UCF Senior Design 1

Title: U.P.R.I.G.H.T.
User Position Recognition Integrated Guiding Height Table

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Initial Project Document and Group Identification
Divide and Conquer

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Chapter 1 - Executive Summary

[Coming Soon]

Chapter 2 - Project Description

This chapter will explain the overall goals and motivation for this project as well as the features planned. This chapter will be split into eight sections in total.

2.1 Background and Motivation

A study on musculoskeletal issues among office workers concluded that lower back pain is a common health problem among office workers with at least one-year experience, with an incidence rate ranging from 23% to 38% [1]. It is also the most common cause of work-related disability in people under the age of 45 [2]. This is a major concern that affects many individuals because, according to the United States Bureau Labor Statistics Occupational Requirements Survey, the average civilian worker dedicated 40.6 percent of their workday to sedentary activities. This number is even higher for certain occupations. For instance, computer programmers sat for 95.7 percent of the workday [3]. This paradigm underscores the pivotal role that the workstation plays in influencing our well-being, productivity, and overall job satisfaction.

In recognizing this connection between the nature of work and the physical environment, our senior design project seeks to address the challenges posed by static workspaces. The conventional desk, while serving as a staple in work and educational settings, may not fully align with the diverse needs of the modern workforce. The motivation to create a smarter, more adaptable workspace becomes evident in regard to the statistics on workplace musculoskeletal issues.

The conventional dichotomy of sitting and standing does not capture the nuanced requirements of today's work demands. The statistics provided by the Bureau of Labor Statistics highlight the need for a workspace that seamlessly transitions between various postures, promoting health, engagement, and performance. To address these issues, we propose a smart desk that will actively assist workers in maintaining an ergonomic work environment.

To address the ergonomic issues that plague the modern workforce, our design needs to go beyond a simple sit/stand desk. On the one hand, any effort the user needs to put into changing their desk orientation will discourage them from using the feature. Additionally, suddenly changing work styles can have adverse effects on the user [4]. To alleviate this, our design will implement smart tracking and reminders to encourage the user to switch between sitting and standing positions and thus avoid overcompensation. This smart tracking will keep track of the sitting to standing ratio and slowly increase the amount of standing so that the user is not adversely affected by the sudden increase of standing.

As we embark on the journey of designing a smart desk, our goal is to redefine the workspace paradigm by integrating intelligence, adaptability, and user-centric features. By leveraging insights into occupational dynamics, our smart desk aims to revolutionize the way individuals interact with their work environment, enhancing not only productivity but also fostering a holistic approach to well-being. The statistics serve as a compelling foundation, urging us to explore innovative solutions that go beyond the traditional confines of desk design and cater to the evolving needs of the modern workforce.

2.2 Features and Functionality

In the ever-evolving landscape of today's work environment, the combination of ergonomic design with cutting-edge technology plays a pivotal role in crafting spaces that enhance productivity while also supporting physical health. Our state-of-the-art electric smart standing desk stands as a testament to this combination, marking a major advancement in the realm of office furniture design. More than just a workstation, it embodies a holistic solution, catering to the complex requirements of modern professionals. Merging automated functionality with personalized user settings, this desk is designed to redefine ergonomic standards in the workplace by offering a transformative approach to how professionals interact with their workspaces.

The desk's defining characteristic is its automated height adjustment. This innovative functionality allows seamless transitioning between sitting and standing positions, eliminating the need for manual adjustment. At the core of this feature is a sophisticated detection system, which includes a camera and a weight-sensitive mat. These components work in unison to accurately discern the user's presence and their intent to either sit or stand. When the user stands, the desk recognizes this action and, after a brief, user-configurable delay (defaulted to 2 seconds), adjusts to a predetermined standing height. Conversely, when the user opts to sit, the desk responds by lowering to the saved sitting height, again after a short delay. For added safety measures we would include a collision detection system. This automated system is designed to prevent unintended desk movements, thus ensuring a seamless user experience.

User profile customization, facilitated through Bluetooth connectivity, adds another layer of personalization to the desk. Users can create and save individual profiles using a desktop/mobile application that communicates with the desk. The initial interaction with the desk involves a user-friendly calibration process. Here, users set their preferred sitting and standing heights. Once these preferences are saved, the desk automatically adjusts to these settings upon subsequent connections. The application is not just a tool for height adjustment; it also offers customized sit-stand reminders. These reminders are adaptable, with settings that cater to each user’s previous standing habits and ergonomic needs. Moreover, the application tracks and logs the duration of sitting and standing periods, offering valuable insights into the user’s ergonomic practices.

The desk's design incorporates a digital display, neatly mounted to the right underside of the desk which helpfully shows key information like the current desk height, the profile of the user currently utilizing the desk, and Bluetooth connectivity status. Adjacent to this display are manual controls. These controls offer users the ability to manually adjust the desk’s height, pair with Bluetooth devices, and toggle the automatic desk adjustment. Such manual options are vital for users who occasionally prefer traditional operation or need to override automatic adjustments for specific tasks.

As workplaces continue to evolve, the need for furniture that adapts to the changing demands of professionals becomes increasingly evident. Our electric standing desk is a response to this need. It represents a harmonious blend of technology and ergonomics, designed to foster a healthier, more dynamic work environment. This desk is more than just a piece of furniture; it is a tool for enhancing productivity and well-being in the workplace. With its innovative features and user-centered design, it is set to redefine the standards of office ergonomics, providing a tangible solution to the challenges of modern office life.

2.3 Goals and Objectives

The objective of our senior design project is to create a standing desk that will be able to adjust its height dynamically depending on whether the user is detected to be standing up or sitting down. The overarching goals of the project are listed below:

Goals and Objectives of the Overall Project

- Develop a reliable system capable of discerning whether the user is standing or seated utilizing an integrated camera for head tracking against a pre-calibrated reference and a weight-sensitive mat for accurate weight assessment.
    - A brief delay will precede any automatic height adjustment to minimize unintended activations of the desk's automatic feature. This delay is preset to three seconds but can be customized by the user via the accompanying app.
- Develop a mobile and desktop application for communicating with the desk via Bluetooth.
- Construct a desk from the ground up, incorporating linear actuators to facilitate its movement.

Objectives for the Mat

- Develop a sensing mat placed beneath the user's chair and feet, designed to accurately measure the user's weight against a calibrated reference.
    - By employing load cells, the mat distinguishes between two distinct scenarios: a lighter weight indicating the user is seated (as the chair's presence reduces the weight applied directly on the mat) and a heavier weight suggesting the user is standing directly on the mat. The load cells will be incorporated under the mat and attached to a custom-built frame. This arrangement facilitates precise weight measurement by evenly distributing the load.
    - A calibration phase will set a baseline for the user's standing weight during the initial set up in the app. Changes from this baseline will inform the system of the user's current position.
    - The dimensions of the mat will be 4x4 feet ensuring it can comfortably accommodate a chair while the user is seated. This size was chosen to

balance the need for space with functional design requirements. In selecting the mat, particular attention was paid to its thickness and firmness; it must be robust enough to support everyday office chair use without hindering functionality, yet sufficiently thick—a desired ½ inch—to house the load cells necessary for accurate weight measurement. This consideration ensures the mat remains unobtrusive in an office setting while fulfilling its critical role in our system.

Goals and Objectives for the Camera

- Develop a camera system within the desk, positioned underneath where the monitor is typically located, to provide an optimal vantage point for head tracking.
  - During the initial setup/calibration, users will define reference points for their head in both sitting and standing positions.
  - To conserve power and extend the camera's lifespan, a feature will be considered that requires a specific action (raising a flag) to activate the camera. This ensures the camera is only operational when necessary, reducing energy consumption.
  - The camera system will employ head tracking, outlined by a predetermined border based on the user's calibration, to ascertain changes in the user's position. If the user's face dips above or below a certain threshold relative to the reference line, the system interprets this as the user sitting down or standing up.

If the parameters for a change in position are met for both the mat and the camera, the desk will then change its position to the height set by the user during the initial calibration.

Additional Goals and Objectives

- Integrate an LCD screen to display information to the user. The screen will be positioned at the edge of the desk, specifically under the bottom right side, and angled upward for optimal visibility to the user.
  - Screen will display critical information, including the desk's current height, the user's posture (sitting or standing), the profile currently in use, and the status of the Bluetooth connection to the app.
- Incorporate a row of buttons in an enclosure positioned adjacent to the LCD screen for easy access.
  - There will be 4 distinct buttons, each assigned a specific function: manually raising or lowering the desk height, toggling the desk's automatic adjustment feature on or off, and initiating pairing with a Bluetooth-enabled device.
- Include collision avoidance system to enhance safety measures.
  - Hoping to include a pre-existing "plug and play" solution for collision detection used in current electric standing desks on the market. Further research is needed.

Mobile/Desktop application Objectives

- Develop applications for both mobile and desktop platforms to enable Bluetooth connectivity with the desk. These applications will enhance user interaction by providing a suit of customizable features and settings.
    - Users can save their profile settings, including preferences for sitting and standing positions.
    - Allows transmission of information to the desk's LCD screen, facilitating real-time updates and notifications.
    - Features an intuitive graphical user interface, which simplifies the calibration process, making it accessible for users to accurately set up their desk preferences.
    - Includes customizable reminders prompting users to alternate between sitting and standing. Users can adjust the frequency and duration of these reminders, tailoring them to fit personal health goals and daily routines.
    - Monitors and tracks the duration of time users spend in seated and standing positions. Will enable users to access and review their usage statistics, offering insights into both current and historical patterns.
    - Feature predefined settings categorized into beginner, intermediate, and advanced levels, tailored to guide users in gradually adapting to standing while working.

Stretch Goals for Desk Operation

- A directional pad, integrated into the mat, offers users an innovative method to engage in physical activity while standing. This feature, coupled with app integration, leverages the mat's sensors to guide users through various activities. Inspired by exercises recommended for seated airplane passengers to enhance lccirculation, this functionality encourages movements that promote health and energy. To implement this, force sensing resistors will be placed within the mat to accurately track the user's foot positions, enabling precise activity tracking and feedback. **(Credit to Dr. Zakhia Abichar)**
- An optional automatic monitor arm accessory can be added to the desk, leveraging the object detection technology utilized for head position tracking. This monitor arm is designed to pan and tilt, adjusting in real-time to maintain the user's optimal viewing angle of their computer screen. This feature ensures ergonomic viewing positions are maintained, enhancing user comfort and reducing strain during both standing and seated sessions.

2.4 Existing product

In the evolving market of ergonomic office solutions, our team initially conceived the idea of a Bluetooth-connected standing desk, believing it to be a novel concept. However, upon further research, we discovered the existence of similar products such as the UPLIFT Desk App combined with the separately sold UPLIFT Bluetooth Adapter [5] and the Autonomous SmartDesk Connect [6]. These products offer functionalities akin to our envisioned design, including movement reminders, daily standing goals, progress tracking, app-controlled height adjustment, and customizable memory settings for desk heights. The Autonomous SmartDesk Connect goes a step further by recommending various standing exercises like lunges and squats, enhancing the user's physical engagement.

Despite these similarities, our product distinguishes itself in several key areas. One of the most notable features setting our desk apart is the automatic transition between standing and sitting positions. This transition is seamless and intuitive, occurring automatically as the user stands or sits, without the need for manual interaction with a smartphone app. This feature is a significant advancement over the existing products, which require manual adjustments through an app for changing desk settings.

Moreover, our standing desk employs a sophisticated system comprising a built-in camera and a weight-sensing mat to accurately track actual usage times. This system is more precise in determining whether the user is actively standing or sitting at the desk, as opposed to the basic session tracking offered by other products, which may not accurately reflect real-time usage.

In addition, as a stretch goal, we aim to integrate sensors into the mat. These sensors would guide users through simple, low-profile exercises designed to promote blood circulation, such as calf raises, foot pumps, and knee lifts. This feature is particularly suited for office environments where more conspicuous activities like pushups or squats might be less appropriate. Our focus is on subtlety and discretion, ensuring that users can maintain a professional demeanor while still benefiting from physical activity.

Our standing desk is specifically tailored for office settings, balancing ergonomic benefits with the practicalities and decorum of a professional workplace. By combining advanced technology with user-friendly features, our product not only aligns with the current market trends but also introduces unique elements that enhance the overall experience of the user in an office environment.

2.5 Requirements and Specifications

The table below illustrates key engineering specifications with quantitative measures for parts that will be used to construct the desk. In addition to the desired values, certain specifications have been highlighted in yellow to denote demonstrable specifications that will be demoed in a prototype at the end of the semester for Senior Design I.

Table 1 – Design Specifications

System(s)	Parameter	Specification
Vertical Adjustability System	Controllable Up/Down Action for Legs on the Desk	Travel Speed of 25mm/sec
Weight Sensing Functionality	Used to Detect Whether User is Standing Up or Sitting Down	Able to Detect/Withstand Within 10% Accuracy Between 500 – 1,000 Newtons (Approximately 110 – 220 Pounds)

Face Tracking	Used for Tracking of the User's Face to Determine if the User is Sitting or Standing	Accuracy of Tracking Between 80 – 90%
Motor Speed Variation	Allows to Adjust the Speed of Up/Down Action of Legs of the Desk	Adjust Speed from 22.5 mm/sec to 27.5 mm/sec
System Controller	Will Control the Different Points of Operation Excluding the Camera	32 KB Flash Memory 4x Analog/GPIO Pins 10x Digital/GPIO Pins 6 PWM Pins

Table 2 - Detailed Design Specifications

System(s)	Parameter	Specification
Vertical Adjustability System	Controllable Up/Down Action for Legs on the Desk	Travel Speed of 25mm/sec Maximum Load of 120 pounds (600N) Input Voltage of 12 VDC 18-inch stroke length
Motor Connection	Allows to Reverse Direction for Up/Down Action of Desk	Input Voltage of 5V 4 Channel
Secondary System Controller	Enables for communication between the system and camera Will be used for object detection to determine user's position	Baud Rate of 9600 2x USB 2.0 SDRAM 2GB
System Controller	Will control the different points of operation excluding the camera Linear actuator/motor controller, LCD, load cell, push buttons, and Raspberry Pi communication	32 KB flash memory 1x UART 1x I2C 1x SPI 4x Analog/GPIO pins 10x Digital/GPIO pins 6 PWM pins
Motor Speed Variation	Allows to Adjust the Speed of Up/Down Action of Legs of the Desk	Adjust Speed by a factor of 10% from the Base Speed From 22.5 mm/sec to 27.5 mm/sec
Weight Sensing Functionality	Used to Detect Whether User is Standing Up or Sitting Down	Able to Detect/Withstand within 10% accuracy between 500 – 1,000 Newtons (approximately 110 – 220 pounds)
Graphical Interface to User	Implemented to Provide User Interface	Able to Display Between 5 – 10 frames per second Resolution of 854x480 pixels
System for OTA Communication	Allows for Remote Communication with Wireless Enabled Devices	Up to 3 Mbps in Enhanced Data Rate Mode Up to 1 Mbps in Low Energy Mode
Peripheral for Face Tracking	Will be used for Object Detection in Conjunction With Pressure Sensing Resistors to Determine Whether User is Standing or Sitting Down	Resolution of 1920x1080 pixels Capable of Displaying 30 frames per second 180 degree viewing angle

Face Tracking	Used for tracking of the user's face to determine if the user is sitting or standing	Accuracy of tracking between 80-90%
User Standing Platform	Sensors Will be Incorporated Inside the Mat	½ inch thickness 4-foot x 4-foot

2.6 Hardware Block Diagram

The hardware block diagram can be seen in Figure 1 below. It details the overall design implementing various features discussed in Section 1.2. A responsibility matrix is also provided that notes the obligation of each team member using color coordination with the individual blocks. Power will be supplied through any generic wall duplex outlet and converted down to 12V DC using a 10A power supply AC to DC power adapter. The 10A power supply is necessary to accommodate at least two linear actuators powerful enough to meet load requirements (Insert requirements). Voltage regulators will be installed to drop voltage to the correct input for the microcontroller unit or any other components.

The central processing needed for the PCB will be handled by the microcontroller unit (MCU), however, further research is still underway to determine the specific MCU to be utilized. Web cameras and load cells within the designed mat will send data to the MCU to determine whether the user is sitting or standing and when they make a transition to the other position. A Bluetooth module will be incorporated to send/receive data from the MCU to a user connected device utilizing a customizable app. The MCU will use the data collected to determine the desired position of the desk and implement that location using a motor control module and the linear actuators. While the desk is moving, infrared sensors (IR sensors) are a possible solution to track any obstacles impeding movement to avoid collisions. Further research is necessary to implement the optimal system for collision avoidance. The relative position of the desk and the duration at the position will be tracked and shown with a built-in LCD display. Override buttons will be installed conveniently next to the LCD to enable manual control for the user and shut off automation.

