BearMax: Social Robot for Social Skills and Emotional Regulation Project

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Section 2: Project Description

Project Narrative:

Robot Assisted Therapy is a growing field, especially for assisting those with Autism Spectrum Disorder. Those with Autism often struggle with recognizing facial expressions and understanding social cues. To help those with autism learn, different robots have been developed with varying degrees of success. One popular therapy robot is the NAO robot.[1] This small robot has been studied and has been proven to be quite effective at helping those with Autism, specifically young children with Autism, to learn and practice social skills. Another example is the BearMax robot, developed by a previous senior design team at the University of Central Florida.[2] Its robot was able to achieve a wide range of motion and was able to be integrated with a mobile application. However, these robots, along with others of its kind, are not without their problems. The NAO lacks the ability to perform facial expressions and has trouble with accurate voice recognition.[1] The BearMax Robot also lacks the ability to use facial expressions and has issues with its power. The developers also wanted to integrate a wearable stress detector bracelet, but were unable to complete it in time.[2] Other robots of its kind face similar issues; some of their major drawbacks include lack of facial expressions and lack of mobility.[1] Our project intends to improve upon these limitations. This group specifically wants to focus on making an improved version of the BearMax robot. We intend to create a version that has an improved stress detector system, more facial expressions, and better electronics.

Project Goals:

The main goal of this project is to create an avenue for children with autism, through the medium of a robotic companion, in order to help deal with the challenges they may face, especially as it comes to learning emotions and dealing with sensory overload. Specifically, we shall be tackling issues that limited the previous iteration of the BearMax robot in its function and building upon the many areas in which the team was able to make massive developments.

One massive drawback of the first design was that only a single breadboard strip was used for all electronics, and as a result once the current exceeded 1 ampere, the electrical system would fail, causing a loss of functionality temporarily until rebooting. A big part of what we desire is improving that electrical structure, implementing a PCB for the components and redesigning the system in order to allow for a larger current limit. Another issue of the previous group was the components for the wearable stress detection device arrived late, meaning that the central function of stress detection was unable to be met. Our goal is to interface the wearable stress detecting device with the robot in order to actually detect stress and allow the robot to respond in an appropriate manner, whether that be the robot itself calming the user, or signaling a caretaker. We plan the robot to have the ability to “see” a potential user in a demo mode if the wearable stress detection device is not currently being worn, but the robot is powered on through the use of computer vision software.

Furthermore, our team's goal is to improve upon the successes of the previous robot. Firstly, the previous robot was semi-autonomous. It did not need an outside controller to move it, but it still needed a caretaker or adult present. Our team plans to implement this in our new design of the robot. A further goal we have is to implement treads or wheels to allow BearMax to move around and detect users. Moreover, it still needs to be able to detect faces and read their emotions. It especially needs to be trained to recognize emotions within autistic children, as their facial expressions may be different from how neurotypical children would express emotions. The previous project was successful in having it recognize emotions. Our team wants to continue training it. Finally, the robot must non-verbally be able to calm the users. Its exterior shape and mannerisms must have a welcoming and comforting appearance. We have noticed that other social robots animatronics have a tendency to become creepy, especially when they are designed to resemble humans. This team aims to avoid that scenario. We plan on making the design smaller, if possible, and to give the robot more spherical shapes in the torso and eyes. That way, the appearance of the robot will seem gentle and safe.

Project Specifications:	
Cost	Less than 500 dollars to manufacture
Dimensions and Weight	The robot must be compact enough to fit within a home on a surface such as a table. The maximum weight should be around 20-30 pounds.
Power requirements:	Power supplied must be 12V. The step down converter must decrease the voltage for the components to 6V
LCD screen eyes	Each LCD "eye" must have a minimum resolution of 320x240 pixels. Or, the size of the LCD could range from 4x4 inches to 6x6 inches.

Stretch Goals

The stretch goals for this project mainly include things that would aid in the overall function of the robot and system. A main thing would be to reduce the size of the shells of the robot in order to minimize the footprint of the robot, as well as increase portability and allow for ease of mobility. Additionally, increasing the joints and dynamic range of mobility of the robot would allow for more fluid movement and flexibility. In order to give the robot the ability to feel more communicative, we also seek to add movable eyes that would track the user, increased verbal responses, and a softer/squishier exterior for the robot to allow for a more friendly tactile stimulation, as well as implement fully automated movement so that BearMax can track its user. Finally, we would create multiple different options for shells of the robot, perhaps not limited just to a bear design, allowing for user customizations options, as well as making all shells interchangeable with a robot, so a household would be able to swap the exterior in case of breakage, or a change of scenery. Although these goals would be nice to meet, and effective in the overall presentation, they may require more time and effort with the implementation of the various other technical features that are simply necessary.

Figure 1: Hardware Block Diagram

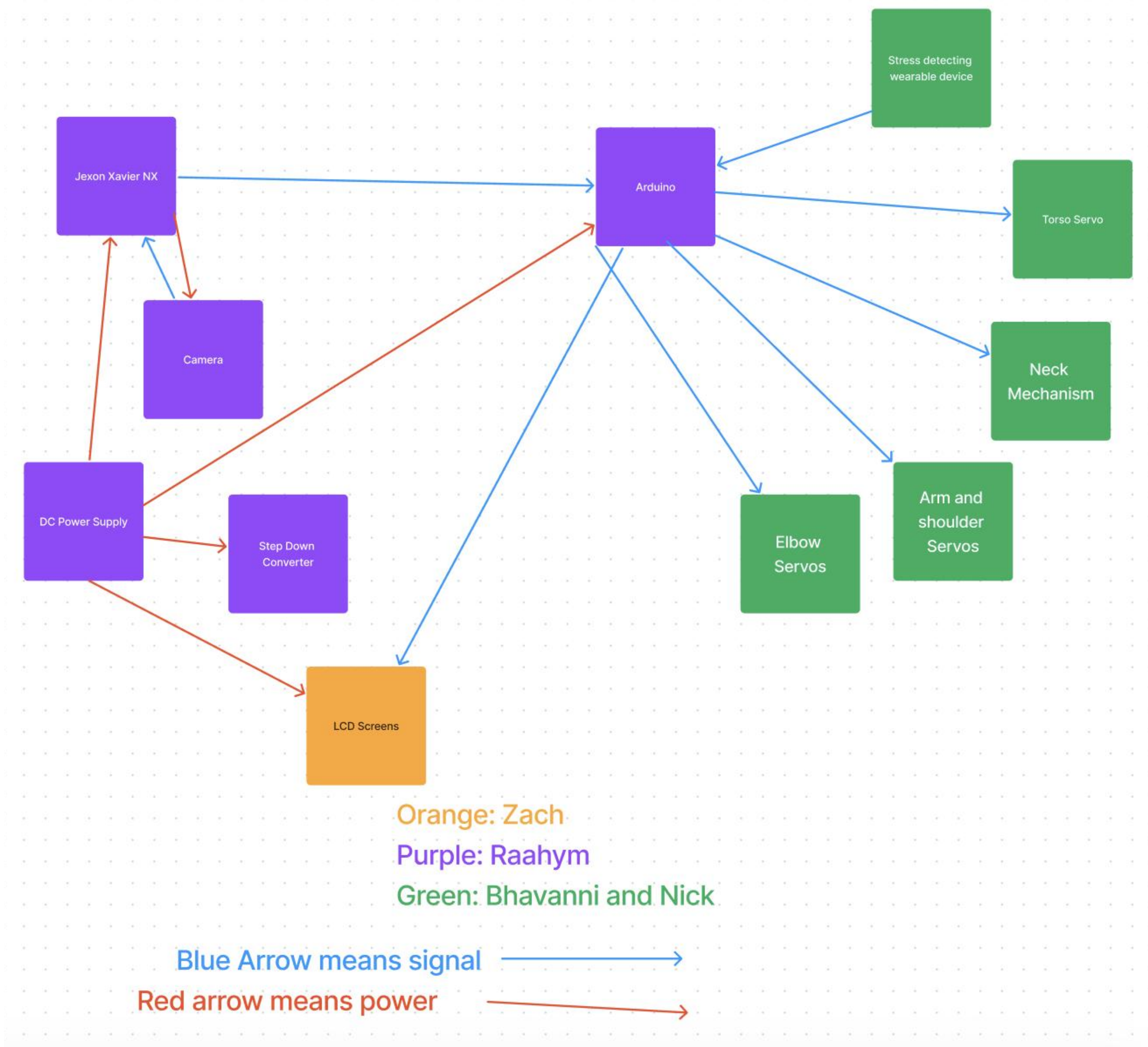


Figure 2: Software Block Diagram:

