## **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** | Spring 2025 |
| **Advisors** | Phil Walter |
| **Team Number** | 15 |
| **Project Title** | αCassiopeiae |

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| Senior Design Students – Team Composition | | | |
| **Name** | **Major** | **Area(s) of Expertise Utilized in Project** | **Expected Graduation Date** |
| Caleb Shinkle | CompE | CPU Design, Rust Programming | May 2025 |
| Nathan Huang | EE | PCB Design, Manufacturing, Assembly, Mechanical Design | May 2025 |
| Seth Deegan | CompE | CPU Design, Rust Programming | May 2025 |
| Brian Lu | CompE | PCB Design, Rust Programming, Mechanical Design | May 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.

## αCassiopeiae is a condensed and simplified clone of the Altair 8800 computer designed by MITS in 1974. Our design includes all the front panel switches and buttons present on the original Altair 8800, but in a reduced form factor. Additionally, much of the original hardware functionality is emulated using Rust, running on RP2350B microcontrollers. These microcontrollers are housed on custom card circuit boards, connected by a backplane circuit board with DDR4 connectors. With cards containing interfaces like UART, users could add/remove cards to get the functionality they desire.

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

## We made this product so people can experience what it was like to use one of the first microcomputers and understand how they work and how to program them. It is intended for hobbyists and computer/electrical engineering students. They can experiment programming them and developing expansion cards, which would give them experience using early computer hardware to understand the fundamentals of computing.

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 for this project began with identifying the need to create a miniature version of the original Altair 8800. One of the major challenges was mimicking the S100 bus connector within our constrained form factor. After evaluating multiple options, we used engineering judgment to select the DIMM connector standard, commonly found in RAM modules, due to its small size, availability, and similar electrical interfacing capabilities. Component selection was another key phase. We evaluated several microcontrollers and concluded that the RP2350 was the best fit due to its high number of GPIO pins, low cost, and the flexibility of its programmable I/O (PIO). We chose to write the firmware in Rust because of its type safety and strong compile-time guarantees, eliminating any runtime errors. For the front panel, which included a high density of switches, buttons, and LEDs, we paid close attention to layout and signal routing during PCB design. Debugging played a crucial role in software development, and to aid this, we incorporated debug vias and ports into the PCB so we could probe internal signals during development and testing. We used CAD tools to verify mechanical fit, placing our PCB models inside a 3D enclosure model to ensure proper alignment and spacing. In power delivery, we experimentally confirmed the current requirements of our LEDs and verified that our chosen USB-C power source, stepped down via a 5V-to-3.3V buck converter, could supply the needed current. These experiments allowed us to validate our design choices and iterate where needed based on real-world results.

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

## Form Factor Constraint: The product had to be a miniature version of the original Altair 8800, which significantly limited available space for connectors and components. This led to the specification of using a DIMM-style connector to simulate the S100 bus, offering a compact yet electrically capable alternative.

## Power Delivery Constraint: Since the product needed to operate from a USB-C 5V power source, we had to ensure all components could run within this constraint. We specified a 5V to 3.3V buck converter to support the voltage needs of the RP2350 microcontroller and ensure sufficient current to power all LEDs and other peripherals reliably.

## Component Density Constraint: The front panel had to support a high number of switches, LEDs, and buttons within a very limited area. This constraint led to the specification of a dense, manually routed PCB layout with careful attention to signal integrity and accessibility. We also included test points and debug vias to maintain development flexibility despite the limited physical space.

Volume Constraint: We choose a very specific enclosure for our entire design to fit into. This meant that we had to fiddle with the size of our PCBs such that they would fit into a 165 x 50 x 220 mm box, with all four cards, the backplane, and the front panel. This constraint led to the specification of some of the signals on the PCB, since we knew that larger traces would not fit onto the PCBs we prescribed.

