Electric Excursion

SP I

By:

Nick DePaolis – Team Leader

Keith Garcia

December 2nd, 2020

Advisor: Dr. Allen Katz

Electric Excursion

By:

Nick DePaolis*

Keith Garcia*

A First Semester Senior Project Report Submitted in Partial Fulfillment for the Degree of Bachelor of Science in Electrical Engineering*

December 2nd, 2020

Abstract (KG)

Personal transport vehicles have emerged throughout college campuses and urban areas over the past couple of years. These “Micro Vehicles” are used for both recreation and commuting while providing a clean and simple propulsion (or ride) from destination to destination. We chose to create an electric motorized skateboard because of storage and weight advantages as well as the ability to modify the individual components to allow for increased customization to a wide variety of user requirements. We refer to the vehicle as an “Electric Excursion Motorized Board” (EEMB). Using a wireless controller, the rider will have control in the palm of his or her hand; this will provide the electronic speed controller, the brain, with information to determine the speed, braking and power consumption of the board during the trip. Sensors and interchangeable wheel sizes will give the user a custom experience to cater the board according to the terrain. The vehicle’s main components will consist of a Lithium-Ion battery, Electronic Speed Controller, Belt Drivetrain configuration and a brushless motor; mainly concealed on the underside of the board. Our team's goal is to create a portable vehicle of lightweight design capable of holding a maximum of 200 lbs. and travel approximately 15 miles while being able to reach speeds of 12-20 mph.

Key Words:

Wireless Controller, Motor, Electronic Speed Controller, Portable Vehicle, Belt Drivetrain

Table of Contents (KG)

List of Tables (KG)

List of Illustrations (KG)

Nomenclature (ND)

ESC	Electronic Speed Controller
BLDC	Brushless DC Electric Motor
VESC	Vedder Electronic Speed Controller
EEMB	Electric Excursion Motorized Board

Introduction (ND)

The use of small-scale transportation is on the rise, especially in cities and on college campuses. The most popular would-be scooters, skateboards, and bicycles. These vehicles increase travel efficiency; we aim to increase their usability and convenience by implementing an electric assistive component. Our main goal is to design an under bodied propellant device to electrically drive the board. Our goals is to also add safety features to make their use more accessible to beginner riders. An electronic speed controller will be used to control the operation of the motor and the speed controller will be controlled through a wireless module held by the rider.

Specifications (ND)

The specifications of the micro vehicle depend on the application it is being used for. This board is being designed with the average college student in mind. The board will be able to carry a student to and from classes assuming an average course load of 4.5 units (18 credits). There are several elements that must be considered when designing a system such as this one. These include, weight, battery capacity, charge time, effective range, top speed, acceleration curve, deceleration curve, and torque. In order for this micro vehicle to be practical for travel to and from classes, it must have an effective range of 10 – 15 miles and have a recharge time of less than five hours. A major factor will be battery size and type as this will determine the charge and discharge properties, which can affect parameters such as speed and effective range. We wanted a top speed between 12 and 20 miles per hour and to have a way to make the acceleration and deceleration safer for beginners. We designed this transportation system with a ten percent hill gradient in mind. Hill gradient is a measure of the steepness of a road or hill. Ten percent is a common gradient found in the real world which is one of the reasons we selected this target value. Hill gradient is calculated by taking the change in elevation and dividing it by the length or distance traveled. For example: A change in elevation of 500 feet over a 5000 feet distance would result in a ten percent gradient.

$$\frac{Change\ in\ Elevation}{Distance} * 100 = Gradient\ \% \tag{1}$$

Ex. $\frac{500\ Feet}{5000\ Feet} * 100 = 10\%$

We would also want to see an effective range of about 15 miles which would account for several times around the TCNJ campus. The TCNJ campus is 289 acres or 0.452 square miles. The distance around the campus once is roughly 1.74 miles. This range gives a good buffer for a student that might travel more than just to their classes. It would also limit the number of times the student would be required to recharge the batteries during the week. We also wanted to see a realistic charge time of less than five hours. Charge time was considered in the selection of the batteries, Lithium-Ion cells that need to be monitored to not overcharge cells that can charge unevenly. The specifications are shown in **Table 1**.