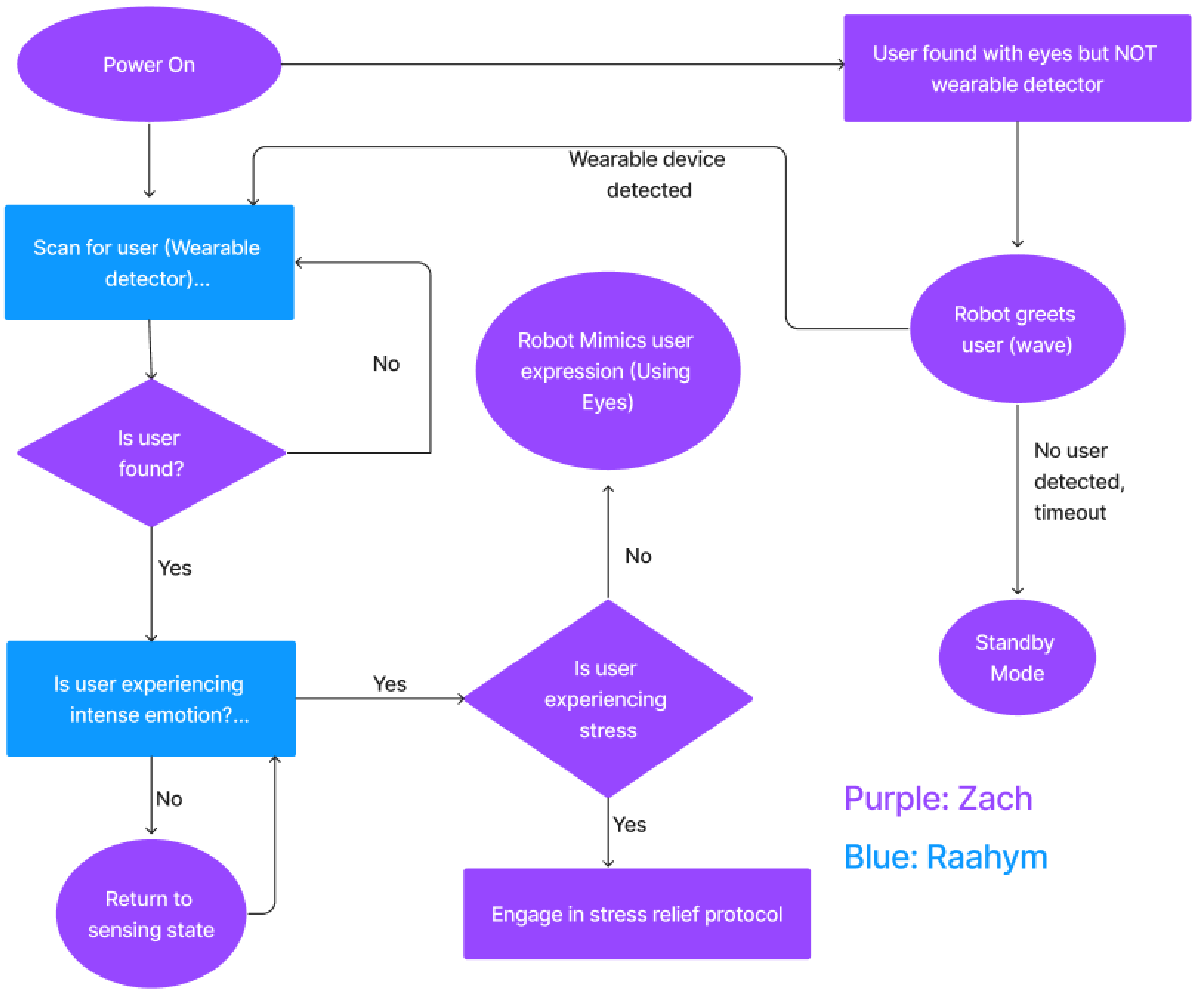


Figure 3: Function Breakdown

Figure 4: Initial Component Breakdown

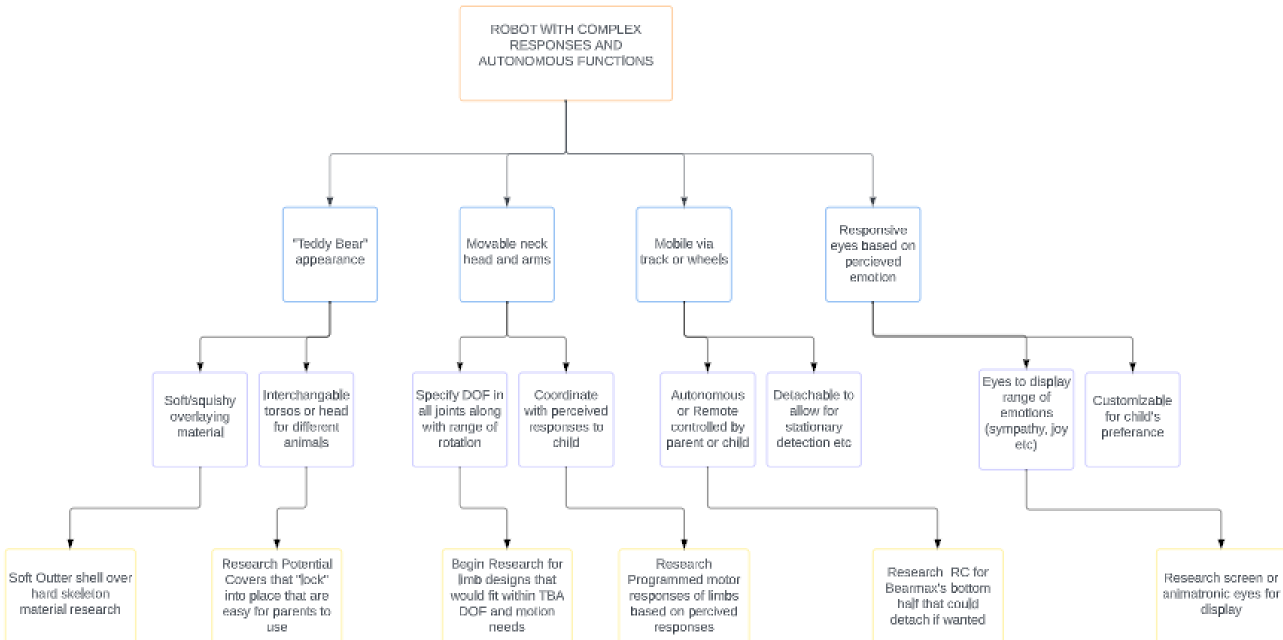


Figure 5: 3D Model of the BearMax Version 1

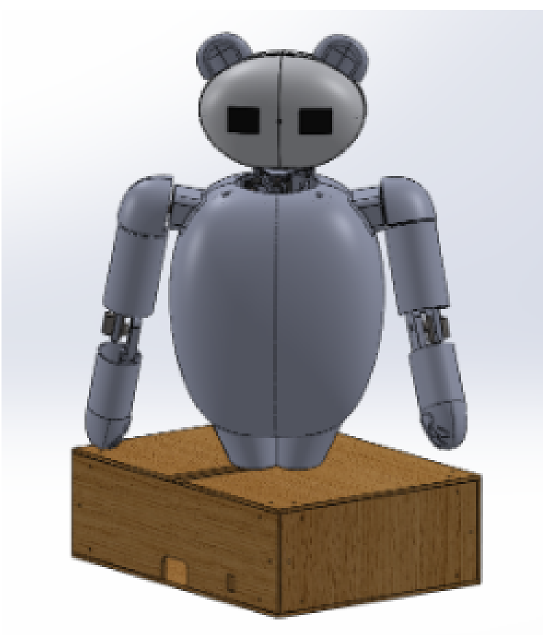
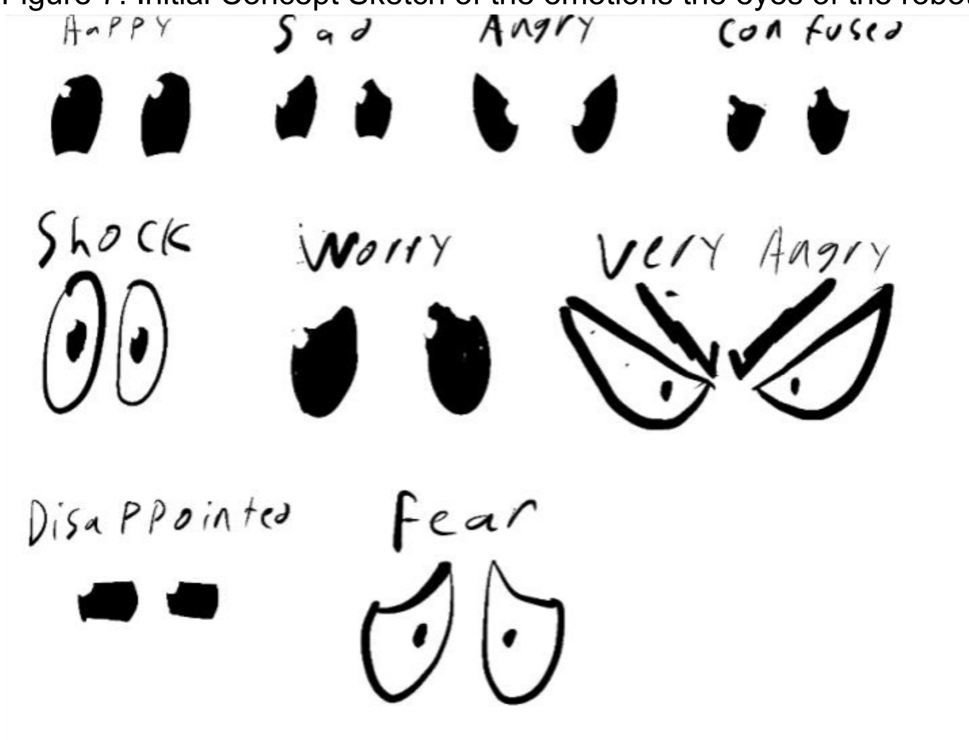


Figure 6: BearMax Version 1 Model

Figure 7: Initial Concept Sketch of the emotions the eyes of the robot should express



Preliminary Research:

There are advantages and disadvantages to being a part of the second version of this project. An advantage is there is a lot of information and a Version 1 model to improve on, however there is also this pressure and expectation to at the minimum meet the previous version's standards and add onto the previous team's accomplishments. From discussion with a previous team member, the previous version's servo motors did not function to their full capabilities due to the large amount of torque pull being required of the motors. Another issue was the electrical system, specifically excessive current drawn from only using one breadboard which was a design choice due to not being able to enclose more components within the size parameters initially set. Finally, for the exterior design, the previous team member discussed that it can be improved, and different materials can also be used. This information provides direction and guidance in research and planning for this project and Version 2 of BearMax.

It is important to consider the target audience of this robot, which is children who are or are not on the spectrum. There are several robots that facilitate learning for children and the bond a child develops with their robot learning companion has positive impacts on their ability to bond with their human peers and teachers [11]. The first step to this is to develop a robotic companion that the child can easily bond with. BearMax Version 1 had a 3D printed hard, plastic exterior. Other robots that are designed for social-emotional learning or interaction, have an exterior similar to stuffed toys like "Mox" in Figure 4 [12]. While Mox still has some stiffer materials used, the robot's surface is mainly soft because of the fabrics used. This robot could make a child feel more comfortable, welcome, and calm prior to and during the interaction. Most children may be used to seeing stuffed animals and toys and taking inspiration from models such as Mox, BearMax could also have a similar exterior that could help create a more familiar and safer environment. For the robot to create a welcoming atmosphere, in addition to the exterior, it is important to ensure the internal components all function as intended.

Figure 12: "Mox" a robot known as a Dragon Bot designed to play games with kids to help learning [12].

A well-designed mechanical and electrical system is required for proper function and for BearMax to be successful. Servo motors were largely used for the first version, and it is important to understand the reason. Servo motors are used commonly in robotics and are considered ideal in circumstances where position precision is a priority as opposed to speed [6]. High torque servo motors can be selected to assist with the robot's motor control, though the issue with current draw still remains and overheating is something else that needs to be considered. While it is possible for a circuit design involving multiple breadboards and an Arduino to work, it should all fit within the BearMax model. The BearMax model's body can be made larger, specifically wider, allowing for two breadboards and more powerful motors to be housed. For overheating, it is recommended to select a motor with lower current, however, it is known that torque is proportional to current; a lower current motor conflicts with the need for high torque [9]. To resolve this, motors can be selected with different torque capabilities and used for different sections. For example, for the head and arms, higher torque servo motors can be selected, whereas for the ears, hands, and other smaller parts, lower torque servo motors can be used. Version 1 only used one breadboard and due to the high number of motors and their current draw, there was overheating. By increasing the body size, this issue has high potential of being resolved by adding a second breadboard. To maximize size, the design can include using one motor driver for two or more servo motors. Depending on the purpose, the motors can be connected in series or parallel. In version 1, the ears were unable to move, and the arms were difficult to move with the motors. This can be addressed as we are aware beforehand of the potential complications, by selecting servo motors with different specifications.

To know the number of components required, the different aspects of the robot need to be considered. This version of BearMax has a focus to increase the degrees of freedom of different components in the system. There are many types of joints that provide the opportunity to have 2 or more degrees of freedom, as shown in Figure 5. A spherical joint has 3 degrees of freedom and is similar to a ball and socket joint, typically used for the eyes of a robot. This can perhaps also be used for the neck of the robot. The neck and head of the robot will be the main focus in version 2, to be able to depict and communicate a wider range of emotions and subtle changes in each emotion. For example, for sadness, the robot might tilt its head down paired with sad eyes, for expressing deeper sadness there could be a deeper head tilt and change in the eyes as well. If we want the robot to express that it is perplexed, we need the head to tilt sideways. This will require a three-axis rotation of pitch, roll, and yaw. We will most likely need to combine multiple types of joints into one system

Figure 13: Table depicting different types of joints and the degrees of freedom it provides and constraints involved [10].

Joint type	dof f	Constraints c between two planar rigid bodies	Constraints c between two spatial rigid bodies
Revolute (R)	1	2	5
Prismatic (P)	1	2	5
Helical (H)	1	N/A	5
Cylindrical (C)	2	N/A	4
Universal (U)	2	N/A	4
Spherical (S)	3	N/A	3

Furthermore, the hands and arms can also be paired/aligned with each emotion being depicted and provide a more expressive response from BearMax. Learning gestures has been found to be closely related to language development in some children with autism [13]. Body language is also difficult to understand for people with autism spectrum disorder (ASD) [7]. BearMax provides that extra step of gesturing with hand motions/movements in addition to head movements and emotions of the screens of the eyes is intended to aid in that gesture and language development, providing an additional factor to the social-emotional learning.

Table X: Robot Comparison

Robot	Target Demographic	Features
Mox [1]	Unspecified age group	Head exterior similar to stuffed animals, plays learning games with children, has touch sensors in place so can react if children pat the head or shake the hand
Moxie [2]	Children ages 5+	AI led chat feature, discuss interesting topics with user, tell jokes, tell stories, practice breathing exercises, help user draw picture. Durable yet soft to touch, huggable material, similar to silicone.
PEERbot: Migo [3]	0-6 years old	Customizable to child's needs; create age-appropriate lessons, read books with child/tell stories. Soft, huggable exterior material like plush toy.
QT robot [4]	8-14 years old	Visually expressive humanoid robots help express children's emotions better and be more expressive with feelings. Helps children with Autism Spectrum Disorder (ASD) to better recognize the emotions of others as

		well as communicate their own needs.
Mabu [5]	Elderly (ages 50+)	Humanoid robot provides reminders of daily tasks, to take medications, makes suggestions of diet options, recommend particles to call a doctor when needed, engages in conversation, has a touch screen tablet for patients to interact with.
Milo [5]	6-18 years old	Verbal lessons paired with various facial expressions, repetitive lessons without tiring the user. Acts as a tutor and encourages learning.
Pepper [6]	6-18 years old	Recognizes faces and basic human emotions, engages in communication through speech and via touch screen tablet on body of the robot (for nonverbal children with ASD), tell stories, play calming music/soothing songs, touch sensors on head and reacts positively when children pet the head.
Yale robot [7]	Unspecified age group	Lead interactive lessons, play games on a separate monitor, help improve and encourage eye contact, help initiate communication, help maintain focus and interest.

