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. The proposal also describes possible solutions and addresses 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 Capstone Design Project Team 4's project is to further enhance the riding experience offered by the existing design by adding a variable of resistance for two modes of operation: the Mario Kart game simulation and a pre-recorded trail ride simulation. To provide a new dimension of realism to the Mario Kart Bike, Team 4 proposes to capture data from an actual trail in Cookeville for use in the pre-recorded trail ride simulation, complete with uphill climbs, downhill coasts, and rugged terrain. Team 4 also proposes to add a variable of resistance for both modes of operation. Resistance will be added by either improving the existing motor resistance design or by replacing the existing motor with a magnetic resistance device that utilizes eddy currents to affect the amount of force required to pedal the simulation bike. Team 4 proposes a solution that includes two kits: the Mario Kart kit and the Ride Replay kit.

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 is 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]. Exercise bikes have proven to be "an efficient and effective way to burn calories and body fat while strengthening your heart, lungs, and muscles" [3]; therefore, merging them with video games is expected to be an effective method to improve the well-being and longevity of the video game playing population.

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. 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 by improving the immersive experience felt by the user, as well as by offering an additional hardware kit that allows users to record custom bike rides and then replay the bike ride on the Mario Kart simulator. The improvements of this design are intended to address the many shortcomings of the previous design, such as the lack of variable resistance felt by the user, fragility of steering system, and replacing wired connections with wireless connections for ease of installation.

As stated previously, in addition to the Mario Kart simulation improvements, a second hardware kit will be designed to attach to the user's personal outdoor bike. This upgraded kit will provide the user the ability to capture 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 Mario Kart simulation bike. Each user will be able to re-experience his or her own recorded bike ride, including the changes in resistance felt by the user due to the inclines encountered.

B. Specifications

The proposal includes two separate, yet complementary hardware kits. The first kit, referred to as the Mario Kart kit, shall include upgraded Mario Kart simulation hardware. The second kit, referred to as the Ride Replay kit, shall include all the necessary hardware to record riding courses on a personal outdoor book and replay the recorded ride on the Mario Kart simulator bike. The scope of work is aimed to provide the user with an improved design of the Mario Kart simulator as well as to provide the option for a secondary kit for replaying a ride. It is necessary to have two separate kits, because one kit will be used only on the Mario Kart simulator to play Mario Kart video games. The optional kit is designed to be attached to a personal bike and then will have the ability to interact with the Mario Kart simulator bike platform.

Table 1 below lists the specifications specific to only the Mario Kart simulation kit.

Table 1. Mario Kart Simulation Kit Specifications

Design Item	Specification
Game event detection	▪Shall consistently trigger a change in resistance in response to the following in-game events: being hit by a shell, using a mushroom, riding offroad, and going over a boost pad.
	▪Resistance shall be reset to the nominal value after the duration of the in-game event has run its course
Steering	▪Steering mechanism shall be strengthened using metal components

Below in Table 2 are the specifications specific to only the Ride Replay simulation kit.

Table 2 Ride Replay Simulation Kit Specifications

Design Item	Specification
Ride data replay/simulation	▪The replay system shall produce a resistance which is within 10 % of the value calculated by the simulation software, provided that the calculated power does not exceed the maximum power which the dissipative mechanism is capable of dissipating at the current speed.
Ride recording (for a bike auxiliary to the exercise bike)	▪Shall synchronously record video, barometric pressure, rear wheel speed, and incline angle; record this data to a non-volatile storage medium
Ride data filtering	▪Shall attenuate frequencies above 1 Hz by at least 80 dB
Elevation	▪Rider elevation shall be recorded while rider is recording bike

Table 3 provides the specifications that are relevant to both the Mario Kart and Ride Replay kits.

Table 3. Specifications for Mario Kart Kit and Ride Replay Kit

Design Item	Specification
Main controller board	▪Shall not crash or overheat under normal operating conditions at or near room temperature (70 ± 5 °F)
Resistance system	▪Shall not surpass 30 V ▪Shall contain at least 85 distinct resistance states
Speed sensor	▪Shall update the controller with at most 40 ms latency
Wireless communication	▪Shall provide a latency of at most 40 ms for data transmission between the sensors and main controller board

Sensing latencies are determined as input delay of less than 40 ms, which averages out to approximately 2.4 frames for a 60-fps game. 40 ms is sufficiently low amount of lag and is achievable given that the theoretical latency is approximately 27.5 ms.

