provide a comprehensive test of how well the designs fulfill the engineering requirements and the needs of the customer. This procedure will test all eight engineering requirements using different tests for each requirement. The eight requirements that will be tested are decreasing the weight, increasing the battery capacity, increasing the range, reducing the cost of production, reducing the number of mounts, keeping the components cool, maximize the power output, and maximize the torque output. These testing procedures will be prone to adjustment during the life of the project as the team advances within the project and learns more about how the project reacts to testing.

3.1 Testing Procedure 1: Weight Testing

This test will provide evidence of the successful completion of the decreasing the weight engineering requirement. The testing will determine the overall weight of the motor mounts, battery mounts as well as all the systems required to run the motor. In this process the team will also keep track of the weight removed with the old systems. This testing will be on the mind of the team throughout the entire project making sure no step is taken without considering the weight impacts.

3.1.1 Testing Procedure 1: Objective

The testing for this requirement will include weighing every item being added and removed from the Honda del sol as it is being added or removed. These will then be calculated into the original weight of the car to determine a rough estimate of what the car is believed to weigh. This will be used as the main source of information during the project to keep track of the weight and whether the team is meeting the requirement. With the completely assembled car the team will bring it to a car weighing company to determine the overall weight. The weight of the car is important as it will directly impact the range, handling and acceleration of the vehicle.

3.1.2 Testing Procedure 1: Resources Required

The needed resources for the testing will be a regular bathroom scale for initial tests that happen during the duration of the project. The final weighing will require the rental of a car weighing system. A possible way to reduce the cost of this test will be to go to a quarry as they often have truck weighing scales and these companies have been known to let people weigh their cars for a small fee. This will reduce the accuracy of the test however if the scale is accurate to within 100 pounds it will provide the team with the needed data.

3.1.3 Testing Procedure 1: Schedule

The schedule for this test will take place throughout the entirety of the 2 semesters with constant measurements of what is being removed and added to the car. The final test will take place in the beginning of March and should take roughly 1 day to complete.

3.2 Testing Procedure 2: Battery Capacity Test

The second test being completed by the team will be determining whether the battery capacity reaches the required 40 kWh. The test will determine the overall capacity of the batteries that the team was able to successfully mount into the car. This testing will be completed throughout the year with the final test being completely in March.

3.2.1 Testing Procedure 2: Objective

The objective of this test is to determine whether the design incorporates enough batteries to meet the minimum capacity required by the customer. This test will be done initially by determining how many cells the team has been able to mount within the car and use the manufacturers stated capacity and total up the overall capacity. Once the team has retrieved the wiring harness from Rywire the team will use the motor and set it to a constant speed and run the system until the batteries are empty. This will allow the team to calculate the overall capacity using the current draw and voltage in the system. This is important to test for since the capacity will directly affect the range of the vehicle

3.2.2 Testing Procedure 2: Resources Required

For the initial testing the team will only require a completed battery system with total number of batteries to ensure proper fit and the manufacturers specification sheet. For the final test the team will need a current controller and a timer.

3.2.3 Testing Procedure 2: Schedule

Initially testing will take place throughout semester one while the mounts are being made. The Final testing will take place in February once the final wiring harness has been made and should take roughly 1 day to determine.

3.3 Testing Procedure 2: Range Test

This test will test the overall range of the vehicle while driving on city roads as well as the highway. This test will involve driving the car for an extended period in a multitude of situations to determine the overall range of the system. This testing will be completed in the latter half of the second semester.

3.3.1 Testing Procedure 2: Objective

This test will be completed by using 4 members of the team driving around for an extended period. The team will drive the car until just before a dead battery to learn the maximum range achievable by the car. The team will start by testing the cars range around city streets close to the shop. Then the team will continue to test the car by driving on the highway at 65 miles per hour to determine the high-speed range. These tests will be repeated 3 to 5 times to determine an average range with a standard deviation to determine whether there is a significant variation between the tests. This test is important since it will be a direct influencer to the potential customers for the validity of the product.

3.3.2 Testing Procedure 2: Resources Required

The resources for this test will be 4 members able to make it to Phoenix as well as a truck capable of towing the car in case the batteries die in an unideal location. A GPS calibrated speedometer and odometer will also be required to decrease the likely hood of error in the measurements and variation in the range between tests.

3.3.3 Testing Procedure 2: Schedule

These tests will begin in late February and likely take 4 to 6 weeks to successfully complete the team will likely only be able to complete 1 to 2 tests a day.