<u>**Pepper Robot from ELTL Review:**</u>

When researching different social robots, our team discovered the Pepper Robot. It is a humanoid social robot that can detect faces and recognize emotions. It also has a tablet on its chest, which can be used for communication. While researching, we found a few studies from a research firm called the Equitable Learning Technologies lab concerning the use of the Pepper Robot in a school for autistic children[22]. In this study, the researchers introduced the Pepper Robot to students for three weeks to study how they would interact with the robot. Unlike other studies, however, the researchers did not define a clear schedule or agenda for how the robot should interact with the students. Rather, the researchers let the students interact with the robot however they wanted. This approach follows the researcher's belief that studies for those with autism should not simply be dictated by researchers. Rather, autistic people participating in these studies should collaborate and voice their own opinions about the research. As they say, "the robot interaction design is typically a top-down process: experts (typically SEN teachers or autism specialists) suggest age- and development-appropriate activities, implemented on the robots by engineers, and deployed in schools." This firm instead wanted to understand the perspective of the autistic children and how they felt about the social robot. After all, the "growth in autism research necessitates corresponding attention to autism research ethics, including ethical and meaningful inclusion of diverse participants." The study proved to be successful as teachers at the school commented that their autistic students became more social and talkative. One teacher even noted that some autistic children, who were previously averse to physical touch, were seen holding hands and hugging the robot. In another scenario, a student, who previously did not talk to people, was seen having conversations with the robot. From this study, our team learned several valuable lessons from these studies. These lessons include what ethical guidelines developers need to follow for developing robots for children, the capabilities of the Pepper Robot and how it helped the autistic children, ways in which social robots can be implemented in schools, and disadvantages of using the robot.

The United Nations Children's Fund, or UNICEF, has outlined several guidelines for developing robots for children. [23] These guidelines include ensuring the inclusion of and for children, protecting children's data and privacy, and supporting children's development and well being. During the research study, ELTL ensured that the use of the Pepper Robot followed these guidelines. Firstly, the study made sure to include children in the development of the robot, rather than having specialists dictate how the interaction with the robot should be. Additionally, the robot's facial recognition feature was not used during group settings. That way, the robot would not single out one student and all the other students could feel like they were participating. For our project, we are also looking into how the cameras in our robot can detect human faces. However, we learned that we ought to consider what to do in group settings. Secondly, the Pepper Robot was not connected to the Internet. That way, no hackers could remotely hijack the robot and steal data or otherwise do any sort of harm. Furthermore, any data that was collected on the children was modified to avoid recording personal information. This included removing the names of the children; they instead assigned letters to the children. For our project, since our robot will be connected to the internet to be connected to a mobile application, it will need to have a robust and secure connection, lest any hackers try to steal data or tamper with the robot. Another way the robot was able to conform to UNICEF guidelines was by providing different activities to support the well being of the participants. These activities included dances, music, and storytelling. Whenever a student felt a specific emotion, such as anger or happiness, the student would notify the robot by pressing one of the emoticon buttons indicating their mood. Then the robot would suggest activities to calm the child. In order to ensure the child did not just skip through the list of activities, and to make sure the child learned to listen when someone is speaking, the robot would verbally name the activities as they were being introduced. For our project, we intend to do the same, except that each emotion will have a specific activity designed to manage it. For example, if a child chooses anger, that child will be introduced mainly to calming music or other activities. Furthermore, there will be an option to go back after choosing an emotion. That way, if a child mistakenly chooses the wrong emotion, they can go back and choose the right one. This happened at least a couple of times with the Pepper robot, so we would like to avoid that. By using these guidelines and understanding how they can be implemented, we can create a safe, welcoming, and positive experience for autistic children using our robot.

Reading these studies also gave this team a thorough understanding of the Pepper robot's capabilities. The robot can converse with individuals, perform dances, recognize faces, and facilitate activities using the tablet on its chest. The robot is also not teleoperated. It can go wherever it is directed to go and operate in a semi-autonomous manner. It still required supervision from the staff, however. Even so, the robot's semi autonomous manner and activities provided students with a meaningful, and fun, experience. While the robot's physical capabilities were apparent, we also observed some unexpected yet unique capabilities of the robot. We observed that the robot has the capability to be a kind of friend to users. When surveyed, many of the children reported that they see the robot as a kind of friend. They certainly treated her like one too. Whenever students passed by the robot, they would say something like "Hi Pepper." Many of the children also enjoyed touching the robot like hugging it, cuddling it, or even placing their head on the head for head massages. Surprisingly, some of these children previously did not accept physical touch; it was like the Pepper robot had shown them how wonderful physical touch can be. Furthermore, the children loved to have conversations with the robot. Some students liked to talk about what they were feeling or how their day went. To them, it was their way of regulating their emotions. The robot, however, could not respond to their conversations, taking more of a listener role. In perhaps a tragic consequence of the experiment, one student was distraught that the robot was leaving towards the end of the study. These events seem to demonstrate that the robot was not only capable of conversing, albeit in a limited manner, and entertaining the children, it was also capable of showing the children how to be a friend. This resulted in the children becoming much more sociable and much better at handling their emotions (citation needed here). In studying this robot, we determined that we should integrate many of the abilities of the Pepper robot, such as the activities and the physical movements. However, we also wanted to add details that could improve the robot. For example, we would like to add eyes that can express emotion to the children. The Pepper robot only has unmoving camera eyes and a smiley face. Although appealing, some have remarked that the unblinking eyes seem rather creepy. It also does not display emotions such as happiness or sadness. Our robot will have eyes through an LCD that can display a range of emotions, from sadness to excitement. Doing this allows for the robot to, in a certain sense, empathize with the users as its emotions can be a response to the user's emotions. The team is also looking into adding large language modeling (LLM) so that it can talk back to users whenever a user says something. By implementing these features, we can ensure that users of this robot are provided with a fulfilling social experience.

While the Pepper robot proved to be promising for the development of autistic children, it also has some downsides. The most notable disadvantage we found was that a couple children hated the Pepper robot. One was afraid of it since they were afraid of technology breaking or malfunctioning. The other simply hated the sight of it. The other staff members had to make sure that this student could avoid the robot at all times. The researchers asked if it would be appropriate to end the study because of these incidents, but the staff insisted on continuing the study. After reading about this, we learned that we must ensure that our robot is functional enough to instill confidence in its users and must appear non-threatening. Moreover, we learned that not everyone will like our robot. As difficult as that is for us to accept, we learned to do so anyway. One other limitation of the Pepper robot is that it could not talk back or have a conversation with the students. A chat-bot-like feature was suggested; which is why our team wants to implement the large language model into our robot. Finally, the Pepper robot can also have some key issues that also prevent other social robots from being implemented. This includes cost, limited interactions on offer, and the inability to use different robots with the same software. The Pepper robot reportedly has a cost of one thousand five hundred dollars and can only be controlled through the tablet and by holding Pepper's hand and guiding it. Although, it does have a wide range of activities for users to explore. For these reasons, we intend to make our robot more affordable and have the ability to move around by itself. We intend for it to be able to see objects in front of it and avoid them. The software that connects to the robot will also be accessible by a mobile application.

The Pepper Robot, according to the study published by the Equitable Learning Technologies Lab, is an effective tool for aiding in the positive development of autistic children. It can play music, dance, read stories, and have conversations with users, all of which can be very beneficial for early childhood development. To better optimize the robot's capabilities, the robot was situated in a controlled environment, which was a school for children with special needs, where an adult supervisor was present and constantly watching the robot. Creating an environment like this allowed for the robot to be used properly according to UNICEF guidelines on AI development and use for children. Staff members reported that student social behaviors noticeably improved after this short study and reported that some of the students even missed the robot. The students themselves noted that they enjoyed their time with the robot and many saw it as a kind of friend. Although it has proven to be effective and provide substantial benefits, it is not perfect. For one, the cost of the robot is too great for many schools as it costs one thousand five hundred dollars. Additionally, the robot could have conversations with children, but they were quite limited. They could not, for example, respond back to a child if that child were expressing their emotions. Finally, it became apparent during the study that not everyone will like using the robot. At least two students in the study reportedly hated or feared the robot and actively avoided it. Our project will keep these findings in mind as we develop our version of a social robot. We will try to implement the best features of the Pepper Robot while also attempting to avoid implementing its drawbacks.

Section 3: Technology Comparison & Parts Selection

Microcontroller Unit Technology Comparison

Embedded systems, as it comes to computers, are a field of engineering/programming in which we design a system with an integrated computer which controls the processes integral to the desired operation [1]. Essentially, this breaks down to a system which uses a computer, but is not a computer in its operation, and is used in many real world applications such as car systems, household appliances, and most relevant, robotics. In applications, we use a type of computer known as a microcontroller unit (MCU), which typically consists of a processor, memory, and I/O peripherals on board. MCUs come for many different types of systems, but in this section we will cover different types of MCUs that are commonly used in the field of robotics, and how we will consider the different specifications of each to use for the BearMax project.

As it comes to a full robot, the needs the MCU must support are very different compared to a regular embedded system, robots need things such as IP connectivity, security functions, and advanced algorithms controlling many aspects of the robot. This means the specs we need in an MCU must meet certain criteria in order to support the whole BearMax functionality, so running the emotional classification database, object and facial recognition, and sensors. Finally, the development board we choose to use shall act as a control hub for the components of the robot such as the power source, motors, distance sensor, camera, microphone, and speakers.

Many MCUs exist for robotics, however in order to determine the best one we will take into account the power consumption, size, cost, software supported, and the ability to run the emotional detection algorithm for the features of BearMax. The needs of the BEARMAX project also necessitate an additional board in order to ease the computing load.

Summary of Development Board Technology Comparison

Development Board	Cost	Clock Speed	Power Consumption	Memory	Size
Arduino Mega Rev3	$40	16 MHz	1 - 5 Watts	8 KB SRAM, 256 KB FLASH	100 x 53 mm

Raspberry Pi 4	$30-$40	1.8 GHz	3 - 5 Watts	8 GB SDRAM	85 x 60 mm
NVIDIA Jetson Xavier NX	$500	1100 MHz	10 - 20 Watts	8 GB LDDR4	69.6 x 45 mm

Arduino
A popular choice in recent years for robotics and many other forms of beginner projects, the Arduino company stands as a prominent contender for an MCU our project could use. While there consist of many different Arduino boards to choose from, the main one we considered was the Arduino Mega Rev3 which boasts 54 digital I/O pins, 16 analog inputs, 4 serial hardware UART ports [2], and many more features that make it especially effective for a large-scale project.

One of the best advantages when it comes to this board is that it offers a great amount of these I/O pins, and since we will be using many separate small components to control the motors, sensors, cameras, and other peripherals, this huge number is definitely necessary. As it comes to things such as power this board is compatible with the overall parts we need as it accepts an input voltage from 3.9-16V [3]. The 8-bit processor and 256 KB of flash memory also are more than enough when it comes to development.

The biggest upside of any Arduino board is the ease of usability; The community online and many peers utilize this hardware for their projects, meaning many resources, libraries, and guides exist online in order to fully tackle most roadblocks and hardships that would arise in our project.

Raspberry Pi
The Raspberry Pi board is another popular choice in beginner projects, boasting many features such as greater processing power, memory, and connectivity options compared to most Arduino boards [4]. The specific Raspberry Pi board we will be looking at in this section is the Raspberry Pi 4, one of the more recent releases from the company, which has a 40 pin GPIO header, about 26 GPIO pins, 4-pole stereo audio and composite audio port, and 1 GB of memory, plenty for any project one would want to take on [5].