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]. However, there is no published documentation that has determined the exact human threshold a human can sense changes in resistance. 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 with a 5% variance for special case changes in resistance. The user resistance system shall not exceed 30 V, as a general safety precaution for the user. Frequency attenuation was determined based on innate natural frequency of bike tires varying significantly depending on the inflation pressure of the tires, which was well over 1 Hz by two orders of magnitude for both 60 and 120 PSI inflation pressures [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 Revision 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 determine 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.

The use of power, as opposed to torque, to determine the resistance which the rider must oppose is done for two reasons. First, the effort required to perform an exercise task is often defined in terms of the power requirement, because it is an easily calculated quantity. It is a valid and common method to use power to quantify the intensity of an exercise task [8]. Correspondingly, the most relevant parameter to determine is the *amount* of exercise that a person has undergone or how many calories of energy said person has expended. Provided power is sampled over a given length of time, its integration over that time is the expended energy. Since power is widely accepted to be a valid means to describe the intensity of an exercise, power-based simulation seems a reasonable choice, especially given the relative ease with which it can be calculated. Only the angle of incline, velocity, and the mass of the rider are necessary to determine the power required by the exercise. Accordingly, as velocity is raised or lowered, the power required of the rider can increase or decrease in tandem.

More specific background will be added per section as needed.

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. We can measure ease of installation by giving users a survey and asking them to describe the difficulty to set up each component. Time is a hard deadline of two semesters, so Team 4 must complete the Revision 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 to mitigate its safety issues. The voltage supplied by the motor system will be no greater than 30 volts, since 30 volts is generally considered an upper limit [9]. Safety is a constraint; Team 4's product must follow all standards listed in the 'Standards' section. 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

Electromagnetics

- 1309 - IEEE Standard for Calibration of Electromagnetic Field Sensors and Probes, Excluding Antennas, from 9 kHz to 40 GHz
- C95.1 - IEEE Standard for Safety Levels with Respect to Human Exposure to Electric,

Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz

Mechanics

- 1926.300b.2 - OSHA Standard for Guarding from Rotating or Moving Parts of Equipment
- ASTM F1250-13 Standard Specification for Stationary Upright and Recumbent Exercise Bicycles and Upper Body Ergometers

Electronics

- 1926.404b OSHA Standard for Wiring Design and Protection
- 1910.137 OSHA Standard for Electrical Protective Equipment

General

- 1910.133a OSHA Standard for Eye and Face Protection

III. Solutions

A. *Measures of Success*

- *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], [10]. 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.
- *Resistance States:* As stated above by Romagnoli and Piacentini [5], participants in their experiment were able to determine which of the two different weights resulted in a higher repetition velocity with a 20% inaccuracy. Since there was little to no research on the exact resistance threshold that a human can sense, Romagnoli and Piacentini's research was the most useful research that could be found. Using half of the 20% value, a MATLAB script was created to determine what angles resulted in 10% ± 5% increases in resistance. This resulted in 85 unique states. Therefore, one measure of success is that the resistance system can produce 85 unique resistance states. This can be tested by using a brute force algorithm that cycles through all resistance states and by measuring them using an external instrument to confirm the resistances are unique.
- *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 of the required power output from the rider with respect to the power output demanded by the programmatically simulated course, provided that the required power does not exceed the amount the chosen dissipative mechanism is capable of dissipating at a given speed. The exact parameters cannot be determined at this time. To do so, it would be necessary to know the strength of the magnet as well as the size of the flywheel (assuming the use of a magnetic resistance system.

B. *Unknowns, Obstacles, and Safety Concerns*

1. *Rumble Data Acquisition:* Due to copyright laws regarding Nintendo, the team is unable to gain access to the game code. This means bike events, such as the resistance system, that occur in response to in-game events must be initiated by controller outputs from the game. The only one event is the rumble states. Rumble states are the collection of bytes the controller uses to initiate vibrations of various magnitudes, frequencies, and durations. The team that engineered Revision 1 briefly considered the utilization of rumble states, but they did not implement such a system due to time constraints. This, in addition to limited documentation from Nintendo, means it is unknown whether the utility of rumble states is possible. Only by exploring the Joycontrol software code can it be determined that rumble states can be accessed and utilized.
2. *Resistance State Quantity:* As stated prior regarding research on the threshold of resistance changes a human can sense, it is unknown whether 85 states will be too many or too few. This number could be

tested by using several trial participants and applying resistance in a slow, gradual manner, having the participants convey when they sense a resistance change. Using the data from multiple trials, the number of resistance states could be refined.

