## **Purdue ECE Senior Design Semester Report**

## **(Team Section)**

| **Course Number and Title** | ECE 47700 *Digital Systems Senior Design Project* |
| --- | --- |
| **Semester / Year** | Spring 2024 |
| **Advisors** | Phil Walter |
| **Team Number** | 2 |
| **Project Title** | M.O.U.S.E. |

| Senior Design Students – Team Composition | | | |
| --- | --- | --- | --- |
| **Name** | **Major** | **Area(s) of Expertise Utilized in Project** | **Expected Graduation Date** |
| Andrew Hall | CompE | Hardware, Mechanical, PCB Layout, Software | Spring 2024 |
| Matthew Ghera | CompE | Software, Hardware, PCB Layout, Physical Assembly (CAD) | Spring 2024 |
| Christopher Miotto | CompE | Hardware, PCB Layout, Physical Assembly | Spring 2025 |
| Braden Kirkendall | CompE | Software, Physical Assembly, Hardware Validation | Spring 2025 |

**Project Description:** Provide a brief (2-3 page) technical description of the design project, as outlined below:

1. Provide a general description of the product to be delivered by this design project.

## The Mobile Observation Unit for Security Equipment (MOUSE) is a mobile surveillance robot intended for indoor use, in corporate office or residential environments. MOUSE is designed as a cost-effective solution to overnight security for detecting movement in residential or corporate environments. MOUSE will be powered by four motors, each controlling its own wheel for mobility. A large battery is used allowing MOUSE to perform surveillance overnight without needing to have its battery replaced or recharged. There is a PIR sensor mounted on a motor to ensure 360-degree coverage of its environment. MOUSE has a viewable and usable UI hosted on AWS which allows for movement controls including manual movement and setting a path for MOUSE to follow. The UI also includes notifications about movement detection. MOUSE also has LEDs on the top to display battery diagnostics.

1. What is the purpose of this product? For whom is it intended?

## MOUSE’s purpose is to be a mobile surveillance robot intended for indoor use, in corporate office or residential environments. This product can be utilized by industry, with the main focusing being on surveillancing high clearance locations that cannot have live camera feed. By using a PIR and not a video feed all information can be kept secretive. MOUSE can also be used in a residential environment for individuals who are uncomfortable with a live video feed, and instead prefer only movement detection.

1. Describe how the engineering design process used to create your product was utilized in this project. Include how you were able to develop and conduct appropriate experiments, analyze and interpret data, and use engineering judgment to draw conclusions related to the development of your product.

## Throughout the development of the MOUSE, the engineering design process was used iteratively to formulate use cases, requirements, solutions, and performance assessments. In formulating the initial MOUSE design, substantial background research was performed in analyzing previous security systems and autonomous robots that had previously been patented and brought to market. The takeaway from these observations were that MOUSE could excel as a cost-effective alternative to these expensive solutions as long as it effectively performed the basic functionality of movement detections. Furthermore, requirements were created for tracking diagnostics, user control of the robot, and data tracking. Using these requirements, specific solutions were theorized and prototyped. One good example of this is the decision to implement a user dashboard from a web server. There were many different possible configurations to provide the user with drive controls, modes of operation, and activity data. Throughout the development process, these options changed on the dashboard as their priority shifted to mirror our design objectives for product functionality. Additional experimentation was performed while working on prototyping the integrated microcontroller setup on a breadboard. While the primary measure of success was the ability to exhibit the functionality within our design requirements, elements such as the motors were subject to meeting multiple specifications for battery-life, speed, and handling. In order to manage these needs, experimentation was performed on the drive train to estimate power consumption and output torque. These measurements were analyzed and informed the choices for battery and use of PWM signal generation. In implementing our final solutions onto the custom PCB, engineering judgment was essential in problem-solving and debugging of our electrical components. For instance, we discovered that our motor driver was erroneously receiving imperceptibly small signals from the microcontroller. It was identified that passing through debugging LEDs was limiting the power output to the motor driver integrated circuit and preventing it from triggering the motor output. Thus, fixing this problem required some ingenuity to flywire in such a way that functionality was preserved while shorting out the unnecessary LEDs.

