Team 4 – Mario Kart Simulation Conceptual Design

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***Abstract*— This report introduces Team 4's Conceptual Design for the Fall 2022 / Spring 2023 Capstone Project. The report begins with an introduction to the problem, followed by the overall objective and scope. Additionally, system description, along with a block diagram and details, background information, constraints, and standards are discussed. The report also describes possible solutions and addresses measures of success, unknowns/obstacles, readily available solutions, safety concerns, and broader implications, ethics, and responsibility associated with the solution. Finally, Team 4's resources for completing the project are described, including the personnel, components, funding, and timeline.**

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

I. INTRODUCTION

With obesity rates on the rise in the United States, the Mario Kart Bike offers a win-win scenario for gaming enthusiasts in that gamers can 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 objective of Capstone Design Project Team 4's project is to further enhance the riding experience offered by the existing design of the Mario Kart Bike by adding a variable of resistance for two modes of operation: the Mario Kart game simulation and a pre-recorded trail ride simulation. The scope of Team 4's project includes the provision of a new dimension of realism to the Mario Kart Bike. Specifically, Team 4 will capture data from an actual trail in Cookeville, TN, for use in the pre-recorded trail ride simulation. Team 4 will also 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's solution includes two kits: the Mario Kart kit and the Ride Replay kit.

The Mario Kart Bike Revision 2 design must adhere to a set of "shall statements" or specifications in order to meet the requirements set by the customer, supervisor, and professor. Specifications specific to only the Mario Kart simulation kit include:

S.1 Game event detection
   a. 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
   b. Resistance shall be reset to the nominal value after the duration of the in-game event has run its course
S.2 Steering
   a. Steering mechanism shall be strengthened using metal components
S.3 Wiring and Equipment Housing
   a. Shall enclose and secure all wiring and components along the bike

Specifications specific to only the Ride Replay simulation kit include:

S.4 Ride data replay/simulation
   a. Shall produce a resistance which is within 10% of the value measures or consistent with the actual ride, provided that the calculated power does not exceed the maximum power which the dissipative mechanism is capable of dissipating at the current speed
S.5 Ride recording (for a bike auxiliary to the exercise bike)
   a. Shall synchronously record video, barometric pressure, rear wheel speed, and incline angle; record this data to a non-volatile storage medium
S.6 Ride data filtering
   a. Shall attenuate frequencies above 1 Hz by at least 80 dB
S.7 Elevation
   a. Rider elevation shall be recorded while rider is recording bike

Specifications that are relevant to both the Mario Kart and Ride Replay kits include:

S.8 Main controller board
   a. Shall not crash or overheat under normal operating conditions at or near room temperature (70 ± 5 °F)
S.9 Resistance system
   a. Shall not surpass 30 V
   b. Shall contain at least 85 distinct resistance states
S.10 Speed sensor
   a. Shall update the controller with at most 40 mms latency
S.11 Wireless communication
   a. Shall provide a latency of at most 40 ms for data transmission between the sensors and main controller board

In addition to adherence to the above mentioned "shall statements," constraints and considerations must be identified and addressed to successfully complete the Mario Kart Bike Revision 2.

C.1 The customer requested that Team 4's design enable easy installation of components such as a phone holder to be 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.

C.2 Additionally, Team 4's professor set a hard deadline of two semesters for the completion of the Mario Kart Bike Revision 2, and he limited the budget to $1,000.

C.3 An ethical consideration is the privacy of others who may be captured during data gathering for the Ride Replay mode. To prevent the invasion of privacy of others, all testing of the Ride Replay mode will be done in public areas where recording is allowed. Additionally, if the Mario Kart Bike can be commercialized, a system to blur out faces must also be implemented, and a report function must be created to flag tracks to be deleted. A committee must be formed to review the flagged tracks.

C.4 Ethical considerations, such as possible copyright infringement arising from Nintendo's exclusive rights to its products, will likely prevent the Mario Kart Bike Revision 2 from being commercialized.

C.5 If the Mario Kart Bike can be commercialized, the Revision 2 design must be minimalized and converted to wireless communication, and the motor system used as a source of resistance must be improved to mitigate its safety issues. The voltage supplied by the motor system can be no greater than 30 volts, which is generally considered an upper limit.

C.6 Team 4's Mario Kart Bike Revision 2 design must adhere to the applicable Institute of Electrical and Electronics Engineers (IEEE) and Occupational Safety and Health Administration (OSHA) standards, including:
   a. IEEE 1309 Standard for Calibration of Electromagnetic Field Sensors and Probes, Excluding Antennas, from 9 kHz to 40 GHz
   b. C95.1 - IEEE Standard for Safety Levels with Respect to Human Exposure to Electric, Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz
   c. 1926.300b.2 - OSHA Standard for Guarding from Rotating or Moving Parts of Equipment; 1910.137 OSHA Standard for Electrical Protective Equipment
   d. 1910.133a OSHA Standard for Eye and Face Protection
   e. 1910.137 OSHA Standard for Electrical Protective Equipment

C.7 The trend of video game addiction is also an ethical consideration. To address this potential for addiction, a system will be implemented to display a message every two hours with the user's total time on the Mario Kart bike and a recommendation to take a break.

C.8 An additional constraint is the use of physics engine creation or implementation to calculate precise, dynamic resistance. A minimum of 85 resistance states will be used to measure the validity of the dynamic resistance system.

The balance of this Conceptual Design Report outlines Team 4's basic plan for adding resistance to the existing Mario Kart bike design and providing an interactive simulated bike on a trail in Cookeville. By replicating the effects of riding an actual trail in Cookeville, residents and alumni can recall a trail once traveled. The following sections include a system description with a block diagram and details, background, constraints, and standards, as well as solutions with measures of success, unknowns, obstacles, and safety concerns, as well as already available solutions. Additionally, resources are defined, including team members, components, project budget, and timeline.