Similar to many other boards, the number of peripherals supported by the Raspberry Pi 4 is great, as this board is used to run projects with high demands when it comes to memory and processor power. This along with the fact that all Raspberry Pi boards come with support for the Linux operating system allows for much more versatility than other development boards such as Arduino's. By default the board supports the C and C++ language, but through installing other software it is possible to compile and run any number of programming languages. Another advantage of the Raspberry Pi hardware is similar to a previous point in a previous section, that the online community is quite large especially as it comes to large scale projects. There exist many tutorials online, libraries to access, and forums one may check in order to get a good idea for most issues.

In terms of technical specifications and support, the Raspberry Pi 4 board competes with many development boards on the market, but being a good development board is not the end all decision of how we can use the board for this project. One issue we run into is cost, as this board has a pretty steep price, especially if wanting better on-board hardware. Further on this point, due to scarcity of some parts, this board becomes unavailable for large periods of time, so if needed the board may arrive much later than is allowed for the project's time frame. Power consumption as it comes to this board is especially high since it has such a powerful processor and supports an entire operating system [4]. Our final issue with this development board comes from the difficulty of use. Although many beginners use this board for projects, it is by no means a beginner board, as installing the operating system, using libraries, and configuration takes more effort than other boards, so despite the benefits and upper-hand the Raspberry Pi 4 has over the Arduino Mega R3, the Arduino is simply an easier board to use. Overall, the Raspberry Pi 4 is powerful and complex, definitely a good choice in most projects, but for our purposes it may be more complex and technical than we need, and we may cut down costs and time by choosing a simpler piece of hardware.

Jetson Xavier NX

An important detail when it comes to the needs of the BearMax project is the ability to store and access the machine learning model associated with emotion detection. Most basic boards on the market do not support the capacity for a large scale AI model, and the ones that do although it is possible can run slow when they have many different sub-components to consider. However, the NVIDIA Jetson Xavier NX is a development board specifically designed for deep learning, large language models, and generally using real-time inferencing and processing of neural networks [6]. With AI performance rated at 21 TOPS (trillions of operations per second), a 384 core GPU, along with insanely fast processor speeds, the Jetson ends up blowing most of the competition out of the water. Finally, allowing for UART, I2C, and SPI I/Os allows for more peripherals to be used between components.

The Jetson's purpose is for AI development, meaning the board supports numerous machine learning libraries such as PyTorch, TensorFlow, along with many others. Due to this, the Jetson is well supported for projects involving image classification, object detection, and large language models, all of which are necessary aspects of the vision of the BearMax project. The emotional detection feature itself requires both image classification and computer vision. Further plans for the automated movement require object detection as well. One of the most important things is the capacity for the Jetson to process real-time requests with the model, known as edge AI computing, this means that the Jetson does not need to have a server along with it to process the requests and feedback response signals, it all happens on board [6].

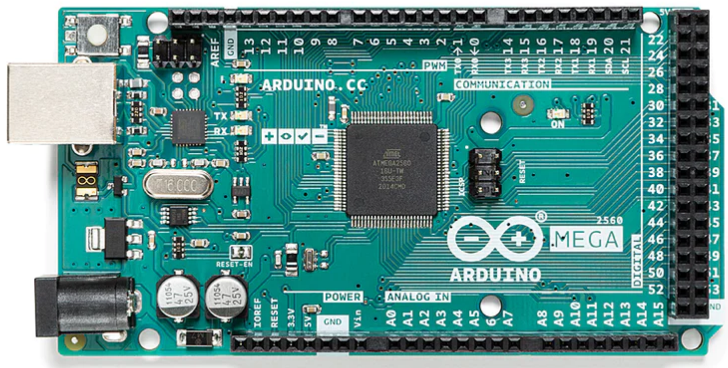
Mentioning a downside is tough to find, but the biggest one is definitely the steep cost for the board, costing an average of $500 for the model we will need. However that being said, certain parts are available to our group for development already, including this board. Meaning that this is not a huge factor. Another downside is power consumption, since the board must run calculations, processes, and interface and communicate with many other separate components of the robot, this board has a power consumption even greater than the Raspberry Pi 4. However, the power consumption overall can be handled by our design as a whole, so even these disadvantages aren't enough to bring the Jetson down too much.

Of the many criteria we need to meet in a development board, the Jetson definitely exceeds expectations. Being able to support AI models, processing them in real-time, and having plenty of compatibility with other parts, we are confident that the Jetson is a big contender when it comes to the viability of completing the various features of the BearMax project. This board is not as widely used as compared to the Arduino and Raspberry Pi boards in projects for beginners, but nonetheless many resources exist in order to aid our overall development using this board.

Development Board Part Selection

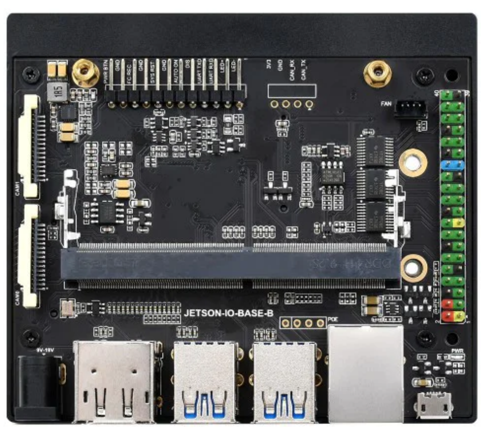
As stated prior the criteria we are most considering are power consumption, size, and the ability for an MCU to act as a hub for all of our electronics, meaning we needed ample GPIO ports available for use, additionally we must be able to house the machine learning models for emotional recognition for the user of BearMax. With this being said, we have decided that for our purposes, we would use both the Arduino and the Jetson boards for their own specific purposes within the robot. Our main reason for doing so is the availability of both boards, as the WEAR lab has the ability to provide us with these with no additional cost, meaning we are able to allocate our expenses to other components that may need it.

The Arduino Mega Rev3 will act as the hub for components such as motors, wires, the camera and other similar components due to the availability of many GPIO pins, ample memory, and fast processing capabilities. Arduino boards are compatible with many different libraries, languages, and support many different types of components that are directly made to be configured with Arduino, such as screens, cameras, speakers, motors, etc. Finally, the size of the Mega R3 board is not an issue, as the designs for the body will have to be specifically modeled to fit the internal components.



Arduino Mega Rev 3 Development Board

The NVIDIA Jetson Xavier NX board will also be used for this project due to its specific purpose being to support embedded edge computing with deep learning and machine learning models. Due to this, we will be using the Jetson in order to store the models created by the CS team for emotional recognition. Additionally, we will have this component linked directly to our power supply, then the Arduino will draw its power from the Jetson, and other components from the Arduino. Our camera will also be directly connected to the Jetson in order to properly implement computer vision capabilities easily, making our plan to have the Jetson communicate to the Arduino the correct movements to take place.



NVIDIA Jetson Xavier NX Board

Camera Technology Comparison

The camera is one of the most crucial parts of the BearMax project, as it is what will be allowing for the robot to see and capture necessary data in order to properly detect the emotional state of the user. Our plan is to connect the camera unit to the Jetson as this is the unit hosting the computer vision capabilities. Furthermore, when choosing a camera for computer vision we have a number of different criteria to consider for the ease of capturing information. We will also be searching for a camera with a built-in microphone, as a microphone is also needed and if we can combine the components and find a microphone that meets our requirements Due to this, we will be considering factors such as camera resolution, size, power consumption, speed that objects can be detected at, serial communication standards used, framerate, and cost, as well as the effectiveness of the microphone [9]. In this section we will break down these factors and highlight why they are important to determine.

As stated prior, in order to have proper emotional detecting behavior, we must look at certain aspects of the camera for the use of computer vision. Since we plan on the robot being able to detect users and objects while it is mobile, the kind of camera used must be able to provide a “good enough” image for use in detection algorithms. This means we must consider resolution, framerate, shutter speed, low-light level functioning, along with other considerations.

Camera resolution is the ability for an image detecting device to resolve two points that are close together [8]. This essentially means that a camera with a high resolution has the ability to detect points that are very close together, or an object that is further away from itself. The resolution the camera itself has is further influenced by the exact dimensions and resolution of the lens on the camera [9]. Some lenses will expand the field of view (wide-angle lens), while some can add depth to the image (telephoto lens), but for our purposes a lens may not be needed to distort the image. Another consideration comes as the frame rate, which refers to the number of images captured and transmitted per second [9]. While this term is usually used when considering video capture footage and display, for static images and displays it can matter greatly. Having too low a frame rate will cause the system to overall be unresponsive, and after a certain frame rate going any higher will simply not make enough of a difference and may in fact consume too much power, memory, and time. As it comes to a robot, we would need a frame rate that is high enough to meet our minimum requirements and detect objects at a reasonable speed. Finally, when it comes to baseline consideration we must talk about monochromatic versus full color capture. Essentially, some applications of computer vision necessitate the use of color analysis, but unless we need said color captured, it is much easier and beneficial to the robot to contain a monochromatic capture, since a monochrome camera has less resources dedicated to color display, meaning that the images it can capture often contain more details than the alternative [9].

Additionally, the way our camera will scan the captured data is hugely important. The two ways a camera will scan in an image are line-scan and area-scan. A line scan camera will take a single line of pixels, sometimes more but typically will stay at a single line, and will build a final image line by line until there is nothing more to scan in [10]. This type of camera has many applications in computer vision, but typically is most effective when being used to observe something that is constantly in motion [10], such as conveyor belt surveillance in factories to find defects, imperfections, or general error when doing large-scale production. Since this type of camera uses pixel line by line capture they tend to be very high resolution. Conversely, an area scan camera will capture an image in a single frame which will have a one to one correlation with pixels on the sensor [10]. This allows for an in depth look at a specific frame, meaning this type of camera is most used in applications such as surveillance cameras outside buildings and in public, imaging, and most importantly robotics. This means that we will most certainly be using an area scan camera within our design of BearMax.

When it comes to image capture, the role of an image sensor is crucial, as this is what converts the actual photons into electrical signals that can be analyzed by other components [11]. Essentially, these break down light and convert it into digital signals, and there are two types of sensors: Complementary Metal-Oxide-Semiconductor (CMOS) and Charge-Coupled Device (CCD). The CMOS sensors are laid out with an array of pixel sensors which can each convert the light information they receive into a digital signal which can be interpreted by code. These pixel sensors are only active when the camera is reading or capturing an image, leading to less of a strain on the power-source and being power efficient [12]. CMOS sensors are widely used in many aspects of life and are the standard for cameras in smartphones, webcameras, and security cameras, as in these applications the goal is simply for information to be captured by the camera, and interpreted by another party or user. The CCD sensor functions slightly differently as compared to the CMOS sensor, as these work by accumulating charge from light information of a row of pixels and transferring this into an amplifier which will convert the data into a digital signal at the end of a row [13]. This design is perfect for capturing light information of dense clusters, as the pixels with more accumulated charge will have a different signal readout at the end which ends up in superior image quality, reduced noise, and exposure control over CMOS sensors [12], but this comes with the additional drawback of having to be drawing power constantly, making them less power efficient than most CMOS sensors. That being said, CCD sensors are hugely useful in many situations and are mainly used in scientific imaging such as spectroscopy, microscopy, as well as very high grade cameras. When comparing CMOS and CCD sensors directly, we can see that CMOS offers a low power consumption, fast image capture, and a low cost, where the CCD has the edge when we consider image resolution, low noise, and overall increased quality, at the cost of being more expensive. While both sensors have their applications, for our purposes and the goals of BearMax, we will most likely use a camera with CMOS image sensors, due to the low cost, high frame rate, and low power consumption meeting the goals necessary for the project.

Camera Part Comparison

In order to select a camera, the baseline we must search for is compatibility with the Jetson Xavier NX which will be used for computer vision functionality as a whole. Due to this, we have a limited type of camera available as there are only some specific models available for the Jetson. For our comparison, we will be looking at the Arducam 4K 8MP autofocus USB, the Waveshare HDMI 8MP, and the Sony 4K e-CAM80_CUNX cameras and see which one will fit our needs for BearMax.