3.4 Testing Procedure 2: Production Cost Test

The fourth testing procedure will be to determine the overall cost of production that the client will have to spend to build one of the designs. The testing procedure will involve testing the build procedure and determine the overall time an employee will spend building the design as well as the cost of the supplies. This is likely to be completed in the final weeks of the second semester as we hand off the design to the client.

3.4.1 Testing Procedure 2: Objective

This testing will begin organizing what is being built into a step-by-step procedure to optimize the building process. Once the process has been organized the team will use a Hasport employee and guide them through the build process and time how long each step takes to complete. With the completion of the build the team will present potential optimization techniques to the client for mass production as well as the overall time and money required to produce one design. This will provide the client an estimated price per design in terms of supplies and employee cost. This is important as it will provide the client insight on how much the product can be sold for and the profit margins available.

3.4.2 Testing Procedure 2: Resources Required

The resources required will by the shop's laser cutter, bending machine, welder specialist, and employee to assemble the kit. The team will also require access to the clients supply chain to determine the cost of supplies.

3.4.3 Testing Procedure 2: Schedule

The test will take place throughout the process of both semesters as the team will always be aware of optimizing the process as we build iterations of the design. The final test will be completed in April to give the client a comprehensive view of what to charge customers.

3.5 Testing Procedure 2: Number of Mounts Test

This test will be completed to determine that the team used the least number of mounts as required to ensure a ridged and durable system. The test will include testing the rigidity of the system as well as the optimization of the system. This test will be completed throughout the entirety of the second semester.

3.5.1 Testing Procedure 2: Objective

This test will be used to optimize the weight of the system as well as ensuring the strength, rigidity, and durability of the design. Initial tests will take place using finite element analysis to determine weak points before the construction of the physical mounts to reduce the chance for error during the final tests. The final test will involve subjecting the mounts to the torque and power of the motor to ensure it is capable of comfortably for an extended period. During this testing the team will visually inspect the mounts to notice any wear and tear and possible places that require strengthening. This process will also include any areas that can be optimized to reduce the number of mounts required to create the system. This is important to allow the customer an easier installation of the design as well as decreasing the cost for the client to product each kit.

3.5.2 Testing Procedure 2: Resources Required

This testing will require a computer loaded with analysis software, as well as a car lift to perform engine load testing with no road forces. Optimization software will also be used to offer a generally idea of how the team can optimize the design.

3.5.3 Testing Procedure 2: Schedule

The initial element analysis will take place throughout the second half of the first semester. The final testing will take place during the entirety of the second semester while making multiple iterations to create a more optimized and successful solution.

3.6 Testing Procedure 2: Cooling Test

The testing of the motor cooling system and how capable of keeping the motor below 150 degrees Fahrenheit will be completed next. Testing will take place by measuring the temperature of the coolant during heavy load activities. This will be taking place alongside the range testing.

3.6.1 Testing Procedure 2: Objective

This test will be completed alongside the range testing. The test will utilize taking a temperature measurement of the coolant prior to the range testing then immediately after the range drive. This will be completely for every range test resulting in 6 to 10 different data sets. Once satisfied with these results the team will begin higher load testing at a racetrack. This more demanding driving will result in a higher operating temperature but should remain below 150 degrees Fahrenheit. The temperature will be tested multiple times throughout the racing experience to ensure no unexpected temperature rises leading to drivetrain failure. This testing is important to ensure safe driving for future customers.

3.6.2 Testing Procedure 2: Resources Required

Successful completion of the range tests is required as well as a temperature sensor. An inline temperature sensor is preferred as this would allow monitoring while driving. In addition to this a racetrack with access to an electric charging port is required to ensure testing can last the entire day.

3.6.3 Testing Procedure 2: Schedule

The testing will take place alongside the range tests during late February for the 4 to 6 weeks as well as another week for the racetrack testing.

3.7 Testing Procedure 2: Power Output Test

This test procedure is to test how well the system can transmit the power to the wheels. This testing will be completed by determining wheel horsepower compared to motor horsepower. This test will be completed late in the second semester.

3.7.1 Testing Procedure 2: Objective

The test will be completed by using the manufacturers stated horsepower that is delivered directly from the motor and comparing it to the measured horsepower that is delivered to the wheels. This is important because the alignment and rigidity of the mounts play a big role in the efficiency of the motor delivering the power. The alignment being off by a few millimeters can create a large efficiency discrepancy. This test could potentially be completed multiple times based on efficiency found.