II. System Description

A. Block Diagram and Detail: Overhead

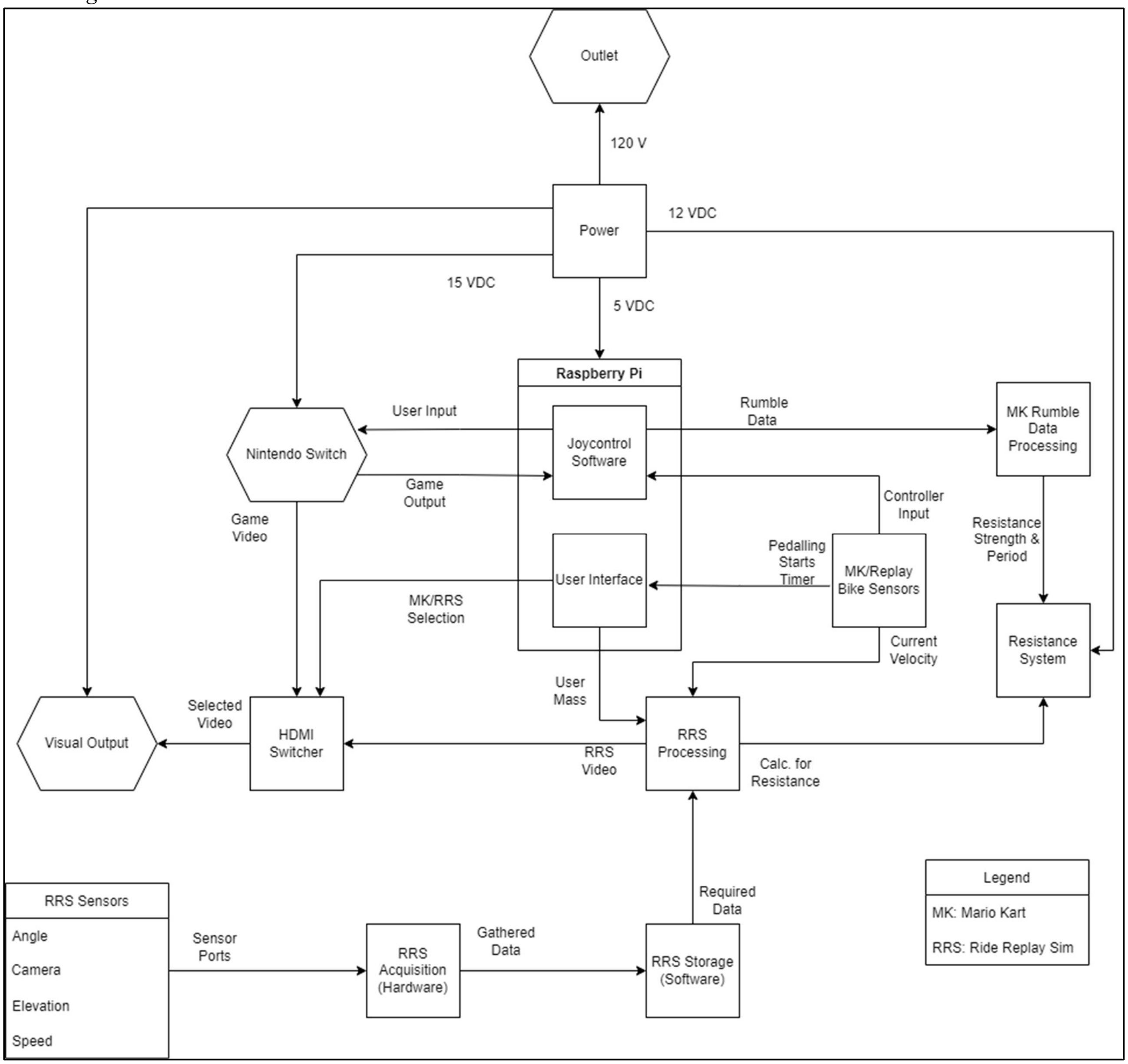

Figure 1. Block Diagram and Detail: Overhead.

1. *Nintendo Switch:* This is the video game console which the JoyControl software controls for Mario Kart Bike operation. The first output of this block is the rumble data, which is the data that initiates vibration in a video game controller. This data will be transmitted over Bluetooth, which is the wireless communication protocol chosen by Nintendo to interface with peripherals. Different in-game events have different rumble states associated with them, and different functionalities are planned to occur in response to different rumble states. Specifically, the resistance faced by the rider is planned to increase when an event occurs that impedes the in-game character's go-kart and to decrease when the in-game character activates a boost. The second output is digital video which will be transmitted through a HDMI cable to a connected TV screen.
2. *Main Power Distribution:* The main power distribution will include an input receptacle of 120 VAC. The 120 VAC input receptacle is located on

the main enclosure box that houses the main control board and is labeled as “120 VAC Input”. The 120 VAC input receptacle will be supplied power by a protected 120 VAC outlet located within the Capstone Laboratory (protection provided by TTU in form of building circuit breaker for outlet only). The inputted 120 VAC will then feed three separate AC-DC step down converters, so the 120 VAC is converted to 5 VDC, 12 VDC, and 15 VDC. The direct current sources will then provide power to the main control board, linear motor, and Nintendo Switch. Protection devices will be installed between all components and the AC-DC step down converter. The wiring to the linear motor will be routed outside the main enclosure by way of an output receptacle installed within the main enclosure. The output receptacle is labeled “Linear Motor Output”.

