# Team 4 – Mario Kart Simulation


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***Abstract*—This proposal introduces Team 4's idea for the Fall 2022 / Spring 2023 Capstone Project. The proposal begins with an introduction to the problem, followed by the formulation of the problem. Additionally, necessary specifications, background information, and constraints are discussed as are possible solutions, measures of success, unknowns/obstacles, readily available solutions, skeleton or top-level solutions, and broader implications, ethics, and responsibility associated with the solution. Finally, Team 4's resources for completing the project are described, including the personnel, materials, funding, timeline, and deliverables**



***Keywords— Capstone Design, gaming, exercise, sensors, magnetic, electromagnetic, engineering, resistance, trail***


## I. Introduction

Imagine an interactive game where you can ride your bike down a trail in Cookeville, TN, or dodge rogue shells and bananas before sailing to the finish line as your favorite Mario Kart character. Team 4 proposes to make this idea a reality. The initial concept for the Mario Kart Bike developed by the previous Capstone Project team provided riders with an interactive Mario Kart character bike ride. In other words, the rider cycled his way through a Mario Cart game – actually pedaling the bike and turning the handlebars to progress down the trail. The objective of Team 4's project is to further enhance the riding experience offered by the existing design. Team 4 has been challenged to develop a means to provide resistance to the bike while playing the game and to develop a simulated trail that replicates an actual trail in Cookeville, complete with uphill climbs, jumps, downhill coasts, and rugged terrain.

Aside from accomplishing an engineering feat, the overarching objective for the initial project was to develop a system that integrates basic physical exercise with the process of playing a video game. This was accomplished. The initial design certainly provides Mario Kart fans with a fun and enjoyable way to work out while gaming. With obesity rates on the rise in the United States, this design offers a win-win scenario for gaming enthusiasts in that gamers can actually participate in physical activity while playing Mario Kart. "According to the Department of Health and Human Services and the CDC, 42.4% of U.S. adults are currently obese. That's up substantially from the 30.5% measured in 2000" [1]. The intent for designing and developing this exercise/gaming innovation is to inspire gamers to participate in physical activity, thereby improving their overall health. With a staggering 66% of Americans playing video games, the Mario Kart Bike could have a significant impact on the general health of society simply by adding a little physical activity to the day-to-day activities of the gaming population [2]. "Riding a stationary exercise bike is an efficient and effective way to burn calories and body fat while strengthening your heart, lungs, and muscles" [3].

To offer a realistic Mario Kart experience, an exercise bike style system is used. The bike is connected to the game, so pedaling and steering motions are connected to the standard control systems of accelerating and steering in Mario Kart. To add a new dimension of realism to the game, Team 4 will add a variable of resistance to simulate uphill climbs, jumps, downhill coasts, and rugged terrain present on an actual trail in Cookeville.

After consulting with the customer and professor to verify the specific Revision 2 requirements, Team 4 will build upon the previous team's foundational work by collaborating to draw upon the specific knowledge each of us brings to the team from Team 4's Electrical Engineering and Computer Engineering majors, as well as various minors. Team 4 will work together to develop and identify concepts for the delivery of an optimum solution, meeting with the professor and customer for routine discussions and reviews.

The balance of this proposal outlines Team 4's basic plan for adding resistance to the existing Mario Kart bike design to provide an interactive simulated bike ride up and down a trail in Cookeville. By replicating the effects of riding an actual trail in Cookeville, residents and alumni can recall a trail possibly once traveled while enjoying a Mario Kart Bike ride anywhere. In the following sections, Team 4 describes in detail the specifications, constraints, and background behind this system. Team 4's proposal also briefly describes the team, Team 4's skills and resources, and the timeframe for the development and delivery of the new capability.

## II. Formulating the Problem

### A. Objective

The objective of this project is to improve upon the previously designed Mario Kart gaming simulation. The improvements of this design are intended to address the shortcomings of the previous design by increasing the realistic experience for the user. This will be achieved through redesigning the dynamic resistance scheme to include an improved response and deliver a realistic resistance structure. The components used in this design will also be compact and easier for the customer to install on his/her bike.