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

## **Public Health, Safety, and Welfare:** Electrical safety is about the only potential concern we could have. Our machine is powered via USB-C, which significantly reduces safety concerns compared to traditional wall-powered systems. USB-C provides a low-voltage, current-limited power source, making it inherently safer for users. Internally, all voltages are regulated down to 3.3V, ensuring that even in the unlikely event a user meets exposed circuitry, there is no risk of electrical harm. We also ensured proper insulation and component spacing to avoid short circuits or accidental contact with sensitive areas, further enhancing overall safety. All our other components are large, not prone to disassembly/shattering, and lightweight, so they pose little risk to small children or general users. The aluminum housing could hurt if dropped, however, it has padded feet to ensure it remains sill when placed on a level surface.

## **Global Factors:** The interface for our design is very basic and true to its original form, allowing people from around the world to be able to use our product without necessarily knowing English. When a language is used, English, the global standard language is used. We also use common physical interfaces (SWD, UART, I2C, DIMM) and a very low-level front panel to provide a good development experience with our device.

## **Cultural Factors:** We chose the Altair 8800 to be the microcomputer we were going to replicate because of its historical significance in the computing timeline/culture. It was the first “computer” formfactor that used a microprocessor. It’s what Bill Gates programmed the Altair BASIC software product for which eventually created the computing company Microsoft. Therefore, our design would mainly appeal to hobbyists around the world who are interested in the history of computers.

## **Social Factors:** Nostalgia and accessibility to a low-cost device that mimics the original Altair 8800 allows us to establish a strong connection with our potential customers and fulfill their needs.

## **Environmental Factors:** Environmental factors had very little influence on our design specifications, as many of the environmental factors outlined in our environmental analysis were related to manufacturing processes of our components, something that we have very little control over. It would theoretically be possible to reduce the size even further, reducing our enclosure and PCB sizes, which would also reduce the environmental impact of the manufacturing processes we rely on.

## **Economic Factors:** We wanted our system to be relatively inexpensive to produce, since original Altair 8800 kits can be extremely hard to find and very expensive, costing upwards of $5000. The impact of this was that we had to choose components and design our PCBs with cost in mind to make sure that the final design was affordable.

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

Our project incorporates several key engineering standards related to legal and regulatory compliance. To be sold in the United States, the device will require Federal Communications Commission (FCC) Class B consumer electronics certification due to its high-frequency radio wave emissions. Furthermore, compliance with either IEC/UL 60950-1 or the more encompassing IEC/UL 62368-1 standards from the International Electrotechnical Commission is necessary for retail distribution in the US. For potential sales within the European Union, the device must obtain a CE mark, signifying adherence to European health, safety, and environmental regulations, including the EMC Directive and the RoHS Directive which restricts the use of toxic materials.

1. Describe the final status of your product.

As of right now, we have our power regulation working as intended. We also have our emulator for the Intel 8080 CPU working, it currently has its own memory and can fetch/execute nearly all the 256 instruction opcodes in the 8080-instruction set. We also have a crude version of the read/write transactions over the bus working, although it is not perfect. We also have a RAM emulator that works as intended, although nothing can really communicate over the bus yet. The front panel buttons and switches are all functional, we still haven’t written the code to translate button presses into GPIO output (so it cannot use the bus yet). We are going to keep working over the next couple of days, but this is where we currently stand. We will be soldering into quiet week, just to ensure that all of us have an Altair we can take home at the end of the semester.

After finishing the project and taking second place at the SPARK challenge, we have 3 working computers and are currently working on the last. The 3 PCBs are enclosed in the aluminum enclosure, held by the DIMM slot connectors and the FFC connectors, with working transactions on the bus, coordinated by working RAM and CPU cards. The packaging is sleek, with the miniaturized version looking like the original and to scale, and the design is, for the most part, completely done.

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.