Arducam
This camera is a Jetson compatible, 4K 8 megapixel camera that is natively compatible with Windows, MacOs, and Linux systems with an IMX219 sensor, allowing for sharp images and color contrast. The Arducam brand has many different types of cameras and lenses compatible with the Jetson, making any one of their choices a strong contender due to the availability and widespread use for many applications, the biggest of which being computer vision. The camera uses rolling shutter and can operate up to 30 frames per second (fps) at 1080 by 720 resolution, uses USB connection, has a 2.96 focal length with a 60 degree field of view, and most importantly contains a microphone able to be used to take in user audio. The camera also has a footprint of 44 by 44 millimeters, being slightly bulkier than most other cameras for its purpose, however we are able to remove the casing on the camera in order to integrate it within the head of the robot much easier. The camera costs more than most for its performance capabilities, but we are able to negate this cost as this specific unit was used in the prior year's BearMax version 1. Due to this, the ease of using this camera is much greater than the others as we are able to reference and use the last group's findings in order to implement its functionality better.

Waveshare
The Waveshare camera shares some of the benefits of the Arducam, being the same 8MP camera with an IMX219 sensor available leading to similar qualities for their picture output. Additional benefits come from this camera having a 160 degree field of view around the lens, and having a focal length of 3.15mm, and using a CMOS sensor. Additionally, the dimensions of this camera are 25 by 24 millimeters and only 0.01 oz, making it an acceptable size and weight to be integrated into the head of the robot. When comparing the Arducam with the Waveshare, they have similar uses as well, but the Waveshare comes a bit ahead as it is slightly cheaper as compared to the Arducam, but, as stated prior, the Arducam model is already available to our group. This camera also supports HDMI technology, and is even wireless through Bluetooth technology, but these factors are not needed for the purposes of BearMax. Finally, although this is marketed as a camera for the Jetson, some online reviews state their frustration with the use, connectivity, and general issues with being able to use it for computer vision purposes.

Sony
The Sony e-CAM80_CUNX is another 4K 8MP camera designed for the Jetson's use. This camera is more in depth than the other two cameras we have looked at, supporting

much higher frame rates, speeds, and image processing capabilities. The biggest selling point for us is the capability of capturing 100 fps at HD resolutions on the Xavier NX, and 40 fps at 4K resolution, meaning the computer vision would have many samples and could update faster than if we used another option. This camera is 30 by 30 millimeters and weighs 0.7 oz, making it an acceptable size and weight to be placed within the head. This camera is also very well supported to low light level conditions due to it being able to automatically connect to the Jetson's exposure control and white-balance control. With these in mind, this camera is hugely useful for computer vision purposes, but the main limiting factor behind this camera is the steep price which would exceed the allowed budget for our project. Additionally, the applications of this are usually industrial applications such as quality inspection and factory automation. Finally, the overall complexity as it comes to this camera is high, which may cause issues when it comes to time management working with the camera in order to get it to work to our specifications.

Camera Selection

Considering the above specifications of each of the camera modules discussed, we decided that the overall needs of the project, balanced with the budget, and availability lead us to select the Arducam for BearMax. The main deciding factor was the availability of this camera from the WEAR lab, of which we have several parts provided, since this camera was used in the original BearMax design, we thought it best to build upon that previous framework and move forward with this part. The options provided are more than necessary, and the Arducam is an overall reliable choice.

Summary of Camera Comparison

Camera	Fps at 1080p	Size	Weight	Cost
Arducam	30 fps	45 x 45 mm (with metal case)	3.2 Oz (with metal case)	$38
Waveshare	15 - 20 fps	25 x 24 mm	0.01 Oz	$20 - $28
Sony	70 fps	30 x 30 mm	0.71 Oz	$150 - $200

Sensor Technology Comparison

For the goals of BearMax the proper sensor must be chosen that can give us an accurate measurement of distance from the robot to another object, for the purposes of object detection for autonomous movement. While autonomous movement is a stretch goal of ours, we found it reasonable to at least research the capacity and capabilities for this autonomous mode. The goal for this sensor would be to send the distance from the robot to another object so that while in motion the robot does not collide with any object, user, or other obstacle, and based on the distance read, move in a direction until the distance is within the threshold for a “collision”. For these purposes we will be comparing different technologies that are capable of rangefinding such as infrared sensors, ultrasonic sensors, and LiDAR sensors. In this section we will understand how each of these functions, how much distance they are able to sense, resolution, and power consumption in order to pick the correct sensor for our goals.

Summary of Sensor Technology Comparison

Sensor Type	Range	Operating Current	Possible Source of Error	Cost
Ultrasonic	4 - 5 meters	2 - 20 mA	Humidity, temperature, sound, surface material	$1 - $30
Infrared	2 - 4 meters	2 - 10 mA	Reflective surfaces, high temperatures, dark lighting	$10 - $50
LiDAR	10 - 30 meters	100 - 500 mA	Reflective/ transparent surfaces, other sensors	$20 - $500

Ultrasonic Sensors

Ultrasonic sensors are one of the most utilized types of sensors in all applications, especially as it comes to range detection. These work like how the name suggests sound waves are emitted at a high frequency in a direction and are reflected if an object is in front of it [14], then distance is estimated using the speed of sound and the time interval that elapsed from emission to receiving the reflection of the waves. These kinds of sensors are used in a variety of different environments and offer many upsides to their use. One being that ultrasonic sensors are available at most sizes and price points, meaning their cost is usually no issue, and that since they usually are a smaller component they consume a low amount of power. Additionally, they are unaffected by some environmental conditions such as high levels of light and small particles through the air, and often feature a wide range of sensing depending on design, often going beyond 200 cm for even a small component [14]. The ability to also sense without making contact, or even being close, to an object is largely beneficial for most situations as well, and these sensors tend to have a high sensitivity as well, but there are definitely some downsides to consider for our design.

For one, ultrasonic sensors are very sensitive to many other environmental conditions, such as humidity, temperature, and atmospheric movements, such as loud sounds or liquid movements [14], this means that the situations that an ultrasonic sensor may be used in may should not involve big changes in these conditions for risk of inaccurate measurements. Ultrasonic sensors tend not to be accurate when they are close to an object, and do not offer too high a resolution leading to imprecise readings. Other disadvantages include: slow refresh rate, inaccurate data when changing surfaces, and narrow coverage [14]. This means that for our purposes an ultrasonic sensor may not be the best choice, as our needs require the sensor to be accurate in motion, on different surfaces, and with close-up objects.

Infrared Sensors

Another very popular type of sensor used in many types of projects and machines is the infrared (IR) sensor. These are aptly named, as they function by emitting infrared light from an LED, then this light travels and propagates until it hits an object, which is then reflected back towards a sensor, where the intensity of the light will determine the overall distance [15]. Typically these sensors come in two varieties, active and passive IR sensors. An active IR sensor will contain both an emitter and a receiver, and capture reflections as stated prior, where a passive IR sensor only includes a detector without a transmitter, meaning these require an infrared source in order to work [15].

The IR sensor shares some advantages with the ultrasonic sensor previously mentioned, being the wide range, low power consumption, and small form factor meaning it can be included with little design changes. IR sensors also have an additional use in that they are able to be operated in low light environments due to the fact that IR light operates in the non-visible frequency of light for humans. A final advantage this has over ultrasonic sensors is that they are unaffected by pressure, water, and some other surfaces and conditions that ultrasonic sensors struggle with, but this does not mean that IR sensors are perfect when it comes to sensing.

A major disadvantage comes from the reliability of reflection. As stated prior, the main way that IR sensors work is by emitting light, light reflecting off a survance, and then receiving the intensity of the reflected light, but that means that if the sensor encounters a highly reflective surface, it may give inaccuracy. Further, dark objects that may give off less IR light, we may have difficulty detecting an object. High temperature could also throw the sensor out of calibration, as IR light is often given off as heat, and in a robotic system with many components running at the same time for a long period of time, the temperature tends to increase the longer the machine is operated. Especially since the goal is to have BearMax used in a house, having something that could be hugely influenced by sunlight, humidity, and ambient temperature is less than ideal [15]. Finally, the biggest flaw with an infrared sensor is the limited range at which this can operate, often only being able to accurately detect an object at a maximum of a meter away from itself, and for our purposes we need this accuracy.

LiDAR Sensors

The final type of sensor we will be looking at in this section is the LiDAR sensor. Theoretically this sensor is very similar to the other two we've looked at. A LiDAR sensor will target an object and then emit a small laser towards it, then, the time that the laser takes to reflect off the object, and return are used to calculate the distance [16]. Essentially, where an ultrasonic sensor uses sound, and an IR sensor uses IR light, LiDAR uses laser technology which travels much faster and further than the other sensors due to these relying on the speed of light as opposed to sound or IR. LiDAR systems are not only used to simply detect range, as the precision of these sensors are so accurate and able to be fine tuned by many parameters, but also this same type of technology can be used to fully map out a 3D object through use of many small laser emissions. This precision is why most applications of LiDAR are for laser scanners able to map geography, architecture, measure distances for construction, as well as automotive and aerospace travel [16]. However, to see whether LiDAR would work for our purposes, we will see the advantages and disadvantages of this sensor and how it fares with distance, speed, and cost.

As to be expected by the above description, LiDAR is highly accurate. Lasers travel fast and can be used for a variety of applications requiring fast response time, as well as having a long range. Due to this, LiDAR sensors can detect at a range far beyond what is needed for this project, as well as being fast enough to be integrated into an autonomous robot. Furthermore, low light conditions have no effect on the overall accuracy, as well as having the ability to sense across different types of terrain, unlike the ultrasonic and IR sensors.

That being said, there are some disadvantages when it comes to LiDAR in a system. The main being the cost of integration, LiDAR sensors usually cost much more as compared to ultrasonic sensors of the same size. Furthermore, since these sensors operate fast they consume a lot of power compared to other sensors, and in a battery operated system like a robot this could lead to over drawing power and failure of the system to operate in an extreme circumstance. LiDAR is also prone to interference in systems with other sensors in use. Finally, similar to the IR sensor, when used on transparent or highly reflective surfaces, the laser may pass through, refract, and reflect away from the sensor, leading to struggles with detection. Despite these disadvantages, the high accuracy in measurement, fast performance, long range, and the ability to detect many small objects and different terrain, this sensor is the most optimal to use for our purposes in BearMax.

Image Display Technology Comparison

In this section, we will cover different types of displays that are commonly used, and comprare the advantages and downsides to using each of them when it comes to the specifications of the BearMax project. For our goals, we need 2 types of displays and 3 in total, 2 to act as the “eyes” of the robot, and one display for the torso region to be used as our interactive device. The needs of these 2 displays differ in many ways, but in order to choose the displays we will be looking at similar criteria between the two. We will focus on many parameters including: quality, resolution, brightness and contrast, durability, and most importantly, how easy they can be integrated in combination with the other parts such as sensors. Now integration with such sensors should not be an issue, as we may simply find a display that is compatible with the Arduino used, and due to the popularity of this hardware the availability of compatible parts is not an issue. In the following parts we will be comparing LCD, LED and OLED, and e-paper technologies and will choose which type to use for our displays.

Liquid Crystal Display (LCD)

Liquid crystal displays, or LCDs, are extremely commonplace in our world today, and are a very useful choice when considering our uses. LCDs are a kind of flat panel display that uses light-modulations and polarization in order to function. This is possible due to the properties of liquid crystal, which is a way of referring to a specific state of matter in which a substance has the properties between that of a liquid and a crystal solid, which comprises the material of the monitor of the display [17]. This type of device by itself is passive, meaning that it is unable to produce light in order to display images, shapes, or movement in general, but it is extremely reliable in altering the light traveling through it. This means every LCD requires an internal or external component to produce or reflect the light, being a backlight or frontlight system. An LCD screen itself is made up of an array of small segments, known as pixels, that transmit red, blue, and green light, often thought of “sub-pixels” [17], which are then refracted through the layers of the screen in order to produce an image. Despite the wide-use of LCDs, we still have to consider the advantages and disadvantages of them for use in our project.

As stated prior, the wide-use of LCD technology means that they have a large variety of benefits over most other alternatives. One of the biggest advantages is the different sizes of screens available, and with this comes a large range of resolutions, meaning that the applied uses can be much greater as it may be used for many different projects and machines. LCDs are also capable of full-color display due to the use of the RGB pixel technology, as well as having good options for brightness control. These 3 things are the main reason LCDs are widely used, as with these we are able to have a reliable method of conveying information. In this same vein, the angles that LCDs are able to be viewed at are extremely wide, so in applications we can stay further back, or to the sides of the robot and the eyes should appear as normal [18]. Finally, due to the way that the pixels on this screen work, when rapidly changing between different images, LCDs are less likely to flicker out or malfunction. For these reasons, LCDs are considered viable in most projects, but they do not come without their downsides.