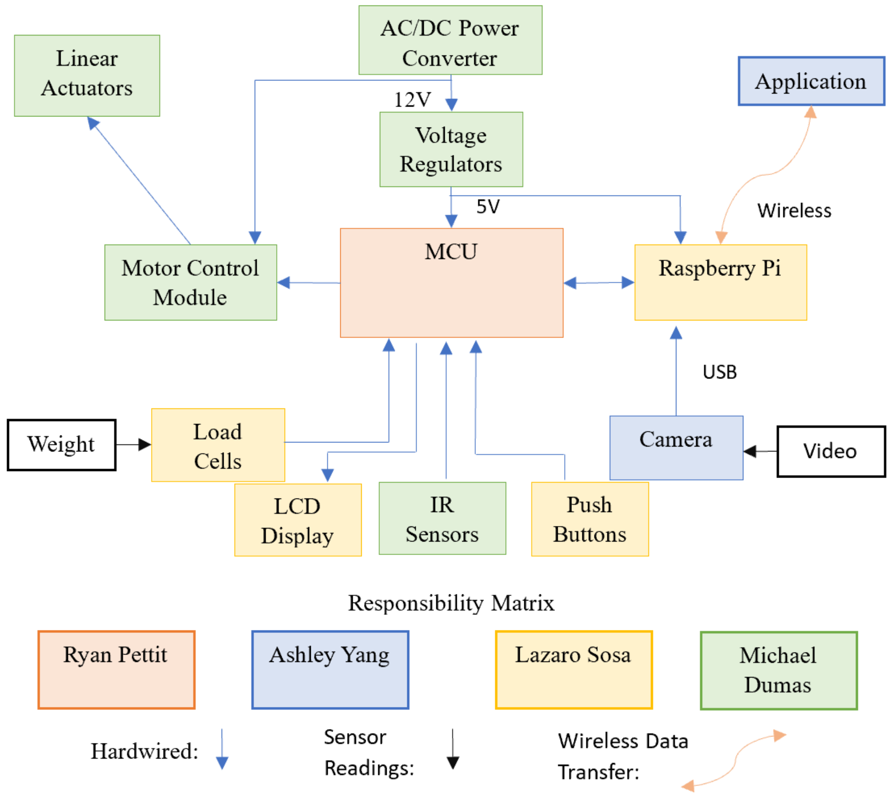

Figure 1- Hardware Block Diagram

2.7 Software Block Diagram

The diagram below details the software decision tree that will be implemented by the system. Flutter will be used to create the application for windows and android devices. The application will be used to save the user preferences and will provide instructions for the user during first time setup. This application will also be used for sending reminders to the user to either sit or stand-up. If the user is a returning user, it will send the saved profile settings to the embedded system through Bluetooth. Once it is determined that the user is at the desk, active tracking will be activated depending on the user's saved preferences. Then, if the user position changes, the desk will go through two checks before toggling between sitting and standing mode.

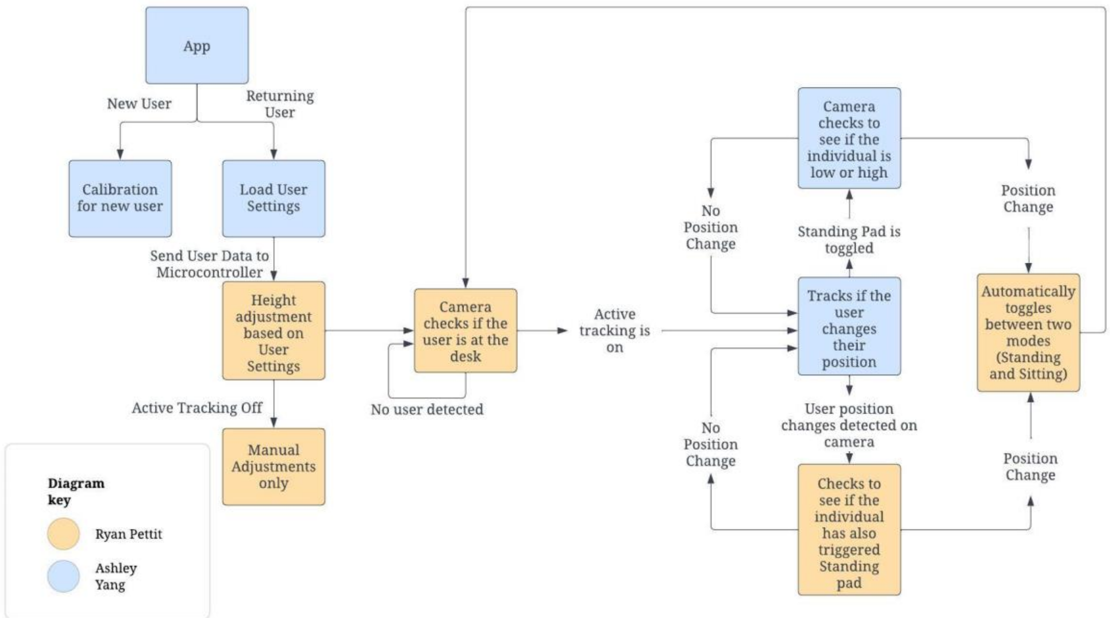

Figure 2 - Software Block Diagram

2.8 House of Quality

The chart below shows the House of Quality diagram for our project for Senior Design. On the right side are the customer specifications. These are the aspects of the desk that a user would value when deciding whether to buy the product. On the top row are the engineering specifications. These are the relevant values and measurements required to get the desk to function. By plotting the desk characteristics in this way, it allows us to evaluate the relationships between the different components. For example, if we wanted to know what effect the build quality of the desk would have on the cost of the product, we could consult the House of Quality diagram to determine that they have an inverse relationship. This means that as the build quality of the desk goes up, the cost of the product goes up even though we desire to minimize the final price.

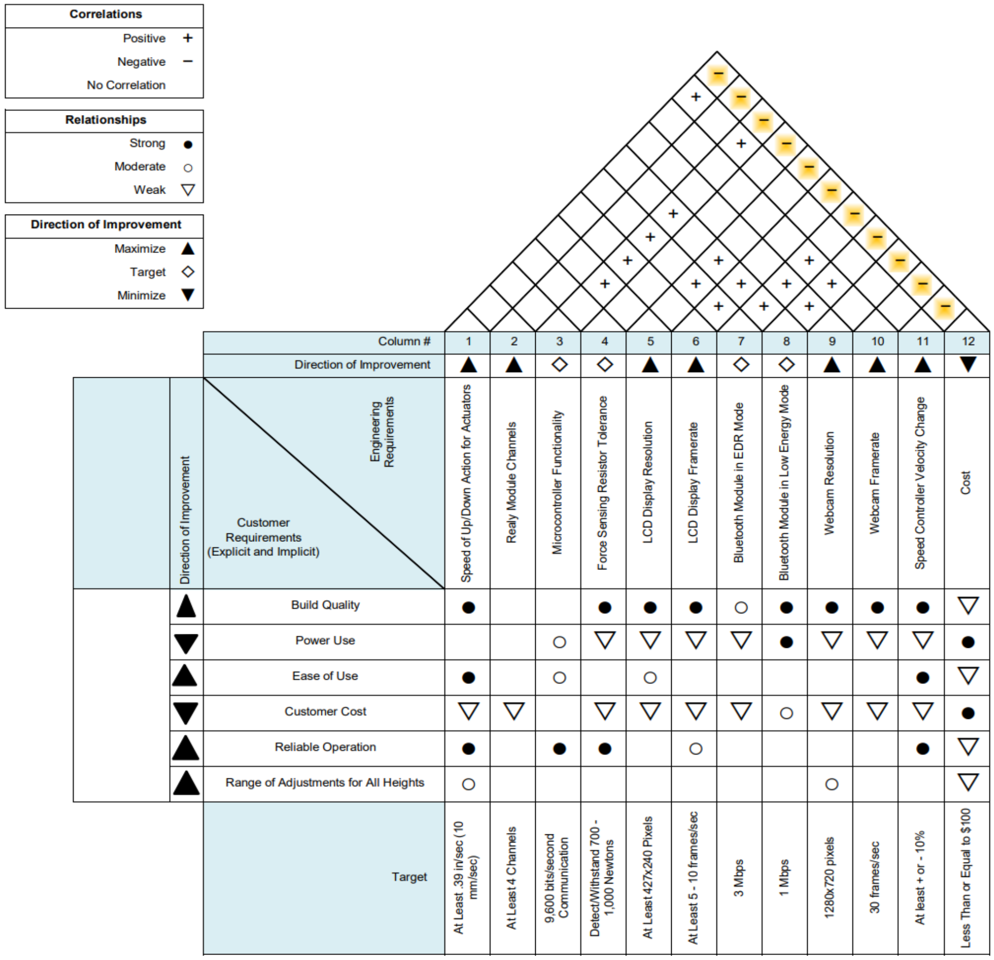

Figure 3 - House of Quality Diagram

Chapter 3 - Research and Investigation

This chapter is split up into two sections. The first section of this chapter is concerned with comparisons between the various technologies utilized in the project and the selection process that was employed to find the most cost-effective parts that would also be able the meet the defined specifications in Chapter 2. This includes a summarization of each comparison using a table and explaining the selection, using one table for each individual comparison of both the software and hardware technologies present in our project.

The second section of Chapter 3 is concerned with the part comparison and selection for the project. Inside this section, summarization of each comparison using a table and explanation of our decisions can be found. In addition to this, Section 2 will include an individual table for each hardware and software part, providing at least three options that were considered for each selection.

Within each section, headers have been included to divide each part and technology into its own subcategory. This has been done to enable easy navigation to find specific parts and technologies used.

3.1 Technology Comparison and Selection

This section is concerned with the technology comparison and selection part of research for our project. Specifically, this section will have more of a focus on how the functionalities of our project require certain technologies in order to meet the goals and objectives present in Chapter 2 of this design document.

This section is distinct from Section 2 in that it will not focus on the specific parts used to meet our design requirements. Instead, it will go into explanations on why certain technologies were used over others. For example, as mentioned in Chapter 2, the desk will require a way to measure pressure so that it can determine whether the user is sitting or standing. In this example, Section 1 would be concerned with the different pressure sensing technologies, while Section 2 would focus on the different parts available once a selection between the various technologies available in made.

3.1.1 Pressure Sensing Technology

This section will be focused on finding the best solutions to sense the pressure of the user that will be sitting or standing on the mat. The pressure sensing technology must be capable of detecting the weight of the user accurately, with a maximum percent error of 10 percent. Anything more than this will impede the operation of the desk and result in the desk changing position even though the user has not actually changed from sitting to standing or vice versa.

These are the technologies available to us that will enable us to sense the weight of the person while they are either sitting or standing on the mat:

- Resistive Pressure Sensors (Force-Sensitive Resistors – FSRs)
- Capacitive Pressure Sensors
- Piezoelectric Sensors
- Load Cells

The first technology discussed will be the resistive pressure sensors. These are a type of sensor that changes their resistance in response to an applied force or pressure. They are constructed from a material whose resistance decreases as pressure is applied to its surface. This characteristic allows them to convert the force exerted on them into an electrical signal, which can be measured and interpreted by the system for our project.

FSRs typically consist of a conductive polymer, which changes resistance under pressure, sandwiched between two conductive electrodes. When pressure is applied to the sensor, the conductive particles within the polymer are forced closer together, reducing the resistance across the sensor. The change in resistance is measured by an electrical circuit, often a simple voltage divider, and converted into a digital signal that indicates the amount of pressure applied.

In the context of our project, FSRs have various advantages and disadvantages. FSRs are relatively straightforward to integrate into electronic systems, requiring minimal additional components to read the pressure values. They can be made thin and flexible, which makes them suitable for placement under a mat without discomfort or obstruction. Generally, FSRs are less expensive than some other types of pressure sensors, which can help keep the overall project costs down. They come in various sizes and shapes, offering flexibility in design depending on the specific needs of our project.

However, FSRs may not offer the same level of precision as some other pressure sensors, which is a drawback because highly accurate pressure measurements are crucial for determining the user's position. Repeated and prolonged use can affect their accuracy over time, as the conductive polymer may degrade or the sensor's sensitivity might change. They have a limited range of sensitivity, which means they might not be able to detect very low pressures or distinguish between very high pressures effectively. Also, the relationship between pressure and resistance change in non-linear, which may require additional calibration and software processing to obtain accurate measurements.

The second technology discussed will be capacitive pressure sensors. Capacitive pressure sensors measure pressure changes through the variation in capacitance, which is the ability of a system to store an electric charge. These sensors are made up of two conductive plates separated by a dielectric material (which does not conduct electricity but can store electrical energy). When pressure is applied, it alters the physical distance between the plates or the dielectric constant of the material between them, leading to a change in capacitance. This change can be measured and converted into an electrical signal to determine the amount of pressure applied.

Capacitive pressure sensors consist of two conductive plates separated by a non-conductive material. One plate is connected to an oscillating circuit that generates a charge, while the other plate measures the charge passing through the dielectric. When pressure is applied to the sensor, it either compresses the dielectric or changes it's area, affecting the capacitance, This change in capacitance is proportional to the pressure applied and is measured by the sensor's circuitry, converting it into a usable electrical signal.

In the context of our project, they are advantageous because they are very sensitive to even slight changes in pressure, making them suitable for accurate pressure measurements. They can provide high-resolution measurements, which can be crucial for detecting subtle changes in the user's position. These sensors tend to have good long-term stability and reliability, with minimal drift over time, which is advantageous for applications requiring consistent performance. They can be designed to be thin and flexible, allowing them to be integrated into the mat, without significant intrusion or discomfort.

However, they can be more complex to design and implement than resistive pressure sensors, potentially increasing our project's cost and complexity. They can be sensitive to environmental factors such as temperature and humidity, which might affect accuracy if not properly compensated for. They may also require more sophisticated calibration and signal processing to achieve accurate measurements, especially given the potential for environmental interference.

The third technology discussed in this section will be the piezoelectric sensors. Piezoelectric sensors consist of a piezoelectric material sandwiched between two electrodes. The material is typically a crystal (like quartz) or a ceramic that exhibits piezoelectric properties. When pressure is applied to the piezoelectric material, it generates a voltage proportional to the pressure. This voltage can be measured, amplified, and converted into a signal that reflects the magnitude of the applied force or pressure.

In the context of our project, they are beneficial because they are extremely sensitive, capable of detecting minute pressure changes. This makes them suitable for applications requiring precise detection of force or pressure. They can measure a broad range of pressures, from very light touched to significant forces, offering flexibility in monitoring different types of interactions with the desk. These sensors respond quickly to changes in pressure, enabling real-time monitoring and adjustments. They also generate their own voltage in response to pressure, so they do not require an external power source for the sensing operation, which can simplify circuit design.

Their disadvantages are that they are most effective for dynamic or changing pressures, For static pressure (where the force remains constant over time), the electrical signal can decrease, making it difficult to measure steady states accurately. Over time, the signal from a piezoelectric sensor under constant pressure can "drift", leading to inaccuracies. The generated signals can be small and require amplification and conditioning, adding complexity to the electronics involved. In addition to this, they can be sensitive to temperature and humidity, which might affect their performance and the accuracy of measurements.

The final technology that was investigated for integration into our project was load cells. A typical load cell consists of a metal body (steel or aluminum) designed to bend under load. Strain gauges are attached to the load cell in locations where the deformation is expected to occur. The arrangement of these gauges can vary depending on the type of load cell and the specific application. When a force is applied to the load cell, it causes the metal body to deform slightly. This deformation changes the length and diameter of the strain gauges, altering their resistance. These changes in resistance are measured through a Wheatstone bridge circuit and converted into an electrical signal that is proportional to the applied force.

Load cells have the most advantages in the context of our project. They can provide very accurate measurements of force or weight, making them suitable for applications where precise force detection is needed. They are available in a wide range of load capacities, from very small to very large forces, allowing for versatility in application. They are designed for industrial use, which means they are generally robust and durable, capable of withstanding harsh conditions and repeated use without significant degradation in performance. Finally, they can maintain their accuracy over time, making them reliable for long-term applications.

Load cells do come with some disadvantages though. These include the fact that they can be more complex and expensive than other types of sensors, such as resistive pressure sensors or capacitive sensors, due to the precision engineering involved. They also are typically more rigid and can be bulkier than other types of pressure sensors, which might limit their placement or integration under the mat. To ensure accuracy, they need to be properly calibrated, which can add to the setup time and complexity. Finally, while robust, they can still be affected by environmental factors such as temperature variations, which can influence their accuracy and require compensation.

This summarizes the pressure sensing technologies considered along with their advantages and disadvantages. A summary of these findings can be found below:

Table 3 - Comparison Between Relevant Pressure Sensing Technologies

Feature and Technology	Resistive Pressure Sensors (FSRs)	Capacitive Pressure Sensors	Piezoelectric Sensors	Load Cells
How They Operate	Resistance changes with applied pressure	Capacitance changes with applied pressure	Generate electrical charge in response to pressure	Convert force into an electrical signal

				using strain gauges
Advantages	Simple to use, between $3.00 - $11.00 (fairly inexpensive), flexible, easy to integrate, temperature range: 0 – 10 MPa typically	Highly sensitive, good for precise measurements, stable, temperature range -40 to +125 degrees C, life expectancy: >10 million cycles	Extremely sensitive, fast response, no power needed for sensing, temperature range: -200 to +200 degrees C for certain materials, Life expectancy: > 10^9 cycles	High accuracy, wide range, durable, stable over time, can measure grams to several tons, temperature range: -10 degrees C to +40 degrees C typically, wider with special designs
Disadvantages	Limited precision – can vary from 10% - 30% of desired value, durability issues - difficult to implement if 670 N of force is exerted, limited sensitivity range, non-linear output, life expectancy: ~1 million cycles	Complex and costly, sensitive to environmental changes, requires calibration, measurement range: 0 – 1 MPa commonly	Effective mainly for dynamic measurements, signal drift, complex signal processing, environmental sensitivity, greater cost, typically start at prices greater than $11.00	Complex and expensive, bulky and rigid, requires calibration, sensitive to environmental conditions, life expectancy: >10^6 load cycles
Application Suitability	Good for applications where cost is the main factor	Suited for applications requiring high sensitivity and precision	Ideal for applications needing quick response and high sensitivity	Best for projects where high accuracy and range are critical
Project Considerations	Measurement range: 0 – 10 MPa typically, Temperature range: -40 to 85 degrees C	Measurement range: 0 – 1 MPa commonly, temperature range: -40 to 125 degrees C	Temperature range: -200 degrees C to +200 degrees C, life expectancy: > 10^9 cycles	Temperature range: -10 to +40 degrees C typically, wider with special designs, life expectancy: >10^6 load cycles

Based off the research done for this section, it was determined that load cells were the most appropriate technology to use for this part of the project. This was because of the accuracy and reliability provided by the load cells as well as how robust they were made them ideal for putting underneath the mat to take the relevant measurements.