3. *HDMI Switcher:* switches the HDMI input for the TV monitor between the ride simulation and Nintendo Switch outputs. This will be accomplished using a multiplexer IC, which will be controlled by the Raspberry Pi.
4. *Joycontrol Software:* This software is the code that manages Bluetooth communications with the Nintendo Switch, allowing the bike to act as a controller. It was originally created by GitHub user mart1nro and was modified by the Revision 1 team to better meet their needs. The bike sensors’ interactions with Joycontrol were specified by the previous team. Slight modifications will be made regarding the steering code to increase steering fidelity. The resistance data obtained by Joycontrol through communication with the Nintendo Switch is to be sent to the Mario Kart Rumble Data (MKRD) subsystem.
5. *MK/Replay Bike Sensors (MRBS):* This block describes all bike-mounted sensors. These sensors will sense the speed of the back wheel of the exercise bike, as well as the angle of the bike headset. This data will be transmitted wirelessly to the relevant device (either the Raspberry Pi, for the Mario Kart Bike, or the Ride Replay Simulator (RRS) Processing block, for the Ride Replay). Note that the steering input is not used for the RRS.
6. *User Interface (UI):* This subsystem is dedicated to user utilization. This system utilizes a touchscreen to allow the user to navigate between the Mario Kart and RRS functionalities. The UI is also where the MET calorie system, previously designed by the Rev. 1 team, is located. Additionally, a pop-up that advises the user to take a break will appear hourly. This will be implemented to combat the potential of addiction with the bike. A more extensive description of the UI can be seen below.
7. *MKRD Processing:* The goal for the resistance system regarding Mario Kart gameplay is to produce resistance depending on game related events. Such events include driving off track and being hit by an item. Due to legal interference, the occurrence of in-game events can only be acknowledged by outputs provided by the game itself rather than directly through the game code. The only output that meets the criteria of being sent to the user by the game regarding in-game events is controller rumble data. The MKRD subsystem consists of three sections: acquisition, storage, and instruction. Rumble data is obtained by the Joycontrol software from the Nintendo Switch. Rumble acquisition can be completed by accessing that data and sending the current state to the storage section. The storage section also includes retrieval of data. The retrieval of data must be as fast as possible to minimize controller latency. Therefore, storage and retrieval will be accomplished using the hash map data structure. Hash maps have a worst-case time complexity of $O(n)$ and an average time complexity of $O(1)$, making hash maps one of the overall fastest data structures to implement. Finally, instruction refers to the values retrieved from the hash maps, specifically resistance magnitude and duration, that are sent to the resistance system.
8. *Resistance System:* This block will produce a resistance which the rider must pedal against using an eddy-current-based system. The resistance will be set by the software block relevant to the current mode of operation (RRS Processing or MKRD Processing) and a linear actuator will be used to modulate the distance of a permanent magnet from the surface of a flywheel.
9. *Sensors:* This block describes the sensors required to gather ride data for the RRS Acquisition (Hardware) block. These sensors are used to detect the incline of the surface on which a bike travels, the speed of the bike, and the elevation (via a barometric sensor), and a video of the ride.
10. *RRS Acquisition (RRSA):* This block describes the hardware device used to capture ride data for use by the RRS. This device should be capable of processing video, storing data to non-volatile memory, and sampling data from external sensors.
11. *RRS Storage (RRSS):* Like the storage section of the MKRD subsystem, the data collected during the acquisitional phase must be stored. The storage system for the simulation will have an ever-growing volume of data to be managed while also not requiring the same execution speed that the MKRD subsystem requires. Game data will be stored in a 256 GB drive that will contain as many tracks as possible. This will be retrieved using an algorithm implemented into the microcontroller that will be used for simulation processing. Whether this processor is the Raspberry Pi already in use or a separate processor is presently unknown.

12. *RRS Processing (RRSP):* This subsystem is the most technically intensive part of the system as it retrieves game data, distributes outputs in the form of resistance values and video displays, obtains user speed inputs, and various other processing components required to operate the simulation. As stated previously, the exact processor that will be utilized is still unknown. However, the processor will be programmed to track the user's present speed. The video display will simulate an increase or decrease in speed by increasing or decreasing the frame rate of the video when the user is faster or slower, respectively, regarding the user's speed at that moment when the ride was recorded. The processor will constantly be updating and sending resistance values to the resistance system depending on user momentum and the gravitational force exerted on the rider at the current incline angle. A more extensive breakdown can be seen below.

    Block Diagram and Detail: RRSP.

1. *Video Speed Comparison:* The purpose of this block is to help determine the framerate of the video. This is accomplished by comparing the stored speed from the original recording to the current speed of the bike during the replay and obtaining the ratio. If the current speed is slower than the recorded speed, the framerate will decrease to compensate by slowing the video. Similarly, if the current speed exceeds the stored speed, the framerate will increase, speeding up the video in the process. The ratio between the two speeds is a value that is then sent to the Framerate Adjustment block.
2. *Framerate Adjustment:* This section is dedicated to determining the actual framerate that the video needs to be set at to produce the necessary speed. The block will include a calculation to determine the framerate change based on the ratio provided by the Video Speed Comparison block. As an example, the kit's camera will run at 30 frames per second. If the rider in the present moment has a speed of twice that of the original recording, then the framerate would increase to 60 fps to compensate. Similarly, if the rider is at half the speed of the original recording, then the