In addition to the Mario Kart simulation improvements, the designed components will be capable of capturing real-life riding data. This captured data will be used in the design to allow customers to create their riding courses and then replay the ride using the simulation bike. Each user will be able to visually experience his or her recorded bike ride along with the different inclines and declines that were encountered throughout the entire ride.

### B. Specifications

The proposal includes an improved design of the Mario Kart simulator that shall adhere to the prescribed specifications listed in this proposal to successfully complete the objective. The proposed design includes two separator modes of operation: the Mario Kart game simulation and the pre-recorded trail ride simulation. Each mode of operation shall include hardware and software components and shall have the ability to be offered as a package unit contained in one box.

The Mario Kart simulation mode shall provide the user with variable resistances that reflect the gameplay of the user. There are two specific occurrences the user of the Mario Kart simulation shall experience when resistance is added to the bike. In the first occurrence, if at any time during the game the user goes off the track, the user shall experience gradually increasing resistance. The gradual resistance changes shall be applied based on the length of time the user is off the track. The user shall experience variable resistance from the bike when encountering obstacles in the Mario Kart game, such as being hit by an opponent's turtle. The resistance experienced by the user shall be greater when first struck by the turtle, then resistance will gradually decrease as the user recovers.

The current simulation bikes on the market today do not allow the user to record bike routes and then simulate the routes later. The proposed design shall provide the user with the capability of pre-recording customer bike trails, and then re-experiencing the recorded trail on the Mario Kart simulation bike. The proposed design shall create a local database that stores trail replay data, where the user can name, navigate, and select rides to be replayed. The proposed design shall include additional hardware that is mountable to the user's outdoor bike. The hardware mounted shall collect data of the bike rider and the environment that the rider is experiencing. The data collected shall include incline/decline angle changes, velocity and acceleration of the rider, distance/time between changes in incline, and the visual effects of the rider. All components used within the mountable kit shall be calibrated within 5% of actual tested measurements. Given the 5% variance of calibration, the power input of the rider shall be within 10% of the simulated resistance provided by the bike. Based on research and medical data gathered, the maximum angle that a cyclist could successfully achieve is around 40 degrees of incline, considering a frictional coefficient of 0.8 [4]. The proposed design shall provide the user with a simulated angle of no greater than 40 degrees. Based on a study conducted by Romagnoli and Piacentini [5], it was found that test subjects could accurately perceive differences in exercise velocity, and in turn resistance changes, approximately 80% of the time, meaning they were inaccurate 20% of the time [6]. The proposed design shall have no less than 85 states of resistance. The 85 separate states of resistance are proposed based on the changes in angle from 0 to +40 degrees in 10% increments, or half of the inaccuracy discovered by Romagnoli and Piacentini, with a 5% variance for special case changes in resistance. Similarly, a motor with 85 states of forward velocity is also proposed for the angles of –40 to 0 degrees, following the same convention.

These tolerances are intended to maintain the real-life experiences as seen and felt by the user. The trail ride camera included in the mountable hardware kit shall be used to collect visual information from the rider's perspective, which shall be replayed on the simulation bike. The camera is intended to provide the user with the first-person simulation experience.

The variable resistance design shall be achieved by either improving the existing motor resistance design or by replacing the existing motor with a magnetic resistance device that utilizes eddy currents that will affect the amount of force required to pedal the simulation bike. The concept of using eddy currents for damping purposes is proven and dates to the 1800s [7]. The components used within this project shall be compact and require only household hand tools to assemble. The components shall be able to be packaged in a manner such that they can be a deliverable item to the customer. The engineering team shall redesign the existing components used in the Mario Kart simulation to make them wireless, while meeting and/or exceeding the existing quality of performance.