Parameter	Requirement	Actual Performance	Verification
Top Speed	12 Mph	TBD	Test
Battery Size	170 Wh	TBD	Inspection
Effective Range	10 Miles	TBD	Test
Recharge Time	< 5 Hours	TBD	Test

Ability to Climb (Hill Gradient)	10 %	TBD	Test
Max Load	160 Pounds	TBD	Analysis

Table 1: Initial Specifications

Chapter 1: Research and Design (ND)

Section 1: Competition Research

The use of small-scale transportation is on the rise, especially in congested spaces like cities and college campuses. Initially, the most popular choices on campuses are bicycles, scooters, and skateboards. Now that electric vehicles are more accessible, there is the potential for an increased use of such vehicles on college campuses. The team conducted research on what electric vehicles such as the one we were planning to design already existed on the market. A comparison table is shown in **Table 2**.

Model	Price	Battery Size	Range	Top Speed	Drive Train
Actonblink S2	$599	158 Wh	14 mi	18 mph	2 x Hub
Electric Excursion	**$672.78**	**185 Wh**	**TBD**	**TBD**	**1 x Belt**
AeBoard AX Mini	$499	117 Wh	13.5 mi	30 mph	2 x Hub
Acton Blink Qu4tro	$1699	240 Wh	22 mi	23 mph	4 x Hub
Apsuboard X1	$593.50	288 Wh	17 mi	26 mph	2 x Belt

Table 2: Electric Longboard Comparison

Section 2: Initial Design Characteristics

Our task was constructing an electrically driven board meeting the characteristics shown in **Table 1** using comparisons to competitors shown in **Table 2**.

Section 3: Regulations

The government and more specifically the FCC have rules and regulations pertaining to the use of radio frequencies and the interference caused by negligent radio transmissions. We plan to use a 2.4 GHz wireless transmitter and receiver to control the electric board. This frequency is widely used and has no restrictions on its operation within the FCC's rules. This is relating to the fact that we are not using this frequency band for long distance manual control of the electric board. If we were to decide to use a different frequency band, the team members would have to check for FCC regulations to operate on that band. If the frequency band requires the operator to possess a HAM radio license, one of the team members is a General class Ham Radio License holder. The team is confident that the 2.4 GHz module we selected will work well for the low proximity operation of the system.

Chapter 2: Mechanical Design/Construction (ND)

Section 1: Drivetrain Components

The parts that make up the drivetrain are: the motor pulley, the wheel pulley, the drive belt, the motor mount, and the truck bracket and gear bracket for mounting the gearing in the wheels. An important factor in finding an estimate of the board's travel distance is the distance per revolution. It is a function of the circumference. The general wheel diameter chosen was

90mm. These wheels provide a good balance between size and cost per unit. To come up with the mounting system underneath the board, we researched the mounting distances used by other boards. We found that the mechanism needs to be kept between 60 and 70mm of each other. This distance corresponds approximately to the length of our belt drive, motor, and wheel gearing. The 90mm wheels offer a good balance between torque and top speed. In general, a smaller wheel diameter yields more torque but a lower top speed, while a larger wheel diameter yields less torque, but a higher top speed.

Section 2: Electric Motor

The team needed to investigate the motors used in other designs to get a good baseline of what kinds of motors to consider. The torque of a motor is given by the following equation:

$$\tau = \frac{(I*V*E*60)}{(1000*2*\pi)} \qquad (2)$$

τ is the motor torque, I is the input current, V is the voltage across the motor, and E is the estimated efficiency of the motor (This will change with different rpm, in this case 1000 was used as a baseline). The voltage across the motor is the sum of the back-EMF and the resistive loss:

$$V = IR_M + \omega \qquad (3)$$

V is the voltage drop, R_m is the motor resistance, and ω is the angular velocity of the motor. Assuming that the motor resistance is negligible, the equation to calculate the power consumed by the motor can be calculated: using equation (4)

$$P \approx A * V * \sqrt{3} \qquad (4)$$

The power that the motor produces can be found as a function of the battery pack and the motor current. Assuming a 5S LiPo pack at 60A, the motor would produce 1110 Watts. This value also depends on the power limit of the motor. It is important when selecting the battery supplies to not cause damage to the motor. After the team completed their research, they found that the most common motor used was a brushless motor. The brushless motor allows for low overall maintenance, high efficiency, long lifespan, and a higher weight to torque ratio. The specific motor selected has a maximum power of 2450 W and a maximum current of 65A with a torque of 7 Newton meter.