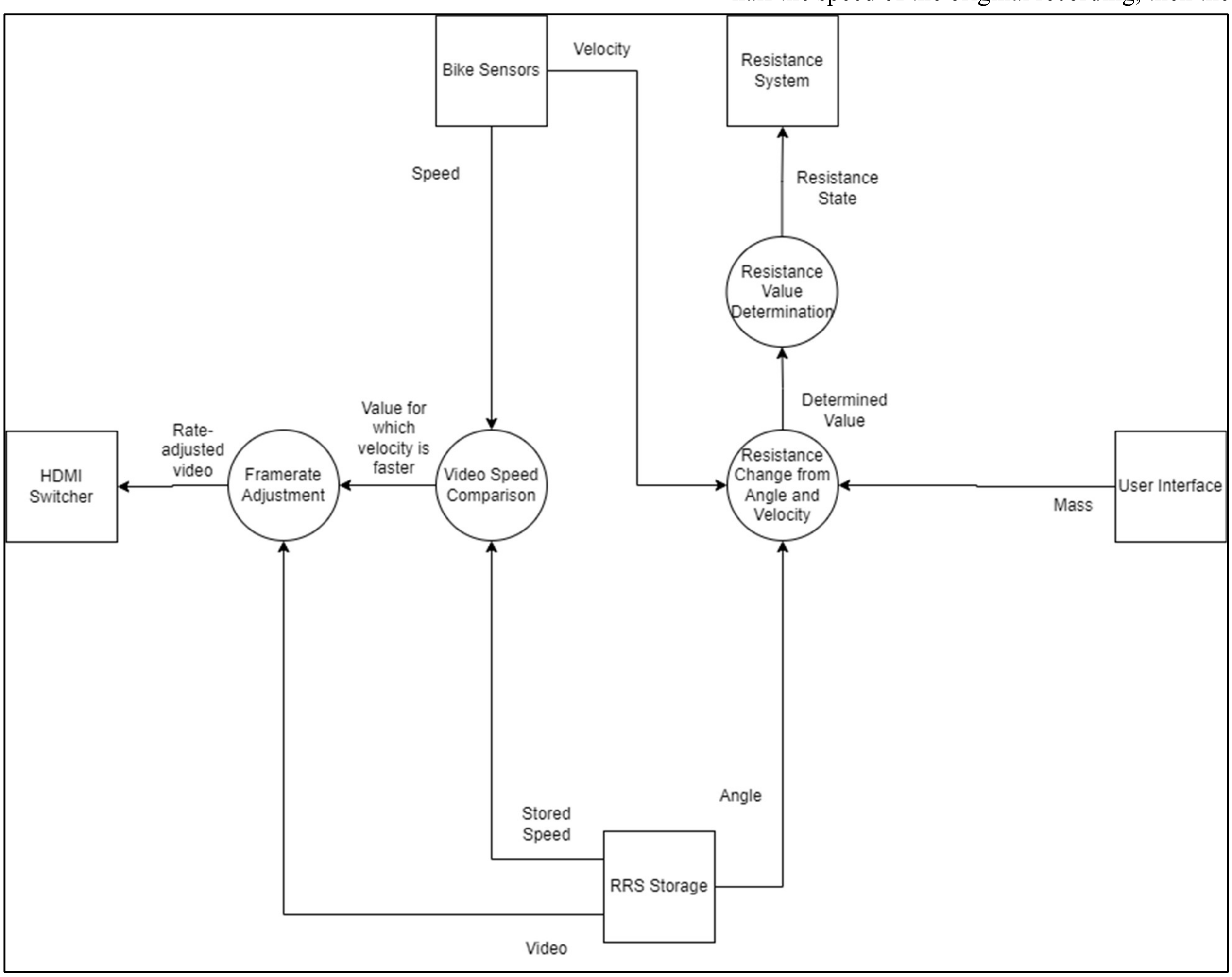

Figure 2. Block Diagram and Detail: RRSP.

framerate would decrease to 15 fps. The maximum framerate will be limited by the refresh rate of the monitor used, and the processing capabilities of the playback device.

3. *Resistance Change from Angle (RCA):* This section is for determining the resistance that needs to be applied to the bike. This value is dependent on the force of gravity at an angle using the equation:

$$F_g = mg\sin(\theta)$$

where m is the mass of the rider plus the bike, g is the gravitational acceleration 9.80 m/s, and θ is the angle of the inclined plane. After deliberation with Dr. John Shriner of the Physics department, it was determined that the resistance that the rider would feel while pedaling is independent of the momentum the rider has before hitting the incline. The mass of the rider is obtained by the MET Calorie System located in the User Interface block. The mass of the bike and gravitational acceleration will be included in the calculations. The value is sent to Resistance Value Storage.
4. *Resistance Value Determination (RVD):* This block is where the values that are to be sent to the Resistance System via the control circuit reside. The RCA block sends the calculated value to the RVD block, in which it is then determined from that data using a mathematical relation between the gravitational force and the necessary distance from the flywheel necessary to simulate it the value that represents the appropriate position of the linear actuator in the Resistance System.

Block Diagram and Detail: UI.

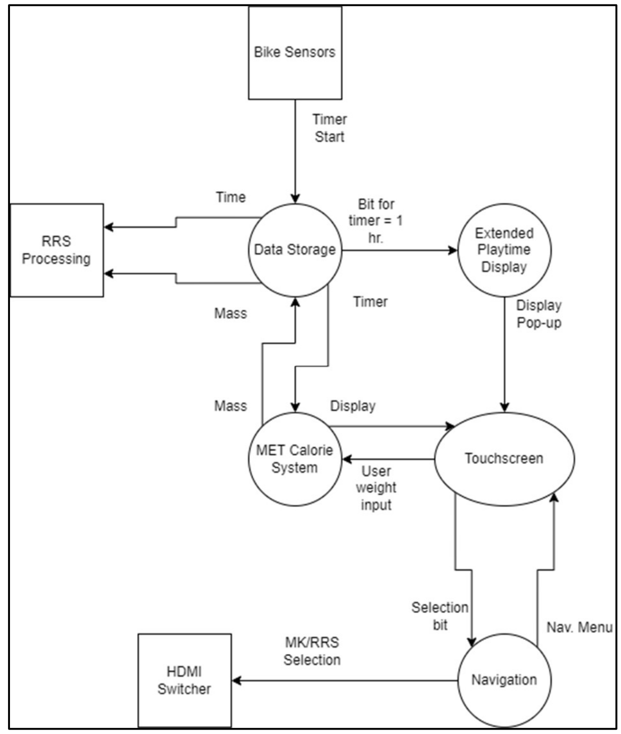

Figure 3. Block Diagram and Detail: UI.

1. *Extended Playtime Display (EPD):* This block is dedicated to the pop-up that warns the user that they have been playing for one hour and should consider taking a break. This block was implemented to combat the potential for addiction of the Mario Kart bike controller and the RRS. When it obtains the enable bit from the Data Storage block, it enables a pop-up on the touchscreen. This display can be cancelled by selecting a button on the touchscreen.
2. *Data Storage:* This block is the hub of the UI block. When the biker begins pedaling, the timer starts and is stored for the duration of the user's playtime. This time is used by the MET Calorie System to calculate the number of calories the user burns while they play. The mass of the user, used for both the MET Calorie System and the RRSP blocks, is also stored here. Finally, when the timer reaches one hour, it sends an enable bit to the EPD pop-up, causing the warning to appear on the touchscreen.
3. *Touchscreen:* This is an output device specific to the UI. This is an LCD connected to the Raspberry Pi to allow for the various displays and user input options required for the UI. This was originally implemented by the team for Rev. 1.
4. *MET Calorie System:* This system was originally developed by the team for Rev. 1 using a Python GUI package. Using attributes input by the user, the MET

system tracks how many calories the user burns over time. The only modification to this system is that the weight input by the user will be used to calculate the mass of the user, which is then sent to Data Storage for use in the RRSP block.

5. *Navigation:* This block is used to allow the user to choose between Mario Kart bike mode and RRS mode. This block will present the user with a navigation menu via the touchscreen. The user can then select which mode they would like to utilize. The selection is then sent to an HDMI switcher.