3.1.2 User Detection Technology

Detecting the user is important in determining when the desk should automatically transition between sitting and standing. In conjunction with the pressure sensing mat, three options were considered to improve user detection. The first option was using a small lidar sensor to detect when there was a user in front of the desk. This option would only determine if there was an object present in front of it. It could not tell what type of object was in front. By itself this option would not be an ideal solution to tracking the user because it could cause a false positive if there was a chair in front with no user present.

The second option considered was using the desk application to determine if the user was present based on login to the computer. This option would work based on setting the desk application to automatically launch on start. Then when the user logins in, it can be determined that someone is present at the desk because they are logged in to the desktop. The only way for this option to determine that the user is finished is if the user logs off the computer. This method has no way of determining whether the user is continuously present. Determining whether the user is continuously present is very important for seamless transition between the two modes of the desk.

The last option considered was using a small camera to track the user. This will work by using facial tracking software in conjunction with the camera. One potential concern with this method is the placement of the camera. To get the best tracking, the camera will need to be placed directly in front of the user at a set distance. If this camera is built into the desk, then there is the potential for the camera to be accidentally blocked by common supplies that the user may put on the desk. Although this may happen, this method still is the most reliable method in determining if there is a user present at the desk since it is using facial tracking. This should allow it to distinguish between a chair and an individual. This method also continuously tracks the user so it can be used as a factor for determining when to automatically transition the desk between modes.

Table 4 - Comparison Between User Detection Technology

Technology	Tracking	Use case
Small lidar sensor	- Detection with 92% accuracy about 4 meters -Able to detect if user leaves desk	Detects any objects in front with no distinction.
Desk application tracking	-Automatic tracking with user login to computer. Tracking user login is 100% accurate. -Not able to detect if user leaves desk	Tracking only when user has logged in to computer. No ability to track when user has left desk
Facial tracking with camera	-Can track with up to 92-94% accuracy within view of camera -Able to detect if a user leaves desk	Tracking user face with ability to determine when there is no face present

3.1.3 Linear Actuator Technology

Linear actuators are a key component of standing desks, and this section will take a closer look at what actuators are, the different types, and the most reasonable design to implement for U.P.R.I.G.H.T. There are many different forms of actuators across various engineering disciplines, and they make up the muscles for vast quantity of machines, however, what is it that makes some of them linear actuators? These are simply devices that take some form of input and translate it into linear motion. That input can range from electrical signals, a hydraulic system, or an actuator that utilizes rotary mechanical motion to convert to linear. One form of mechanical system is already utilized in standing desks today, the hand crank model, which requires manual operation. It would be possible to incorporate an external electric motor that would turn the hand crank, however that would add an unnecessary layer of the system. Mechanical actuator technology can be dismissed for use in the U.P.R.I.G.H.T because automation is the key functionality goal. Which leads to hydraulic linear actuators.

Fluid pressure is utilized in hydraulic linear actuators to generate linear motion and generally consists of a cylinder, piston, and hydraulic fluid. As pressure is applied to the fluid via an electrical or hand pump, the fluid pushes against the piston, causing it to move linearly. This is one possible solution for height adjustment of a standing desk. There are a few positives regarding hydraulic actuators, particularly their high force output and smooth operation. The most common applications that utilize this type of actuator are ones that include exceptionally heavy load requirements. They are generally considered the highest-powered actuator type on the market.

On the other hand, electric linear actuators rely on electrical energy utilized with a motor to produce linear motion in the form of a screw and nut mechanism. As a motor is energized, it rotates the lead screw, turning the nut along the threads, and results in linear motion. Electric actuators have many advantages including precise positioning, quiet operation, and control customization. They are commonly used in applications that require precision, speed, and minimal maintenance, such as in automated manufacturing processes or standing desks.

Having looked at both hydraulic and electrical linear actuators, it should come as no surprise that the technology most suitable for the U.P.R.I.G.H.T is electrical. Hydraulic actuators are not self-contained but require an existing plumbing infrastructure to become operational. Not only can this be expensive if that infrastructure is not in place but is also costly to keep maintained for system efficiency and to avoid any damage and leakage. The greatest advantage that hydraulic has over electric is higher load capacity, with many models able to withstand and displace thousands of pounds. However, for the purpose of a standing desk, electric actuators provide plenty of load capacity. In addition, electric powered actuators provide a plethora of easy to control capabilities. With connection to a motor control module or microcontroller, speed and position can be easily controlled and automated with precision that a hydraulic actuator cannot come close to matching. Electric actuators are also self-contained, meaning that they do not require any external system, pump, or motor to operate, only a power supply. These attributes make electric linear actuators a no-brainer for U.P.R.I.G.H.T.

Table 5 - Linear Actuator Technology Comparison

Feature/Technology	Mechanical Linear Actuators	Hydraulic Linear Actuators	Electric Linear Actuators
How They Operate	Rotary mechanical energy turned into linear motion	Linear motion of a rod occurs with pressurized fluid	Electrical energy turned into linear motion by motor, gears, screw, and nut
Advantages	Cheap and simple to implement	Extremely high load capability and long service life	Self-contained and efficient with precise speed and position control
Disadvantages	Lack of automation or complex capabilities	Numerous expensive and required external components. Poor speed control and vulnerable to high temperatures	Prone to overheating with prolonged, continuous operation. Typically, more expensive front-loaded cost
Application Suitability	Good for cost sensitive and simplistic projects	Ideal for applications requiring exceptionally high loads	Suited best for applications that require automation and high degrees of speed and position control
Project Considerations	Cost effective and easy implementation	Able to withstand force from a very large or heavy table when raising or lowering	Automated, efficient control over speed and position of desk

There are some secondary factors that need to be considered for electric linear actuators, namely regarding the internal motor type. The factor that will be examined in this section will pertain to whether an AC or DC motor will be the driving motor within the actuator, while the voltage rating will be discussed in part comparison and selection of section 2. First off, both motor types are based on the same principle, that alternating magnetic fields induced by alternating directions of current will cause a shaft to rotate. DC refers to direct current, which has a constant and continuous flow in the same direction, while alternating current, AC, alternates current direction at a certain frequency. The standard frequency for alternating current within the United States is 60 Hertz, or 60 times per second. For high powered applications, alternating current is the most common power source because it is relatively easy to change voltage and highly efficient with minimal power loss at higher voltages and longer distances travelled. Many smaller, low powered applications use DC. For instance, anything powered by a battery is using DC. The difference between AC and DC causes certain characteristics within motors that help determine each type's applicable suitability. AC motors generally have greater durability and life expectancy because they do not have any touching parts. However, DC motor speeds are far easier to control. Since a direct current motor's speed is proportional to the current that is feeding it, simply by introducing certain voltage regulation, the speed can be controlled. It is not that simple for

AC motors because of the frequency, and generally a VFD, or variable frequency drive is needed to operate an AC motor. These VFDs can be quite expensive and add another layer of complexity. For this reason, and the fact that converting typical residential AC power to DC is simple, U.P.R.I.G.H.T. will utilize DC linear actuators.

3.1.4 Feedback System Technology for Electric Linear Actuators

This section will dive into the main technologies that are utilized for feedback systems in electric linear actuators. Not all actuators include a feedback system, in fact many of the base models do not. For simple applications that require an actuator to just extend and retract to one position, there is no need for feedback functionality. As projects become more complex, feedback systems were designed to help maintain real time position tracking of the stroke for accurate position control and assist with speed control. As linear actuators have continued to progress, there have been three main technologies that continue to be utilized in feedback systems listed below. The goal of this section is to determine which technology will be the best suited for utilization within the U.P.R.I.G.H.T.

- Potentiometers, also referred to as POT sensors
- Hall Sensors
- Optical Sensors

Most electric linear actuators on the market that incorporate a feedback system do so with potentiometers. Their cost effectiveness and adaptability of being utilized internally or externally are the leading factors that contribute to their wide range of use. POT sensors are especially simple in their application, as they simply output a resistance value that correlates with the position of the stroke. This is accomplished by using a thin layer of resistant material, applying a voltage, and reading the voltage at different positions of the material. The voltage readings close to a 12V voltage being supplied will be almost 12V and readings halfway along the material will be roughly half the voltage. As the readings increase in distance away from the source they will decrease in voltage until it is zero, basically providing a certain kind of position tracking. This output can be used by a MCU to scan the position of the stroke and help with synchronous positioning and speed across multiple actuators.

The next two technologies used in feedback systems, hall sensors and optical sensors, are very similar in their design, however hall sensors use magnets and optical sensors utilize optics. The main premise in hall sensors is that a thin, magnetic disk with slight ridges around the edge is installed somewhere in the gearbox of the actuator and rotates as the motor extends or retracts the stroke. As the magnetic disk spins a magnetic sensor will produce a voltage pulse each time the disk rotates 360 degrees. The greater number of rotations and pulses from the hall sensor throughout the extension of the stroke, the more precise the position control can be. For instance, U.P.R.I.G.H.T will utilize 18” strokes, and if the hall sensor sends 1000 pulses, that would be 1000/18” = 55.55 pulses per inch, in other words, 1 pulse per 0.018”. This means that this hall sensor could provide accurate position control up to about half a millimeter. This tends to be much more precise than potentiometers, however there is a drawback. Standard hall sensors are not able to track if the actuator is extending or retracting and must therefore return to a starting point (usually fully retracted) before the position of the stroke can be controlled.

Optical sensors employ the same design concept as hall sensors but utilize a disk with slots cut out around the edge. The optic sensor will read an LED that shines through the slits in the disk and will pulse an output as the disk rotates. With this design, the frequency of pulses can be much higher than the hall sensor, providing greater precision and accuracy with position control. This technology, however, also has the same drawback as hall sensors of needing a homing cycle back to a starting point before it is calibrated for position control. For an overview, see the table below for the specific advantages and disadvantages attributed to these technologies. [7] [8]

Table 6 - Feedback System Technology Comparison

Feature/Technology	**Potentiometers POT sensors**	**Hall Sensors**	**Optical Sensors**
How They Operate	Resistant values are output that correspond to stroke position.	5V pulses are output as voltage is induced from a magnetic sensor reading the rotations of a magnetic disk.	5V pulses are output as an optic sensor reads flashes from a LED through the slits of a rotating disk.
Power Startup	Does not require calibration on startup.	Requires calibration on each startup or disruption of power.	Requires calibration on each startup or disruption of power.
Output	Varying resistance values as the stroke moves. Acts as a simple voltage divider when connected to a source.	Stable 5V digital pulse as stroke moves.	Stable 5V digital pulse as stroke moves.
Accuracy	Low The resistance values of different POT sensors are not universal.	High Control within 0.6mm	Very High Ten times as precise as Hall sensors with control of 0.06mm
Price	\$140.00-\$150.00 From Progressive Automations and Electric Linear Actuators	\$180.00-\$186.00 From Firgelli Automations and Progressive Automations	\$160.00-\$180.00 From Firgelli Automations

In conclusion, the best technology suitable for the U.P.R.I.G.H.T is potentiometers, with the main factor being no required calibration for power ups. POT sensors are less durable and accurate compared to optical sensors, but no need for constant calibration will help with U.P.R.I.G.H.T's goals of automation and immersion. Another tradeoff with POT sensors will be synchronous control, which is not impossible with potentiometers but will require more initial testing and prototyping, and acceptable tradeoff.

3.1.5 Motor Control Technology

Motor Control of the linear actuators utilized for U.P.R.I.G.H.T will play a critical role in the functionality of the desk. There are a multitude of avenues to control motors that include relays, voltage regulation, motor drivers and full-blown motor controllers. The selection of motor control technology will derive from critical factors of motor type being used and the desired project functionality. The U.P.R.I.G.H.T will be designed to include many automated features, which the control method of the motors will need to take that into account, eliminating the need for further conversation on relays or voltage regulation. As discussed in linear actuator technology and linear actuator selection, specifically 12V brushed DC motors will be used for the desk. This type of motor is almost exclusively controlled by H-Bridge motor drivers.

H-Bridge motor drivers utilize H-bridge circuits and PWM (pulse width modulation) to flip the direction and speed of the motor respectively. The conceptual design of H-Bridge circuits is actually fairly simple, by using four “switches” in an H pattern with the motor sitting on the bridge or horizontal line of the H, different configuration of switches can change the voltage polarity on the motor causing it to reverse direction. Generally speaking, if all switches are open there will be no voltage across the motor, but closing the top left and bottom right switch will cause the motor to spin. By opening those switches and closing the other two, the polarity on the motor will shift and the motor will rotate in the other direction. Any other switch configuration can cause a short in the circuit. The actual components utilized in H-Bridge circuits are not switches, otherwise a simple relay or double pole, double throw (DPDT) switch could be used just as effectively. These circuits are actually realized using bipolar transistors or MOSFETs. Many of the older models use bipolar transistors, while new designs utilize MOSFETs because they are significantly more energy efficient. The main reason for this characteristic is the amount of voltage drop created by the components. When bipolar transistors are turned on, there is about a 0.7V drop across the transistor, whereas there is only about a 0.1V drop across a MOSFET. The drop in voltage is usually dissipated as heat and depending on the amount of current necessary to drive the motor(s), this heat can exceed the thermal ratings of electric components used in the driver, damaging it beyond repair. This is the reason why many drivers include heat sinks that can account for the wasted energy, especially ones that utilize bipolar transistors. When selecting the driver for this project, it will be important to keep in mind its power efficiency ratings and how well it can handle any wasted heat. Ultimately, these H-Bridge circuits will help with directional control of our motors; however, speed control will be handled using pulse width modulation. [9]

PWM is the most common speed control method of motor drivers used within the industry for smaller DC motors, and it employs a fairly simple premise. A motor’s speed will be at full capacity when being supplied with its particular voltage rating (12V for our DC motors) and will lessen the speed as the supplied voltage is decreased. The problem with this method is that the motor’s torque will also decrease along with the speed. PWM solves this issue by sending pulses at the rated voltage to drive the motor. The pulse width will determine the speed of the motor, with the motor spinning faster with wider pulses, while the available torque will not drop because the voltage has not changed. It is important to note that PWM can cause certain negative characteristics if its frequency is too low: they include a jerky, inefficient, or noisy motor, but parts with low PWM frequency ratings are less expensive. As the frequency is increased the supplied power acts proportionally more like a continuous supplied DC voltage. It will be essential that the U.P.R.I.G.H.T include the capability for higher PWM frequency, to ensure that noise or jerky movement when the actuators are activated are not noticeable to the user. It is recommended that the frequency range be between 16-20 kHz. [10] Generally PWM is communicated with the motor controller through a microcontroller, utilizing various PWM and standard I/O pin configurations. These will be explored during selection. Both PWM and H-Bridge circuits will be utilized within the motor driver chosen for the U.P.R.I.G.H.T, which is explored more in the Motor Controller Selection section.

3.1.6 Display Panel Technology

This section will be focused on finding the best solution for displaying information to the user using a display panel technology. In our quest to enhance the interactive experience of our automatic standing desk, we will delve into a comparative analysis of various display panel technologies, aiming to identify the most suitable option for integration with our chosen microcontroller. This exploration will cover a range of technologies, each offering unique advantages in terms of visibility, power consumption, and interface compatibility. The contenders in this comparison are as follows:

- LCD (Liquid Crystal Display)
- OLED (Organic Light Emitting Diode)
- TFT (Thin Film Transistor) displays
- E-Paper displays

Our objective is to assess these technologies comprehensively, determining which aligns best with our project’s requirements for an optimal user interface solution.

In the realm of display technologies suitable for integration with our chosen microcontroller, Liquid Crystal Display (LCD) panels stand out as a versatile and energy-efficient option. LCDs, characterized by their low power consumption and cost-effectiveness, offer a practical solution for projects that require text and basic graphical output. Their simplicity in interfacing with microcontrollers, through either parallel or serial (I2C/SPI) communication, makes them particularly appealing for embedded applications. The ease of integration is complemented by the availability of a wide range of sizes and configurations, from simple character displays to more complex graphical modules, allowing for flexibility in design according to our project’s display requirements.