1. Describe the design constraints, and resulting specifications, incorporated into your product (list a minimum of 3).

## The design of the MOUSE is intended to be a long-lasting security robot that can traverse an industrial area semi-autonomously. As a result there are constraints for its performance in the areas of battery life, control responsiveness from the web-based dashboard, and display of live diagnostic data and security alerts. It was determined that battery life should exceed the duration of a full night shift for proper application. Thus, our design had to adhere to a high-capacity battery requiring power management from 18V to 5V through a buck converter. In addition, the mechanical design of the MOUSE had to be able to house a battery of significant mass and size. These implementations drove the design of the PCB and the CAD modeling of the packaging shell. The next important feature was responsiveness of the drive system to user commands from the web dashboard. In order for the drive control to be functional from a user’s perspective, the latency of the directional inputs to the motor activation of the MOUSE should be under one second. The resultant specifications of this constraint were limited size in the data transmissions on the web server to micro socket interfaces. In addition, the process itself was limited in computational complexity to minimize stalling. The resultant conditions that we were able to achieve had an average latency of about 0.5 seconds. Lastly, the design needed to effectively communicate to the user when diagnostic and security events occurred. If an operator were to be using MOUSE for the duration of a night shift, they would need to be able to know if motion was detected or power was low. Various mechanisms had to be incorporated into the MOUSE to make these communication. This includes the shift register LEDs and popups on the online user dashboard. The LEDs provide a visual representation of the battery life of the robot and a log shows up to tell the user on the dashboard of any alerts related to motion detection. This live communication allows responsive action to take place if necessary whether that be setting off an alarm or recharging the battery.

1. Describe how each of the following factors influenced your design specifications and constraints.

## **Public Health, Safety, and Welfare:** Due to the close encounters that a surveillance robot like MOUSE is likely to have with operators, client employees, and recreational owners, the device is designed to be safe. This includes limiting the weight of the chassis to prevent ability to injure individuals on contact. Furthermore, the speed of the MOUSE was limited for a similar reason, preventing high speed collisions and injuries due to friction with moving wheels. This was incorporated into the design of our PWM signals for motor control as well as the decision to use 5V into the motor drivers. Both of these design choices limited the maximum current draw of the motors to a reasonable level. Other safety features include circuit design to prevent electrostatic discharge and chip burnout as well as releasing of a user manual as part of our design documentation.

## **Global Factors:** In a global context, MOUSE is responsible for upholding sensitive security surveillance data. This information could be sensitive to foreign interests in any regions that it is being deployed. For this reason, it is essential to consider the cybersecurity measures that need to be employed such that data transmission to and from the MOUSE remains confidential. A breach in security data for a military contractor could result in serious global ramifications. Additionally, the customizable path feature of the MOUSE can adhere to the different environments presented for operation around the globe. Despite different norms for spaces to surveil, MOUSE is able to be effective regardless of the environment.

## **Cultural Factors:** Cultural factors were taken into account in designing the dashboard and the mechanisms by which it shares messages with the user. In an attempt to be inclusive to as many people as possible, states are shown using red/green coloration to indicate success/failure. In addition, the joystick is designed using shapes to universally reflect the directional movement options of up, right, left, down, and stop. An additional consideration was using green, yellow, and red LEDs to indicate power level. The green range indicates strong battery health. The yellow range indicates moderate battery health. The red range indicates low battery health. Universal symbolism is used to combat differences in cultural interpretations of MOUSE’s communication channels.

## **Social Factors:** From a social perspective, MOUSE uses an unimposing exterior design. For product owners, the star-wars-inspired design adds a layer of friendliness and charm for something that they may encounter day-to-day. MOUSE is designed as something to keep people and information safe - something that provides universal absolvement of social stresses. Along this same vein, MOUSE is designed to be safe to interact with, even while operating. The dashboard interface for the user is minimal and provides a streamlined way to interact with key robot functions. Rather than overwhelm consumers with options, MOUSE sticks to a simplistic user interface that highlights core functionality. A key design decision for the social implications of MOUSE is the sensitivity with which it detects movement. A detection system that is too sensitive will consistently produce false alarms, nullifying the validity of results to an operator. Conversely, a detection system that is not sensitive enough risks not being an effective surveillance tool. While there is not a perfect balance between these calibration levels, MOUSE is risk-averse in being more sensitive since the consequences of a false alarm are much less severe than those of a failure to generate an alert.

## **Environmental Factors:** MOUSE interacts with the environment through the stages of manufacturing, standard use, and disposal of its components during its lifecycle. In development of the PCB board, the manufacturing process generates toxic sludge passed through wastewater treatment. This process has been shown to harm the ecosystem and deplete the ozone layer. In order to limit these effects, the physical footprint of the PCB design is limited in size and should be recycled allowing reuse of its components in the future. The chassis is manufactured using subtractive manufacturing and thus generates metal waste that can be harmful to dispose of. By using commonly developed shapes with simple geometries, the amount of waste is significantly reduced. Even for the prototype, an existing chassis was reused and altered to meet our needs. The Li-Po battery is essential for the long-lasting functionality of the MOUSE, but introduces toxic chemicals that are hazardous if not properly disposed of. Potential for combustion to occur adds additional environmental damage, even if contained in a landfill. Lastly, the shell of the MOUSE is created through 3d printed material and was custom-designed to our application. The plastic waste from this process can be limited through conservative use of filament and optimized geometries. This material is also able to be recycled at the end of the product's lifetime.