## Brian was the Systems Lead for our project since he had the best idea of how our project was going to come together. His main role was keeping track of all of the components of our project to make sure that everything came together properly. He also oversaw a good majority of the PCB design. Caleb was the Software Lead for our project, he worked on the implementation of the software packages, including CPU and RAM emulation. For the CPU emulator, he implemented the functionality of 254 out of the 256 opcodes in the instruction set we used for our project. Seth was the Team Lead for our project, he outlined the timeline for our project and made sure that tasks were getting done as needed. He also set up a lot of the framework for our software packages and did a lot of debugging regarding getting software running on our final hardware. Nathan was the Hardware Lead for our project, he worked on designing our PCBs as he had a lot of prior experience with PCB design. He also worked on the enclosure/packaging to make sure that our system could be packaged properly and got the final design together.

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.

## Our project needed a user manual so that users will know how to operate the computer, since it is very different from programming on modern machines. The user manual includes details about what the various buttons/switches on the front panel do, as well as the instruction set needed to program on the machine. This manual was designed for users, who are likely computer hobbyists.

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

## For the final oral design review, the panel of reviewers will consist of the instructors and a group of peer reviewers, consisting of members of other teams. The other teams will have worked on projects in a similar fashion to ours, so they will understand most of the grunt effort we put into the project. \*add more here to reflect after final presentation\*

## **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** | Spring 2025 |
| **Advisors** | Phil Walter |
| **Team Number** | 15 |
| **Project Title** | AlphaCassiopeiae |

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| Senior Design Student Completing This Section | | | |
| **Name** | **Major** | **Area(s) of Expertise Utilized in Project** | **Expected Graduation Date** |
| Caleb Shinkle | CompE | CPU Design, Rust Programming | May 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 mostly worked on the software for our project, specifically the Intel 8080 emulator and the RAM emulator. I also set up some communication interfaces between software packages, providing a good starting point for interfacing our software packages together. I did much of the documentation and technical writing on team assignments, making sure that our work was documented with enough detail to be understood by the instructors.

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

## I used much of the knowledge regarding CPU design that I learned in ECE 437 (Computer Design & Prototyping) when writing the CPU emulator. After reading the Intel 8080 documentation, I was able to combine those details with my experience in CPU design to mimic the behavior of the Intel 8080 CPU in software. My vast prior programming experience also came into effect, as I had to rely on my knowledge of data structures/algorithms and good programming technique to write high-quality software for our project.

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?

## In order to work on our project, I had to learn Rust since I had never used Rust before. I have had to learn new programming languages in the past, so I used a very similar strategy when learning Rust, which was just to sit down and program, looking up syntax details as needed. I also used an open-source tool called Rustlings to aid in this process, which provides structured programming problems to guide the learning of all of Rust’s features. I also had to learn about CPU emulation, which borrows a lot of concepts from the CPU hardware design I mentioned earlier. I used several resources to learn about how to write a structured emulator, including a YouTube series about writing a 6502 emulator in C++ and an existing emulator for the Intel 8080 written in Rust.

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

## First and foremost, since I was referencing material written by others when writing my software, I had to ensure that the work I did for the project was my own work in the interest of academic integrity. I made sure to use the references to understand concepts and develop a good structure for my software, but all of the code I wrote was my own, making sure to adhere to academic integrity standards. I also made sure to keep my work as organized as possible, documenting as accurately as I could so that my teammates and the instructors could understand exactly what I was working on. Despite the incentive to log higer numbers of hours working on the project to keep up with my teammates who put a lot of hours into PCB design, I kept myself honest and kept my log of work done as professional and accurate as possible.

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?