A big disadvantage when it comes to LCDs comes from the same properties that allow it to let light pass through itself. When in an environment where sunlight or other lights are bright, they can interfere with the readability and visibility of the display. Additionally, in high temperatures the internal components may malfunction and the display's contrast may suffer, which in a robot filled with multiple components running for a period of time runs a high risk. This hits another issue, LCDs are not as durable as other technologies, meaning that if the robot is to suffer some damage these components may get permanently changed. Finally, the backlight itself takes additional power to work, and since this is a necessary component this adds more power consumed by this part, and at times the backlight itself may appear uneven, and overuse may even begin to fade certain colors [18]. Overall, LCDs come with many benefits such as good display capabilities, however may suffer when it comes to durability and readability outdoors.

Light Emitting Diode & Organic Light Emitting Diode Display (LED & OLED)

An LED is a semiconductor device that gives off light once a current passes through it, and offers many reasons as to why they may be used for display technology. Similar to the LCD pixel displays, containing red, green, and blue sub-pixels, and LED display will have many small LEDs, also colored red, green, and blue, closely spaced out and have the ability to adjust the color and brightness of the overall image, allowing for the display of images and animations [19]. The way OLEDs differ from regular LEDs comes from the addition of an organic film within the electrodes of the diodes, which allow a much brighter light to emit once an electric current passes through the device [20]. Although we are including LEDs in this section, it is important to note that LEDs in displays are typically used with an LCD screen in front of it, meaning that this section will mostly focus on OLED screens, as this is what is typically used in digital screens in many different machines and systems. LED displays are typically used for simple segmented displays, such as the ones appearing on digital clocks and many small household appliances. Regardless, in this section we will discuss the advantages and disadvantages of an OLED display for the purposes of the BearMax project.

One of the biggest advantages of an OLED display comes from the fact that OLEDs emit their own light once current passes through, so unlike LCD displays a backlight or reflector is not required for these. OLEDs are also able to display very deep black colors, bright white light, and have an extremely high contrast ratio [20]. For the above reasons, OLEDS actually are considered to consume less power, as by removing the power to the device it is able to truly display black, and they generate their own light directly [21]. The layers of an OLED are extremely thin and offer a small form factor in most applications, meaning they are flexible and durable. Finally, OLEDs offer fast response time allowing for fast movement to be displayed with little to no screen flickering [20].

OLEDs do not come without their downsides, of which some are shared with LCDs as well. For one, the outdoor visibility of OLEDs is worse than LCDs, since LCDs may have reflectors in place for their light allowing for some visibility, OLEDs rely on its own ability to convert electricity into light, thereby making these unreadable outdoors [20]. Furthermore, the lifespan of these devices is hugely limited by the addition of these organic materials, which degrade much faster with use than inorganic layers, of which blue light given off degrades the fastest [20], which leads to color imbalance. Finally, it comes to cost, as OLEDs are relatively new technology, the cost of manufacturing is considerably high as compared to other options available. So overall, OLEDs come with the benefits of having better overall display capabilities, but risk chances of screen degradation, poor visibility in sunlight, and high manufacturing costs.

E-Paper

Electronic Paper, or e-paper, refers to a type of display technology that mimics the feel of paper, and is used in applications to mimic the effect of a “real book” with ink on paper, as well as being used for digital signs, billboards, and e--readers. Unlike other displays, e-paper functions not by emitting light but by reflecting ambient light [21], much like paper itself. E-paper is extremely energy efficient due to the fact that no internal light component must be used in order to allow the screen to work, and for the most part e-paper will only consume additional power when changing the image on the screen, if we persist on an image virtually no power is consumed [21]. That being said, most applications of e-paper stick to static, or mostly static, displays, which may not fully meet our purposes, among other disadvantages when it comes to the technology.

The biggest downside in most e-paper displays comes from the fact that most are monochromatic, which limits the amount of interactivity to a large degree when it comes to the BearMax’s displays [21], as the interactive display must be able to play certain animations and images, of which the message and interpretation from the robot may be ambiguous without color capabilities. As stated earlier, the main uses are for static displays, so the refresh rate when images are changed are highly limited and often have no smooth transition [21], meaning that for devices that need constant updates this will not satisfy. Additionally, high exposure to sunlight or constant updates may cause the screen to start to fade in quality anyways, so the added benefit of readability in ambient lighting can decay over time [21], and coupled with the fact that even some small e-paper displays can cost up to $80. So although e-paper technology is highly utilized and applicable in many different situations due to its low power consumption and ease to use, the drawbacks of having no color support, limited refresh rate, and a small life-span make it wholly unsuitable for the BearMax robot’s goals.

Motor Technology Comparison

For the 2nd iteration of Bearmax to function as a social emotional learning tool, it’s vital that the body language for each emotion is executed properly. This means that Bearmax requires a complex joint and motor system to emulate specific emotions such as excitement or fear.
These motors will be controlled by the arduino system. This will involve approximate calculations for necessary torque to move joints which will influence how we program the arduino.

We are planning to use more than one kind of motor for Bearmax depending on the needs of the section we are designing. For example motors in the track system will likely be different from those moving the neck.
In this section we will be covering the two different kinds of motors we will be using for movement in the joint system as well as the reasoning for why we avoided others.

DC Motors
Most commonly used in robotics, DC motors convert direct electrical energy into mechanical energy. DC motors work well for robots that must be battery operated such as mobile and collaborative robots. DC motors are advantageous in that you can vary the speed by adjusting the supply voltage, armature voltage drop, or flux due to the field findings. A downside to DC motors is that they will rotate continuously, this makes precise control difficult as they are not designed to be able to stop at a certain position. This ability to vary speed can give lots of options for the abilities of your robot.
We will likely be using DC motors for the track platform at the base which will allow the robot to be mobile via remote control.(1)

Stepper Motors
Stepper motors are made up of a rotor with permanent magnets and a stationary stator that carries the windings. Stepper motors work by moving in “steps”, there are so many of these steps that the motion looks continuous.
Due to the fact that they work in steps, there is a high degree of control around the position of the motor without the need of an encoder. A major downside is the decrease in torque as speed increases. Overall stepper motors tend to be more inexpensive compared to servos but are not as precise.

Servo Motors
A difference between servo motors and stepper motors is the amount of poles. Servos motors have less poles than stepper motors. Consequently, servos must be run as a closed loop system and have an encoder as opposed to stepper motors mentioned earlier. However, when used with a gearbox, this allows the servo motors to deliver much higher torque at higher speeds. It is for this increased precision and torque capabilities that servos will mainly be used for our joint system as opposed to stepper motors.(2)

CAD Software Technology Comparison
AutoCAD is a Computer aided design package that has powerful 2D drafting capabilities. Its purpose initially was to replace drafting done by hand therefore reducing man hours and increasing efficiency. Since the initial intention was not for 3D modeling. AutoCAD is seen as rather limited for that purpose relative to other 3D modeling software. Bearmax will require hundreds of hours of modeling to finalize the design, it is therefore crucial to use the most effective 3D modeling software which will allow us to complete our design in the most effective manner.(3)

Solidworks is a parametric 3D modeling package. This allows for fast editing of object dimensions without having to redraw the entire design. It allows users to design and assemble individual parts in a 3D space. Furthermore there are packages which expand its versatility to things such as electrical components. Solidoworks includes analysis methods such as finite element analysis which will allow us to perform stress tests on different sections of Bearmax. Solidoworks also has CAM(Computer aided manufacturing) capabilities which will allow us to design how each part will be milled and constructed. A downside of Solidworks is its lack of 2D drafting however that is not essential for our goals in the Bearmax design.(4)
Onshape is also a parametric 3D modeling package, it has a lot of similar functionality to Solidworks. Aside from format changes, the biggest differences between the two software centers around how data is stored. Onshape uses the cloud which makes sharing data and editing with multiple users much easier. This requires internet connection whereas Solidworks could be used offline. We decided against using Onshape as our two mechanical engineers would be working on different sections independently so the benefit of working simultaneously on the same part wasn't seen as necessary.(5)

Speaker Technology Comparison

The speaker would be used to play music and say formal recorded greetings. The arduino community has several different speaker designs formatted for easy integration into the arduino system.
The speaker system must be capable of playing multiple files to allow for multiple songs and greetings. This means it will likely be using an SD card as part of its system for sound selection.
While helpful to the goal of social emotional learning, speakers are not the primary emphasis so a cost effective model that meets our requirements from M2 would be sufficient. It is for this reason we have selected the SP-3605 speaker. It is inexpensive, works well with the arduino and meets the volume requirements per our M2.(6)

Robot Material Selection

Many factors dictate the material of a product, function, budget, machinability, durability, etc. and for BearMax, it's no different. BearMax has several components including the head, neck, body, shoulders, arms, digits, track system, and frame. For the shoulders, arms, and digits, the focus is on functionality, in this case movement. For the head and neck, movement is vital but as is weight. The neck and head joints will be supported by the body so they must be durable, yet still lightweight to ensure little load is being applied on the body. The appearance of BearMax is also very important as it can contribute to a child's ability to bond with BearMax and to feel comfortable. We also want to allow the child or user to physically interact with BearMax with hugs or high fives, similar to other robots facilitating social-emotional learning [2]. For this, safety is of utmost importance so materials there cannot be sharp edges or surfaces that are exposed. The material and texture of the frame or exoskeleton needs to be carefully selected as well as a lot of people with Autism Spectrum Disorder (ASD) experience sensory issues which need to be considered [9]. These sensory issues need to be accounted for so users can feel comfortable interacting with BearMax physically if they so choose and the exterior also needs to be appealing to make the user feel as comfortable as possible. Table X shows comparisons of different robots and discusses physical and functional differences. Several robots have hard exteriors and still are able to bond with users very easily and have touch sensors in place to record and respond to physical contact. Others have a hard exterior but have some components which are similar to stuffed animals or toys, such as Mox, a “dragon bot” that has a head surrounded by soft material similar to the mane of a stuffed lion toy [2]. Other robots are designed with a soft, huggable material completely. The goal for BearMax is to have an exterior that resembles a stuffed bear and be very soft and comfortable. While this is possible, the exoskeleton still needs to be sufficiently durable which cloth cannot accomplish alone. For this reason, the decision was made to have the exterior cloth purely for cosmetics and choose a frame that is durable and can protect all of the components of the robot.

Chapter 4: Standards and Design Constraints

UNICEF Design Constraints

One of the primary guidelines we will be following is the UNICEF Guidelines on AI for children, known as the "Policy guidance on AI for children."[20] This guideline will dictate how we will be approaching the development of the machine learning and programming of the robotic system. The report recognizes that there are potential uses of artificial intelligence for the positive development of children. It recognizes that artificial intelligence can aid in educating children by enabling adaptive learning platforms that can devise a curriculum for each student. The report also recognizes that AI can create educational opportunities through interactive games, chat bots, and robots. According to the report, AI-based interaction games run by social robots can help young children learn to read and tell stories, increase their vocabulary, and learn to draw images (citation needed). Furthermore, the report recognizes that AI has the potential to provide emotional support for children. It explains that, under the right supervision and in a controlled environment, AI-enabled products can be used to detect children's moods and help with behavioral regulation (citation needed here). Of course, the report clarifies that children should always be directed to online and offline human support for complex, sensitive scenarios like bullying. Even though it recognizes potential positive uses for AI, it also explains that AI can be used in harmful ways against children. One potential harm is that AI can be hindered by what is called algorithm bias. This is when datasets that inform the AI create negative biases within the AI, which translates to real harm in people. Algorithmic bias is often seen with surveillance AI, which has shown to profile ethnic minorities as dangerous because of biased data in its dataset. Another potential harm of AI is the privacy risks associated with it. Since this is an AI for children, it will rely on collecting data on children. If a hacker were to gain access to this data, it would create a dangerous situation. Finally, the development of AI could contribute to a kind of digital divide where only wealthy nations can access the benefits of this technology while developing nations will obtain modest gains at best (citation needed here). Understanding these guidelines will allow us to construct our robot in a safe, child friendly, and ethical manner. These guidelines include supporting children's development and well being, ensuring the safety for children, and to prioritize fairness and non-discrimination for children.