However, the utility of LCD technology comes with its limitations. The primary drawbacks include relatively low contrast ratios and limited viewing angles compared to more advanced display technologies like OLEDs or TFT LCDs. Additionally, LCDs typically require a backlight for visibility in low-light conditions, which can increase power consumption and affect the overall design compactness. The performance of LCDs under direct sunlight is also a concern, as readability can significantly diminish in bright environments. Despite these challenges, LCDs are still viable for our project because of their proven reliability, ease of use, and the ability to efficiently convey information without draining the power resources of the low-power microcontrollers available to us.

The next technology that will be discussed are OLED panels. OLED (Organic Light Emitting Diode) displays, with their self-illuminating pixels, offer unmatched contrast and color vibrancy, enhancing the visual appeal of any application. This technology allows for thinner, more flexible display options, making it an excellent choice for our project to implement an aesthetically pleasing design. The absence of a backlight not only contributed to energy efficiency but also enables true blacks, providing a significant boost to the display's dynamic range and overall image quality.

Despite these advantages, OLED displays have their drawbacks. They are typically more costly then LCDs, which may impact budget considerations for our project. Additionally, OLED screens can suffer from burn-in, where static images persist on the display over time, posing a challenge for interface with fixed elements. Their longevity is also a concern, as the organic materials used in OLEDs degrade faster than the inorganic materials of LCDs, potentially leading to dimming and color shifts. These factors necessitate a careful evaluation of the application's requirements and usage patterns to ensure that the benefits of OLED technology align with our standing desk's long-term needs and objectives.

The next technology that will be discussed are TFT displays. TFT (Thin Film Transistor) displays bring a significant enhancement in visual quality to the table, characterized by their high resolution and vibrant color depth. This leap in display technology ensures that applications requiring detailed graphics and accurate color representation are well-served, making TFT displays particularly suitable for applications where visual fidelity is paramount. The individual control over each pixel allows for sharp images and swift refresh rates, critical for rendering dynamic content and smooth video playback.

However, the benefits of TFT technology come with their set of challenges. The complexity of these displays leads to greater power consumption, which could be a limiting factor for portable devices powered by a variety of microcontrollers. Furthermore, the increased cost and technical demands for interfacing with TFT displays might pose budgetary and developmental hurdles. These factors necessitate a careful evaluation of project requirements against the backdrop of TFT technology's advantages and limitations, ensuring that the choice of display aligns with our project's goals and resource constraints.

The last technology to be discussed will be E-Paper displays. E-Paper displays, with their distinctive low-power consumption and paper-like readability, offer a unique advantage for devices prioritizing energy efficiency and legibility in various lighting conditions. This technology is particularly suited for applications where the display content changes infrequently, such as e-readers or digital signage, due to its ability to maintain an image without power.

However, the limitations of E-Paper, including slower refresh rates and predominantly grayscale output, make it less ideal for dynamic content or applications requiring vibrant color displays. While these displays excel in visibility and energy conservation, their application is best suited to specific use cases where these advantages align with our project's primary goals, highlighting a trade-off between display dynamics and power efficiency.

Taking into account all of the choices available to us for our project, it was decided that an LCD display will be chosen as the display panel technology to be used in our project. The decision to utilize an LCD for our desk project is driven by its optimal balance between performance, power efficiency, and cost. LCDs offer clear visibility and sufficient resolution for displaying user interface elements and information, which is essential for enhancing user interaction. Their low power consumption aligns with our goal of creating an energy-efficient device, ensuring prolonged use without frequent power needs. Additionally, the widespread availability and affordability of LCD technology facilitate ease of integration and maintenance, making it an ideal choice for our project's display requirements.

The following table summarizes the display panel technologies considered along with their advantages and disadvantages. A summary of these findings can be found below:

Table 7 - Relevant Display Panel Technologies Comparison

Technology	Pros	Cons
LCD	Energy efficiency – 1-2 mA without backlight and up to 20 mA with LED backlight at 5V, cost-effective - $3-$5, longevity: lifespan of 50,000 to 100,000 hours	Limited viewing angles: typically around 60 degrees horizontally and vertically, slower refresh rates: typical refresh rates might range from 60 to 75 Hz
OLED	High contrast and color depth: often around 1,000,000:1, viewing angles: near-perfect angles close to 180 degrees, response time: typically around 0.1 milliseconds	Higher cost, susceptible to burn-in, shorter lifespan: typical lifespan is around 14,000 to 20,000 hours
TFT	Brightness: typically around 250 to 500 nits, cost: can be as low as $10 to $20 for small sizes	Viewing angles: usually around 70 degrees from the center, power consumption: typically ranging from 100 mA to 500 mA, contrast ratio: typically around 600:1 to 1,000:1, response time: generally around 5 to 16 milliseconds
E-Paper	Visibility: viewing angles close to 180 degrees	Slow refresh rates: typically several seconds, limited color capabilities: black and white color palette

3.2 Part Comparison and Selection

This section of Chapter 3 is mainly concerned with comparing the specific parts available for integration into the project. Since Section 1 dealt with technology selection and comparison, the parts in this section must fall within the category chosen for the specific technology outlined in Section 1. For example, because load cells were chosen as the appropriate pressure sensing technology to include in the mat, all of the parts mentioned in this section concerned with pressure sensing must be load cells.

This section has been divided into relevant subcategories to ease in navigation of this design document. The specific part selection and comparisons for the relevant technologies continue below.

3.2.1 Load Cell Selection

Since it was decided that load cells were the most appropriate technology to use for the pressure sensors under the mat, various considerations must be made the ensure that they will be effective in the overall operation of the system. The relevant considerations are outlined below:

- Capacity and Range
- Accuracy
- Sensitivity
- Environmental Conditions
- Physical Size and Shape
- Material Output Signal Type
- Calibration
- Compatibility with Electronics
- Cost and Availability

The first relevant consideration was capacity and range. It is important that the load cells have a maximum capacity that exceeds the highest expected force (including the weight of the user and any additional load they might place on the mat, such as their chair) to avoid overloading and damaging the sensor. The range should be appropriate for the smallest and largest force we anticipate measuring. A too high capacity might reduce sensitivity for detecting small weight changes. The main value that was taken into account here was 200 kg. It was determined that this was the maximum mass our load cells should be able to accommodate.

The next consideration was accuracy. We wanted to ensure the load cells could provide the resolution needed for our system. Higher resolution allows for more precise weight measurements. When taking this into consideration, it was important to look at the accuracy specifications, including non-linearity, hysteresis, and repeatability. These factors affect how closely the load cell’s measurements match the actual applied force.

The third consideration was sensitivity. The sensitivity of a load cell indicates how much electrical output (in millivolts per volt of excitation) changes for a given change in force. This is crucial for detecting subtle changes in weight distribution when determining if a user is sitting or standing.

The fourth consideration was environmental conditions. It is important to consider the environmental conditions where the desk will be used. Temperature, humidity, and the presence of any corrosive materials can affect the performance and lifespan of load cells. Some load cells come with environmental protection (e.g., waterproof or dustproof ratings).

The next factor to take into account was the physical size and shape of the load cells. The physical dimensions of the load cells must fit within the design constraints of our mat. Additionally, we needed to consider the mounting requirements and whether the load cells' shape and size would facilitate easy integration.

The next step was looking at the material of the load cells. Load cells are typically made from aluminum, stainless steel, or allow steel. The choice of material impacts the load cells' durability, cost, and suitability for different environments (e.g., stainless steel is preferred for corrosive environments).

The seventh aspect that was taken into account when choosing appropriate load cells was the output signal type that was supported. Load cells can provide analog or digital outputs. Analog load cells typically output a millivolt signal proportional to the load, requiring additional signal conditioning. Digital load cells offer a direct digital output, simplifying data acquisition but potentially increasing cost.

The eighth consideration for our load cells was how they would be calibrated. Before choosing, we needed to determine how the load cells would be calibrated with the system. Calibration is critical for accurate measurements. Some load cells come pre-calibrated, while others may require setup with our specific hardware and software.

It was then time to check the chosen load cells' compatibility with our electronics used in the project, mainly the parts that would be included on our PCB. We needed to ensure compatibility with our planned data acquisition system. This includes matching the load cells' output signal type and voltage levels with the input requirements of our amplifiers, ADCs (Analog-to-Digital Converters), and microcontroller(s).

The final and one of the most important considerations that was taken into account was the cost and availability of the specific load cells chosen. We needed to consider the load cells in the context of our project's relatively limited budget. Also, we needed to assess the availability of the load cells, including lead times for delivery, which would impact our project timeline.

Finally, after taking all of these aspects into account, three load cells were chosen that fulfilled the requirements stated in this section. When the research was conducted into what parts were appropriate, it was determined that there was a cost/benefit analysis that needed to be done for the final parts. This was because there was no single load cell that could satisfy all of the requirements. For example, there were load cells that were looked at that fulfilled every requirement other than the physical size and shape constraints. Because of this, they had to be removed from consideration for that fact alone because they were too big to be integrated underneath/into the mat.

With the context provided in this section and the information included in Section 1, we finalized the potential load cells down to three potential candidates. A table below is included to demonstrate the advantages and disadvantages of each, in order to justify the final choice selected for this section:

Table 8 - Part Comparison for Load Cell Selection

Feature/Specification	Load Cell 1	Load Cell 2	Load Cell 3
Capacity	3 – 200 kg (aluminum); 80 – 200 kg (alloy steel)	10 – 200 lbf (50 – 1,000 N)	40 – 50 kg
Rated Output	1.0 ± 0.15 mV/V	Unamplified span sensitivity of 20 mV/V	1.0 ± 0.1 mV/V
Safe Overload	120% FS	2.5X rated	150% FS
Excitation Voltage	5 ~ 10 Vdc	1.00 – 6.0 V (Analog), 2.7 – 5.5 V (Digital)	≤ 10 V
Operating Temperature Range	-10 ≤ + 55 °C	-40 ~ + 85 °C	0 - + 50 °C

It was determined due to the specification and considerations made for how our system will function, that the load cells in column 4 would be the most effective for our system. The specifications above played a part in this selection as well as the price. They were by far the cheapest parts in terms of cost that made it to the final selection. Prices for load cells 1, 2, and 3 were $9.69 per unit, $34.68 per unit, and $4.50 per unit, respectively. The name for load cell 3 was the SEN-10245, manufactured by SparkFun Electronics.

3.2.2 Electric Linear Actuator Selection

This section will detail the various criteria needed of the DC linear actuators for the U.P.R.I.G.H.T desk, while exploring specific actuators and how they meet each of the criteria listed below. After careful consideration and a cost benefit analysis, a linear actuator type will be chosen for purchase. Further testing and implementation with the desk will be carried out to ensure that all specifications are met and detailed in chapter 9. Listed below are the criteria and specifications that each actuator will be checked for:

- Voltage Rating
- Max Current/Continuous current ratings
- Load Capacity
- Pushing/Retracting Force
- Stroke Length
- Speed

- Feedback Capability

There are two standard voltage ratings for DC linear actuators, 12V and 24V, both possessing unique properties and advantages. 24V actuators are characterized as having slightly better specs than their counterpart, because the 24V internal motor is able to generate greater torque with a higher voltage. This leads to greater possible speed, improved efficiency, and better load capability in relation to the 12V actuator. With enhanced specifications, higher voltage actuators are usually seen in industrial applications, not however without some tradeoffs. The major drawback is monetary, simply put 24V actuators require both better infrastructure and more specialized components to operate. This can be seen in the motors themselves, as the voltage increases more windings around the motor coils are needed to accommodate for the rise of voltage. Ultimately, 24V linear actuators cost more for their increase of efficiency.

These factors are why 12V DC linear actuators are mainly seen in less demanding applications, where they are more cost effective. If the specifications of 12V actuator meet the criteria of an application, not only will it save money for that project, but will also be more energy efficient than going overboard with a higher voltage rated actuator. This is one of the reasons that 12V linear actuators will be used in UPRIGHT, along with the cost saving for both the power supply and voltage regulators discussed in section 3.1.

The next criteria that must be considered is the max current and continuous current ratings of the actuator. These ratings will heavily influence the type of power supply and motor controllers compatible with U.P.R.I.G.H.T. Most 12V actuators on the market that meet our specifications fall somewhere in between 1-3 Amps for continuous use and 3-10A max rating. Generally, as the amperage rating increases so does the cost of power converters, motor controllers, and the actuator itself, however load capacity and speed will also increase. There is not a specific max current rating that is required for this project, and this is why it is important to cross-reference cost, ampere rating, and specifications for the specific actuators in question.

The third decisive factor necessary for U.P.R.I.G.H.T is load capacity, or how much static force the actuator can handle. For clarification, load capacity generally details the force an actuator can withstand while at rest, or when the locking mechanism is engaged. Max dynamic load capacity is the terminology for max applied force the actuator can generate while in motion. It is very important to read through the manufacturing specifications for each actuator because some utilize these two terms interchangeably while others do not. Some of the guides will say load capacity but mean thrust or the force the actuator can generate while in motion, whereas others will clarify load capacity as static and have a different value for max dynamic load. For the U.P.R.I.G.H.T, the required spec for load capacity will be a total of 600N dynamic load capacity with a load capacity that meets are exceeds that value.

Pushing and retractive force specifications are closely tied to dynamic load capacity, in that it specifies how much force an actuator can generate while extending the stroke or the amount of force it can pull a load while retracting the stroke. Generally, the value of these two are not the same, with pushing force capability ranging from slightly to extensively greater than the pulling capability. Some actuators do not include the ability for pulling a load at all. The U.P.R.I.G.H.T will not be used for the pulling functionality in an actuator because it will rely on gravity when retracting. The pushing capability, however, will need to match the load capacity spec of 600N, or slightly above 120 lbs.

The fifth specification is the stroke length, which will determine the possible positions that are feasible for the U.P.R.I.G.H.T. The general standards for standing desks are given by a sub-organization of ANSI (American National Standards Institute): the BIFMA (Business + Institutional Furniture Manufacturer's Association). Please see chapter 4 for further details regarding standards. BIFMA writes a myriad of standards for standing desks, however, they only provide guidelines for typical heights. [11] Their recommendation is that standing desks be adjustable from a minimum of 22" to a maximum of 46.5". However, the typical non standing desk on the market ranges commonly sits between 28"-30". With these values in mind, the U.P.R.I.G.H.T will have an adjustable range from around 26"-28" to a max height between 44"-46". A stroke length of 18" or 450mm on the linear actuators guarantees that our desk can meet this specification.

The next criterion of speed has many tradeoffs with the other required specifications. In order to meet our goal of 25mm/second velocity, these tradeoffs will have to be cross-examined to ensure that U.P.R.I.G.H.T will maximize power efficiency and cost savings. To fully understand this objective, further definition is required. Linear actuators max speed refers to when no load is present and while straining under load, velocity is inversely proportional to load force. Voltage rating has a direct impact on the speed capability of the actuator, as voltage increases so does its load capacity, max speed, and speed under load. However, there are still 12V models that can achieve the velocity goal, but they will draw more current, increasing the actuator current rating. This is important to take note of when researching specific linear actuators and keep in mind how the increase of current will affect other systems, as in power supply and motor control.
The last specification required for the U.P.R.I.G.H.T is whether the actuator has a feedback system, and what the type of feedback is. One of the most common feedback devices for linear actuators are potentiometers, or POT sensors. These utilize resistance, and the resistance will change as the stroke extends or retracts. The resistant value sent back as an output corresponds with the stroke's position. The other typical feedback system utilizes hall sensors, which in simplistic terms is a magnetic sensor that outputs a voltage pulse every time a disk-shaped magnet spins a full 360 degrees. The magnetic disk is usually located in the gear box and its rotation is caused by the stroke moving. A feedback system is necessary in linear actuators for applications that require position tracking or synchronous utilization between multiple actuators. U.P.R.I.G.H.T will use two linear actuators, one for each leg of the desk, making feedback functionality a required specification.

Please see table 2 below for details regarding each linear actuator in question and how they perform for each criteria listed above:

Table 9 - Electric Linear Actuator Comparison

Linear Actuator	Progressive Automations Model: PA-14P-18-xx	Firgelli Automations Model: FA-OS-xx-12-18	Electric Linear Actuators Model: 0041670
Voltage Rating	12V DC	12V DC	12V DC or 24V DC
Max Current/ Continuous Current	Max Current: 5A No load current: 1A	Max currant: 5A	Max load current: 3-6A No load current: 1.5-3A
Load Capacity	Dynamic load is equal to static load. Load options (lbs): 35/50/75/110/150	Load capacity options: (lbs) 200/500/800	Dynamic Load capacity options: (lbs) 60/110/160
Pushing Force	Same as load capacity: (lbs) 35/50/75/110/150	Pushing force: (lbs) 35/200/400	Pushing force: (lbs) 60/110/160
Price	$150.00	$159.99	$145.00
Speed	Non-Load speeds (in/sec): 2.0/1.14/0.95/0.79/0.37 Full-load speeds (in/sec): 1.38/0.83/0.70/0.59/0.28	Non-load speeds: (in/sec) 2.0/0.3/0.3	Non-load speeds: (mm/sec) 50/30/20
Feedback System	Yes, Potentiometer system	Yes, Optical sensor system	Yes, Potentiometer system. Also include internal limit switches

In conclusion, the U.P.R.I.G.H.T will utilize the linear actuators from Electric Linear Actuators, specifically model 0041670. There were a few reasons for this, but the main one came down to the load capacity vs stroke speed constraint and the ability to create seamless transitions of the desk via speed of the actuators. This model was able to deliver a greater ratio between speed and load capacity, and still achieve the desired speed spec of 25mm/s while maintaining 60 or 110 pounds of load depending on the make. The actuator from Progressive was able to meet the speed specification with a load capacity of 50 pounds, while the model from Firgelli could only guarantee 35 pounds. The ratings given are also only from non-load speeds, and when any of these actuators are operating under a load, their speed capability will drop. For this reason, the Electric Linear Actuators with the non-load speed rating of 50mm/s and dynamic load capacity rating of 60lbs will be purchased for the desk, ensuring that both specifications for load (600N/120lbs) and speed (25mm/s) will be met.