## **Economic Factors:** From an economic standpoint, MOUSE is inherently designed to be more affordable than existing products in the market. Other companies in the market offer patrolling security robots for order in the $10,000 to $20,000 range and feature state of the art technology for fleet management and autonomous movement. Instead, MOUSE was created with a relatively limited budget. As a result, functionality and costs were analyzed to determine the inclusion or exclusion of a variety of movement and detection features such as lidar sensors, fleet management software, and PIR sensors. From a design specifications standpoint, we started to prioritize parts that we had free access to in the lab and built out our design around those components. For instance, the entire chassis of our robot came from the lab station as well as the DC motors for each of the wheels. As a result, motor drivers were selected based on their ability to overcome the 1 Amp stall current and generate a 0.5 Amp continuous current output as indicated by the motor documentation for operation. In this way, finances directly impacted the design process. As a prospective product in the market, it would make sense to develop different versions of MOUSE with varying qualities of motion detection sensors and drive controls. Customers would have a variety of needs in their applications and should be able to incorporate more expensive components should they see it as the best fit for their needs. For instance, adding a camera for imaging or audio recording. A final cost associated with the MOUSE that was not assessed in prototyping is the addition and maintenance of databases to store the logs for each device, user information, and path recording data. In order to sell this product, a scalable software architecture needs to be implemented as opposed to the rudimentary local storage system used in our prototype.

1. Describe the appropriate engineering standards incorporated into the creation of your product.

Under FCC guidelines, the 48 MHz frequency of the ESP32S3 microcontroller core contained within the MOUSE is subject to the classification of “Unintentional radiators” as outlined in Part 15, subpart B due to its operating frequency between 9 kHz and 3000 GHz and its commercial availability for public or private use. This means that before entering the market, the MOUSE must be validated to ensure compliance with the guidelines set by the FCC as established by the Supplier’s Declaration of Conformity procedure. The same applies to the DC motors which may incidentally produce emissions over 9kHz. Furthermore, IEEE standard 1625-2008 states requirements for rechargeable batteries for multi-cell mobile computing devices which the MOUSE’s LIPO battery would fall under. IEEE 802.11 also dictates the protocols and specifications of wireless communication. The ESP32S3 uses wireless sockets to communicate over the internet with the webserver and adheres to these standards for the 2.4 GHz and 5.0 GHz frequency bands. Additionally, in the future MOUSE will need to adhere to cybersecurity standards regarding transfer of security data. The relevant standards for such operation are NIST SP 800-53 and ISO/IEC 27001.

1. Describe the final status of your product.

In its final form MOUSE completes the primary functionality we wanted to achieve. Its movement can be controlled through the web UI both with manual control and recording a path then following the recorded path. The four powered wheels on MOUSE enable efficient mobility. There is very little delay between inputs to the web UI and the wifi-based communication to MOUSE. MOUSE has a PIR sensor mounted to a motor on the top of its shell which works well to detect movement on all sides of the device. When movement is detected, it shows up on the UI with a timestamp of when the movement was detected. The LEDs are able to display the battery life remaining.

1. Describe the makeup of your project team and how you were organized to establish goals, plan tasks, and meet the objectives of this project.

## Our project team consisted of four computer engineering students each with a role. Andrew Hall is the team lead, Matthew Ghera is the software lead, Christopher Miotto is the hardware lead, and Braden Kirkendall is the systems lead. As team lead, Andrew made sure we were on track for weekly assignments and overall project completion. With the team members’ input, Andrew also created weekly goals and delegated each person a component of that goal to work based on their interests and knowledge of the project. Chris kept track of each component that needed to be added to the PCB, when working on schematic, layout and assembly. Matt led the software organization and efforts to ensure the software was completed. Braden monitored software and hardware integration efforts and developed block diagrams to model system interconnects. Debugging and solving major issues throughout the project was a collective effort, and we all worked together to get the project to its final completed state. Especially when it came to debugging, communication between members was key to ensure the same thing was not tried multiple times and the project was completed in a timely and efficient manner.

1. Did your project require the production of any written documentation other than this document (i.e., manuals, educational materials, etc.)? If so, describe the types, composition, and nature of the audiences for whom these materials were intended.

The project generated 13 different written documents. These documents included the initial and final project proposals composed of our project outline, and the course staff was the audience. The functional specification gave an outline on the overall project functionality with the audience being stakeholders and potential consumers. The software, electrical and mechanical overview documents provided an overview of the software, electrical, and mechanical functionality respectively; the audience of these documents is project stakeholders and consumers. The component analysis provided an outline of the major components we intended to use, and the audience is stakeholders and consumers. The bill of materials provided a list of components needed to fabricate our project, and the intended audience was the project manufacturer and stakeholders. The software formalization document provided a finalization of all software functionality with the audience being stakeholders and consumers. The legal and regulatory analysis covered all related standards that impact our project and need to be met with the intended audience as stakeholders and producers of the project. The reliability and safety analysis document analyzed the risks that could arise from our project and expected component failure rates; this document’s intended audience is stakeholders and producers. The electrical and environmental analysis provided a summary of all potential ethical and environmental concerns which could arise from our project with the intended audience being stakeholders and producers. The final document was the user manual which provides a user guide for operation and functionality of our project with the intended audience as stakeholders, producers and consumers.

