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

## **(Team Section)**

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| **Course Number and Title** | ECE 47700 *Digital Systems Senior Design Project* |
| **Semester / Year** | Fall 2022 |
| **Advisors** | Phil Walter and Shreyas Sen |
| **Team Number** | 8 |
| **Project Title** | Hermes |

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| Senior Design Students – Team Composition | | | |
| **Name** | **Major** | **Area(s) of Expertise Utilized in Project** | **Expected Graduation Date** |
| Michael Langford | EE | System Design Schematic and PCB Layout, Software, Soldering | December 2022 |
| Owen Mandel | Comp E | Software | May 2022 |
| Jonathan Wosiak | Comp E | Software | December 2022 |
| Santiago J Garcia Delgado | Comp E | Software | May 2022 |

**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.

## Hermes is an Autonomous Search drone that will allow people find the location of people trapped inside collapsed building. Many times, people are trapped in spaces too tight or dangerous to navigate and find people in, and this device fills that gap. The Hermes will have two modes of operation, manual operation and autonomous operation. During manual control the user should be able to utilize the radio controller to operate the drone, and maneuver around. In autonomous mode, the drone will fly around in a circular pattern around the room until it has identified the target it is looking for. In a final use case, this would consist of identifying people via visual or thermal camera, relaying this information back to the operators either by returning or by wireless comms. For this prototype, it identifies simple objects by color detection, and commands the flight controller to hover above the object and land. To enter autonomous mode, the drone must have taken off using manual controls, after which it can enter its autonomous search pattern.

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

## The Hermes is intended to be used in tight confined spaces such as those found in collapsed building to find injured people. Many times, these people are trapped in areas too small and narrow for rescuers to be able to determine the trapped people’s location. This product is aimed to be used by police departments, fire departments and not intended for use by hobbyist.

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.

## The engineering design process started by identifying the problem that we wanted to solve. The problem we identified was the need to aid search and rescue operators to ensure their safety and make sure that they were more effective at their job. We found that the best way to solve this problem was providing a drone that will aid them in finding injured people without having to put their lives in danger. Knowing what our goal would be, we selected our minimum feasible criteria that we felt would result in our solution effectively aiding in search and rescue. When we finished, we split our project into hardware requirements and software requirements. Then we began prototyping on our dev boards, testing out the functionality that would be needed and how much is needed. While prototyping we began ordering components and assembling them into the drone. After this was done, we began ordering the printed circuit board for our final packaging. Finally, we began running tests on our final drone project trying to ensure that it would be able to fly and that it would operate autonomously. The development of the software and the selection of hardware involved experimentation and simulation, signal processing algorithms which had to be mathematically analyzed to determine their behavior and select the best solution. A data logging feature was integral to the hardware, allowing data to be tracked at a high sample rate and enabling experimentation and data analysis to drive development of all necessary algorithms.

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

## One of the original major design constraints that we originally faced was the needed flight time to demonstrate prototype search functionality. We determined that the prototype functionality of a simple search pattern and navigation could be accomplished in just under 2 minutes, and so this criterion drove our selection of batteries, motors, frame, etc.

## A second design constraints was the necessary control loop bandwidth needed to stabilize an inherently unstable flight platform such as a quadcopter drone. Without enough processing speed and high enough data rate from IMU sensors, it would be impossible to fly the drone controllably let alone perform the search and rescue functionality. From analysis and research, it was determined that 500Hz was likely near the minimum loop frequency tolerable, and likely a higher gyro sampling rate would be needed for an accurate estimation of the attitude (>1KHz).

## The third design constraint that we faced was the image processing frame rate necessary to identify a prototype target (the colored object) – the stand-in for the long-term goal of human identification – while flying along doing a search pattern within the time constraint already mentioned. Due to the simplicity of the target being identified, this was allowed to be rather low compared to a more complex object, it became a driving factor behind the selection of the single board computer and the camera chosen and its resolution. Between this and the other constraint, 5 fps became the selected constraint.

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

## **Public Health, Safety, and Welfare:** There are certainly a few safety concerns; since the blades are open, the risk of injury is quite high if you were to grab the drone during operation, and any crashes would also result in damage and possibly injury. To mitigate the risk of injury to the pilot when turning on the drone we place. Zip ties through the motors to impede sudden movement of the blades upon startup, then remove once the startup sequence has finished. Apart from that we encourage the users to maintain a distance of at least 6 feet from people when taking off and to be careful when operating the blades.

## **Global Factors:** The device is designed to be utilized exclusively in indoors areas; this impacted a lot of the fine tuning on the drone. Meaning that if flown outside or in high altitudes it could result in possible damage to the drone and possible damages to people nearby the drone.