3.7.2 Testing Procedure 2: Resources Required

The only item needed for this test is a dyno machine. This is a large machine that requires the car to drive on top of it as it determines the power output from the wheels.

3.7.3 Testing Procedure 2: Schedule

This testing will take place after the range and cooling tests. It will take roughly 1 day unless the team decides to make minor adjustments to improve the results. Each test will take approximately 1 day to complete.

3.8 Testing Procedure 2: Torque Output Test

This test procedure will be to determine the efficient of the torque output to the wheels of the vehicle. The testing will determine how capable the mounts are at delivering the available motor torque to the wheels of the vehicle. This testing will take place in conjuncture with the power output tests.

3.8.1 Testing Procedure 2: Objective

This test will be completed by using the manufacturers stated torque and comparing it to the torque found during the dyno machine test. This will be important as any slight misalignment of the mounts can affect the efficiency and will give the team insight of any adjustments that need to be made. This will allow the team to make the most efficient system possible.

3.8.2 Testing Procedure 2: Resources Required

A dyno machine is the only tool needed for this testing. Multiple uses of the dyno could potentially be used to help create a better design.

3.8.3 Testing Procedure 2: Schedule

This will be completed in conjunction with the power tests. These tests plan to be completed by the middle of April. With the completion of all tests the team will feel confident in the design and will begin to turn the project over to the client to allow them time to prepare the kit for mass production and sale.

4 Risk Analysis and Mitigation

This section details the risk analysis performed by the team on the proposed design. It will detail the most critical areas of risk, as well as the team's plan to mitigate these risks. Finally, it will detail the risks trade off analysis that led to many design decisions and still helps to inform design philosophy.

4.1 Critical Failures

4.1.1 Potential Critical Failure 1: Motor Mount Torsional Failure

A major failure point of this design, and perhaps the most predicted, stems from the load applied to the motor mounts by the motor. The Tesla Front SDU is predicted to output 300 horsepower and 250 ft-lbs of torque. These numbers are far higher than the factory output, meaning that our proposed solution must be able to handle far greater forces. This failure would likely manifest itself as a shearing of the mounts themselves. To counteract this, the team ensured that strong materials were selected. The design of the subframe was also made to maximize strength and rigidity, doubling up material and parts as necessary. FEA will be performed, and the car will be thoroughly driven and tested before ever being on public roads or in customer vehicles.

4.1.2 Potential Critical Failure 2: CV Axle Snapping

When changing the driveline of any vehicle, all driveline components must be examined for strength. The main weak point in this design will actually be the CV axles, as they will be longer than the factory ones and need to transfer nearly triple the power. This means that any axles we machine will need to be beefier than stock. To minimize this risk, we will be machining custom axles in house to be thicker and of a higher-grade steel than the OEM CV axles. As with the motor mounts, we will be vigorously testing off of public roads before ever venturing onto them, as well as testing extensively before shipping any axles to a customer. If necessary, we will heat treat the axles as well.

4.1.3 Potential Critical Failure 3: Battery Overheating

EV batteries generate heat when charging and discharging. This heat can become a fire hazard if not managed properly. To combat this, the team will be designing a coolant system to dissipate heat. This system will be based on experimental results from lab testing, as well as anticipated environmental heat from the client's location in Tempe, AZ. The battery system will be tested in a variety of environments and will be validated for use in most climates prior to being recommended/sold to any customers.

4.1.4 Potential Critical Failure 4: Battery Mount Collision

The battery mount design the team has created will be situated where the gas tank used to reside. This will expose it to potential hazards in the road, especially if a driver attempts to drive over tall hazards. To mitigate this issue, the team will design the battery holding bracket to hang no lower than the factory fuel tank. Honda took care to mount the fuel tank in a place that is shielded and protected from the hazards of the road, and we will take advantage of this to make our product just as protective. We will also incorporate a skid plate in the design, which will provide even more protection than the factory fuel tank.

4.1.5 Potential Critical Failure 5: Electrical Fire

The electrical components in any vehicle heat up as current passes through them, and this risk is amplified even more in an EV as the energy travelling through the wires is much higher. If an unregulated current passes through any of the wires, a fire will likely break out this. Like a traditional car, the team will be using fuses to provide an emergency shut down in case of a short. They will also be routing wires in such a way that they have no direct contact with flammable objects, such as carpet. They will primarily be routed through the exhaust tunnel. The group will also be leaving the 12-volt electrical system untouched, which will prevent any issues with using that system.