### C. Background

In the initial version of the Mario Kart Bike, the goal was to design a system (Bluetooth controller) that integrates physical exercise with the process of playing a video game. The initial version performed this task correctly; however, some improvements are requested for Version 2. To begin, the dynamic resistance will be improved by using a physics engine implemented in the software. This approach was chosen because many factors must be taken into consideration and calculated to calculate the precise resistances that should be applied to the bike. A system of this precision needs a physics engine dedicated to providing correct resistance. This engine will collect game data in the case of Mario Kart play and data collected from the user's phone in the case of the bike trail replay to determine correct resistances.

Looking at the initial version of the Mario Kart Bike, one thing that catches the eye is the large motor that sits behind the bike. Although this motor is rated for 180 volts, it can reach higher numbers in an open circuit. This amount of power could be quite a hazard for users if not properly contained. The larger the voltage connected to the bike; the more current that will feed into it (with the same resistance). Because this product is an exercise bike, users will most likely be sweating at any time during use. This is a cause for focus, as sweat leads to less resistance (more current). To commercialize the bike, Team 4 is investigating options to make this power source safer, limiting power supplied as much as possible, while still allowing for the bike to function properly.

### D. Constraints

Components such as a phone holder (used to hold a phone on a bike for gathering data on the route to be replayed or to enable the users to see themselves play Mario Kart in the game) must be able to be installed onto the bike easily. Time is a hard deadline of two semesters, so Team 4 must complete the Rev. 2 project in that timeframe. Another constraint is the budget, which will be no greater than approximately $1,000. To commercialize this product, making the design more minimal and wireless, Team 4 must address the constraints such as revising the motor system as a whole to mitigate its safety issues. The voltage supplied by the motor system will be no greater than 30 volts, as 30 volts is generally considered an upper limit [8]. Safety is a constraint, as Team 4's product must follow all related standards (i.e., IEEE and OSHA). Physics engine creation or implementation must be used to calculate precise, dynamic resistance. To measure the validity of the dynamic resistance system, a minimum of 85 resistance states will be used.

### E. Standards

1. Electromagnetics
   - 299 - IEEE Standard Method for Measuring the Effectiveness of Electromagnetic Shielding Enclosures
   - 299.1 - IEEE Standard Method for Measuring the Shielding Effectiveness of Enclosures and Boxes Having all Dimensions between 0.1 m and 2 m
   - 1309 - IEEE Standard for Calibration of Electromagnetic Field Sensors and Probes, Excluding Antennas, from 9 kHz to 40 GHz
   - C63.2 - American National Standard for Electromagnetic Noise and Field Strength Instrumentation, 10 Hz to 40 GHz Specifications
   - C63.14 - American National Standard Dictionary of Electromagnetic Compatibility (EMC) including Electromagnetic Environmental Effects (E3)
   - C95.1 - IEEE Standard for Safety Levels with Respect to Human Exposure to Electric, Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz

2. Electronics
   - NESC HBK - National Electrical Safety Code (NESC) Handbook
   - 2017 National Electric Safety Code(R) (NESC(R))

3. Batteries
   - 946-2020 - IEEE Recommended Practice for the Design of DC Power Systems for Stationary Applications

## III. Solutions

### A. Measures of Success

1. *Game Latency:* The first revision of the Mario Kart Bike determined that an input delay of less than 40 ms, which averages out to approximately 2.4 frames for a 60-fps game, would be a sufficiently low amount of lag. Using the controller byte data for joycons that dekuNukem determined, being a 13-byte request after 15 ms and a 61-byte answer after 4 ms, and the latency for a packet size of 100 bytes being ~8.5 ms, it can be determined that there is a theoretical minimum latency of 27.5 ms [5], [9]. This can be confirmed in the future by designing a program that will time the periods between game requests and controller responses. This means that a delay of less than 40 ms is theoretically possible if the code for data processing is 12.5 ms. Similar to testing data transmission latency, this can be tested quantitatively by adding code to the system that times the period between obtaining the game data and sending a response. Qualitatively, user satisfaction can be determined via user surveys. The measure of

success for this project will be to maintain a level of 40 ms latency or better after completion of design.