3.2.3 Motor Controller Selection

This section will focus on the parameters that went into determining the particular motor controller to be utilized for the U.P.R.I.G.H.T, and why those specific parameters were important to the selection process. Now that the linear actuators have been researched and purchased, their electrical specifications will be the base line for determining factors. Also, as discussed in the Motor Control Technology section, the MCU will need to control the linear actuators speed and direction of movement through the motor driver, and this is accomplished with varied pin configurations between the two. There are not standard pin configurations for every motor controller, making this a factor that must be explored as well. Ultimately, the critical factors that will be discussed in this section are listed below.

- Motor Supply Voltage
- Continuous Current Rating
- Peak Current Rating
- Number of Channels
- Input Logic Voltage
- Pin Requirements
- PWM Frequency

It is absolutely essential that the first three factors for the motor controller accept the ratings of the actual motors, otherwise the PCB or motor controller will be damaged beyond repair. The linear actuators that were purchased for the U.P.R.I.G.H.T are utilizing 12V brushed DC motors that operate at a continuous current rating of one to five amps and a peak current rating of three to six amps. The reason that there is a wide range of current limits can be explained from the difference in current draw when there is no load or full load on the actuators. It is vital that the motor controller has bounds that exceed the upper limits of the DC motors, in both continuous and peak current. This will ensure smooth operation and mitigate any chance of damage to the controller or motors. Generally, there is a wide voltage range that the controller will accept making it less of a constraint when selecting the specific one, however it must still be verified that 12 volts falls within that range.

The number of channels ties directly into how many motors the driver can control, which this desk utilizes two DC motors, making it essential that the driver includes at least two channels. The input logic voltage should be similar to standard microcontroller voltages of 3.3V or 5V. It is important to verify that this voltage range is included in the specific driver that is selected. Another factor that must be considered is whether the voltage and current ratings are for the entire driver or just a single channel, in which case would need to be multiplied by two. The power efficiency of the motor controller is a factor not listed, but still important to investigate for each model. How efficiently the controller can convert the input logic PWM signals into the higher voltage supplying the motor, will determine the overall effectiveness of the DC motors. If any heat dissipation is required, from a lack of efficiency, the controller must be able to handle it through the use of heat sinks.

The MCU will need to communicate with the driver utilizing a certain configuration of PWM capable pins and standard I/O pins. This configuration of pins is different among various motor controllers. A general setup includes a PWM capable pin to send the pulse width modulation signal, and a couple I/O pins that will help communicate the desired H-bridge circuit for directional control of the motor. The employment of a MCU and its software for instructional communication to the driver is imperative to realize the quick, precise speed and directional instructions needed for automated functionality.

The final key factor that must be analyzed is the PWM frequency capability of each motor controller. The higher the rating, the more functional the motors will be in their operation, however at a high enough frequency the MOSFETs utilized in most designs will not keep up and start to miss pulses. [12] At high PWM frequencies, but at a lower frequency which this event occurs, motors tend to run smoother with less generated noise. There is not an optimal frequency however, and it will be important that the motors are tested at varying frequency to determine the ideal functionality of U.P.R.I.G.H.T. See below for a table of the motor controllers in question.

Table 10 - Motor Controller Selection Comparison

Motor Controller	**Elecrow Model #ACS70028DH**	**DFRobot Model #DRI0041**	**Cytron Model # MDD10A**
Motor Supply Voltage	6-22V	Input: 6.5-27V Output: 7-24V	5-30V
Continuous Current Rating	8A per motor	7A per motor	10A per motor
Peak Current Rating	15A	50A	30A per motor
Logic Input Voltage	4.5-5.5V	3-6.5V	3.3-5V
Pin Requirements	(1) PWM and (2) I/O pins per motor channel	(1) PWM and (2) I/O pins per motor channel	(1) PWM and (1) I/O direction pin per motor channel
Cost and Availability	$16.00 In stock at elecrow.com	$21.59 @ RobotShop (1 stock)	$23.50 @ Cytron Marketplace (682 in stock)
PWM Frequency	Not listed	Minimum pulse width length of 5 microseconds	20kHz

All of the motor controllers in question were dual channel that utilized MOSFETs in their design, while those that used transistors were not included in the final consideration because of the large, blocky design necessary to incorporate heat sinks. The Elecrow driver was the most cost efficient, however it also did not specify PWM frequency rating and had the lowest peak current rating. When considering the peak current, or stall current, we wanted the driver in question to have about 30% greater rating than the motors. This puts the ACS70028DH right on the edge. Overall, the DFRobot DRI0041 and Cytron MDD10A met all the critical factors we were looking at, including a very high PWM frequency capability and plenty of current carrying capacity. The model from DFRobot however, had a 4-week lead time while the Cytron was in stock at multiple locations. This led us to choose the Cytron MDD10A and capitalize on the shorter ship duration with additional time for testing and prototyping.

3.2.4 Microcontroller Selection

At the outset of our senior design project, the selection of the microcontroller (MCU) quickly emerged as a pivotal decision, foundational to the project's success. This choice was critical, as the MCU not only dictates the operational speed and efficiency of our system but also establishes the compatibility and integration capability with peripheral devices and sensors, thereby defining the range and complexity of functions that can be implemented in the project. Moreover, the selected MCU's memory capacity would directly impact our ability to develop and store complex software solutions, making the availability of robust documentation, a supportive Integrated Development Environment (IDE), and comprehensive libraries indispensable for efficient troubleshooting and development. Aware of the potential pitfalls of an ill-suited MCU, ranging from hardware incompatibilities to software limitations, our team prioritized this decision. We embarked on a thorough evaluation of MCUs, considering not only their technical specifications but also the ecosystem surrounding them, including development tools, community support, and scalability for future enhancements. This comprehensive strategy ensured our choice would facilitate a seamless integration of components, establishing a solid foundation for a system that operates in harmony and meets our project's ambitious goals.

Our microcontroller will be in charge of communicating/receiving inputs from a variety of peripherals including push buttons, a DC motor controller which is attached to two linear actuators, receiving feedback from the onboard potentiometers aboard the actuators, sending and receiving data from a raspberry pi, controlling a display panel, receiving input from our load cell sensors, and possibly several others. Thus, the communication protocols and features of our MCU are very important in order to host such a variety of peripherals. We plan on using all of the three major communication protocols in our project which our Serial Peripheral Interface(SPI), Universal Asynchronous Receiver Transmitter (UART) and Inter-Integrated Circuit (I2C). Based on the requirements of our project these three protocols should serve us well in terms of interfacing with the majority of peripherals we plan to include. However, each of the protocols have their own strengths and weaknesses, so we also would like to maintain flexibility in our design and give ourselves room to add extra peripherals or adapt if one communication protocol turns out not to be best suited. So, it would be ideal if the MCU we choose would have multiple options for each of these protocols. Another consideration is the possible need to employ an Analog to Digital Converter in our design. There is a chance the DC motor controller might have this included but we would once again, like to give ourselves room to learn and experiment. Another consideration for the motor controller is the likely need to employ Pulse Width Modulation (PWM) in order to control our linear actuators at precise speeds of our choosing at a constant and steady rate. Thus, we would like to have multiple options for PWM channels as well.

In our project, the chosen microcontroller will manage communications and inputs from a diverse array of peripherals, including push buttons, a DC motor controller connected to two linear actuators, potentiometers on the actuators for feedback, a Raspberry Pi for data exchange, a display panel for user interaction, and load cell sensors for weight measurements, among potential others. Consequently, the microcontroller's support for various communication protocols is crucial to accommodate this wide range of peripherals. We intend to utilize the three primary communication protocols: Serial Peripheral Interface (SPI), Universal Asynchronous Receiver Transmitter (UART), and Inter-Integrated Circuit (I2C), which are anticipated to meet most of our interfacing needs with the planned peripherals. Nevertheless, recognizing the inherent strengths and limitations of each protocol, we aim to incorporate design flexibility to easily integrate additional peripherals or switch protocols if necessary. Therefore, selecting a microcontroller that offers multiple channels or options for SPI, UART, and I2C is a priority. Additionally, we are considering the inclusion of an Analog to Digital Converter (ADC) in our design, to accommodate sensors that provide analog outputs, noting that the DC motor controller might already feature this capability. Additionally, precise speed control of the linear actuators, achievable through Pulse Width Modulation (PWM), necessitates a microcontroller with ample PWM channels. This will allow us to adjust the actuators' speeds accurately and maintain a consistent rate.

Another similar, but equally important aspect to consider when choosing our MCU are the availability of general-purpose input/output (GPIO) pins. Most MCU’s we have been researching have at least 20 GPIO pins which would likely accommodate our needs; however, we recognize things could change at any time during our prototyping phase. We also recognize that the total number of GPIO pins listed on an MCU’s specifications sheet could be deceiving at first glance. For example, many of the pins that are labeled as GPIO have multiple functionalities and are tied to important functions such as PWM or ADC. So we have decided to aim for a board with more than enough GPIO pins.

Another similar, but equally important aspect to consider when choosing our MCU are the availability and versatility of general-purpose input/output (GPIO) pins. While most MCUs we've evaluated include a baseline of around 20 GPIO pins, likely sufficient for our initial design, we're mindful that project requirements could shift unpredictably during the prototyping phase. It's important to recognize that the total GPIO count provided in an MCU's spec sheet might not offer a complete picture; many GPIO pins are multifunctional, serving essential roles in specialized tasks such as Pulse Width Modulation (PWM) or Analog to Digital Conversion (ADC), which could limit their availability for generic I/O purposes. Therefore, we're inclined to select an MCU offering an ample number of GPIO pins, surpassing our present needs. This strategy aims to afford us the flexibility to accommodate unforeseen changes and additions to our project, ensuring we're not restricted by hardware limitations.

Memory considerations play a pivotal role in ensuring our design remains flexible and scalable without being constrained by codebase size or the inclusion of various libraries. Our investigation into memory requirements revealed the challenge of estimating the precise memory footprint for our microcontroller (MCU), as it's influenced by both our code and the libraries we incorporate. Given that modern compilers optimize through link time optimization (LTO) by only including necessary library components, memory management becomes more efficient. However, we're planning to choose an MCU with ample memory to ensure we have the freedom to use any libraries we find useful without memory constraints. This decision, aimed at future-proofing our project, allows us to focus on developing logical and efficient solutions within our time constraints, rather than rewriting code or eliminating libraries due to memory limitations as our Senior Design project progresses. Small projects might suffice with 32KB to 64KB of flash memory but considering our need for a range of functionalities and the inclusion of various libraries, opting for an MCU with at least 128KB to 256KB of flash and 16KB to 64KB of RAM would provide a comfortable buffer. This generous memory allocation ensures our project remains robust and adaptable, supporting our evolving requirements and facilitating innovation and growth without hardware restrictions.

In selecting the clock speed for our microcontroller (MCU), 16MHz emerged as a well-considered baseline, informed by an evaluation of low to medium-end MCUs used in various home-based and educational projects, including notable development boards like the Arduino Uno Rev3 and the MSP430FR6989 LaunchPad, both of which operate at this speed. This choice was reinforced by our firsthand experience with the MSP430 in an embedded systems course, where it proved adept at handling a wide range of tasks, from interfacing with sensors to managing communication protocols, suggesting that 16MHz is sufficiently robust for diverse applications. While the adage 'more is almost always better' often holds in the context of MCU specifications like clock speed and memory—especially when considering budgetary allowances and desired functionalities—this principle is counterbalanced by considerations of energy consumption. Higher clock speeds, while potentially enhancing performance, significantly increase power demand. Therefore, if opting for an MCU with a clock speed substantially above 16MHz, careful attention to power management strategies, such as utilizing clock dividers and low-power operational modes, becomes crucial to maintain efficiency and reliability. Consequently, 16MHz stands as our preferred minimum, guiding us toward selecting the highest feasible clock speed within our project's specifications and budget constraints, aiming for a balance between performance, cost, and energy efficiency, and ensuring our system is both adaptable and capable of scaling with project demands.

As we delve into our system's design, a pivotal aspect we're evaluating is the need for multiple cores or the integration of a real-time operating system (RTOS) functionality. Opting for FreeRTOS, a lightweight, open-source RTOS, could afford us granular control over task management and the ability to employ multithreading, ensuring seamless task execution without interference. However, the necessity of implementing an RTOS like FreeRTOS in our project warrants further exploration. Effective task scheduling and resource management might also be attainable through a meticulously structured software approach, utilizing timers and interrupts for efficient task switching. This consideration necessitates additional research to fully understand our project's requirements. Ideally, we aim to choose a microcontroller (MCU) that keeps our options open, allowing us the flexibility to incorporate an RTOS should our project's complexity and performance criteria demand it.

Additionally, deciding on the microcontroller unit for our project, a pivotal consideration for our group was the richness of learning resources, community support, and the extent of documentation available. Given the venture into largely uncharted territories for our team members, the accessibility to resources that facilitate self-education on necessary technologies and features is paramount. We are inclined towards selecting a board that not only is compatible with comprehensive integrated development environments (IDEs) but also boasts a substantial library ecosystem to mitigate our learning curve amidst the tight deadlines of our senior design project. Achieving a balance between user-friendliness and complexity to deliver a sophisticated, fully functional project within our time constraints is critical. This balance is also vital for arming us with the knowledge and practical experience necessary for a smooth transition into the professional realm post-graduation. The temptation to default to components with extensive Arduino library support for their simplicity is considerable. Nonetheless, opting for the path of least resistance without due forward-thinking introduces inherent risks, including limited portability, scalability challenges, potential negative perceptions among industry professionals, and compromised real-time performance. That said, outright dismissal of the Arduino platform may be premature. Investigating ways to harness Arduino libraries within a more advanced IDE could present a balanced solution, though this avenue demands further exploration to ensure seamless code compilation. On the other hand, choosing an MCU with lacking community support, sparse documentation, or a limited selection of libraries could severely hamper our project's progress, potentially derailing our timeline over trivial issues. Thus, our search is for a professionally challenging yet accessible MCU option that doesn't necessitate reinventing the wheel for each aspect of our implementation. This strategy aims to not only meet our project's immediate needs but also ensure we're well-prepared for future professional challenges, combining the drive to push our technical boundaries with the practical necessity of timely project completion.

One of the final, yet crucial, considerations for selecting our microcontroller unit hinges on the availability of a consistent and reliable inventory. The ideal MCU for our project becomes meaningless if we're unable to procure it in time for the prototyping phase and subsequent construction of our printed circuit board (PCB). Therefore, our strategy involves shortlisting several viable MCU options and researching both their market availability and cost per unit. Price, of course, plays a pivotal role in a project like ours. While individual components priced at ten or twenty dollars might seem economical at a glance, the cumulative cost can escalate rapidly, significantly impacting the overall budget by the project's end. This consideration is especially poignant for us as students operating without substantial financial resources, emphasizing the necessity of frugality in our project management. Moreover, this practice mirrors a critical aspect of project planning in the professional realm; the industry constantly grapples with the delicate balance between cost and performance. Optimal component selection goes well beyond mere technical suitability, entailing a careful evaluation of financial implications. Indeed, superior performance is always within reach with a higher expenditure, yet adhering to a predefined budget is paramount. Overspending can jeopardize the project's viability, rendering it unattractive or impractical from a commercial standpoint. Consequently, our decision-making process not only reflects our immediate academic objectives but also instills a foundational principle of project management in the industry: the imperative to balance technical requirements with economic constraints, ensuring the deliverable remains within budgetary bounds while meeting or exceeding performance expectations.

Table 11 – Comparison of Acceptable Microcontroller Options

Microcontroller	ATmega328P (PDIP)	MSP-430fr6989	ESP32-WROOM-32E-N8
Clock Speed	16 *MHz*	16 *MHz*	240 *MHz*
Communication Protocols	6 PWM 1 USART 1 SPI	14 PWM 2 UART 4 SPI	16 PWM 3 UART 4 SPI
GPIO	23 GPIOs	83 GPIO	26 GPIO
Memory	32KB Flash 2KB SRAM	127KB FRAM 2KB RAM	8MB Flash 520KB SRAM
Operating Voltage	1.8 - 5.5 V	1.8 - 3.6V	3 – 3.6V
Availability	49,053 in stock on Mouser $2.65 each	990 In stock on Mouser $8.70 each	1,270 in stock on Mouser $2.80 each

After careful consideration, our group has selected the MSP430FR6989 as our MCU of choice, over the ATmega328P and ESP32-WROOM-32E-N8. The ATmega328P was not selected primarily due to its lack of memory compared to the other two options. Despite its higher cost, the MSP430FR6989's extensive GPIO capabilities, with 83 pins, and its diverse communication protocols (SPI, UART, I2C) afford us the desired flexibility. It should be noted that although the MSP430-fr6989 MCU is more expensive, we will be saving money in the development phase due to one of our team members already owning a development board with this MCU incorporated. While its 16MHz clock speed is slower than the ESP32's 240MHz, we deem it sufficient for our project's needs, particularly given our group's prior experience with this MCU and Dr. Abichar's expert guidance. Although the RTOS support for the MSP-430fr69 is less robust than the ESP32's, we are exploring workarounds for efficient task management if needed. This decision balances our technical requirements, project familiarity, and expert support, positioning us for successful project execution.