4.1.6 Potential Critical Failure 6: Bolt Shear Failure

One of the top ten critical failure points in the motor mount subsystem is bolt failure. The bolts used in this analysis are metric M10 bolts, and there are 6 between the two sides of the motor subsystem. These bolts are critical failure points since sheared bolts results in a destroyed motor, the integral propulsion system in the vehicle. The M10 bolts are standard size for motor swaps and there are six bolts for an electric motor that weighs less than the factory gas engine. Although there is little concern that the bolts will shear from the weight of the motor, the torsional strain and shear load on the bolts is a main concern at various RPM ranges with the vehicle in motion. Although no issues for the shearing is suspected, a simple loads analysis performed prior to selecting the final design ensures that the torsion and bending moments on the diameters of the bolts results in positive margins and no bolt gapping.

4.1.7 Potential Critical Failure 7: Insufficient Electric Motor Lubrication

Another potential failure point in the motor subsystem is a scenario where the motor receives insufficient oil lubrication. Since the factory oil pump has been removed because of the motor orientation in the vehicle, a main concern is that the gears inside the motor are not lubricated properly due to pressure or flow rate differences from the factory pump. To ensure that the motor is properly lubricated, pressure tests are necessary along with a pulse width modulation device to regulate the pump pressure to the same specification as the factory pump. The main concern is that once the components are put back in place the specific lubrication of internal gears is unknown and will need to be road tested for safety. To mitigate this potential failure, pressure tests are conducted to ensure proper pressure, and similar pump line sizes installed into the motor will keep the flow rate to the same specification as the original pump.

4.1.8 Potential Critical Failure 8: Insufficient Voltage Supply

A specific voltage range feeds the electric motor present in the vehicle. If the combined voltage from all the batteries is too low, the motor will not run. The motor has a range of acceptable voltage requirements, 240-400 VDC, and the current voltage estimate from the 6 Pacifica batteries placed into the vehicle is roughly 350 V. Although this value falls within the range for the motor, the motor needs to be tested to ensure this voltage supply is sufficient for continuous use of the vehicle. To mitigate a potential lack of voltage for the motor, the number of batteries can be increased to increase capacity and voltage for the vehicle.

4.1.9 Potential Critical Failure 9: Shortage in High Voltage Circuit

The voltage lines that carry high voltage to the electric motor and several other components need a fuse to ensure safety of the human body when around electricity. A potential failure point is the shortage of the HVDC lines frying crucial components of the electrical subsystem. The fuse in the system should prevent this type of failure, but in case of a crucial failure, a main switch will be installed to mitigate the number of lines powered up at any time. Reducing the numbers of offshoots with HVDC and line length also mitigates a potential shortage in the electrical harness subsystem.

4.1.10 Potential Critical Failure 10: Electrical Connection Corrosion

Since there are many electrical connections in an electric vehicle, corrosion is a potential failure point. The corrosion can lead to a fire if serious enough. The batteries along with the harness connections to the motor are exposed to dust, debris, salt, moisture, and rapid temperature changes which can lead to corrosion on the electrical terminals. To reduce the risk of a corrosion event on this vehicle, di-electric grease and thorough cleaning of the battery terminals prior to installation will ensure that the batteries stay clean and free of debris from the road.

4.2 Risks and Trade-offs Analysis

The ten critical failures in the above analysis list the most critical of all the subsystems. Since some of the failure points conflict there are limitations to which of the failure points is addressed in the design process. For example, the insufficient voltage supply and line shortage are in direct conflict with each other, however supplying the motor with enough voltage to run is more critical than ensuring there are no shorts in the electrical wiring. Also, some are in conjunction with one another, for example, the potential electrical connection corrosion aligns with preventing an electrical fire hazard in the vehicle.

The bolt shearing and CV axle breakage are both material failures. Since the bolts are in the same subsystem as the CV axles, one may affect another. For example, if the bolts stay in place and prevent material failure, the CV axles would be the main design consideration. Keeping the wheels running with the newly adapted axles is far more critically important to engineer properly.

In terms of the battery mounts, a battery collision and electrical fire correlate closely. For example, if the batteries get hit by road debris and cause the batteries to overheat and create an electrical fire. One thing leads to the next when the batteries get damaged. So, the design consideration for the batteries is to ensure that they receive proper cooling and mounting solutions to prevent a slew of other critical failure points.