Section 3: Component Identification

The design of an electric skateboard requires a multitude of components and tools to construct it properly. We decided on first constructing a test fixture to safely gather information and take measurements in a controlled environment before continuing the production of a usable prototype. We needed to decide on specifically what motor, controller, battery, remote, deck, wheels, trucks, connectors, power switch, safety switch, charger, tooling, brackets, insulation, etc. to use in the design. All these components were selected during the research and specifications development. When evaluating costs and the practicality of this project, we knew that additional funding would be required from the school to accommodate all the components required in this system. We reached out to the Dean of The School of Engineering Dr. Steve O'Brien and presented our case. Dr. O'Brien generously approved the increased budget of ~$673 to cover the costs of all the products. We worked closely with Dr. Allen Katz in identifying alternative sources of parts to drive the cost down before approaching the Dean for assistance. Thus far, we have successfully built the Test Fixture Version 1.0 and aims to have the actual prototype developed and successfully constructed during the second half of the project. The parts installed on the test fixture shown in **Table 3.**

Part Index	Component
1	Flipsky 6354 BLDC Motor
2	2.4G Wireless Receiver
3	Flipsky FSESC V4.12 50A ESC
15	Flipsky Electric 280A Anti Spark Switch
19	**TBD (**2 x Turnigy 5S 20C LiPo pack**)**

Table 3: Parts Mounted on Test Fixture

Chapter 3: Electronics (ND)

Section 1: ESC, Motor and Battery

Throughout the research and planning phases, we were consistently checking to ensure that the expected performance would be within acceptable limits of the specifications.

We first investigated the electronic speed controller (ESC). We wanted a system that was both robust, and easy to use. We decided to use a system that was both compatible with open-source software and with the selected motor. The ESC is rated for a continuous current of 50A and an instantaneous current of 240 A. The usable voltages range from 8V to 60V. The current and voltage requirements were well within the ranges that were specified and allowed for some margin in case the system is eventually upgraded. A concern with the ESC was that it did not come with a protective housing. We had to find a suitable housing that was both scratch and impact resistant to protect the delicate components that were affixed to the underbelly of the board.

Figure 1: Flipsky FSESC V4.12 50A ESC

Next we selected the battery(s). We needed to consider the rating of the. The Flipsky 6354 190KV 2450W BLDC Brushless Belt Sensored Motor, was rated for 12 S, 2 x 6 cells in series, with a max current of 65A. We eventually chose the Turnigy 5000mAh 5S 20C LiPo battery pack for the power source. The team wanted two of these packs yielding a 10 S serial configuration, which would allow for a higher top speed and longer run time. These values were within maximum ratings of both the controller and the motor.

Figure 2: Flipsky 6354 BLDC Brushless Motor

Figure 3: Turnigy 5000mAh 5S 20C LiPo Pack

Section 2: Power Switch

The ESC is useless if the user is unable to easily switch the system on and off. This switch would obviously increase the longevity of the batteries and the time before a recharge is required. We utilized an anti-spark 280 A switch to connect between the power supply and the ESC. XT60 male and female connectors were used for easy connect and disconnect and to preserve the modularity of the system.

Figure 4: Flipsky Electric Skateboard 280A Anti Spark Switch Pro

Section 3: Handheld Controller

We wanted a controller that was low in power, small in size and robust to survive use on a motorized board. We also wanted an ample wireless communications range in case the rider needed to dismount the board for safety reasons. The final selection was based on the recommendation during a design review. We were initially considering using a Bluetooth module, but used a wireless 2.4GHz transmit/receive module to adequately meet our needs. The wireless module allowed for a reliable and easy installation of the ESC and provided a large communication range without losing the wireless connection. Its performance was demonstrated during our initial testing done with the test fixture version 1.0.

Figure 5: VANPRO V2 Edition 2.4G Wireless Remote Control

Section 4: Drive Train

The parts necessary to get the board moving are consolidated in the drivetrain. The motor needs to be mounted and be able to supply sufficient torque by means of the drivetrain to get the board moving. We chose a vanpro 83MM 90MM 97MM PU wheel pulleys kit. The drive gear, pulley, wheel bracket and belt were included in this kit. Next, the mounting brackets and trucks used to mount the motor were selected. We used components that were compatible with each other, shown in **Figures 6, 7** and **8**.