## The economic impact of our design is minimal. Our design is geared towards hobbyists, not for widespread sale as revolutionary technology, and it is fairly inexpensive, but I would wtill choose the most affordable parts possible (that are still high-quality) to make sure the machine is affordable. The only environmental impact of our design comes from the manufacturing of PCBs and enclosures, as well as the electricity needed to power our machine (which is not a lot). Very little can be done from our end to reduce this already low impact, but making sure that our PCB designs are as minimal as possible could reduce the environmental impact. Our computer uses a worldwide standardized instruction set, so if we were to provide a user manual in multiple laguages, there would be no real global restrictions in that aspect. We would have to make sure that our product got certifications that are valid in any countries of sale to make sure that we are compliant in all nations. Overall, our product has no societal drawbacks, it just provides a product for hobbyists to enjoy and interact with a clone of an important part in computing history.

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## **(Individual Reflections Section)**

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| Senior Design Student Completing This Section | | | |
| **Name** | **Major** | **Area(s) of Expertise Utilized in Project** | **Expected Graduation Date** |
| Nathan Huang | EE | PCB Design, Manufacturing, Assembly; Mechanical | May 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.

## Many of my contributions were focused on the PCB and getting all four enclosures with the PCBs inserted, as well as the EDA design for all three of the PCBs. I created the backplane PCB, which is a PCB with four DDR4 DIMM slots, an FFC connector, and a buck converter that steps down the voltage from 5 V (from an USB-C power source) to a 3.3 V source. The PCB was designed in KiCad, and I made steps to ensure that the schematic passed the ERC as well as the DRC checks, which took a long time to validate. I also created the front panel schematic and layout, which took a long time because we messed up by converting our schematics to KiCad 9.0.0, which was not backwards compatible with KiCad 8.0.0. I had to make the front panel schematic, with the 36 LEDs, RP2350 microcontroller, 16 switches, and 13 buttons. I had to make this schematic twice, and ensure that it passed all specifications, which took many nights. I also had to create a working layout within the design constraints of our enclosure, so I had to set a lot of constraints for the PCB and change them when it didn’t work. My first attempt was around twice as large as necessary, which I had to redo.

## Other than the EDA design, I had to solder a lot of components onto our manufactured PCBs. I had to create four backplane PCBs complete with parts, which involved soldering with a hot plate and then soldering each of the 288 pins, pin by pin, until we could verify that it was correct. I had to solder all the LEDs on the front panels, and then all the connectors onto the cards. I had a lot of experience soldering and desoldering, as well as experimenting with different soldering techniques.

## I also had to create the final assembly that we would be showcasing at the Design Expo and the Spark Challenge. I sprayed painted the enclosures light blue, making it appear like the original Altair, and got all the bezels milled such that the front panel components were visible through the front bezel. Then I printed out a sticker of the original silkscreen and pasted that one in front of the completed design.

## 

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

Some of the past knowledge that was able to help me when I was building this project would be my work in ECE 362 working with the microcontroller datasheets, as well as with debugging. Another experience which I would consider extremely helpful would be my experience as an ECE 270 TA. In ECE 270, I had to debug a lot of circuits, well over 100, so this knowledge allowed me to avoid a lot of pitfalls when creating a circuit on a breadboard, so the hardware prototyping portion of this course was a lot less difficult than it could have been. With the knowledge gained from being an undergraduate teaching assistant for four semesters, I was able to create all three breadboard prototypes for the front panel, the back plane, and the card, with a working buck converter created from the switching regulator chip as well as a LMC555 based buck converter.

The knowledge I gained from ECE 20008 helped me create this buck converter, because buck, boost and buck-boost converters were part of our labs for the semester. Additionally, the introductory soldering skills that were introduced in ECE 20008 gave me a strong foundation to hone my skills, which I did when creating all four back planes. The last personal experience which I believe improved my experience while creating our project would be my role as head of electronics in the Autonomous Robotics Club (ARC), where I did a lot of PCB design in KiCad. By creating a lot of KiCad designs for testing the hands which we were trying to get working, I learned the entirety of the KiCad suite and what it was capable of.

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 had to learn a lot more about KiCad than I had originally thought. I realized I needed to establish the keep-out regions of our board, as well as how to set custom track widths and set the constraints such that a PCB was ready for manufacturing. I also learned how to deprecate from KiCad 9.0.0 to 8.0.0, through a process of trial and error. I applied this knowledge because I had to meet impending deadlines for our project.