## **Cultural Factors:** We wanted to make sure that people who were familiar with drones could understand some important things. Firstly, we wanted to make the battery easily identifiable and removable, by placing it at the bottom of the drone and not requiring any tool to remove the battery. Secondly, we utilized a remote control that people who have flown other drone could easily pick up and utilize.

## **Social Factors:** First of all, a practical problem could be not understanding how to utilize the drone properly. Hopefully people handling the drone would be able to understand drone controls. More seriously, people could be highly distrustful of an autonomous system such as this, even if it had limited human control during usage. People could easily mistrust it to not lose control, or to crash and destabilize a partially collapsed building. Rescuers would have to be very familiar with the drone to be confident in using it in a real-life scenario when risks are extremely high. To hopefully mitigate the fear people might have dealing with this automated technology we’ve tried to make appear as compact as possible so as to not intimidate people.

## **Environmental Factors:** The main environmental impact would come from the manufacturing and the end-of-life use of the product. To try to extend the life cycle of our product and reduce some of this waste is by making the batteries rechargeable.

## **Economic Factors:** We decided to make drone durable and reliable and able to operate in tight confined spaces. There are two parts that would need replacements in case of crashes or damages that might occur over time: The batteries and the blades.

1. Describe the appropriate engineering standards incorporated into the creation of your product.  
     
   The engineering standards that were incorporated into the creation of the product include technical requirements and functional specifications, and FAA regulations that our drone must follow. We try to ensure that it can be deployed and comply with the regulations of that area. We also had worries about the electromagnetic interference issues that may have needed shielding to mitigate. However, we were able to determine that due to the shielding inherent in the motor cowlings and motor controller, that it was satisfactory for a prototype.
2. Describe the final status of your product.

The product is still not fully operational. Our project is complicated as it not only need to fly using a controller, but it also needs to operate in an autonomous mode. We are still working on attaching the pi Zero and attaching the LIDAR sensors. We have the flight controller working, motors and controller communicating, meaning we have the manual controller working. Autonomous mode is still quite not implemented yet, primarily because we have yet to implement the navigation computer.

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 is composed of an electrical engineer, that primarily focused on embedded software, soldering, PCB design, and three computer engineers with a focus on high level software and mechanical design. Although we were originally specific roles, we decided it was much more prudent to assist each other in different tasks instead of sticking to our roles. The team met at least once a week and communicated frequently throughout the week. The team had a GitHub where they were able to share code, and important documents. We also employed a discord used for communications, sharing important and relevant links. Finally at the beginning of the semester we also employed a OneDrive, but we migrated that mostly to GitHub. In meetings is when we were given different assignments and assisted each other in making sure everything was flowing along as planned.

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.

## In the process of making the Hermes drone there was a thorough documentation of our drone primarily intended for internal use of the team to make sure we had a thorough understanding of our development process. These documents were things such as project proposals, functional specifications, component analysis, bill of materials, and detailed progress reports. In addition to mandatory documentation, a master Excel file was created the spelled-out requirements, specifications, computations, bill of materials, purchase logs, etc. that drove the system design and parameterization of each subsystem.

## There were also important documents made for internal purposes so we could understand different components of the project from software to the hardware components of our project. These were documents such as the Software Overview, Electrical Overview, Mechanical Overview and Software Formalization.

## The last set of documents were documents that were meant for other people to understand the ramification of our project and to understand the operation of our drone. This set of documents included Legal and Regulatory Analysis, Reliability and Safety Analysis, Ethical and Environmental Analysis, and a user manual.

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 audience will be composed of other teams and professors from ECE477. In preparation we made a presentation and went over it multiple times to ensure that what we presented was correct and we could handle any question that was thrown at us. Thankfully our midterm design review presentation focused on the different design aspects of the PCB and the overall design of the Hermes drone so this should prepare us for technical questions that could be asked.

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

## **(Individual Reflections Section)**

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| **Course Number and Title** | ECE 47700 *Digital Systems Senior Design Project* |
| **Semester / Year** | Fall 2022 |
| **Advisors** | Phil Walter and Shreyas Sen |
| **Team Number** | 8 |
| **Project Title** | Hermes Drone |

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| Senior Design Student Completing This Section | | | |
| **Name** | **Major** | **Area(s) of Expertise Utilized in Project** | **Expected Graduation Date** |
| Michael Langford | EE | System design, schematic and PCB design, soldering and hardware, embedded firmware, signal processing, controls | Fall 2022 |