Block Diagram and Detail: Resistance System

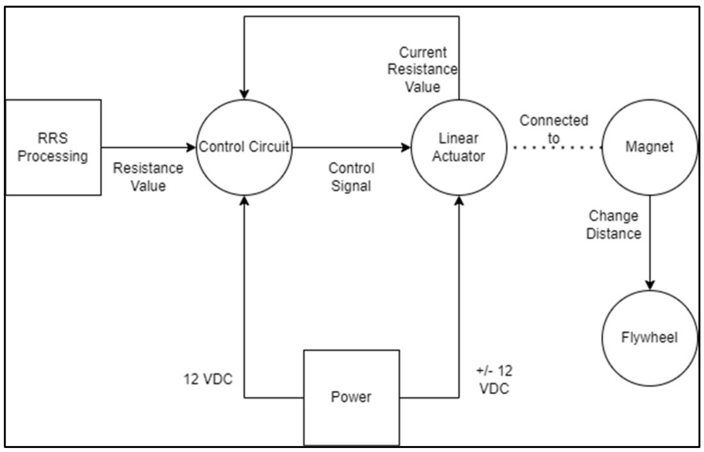

Figure 4. Block Diagram and Detail. Resistance System.

1. *Control Circuit:* This circuit acts as a driver for the linear actuator. Using a H-bridge, the actuator can be operated in forward and reverse directions and switched on and off according to the set point determined by the resistance value input.
2. *Linear Actuator/Magnet:* This component adjusts the effective resistance imposed on the rider by varying the intensity of the magnetic field in which the conductive flywheel is moving, thus modulating the power dissipation within the flywheel. It accomplishes this by altering the distance between the magnet and the flywheel.
3. *Flywheel:* This component dissipates power through the principle of electromagnetic induction. It also acts to store kinetic energy and resist sudden changes in velocity.
4. *Power Supply:* This component provides the power necessary to drive the linear actuator and control circuitry. The voltage is tentatively set to 12 VDC, as this is sufficient to power many linear actuators on the market. Although this may be changed depending on the linear actuator use, it may never exceed 30 VDC as previously stipulated.

Block Diagram and Detail: RRSA

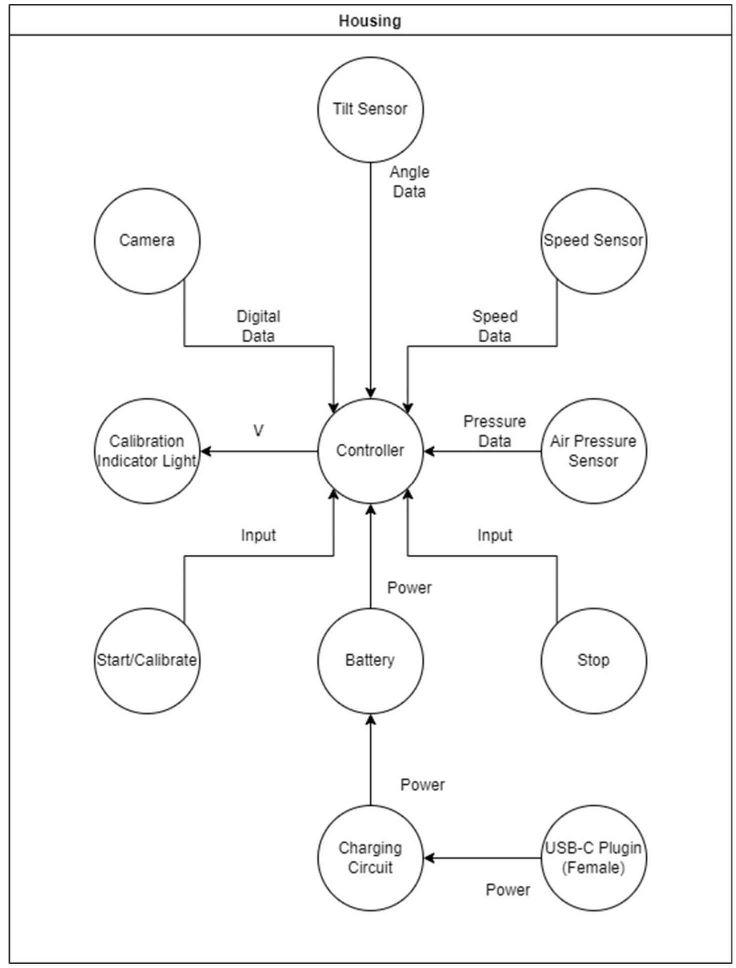

Figure 5. Block Diagram and Detail: RRSA.

1. *Controller:* This component records ride data and accepts user inputs.
2. *Camera:* This component provides a visual recording of the ride.
3. *Interface buttons:* Tactile buttons will be provided as a means to implement control over the following controller functions: calibration of the tilt sensor with respect to its orientation on the bike, initiation of recording, and stopping/finalizing a recording.
4. *Calibration Indicator Light:* This component is present as an output from the microcontroller. The purpose of this light is to inform the user when they are in calibration mode.
5. *Tilt Sensor:* This component records the tilt of the bike relative to a set point determined when ride recording starts. This angle is meant to represent the incline of the surface on which the bike rolls.
6. *Speed Sensor:* This sensor records the speed of the front wheel of the bike during a ride. This is the only

sensor which must be placed outside the main housing of this block.

7. *Air Pressure Sensor:* This device measures the atmospheric pressure in the surrounding air, allowing the current elevation to be determined. Note that although variation in weather patterns may affect the collected data, there is no plan to account for this.
8. *Charging Circuit:* This circuit regulates the charging of the battery used to power the controller and sensors.

Block Diagram and Detail: MRBS

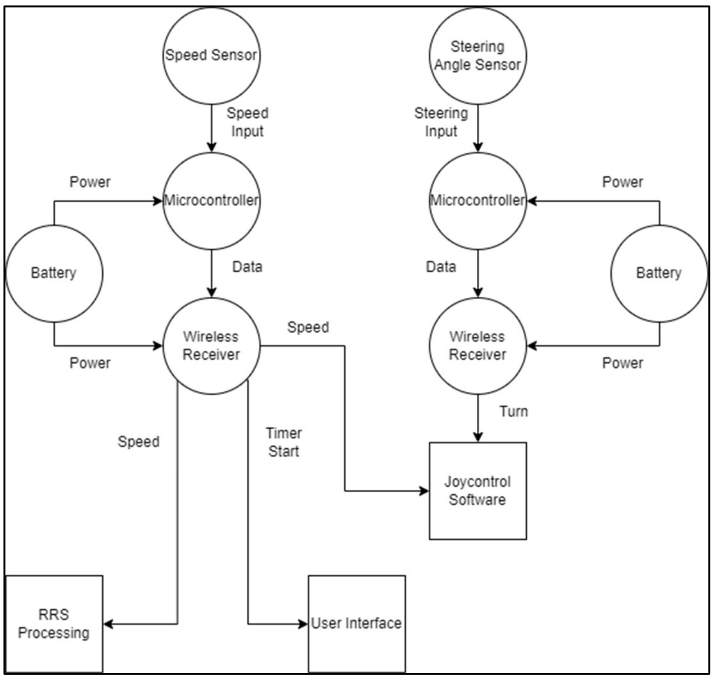

Figure 6. Block Diagram and Detail: MRBS.