I used many learning strategies to acquire the concepts I detailed above. One of the major ones I utilized for this project was case studies, as there were plenty of examples online which adhered to the application I was trying to create at a given time. I also used experimental learning a lot, as a lot of the project was trial and error to get it all done.

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

The ethical and professional responsibilities I learned and now must apply forward include the safe manufacturing of devices, specifically electronics, such that they can be safely disposed of and do not fail when still in use. I explored these realms when working on A10, the safety regulations assignment. This content was very useful to me because I could see when exactly a product was planned to fail. This was useful to create the design of all the PCBs because I was able to space out the components with the highest failure rates, especially the buck converter and the RP2350b microcontroller chips, which were spaced to opposite sides of the backplane and card boards.

I also learned that I have a professional obligation to make sure that all licenses, regulations, and policies by regulatory agencies are adhered to when creating any software or hardware.

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?

In summary, our project does not have the largest environmental impact. To make an informed judgment about the impact and scale of our project, I measured its effects in each of the four categories. The largest cause of concern would be the gold-plated DIMM slot connectors that we are using in each of the card slots. I considered the potential ecological cost of gold mining to do this, weighing the ecological and environmental impact of gold mining, determining that it resulted in an overall small environmental impact. Next, I assessed the culture impacts of our project, using the community of old computer collectors online, through Facebook and other groups as a reference. For these collectors and enthusiasts, it would likely help them, as it would allow them to relive the early days of personal computing and connect with a pioneering moment in technology, interfacing with the first microcomputer 50 years ago. To consider the economic impacts, I looked at other Altair’s being sold online. The price tags for these emulators were at the high end, costing upwards of $7000 dollars. I confidently think that our miniaturized version could accomplish a shift in this space, because we were able to make four computers for only around $500. If other collectors could make our product for a similar cost, I think the impact would be positive. Globally, I assessed this product by linking it to its global impact, as this product stands alone as a testament to the Altair 8800, which is especially pivotal as we are hitting its 50th anniversary. Culturally, it represents a major shift to the creation of the personal computer, sparking the creation of Apple and Microsoft.

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## **(Individual Reflections Section)**

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| **Advisors** | Phil Walter |
| **Team Number** | 15 |
| **Project Title** | αCassiopeiae |

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| Senior Design Student Completing This Section | | | |
| **Name** | **Major** | **Area(s) of Expertise Utilized in Project** | **Expected Graduation Date** |
| Seth Deegan | CompE | CPU Design, Rust Programming | May 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 learned how PIO (the programmable I/O interface) worked on our microcontroller using the PIO manual and online videos, and implemented bus read and write operations Rust code using it. I did the first PCB layout of our backplane PCB using KiCAD which connected the cards together. I got our microcontroller to be able to be programmed with Rust and researched and tested Rust HALs to program the micro with. I did the prototype breadboarding of our dev board, connecting our two microcontrollers dev boards to our front panel physical interface of buttons, LEDs, and switches. I learned how to debug our microcontroller using probe-rs, OpenOCD, and the ARM toolchain. I created team documentation for how our bus is laid out and the order of internal transactions that occur for our machine to operate properly using Notion and Excel. I wrote Rust code for handling the front panel PCB operation. I learned how the 8080 microprocessor works, its instruction set, and laid out an outline of how we would code an emulator for it using various 8080 manuals. I created a timeline for our team’s progress so we could have good project management using Notion. I arranged daily times which we would all meet outside of assigned lab time to work on the project throughout the semester using scheduling software.