To support children's development and well being with our project, we will follow UNICEF's specific recommendations for their approaches in developing child-friendly AI. The primary recommendation is to develop it with a child-rights approach. This means recognizing a child's right to privacy, safety, and inclusion by design. To ensure that the data the robot collects is secure, we will be collaborating with a team of Computer Science students to develop secure systems. This is the team that will also be developing a companion mobile application along with the machine learning system that will enable the robot to recognize faces and emotions. They will implement fundamental security features, such as JSON Web Tokens. The next way is to integrate metrics and processes to support children's well being. Our approach for achieving this guideline is to include a device that detects stress, implement a set of activities known for mitigating stress, and program the robot to recognize emotions. The stress detecting device will be a wristband that detects the heartbeat of the user. If the user's heartbeat is elevated, the robot will recognize that and respond accordingly. It will first express concern for the user, then it will notify a nearby professional, and then it will offer a range of calming activities. These common activities will range from playing calming music to starting a storytelling activity. Furthermore, it will be able to see faces of children and recognize emotions. It will be trained on a large dataset of multiple faces expressing a range of different emotions, like sadness, stress, and excitement. Lastly, the report recommends that developers prioritize ways that AI systems can benefit children and to be aware of any risks. To achieve this, our team will do extensive research on the ways in which AI can be beneficial and we will search methods to prevent any risks, such as algorithmic bias. By researching the ways AI can be beneficial or harmful, developing systems for measuring the well being of users, and implementing security measures, we can develop a robot that ensures that the rights of children are respected and protected.

In order to ensure the safety of children, our team will follow UNICEF guidelines and create mechanisms for continually monitoring the impact of the Robot on children, continually assess its impact, and test the robot's safety features continuously. The mechanisms for monitoring the impact of children will be through its companion mobile application and through the required supervision of a mental health professional. The mobile application will be developed by the computer science team while our team will design the robot to send any relevant information to the application. Such information could be potential stressors of children, favorite activities of specific children, and emotional state of the children at different periods. This transmission of information will be secured to prevent malicious hackers from viewing or stealing it. Even with the security measures, however, it will still be accessible to mental health professionals and caregivers. In order to obtain a professional opinion on the impact of children, the robot will also require a mental health professional to be supervising the robot and its activities. Doing so allows for the professional to directly observe how the robot is helping or otherwise impacting the children. Moreover, the presence of a professional guarantees that the children using the robot will be completely safe. To continually assess its impact, the professional observing the robot working with the children will have to monitor the children long term to see how the robot affects their development. Our team also has researched, and will continue to research, how other types of social robots affect development of children in a positive way. We will take note of the methods by which these robots help the children and incorporate them into our robot. Finally, we will continually test the robot's features throughout the development process. We will converse with the robot's chatbot-like feature to ensure that the robot speaks in a polite, kind, and unproblematic manner. Furthermore, we will be testing and evaluating the data collection and transfer features of the robot to ensure that these features are as secure as possible. Finally, we will design the robot in a way that it cannot physically harm a child in a significant way. For instance, we will make the robot small so that it will not tip over and fall on a child, hurting them significantly. We will also incorporate rounded corners on the robot so no child will be in pain if it bumps into the robot. Furthermore, we will make the robot light enough so that if it falls on a child or rolls over a child's foot, it will not significantly harm the child. By incorporating child-friendly design features, enabling the robot to share information through a secure mobile application, and requiring the presence of a supervisor to observe the robot, we can ensure that the robot will not endanger children in any way.

Our goal with this social robot is for it to be accessible to as many children as possible, if not to all children. In order to accomplish this, we must develop the robot to be fair and non-discriminatory. The UNICEF guidelines recommend developing datasets that represent a diversity of children's data and actively support marginalized children so they too may benefit from this system. To diversify the dataset, we will collaborate with the computer science team to ensure that we have a dataset that fairly represents children of all ethnicities, social statuses, and backgrounds. Additionally, since our project focuses on autistic children, we will use datasets that provide essential information for children with autism. Furthermore, we will research each dataset we use and be mindful of any drawbacks or weaknesses of each one. That way, we can avoid instilling any kind of algorithmic bias into the robot. In order to support marginalized children, we will be researching numerous ways that our robot can assist children of more marginalized backgrounds. One method we have considered is making the robot as affordable as possible. That way, schools can afford to purchase these robots and incorporate them into their curriculum, thus allowing for widespread use. In addition to schools, therapy organizations, especially those that aid in the development of autistic children, should be able to afford these robots and use them. Additionally, one of our team members has also been in contact with an organization dedicated to researching how to help autistic individuals using science and technology. The organization in question is the Equitable Learning Technologies Lab, a firm affiliated with the University of Florida. This firm has experience researching how the Pepper Robot can be used to assist in the positive development of autistic children. It has shared its findings with our team and we have been learning how to implement the helpful features of the Pepper Robot while also being mindful of its drawbacks. Furthermore, members of our team are well acquainted with disabilities. For example, one of our team members is autistic and has been in behavioral therapy for much of his childhood. In addition, he has experience volunteering for an autism therapy organization and is currently a part time employee of the Equitable Learning Technologies Lab mentioned before. He has been reflecting on his own experiences with autism therapy and has been using them to guide us in the development of the robot. By including our autistic teammate in our discussions of the robot, relying on the advice from organizations whose aim is to help autistic individuals, and doing extensive research on accessibility and fairness practices, our organization can design a robot that is accessible and respects the diversity of children that will likely use it.

The goal of our social robot is to develop it to support children's development, ensure their safety, and ensure that it is fair and non-discriminatory. To support their development, we plan to implement privacy features into the robot, allow the robot to measure the emotional state of children, and to provide a variety of activities which can help users manage their emotional states. To ensure their safety, we will allow for the robot to monitor the emotional state of the user, enable the robot to provide data to caregivers for continuous assessments of its impact, and test its safety features throughout the project. To ensure the robot is fair and non-discriminatory, we will select datasets which include a diverse portrayal of children, research ways in which this robot can be accessible to marginalized children, and will listen to the guidance from autistic individuals and autism-related organizations. Developing the robot with these guidelines in mind will allow us to conform to UNICEF recommendations for developing AI for children.

Other design constraints UNICEF recommends are ensuring the inclusion of and for children, protecting children's data and privacy, providing transparency, empowering governments and businesses with knowledge of AI and children's rights, preparing children for present and future developments in AI, and creating an enabling environment. Including children in our project development will be difficult as it requires a completed prototype. This team will need to complete a working prototype of the robot and thoroughly test its features before testing this robot with children. If we were to test the robot with children, however, we would schedule a time for the child to interact with the robot. We would have an adult supervisor or a mental health professional be present in the room to evaluate how effective our system is. After fulfilling those requirements, we will then let the child interact with the robot without us interfering. We will be taking extensive notes on which features the child paid more attention to and take note of any errors that occur during our program. If we have the opportunity to do a test with multiple children, we will go through the same procedure. This is a goal we hope to achieve in the future. We have considered ways the robot and companion mobile application can protect the children's data. We have discussed JSON web tokens and other secure programming practices with the Computer Science team. We will keep this constraint in mind as we develop the robot's features. To provide transparency to users and caregivers, we will think of ways we can explain how the technology works in a non-technical and simple manner. Additionally, the robot will clearly remind users that it is an AI, not a human. This is to avoid a potentially problematic situation of a child becoming too attached to the robot and seeing it as if it were a human. The robot will not be able to help children as much as a professional adult can; it is only designed to help educate children in a more personalized manner. We have no plans to design the robot in such a way that it can replace human therapists. As for empowering businesses and governments with the knowledge of AI and child rights, we will fulfill this requirement by speaking about children's rights and the potential of AI to our review committees. During our presentations, we will discuss the ways in which children's rights must be protected throughout the development process of AI, how the robot fulfills these requirements, and ways in which future versions could continue to respect children's rights. As for preparing future children for present and future developments in AI, we hope that our project can be a shining example to professors, engineers, and future students of how technology can be used to help not only autistic children, but children in general. Admittedly, this approach is indirect, but unless we will be presenting our project to schools or therapy organizations, we will not have many opportunities to directly interact with children until our project is complete. Finally, for creating enabling environments, we hope our project can be an example of how technology can be used to help children. We also hope that our project is affordable enough so that it can be used in rural and underprivileged areas. Furthermore, we hope that our presentation can inspire observers and future students to keep working to reduce the current "digital divide." This digital divide is where the majority of the benefits of technology can only be enjoyed by the wealthy and powerful, while people of developing nations and underprivileged areas struggle to receive the benefits. By following these UNICEF guidelines, we hope that our project helps discover new ways artificial intelligence can be optimized to help children and to make the project as accessible as possible in order to reduce, or even end, the digital divide.

IEEE Robot Standards

The Institute of Electrical and Electronics Engineers, or IEEE, has numerous standards for the development of robots. For our project, this team will focus on the standards IEEE 1872, which is the Standard Ontologies for Robotics and Automation; IEEE 7007, which is the Ontological Standard for Ethically Driven Robotics and Automation Systems; and IEEE 7008, the Standard for Ethically Driven Nudging for Robotics, Intelligent and Autonomous Systems. After all, these standards are the most relevant to our project. IEEE 1872 is a standard that focuses on core design patterns in robotics, general use cases for robotics, and general ontological concepts to consider. IEEE 7007 defines concepts, definitions, and use cases for ethically driven robot development without considering practical applications. It is a kind of general guide for robotics engineers. IEEE 7008 defines how "nudges," or overt or hidden suggestions meant to implement the behavior or emotions of a user, should be developed. All these standards define potential ethical issues with robotics, who will be affected by this issue, how to address these issues, and who will be responsible for the robot's failures.

For our team to follow IEEE 1872, we need to follow the Core Ontology for Robotics and Automation, or CORA, it defines. This ontology guides all different kinds of robots, from autonomous robots to industrial and medical robots. The main element of this ontology is that we must organize the robot's tasks, jobs, and resources into a coherent diagram. This diagram must explain all the ways each part relates to each other, whether they contain the functions of another part or operating simultaneously with another part. For our purposes, our diagram will have groups for each part of our robot, including the camera, the track system, and the robot limbs. We will use phrases like prompts or activates since each sensor in the robot prompts another part or activates a function. For example, the camera detecting the face prompts the neck mechanism to move to follow the face. Similarly, input from the separate stress detecting wearable device prompts the robot to adopt a calming demeanor, ask what the user is feeling, and notify the caretaker supervising the robot. Finally, buttons pressed on the touchscreen on its chest prompts it to perform certain actions, like dancing or telling stories or displaying particular emotions. By forming a coherent diagram explaining the robot's behaviors, functions, and working process, our team will be able to present how the robot functions and thinks. This standard also requires us to consider common definitions used for ontologies, such as this one. For example, when the standard refers to the environment, like a physical environment, it refers to the region where an object of interest is located. This is known as an Object-centered environment. It considers all entities that the robot can encounter. For our project, the object would be the child user whom the robot recognizes. If it is a group of children, the group is the object in the environment. When all the objects are considered, it affects the robot's interaction with the objects. Being able to understand and model these relations will aid us in both communicating our vision and will provide an outline for us when designing and building the robot.

As this team designs and builds our social robot, we will need to consider the proper format to outline the process by which it functions. To suit this purpose, we will be following the IEEE 1872 standard. This standard defines terminology and formats for developing an ontology, or ethical guideline, for robots, especially autonomous robots. We will follow this standard by creating a flowchart depicting what each component does and how they relate to each other. Next, we will consider how the robot interacts with the environment and any objects of interest. In this case, the environment will be a school or therapy organization where the robot will be situated. The object in this case will be the child or children that the robot interacts with. Following this format will not only allow us to have a coherent guideline to developing our robot, but also an excellent way of communicating our ideas and plans. Furthermore, it will allow us to follow IEEE's ethical guidelines for developing robots, whether they be autonomous or controlled. Some of these guidelines include IEEE 7007 and IEEE 7008 standards. IEEE 7007 defines more ontologies for developing ethically driven robots and automation systems [15]. IEEE 7008 offers guidance for developers of intelligent systems that seek to "nudge" humans [24]. To nudge a human in this context means to subtly influence its behavior. In the case of our robot, our robot intends to nudge autistic children into learning how to communicate, manage their emotions, and understand social interactions. By following these standards, this team can ensure that our robot follows IEEE standards and respects the rights of humans. Such rights include the right to privacy and the right to human dignity.