Table 12 – Detailed Comparison of Acceptable Microcontroller Options

Microcontroller	ATmega328P (PDIP)	MSP-430fr6989	ESP32-WROOM-32E-N8
Clock Speed	16 *MHz*	16 *MHz*	240 *MHz*

Communication Protocols	6 PWM 6 10-bit ADC 1 USART 1 SPI 1 I2C	14 PWM 16 12-bit ADC 2 UART 4 SPI 2 I2C	16 PWM 18 2*12-bit ADC 3 UART 4 SPI 2 I2C
GPIO	23 GPIOs	83 GPIO	26 GPIO
Memory	32KB Flash 1KB EEPROM 2KB SRAM	127KB FRAM 2KB RAM 256B ROM	8MB Flash 520KB SRAM 448KB ROM 16KB SRAM in RTC
Power Consumption	Operating Voltage: 1.8 - 5.5 V Operating Current: 0.2mA Active Mode 0.1uA Power-down Mode 0.75 uA Power-save Mode	Operating Voltage: 1.8 - 3.6V Operating Current: 100uA/MHz Active Mode 0.4uA (typical) Standby 0.2uA (typical) Shutdown	Operating Voltage: 3 – 3.6V Operating Current: 5uA Hibernation Mode
Availability	49,053 in stock on Mouser $2.65 each	990 In stock on Mouser $8.70 each	1,270 in stock on Mouser $2.80 each
IDE	Arduino, Atmel Studios	CCS	VSC with ESP32-IDF ESP32-IDF Arduino
Additional Features	Arduino Libraries are built with this chip in mind Mounting style: through hole	Experience with via coursework, Dr. Abichar’s recommended choice Mounting Style: SMD/SMT	FreeRTOS support, Dr. Weeks’s recommended choice Mounting Style: SMD

3.2.1 Raspberry Pi

The project goal is to create a smart ergonomic tracking desk. One such feature discussed was to determine if a user is present using facial tracking. The software and library selected was decided in section 3.2.2 Facial Tracking Software and 3.2.7 Programming Language Computer Vision: Python. To run the facial tracking software, Raspberry Pi was selected because of the wide capabilities and community support of the device. Raspberry Pi Foundation in the United Kingdom created a series of single-board computers called Raspberry Pi. The goal of this foundation was to make computing education more accessible by creating an affordable computer. The basis of Raspberry Pi runs Linux and typically consists of general-purpose input/output pins that allow the user to control a multitude of electronic components for physical computing. There are five main Raspberry Pi models currently but only the latest 3 models will be compared and selected for this project. [13]

3.2.1.1 Raspberry Pi 3 Model B

Raspberry Pi 3 was released in 2016 and is the third-generation model in the series. This series features a Quad Core 1.2GHz Broadcom BCM2837 64bit CPU. A bonus of this system is the affordability of the system. This allows individuals around the world to learn to build hardware and programming projects. With this wide range of affordability there is a lot of user support. Since this is a few generations old that means this version is very stable since there are a few firmware updates that address some of the concerns with new models. One downside to this model is the limited amount of memory it comes with. This is due to keeping the model affordable, but this may make it not suitable for some projects. The main communication between the mobile and desktop application with the desk tracking features is going to be through Bluetooth. So, it is important that the Raspberry Pi model used can use Bluetooth. This model does come with a Bluetooth Low Energy (BLE) which is a lower power consumption Bluetooth that is also referred to as Bluetooth 4.0.

3.2.1.2 Raspberry Pi 4 Model B

Raspberry Pi 4 is the fourth-generation model in the series that was released in 2019. This model comes with Quad core Cortex-A72 (ARM v8) 64-bit SoC @ 1.8GHz. This model is sold with different sizes of RAM such as 1GB, 2GB, 4GB or 8GB. It also has 2 USB 3.0 ports that allow for faster data transfer. Another bonus feature of this model is that there are two power sources via USB-C and GPIO header. This model also comes with both Bluetooth 5.0 and Bluetooth Low Energy (BLE).

3.2.1.3 Raspberry Pi 5

Raspberry Pi 5 was the most recent model that was released in October 2023. This latest generation features a Broadcom BCM2712 quad-core Arm Cortex A76 processor @ 2.4GHz. A few notable new features of Raspberry Pi 5 are that it comes with a power button, Real-time clock (RTC), and UART debug port. This model was also built with what is known as the RP1 I/O controller. The package also has silicon that was designed by Raspberry Pi.

3.2.1.4 Comparison & Selection between the Models

The main functionality of the Raspberry Pi in this project is to run the facial tracking software and to relay information between the MCU and the mobile application. The main requirement for this is Bluetooth communication and the ability to run the face tracking software that was selected in Facial Tracking Software Selection. One requirement to download the library selected is at least 4GB of RAM. This automatically eliminates the Raspberry Pi 3 B because it only comes with 1GB of RAM. The last two models are very similar with the CPU of Pi 5 being much faster. Although the Pi 5 has a fast-processing speed, this is not needed to run the facial tracking software. The next consideration was cost. In this category, Raspberry Pi 4 B was cheaper compared to Pi 5. With the rest of the capabilities being similar the Raspberry Pi 4 B was chosen due to the cheaper price.

Table 13 - Raspberry Pi Comparisons

Model	CPU	RAM	Wi-fi	Bluetooth	Cost

Raspberry Pi 3 B	Quad Core 1.2GHz Broadcom BCM2837 64bit CPU	1GB	802.11n	4.1 Bluetooth Low Energy (BLE)	$41.09
Raspberry Pi 4 B	Broadcom BCM2711, Quad core Cortex-A72 (ARM v8) 64-bit SoC @ 1.8GHz	1GB, 2GB, 4GB, 8GB	2.4GHz / 5GHz 802.11ac	Bluetooth Low Energy (BLE) / Bluetooth 5.0	$55.00
Raspberry Pi 5	Broadcom BCM2712 quad-core Arm Cortex A76 processor @ 2.4GHz	4GB, 8GB	2.4GHz / 5GHz 802.11ac	Bluetooth Low Energy (BLE) / Bluetooth 5.0	$60.00

3.2.2 Display Panel Selection

This section will focus on the parameters that went into determining the display panel selection for the project. The relevant considerations are outlined below:

- Technology
- Supported Interface(s)
- Physical Size
- Power Characteristics
- Ease of use
- Graphical Flexibility
- Controller used for programming
- Availability/Price

The initial factor in our display selection process is the underlying technology, which directly affects performance attributes including response time, color representation, and viewing angles. Our project intends to employ an LCD display, but we're expanding our scope to include TFT LCD displays as potential options. A TFT LCD can provide a vivid, high-resolution image, perfect for intricate graphics such as project logos and personalized welcome messages. This capability could significantly elevate the user interface and branding experience. On the other hand, a standard character LCD, with its more basic output, aligns well with the fundamental requirement of showing the desk's height setting. While a character LCD would adequately fulfill our primary need, opting for a TFT display could afford us additional creative latitude to offer users an aesthetically richer interaction, should we choose to prioritize an enhanced visual engagement over simplicity.

The interface of the display panel plays a pivotal role in determining the ease of integration with our desk's control system. To conserve GPIO pins on our microcontroller unit (MCU), we have prioritized displays compatible with either SPI or I2C protocols—both of which are efficient in terms of pin usage. The choice between these communication protocols will also influence the intricacy of coding required for interaction between the MCU and the display. Opting for a TFT display necessitates more sophisticated programming to handle its rich graphical output, while a 16x2 character LCD, with its straightforward character-based output, promises a less complex implementation. Our decision will hinge on finding a balance between the desired functionality and the development resources available, ensuring streamlined communication within the device's architecture without overcomplicating the system.

The dimensions of the display panel are a key factor, as they need to complement the desk's design both functionally and visually. An optimally sized TFT display can offer enriched content and interactive opportunities, albeit at the expense of increased power usage and the necessity for more installation space. In contrast, the more compact character LCD, with its lower power requirement, offers a subtler presence. The display will be positioned under the desk surface, ensuring that the information is easily viewable without requiring users to adjust their posture. It's essential that the display is neither too small, which would make it difficult to read, nor excessively large, which could become obtrusive and not economical given the limited amount of information it needs to convey. The goal is to strike a balance that maximizes visibility and utility while minimizing distractions, power consumption, and costs.

Power consumption is a critical factor in our choice of display panel, especially considering our requirement for a backlight to ensure visibility regardless of ambient lighting. TFT displays generally have higher power needs, not just for the display itself but also for the backlighting that enhances visibility. Character LCDs, while more modest in power demand, also are available with backlighting for clear readability in any lighting condition. Although our standing desk will be powered via a wall outlet, which eases concerns about power limitations, energy efficiency remains a priority. Therefore, the decision between a power-intensive TFT and a more energy-efficient character LCD will also factor in the potential impact on overall energy consumption of the desk.

When considering ease of use, we are focusing on the programming aspect for our development team. Character LCDs typically offer a straightforward programming interface, which could accelerate development and simplify troubleshooting. Their simplicity would allow us to efficiently program the functionality needed to display the desk height setting. On the other hand, programming a full-color TFT display would be more complex due to its rich graphical capabilities. While this complexity could enhance the end-user experience with visually appealing interfaces, it requires more time and expertise to implement. Since our standing desk project demands a balance between functionality and development efficiency, we must weigh the benefits of a TFT's advanced features against the simplicity and quicker implementation time of a character LCD.

The selection of the display panel's controller is a significant consideration, as it directly influences our programming approach and the development timeline. A controller that has widely available drivers and libraries can greatly enhance our productivity, reducing both the learning curve and the time spent on development. For instance, a controller with substantial community support and pre-existing code examples would allow us to quickly integrate the display with our standing desk's system, streamline the coding process, and focus on refining user features. Therefore, while evaluating our display options, we are giving preference to those with controllers backed by robust support and resources, ensuring we can leverage these advantages to expedite our project's progress.

For the final consideration, availability and cost are of paramount importance. Ensuring that our chosen display is in stock avoids delays in development and keeps our project timeline on schedule. Equally critical is adhering to our budget, particularly during the prototyping stage and subsequent production of our final design. We seek a display panel that is both economically priced and readily available, allowing us to manage our resources effectively and avoid costly hold-ups. This pragmatic approach will facilitate a seamless development process and contribute to the overall financial feasibility of project.

Table 14 –Display Panels Comparisons

Feature	**CFAF128128B1-0145T**	**CFAF80160A0-0096TN**	**NHD-C0216CZ-NSW-BBW-3V3**
Technology	Full Color TFT, 128 x 128 Dot Matrix	Full Color TFT, 80 x 160 Dot Matrix	COG (Chip-on-Glass) 16 x 2 Character LCD
Interface	SPI	SPI	SPI or I2C
Size (W x H x D) (mm)	Module Dimension: 33.3 x 38.2 x 2.3 Active Area: 25.498 x 26.496	Module Dimensions: 13.5 x 27.95 x 1.54 Active Area: 10.8 x 21.696	Module Dimension: 41.4 x 24.3 x 4 Active Area: 37.6 x 12.8
Controller (integrated)	Sitronix ST7735S	Sitronix ST7735S	Sitronix ST7032
Availability/ Price	>1000 in stock from Crystalfontz $9.21 each	>1000 in stock from Crystalfontz $12.58 each	>1000 in stock from Mouser $12.75 each

Final Determination TBD****

Table 15 – Detailed Display Panels Comparisons

Feature	**CFAF128128B1-0145T**	**CFAF80160A0-0096TN**	**NHD-C0216CZ-NSW-BBW-3V3**
Technology	Full Color TFT, 128 x 128 Dot Matrix	Full Color TFT, 80 x 160 Dot Matrix	COG (Chip-on-Glass) 16 x 2 Character LCD, White Backlight
Interface	SPI	SPI	SPI or I2C
Size (W x H x D) (mm)	-Module Dimension: 33.3 x 38.2 x 2.3, -Active Area: 25.498 x 26.496	-Module Dimensions: 13.5 x 27.95 x 1.54 -Active Area: 10.8 x 21.696	-Module Dimension: 41.4 x 24.3 x 4 -Active Area: 37.6 x 12.8
Power Characteristics	-Supply Voltage for Logic (VDD): 3.0 Min, 3.3 Typ, 3.6 Max V,	-Supply Voltage for Logic (VDD): 3.0 Min, 3.3 Typ, 3.6 Max V,	-Supply Voltage (VDD): 3.0 Min, 3.3 Typ, 3.6 Max V, -Supply Current (3.3V):

	-Supply Current for LCM (3.3V): 1.7 Typ, 2.55 Max mA, -Input High Voltage: 0.7 * VDD Min, VDD Max V, -Input Low Voltage: GND Low, 0.3 * VDD Max V, -Backlight Supply Current (3.2V): 20 mA Typ, -Backlight Supply Voltage: 2.7 Min, 3.0 Typ, 3.3 Max V	-Supply Current for LCM (3.3V): 2.0 Max mA, -Input High Voltage: 0.7 * VDD Min, VDD Max V, -Input Low Voltage: GND Low, 0.3 * VDD Max V, -Backlight Supply Current (3.2V): 20 mA Typ, -Backlight Supply Voltage: 2.8 Min, 3.0 Typ, 3.3 Max V	40 Min, 170 Typ, 300 Max uA, -Supply for LCD (contrast): 5.2 Min, 5.5 Typ, 5.8 Max V, -Backlight Supply Voltage: 3.0 Min, 3.1 Typ, 3.2 Max V, -Backlight Supply Current (VLED = 3.1V): 10 min, 30 Typ, 36 Max mA
Optimal Viewing Angle	Top 35 degrees, Bottom: 15 degrees, Left/Right: 45 degrees, Viewing Direction: 6 o'clock	Top/Bottom/Left/Right: 80 degrees, Condition: Contrast Ratio >= 10	Top: 20 degrees, Bottom/Left/Right: 40 deg Viewing Direction: 6 o'clock
Controller (integrated)	Sitronix ST7735S	Sitronix ST7735S	Sitronix ST7032
Availability/ Price	>1000 in stock from Crystalfontz $9.21 each	>1000 in stock from Crystalfontz $12.58 each	>1000 in stock from Mouser $12.75 each

Figure 4 - Side by side Visual Comparison of Displays

3.2.3 Programming Language for Embedded System Selection

C is renowned for its exceptional performance and direct hardware manipulation capabilities, vital in embedded systems where resource optimization is paramount. Its efficient memory management promotes compact code essential for the limited memory space in microcontrollers. This performance and memory efficiency make C highly suitable for real-time capabilities required in embedded systems. Despite these advantages, C's manual memory management and the absence of object-oriented programming necessitate more groundwork for developing complex applications, potentially slowing down development. This situation underscores the language's extensive use in environments where system-level control and efficiency outweigh the drawbacks of increased complexity and lower code reusability.

C++, by extending C with object-oriented features like classes, inheritance, and polymorphism, facilitates structured and maintainable code. It inherits C's performance and control while introducing abstractions that simplify complex system management. C++ enhances code reusability and modularity, crucial for scalable embedded systems development. However, the intricacies of its features may elevate the learning curve and risk of bugs. Despite these challenges, C++'s rich standard library and template support expedite development, demonstrating its capacity to balance performance with developer productivity, even in constrained environments. The advanced concurrency support in C++ further underscores its suitability for sophisticated embedded projects that demand both efficiency and advanced programming paradigms.

Python stands out for its simplicity and rapid development features, attributed to its high-level syntax and comprehensive standard library. Ideal for scripting and developing high-level applications, Python's ease of programming significantly accelerates the development process. Yet, its interpreted nature and resultant runtime overhead render it less fitting for the core, performance-critical tasks of microcontroller-based embedded systems. Although MicroPython attempts to bridge Python to embedded contexts, performance and memory limitations may still present challenges. Despite these concerns, Python's extensive ecosystem and support for embedded development through interfaces like MicroPython highlight its potential for certain aspects of embedded projects, particularly those not constrained by real-time performance or severe resource limitations.

Table 16 – Summary of Embedded Software Language

Feature	C	C++	Python
Performance	High	High	Moderate
Memory Efficiency	Excellent	Excellent	Good
Easy of Programming	Moderate	Moderate	High
Real-time Capability	Excellent	Excellent	Moderate
Object-Oriented	No	Yes	Yes
Embedded Ecosystem	Extensive	Extensive	Limited
Integration with Embedded Hardware and Sensors	Direct and extensive	Direct and extensive	Via interfaces like MicroPython

For our envisioned project, C surfaces as the primary choice for microcontroller programming due to its superior performance, efficiency, and precision in hardware control—qualities essential for the MSP430FR6989 microcontroller's real-time operation and sensor interaction. These advantages, coupled with the extensive development tools, IDE support, and the robust embedded development ecosystem, ensure that C provides a solid foundation for achieving the project's objectives while navigating the complexities of embedded system programming. [14]

3.2.4 Programming Language for Facial Tracking

Python is a high-level programming language with dynamic typing and binding. It is a popular object-oriented and interpreted language. A benefit to using this programming language is the user-friendly syntax. There is also no compilation step which can speed up the overall development cycle. Another benefit is that the Python interpreter is extremely efficient and when it discovers an issue it will raise an exception. This is an excellent feature because bad input or bugs in some other programming languages would cause segmentation faults. Whereas the Python interpreter will catch this error as either an exception or print a stack trace. Python is often compared to other programming languages such as JavaScript and Java.