5 DESIGN SELECTED – First Semester

This section contains the final design the group selected, as well as the plan to implement the design. It will also detail the plan to implement the design, which will specifically include plans for prototyping and manufacturing the final product.

5.1 Design Description

The final design the group decided to implement was a subframe replacement design. This will allow customers to directly swap their motor without modification to the vehicle. It will also provide factory suspension characteristics without needing further calculations. We will be using a cradle that sits in the gas tank for battery storage, allowing for maximum protection and rigidity based on the stress analysis performed by the team. This stress analysis also showed that .1875 inch steel would be the ideal strength to weight ratio. Figures DN and DN below show this final design.

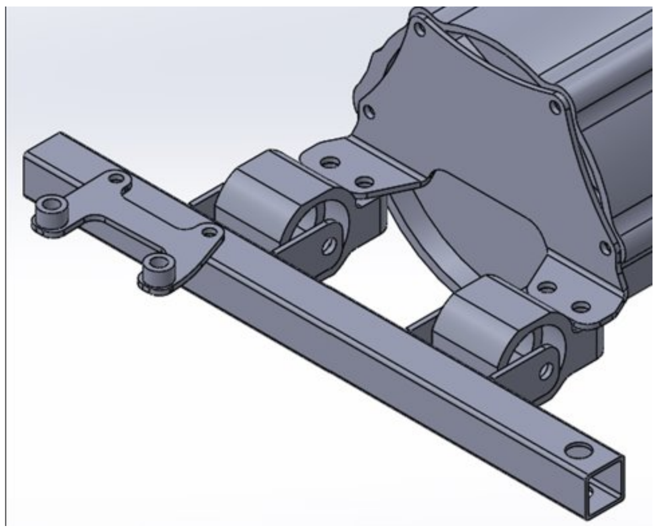

Figure DN: Final design, passenger side

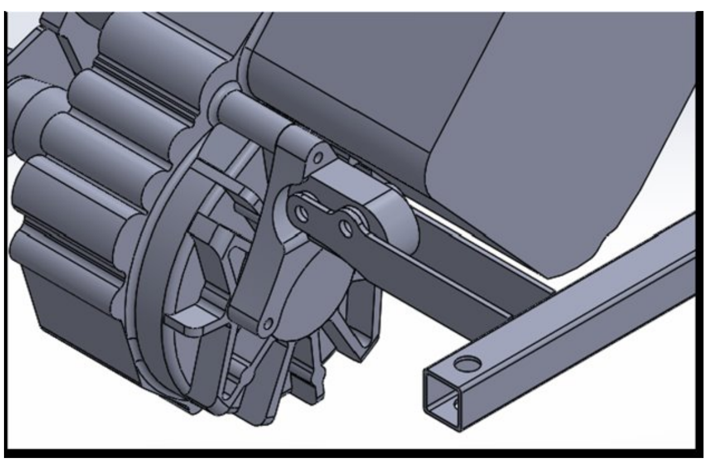

Figure DN: Final design, driver side

The team fabricated this design in the first prototype, shown in figure DN below.

Figure DN: Prototype in vehicle

5.2 Implementation Plan

This Capstone project is simpler for the fabrication phase since the budget and materials are provided by the client. Each subsystem including the motor mounts, battery mounts, and electrical harness have custom fabricated parts. The team is completing two prototypes for the motor and battery mounts. A proof-of-concept idea of our CAD is used for the major components. The facilities at Hasport Performance include a laser cutter, manual and CNC mills. Since most of the major mounts are fabricated from 0.188" sheet steel, the laser cutter is the main piece of useful equipment used in the process. The people involved with assisting the students working on the project are Brian, Scott and Rob that are full-time employees of Hasport. When using equipment such as the laser cutter and press brake, specific use of this equipment is necessary. Even though Hasport Performance absorbs most of the cost of the project, the bill of materials keeps track of the overall cost of the project. Most of the components are purchased part and a current BOM of the project items are illustrated below.