Figure 6: Vanpro 83,90,97 mm wheel pulley belt kit

Figure 7: Motor Mount (Caliber II Truck Compatible)

Figure 8: Caliber II Trucks (set of two)

Section 5: General Test Fixture Mockup

After the components for the board were determined and acquired, we then moved into the construction phase. To obtain useful measurements, we constructed a test fixture to take measurements in a safe and controlled environment before moving to field testing. The design and fabrication of the test fixture was done in two stages as illustrated in Figures 9 and 10.

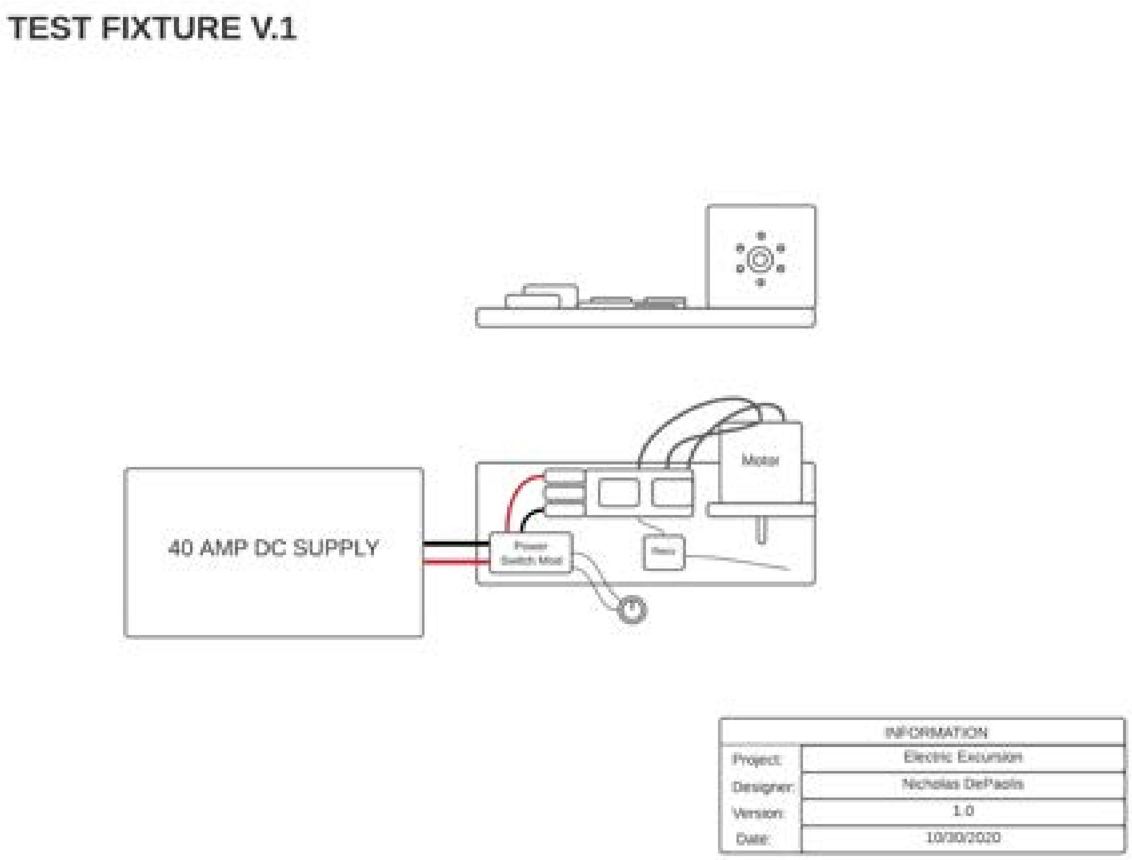


Figure 9: Test Fixture Version 1.0

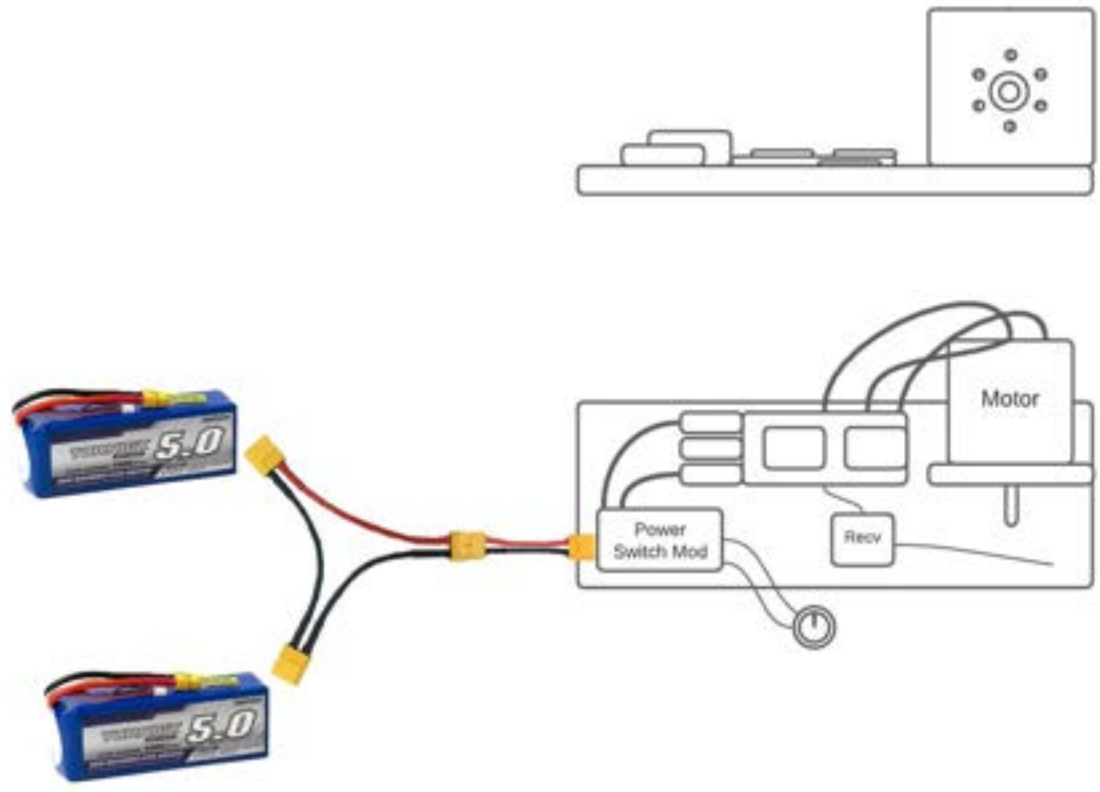


Figure 10: Test Fixture Version 2.0

Chapter 4: Software (KG)

Section 1: VESC Open-Source Software

The software used to configure the controller, motor, and input devices is the VESC open-source software package. The ESC comes preloaded with the V3.38 firmware already loaded. Upon first launch, the firmware needed to be updated. This must be completed before configuring the profiles to ensure no firmware incompatibilities are present. The software is free to everyone and can be downloaded from the VESC tool page, but an account and free license must be purchased beforehand. This process takes anywhere for two to five minutes.

The software was used to test the ESC and motor in an initial start up and to identify the sensors. Next, the acceleration and rise time were tested to reduce stutter upon startup of the motor. Finally, a test was performed using a Motorola R-1011B DC Power Supply 0-40 A to estimate the power consumption of the ESC and motor in Test Fixture 1.0 illustrated in Figure 9.