1. *Speed Sensor:* This sensor will determine the user's speed by measuring the RPM of the back wheel. This data will be sent to the Joycontrol software for bike speed when playing Mario Kart, UI to inform the system to start the timer since the user is playing, and RRSP to allow for calculations for the resistance system and the framerate adjustment system.
2. *Steering Angle Sensor:* The Steering Angle Sensor determines the magnitude of the user's turn when playing Mario Kart. This system was originally developed by the team for Rev. 1. They used a potentiometer to accomplish this. The hardware for this system is being improved by the Mechanical Engineering team. The sensor will be adapted for wireless transmission, and the fidelity of the sensor will be improved in the software.
3. *Microcontrollers:* Each sensor is in their own location on the bike. The Speed Sensor is located at the back wheel to obtain speed from the RPM of the wheel, and the Steering Angle Sensor is located at the handlebars to obtain data on where the handlebars are positioned. This, in conjunction with the necessity for wireless communication, requires each sensor to have its own microcontroller. Each microcontroller will power and process sensor data and drive wireless communication. Data sent to Joycontrol will be adapted for wireless communications.
4. *Wireless Receivers:* Due to the nature of this project, it is necessary to transfer data between components without the excess use of wires. It is for this reason that wireless receivers will be used to send data from subsystem to subsystem. The wireless receivers in this section will send data to RRSP, UI, and Joycontrol without the use of wires.

B. Subsystem Compliance & Validation

Below describes the analytical method employed to validate the constraint complies within specifications.

<u>Mario Kart Simulator Specific:</u>

MK.1 *Game event detection:* Verification that all data transfers during acquisition, storage, and instruction sent and received are as commanded.

MK.2 *Steering:* Verification of steering mechanism is metal in material and secured to Mario Kart simulation bike.

MK.3 *Nintendo Switch:* Verification of the Bluetooth signal transmission between the Nintendo Switch and the main controller. Verify that the main controller receives accurate rumble data from the Nintendo switch via Bluetooth.

<u>Ride Replay Simulator Specific:</u>

RRS.1 *Ride data replay/simulation:* Validate distribution outputs in the form of resistance values and video display corresponds accurately based on recorded data. Resistance must be within 10% of the value calculated by the simulation software.

RRS.2 *Ride recording:* Validation of data recorded from bike sensors are accessible and readable on data storage device. For the safety of the user, it is important that this subsystem be highly unobtrusive and not distract the user during operation. To evaluate this constraint, we will ensure that the device housing is free of bright colors, there are not suddenly triggering audible or visual stimuli originating from the device, and the device, when mounted, does not obstruct the rider's field of vision significantly.

RRS.3 *Ride data filtering*: Verification of frequency attenuation at 80dB above 1 Hz. To evaluate this specification, the bode plot of the digital filter used can be evaluated in a CAD software, such as MATLAB, to ensure that it has the desired characteristics.

RRS.4 *Elevation*: Verify accuracy of recorded elevation with 5% of actual elevation. To evaluate this specification, the recorded data for a specific location will be compared to the published elevation of that location in Google Earth.

Both Mario Kart & Ride Replay Simulator:

B.1 Main control board: Validate that there are no error messages or operational malfunctions of the main control board 70 ± 5 °F. To evaluate this specification, the device will be operated continuously for a duration of 15 minutes at both the upper and lower limits of the specified thermal tolerance.

B.2 User interface: to avoid the potential broader impact of addiction, the interface will provide a warning to users who operate the device for over an hour continuously. Users will be able to change system between the Mario Kart Simulator and the Ride Replay Simulator from the user interface.

B.3 Resistance system: Validate that the resistance system receives all 85 resistance states and adjusts resistance accurately. This specification will be evaluated by visual inspection during a sweep of all states to ensure smoothness and no oscillation. Measure system voltage to be less than 30 VDC.

B.4 Speed sensor: Verification of 40 ms latency to be measured at the main control board.

B.5 Wireless communication: Validate all sensors are wireless. Verify 40 ms latency to be measured at the main control board.

B.6 Power Distribution: The power distribution must have labels located on the outside of the enclosure for all power inputs and outputs. Power system is to provide power to the main controller, linear motor, and Nintendo switch without triggering any protection devices within the circuit.

B.7 HDMI Switcher: The HDMI switcher is intended to switch the HDMI output between the Mario Kart Simulator and the Ride Replay Simulator. The HDMI switcher will switch between the Mario Kart Simulator and the Ride Replay Simulator via the user interface without any visual or audio distortions.

III. Timeline and Conceptual design fit

A. Timeline

The conceptual design and planning section is separated into the critical components of the conceptual design report. Each team member's specific task for the conceptual design phase is shown below in Figure 7. This figure reflects the tasks from the beginning of the project until 10/30/2020.

The next stage of the timeline is to complete the presentation/design review, which is indicated as a milestone on the Gantt chart, as this is a significant step for approval and feedback of design. After presentation/design review, the next stage of the project is to complete the detail design of the subsystems. For addition task information and timeline, refer to the entire project Gantt chart in Figure 8, that is in the appendix of this report.