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.

- Commercial solutions:
  - RealRyder Hong Kong Bikes at Pure Fitness [11]

    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 [12]

    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 [13]

    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 [14]

    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 [15]

    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.
  - Garmin Edge 130 [16]

    This device is an example of a common bike accessory called a bike computer. The Garmin Edge 130 is capable of recording the user's power output, elevation, speed, calories burned, and a number of other biometric data of interest to bikers. It is capable of measuring all data that we wish to collect with our ride data collection system, aside from optical data. Price: $199.99.
  - Unisky Bike Trainer Stand [22]

    This device is meant to support a mountain bike in a stationary position so it may be used as an exercise bike. It produces resistance by means of a magnet and flywheel system, which is set by the user to determine the resistance of the bike. This device was previously purchased as part of the original design; though it is currently only being used as a support and flywheel; the portion which modulates the resistance has been removed but is still within inventory. Price: $89.99.

- Hobbyist Solutions:
  - Xbox Exercise Bike Controller [17]

    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 [18]

    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 [19]

    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 [20]

    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.

- 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 module: this component acts 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: this is a retrofitted mountain bike.
- Ride recorder: this component will record data from a bike ride, including angle of the bike relative to the horizontal plane, speed, altitude, caloric output, 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. Typical road noise is broad-spectrum, mostly concentrated on the order-of-magnitude of 1000 Hz [21]. The innate natural frequency of bike tires varies significantly depending of the inflation pressure of the tires, but was well over 1 Hz by two orders of magnitude for both 60 and 120 PSI inflation pressures [7]. Since the tires form the interface between the bike and the ground, frequencies significantly above or below natural frequency of the tires are attenuated, while those near the natural frequency are transferred very effectively. A LPF with a cut-off region starting at 1 Hz could reasonably be expected to produce the desired effect. It would ensure good attenuation of the natural frequency, while allowing fast enough changes to update the resistance according to a change in incline resulting from a hill (at any reasonable speed, a typical hill would take well over 1 s to traverse).
- Playback: this programmatic component handles playback of recorded data and synchronizes 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.

- 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, with game developers constantly pushing toward more realistic, immersive gaming. Recently, however, 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. This inclusion of exercise in gaming is important, as obesity rates continue to climb throughout the country [1]. To combat this trend, exercise needs to be encouraged in any way it can. Combining it with an industry that has over 3.24 billion consumers as of 2022 is an excellent way [22]. An increase in the number of people using the Mario Kart Bike (and products like it) equates to more people exercising and fighting the obesity epidemic.

  Video game addiction is an issue in America as well; 3-4% of gamers are addicted [23]. Theoretically, the Mario Kart Bike could cause users to spend even more time indoors, as well as contribute to the video game addiction trend. One way to tackle this issue is to display a message stating that the user should take a break after they have been playing for an exceptionally long time, like 8 hours. While not the strongest prevention, this will at least allow users to understand that they may be playing for too long.

In the Ride Replay system, there could be the potential issue of someone filming something they should not be filming, such as a person in their private property or potentially something graphic or illegal. To combat this, a 'report' system could be implemented to allow users to report tracks. If this product was to be commercialized, a team would be tasked with going through reported tracks and determining if said tracks should be removed from the server.

During the process of modifying the Mario Kart Bike, it is important that Team 4 does not break the copyright laws that have been granted to protect Nintendo's intellectual property [24]. 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. This is due to the fact that the 'Mario Kart' name is classified as Nintendo intellectual property. Commercializing this product with the 'Mario Kart' name would be considered copyright infringement.