Table DN: The BOM and cost

Part	Cost
12 ft of 1.5 in square, 11-gauge steel tube	$55 [11]
16 square ft of .187 in thick sheet steel	$100 [11]
2 Hasport K-Flip3 mounts	$350
25 M12 bolts	$23.45 [12]
25 M12 nuts	$16.20 [12]
4x8 Sheet of 7/16" OSB	$17.60 [16]
2x4x8 Lumber	$25.54
Tesla SDU	$1500

The cost of implementing a plan for using the above materials includes materials for prototyping. The official budget for the vehicle is to remain below $15,000 for the entire project cost. In the second semester of this Capstone project, final iterations of the mounts will be fabricated in early January. The wiring harness, cool systems, brake booster, and other accessories will be bolted up soon after to get the vehicle running. Then the tests to ensure load legality and safety will meet state requirements occur. Then, the back hatch of the vehicle will need to be replaced, along with the interior vacuumed and exterior repainted. Once these objectives are met, the vehicle may be taken to several car events and performance tested.

The image below is an exploded view of the current motor assembly. This assembly is only the motor subsystem, but there is another subsystem showing the battery assembly in the fuel tank area below.

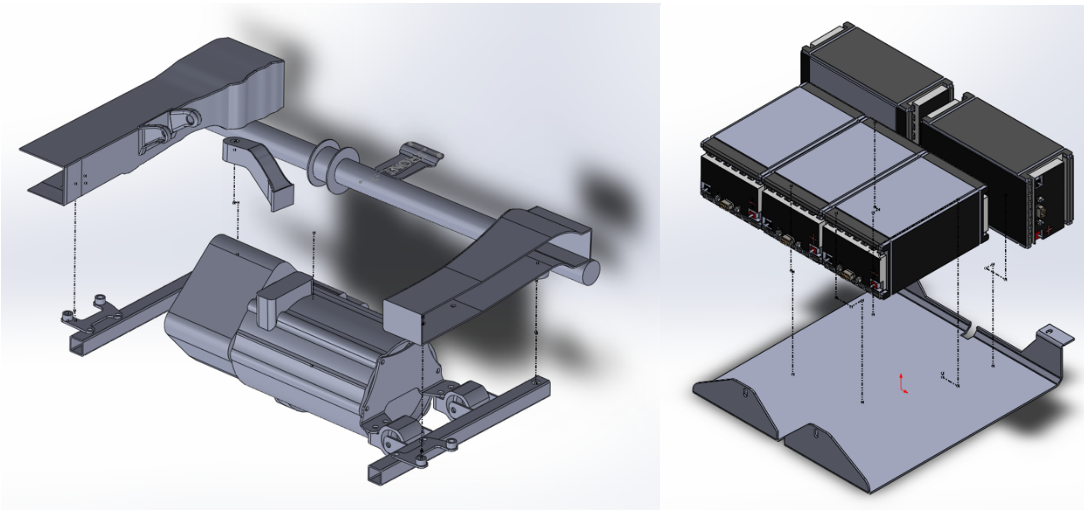

Figure X: Exploded view of assemblies

6 CONCLUSIONS

The proposed design meets all of the critical requirements from our client. It uses an existing Hasport part to provide some copyright protection to the design, does not modify the exiting vehicle, and provides mounts for the motor and more batteries than required to reach the voltage minimum for the motor. The design has a plate connected on the driver's side of the motor and the factory mount on the passenger side of the motor. The plate is bolted to 2 of Hasport's K-Flip3 mounts. The factory mount and K-Flip3 mounts bolt to sets of bunny ears, which are welded to subframe rails that bolt to the frame of the car. The battery tray in the gas tank of the vehicle holds six batteries, which provides the necessary 400V to run the motor at full capacity.

Overall, the semester was productive, and the project is ahead of schedule, with fabrication starting before the semester's end. The project still has much to be done and issues may still arise, but the additional time saved in the early stages of the project will certainly counteract the time required to fix these issues. The final product of the project will be a benchmark in the electric vehicle swap market and will make Hasport performance a large name

[Provide here a summary of the contents of the report and the overall outcome of the semester. Start with a brief summary of the project description itself including the critical requirements of the project. Include a summary of the final solution proposed for your project as well.]

7 REFERENCES

[Include here all references cited, following the reference style described in the syllabus. There should only be one Reference list in this report, so all individual section or subsection reference lists must be compiled here with the main report references. If you wish to include a bibliography, which lists not only references cited but other relevant literature, include it as an Appendix.]

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8 APPENDICES

[Use Appendices to include lengthy technical details or other content that would otherwise break up the text of the main body of the report. These can contain engineering calculations, engineering drawings, bills of materials, current system analyses, and surveys or questionnaires. Letter the Appendices and provide descriptive titles. For example: Appendix A-House of Quality, Appendix B- Budget Analysis, etc.]

8.1 Appendix A: Descriptive Title

8.2 Appendix B: Descriptive Title