**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.

While working on this project, I was able to contribute to individual systems as well as the whole. I’ve acted as the primary system designer for the drone, selecting the system interfaces and components, as well as the internal design of any subsystems. This meant selecting the drone size, weight, frame, motors, battery, flight controller components and interfaces, radio controller, radio transmitter, Pi Zero, and coordinating with team members on selection of LiDAR. I primarily built the physical drone, assembling the frame, motors, motor controller, and the electrical systems. I designed the schematic and the PCB, as well as built and tested the PCB once it arrived. I purchased all hardware for the drone, and ordered all PCB components. I designed the flight controller at the subsystem level, dictating the necessary parameters for each driver, and wrote the majority of the software onboard. In particular this meant developing the radio receiver driver to parse incoming data, adapting PWM code to satisfy a high-speed motor control protocol, developing IMU drivers off of Owen’s IMU demo code, writing UART drivers for multiple UARTs onboard, Pi communication drivers, sensor fusion algorithms, PID loop code, auto-throttle, safety code, clock configuration, timing, etc. I then integrated and tested all parts of the flight controller and related assemblies into the final drone and flight-tested and tuned the drone. I of course also either wrote or wrote parts of the many required design documents needed throughout the course of the semester.

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

I found that ECE362 was of course helpful, and got things off to a solid start on hardware and software. In addition, I found ECE438 (DSP) and ECE382 (Controls) to be very helpful and relevant to a self-stabilizing drone. To be quite honest though, most of my experience came from personal projects as this is not my first custom drone, and work in industry, where I used 32-bit microcontrollers extensively.

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?

I found that course staff are always incredibly helpful, but that frequently if I wasn’t able to figure something out it would require hours of digging online, due to using chips and parts that are typically used within closed systems that people rarely interface with directly, and so were very poorly documented.

Forums, old datasheets, poring over open source code for other projects, etc. came in very handy. Google has certainly been my friend.

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

As the designer of the flight controller, I have to be very confident that the drone won’t suddenly lose control or have any rapid changes in flight parameters, as this is a real and serious concern especially early on during testing. Any issues here could easily lead to injury and damage to the drone.

Professionally, I see it as my responsibility to write excellent code, put forth my best work on electrical design, and see to it everything is documented well. This always makes sure that things work, and work well all the time, and that I can always go back to see how I did something.

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?

If this project is taken further to the capabilities necessary for its intended purpose, it is clear that it will have excellent utility and be an asset for many police and fire departments as well as many rescue teams. Economically this isn’t going to be a huge seller, though it would be quite expensive, so a good monetary prospect for the manufacturer. Societally, I see it as a toss-up; I think people are very wary of autonomous technology, and rightly so. However I also think that in extreme situations such as this, people are more willing to allow technology to assist in a situation that is otherwise beyond human help. Environmentally, it should have about the same impact as any other consumer electronics, with the caveat that the batteries on drones are significantly larger, and batteries are a huge driver of pollution. Globally, the impact will be larger in areas often impacted by either war, natural disasters, or collapse of infrastructure, as if the drone could be used, it would find much work in areas such as these.

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

## **(Individual Reflections Section)**

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| **Course Number and Title** | ECE 47700 *Digital Systems Senior Design Project* |
| **Semester / Year** | Fall 2022 |
| **Advisors** | Phil Walter and Shreyas Sen |
| **Team Number** | 8 |
| **Project Title** | Hermes Drone |

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| Senior Design Student Completing This Section | | | |
| **Name** | **Major** | **Area(s) of Expertise Utilized in Project** | **Expected Graduation Date** |
| Owen Mandel | CompE | Software | May 2023 |

**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 personal contributions to the Hermes drone were mainly the SPI for the LSM6DS3 6-axis gyro and accelerometer, navigation computer communication, navigation commands, and VL53L1X LiDAR sensor implementation on the navigation computer. I also did the documentation for the Software Overview and the Ethical and Environmental Analysis.

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

## The work that I did on this project mainly stemmed from ECE362 Microprocessors and ECE 368 Data Structures. Microprocessors taught me how to do the communication for both the UART on the Pi, I2C for the LiDAR sensors and the SPI for the gyroscope. Data structures was also extremely important to developing all of the navigation commands on the Pi.

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?

## Overall, my teammates helped and led me to all the knowledge needed to complete my desired tasks. Michael really helped in the implementation of the gyroscope, as I had not done communication with such a device before. Santiago was really helpful for getting the VL53L1X to work initially on the Pi as he had done work to get the device to work on the STM32F4 before the functionality was decided to be moved to the Pi. Also, Jon was really helpful in the actual object detection that was being implemented on the Pi due to his previous experience with computer vision. Lastly, if somehow the team didn’t know how to do something Google was a very friendly tool as well.