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

## CPU/ASIC design was a critical part as it helped me understand how CPUs are structured, how instruction sets work, and how buses work. Additionally, operating systems helped me understand how our program is loaded onto the microcontroller and how the 8080 CPU was able to execute operating systems and utilize a bootloader. Finally, personal knowledge and knowledge from systems programming courses like C allowed me to better understand how the Rust programming language works as I had never coded in it before. 362 (Microprocessors) helped me immensely in knowing how to work with our microcontroller, however, I needed to review many things such as how register layout, interrupts, and GIPOs work.

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 acquired new knowledge by reading through the manuals of the original Altair 8800, and the Intel 8080 processor. I also watched videos on how to operate the Altair 8800, how the Programmable IO feature of our RP2350 microcontroller works, and how our microcontroller bootloader works. I also used ChatGPT to help me understand all aspects of our project such as how bus transactions work, how to program in Rust, and understand communication protocols. I browsed GitHub repositories such as the rp-80 one to understand how an 8080 emulator is implemented; how the Rust-based HALs for the RP2350 microprocessor compared, worked, and their examples; and how the various debuggers available for our microcontroller worked. I also reviewed the documentation for the Rust libraries we were using to see what objects and their methods were available. Finally, I consulted with my teammates about various knowledge they had regarding our project such as how our microcontroller works and what our bus design was going to look like. I reviewed the basics of the Rust programming language such as structs, slices, and mutability using the Rust book.

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

## I am expected to follow ethical responsibilities of maintaining that my engineering project experience and the product I develop is done in a safe, ethical, and professional way. I also am expected to maintain honesty in reporting to my teammates and project instructors what I had done and what I was struggling with. This was done in my engineering experience through weekly meetings and journal entries. I am also bound to follow the regulations of the jurisdiction I'm developing the product in and the regulations I am selling my product in. The jurisdiction I am developing the product in would be my school’s lab environment which I need to follow the rules of the lab. We maintained a clean lab environment and used proper safety equipment when soldering and probing throughout our engineering work. We are simulating selling our product in global markets, so getting safety and environmental certification from UL, FCC, CE, etc. is a necessary professional responsibility. A regulatory assignment was completed during the experience to fulfill this goal. Making sure our product informs our customers correctly is also an ethical responsibility to ensure they can use it correctly and in a safe manner. A manual/documentation is a way to accomplish this and was completed during our design experience.

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 product will not have a large economic impact. It is just meant to be a hobbyist product produced at low volumes for a niche market. For this reason, it won’t have much environmental impact other than the manufacturing and eventual disposal of the product which could be environmentally intensive due to the difficulty of disposing of electronics. The societal impact would be small, but meaningful. Our product would likely be the best Altair 8800 replica on the market for the lowest cost. Hobbyists or students could be reinvigorated to learn about the early computing days and the experience of working at a low level of hardware by using our product. This would inspire future students to learn computer engineering knowledge in a hands-on manner. On a global level, our product would be accessible if we were to sell it online and its existence could further computer engineering knowledge at a global level as well.

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## **(Individual Reflections Section)**

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| Senior Design Student Completing This Section | | | |
| **Name** | **Major** | **Area(s) of Expertise Utilized in Project** | **Expected Graduation Date** |
| Brian Lu | CompE | PCB Design, Embedded Rust Programming, Mechanical Design | May 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 created the original proposal for a multi-board design replication of the Altair 8800, which involved the functional definition of the design of 3 unique PCB designs (the front panel, power and signal backplane, and a common card module of which multiple are used). I based the design of the interface to be relatively unconventional compared to standard digital design projects, by defining the interface between microcontrollers as being a wide parallel bus, synchronized by a clock signal and control lines, in the same style as that of the Altair 8800. I made the choice to build the project around several of the new Raspberry Pi RP2350B microcontroller because of its large GPIO pin count and very powerful acceleration of GPIO functionality (provided by its PIO programmable I/O peripherals, and its GPIO co-processor). Additionally, I integrated the PCB design architecture to work mechanically with an extruded aluminum enclosure, which reduced development time on an enclosure and had a similar aesthetic to the original Altair 8800  
     