Name	Resources	Begin date	End date	Comple...
Teamwork Contract		8/25/22	9/15/22	100
Project Proposal		9/16/22	10/14/22	100
Proposal Submittal		9/16/22	9/25/22	100
Proposal Presentations		10/3/22	10/3/22	100
Proposal Revision		10/3/22	10/14/22	100
Conceptual Design & Planning		9/26/22	10/29/22	100
Conceptual Design Draft Due		9/26/22	10/16/22	100
Introduction	Blake P.	9/26/22	10/16/22	100
Block Diagram	Benjamin R.,Tyler C.	9/26/22	10/16/22	100
Solutions & Timeline	Ray D	9/26/22	10/16/22	100
Ethics, Standards, & Broader Implications	Sage H.	9/26/22	10/16/22	100
Conceptual Design Final Draft		10/30/22	10/30/22	100

Figure 7. Gantt Chart Task List from Project Start to 10/30/22.

B. Conceptual Design Fit

The conceptual design document created is intended to be used as an analytical document that aims to identify and understand critical design aspects within the project. A critical component for project success is to develop and identify the critical elements of the project. A full matrix is shown in Table 1 in the appendix. Table 2 below represents the order of critical tasks. The four criteria of each constraint are complexity, project impact, availability, and cost. Each criterion is weighted, and justification for weight of each criterion is defined in Table 2.

Table 1. Critical Components/Subsystems Ranking.

Critical Components/Subsystems	System Used On	Rank
Resistance system	Both	1
Ride recording (for a bike auxiliary to the exercise bike)	Ride Replay Sim	2
Power Distribution	Both	3
Speed sensor	Both	4
Wireless communication	Both	5
User Interface	Both	6
Ride data replay/simulation Accuracy	Ride Replay Sim	7
Ride data filtering	Ride Replay Sim	8
Main controller board	Both	9
Nintendo Switch	Mario Kart Sim	10
HDMI Switcher	Both	11
Steering	Mario Kart Sim	12
Game Event Detection	Mario Kart Sim	13

IV. Ethical, Professional, & Standards Considerations

A. Ethical Considerations

One ethical consideration involves the Ride Replay mode of the Mario Kart Bike. In gathering data (riding a route) for this mode, the user will be recording whatever is in front of their bike during the route. While recording the ride, there lies the chance that the user may record something that they should not be. This could range from a variety of things, from filming individuals inside their homes, to filming customers inside a building with a no-photo policy, to even something graphic or illegal. While the chances of this happening are most likely slim, they still need to be considered, so as not to impose on the privacy and safety of others. Because of this, a constraint on product testing is needed: all testing of the Ride Replay mode shall be done in public areas where recording is allowed. By testing in these specific areas, we can be sure that the privacy of others is protected. If this bike were to be commercialized, implementation of a system to blur out faces detected would be used, along with a report function that would flag tracks that potentially need to be deleted. A team dedicated to reviewing these flags would be created.

Another ethical consideration involves the trend of video game addiction in the world, with 3-4% of gamers being addicted [4]. Theoretically, the Mario Kart Bike could cause users to spend even more time indoors, as well as contribute to the video game addiction trend. To combat this, a system shall be implemented that displays a message every hour, telling the user that they may want to take a break. This message will also display the total time the user has been using the bike. While this is not the most effective way to fight the video game addiction problem, it will at least let the user think about how long they have been playing.

B. Professional Considerations

A professional consideration is necessary when thinking about commercialization of the Mario Kart Bike. It is important that throughout the design process, the copyright laws provided to Nintendo by the law are not infringed upon [5]. These laws provide Nintendo with exclusive rights to its products, these including anti-piracy of Nintendo products, use of circumvention devices, and intellectual property. Intellectual property is any innovation, commercial or artistic, or any unique name, symbol, design, or logo used commercially. Nintendo has a lot of intellectual property, including Donkey Kong, The Legend of Zelda, and Mario Kart. These laws provide two constraints for the design process. First, while Team 4 plans to redesign the bike to be in a more commercialized, clean form, actual commercialization of the bike shall not occur, as doing so is not legal as of now. This is mainly due to the naming of the bike, as Mario Kart is trademarked intellectual property owned by Nintendo. Second, Nintendo games are also protected by copyright laws, and Nintendo does not allow modification, or even viewing of game code. This is an issue because game data must be gathered to properly implement the dynamic resistance system in Mario Kart. To solve this, gathering of game data shall be accomplished through rumble state data acquisition.

As stated previously, while actual commercialization will not occur, Team 4 will design the first version of the bike to have a more commercialized, clean, wireless form. Looking at almost every product in every commercial market (where electricity is used), loose wires are almost never found. Products have 'cased' designs where circuitry needed for said product to function is hidden inside the component, away from simple access to the user. The previous team slightly did this, covering up the main Raspberry Pi and other components in a 3D printed casing under the monitor. However, wiring running along the bike and sensors near the rear wheel were left completely exposed, not to mention the large induction motor behind the rear wheel (that also provided too much power). Because of these design issues, Team 4 shall enclose all wiring along the bike, as well as components such as sensors (as much as possible without inhibiting data collection), in a secure casing (using screws). Team 4 shall also improve the resistance system of the bike, eliminating the induction motor and using a much safer electromagnetic eddy current system.

C. Standards

IEEE 1309 Standard for Calibration of Electromagnetic Field Sensors and Probes, Excluding Antennas, from 9 kHz to 40 GHz: In this standard, orientation of electromagnetic field sensors and their calibration methods are discussed. Since Team 4 will be implementing an electromagnetic resistance device that utilizes eddy currents, we will want to be able to precisely measure associated fields. This standard goes over three main methods for field sensor calibration; Team 4 shall use Method B for calibration of the electromagnetic field sensors used. This method states that the unit under calibration is placed in a calculated reference field based on the geometry of the field source and the field source measured input parameters. From here, Team 4 can compare the measured field with the calculated one in order to determine if the sensor is correctly calculated. This constraint affects the Bike Sensors subsystem.

C95.1 - IEEE Standard for Safety Levels with Respect to Human Exposure to Electric, Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz: In this standard, various safety levels are given for magnetic and electric field magnitudes. These limits change based on the frequency of the waves, and what body part is under the field. We will be constrained by these limits to follow safety standards.

1926.300b.2 - OSHA Standard for Guarding from Rotating or Moving Parts of Equipment: These standard states that belts, gears, shafts, pulleys, sprockets, spindles, drums, flywheels, chains, or other reciprocating, rotating, or moving parts of equipment shall be guarded if such parts are exposed to contact by employees (users in this case) or otherwise create a hazard. Team 4 will be using a flywheel for the Mario Kart Bike, so the flywheel shall be guarded if it could potentially create a hazard for the user.