1. Describe the types, composition, and nature of the audiences in attendance for the final oral design review. Discuss how you prepared for this audience.

## 

## The audiences for the final oral design review are, at least in theory, potential clientele, investors, the course staff, regulatory agents, and peers developing their own product. Potential clientele are focused on seeing the value in the product from a standpoint of the costs and benefits that it is able to provide. Our preparation for potential clients includes outlining and selling the benefits of a low-cost security robot and the convenience it provides. The demonstration video seeks to support these ideas by showing the products effectiveness at traversal and showing the various features offered by the user dashboard. Potential investors are interested in similar ideas as potential clientele but they are focused on areas for development and scalability to ensure that their funds will generate a high return on investment. To appease this audience, our presentation highlights the potential growth efforts of using a fleet of MOUSE robots simultaneously for full surveillance coverage. In addition, explaining the scalability of the web server using databases for user login and data encryption. Furthermore, they have to believe that there is a demand for this product in the market, so we will show uses of similar products currently available. The course staff is interested in the soundness of the electrical engineering techniques present in the technical implementation of the project. To prepare, our presentation highlights the engineering design process that we went through to reach our final design as well as design decisions that were made along the way. Our design features detailed technical descriptions to show the course staff our thought processes. While perhaps not directly present at the final design review, the material is relevant to regulatory agencies who are interested in the adherence of the design to legal and product classification standards. The final group of interest is peers who are presenting their own project simultaneously. These individuals are curious about how the electrical engineering principles they have learned apply to a new application. Thus, we will use the experience gained from classes taken at Purdue as a baseline for technical descriptions, allowing them to learn and understand the logic behind our application.

## **Purdue ECE Senior Design Semester Report**

## **(Individual Reflections Section)**

| **Course Number and Title** | ECE 47700 *Digital Systems Senior Design Project* |
| --- | --- |
| **Semester / Year** | Spring 2024 |
| **Advisors** | Phil Walter |
| **Team Number** | 2 |
| **Project Title** | M.O.U.S.E. |

| Senior Design Student Completing This Section | | | |
| --- | --- | --- | --- |
| **Name** | **Major** | **Area(s) of Expertise Utilized in Project** | **Expected Graduation Date** |
| Andrew Hall | CompE | Hardware, Mechanical, PCB Layout, Software | Spring 2024 |

**Individual Reflection:** Provide a brief (1-2 page) individual reflection of the design project, as outlined below:

1. Describe your personal contributions to the project.

## I adapted the drive chassis we were able to borrow from the course staff to fit our application which included changing it from six wheel drive to four wheel drive. I prototyped the shift registers and LEDs and wrote an Arduino script to test controlling the LEDs, turning on all 24 LEDs through the daisy-chained shift registers. I contributed to multiple areas of the circuit schematic including the bucking step-down circuit from 18.5V to 5V based on a TI Webench design, the shift registers and LEDs, motor drivers and PIR sensors. I contributed to the PCB layout by routing the 18.5V to 5V step down and other minor contributions. I helped solder many components onto our PCB and the protoboard for the shift registers after I realized the mistake in the layout for the shift registers on our PCB. I also filled out many order forms for components, keeping track of the components we were using and needed more of. I also worked on debugging, systematically working to find the root cause of issues. I also made minor contributions to the server-side software code related to the microcontroller knowing if playback mode was in use.

1. Describe how your contributions to this project built on the knowledge and skills you acquired in earlier course work.

## Previous courses familiarized me with designing circuits on breadboards, understanding the role of certain circuit components such as resistors and capacitors. I was able to build on this knowledge of circuits and circuit debugging when both prototyping and working on the schematic and PCB layout then debugging issues in our PCB. The classes that provided me with these circuit skills and knowledge include ECE 2k1, ECE 2k7, ECE 2k2 and ECE 270. I was able to build on the knowledge of microcontrollers and ICs from ECE 362 when choosing what microcontroller to use for the project and how each IC would be communicated with. I was also able to apply programming principles and my understanding of different languages I learned in previous courses including ECE 362 and ECE 461 to various aspects of the project including prototyping, debugging microcontroller code, and understanding and updating server-side code.

1. Describe how you acquired and applied new knowledge as needed to contribute to this project. What learning strategies did you employ to do so?