   I assembled the prototype wire harnesses and the bus and debug probe section of the breadboard-based prototype test bed for the device. I performed the power, flash, oscillator, and signal layout for the microcontroller PCB design, which has commonality between the card and panel designs. I also performed the final layout and PCB routing for the card and front panel designs. The card design was relatively simple, amounting to a break-out of microcontroller signals to a DDR4 edge connector to allow for cards to interface with the parallel bus via the backplane, but the front panel routing required connecting signals from the flex connector to both LED drivers, as well as the front panel controller, while making room for LEDs, buttons, switches, and I/O expansion chips. I worked on the assembly of components onto the PCB using a combination of hot plates, manual soldering, and cut-and-splice rework techniques (to alleviate PCB design errors).  
     
   Our software stack is written in the Rust programming language, using the SDK provided by the Embassy Rust project. Due to the relative novelty of the RP2350 line of microcontrollers, the Rust toolchain did not have full support for programming and debugging the device. I brought up an alternative toolchain based on the Arm reference GDB and Raspberry Pi reference OpenOCD distributions to allow Rust programs to be loaded and debugged without using the Rust-native programmers/debuggers. Additionally, I assisted with the programming of the software system for bus transaction control logic.
2. Describe how your contributions to this project built on the knowledge and skills you acquired in earlier course work.

## This project built off significantly on the skills I had learned in the microprocessor systems and interfacing course at the University. In particular, the course’s emphasis on breadboard prototyping, understanding how to read datasheets of microcontrollers, their various subsystems (peripherals, interrupts, clocks, etc.), and the peculiarities of embedded programming environments, helped significantly in allowing me to continue working on this project with greater confidence and speed. In addition, the ASIC design course helped introduce me to the semantics of bus control, and experience with AMBA buses helped with the design and programming of the bespoke 8800-like bus design.

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?

## Because RP2350B is a new chip, none of us had worked with it before, but learning the ins and outs of the chip required a close reading of all of the documentation that Raspberry Pi published about the device, including datasheets, hardware design guides, software quick-starts, SDK reference guides, register maps etc. Because of the novelty of both the chip and the toolchain surrounding it, being diligent in understanding every facet of the chip we were working with because very important. Additionally, our usage of a newly minted Rust SDK implementation also meant that a significant amount of the surface area of the SDK was untested. Whenever something went wrong, in order to find the root cause, it was important to consider all possible options: hardware issues, software issues, SDK issues, and even issues with the tooling surrounding the SDK, all of which need to be methodically found and fixed, to avoid spinning around in circles.

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

## Throughout the project, I adhered to ethical and professional standards by prioritizing transparency, safety, and responsibility, guided by principles outlined in the IEEE Code of Ethics. Specifically, I emphasized honesty and integrity by openly communicating design flaws and errors to the team and stakeholders, promptly addressing these through thorough debugging and meticulous rework techniques. I upheld the welfare and safety of the end-users by ensuring rigorous testing and validation of the electrical and software systems to prevent potential hazards. Professionally, I fostered a collaborative environment, valuing peer input, respecting intellectual property through appropriate attribution of external documentation and tools (such as the Raspberry Pi documentation and Embassy Rust SDK), and committed to continual learning and improvement in my technical competencies.

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, the project has potential niche market appeal among enthusiasts of vintage computing, which could stimulate specialized manufacturing or kit distribution. Environmentally, careful material selection and modular PCB design aimed to minimize electronic waste by facilitating easier repairs and upgrades. Societally, the project can enhance interest in historical computing technologies and foster educational opportunities in embedded systems, retro computing, and digital design. Globally, though its direct impact may be limited, sharing comprehensive documentation and open-source designs could encourage international collaboration and knowledge exchange in engineering communities. My judgments on these impacts were informed by comparing our design practices against sustainable electronics guidelines, market analysis of similar hobbyist projects, and evaluating the educational and community-building potentials.