2. *Immersion*: In addition to an improvement to immersion and consistency in regards to the Mario Kart Bike's handling and variable resistance components, an immersive experience must be achieved when utilizing the bike route recreation function. Accomplishing this would create a truly dynamic and engaging exercise experience. This will be tested using a variety of survey parameters to ensure customer satisfaction. The measure of success will be that a majority of testers state that they find the Mario Kart functionality to be more immersive than playing the game on the Nintendo Switch.
3. *Resistance Variance (RV):* An extension of the Immersion measure of success, the RV, that is the number of states required for immersive and safe gameplay, must be such that it is difficult or impossible for a user to detect a discrepancy between the any given resistance state and it's nearest neighbors. The original design only suggested three resistance levels. While this was acceptable for the Mario Kart design, this is too few states for an immersive trail recreation. The RV can be quantitatively determined by running an exhaustive test of all resistance values to determine if each one produces a unique resistance. A survey will be conducted to determine the variable resistance experience. Participants will rate the smoothness between states of resistance. The measure of success is that the majority of surveyed participants will state that the transition of resistance levels is smooth.
4. *Physics Accuracy:* Physics accuracy represents how accurate the recorded values are to the actual values the rider is experiencing. The values that are used for the equations are distance, velocity, acceleration, time, height of incline, and incline angle. Distance, height, time, and angle can be measured manually and compared to the values recorded by the sensors. Velocity and acceleration can be derived from distance and time. The simulated resistance is designed to reflect the resistance that would be experienced by a rider in still air traveling at the recorded speed and angle on a flat plane. The measure of success will be 10% accuracy in accordance with the recorded speed and angle.

### *B. Unknowns, Obstacles, and Safety Concerns*

1. *Obtaining Game Data:* Previously, the team who worked on Rev. 1 of the Mario Kart bike anticipated utilizing a large quantity of game data values from an emulator. The current state of the bike, while a much more accessible design by using Bluetooth with the actual Nintendo Switch and Mario Kart 8 game, is also much more restrictive in regard to how the game data can be manipulated. Since the current design utilizes the user's actual Nintendo Switch console, Team 4 is not allowed to manipulate the game and console. Team 4 can only use whatever feedback the game provides through the controller, and the only controller gameplay feedback is the rumble states. The difficulty will likely be obtaining these data bytes, determining which bytes belong to which game states, and storing these states for future use.
2. *Retrieving Game Data:* The current idea for rumble state storage is a repository of the different rumble states Team 4 will use in Python that will pull resistance duration and magnitude depending on the rumble state that is received by the game. However, retrieving this data in a timely manner and sending that information to the resistance system is likely to require extensive fine-tuning to ensure proper functionality.
3. *Resistance Variance:* A few issues are expected to arise with resistance variance. It is possible that calculating resistance and applying said resistance to the bike in an appropriately accurate manner will be inconsistent and difficult. The quantity of states, the strength of their resistances, and the transition time between states could result in injury if the transitions are too fast or a non-immersive experience if they are too slow. It may prove to be difficult to find a sufficient balance to ensure a safe, immersive experience.
4. *Trail Replication Kit:* The kit, being the newest modification to the system, may prove to be very difficult. It may be complicated to create a kit that, when installed, does not impede user visibility and mobility while riding.

### *C. Already Available Solutions*

Many similar solutions exist; however, Team 4's project seeks to implement more total functionality than any currently available. Below are some examples of exercise bikes being used as game controllers or similar. Herein, hobbyist solutions refer to those solutions which are not available for public use or purchase in any capacity beyond an idea.