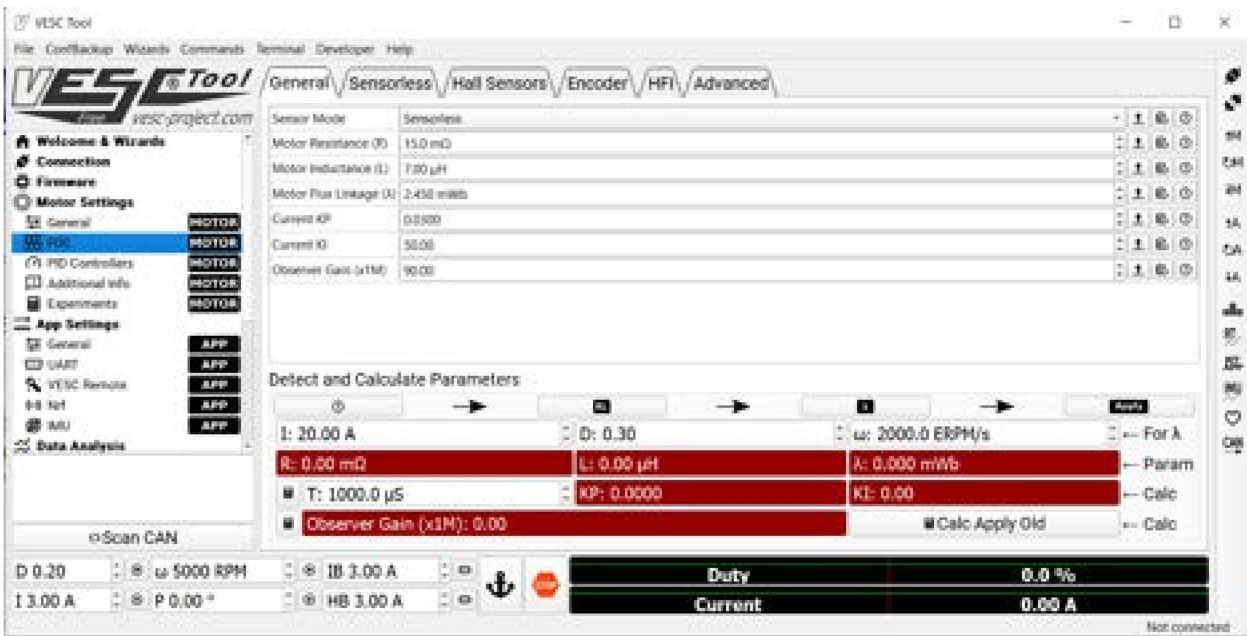


Figure 11: VESC Software Overview

Chapter 5: Conclusion (ND & KG)

The Electric Excursion board is intended to be used as a means of consistent and efficient transportation around campus. We have completed the design and 90% of fabrication of the EEMB. Through this effort we have gain in our electrical and mechanical engineering skills and grown in our overall engineering knowledge. A test fixture was designed for testing EEMB's motor and drivetrain under various loads. The test fixture is wired up with drive components in place. We are awaiting the receipt of the batteries to start the testing. The VESC software has aided the team in having an easy and intuitive approach to configure and control the EEMB accurately. It provided a solid base to develop and test the safety features. This software package allowed for the instantaneous collection of the initial setup and sensor classification as well as basic acceleration and rise time in a controlled environment. We dealt with budget constraints and gone through the budget increase application process. We determined the proper legal precautions required by the FCC to use our communication module. We have applied; engineering design considerations, including mechanical and mechanism analyses to ensure EEMB riders will be able to utilize this device safely.

The second half of this project will be focused on the final design of the board and the implementation into a rideable and functional prototype for field testing. Once the vehicle is constructed, the team will be able to obtain even more pertinent information and measurements.

Safety, feasibility, and ethics are the focus of this engineering design. This project intends to create a safe and efficient method of transportation for students or others that require a compact and reliable form of transportation in congested spaces.

References (KG)

Great Scott Video: https://www.youtube.com/watch?v=XworvxoQleY

Appendix

A. Project Overview (KG & ND)

A-1: **Team Biographies**

Nick DePaolis is an Electrical Engineering major at TCNJ. He enjoys tinkering with various electronics and HAM radio. Nick is a licensed General Class amateur radio operator. His interests are in D-STAR and various simplex communications with his relatives in neighboring states. His responsibilities for this project include: Mechanical and Electronic design, physical construction, testing, theoretical analysis and safety research and applications.

Keith Garcia is an Electrical Engineering major at TCNJ. He enjoys outdoor activities and sports; including: hiking, snowboarding, soccer and running. Keith was a member of the MUSE 19’ Summer Research Program focusing on low-power sensor devices for temporary construction assets. His responsibilities for this project include research/design, safety and VESC software implementation/analysis.