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

## The engineering design process that was used when creating this project showed me the necessary rules to act professionally in both the work that is done as well as how you communicate with your teammates. It is also important to consider how your project is going to be used when designing it as shown with our project, where the ethical implications of how it is used is extremely important, as drones, while very helpful in contexts such as search and rescue, they can also be used immorally and also dangerously. This is why all the safety aspects of arming the drone and other measures needed to be taken into account when making it.

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?

## Our project is part of an extremely growing and important field going into the future, which is the field of automation. Economically, automation products such as the Hermes drone can be in extremely high demand in fields such as search and rescue, construction, and plenty of other fields as well. This leads well into both environmental and societal contexts as automation is helpful societally as it can make dangerous tasks less risky, but environmentally it can be a bit dangerous due to lithium usage and other toxic elements used in the project. Obviously, with regard to our project, a lot of these impacts are on a much smaller scale as we only have a prototype, however, if we were to mass-produce the Hermes drone, the LiPo batteries would cause potential environmental issues, the automation could be extremely helpful in certain contexts as described before, but in its current iteration, the main impacts on society, the economy and the environment are significantly reduced.

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

## **(Individual Reflections Section)**

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| **Course Number and Title** | ECE 47700 *Digital Systems Senior Design Project* |
| **Semester / Year** | Fall 2022 |
| **Advisors** | Phil Walter and Shreyas Sen |
| **Team Number** | Team 08 |
| **Project Title** | Hermes |

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| Senior Design Student Completing This Section | | | |
| **Name** | **Major** | **Area(s) of Expertise Utilized in Project** | **Expected Graduation Date** |
| Jonathan Wosiak | CompE | Software | December 2022 |

**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 personal contributions include 3D printing and modeling mechanical components, computer vision for object detection, LiDAR, preliminary I2C for the VL53L1X, converting PID loop code from C++ to C, software formalization, and legal and regulatory analysis.

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

The two classes that have assisted me the most in this project are ECE 595CVES Computer Vision for Embedded Systems for developing our object detection, and of course I extensively used my knowledge of microcontrollers and I2C/UART from ECE 362.

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?

## I learned quite a lot while contributing to this project, and my first and most immediate resource were my teammates. I learned how to solder from Michael, and I learned a lot through working with Santiago on I2C, if there was something I didn’t know and neither did my teammates or they were not with me I would always consult the internet.

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

## I believe this engineering design experience has been a great professional experience, I would say it is similar to working in a team environment during my internship. Ethically speaking as well, I can relate this experience back to my internship in the same way where I am responsible for the work which I put forth and the consequences of that work.

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?

## Our project has the potential for far reaching economic, environmental, societal, and global contexts. I believe our project has the potential to support a viable business model, where in a global context, our project could be used anywhere in the world in search and rescue to save lives whilst having virtually no negative impacts on the environment. I could see our project being used by governmental departments after disasters in search and rescue, tying together economic and environmental contexts. Additionally, I think if this technology became common place, it would have far reaching societal impacts through its ability to save lives and the comfort that it may provide as a potential way to find people in disaster situations.

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

## **(Individual Reflections Section)**

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| **Semester / Year** | Fall 2022 |
| **Advisors** | Phil Walter and Shreyas Sen |
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| Senior Design Student Completing This Section | | | |
| **Name** | **Major** | **Area(s) of Expertise Utilized in Project** | **Expected Graduation Date** |
| Santiago J Garcia Delgado | Comp E | Software | May 2022 |

**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 personal contributions to the project were primarily based around the software side of the project and interfacing with the TMF8801 and the VL53L1X, we ended up using the TMF8801, and the PWM code that Michael used for the motor controller. I also worked on the User manual and the mechanical overview.

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

## I primarily used my knowledge from ECE36200 for the microcontroller and interfacing with the sensors as the TMF8801 and the VL53L1X.

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?

My primary tool for acquiring needed information to go about my task was to first consult my teammates. Michael had previously worked on a drone was able to guide me and give tips and if he wasn’t able to help, he quickly guided me too resources that could help me. I also applied a lot of techniques learned from ECE36200, specifically how to search user manuals for information that is needed.

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

This engineering experience has been great learning experience in how important documentation for every step is, and how not doing so could lead to further problems when you try to implement changes. It was also a great experience because it showed me how important constant communication among all members of a team is for that team to be productive.

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?

Our project has the possibility to have far reaching implications in important societal and global context. Possibly contributing to the further automation of the world, which could contribute to increasing production of many resources. It’s also possible that socially speaking that this could impact in making further automation be seen as a good thing as it will continue to provide assistance in many of the most dangerous jobs that exist. And environmentally, it could have possible negative effects due to the waste that could be generated by the production of many of the necessary components.