1. Commercial solutions:
   - RealRyder Hong Kong Bikes at Pure Fitness [10]

     Acts as a steering input with which to play Mario Cart. Lacks the ability to modulate the game input based on pedaling speed or apply resistance based on in-game events, which are features Team 4 wishes to implement. The only associated cost for the end user is a gym membership at Pure Fitness Gym in Hong Kong.
   - Cyber ExerCycle [11]

     Controls the game using a magnetic speed sensor and accompanying traditional handheld controller. Meant for use with PC games but seeks to accomplish a conceptually similar functionality. The cost for the standard version is $99.

- Wii Cyberbike Magnetic Edition [12]

  A Wii controller is meant to control Cyberbike using speed and steering data. The resistance is adjustable; however, it is not in any way related to the game. The cost is $199.99.

- Expresso Bikes [13]

  These exercise bikes are designed to provide a full ride simulation experience, including steering input and computer-controlled variable resistance. The bike includes a display and computer with installed simulation games. Said games have notably dated graphics. The cost is not publicly available, though the bike is currently for sale to the public.

- Echelon EX-8s Connect Bike [14]

  This solution implements variable resistance and ride simulation. It does not include steering, and it is not possible to simulate a user-recorded ride. The cost is $2,299.99.

2. Hobbyist Solutions:

- Xbox Exercise Bike Controller [15]

  Using an Xbox controller, an Arduino Micro, and a magnetic speed sensor, this Youtube user was able to control the speed and steering of a GTA character riding a bike. Though this represents an entirely different console, the functionality is similar to what Team 4 seeks to implement.

- General Arduino-Based Exercise Bike Controller [16]

  This solution is a general-purpose method, meant to be applied to a dedicated exercise bike, rather than a retrofitted frame. The only input data taken from the bike itself is the angular velocity of the flywheel, which is used to modulate one specific part of controlling the game

- Exercise Bike PC Game Controller [17]

  This project allows one to control a PC game using a speed reading from an exercise bike. This is one piece of the functionality Team 4 wishes to implement.

- Nintendo Fit Labo Cart [18]

  This solution implements a wireless physical manipulator to physically make inputs on the OEM controller, rather than transmitting data directly to the game console. The user input is the speed of the exercise bike flywheel, as well as steering and button inputs on a ring-con (a circular type of controller for the Nintendo Switch). This solution affects a binary a-press, where the button is pressed only after surpassing a certain set speed. Team 4, on the other hand, aims to modulate the a-presses in such a way that the movement of the cart varies up to a certain speed. The steering is done similarly to a car and requires that the user not hold on to the handlebars of the bike with his/her hands. This solution provides no resistance modulation.

3. Top-Level Solutions

   The following is an outline of key components which have either already been incorporated or that must be incorporated during the design process. This list is not exhaustive, and not all components may be used in the form/functionality specified.

- Resistance element: this component will act to produce a variable mechanical resistance and (if it is capable) to charge a battery or capacitor to power the sensors.
- Speed sensor: this component will monitor the speed of the rear wheel of the bike.
- Raspberry Pi: this component acts as the main controller of the device, and interfaces with a touchscreen that provides an HID.
- Wireless modules: these components act to transmit data between devices mounted on the bike and the Raspberry Pi.
- Power dissipation controller: this controller will modulate the effective physical resistance experienced by the rider.
- Power regulation/charging module: this component will regulate the output of the motor to be suitable for charging the utilized accumulator element and powering the attached devices. Alternatively, this component will act as a power source for a linear actuator should Team 4 opt for magnetic resistance.
- Steering sensor: this component acts to convert the angle of the bike steering column into a game input. It will not be used during simulations.
- Sensor microcontroller: this component calculates the rear wheel speed and the power dissipation, and relays this to the Rasberry Pi via an attached wireless module.
- Button input(s): this component allows the user to input a button press from a handlebar-mounted device (this is required for full control of the video game).
- Frame: this component acts as the physical stand for the bike.
- Bike: a retrofitted mountain bike.
- Ride recorder: this component will record data from a bike ride, including angle relative to the horizontal plane, speed, and video for playback during simulations, and store this data in a manner that can be readily shared with other users.
- Ride data filter: this programmatic component filters noise and undesirably rapid changes in angle and speed out of the recorded data.
- Playback: this programmatic component handles playback of recorded data and syncs the recording frame rate with the current speed of the rider.