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

- 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
- 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
- Budget

Team 4 can expect to require a budget of approximately $537 to complete the revisions to the current bike system. Table 4 summarizes the expected costs associated with the project is included below. Note that the considered costs are only those associated with the portion of the project assigned to this team; the table does not include the portions assigned to the mechanical team. These costs are by no means expected to be complete or wholly accurate, because it is not yet possible at this design phase to produce a workable bill of materials (BOM). Prices do not include shipping, because this will depend on the specific merchant services employed as well as the total number of orders placed.

Table 4. Tentative Summary of Expected Project Costs

Item	Cost (USD)	Link to Example
Linear actuator	151	https://www.progressiveautomations.com/products/tubular-high-speed-linear-actuator?variant=18277287100483
Driver for linear actuator (includes H-bridge, heatsink, and PCB board)	19.95	https://www.sparkfun.com/products/9540 https://www.sparkfun.com/products/9479 https://www.sparkfun.com/products/9576
Power supply for linear actuator	37.95	https://www.jameco.com/z/2ABU120F-Jameco-Reliapro-12-Volt-10-Amp-120-Watt-Switching-Table-Top-Power-Supply-2-5mm-Plug_2333855.html
Wireless module	27.28	https://www.jameco.com/z/410-214-Digilent-Pmod-BT2-Bluetooth-Interface-Module_2335191.html
Large N52 Neodymium magnet	22.25	https://appliedmagnets.com/n52-neodymium-magnets-2-in-x-1-in-x-1-2-in-bar-w-2-countersunk-holes/
Data gathering module enclosure	13.95	https://www.jameco.com/z/1553CBKBAT-Hammond-Manufacturing-Black-Plastic-Handheld-Project-Enclosure_2243962.html
Tilt sensor	9.99	https://www.jameco.com/z/28036-Parallax-4-Direction-Tilt-Sensor-Memsic-2125-Dual-Axis-Accelerometer_2161481.html
Optical sensor (camera)	30.90	https://www.amazon.com/Raspberry-Pi-Camera-Module-Megapixel/dp/B01ER2SKFS?th=1
Elevation (pressure) sensor	4.95	https://www.sparkfun.com/products/17001
Speed sensor	21.64	https://www.phoenixamerica.com/products/sensors/speed/s3-speed-sensor.html
Microcomputer for data capture	5	https://www.adafruit.com/product/2885
Storage media	39.99	https://www.amazon.com/SAMSUNG-microSDXC-Expanded-MB-ME256KA-AM/dp/B09B1GXM16/ref=sr_1_6?keywords=256gb+sd+card&qid=1665613738&qu=eyJxc2MiOiI0LjY3IiwicXNhIjoiNC4zOSIsInFzcCI6IjQuMjAifQ%3D%3D&sr=8-6
Battery for data gathering module	24.50	https://www.adafruit.com/product/353
PSU/charging circuitry for data gathering module	19.95	https://www.adafruit.com/product/2465
Allowance to compensate for misc. components (i.e., mounting hardware, fasteners, PCBs, cables, discrete passive components)	107.33	[25 % of above items]
Total	**$536.63**	

C. 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. The Gantt chart data for the project can be seen below in Figure 1. Also, the entire Gantt chart diagram can be seen in Figure 2 on the last page of this document, as it is an oversized figure. Based on the scheduled tasks, there is no slack available prior to the final presentation date of 12/11/22. Even though there is no slack available, the tasks within the Gantt chart are achievable given there is no unforeseen delays such as medical or unexpected school closures. Milestones are also created in the scheduled as a point of reverse to ensure the project is on schedule.

Mario Kart Simulation

Read-only view, generated on 26 Sep 2022

	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%

Figure 1. Team 4 Gantt Chart Activities Data.