1910.137 OSHA Standard for Electrical Protective Equipment: This standard goes over various electrical protective equipment standards, and specifically tests to determine the effectiveness of protective equipment. This is a constraint, as Team 4 shall wear necessary protective equipment while working with electricity and perform effectiveness tests on each article of equipment.

1910.133a OSHA Standard for Eye and Face Protection: These standard states that the employer shall ensure that each affected employee (member of Team 4 in this case) uses appropriate eye or face protection when exposed to eye or face hazards from flying particles, molten metal, liquid chemicals, acids or caustic liquids, chemical gases or vapors, or potentially injurious light radiation. This will be a necessary constraint if, and when soldering is performed.

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APPENDIX

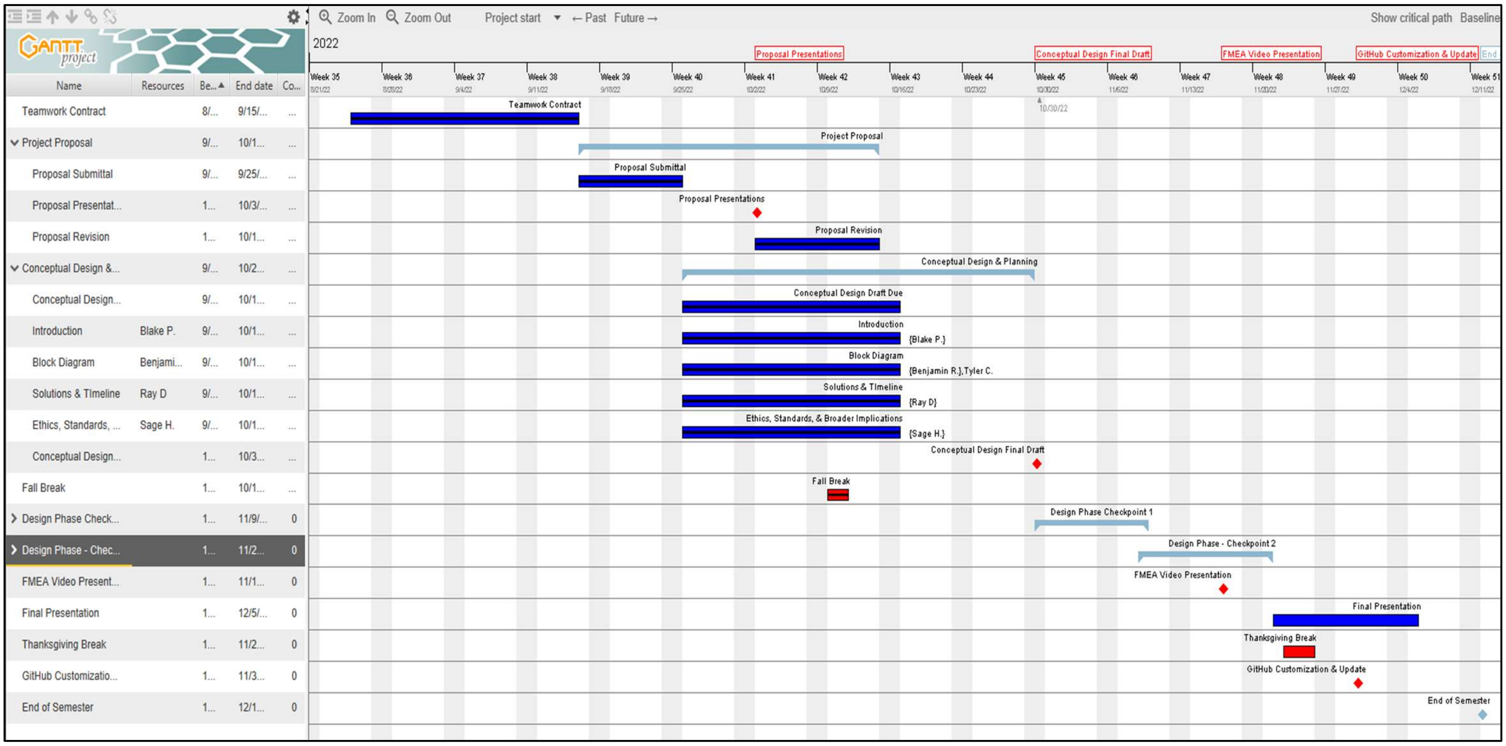

Figure 8. Gantt Chart of Team 4 Project.

Table 2. Critical Components/Subsystems Decision Matrix.

Critical Component Decision Matrix

		Weight	1	Weight	3	Weight	2	Weight	2	
Critical Component/Subsystems	**System Used On**	**Complexity**	**Score**	**Project Impact**	**Score**	**Cost**	**Score**	**Availability**	**Score**	**Total Score**
Resistance system	Both	2	2	3	9	3	6	3	6	23
Speed sensor	Both	1	1	3	9	2	4	2	4	18
Wireless communication	Both	2	2	2	6	3	6	2	4	18
Main controller board	Both	2	2	3	9	1	2	1	2	15
Power Distribution	Both	2	2	3	9	2	4	2	4	19
HDMI Switcher	Both	3	3	2	6	1	2	1	2	13
User Interface	Both	3	3	3	9	1	2	1	2	16
Steering	Mario Kart Sim	1	1	1	3	2	4	1	2	10
Game Event Detection	Mario Kart Sim	2	2	1	3	1	2	1	2	9
Nintendo Switch	Mario Kart Sim	2	2	3	9	1	2	1	2	15
Ride recording (for a bike auxiliary to the exercise bike)	Ride Replay Sim	1	1	3	9	3	6	3	6	22
Ride data replay/simulation Accuracy	Ride Replay Sim	3	3	3	9	1	2	1	2	16
Ride data filtering	Ride Replay Sim	2	2	2	6	2	4	2	4	16
Elevation	Ride Replay Sim	1	1	1	3	1	2	1	2	8

Priority	**Level**
Low	1
Medium	2
High	3

Criteria	**Weight**	**Weight Priority Justification**
Complexity	1	Low: There is sufficient time in project for research and analytical testing
Project Impact	3	High: Single component failure could lead to complete project failure
Cost	2	Moderate: The budget is very small for this project
Availability	2	Moderate: Order process may be lengthy; Without a specific component a constraint may not met