- Game event detector: this programmatic component detects events within the Mario Kart game and adjusts the pedaling resistance accordingly.
- Power calculator: this programmatic component calculates the instantaneous power required to stay at a given speed during simulations and adjusts pedaling resistance accordingly. This element requires input variables: rider weight, current speed, and incline angle. It outputs a signal usable by the power dissipation controller.

4. Broader Implications, Ethics, & Responsibility:

This product is another addition to the growing trend of immersion in video games. This trend has always been a thing, constantly pushing toward more realistic, immersive gaming, but recently technology has expanded even more, leading to innovations such as the VR headset that push the limits of immersive gaming. The Mario Kart Bike is also part of the subset of video games that encourage physical exercise. From the Wii, the pioneer of linking exercise with gaming, to the more recent Pokémon GO that took the world by storm, this category of gaming seems to be here to stay. The Mario Kart Bike is intended to combine the immersive gaming experience with exercise that anyone can enjoy.

During the process of modifying the Mario Kart Bike, it is important that Team 4 does not break Nintendo's copyright laws [19]. These laws include anti-piracy of Nintendo products, use of circumvention devices, and intellectual property. Although Team 4 plans to improve on the first revision of the Mario Kart Bike and make the product more commercialized, it will not actually be commercialized, so as not to infringe on Nintendo's intellectual property.

The safety of the user is the engineer's responsibility, so Team 4 will improve the safety of the power system of the first revision of the product, as well as the jolting nature of the dynamic resistance system. Limiting the voltage supplied to the bike will be implemented to eliminate electrical hazards in using the bike. Smoothness of resistance changes will not only improve the function of the bike; it will also make the device safer for those who use it.

## IV. Resources

### A. Team Members

The following list is meant to reflect the key proficiencies of each team member.

Blake Pickett

- Project management
- Power generation
- Power distribution
- Soldering
- Welding
- Wiring
- Mechanic work
- Spice simulation

Tyler Chittum

- Soldering
- KiCAD drafting
- SPICE simulation
- Electronics
- Basic bike mechanic ability
- Technical writing

Benjamin Reed

- Python, C/C++, Java
- RStudio, MATLAB
- Soldering
- Digital/embedded systems

Ray Durlin

- Power generation
- Project management
- Power distribution
- SPICE simulation

Sage Mooneyham

- C/C++
- Debugging
- Digital/embedded systems
- Signals
- Electronics
- Soldering

### B. Components and Project Budget

1. Items Needed (Tentative)
   - Wireless transmitters
   - Linear actuator
   - Aluminum flywheel
   - Neodymium magnet
   - Motor
   - DC-DC conversion circuitry and housing
   - Speed sensor
   - Pedaling resistance modulation circuit

- Another bicycle

2. Current Inventory

- Bicycle
- 180 V 1/3 hp PMDC motor
- Raspberry pi and touchscreen display
- Arduino
- LED-based digital tachometer
- Potentiometer
- Wires (likely sufficient for Team 4's plans to use wireless communications)
- Project box with forced convection
- Frame and flywheel
- Television monitor

3. Budget

Team 4 can expect to require a budget of approximately $400 to complete the revisions to the current bike system. To complete a second bike, Team 4 will require a budget of approximately $600 in addition to the prior amount, as the costs associated with the computer, frame, flywheel, project box, and monitor will come into play.

4. Timeline

The timeline for this project is classified by six sections:

- Team Contract
- Project Proposal
- Conceptual Designing and Planning
- Detail Design Phase
- Additional Course Due Date
- Important Dates

All due dates reflect published project due dates established by Mr. Roberts. Tasks have assignees and are represented on the timeline by each team member's initials.