## Prior to the project, I had very little experience working on large schematics and PCB routing, but I had some knowledge of how to use KiCAD. I followed online tutorials to familiarize myself with the skills required for these tasks, following their steps to create a simple design then apply that to the larger design I was working on. I also used trial and error and referencing various online resources to try different solutions and find which one worked best for the application. I also had no experience soldering SMD components prior to this project. I learned this soldering skill by asking my teammates for advice, watching YouTube videos, and practicing on test PCBs provided by the course.

1. Discuss your ethical and professional responsibilities as they relate to this engineering design experience.

## Within this engineering experience, I had an ethical responsibility to ensure the project was as safe as possible and did not have any extremely dangerous elements that would cause harm to someone using the product created. Decisions related to keeping MOUSE safe for users included keeping the battery in a LiPo-safe bag and having an easily identifiable and accessible power switch. These decisions significantly limit the amount of physical harm that could be done by MOUSE, even in the event of a major failure. I also had to maintain clear and professional communication with my teammates, especially through disagreements or conflict. While there were many conflicts, I had to be careful with how I approached conversations related to components needing to be changed or work that needed to be redone, understanding how much time and effort someone put into the component or area of the project being changed. I also made sure I was supportive of my teammates in what they were working on and continuously made myself available for questions and providing help when needed. Throughout this experience, I had to take accountability whenever I made a mistake relating to the project, and do my best to remedy these mistakes to reduce the impact on the project and my teammates.

1. Consider what the impact of the product of this engineering design experience could have in economic, environmental, societal, and global contexts. Discuss how you would make (or did make) an informed judgement as to your product’s impact in each of these four contexts?

## Economically, we wanted to keep our product as budget-friendly as possible due to the expense of other security robots on the market. If this product were to be produced, it would make mobile surveillance technology much more accessible. The environmental impact of MOUSE is primarily related to its power consumption. To improve its use of power to minimize its environmental impact, I would have made sure we were using the most efficient components possible, particularly when choosing our step-down circuit. There could also be an analysis if all four drive motors are necessary as this would reduce the power used by the device. In a societal context, this product had to be designed as user-friendly so it would not frighten anyone who came into contact with it. An informed judgement about this could be made to ensure people have positive interactions with the device even if they see it in an unexpected situation. From a global context, I believe this project could contribute to increasing privacy in security efforts by using sensors that detect movement as opposed to cameras that may take a picture of a person.

## **Purdue ECE Senior Design Semester Report**

## **(Individual Reflections Section)**

| **Course Number and Title** | ECE 47700 *Digital Systems Senior Design Project* |
| --- | --- |
| **Semester / Year** | Spring 2024 |
| **Advisors** | Phil Walter |
| **Team Number** | 2 |
| **Project Title** | M.O.U.S.E. |

| Senior Design Student Completing This Section | | | |
| --- | --- | --- | --- |
| **Name** | **Major** | **Area(s) of Expertise Utilized in Project** | **Expected Graduation Date** |
| Matthew Ghera | CompE | Software, Hardware, PCB Layout, Physical Assembly (CAD) | Spring 2024 |

**Individual Reflection:** Provide a brief (1-2 page) individual reflection of the design project, as outlined below:

1. Describe your personal contributions to the project.

## Although my main focus on this project was software, I touched every aspect of this project. Starting with software, I wrote a large majority of the microcontroller code. This includes the software to connect with WiFi, communicate and parse messages from/with the websocket, controlling the shift registers, controlling the DC and stepper motors, reading in the PIR sensors. I also wrote a large portion of the web server/socket code. This includes creating the initial infrastructure for the websocket and the user interface, creating a portion of the endpoints and all the helper functions that they use to store and manipulate stored data, and styling of the web page. Moving away from software, I made the CAD of our package and printed every piece. I also helped with a portion of constructing the packaging by gluing some pieces, helping to cut the wood and other miscellaneous construction pieces. I also helped with a portion of making the circuit schematic and PCB; I helped with the shift register section, DC motor control section, stepper motor control section, and coulomb counter section. I also helped with the soldering of our PCBs and testing them.

1. Describe how your contributions to this project built on the knowledge and skills you acquired in earlier course work.

## I learned how to do web development programming and API code development in ECE461. In this project, I expanded upon that by creating a web interface and websocket code that is similar to API code but has a few differences. I learned how to do microcontroller programming in ECE362 and that taught me a lot of the basics and fundamentals for programming a microcontroller in C (the stm32). In this project, I expanded upon this by programming a different microcontroller in C (the stm32), and although the environment was very different, I was still able to use a lot of the skills and knowledge I learned in 362 when programming the ESP. I learned how to do basic circuit analysis, development, and testing in ECE2k1, ECE2k7, ECE270, and ECE2k2. Of course, when creating prototyping circuits on a breadboard, creating circuit schematics and the PCB, and when debugging the PCB, all the skills learned in those 4 courses were utilized.

1. Describe how you acquired and applied new knowledge as needed to contribute to this project. What learning strategies did you employ to do so?