JavaScript and Java are also another interpreted language like Python. The programs written in Java are usually expected to run faster than Python programs. However, python programs usually take less time to create, and the actual programs are usually shorter in comparison to the same Java program. Python also has an advantage over Java in that it uses variables and simple functions without the need for a class definition. JavaScript also has this advantage over Java in being object-based but that is all it has. While for Python it supports code reuse and large programs in a true object-oriented style. This is where inheritance and class can play a useful role. [15]

This project is using facial tracking to help determine if the user is present at the desk. In doing so, it is important to decide on the programming language that will be used for this task. Python is a possible choice for this portion of the project because it has powerful computer vision libraries such as NumPy, OpenCV and SciKit-image. Since Python has these libraries, this makes Python an ideal choice for the project. [16]

3.2.5 Facial Tracking Software Selection

Using a camera in conjunction with face tracking software was determined to be the best method out of the three options mentioned. For the facial tracking software there are various options available. A few considerations before picking the software are determining the device compatibility and ease of use. As a result of this consideration Raspberry Pi was selected due to the capabilities of the device and the wide community support. After determining the device that the potential software would be running on, five potential face tracking software were selected for comparison.

OpenCV is an open-source machine learning and computer vision software library. The library includes a comprehensive set with more than 2500 optimized algorithms and can be used for more than just facial tracking such as classify human actions, extract 3D models, follow eye movement and much more [17]. One of the main advantages of using

OpenCV is the potential to further expand the capabilities of the software because of the wide support this library has in terms of other algorithms. For example, classification of human action may become useful if this project wants to further improve the tracking on user movement to provide useful feedback. Another advantage to using this library is the vast amount of support. This includes C++, Python, Java, MATLAB for programming languages and Windows, Linux, Android, Mac OS for operating systems. Lastly the library is used by many well-established companies and individuals. This can make it easier to use because there may already be multiple answers to common problems since there is a wide usage of the library.

Dlib is a C++ machine learning and computer vision library that is also open-source and free. A few machine learning algorithms this library include are structural SVM for object detection, deep learning and general-purpose multiclass classification tools [18]. One main benefit of using Dlib is that the documentation of this library is known for being very complete and precise. Another advantage of using the Dlib library is the high-quality portable code that also has a good ratio of unit test lines. The reason having great portable code is important is because of ease of use in a project. This library also has image processing and tools needed for frontal face detection and pose estimation that is needed for this part of the project.

Face_recognition library is a simple face recognition library that can be used for facial tracking. This library was built using Dlib library's face recognition algorithm that was created with deep learning. The main advantage of this is the ease of use of this library and its high accuracy. This tool allows for simple face recognition through the command line on a folder of images and has an accuracy of 99.38% [19]. One disadvantage of this library is that it is only designed for face recognition and cannot be used for further expansion if more capabilities are desired in the future such as pose classification.

OpenFace is another free and open-source face recognition library using deep learning. It is a face recognition implementation that uses Torch and Python with deep learning techniques. Specifically, it uses FaceNet and Torch allows it to be used with either CUDA or CPU [20].

This this portion of the project is going to be running on Raspberry pi so it is important to choose the software that will work well on this device. With these considerations, Face_recognition library was chosen as the main library for facial tracking. It is simple and lightweight with an accuracy of 99.38%. The focus of this project is to provide useful ergonomic transitions and metrics through a combination of components. The main goal for facial tracking is accuracy and not of a wide range of object detections that the other libraries would be providing as the main source. OpenCV and Dlib will also be used in this project but won't be the main source of the tracking. OpenCV will be used to access the camera and Dlib library is used by Face_recognition library.

Table 17 - Facial Tracking Software Comparison

Software	**Interfaces**	**Accuracy**	**Use case**

OpenCV	Python	Depends on the data on which the model was trained	Camera, video manipulation, object tracking, computer vision libraries
Dlib	C++, Python	Accuracy of 99.38%	Camera, video manipulation, object tracking, computer vision libraries
Face_recognition	Python	Accuracy of 99.38%	Facial tracking
OpenFace	Python	Accuracy of 97.38%	Facial tracking and Pose tracking

3.2.6 Application Development Software

It was decided that the main application created will be for windows and android. This application will serve as an initial guide for first time users and store user preference settings for desk height. The user will have the choice to use either options of the windows or android application. To build these applications, a few options compared were react, react native and flutter.

3.2.6.1 React

React is a library created by Facebook that is used to build web and native interfaces [21]. React consists of building interfaces through pieces called components. Then these components are combined to create entire pages and apps. This works by using HTML inside JavaScript which makes the syntax look like HTML which makes it familiar to individuals with some web design experience. One major benefit to using React is the wide support and current usage in the community. Since React was created by Facebook, it has the support and resources from that major company. It also has been around for open-source use since 2013 which means that there is now a large community following and using React. One downside to using React is that since it was created with mainly web development in mind, it means other tools and plugins will be needed to create a desktop or phone application.

3.2.6.2 React Native

React Native is a JavaScript framework for creating mobile platforms that is based on React. Since it was created based on React, it allows those who are familiar with developing in React to easily switch over to React Native. Since React was created to be easy to use for those who already have basic web development experience, React Native by extension is intuitive to learn as well. Some call it native because it allows for design and management of code in a format that they are used to working with in web design. This makes it easier for those who are already familiar with web-based development to also write mobile applications. [22] React Native contains most JavaScript libraries with the ability to be shared between platforms. This makes development for both iOS and Android possible to simultaneously be created and worked on. React Native also uses APIs and native UI components while React uses traditional CSS, HTML and JavaScript. Both use the same syntax so users of React can easily transition to using React Native easily. A useful feature of React Native is that it can use platform features through JavaScript interfaces. Some of these platform features include visual, audio and Bluetooth. React Native also has useful capabilities for developers. One such feature is the ability to see changes without the need to rebuild the entire application. Tools that can shorten development time can save time that can be used in other areas.

3.2.6.3 Flutter

Flutter is another open-source software development platform that was created by Google in 2017. It was designed for building a multitude of applications such as android, iOS, Windows, Linux, and web browsers. Flutter works for a wide range of applications by running them through a virtual machine. Then the applications created through Flutter are compiled straight into machine code which allows for it to be cross platform compatible. [23]

Structurally Flutter works through widgets where these new widgets are used in other widgets until the desired application is created. Each widget can be specific components of the application such as button style, navigation bar, font, layout and more. Flutter also has access to the device's tools such as Bluetooth, camera and notifications which make this an ideal tool for developers of a wide range of applications. Flutter itself runs on the Flutter engine which is written using mainly C++. While the core engine was built using C++, the applications created by Flutter is completed using the programming language Dart. This programming language was developed by Google and is object-oriented, has garbage collection and is class-based. [24]

3.2.6.4 Comparison between the mobile development platforms

Each of the previously mentioned development platforms has its strengths and weaknesses. To select the best development platform for this project, the three platforms mentioned will be compared in this section. In the current project the main application is going to be for Android with a plan to also add a Window's application. React is known to be a great platform for developing web applications and can be used for making a desktop application with the use of a plugin. A reason to consider React in this project is that there is large community support for React since it has been around since 2015. React is also very user friendly and can easily be picked up if the developer has previous web programming experience. A major downside to React is that it is not really made for mobile programming so another platform would need to be used.

React Native is a tool that is mainly used with mobile programming. This application is a better fit than using React for this project because the main application is going to be an Android application. React Native also has a wide range of error reporting and debugging tools that enhances the development experience on this platform. This platform also shares the same syntax as React, so this makes it easy for developers to switch between the two platforms. However, in this project the current goal is to make a mobile application with a desktop counterpart. React Native was mainly created for mobile applications and not for applications on the desktop. As a result, React Native by itself would not serve as a good tool for this project. The platform would need to be used conjunctionally with React to be of full use to this project. Using both platforms could work as they share the same syntax. However, they are structured differently from each other, so it is not easy to share code from both applications.

Flutter is considered very new to the development world. This means there are less tutorials and community support. There is also the chance for early libraries to be quickly retired and replaced because the support is relatively new compared to React and React Native. Although it is new compared to the other platforms, it has gained a great deal of traction because it was created by Google. Another disadvantage to using flutter is that for testing android applications there is the need for using android studios for an emulator if one does not have a device available. However, this limitation can be overcome by using an actual android phone for development. Flutter uses a new programming language called Dart. This programming language was created by Google for Flutter. Through this it uses widgets, and the structure does not resemble traditional html or JavaScript like React and React Native. Even so Flutter was created to be object-oriented, so it is easy to pick up for most programmers.

Even though Flutter has a few disadvantages it still has a lot of advantages. One major advantage is the ability for hot reloading and seeing live changes without the need for a build. This speeds up development a great deal and saves countless hours. Flutter was also made for creation of applications across multiple platforms. This means that mainly only one application needs to be created and it can be complied on for different devices. This allows for easy sharing of code between applications and potentially ease the amount of code needed overall. Another benefit to Flutter is that it was created by Google which is a large company. This means that it will have support for a long time and have a better chance of being adopted into the community in the long term.

In conclusion, React and React Native by themselves would not be a good fit for the project. However, using both together would make them a good combination for this project. Flutter on the other side would be ideal for the project by itself since it would not need another platform to perform well for the project. Overall, the most influential factor in deciding between the platforms is the experience of the team in using each. This is because no matter how long one has been programming, it takes time to learn a new platform. This means that it will save time to use the platform that the team has the most experience in. Most of the members on the team do not have experience in mobile or web development. However, the main team members designing and building this portion of this project do have experience in mobile and web development, so it is important to decide on a platform to use based on their experience. The reason for this is that since they have experience in that field, they can easily share the knowledge and skills with the other members. That specific team member has experience building applications with Flutter and React. To limit the number of platform setup it would be best to only use one. With that consideration, this would mean that Flutter would be the most ideal fit and is what the team decided to use for this project.

Table 18 - Comparison Table of development platforms

Development Platforms	Application	Team Experience with Platform	Use case
React	Web applications	- 1 member with experience on this platform	- Only used for web development
React Native	Mobile applications	- 0 members with experience on this platform	- Only used for mobile development
Flutter	Cross platform applications	- 1 member with experience on this platform	-Used for both mobile and web development

Chapter 4 - Standards and Design Constraints

This chapter will consist of three sections. The first section of this chapter will include a discussion of one to two standards in detail. The second section will be concerned mainly with discussing two to three design constraints in detail. The third section will include the remaining relevant standards and design constraints of the project that must be included but will be discussed briefly.

Within each section, headers have been included to divide each part and technology into its own subcategory. This has been done to enable easy navigation to find specific parts and technologies used.

4.1 Standards

This section will be concerned with a discussion of the main standards that will be used for our automatic desk project. Information from this section was sourced mainly from the manufacturers of the standards as well as various standards licensing committees. Information in this section was summarized from the technical documentation for the most relevant parts to be included in the project.

4.1.1 Standard for LCD Communication Through SPI

Information from this section was taken from standard document ETSI TS 103 713 V18.0.0. This was relevant for the section of our project concerned with our LCD because it leverages the SPI interface for communication between the microcontroller and display module.

The Serial Peripheral Interface (SPI) is a synchronous serial communication protocol widely used in embedded systems for connecting microcontrollers and peripheral devices. Known for its simplicity and speed, SPI facilitates full-duplex communication between a single master device and one or more slave devices. This section outlines the operational principles, signal characteristics, and implementation guidelines of SPI.

The first part to be discussed are the operational principles of SPI. SPI operates on a master-slave architecture, where the master device initiates communication and controls the clock signal. Communication occurs over four primary lines:

- Master Out Slave In (MOSI): Transfers data from the master to the slave.
- Master In Slave Out (MISO): Carries data from the slave back to the master.
- Serial Clock (SCK): Clock signal generated by the master to synchronize data transmission.
- Slave Select (SS): Active-low signal used by the master to enable individual slave devices.

Data transmission is full-duplex, allowing simultaneous data exchange between the master and the slave. Each SPI transaction begins with the master selecting a slave device by pulling its SS line low and ends with the SS line being released high.

The next part of this section will discuss the signal characteristics of the SPI protocol for data transmission. The characteristics for the signal can be broken down into the following sections:

- Clock Polarity (CPOL) and Clock Phase (CPHA): SPI communication can operate under four different clock modes determined by two parameters: CPOL (clock polarity) and CPHA (clock phase). These parameters define the idle state of the clock signal and the data capture edge, allowing for compatibility with devices having different timing requirements.
- Data Frame Format: SPI does not inherently specify a data frame size; however, 8-bit data frames are most common. Systems can configure the frame size to accommodate specific needs, ranging from a few bits to several words.
- Speed: The SPI protocol does not impose a maximum clock frequency, making the achievable speed device-dependent. Factors such as the microcontroller's capabilities, the slave device's response time, and signal integrity considerations (e.g., cable length and electromagnetic interference) influence the operational speed.

The next section discusses the best practices and implementation guidelines for incorporating SPI into a design as per the information included in the standards document.

Implementing SPI communication requires attention to hardware capabilities, software configuration, and signal integrity. Key considerations include:

- Hardware Selection: We chose specific microcontrollers and peripheral devices with SPI support that will meet the project's speed, power, and compatibility requirements. We also assessed the number of available SPI ports and slave select lines to accommodate the desired peripherals.
- Software Configuration: We will utilize our microcontroller's SPI module configuration settings to set the clock polarity and phase, data frame size, and clock frequency. This also includes implementing robust error handling and data validation mechanisms to ensure reliable communication.
- Signal Integrity: We will ensure proper PCB design practices to minimize signal degradation and electromagnetic interference. This will involve using pull-up and/or pull-down resistors on the SS lines, employing signal conditioning techniques, and implementing proper grounding and shielding methods.

SPI's versatility allows its application across various domains, from simple sensor data acquisition systems to complex multimedia interfaces. Although SPI's fundamental operation remains consistent, variants and extensions exist to cater to specific needs that may be required for the design of our project. These include quad-SPI (QSPI) for higher data throughput and multi-master SPI configurations for dynamic systems requiring multiple controlling devices.

The standard documentation concerning the SPI protocol shows that it embodies a crucial component in the design and implementation of embedded systems. It is for this reason that it is important for use in our project's design. By adhering to the operational principles, signal characteristics, and implementation guidelines outlined in ETSI TS 103 713 V18.0.0, we can leverage SPI's full potential to achieve efficient, reliable communication between a microcontroller and peripheral devices, such as our LCD. As electronic systems evolve, the foundational role of SPI facilitating device interconnectivity continues to be of paramount importance.

4.1.2 Standard for Bluetooth Communication

Bluetooth will be used in our project for communication between our Raspberry Pi and application. Information for this document has been taken from the Bluetooth Core Specification document for the revision version 5.3. The revision date for this document is July 13, 2021. This document was prepared by the Core Specification Working Group which is part of the Bluetooth Special Interest Group (SIG), which oversees the development of the specification, manages the qualification programs, and protects the trademarks. The document defines the technologies required to create interoperable Bluetooth devices.

Bluetooth technology is a global wireless communication standard that enables the exchange of data between fixed and mobile devices over short distances. Utilizing UHF radio waves in the ISM band from 2.400 GHz to 2.485 GHz, Bluetooth facilitates connectivity in a wide range of products including phones, speakers, cars, and smart home devices. Governed by the Bluetooth Special Interest Group (SIG), the standard has evolved through various versions, enhancing speed, range, and security.

Conceived as a wireless alternative to RS-232 data cables, Bluetooth technology was named after Harald Bluetooth, a 10^{th}-century king known for unifying Denmark and Norway. Introduced in the late 1990s, the standard aimed to unify different industries under one wireless protocol. The Bluetooth SIG, formed by leaders in telecommunications, computing, and consumer electronics, continues to expand and refine the specifications.

Bluetooth operates on a radio-frequency standard that allows devices to communicate in the 2.4 GHz band. It uses a spread spectrum, frequency hopping, full-duplex signal at a rate of 1,600 hops/sec. This method minimizes interference from other wireless devices and ensures secure communication. Bluetooth devices are categorized into three power classes: Class 1 (100 mW, up to 100 meters range), Class 2 (2.5 mW, up to 10 meters range), and Class 3 (1 mW, up to 1 meter range).

The Bluetooth stack is composed of a "controller" (the physical radio layer) and a "host" (handling the higher layer protocols). The core system architecture includes the

Link Controller (LC), Link Manager (LM), Logical Link Control and Adaptation Protocol (L2CAP), and Host Controller Interface (HCI). The LC and LM manage physical and logical links, respectively, while L2CAP provides multiplexing and segmentation of higher layer protocols. HCI serves as the interface between the host and controller.