A-2: **Realistic Constraints and Engineering Standards**

Project: Electric Excursion

Team Leader: Nicholas DePaolis

Checklist Completed: ___________________________ ____________________

Advisor: Dr. Allen Katz **Date:**

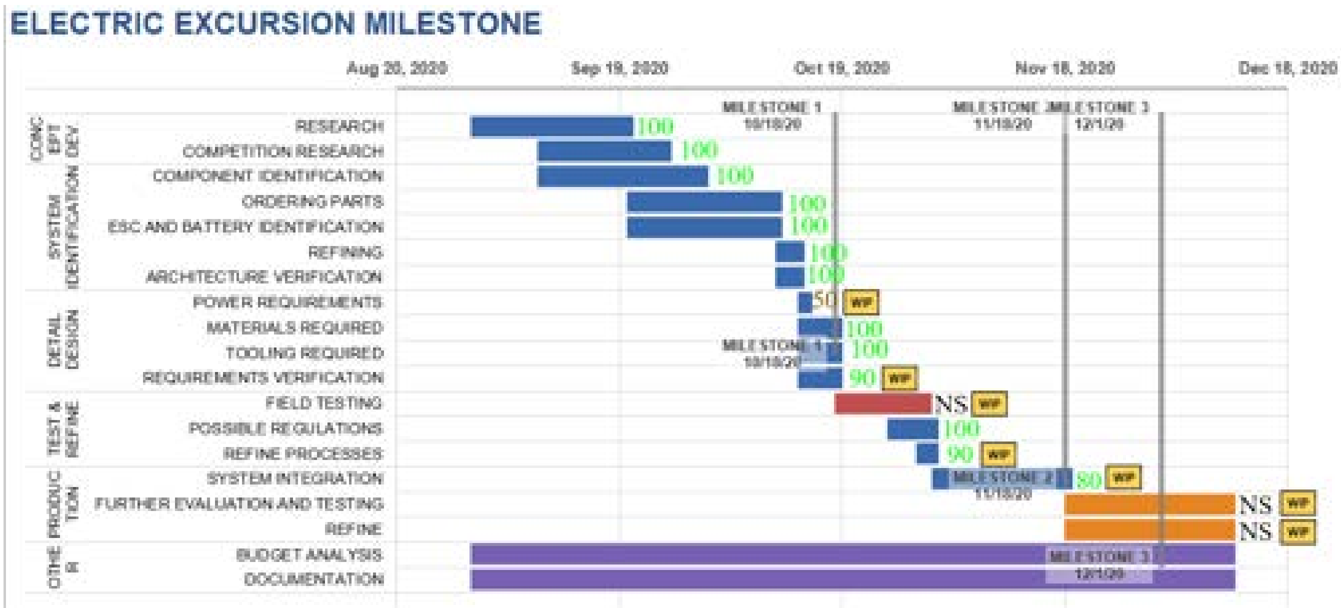
Directions:

This checklist should be completed by the team leader and signed by their advisor.

In the self-check column, place a C if covered in body of report, a N if not covered in body of report but is covered in the remarks column, and a N/A if not applicable (in all cases, C, N, or N/A, include a justification in the remarks column).

	Self-Check C	N	N/A		Remarks
Economic	X				Budget is discussed in B-6
Environmental		X			The system does have some environmental constraints such as the production of the batteries and the waste if a system was improperly disposed of. The solution to this issue is to have a robust maintenance and support plan along with a full life cycle sustainment plan.
Social			X		This system has no social implications.
Political			X		This system has no political implications.
Ethical		X			The system proposed is ethical due to its focus on rider safety and its ability to efficiently transport its rider.
Health and Safety		X			Safety was the forefront of this design. The health and safety of the rider and the pedestrians was considered, and a future iteration will implement blinking lights to make others aware of its presence.
Manufacturability		X			The system proposed would be able to be reproduced and sold for cheaper rates when selling and sourcing parts on a much larger scale.
Sustainability		X			The rider would need to perform self-checks after every ride to ensure no damage was done to the compartment during use.
Standards	X				Standards were discussed in the body of the report when pertinent to the design or methods.