## This was my first time ever soldering a PCB, so everything to do with soldering techniques for surface mounts or 0805s/0603s was new to me. I learned mostly by watching and getting tips from Joe and Chris who had more soldering experience. I also had never created a websocket before; however, I had created an API before as I said in part B. Because of this, I was able to use my prior experience with a related concept and lean on that to get me most places, and when I was stuck I would look up resources online for how to do certain aspects of setting up and communicating with the websocket. I have also not had prior experience with programming in the esp-idf environment, but I have programmed other types of microcontrollers before in different environments (as I said in part B), so I was able to use this past experience to guide my learning of this new environment. Almost every issue I ran into when interfacing with internal and external peripherals I had run into with another type of microcontroller, so I knew where to look and what to look up online to understand how to get past any issues.

1. Discuss your ethical and professional responsibilities as they relate to this engineering design experience.

## For this engineering design experience, I had to really focus on my ethical and professional responsibilities when it came to communication, conflicts, and maintaining a good team culture. Of course, communication was an important factor in this project as we were working on a complex system with a small window of time to work on it, so one of my responsibilities I tried to always fulfill was to update my teammates when I was working on something and my progress on whatever I got done. Conflicts fortunately were not a large responsibility, but whenever they came up, my personal responsibility was to make sure they never escalated to become a larger problem that hindered our progress. Also, maintaining a good team culture is important so that they don’t in turn lead to conflicts and this also was not a large responsibility as my teammates are all friends outside of the project, but an important responsibility to make sure I was always supportive of my teammates in whatever they were working on. In terms of the ethical responsibilities when it comes to the project, this mostly pertained to the security in the software I worked on. I made sure that there were no potential vulnerabilities in the server for losing personal information.

1. Consider what the impact of the product of this engineering design experience could have in economic, environmental, societal, and global contexts. Discuss how you would make (or did make) an informed judgement as to your product’s impact in each of these four contexts?

## We made this robot with the intention of it being an economical option for security in a home or business setting. Due to this, it has an obvious economic context as we tried to make it as cheap as possible so that small businesses or families could purchase it without worrying about the cost. Also due to this intention, it has the ability to impact a societal context because of its purpose it was built for being for home and business security; with this robot, less crime would be committed or unresolved as this robot could aid with detection of burglaries or other crimes. In terms of environmental impact, it was important to consider how we were powering this robot. We originally planned to use a lead acid battery which is not very environmentally conscious; however, after switching to a lipo battery this situation was improved. As a further improvement, we could consider using solar power or some other form of renewable charging/recharging. Lastly, for the global context, this robot is a very small-scale product, so it doesn’t have an obvious global impact. However, this robot could be used globally to help people all around the world, especially since there are not many privacy concerns since there are no cameras being used for motion detection.

## **Purdue ECE Senior Design Semester Report**

## **(Individual Reflections Section)**

| **Course Number and Title** | ECE 47700 *Digital Systems Senior Design Project* |
| --- | --- |
| **Semester / Year** | Spring 2024 |
| **Advisors** | Phil Walter |
| **Team Number** | Team 2 |
| **Project Title** | M.O.U.S.E. |

| Senior Design Student Completing This Section | | | |
| --- | --- | --- | --- |
| **Name** | **Major** | **Area(s) of Expertise Utilized in Project** | **Expected Graduation Date** |
| Christopher Miotto | CompE | Hardware, PCB Layout, Physical Assembly | Spring 2025 |

**Individual Reflection:** Provide a brief (1-2 page) individual reflection of the design project, as outlined below:

1. Describe your personal contributions to the project.

## My focus throughout was mainly on hardware prototyping and implementation. I prototyped power step down circuits including LDO and buck, motor drive controller, and PIR sensors. I created the schematic for the ESP supporting circuitry including USB to ESP, USB to UART. I created the buck converter and LDO schematic, I used TI webench to help generate the buck converter schematic. I helped with the motor drive, shift register, and sonar/PIR schematic. For PCB I had multiple contributions. I layed out all the initial parts on the PCB. I routed all ESP supporting components. I created a power plane on top, and GND plane on bottom and routed all power/GND pins accordingly, using relief pads for power. Also routed all components back to the ESP, and helped with routing of other components. I helped solder on many components for all PCBs that we used, and debugged multiple components. Finally I helped with gluing packaging together and resizing.

1. Describe how your contributions to this project built on the knowledge and skills you acquired in earlier course work.

## My previous courses helped me largely with circuit design principles. For example ECE 2k1, 2k2, 2k7, and 270 all helped with circuit design. Also knowledge from ECE 270 on how to use Ki-Cad was very useful for creating the schematics for all components, as well as for the PCB layout. My previous classes on microcontrollers like ECE 362 allowed me to prototype certain components that needed communication between ICs and a microcontroller. My previous programming classes like ECE 264 and 368 allowed me to more easily program the microcontroller in whichever language was needed. Also debugging the circuits on breadboards and PCB, as well as debugging software was built upon the countless hours of debugging within my other courses.