Bluetooth technology defines a wide range of profiles that specify the general behaviors through which Bluetooth-enabled devices communicate with other devices. Profiles such as the Advanced Audio Distribution Profile (A2DP) for audio streaming, Hands-Free Profile (HFP) for voice calling, and Human Interface Device (HID) for connecting mice, keyboards, and other input devices ensure interoperability among devices from different manufacturers. Underpinning these profiles are protocols such as the Serial Port Profile (SPP) and Generic Attribute Profile (GATT), which define the underlying data structures and communication patterns.

Security is a fundamental aspect of Bluetooth technology, incorporating features such as pairing, encryption, and authentication. The Secure Simple Pairing (SSP) process uses a shared secret technique to protect against eavesdropping and man-in-the-middle attacks. Bluetooth devices also support transport layer security and encryption based on user-configurable keys, ensuring secure communication.

Bluetooth technology has significantly evolved, with major versions introducing improvements in speed, range, and energy efficiency. Notable versions include Bluetooth 2.0 + EDR (Enhanced Data Rate), offering faster data transfer rates; Bluetooth 4.0, introducing Bluetooth Low Energy (BLE) for low-power applications; and Bluetooth 5.0, which further increases range and speed and introduces capabilities for IoT devices.

Bluetooth technology is ubiquitous in modern life, found in consumer electronics, automotive, healthcare, and smart home devices. Its applications range from wireless audio and wearable fitness trackers to industrial monitoring systems. The future of Bluetooth lies in enhancing IoT connectivity, improving security features, and further increasing energy efficiency to enable new applications in smart cities, advanced healthcare, and beyond.

As a pivotal technology in the wireless communication landscape, Bluetooth continues to adapt and expand its capabilities to meet the evolving needs of users and industries. Its ongoing development by the Bluetooth SIG ensures that it remains at the forefront of secure, reliable, and convenient wireless connectivity.

4.1.3 Bluetooth Core Architecture

At the heart of the Bluetooth device is the Link Controller (LC), which operates within the physical layer. It is responsible for managing the physical channel and direct link between Bluetooth devices. This includes tasks such as frequency hopping sequence generation, timing and synchronization, and data packet transmission and reception.

The LC works closely with the baseband protocol, which defines the specifications for device discovery, connection establishment, and the types of packets exchanged between devices. The baseband protocol also manages the asynchronous and synchronous links, enabling both data and voice communication.

The Link Manager (LM) operates above the LC and is responsible for the establishment and management of the connection between Bluetooth devices. It uses the Link Manager Protocol (LMP) to communicate with the LM of other devices. LMP handles tasks such as pairing, authentication, and encryption setup. It also manages power control and ensures that communication parameters are optimized for the conditions of the link, adjusting the power and frequency of transmission as necessary to maintain a stable connection.

L2CAP provides multiplexing and segmentation of higher-layer protocols over the baseband. It abstracts the baseband and Link Manager's functionalities to the upper layers, allowing for the simultaneous communication of multiple higher-level protocols over a single physical link. L2CAP enables the segmentation and reassembly of large packets and provides both connection-oriented and connectionless data services to upper layer protocols and applications.

4.2 Software Standards:

4.2.1 ISO/IEC 9899:2011 – Programming Languages – C

In the selection of a programming standard for our project, we have opted for the ISO/IEC 9899:2011 standard, known as C11, owing to its modern features and strong emphasis on security and concurrency. This decision was underpinned by the capabilities of Code Composer Studio (CCS), our chosen development environment, which provides comprehensive support for ANSI C89, C99, and C11 standards. The alignment with C11 allows us to leverage CCS's features to the fullest extent, capitalizing on C11's advancements such as multi-threading, atomic operations, and improved memory alignment, which are pivotal for our project's goals in systems programming. [25]

By choosing C11, we ensure that our software conforms to the latest C standard supported by CCS, granting us the ability to write code that is both forward compatible and optimized for performance on current and future hardware architectures.

Chapter 5 - Comparison of ChatGPT with Similar Platforms

Developed by OpenAI, ChatGPT is an advanced language model trained by hundreds of billions of words from the internet. The latest version is powered by GPT-4, which is a part of a series of generative pre-trained transformers. ChatGPT can be used to perform a lot of tasks like classification, summarizing topics, and even perform error correction of code while responding with human like replies. ChatGPT is often compared to era changing technology like the iPhone because of the huge impact this technology is currently having in the world. One such consequence of this is the streamlining productivity that is also leaving groups of individuals to feel anxious about the potential risk of becoming unemployed due to these advancements. [26] [27]

5.1 Alternatives to ChatGPT

ChatGPT is great for certain applications, but it might not be a good fit for all needs. Also, due to high traffic, it sometimes reaches capacity, and the user cannot use it until it lowers to a certain point. It was mainly designed to engage in conversations in response to user prompts, and while it can be used for a wide range of activities there are alternatives to the traditional OpenAI ChatGPT platform. Some popular AI alternatives to ChatGPT include Chatsonic, Gemini AI, Codewhisperer, DeepL Write and Elicit. Each of these has slightly different uses and can be helpful in a variety of tasks.

5.1.1 Chatsonic

Chatsonic is an AI platform powered by GPT-4 as well as containing some of its own custom models. It was created by Writesonic and the main use of it is to fill in the limitations of ChatGPT. This includes providing real-time image, data and content creation capabilities that is not currently available on the OpenAI platform. [28] It also uses persona to customize AI chat experience. This works by creating distinct personalities and vocabulary which make it seem like the user is chatting to different individuals. It is also integrated with Google Knowledge Graph which can provide relevant and trending content on topic [26]. Another useful feature that OpenAI's ChatGPT is limited by is creating art. Chatsonic can create art using two different models, the Stable diffusion and DALL-E. Another useful feature is that Chatsonic has a chrome extension that enables generative AI capabilities on many websites. This extension has been used almost like a personal secretary that summarizes documents and replies to social media posts. Chatsonic also has an AI chatbot builder extension called Botsonic. This can be used to train ChatGPT on specified data for either business or personal use. [26]

Some similarities to ChatGPT are that it can remember previous parts of conversations and use it in generating a response to future questions in the same chat. Each of these chats can then be saved and used again when the user wants to continue a conversation topic. Like ChatGPT, Chatsonic also has a mobile application that supports all its features. It also offers free generative AI prompts that can be used on ChatGPT or Chatsonic without the need of an extension.

5.1.2 Gemini AI

To keep up with the latest AI race, Google announced that it is also producing its own AI model. Bard AI (renamed to Gemini AI recently) is also a chatbot like ChatGPT. Gemini AI was developed using Google's Transformer and Mixture-of-Experts (MoE) architecture [29]. Currently it is an experimental conversational AI service that shows promising results however is not quite on par with ChatGPT yet. Gemini AI just released version 1.5 and claims that its natural language processing capabilities have improved comprehension and response to user input with greater accuracy. It also claims to have reduced the restriction of having data limited to a specific year and they aim to have it be integrated as a future personal assistant that analyses input text and provides document summaries.

5.1.3 Codewhisperer

Although OpenAI's ChatGPT can generate code, it is not known for being the most accurate or consistent platform for generating code. A few AI platforms have focused its main functionality on generating code instead of a more traditional conversational bot like ChatGPT. One such platform is Amazon's Codewhisperer. Amazon created this platform to give developers an efficient way to debug, analyze and decipher code problems. It is not meant to be a replacement for coders but is supposed to make the developer's work easier in helping to identify problems faster. It does this by utilizing natural language processing techniques to review code and uses machine learning algorithms to identify errors in the code. Often a developer may take hours to identify a single problem and this platform aims to minimize the effort needed to identify and resolve issues in the code.

The main benefit to CodeWhisper is that it was designed to be user-friendly and intuitive. This is achieved by the variety of customizations which can be adjusted for use from beginners to advanced developers. Amazon also created this with the plan to be able to handle large code bases and made it integrated with popular development tools such as GitHub. Thanks to this it can be easily and quickly integrated into current existing projects which will support faster use rates of CodeWhisper adoption. [26]

5.1.4 DeepL Write

DeepL is a firm that specializes in AI language translation and created in 2017 in Germany. With language translation as the main goal of this company, DeepL created an AI assistant called DeepL Write. Currently this is still only a beta product, but it was created with the aim of being a writing assistant. This AI is meant to be used to help refine writing accuracy and quality. It currently provides helpful suggestions and recommendations on style, quality, phrasing, and tone. It also helps with identifying grammar corrections and suggestions to word choices to improve overall writing and communication. One advantage available on this platform is that there is the read aloud functionality. Currently OpenAI's ChatGPT platform does not have a built-in functionality that will read aloud the text. [30]

5.1.5 Elicit

Elicit is another AI platform that uses language models similar to GPT-3. The difference between this platform and OpenAI's ChatGPT is that Elicit was designed for helping the research process. This works through reviewing literature that researchers need to process. After inputting an initial inquiry to Elicit, it will then go through and summarize documents that are highly rated and related to the inquiry. The idea behind this platform is to provide summaries on dependable sources which can then be used in research. While this platform could be useful for getting summaries on potential research sources, many use this to find relevant papers. Oftentimes it is difficult to track down relevant sources so students and researchers alike will use Elicit to get relevant papers and to find other potential research that could be used as potential citations relevant to their research and work. [31]

5.2 Comparison of different Platforms to ChatGPT

This section will compare similar platforms to ChatGPT and discuss the potential use case of each.

A major benefit of using Chatsonic is that it was created to fill in the limitations of OpenAI's ChatGPT. One such limitation that Chatsonic fills in for is having access to the latest information. With Chatsonic having access to the latest information, this allows for more up to date generalization of relevant data. This feature could be useful for this project as it can be used to generalize the latest information regarding current breakthroughs. Another ChatGPT limitation that Chatsonic makes up for is being able to generate art. This feature could be useful for generating diagram layout ideas. Although it could be useful in generating diagram ideas, it does not guarantee the most efficient layout for the project needs. Hence this feature would be needless and could potentially create more problems than it is worth.

While showing promising results Gemini AI is still in its infancy stages compared to OpenAI's ChatGPT since it is not fully accessible to the public yet. Although this is the case, this platform can still potentially be of use soon as it was built by Google with plans to compete with OpenAI's ChatGPT. This brings potential usage as Google plans to integrate it with Google Nest. This in turn could potentially be integrated into this project by integrating existing google Nest into the smart desk and mobile app. However, that is beyond the scope of this project and would be more of a future expansion of this project.

Codewhisperer is a platform that aims more towards the developer community compared to ChatGPT. Although ChatGPT can generate code, it has issues with accuracy, and it doesn't always do a good job with analyzing the code. This grey area is what Codewhisperer aims to fill by providing a user-friendly platform for debugging and code analyzation. One downside to this platform is that for in-depth analysis and debugging, that means providing access to the code. This can cause potential issues with security as it has access to all the code given to it and therefore the company behind this platform would also have access to the code. There is also no guarantee that the generated code is one hundred percent correct. However, since this platform is aimed towards developers it is more correct in comparison to ChatGPT.

ChatGPT can be used as a writing assistant, but it struggles with refining and giving quality recommendations. This is what DeepL Write aims to achieve on their platform. Another useful feature of this platform is that it can read text aloud. Being able to read aloud text means that the user will be able to continue working without having to stop and read its suggested recommendations.

A major benefit to Elicit compared to the other platforms is that it was created to help with the research process. This means it can help save researchers hours by providing summaries on dependable sources. This is something that ChatGPT lacks because it doesn't have access to the latest documents and information after a certain cutoff time. While it was created with the idea of summarizing a great deal at once, it shines in helping researchers find relevant sources related to their current search. With this fast help in finding relevant sources, the researchers can focus on reading and understanding the sorted sources.

While each of these different platforms have their specializations, they are only useful in that specific context. This is where ChatGPT shines the most as it is a multipurpose platform that may one day have all these features in one area. As the popularity of AI platforms increases, it also brings with it many controversies with the increase and potential usage of it. Therefore, no matter how the platform is used, it should be used with caution and should not be something to be fully reliant on.

Table 19 - AI platform Summary

Platform	Usage	Pros	Cons
ChatGPT-3	- General conversation	- Very versatile platform that is widely used for a range of topics	- Doesn't have the latest news from the most recent years - The next tier is for paid members only
Chatsonic	- Generalization of information - Generation of art - Conversations	- Access to current events and information - Ability to generate art - Usage of Persona	- Potential ethical issues with the generation of art
Gemini AI	- General conversation - Smart home appliances integration	- Potential to increase the usability of smart home appliances with its integration into Google Nest	- Not fully accessible to the public yet - Features not fully developed yet
Codewhisperer	- Generation of code - Analysis of code	- Saves developers hours in debugging code - Can help speed up the development process by generating efficient code	- No guarantee that the generated code is 100% correct - Potential security issues
DeepL Write	- Writing assistant	- Gives useful writing suggestions and refinement - Ability to read text aloud	- Still only a beta product

Elicit	- Research assistant	- Summarizes documents from dependable sources - Can help researchers find potential sources in a shorter amount of time	- May have limited access to certain dependable sources

Chapter 6 - Hardware Design

Coming Soon…

Chapter 7 - Software Design

Coming Soon…

Chapter 8 - System Fabrication/Prototype Construction

Coming Soon…

Chapter 9 - System Testing and Evaluation

Coming Soon…

Chapter 10 - Administrative Content

This chapter will cover the administrative content of the project which includes finance, budget, and overall milestone for the project. This will be represented in three sections total.

10.1 Budget

Budgeting is a crucial part of sustainability for the U.P.R.I.G.H.T, and the price of this desk will make or break its feasibility. One goal of this project is to create a product with a budget that can maximize market longevity. Our aim is to create a price point that matches the standard rates near the middle of the market. A quick search online shows a plethora of small, cheap desks priced right around $100.00, however none of these desks have any programmable or automated features. As discussed in section 1.4, desks from Uplift are installed with similar functionalities as those envisioned for this project, however they are also quite expensive. The base model starts at $569.00 and ranges up to and over $2,000 [5]. Another similar example comes from Eureka Ergonomics' Ark Standing Desk line, offering their cheapest model at $2,000 as well [32]. Keeping this in mind, if the budget can achieve a price point on the lower end of these examples, the U.P.R.I.G.H.T should be able to have a few competitive advantages: not only will it include a sophisticated mat, but it would also include tracking functionality. However, all expenses for this project will be shared among the group members. To maximize these advantages, while not breaking the bank, the budget will be set at $800.00.

10.2 Bill of Materials

See Table 2 below for the estimated bill of material (BOM) needed to complete this project. The list is a general approximation of cost and will be updated as specific components are researched and selected. Also take note that some of the items included would not be in the final version of the U.P.R.I.G.H.T BOM. Duplicate items such as PCB and microcontrollers are included to ensure the capability for prototyping and demo throughout the design process. To guarantee that this project will operate under budget, these extra line items are included in the bill of material. The BOM shows a total price less than the budget set in the previous section.

Table 20 - Bill of Materials

Item	Estimated Cost	Actual Cost
Materials for Desk	$200.00	TBD
Office Floor Mat	$50.00	TBD
Load Cells	$20.00	TBD
Housing design for Load Cells	$10.00	TBD
AC/DC Power Supply Convertor	$20.00	TBD
PCB(s)	$50.00	TBD
MCU	$5.00	TBD
Development Board and Raspberry Pi	$70.00	TBD
Motor Control Module	$20.00	TBD
Linear Actuators	$150.00	TBD
LCD Display	$30.00	TBD
Push Buttons	$5.00	TBD
Housing Design for user interface	$25.00	TBD
Web Camera	$25.00	TBD
Misc. items	$50.00	TBD
Total:	**$750.00**	TBD

10.3 Project Milestones

Team 11 formed at the beginning of Senior Design I in the spring of 2024 with plans to attend Senior Design II in the summer of 2024. The following tables have been created to reflect the milestones and goals for this schedule selection.

Table 21 - Senior Design I Timeline Spring 2024

Task	Start Date	Anticipated End Date	Status
Project Idea Discussion	1/8/2024	1/17/2024	Complete
Project Selection and Committee Formed	1/17/2024	1/26/2024	Complete
Divide and Conquer Completion	1/22/2024	2/2/2024	Complete
30-Page Milestone	2/2/2024	2/23/2024	Complete
Individual System Design	2/2/2024	2/23/2024	Complete
60-Page Milestone	2/23/2024	3/22/2024	Complete
Individual System Testing	3/22/2024	4/5/2024	Current
90-Page Milestone	3/22/2024	4/5/2024	Current
Breadboard Prototyping	4/5/2024	4/19/2024	Not yet started
120-Page Milestone	4/5/2024	4/19/2024	Not yet started
Final Draft	4/19/2024	4/23/2024	Not yet started
Final PCB Design/Ordering	4/23/2024	4/30/2024	Not yet started

Table 22 - Senior Design II Timeline Summer 2024

Task	Start Date	Anticipated End Date	Status
PCB Assembly and Testing	5/13/2024	5/24/2024	Not yet started
System Integration/Testing	5/24/2024	6/21/2024	Not yet started
Practice Project Demo	6/21/2024	7/5/2024	Not yet started
Finalize Documentation	7/5/2024	7/19/2024	Not yet started
Practice Final Presentation	7/19/2024	7/26/2024	Not yet started
Final Presentation	TBD	TBD	Not yet started

Declaration

We hereby declare that we have not copied more than 7 pages from the Large Language Model (LLM). We have utilized LLM for drafting, outlining, comparing, summarizing, and proofreading purposes.

Appendix
Chapter 11 - References

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