B. Management (ND & KG)



B-1: **Milestone Chart**

Date	**Time (Hours)**	**Topic**
August 31st	40	Research/Background
September 7th	14	Research/Background
September 14th	16	Research/Background
September 21st	17	Component Identification
September 28th	12	Component Identification
October 5th	13	Component Identification
October 12th	14	Component Identification
October 19th	14	Began Initial Ordering
October 26th	14	Ordering/Verification
November 2nd	19	Began Construction
November 9th	22	Construction
November 16th	29	Construction
November 23rd	20	Budget Increase/Construction
November 30th	23	Final Report/Presentation

B-2: Timesheet

Contact	Role
Dr. Allen Katz	Senior Project Advisor
Dr. Steve O’Brien	Dean of Engineering, Budget Approval

B-3: **List of Contacts**

Component	Purpose
Switch	Sensory safety protocol for motor function
Dual-grip Controller	Dual-point authentication for throttle
Wrist Strap	Secures controller around user’s wrist
Helmet	Primary PPE to protect the head
Wrist Guards	Secondary PPE to aid user if falling forward
Knee Pads	Alternate protection for users when falling and sliding

B-4: **Safety**

Product	Place of Purchase
1: Flipsky 6354 190KV 2450W BLDC Brushless Belt Sensored Motor	Amazon
2: VANPRO Electric Skateboard DIY V2 Edition 2.4G Mini Wireless Remote Control Receiver	Amazon
3: HGLRC Flipsky FSESC V4.12 50A ESC	Amazon
4: MXRS SPDT 1NO 1NC Hinge Lever Momentary Push Button Micro Limit Switch AC 5A 125V 250V 3 Pins 12 Pcs	Amazon
5: ISDT 608AC Battgo Lipo Battery Charger 6S 8A 200W AC/DC Smart Charger for LiFe, LiIon, LiPo, LiHv / Pb / NiMH Battery Balance Charger Discharger	Amazon
6: Premium DIY Electric Skateboard Motor Mount	Amazon
7: Caliber Trucks Cal II 50° RKP Longboard Trucks - set of two	Amazon
8: 2Packs XT60 Series Connector 1 Female to 2 Male XT60 Plug in Series Power Connector	Amazon
9: DIYE Mini Electric Skateboard Enclosure for Battery Electronics	Amazon
10: MCIGICM 10 Pair XT60H (XT60 Upgrade) Male Female Bullet Connectors Power Plugs	Amazon
11: RC On Off Switch with XT60 Plug and High Current XT60 200mm 14AWG	Amazon
12: VinTeam 10 Pairs XT60 XT-60 Male Female Bullet Connectors Power Plugs with 5mm Heat Shrink Tubing for RC Lipo Battery	Amazon
13: APIELE (6 Pcs) API-163-1C25 Micro Limit Switch Long Hinge Roller Momentary Push Button SPDT Snap Action	Amazon
14: NIDICI XT60 Lipo Battery Charger 2-6S Parallel Balanced Charging Board Charging Plate for Imax B6AC 720i Lithium Batteries	Amazon
15: Flipsky Electric Skateboard 280A Anti Spark Switch Pro	Amazon
16: vanpro DIY Electric Skateboard 83MM 90MM 97MM PU Wheel Pulleys Kit Set 36/18 Tooth Belt 15MM 5M (Snow Black, Pack of 1)	Amazon
17: vanpro DIY Electric Skateboard Longboards Wheel 90MM 9052 pu for Cruising, Carving, Free-Style, Wheels Flywheels 608rs Precision Bearings	Amazon
18: Zeato All-in-One Skate Tools Multi-Function Portable Skateboard T Tool Accessory with T-Type Allen Key and L-Type Phillips Head Wrench Screwdriver	Amazon
19: Turnigy 5000mAh 5S 20C Lipo Pack W/XT-60	HobbyKing

B-5: **Materials List**

Cost(Tax not Included)	Order Total	Order Index
$76.99	$81.61	1
$27.90	$31.77	2
$76.99	$81.61	3
$6.69		4
$59.90		5
$39.69		6
$49.95		7
$8.99		8
$20.99		9
$8.99	$206.56	10
$11.99		11
$7.99	$21.18	12
$7.99	$8.47	13
$12.59	$13.35	14
$49.00	$51.94	15
$25.90	$27.45	16
$30.60	$32.44	17
$6.98	$7.40	18
$95.60	$109.00	19
Additional Funding Required	**Total Cost**	
$472.78	$672.78	
	Allocated Budget	
	$200	

B-6: **Financial Budge**