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# Mario Kart Simulation

Read-only view, generated on 26 Sep 2022

Instagantt

| # | ACTIVITIES | ASSIGNEE | EH | START | DUE | % |
|---|---|---|---|---|---|---|
| | **Team Contract:** | | - | **01/Sep** | **15/Sep** | **100%** |
| 1 | Team Contract Submission | All Team Memb... | - | 01/Sep | 15/Sep | 100% |
| | **Project Proposal:** | | - | **16/Sep** | **12/Oct** | **43%** |
| 3 | Proposal Submittal Due | All Team Memb... | - | 16/Sep | 25/Sep | 100% |
| 4 | Proposal Presentations | All Team Memb... | - | 03/Oct | 03/Oct | 0% |
| 5 | Proposal Revisions Due | All Team Memb... | - | 04/Oct | 12/Oct | 0% |
| | **Conceptual Design & Planning:** | | - | **26/Sep** | **30/Oct** | **0%** |
| | Conceptual Design & Planni... | All Team Memb... | - | 26/Sep | 17/Oct | 0% |
| 8 | Resistance & Sensors D... | BP, TC, RD | - | 26/Sep | 16/Oct | 0% |
| 9 | Logic Design | BR, SM | - | 26/Sep | 16/Oct | 0% |
| 10 | Ride Replay Simulation | All Team Memb... | - | 26/Sep | 16/Oct | 0% |
| 11 | Design Review | All Team Memb... | - | 17/Oct | 17/Oct | 0% |
| | Conceptual Design & Planni... | All Team Memb... | - | 18/Oct | 30/Oct | 0% |
| 13 | Ride Replay Simulation ... | All Team Memb... | - | 18/Oct | 30/Oct | 0% |
| 14 | Logic Design Revisions | BR, SM | - | 18/Oct | 30/Oct | 0% |
| 15 | Resistance & Sensors D... | RD, TC, BP | - | 18/Oct | 30/Oct | 0% |
| | **Detail Design Phase:** | | - | **01/Nov** | **24/Nov** | **0%** |
| | Detail Design Checkpoint 1 | All Team Memb... | - | 01/Nov | 10/Nov | 0% |
| 18 | Ride Replay Simulation ... | All Team Memb... | - | 01/Nov | 10/Nov | 0% |
| 19 | Logic Detail Design | BR, SM | - | 01/Nov | 10/Nov | 0% |
| 20 | Resistance & Sensors D... | BP, TC, RD | - | 01/Nov | 10/Nov | 0% |
| | Detail Design Checkpoint 2 | All Team Memb... | - | 11/Nov | 24/Nov | 0% |
| 22 | Resistance & Sensors D... | RD, BP, TC | - | 11/Nov | 24/Nov | 0% |
| 23 | Logic Detail 2 | BR, SM | - | 11/Nov | 24/Nov | 0% |
| 24 | Ride Replay Detail 2 | All Team Memb... | - | 11/Nov | 24/Nov | 0% |
| | **Additonal Course Due Dates:** | | - | **17/Nov** | **11/Dec** | **0%** |
| 26 | FMEA Video Presentation | All Team Memb... | - | 17/Nov | 17/Nov | 0% |
| 27 | Capstone 1 End of Course P... | All Team Memb... | - | 11/Dec | 11/Dec | 0% |
| 28 | Final Presentation | All Team Memb... | - | 11/Dec | 11/Dec | 0% |
| | **Important Dates:** | | - | **11/Oct** | **12/Dec** | **0%** |
| 30 | Thanksgiving | All Team Memb... | - | 28/Nov | 28/Nov | 0% |
| 31 | Fall Break | All Team Memb... | - | 11/Oct | 11/Oct | 0% |
| 32 | End of semester | All Team Memb... | - | 12/Dec | 12/Dec | 0% |