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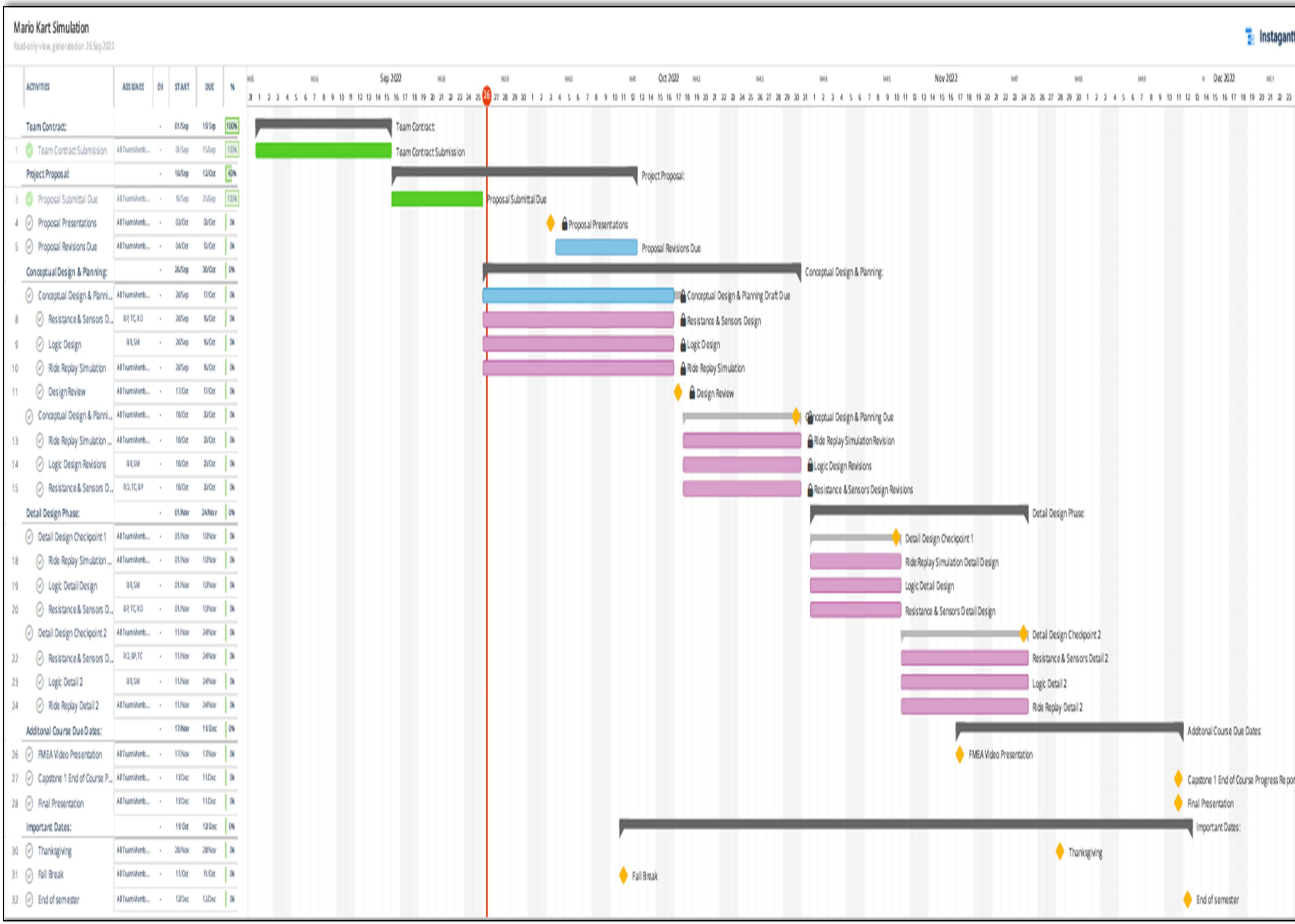
Mario Kart Simulation
Instagantt
Sep 2022
Oct 2022
Nov 2022
Dec 2022
ACTIVITIES
ASSIGNEE
START
DUE
%
Team Contract:
Team Contract Submission
Project Proposal:
Proposal Submittal Due
Proposal Presentations
Proposal Revisions Due
Conceptual Design & Planning:
Conceptual Design & Planning Draft Due
Resistance & Sensors Design
Logic Design
Ride Replay Simulation
Design Review
Conceptual Design & Planning Due
Ride Replay Simulation Revision
Logic Design Revisions
Resistance & Sensors Design Revisions
Detail Design Phase:
Detail Design Checkpoint 1
Ride Replay Simulation Detail Design
Logic Detail Design
Resistance & Sensors Detail Design
Detail Design Checkpoint 2
Resistance & Sensors Detail 2
Logic Detail 2
Ride Replay Detail 2
Additonal Course Due Dates:
FMEA Video Presentation
Capstone 1 End of Course Progress Report
Final Presentation
Important Dates:
Thanksgiving
Fall Break
End of semester