1. Describe how you acquired and applied new knowledge as needed to contribute to this project. What learning strategies did you employ to do so?

## Due to being a CompE I had not taken power classes, so learning what a buck and LDO were was hard, but with my knowledge from my circuit classes I was able to figure out how they worked. I was able to use online resources as well as reaching out to professors to help me gain this newly needed knowledge. I also had trouble understanding the intricacies of motors. So I had to learn the aspects of motors, mainly what stall current is and how to overcome it, as well as the specifications needed for motor drive ICs to run the paired motor. I also employed the usage of online resources and help from professors to overcome this. For PCB I had never done a proper layout, so I had to research how to create a PCB layout within KiCad. I employed the usage of online resources for this too. For soldering the PCB I have had some previous experience with soldering, however there was still a lot for me to learn specifically from Joe who was always a great resource whenever I was confused.

1. Discuss your ethical and professional responsibilities as they relate to this engineering design experience.

## During ideation ethical and professional responsibilities were at the forefront of my mind. With the experience gathered from my seminar classes as well as the lectures within senior design I was able to use my responsibilities to guide me into making the correct decisions. For ethical considerations I always made sure that if something was to go wrong, that it couldn't impact the user in a negative way. This can be seen by using a supply voltage that was relatively low, as well as under powering the motors so they could be less harmful. I also made sure to have an accessible power switch on the outside to make sure that if something malicious were to happen it could be dealt with. With my professional responsibilities I mainly focused on good communication and conflict management within my team. I always tried to communicate clearly on what and why my decision making was, and if there was a conflict to consider both sides and proceed with whichever is the better decision. When conflicts arise I try to use an open dialog to break down what exactly the conflict is and how we can address it quickly, so it does not fester and break down our team. Thankfully we never had very large conflicts so many times this was not needed.

1. Consider what the impact of the product of this engineering design experience could have in economic, environmental, societal, and global contexts. Discuss how you would make (or did make) an informed judgement as to your product’s impact in each of these four contexts?

## Within the economical context our project can have an impact by being a less expensive alternative to the current surveillance equipment market. By using components that were relatively inexpensive our product can cost much less than the current mobile surveillance units on the market, and thus could be used in a lower income residential area or smaller firm. For the environmental impact we made sure to minimize the possible waste of our product during its main life cycle. For production we tried to use off the shelf components to allow for less waste to be produced. During the nominal use the only issue would be battery power, however by using rechargeable batteries there should be minimal waste. During disposal there are some possible impacts, however if disposed of properly these should not be an issue. For societal impacts a less expensive mobile surveillance device may allow for lower class consumers to be safer due to having access to this usually expensive technology. For global contexts, our product can help all people who may have privacy concerns when it comes to having a live video feed for surveillance in their house. By using only a motion detection system these people can still be at ease for safety, while not violating their privacy.

## **Purdue ECE Senior Design Semester Report**

## **(Individual Reflections Section)**

| **Course Number and Title** | ECE 47700 *Digital Systems Senior Design Project* |
| --- | --- |
| **Semester / Year** | Spring 2024 |
| **Advisors** | Phil Walter |
| **Team Number** | 2 |
| **Project Title** | MOUSE |

| Senior Design Student Completing This Section | | | |
| --- | --- | --- | --- |
| **Name** | **Major** | **Area(s) of Expertise Utilized in Project** | **Expected Graduation Date** |
| Braden Kirkendall | CompE | Software, Physical Assembly, Hardware Validation | Spring 2025 |

**Individual Reflection:** Provide a brief (1-2 page) individual reflection of the design project, as outlined below:

1. Describe your personal contributions to the project.

## I was designated as the systems lead for this project and primarily worked with software components on the webserver and the microcontroller. Initially, I learned about Node.js and the Vue.js framework to implement server backend for the user dashboard. After implementing features such as vehicle states, connection statuses, and joystick controls on the web server, our software was far ahead of our hardware prototyping. Thus, I moved into prototyping motor drivers and PWM on the ESP32. When the rest of the team was developing the PCB, I was able to implement the server-side handling for the recording and playback feature of the MOUSE. I merged my prototyping code into Matt’s existing codebase and debugged integration of the various prototyped hardware systems. In addition, I re-prototyped and developed code for the LED shift register configuration since our on-board implementation was faulty. The team experienced significant setbacks in PCB soldering which I had little experience in. This led me to work on mechanical construction of the 3d-printed parts for the outer shell of the MOUSE as there was a backlog in being able to test code. In addition, I individually authored two design documents and created systems diagrams for the software and hardware components of our design.

1. Describe how your contributions to this project built on the knowledge and skills you acquired in earlier course work.

## In ECE 264/368 I learned general C programming and data structures which aided my ability to create complex structures for data storage and retrieval, specifically during design for the webserver. ECE39595 introduced me to timing in program execution and guided me through processes in the multicore usage of the ESP32 and the real time processing for path recording and playback. ECE362 introduced me to the idea of microcontroller programming on the stm32 microcontroller which mirrored the behavior that I wanted to achieve on the ESP32. Specific concepts that carried over include GPIO initialization, PWM, and interrupts. ECE270 overviewed digital logic and I was introduced to using KiCad to create basic schematic ICs. This carried over to being able to design and parse through schematics for design of our PCB boards. ECE369 taught me the basics of discrete math and logic which was used to organize the product as a state machine and analyze its modes of operation.

1. Describe how you acquired and applied new knowledge as needed to contribute to this project. What learning strategies did you employ to do so?

## Throughout this project, most of the things I did involved acquiring new knowledge or applying ideas that I was familiar with to new applications. The general process that I followed to get a working understanding of each component was the following: define the problem that needed to be solved, research previous solutions and their documentation, assess feasibility, and then implement it into the design. While this general framework was applied, each piece of acquired knowledge had its own strategies that I implemented. For instance, in using the ESPRESSIF IDF I was exposed to a wealth of sample code and documentation that performed similar functionality to what I wanted to achieve. However, there were many different ways to complete the same task of creating a PWM signal. It was essential for me to revisit the application of activating a motor driver to determine which library would be most effective. While the ESPRESSIF IDF had more specialized sources of information, the process of learning frontend and backend development for the web server came from much more general guides. Rather than attempt to tackle the whole problem at once, I would research one specific implementation detail at a time. For instance, I had to learn how to create an exposed endpoint on Node.js and use it to communicate back to the frontend. Once I had mastered this skill, communications in general became pattern-matching of a code structure that I had already developed and understood. Coming into this class with no prior javascript experience, one of the challenges was learning the intricacies of its synchronous program execution to apply correct timing intervals for recording and playback mechanisms. This was a lot of trial and error in using javascript-specific structure like promises and callbacks to achieve the desired result. Upon each iteration of the code, I would analyze the output and determine potential modes of failure. Then, I would incorporate a new solution and look at the difference between the new output compared to the previous one, using it as a guidepost to measure progress. This process repeated iteratively until a correct implementation was found. When learning, if I encountered a problem that seemed daunting I would turn to my teammates or the course staff and determine their recommended course of action to guide my discovery.

1. Discuss your ethical and professional responsibilities as they relate to this engineering design experience.

## While designing MOUSE, many core principles from our engineering seminar classes resonated with me to make sure that our product generated a positive impact. Firstly, from a safety standpoint, much of my analysis focused on modes of failure that could harm a user. This informed decisions about battery size and usage, the max speed attained by the wheels, and the types of materials used to construct the body. All of these attributes of the design could be dangerous if not monitored and limited sufficiently for use in a public setting. Ethically, this robot could pose questions about the moral right to surveillance. Ideally, MOUSE serves an ethical role as a protector of information or resources. However, used in a malicious way it could be controlling or used to protect dangerous things. There becomes an ethical dilemma in the morals of who is permitted to look at the logged data that the MOUSE provides, especially if there is governmental pressure involved. While some of these ideas are beyond the prototyping implementation created, all of these ideas contributed to the greater vision for a scalable product that could be brought to market.

1. Consider what the impact of the product of this engineering design experience could have in economic, environmental, societal, and global contexts. Discuss how you would make (or did make) an informed judgement as to your product’s impact in each of these four contexts?

## MOUSE has facets to impact economic, environmental, societal, and global contexts directly and indirectly. To make an informed judgement on MOUSE’s impact in each of these areas, I would assess them on a prototype level and on a scaled version of this product should it reach the market. Economically, MOUSE is designed as a cost-effective alternative to traditional security robots. Coming with a fraction of the features, it offers a streamlined user experience for core surveillance functionality. If done effectively, the surveillance market could shift to seeing more prominence of cheaper options. For development at scale, the environmental effects of copper, metal, and plastic waste are serious considerations. Relative to other products, the footprint of MOUSE would be relatively small, but producing fleets of robots would add up considerably and would require optimized manufacturing solutions for part recycling and reuse to be green. Socially, MOUSE capitalizes on the idea of safety and security. Product users should feel confident that their immediate area is free of potential intruders or threats. The unimposing design of the shell should contribute to this societal view as a sign of comfort rather than fear. However, the robot could still provide a deterrent to potential intruders. Globally, the design of this robot is able to be applied anywhere to protect a variety of information. The context of who is manning the vehicle and the contents of what they want to protect is not strictly defined. If adopted into high security authorization zones, MOUSE could have serious global ramifications for ensuring and enabling government secrets. In extreme circumstances, this could present national pressures on the product’s operation and data.