Designing the Mind of a Social Robot Requirements:

To familiarize ourselves with the process of designing a social robot, we read the paper "Designing the Mind of a Social Robot," From MDPI Open Access Journals [17]. This paper provides specific guidelines for designing the robot and provides an example of how those guidelines can be implemented. The primary guidelines provided by the paper include designing a sensing and thinking framework, implementing a low-level control architecture, and implementing a high-level pattern recognition and reasoning architecture. The sensing and thinking frameworks in this paper include three models: the hierarchical paradigm, the reactive paradigm, and the hybrid deliberative/reactive paradigm. The hierarchical paradigm dictates that the robot gathers data from its sensors, devises a plan on how to react to those standards, then acts according to that plan. While this process allows for the robot to be meticulous and well mannered, it could become too slow and complex to use. The reactive paradigm seeks to overcome this issue by only including the sensing part and the reacting part. That way, when a robot senses something, it immediately acts on how it was programmed to do so. This allows the robot to be fast, but this framework does not allow for any careful planning or consideration before any action. In social situations, this can prove to be costly as the robot could act inappropriately in a situation based on its sensor data. In such a situation, the data from its sensors could be wrong. They could also be correct, but since the robot does not think through its actions beforehand based on its sensor data, it could act too quickly and inappropriately. The paper recommends using the hybrid deliberative/reactive paradigm. This paradigm includes the sense and act cycle that the reactive paradigm uses, but also includes a planning capability that can interfere and assist when needed. Using this paradigm, the robot can act quickly when needed, but if it is in a complicated social situation, it can stop and plan its next action. In addition to the basic paradigms, the paper also recommends having a working low-level architecture to control the robot. This means that developers need to design architecture that allows robots to sense and perceive the world around it along with controlling its movements. For our project, this low level architecture would require using operating systems specifically designed for robotics and to incorporate embedded systems such as microcontrollers and sensors into the functions of the robot. Finally, the robot recommends implementing a certain high level architecture that allows the robot to recognize human emotions, recognize faces, and have a framework for understanding how to respond in social situations. For our project, this will involve working with a Computer Science Team to develop a way for the robot to see and recognize human faces along with their emotions. By choosing to use and outline a hybrid deliberative/reactive paradigm, a working low-level control architecture, and a multifaceted higher level architecture into the robot, we can ensure that our social robot matches the kind of quality the paper expects.

For our project’s purposes, we will develop a hybrid deliberative/reactive paradigm framework that will dictate how the robot will act. In some circumstances, whenever its sensors detect something, it will immediately act according to its programming. For example, the team has discussed what it would do if it bumped into a wall, object, or any other obstacle. One team member proposed that the robot can have buttons on its front to detect collisions, much like a Roomba. When that happens, the robot will yelp in pain. If it bumps into objects too many times, it will then adopt a sad demeanor and refuse any inputs from its controller. The user must tell the robot they are sorry if they want the robot to be controlled again. Another idea that has been proposed is to have the robot use ultrasonic sensors to detect objects close to it. If it senses one, it will stop or purposely redirect itself to avoid the obstacle. In both of these scenarios, the robot senses an object, such as a wall, it will then have an immediate reaction. No planning is required in these scenarios. However, other scenarios require that the robot has a more planned and cautious action. In these scenarios, the robot needs to consider its protocols in order to plan for the correct response. For example, if the robot notices that the child is sad or stressed, it will enact specific protocols such as offering comforting activities like telling stories or playing music. The robot will detect stress using a wearable device the user wears, which we plan to detect the user's heartbeat. If the heartbeat is elevated, the robot will then notify the supervisor nearby. Next, it will offer the stressed child a range of activities meant to calm and manage stress. Such activities include calming music, games, or dances. In this case, the sensing was the robot detecting an elevated heart rate, the planning was asking the child what would calm them down and initiating an action based on that input, and the action would be notifying a supervisor and acting upon its previously formed plan. By using this framework of sensing and acting in certain scenarios, but utilizing planning when in more complex situations, the robot can engage with users in a way that is socially appropriate. Whenever the robot faces a more immediate situation, such as bumping into a wall, it has an immediate reaction, which in this case would be yelping in pain. No planning is required. However, when the robot faces a more delicate situation, such as a child expressing sadness, the robot will need to consider its protocols and determine the best action to undertake, thus including the planning aspect.

Properly controlling the robot will require a sophisticated, yet well designed low-level computer architecture. It will consist of sensors, motors, and robot-specific programming. The paper cited here also requires that the hardware platform used should be easily adapted to various robotics platforms to be used in future research. To program this, this team will be implementing an Arduino Microcontroller into the robot for the main control of its limbs, for controlling the eye expressions, and for connecting to the wearable stress-detecting device. Additionally, the robot's movements will be programmed using Robotic Operating Systems 2, or ROS 2. Collecting data from the camera and connecting with the machine learning aspects of the robot will be handled by the Jetson computer embedded in the robot. When it comes to controlling the robot, the paper requires that the movements and behavior of the robot are easy to read. Doing so allows for neuroscientists and behavioral psychologists to incorporate their theoretical models into the robot to see if they work. Of course, these theoretical models will need to be formatted into executable scripts for the robot to follow. If these scripts were to be uploaded to the robot, they would first be uploaded to the Jetson. Next, that Jetson will send its data to the Arduino to mandate the robot's behavior. Thus, the requirement for a deliberative reasoning high-level architecture for implementing behavioral and emotional models is fulfilled. The current plans for the robot include programming the robot to be able to express a wide range of emotions, from happiness to sadness. To do so, it will utilize body language and eye expressions. It's body will adopt specific demeanors to appear happy. For example, if it is sad, it's head will look down, its body will slump forward, and its hands will reach its face and make a crying motion. Additionally, its LCD eyes will portray sad-looking cartoon eyes. Similarly, if the robot is happy, it will raise its arms in the air and tilt its head to portray a happy demeanor. Its eyes will display happy-looking cartoon eyes. Doing so allows for child users to practice recognizing emotions. The robot will even include a game where it acts out an emotion and the students will have to guess what the emotion is. Giving the robot the ability to express itself also allows for users to form a kind of connection to the robot. Users will be able to recognize these emotions, carry conversations with the robot, and see it as a kind of friend or even a pet. Furthermore, these emotional models can be used for future research purposes. Another element of its low level architecture is the way it reacts to receiving headpats. The robot will have a touch or light sensor on the top of its head to detect when a person is giving the robot a head pat. It will be programmed to accept headpats happily if the user asks for permission using the mobile application. If the user does not ask for permission and reaches for a headpats, the robot will become scared and shy away at first. If the user continues to reach for the head, the robot will become angry and tell the user not to touch it. If the user wants the robot to exit this state, they must apologize to the robot. Doing this will teach users a valuable lesson about respecting other people's boundaries. The last form of the low-level control architecture will be the motors and track system implemented into the robot. The robot will move using a track system and this system will be controlled by a separate remote controller. The robot will also have a LiDAR system on its face that allows it to detect objects in front of it. It will be programmed to yell in fright if it starts driving too close to an object. Additionally, the robot will have buttons at the front or the back that will detect when a robot hits an object, much like a Roomba detects objects. If it gets hit, it will yelp in pain. If it bumps into an object too many times, it will adopt a sad demeanor, communicating that it is in pain. When in this state, the users will need to apologize to the robot if they want the remote controller to work again. By implementing this control architecture at the low level, future researchers will be able to study their behavioral models and users will be able to connect to the robot like a kind of friend, which thus fulfills the low level hardware requirements of this paper.

In addition to a well designed low-level control architecture, the paper also requires a high-level architecture that manages the social perception system, the reasoning, the storage and communication, and a method for implementing any behavioral or emotional models. This architecture level will be handled by the computer science team, but we will be collaborating with them to make sure the robot fulfills all its requirements. For our robot, the social perception system will consist of a camera in the robot's head that can detect faces and their emotions. This camera will be connected to the Jetson and the robot will undergo machine learning to be able to recognize faces and their emotions. After recognizing their emotions, the robot will be able to respond in an appropriate and caring manner. For example, if a child is sad, the robot will recognize that emotion, adopt a caring demeanor, notify a supervisor, and ask the child what would make them feel better. The reasoning part of the robot will be developed in the Jetson as well and will consist of different greetings and mannerisms for interacting with the child along with logic frameworks for maintaining the child's attention long-term. For example, when the child greets the robot, the robot will then allow the child to choose from a range of activities, from music to dancing to games. After choosing an option, the robot will initiate that chosen activity until finished. For the communication and storage element, the robot will be storing the data into an online mobile application. Such data will be made secure so malicious hackers cannot access it. Finally, the implementation of the behavioral and emotional models will be handled by this team since we will be directly concerned with programming the robot’s movements, mannerisms, and expressions. By implementing a logic framework, a method of implementing behavioral and emotional models, a communication and data storage method, and a social perception system, we can develop a social robot that can recognize and understand emotions, manage itself in social situations, and provide necessary activities for helping autistic children.

By developing a hybrid deliberative/reactive framework, implementing a sophisticated control architecture, and a high level pattern recognition and reasoning architecture, we will be able to develop a robot that can fulfill its purpose of helping autistic children. Moreover, future researchers will be able to modify it to experiment with new behavioral or emotional models. Thus, our project will be fulfilling the requirements of the paper “Designing the Mind of a Social Robot.” The paper itself acknowledges that social robots have the potential for being useful machines for the treatment of those with Autism Spectrum Disorders, or ASD. The paper reviews a certain social robot called FACE, which stands for Facial Automation for Conveying Emotions. This robot was designed to resemble a human and convey facial expressions like a human does. It could perceive its environment and recognize human faces, demonstrate the necessary social awareness to conduct itself in social situations, and could convey emotions using complex algorithms and motors. When tested with participants with ASD, it was proven to be effective. Our project is similar in that it will be able to conduct itself in social situations, recognize human faces, and express emotions. However, there are significant differences between FACE and our project. While FACE is designed to resemble a human, our robot resembles a teddy bear. Also, while FACE is designed to emulate human emotions, our project will only use LCD eyes and body language to convey emotions. The LCD eyes will also resemble cartoon eyes. Finally, our project’s facial and emotional recognition capabilities may not be as complex as FACE’s capabilities.

Indoor and Outdoor ASHRAE Standards:

Bearmax 2.0 will likely be operating inside schools and homes but could be stored in unconditioned indoor environments such as attics. It was therefore crucial to make note of the kind of temperature conditions that would be affecting the internal components, especially the more delicate controllers.

ASHRAE (American society of heating, refrigerating and air conditions engineers) have released the 9th edition of “Principles of Heating, ventilation, and air conditioning” in which they detail the methods surrounding the parameters for both indoor and outdoor design conditions.It is based on these guidelines that we will make assumptions about the climate influences on our design. Bearmax will be functioning in comfortable indoor conditions where the dry bulb temperature does not break from an average of 75 degrees. Dry bulb temperature refers to the temperature at which it is not affected by humidity. As for the relative humidity of indoor design conditions that would be within the range of 30-60% These would be under the ASHRAE Standard 62.1-2016. Specific standards supporting the full range of design conditions can be found in the ASHRAE standard 55.

Being a social emotional learning tool, unless Bearmax is in storage it will be indoors under the specified design conditions however, the clinician or child may want to go outside and expose Bearmex to central Florida outdoor conditions. Florida has a dry bulb temperature of 99.6 degrees corresponding to 99% frequency per the 2021 ASHRAE design conditions for the Orlando executive airport. For our design, it's imperative to consider how such high temperatures could affect Bearmax's performance and ensure that it can operate under such conditions through extensive testing.[26]

Section 5: Comparison of Chat GPT and Other Platforms

Relying on ChatGPT, although tempting, is problematic. Some of our members have experience using it and are well aware of not only its positives, but also its downfalls. While it can write sections of code and paragraphs for us, it lacks the contextual knowledge required for the writing to be effective. When asked to write text according to a specific prompt, it will give generic answers based on the text it has been trained on. When asking it to write code for a program, it can certainly provide some code to use, but there is no guarantee that the code will be useful. Finally, ChatGPT has been known for giving false information at times. OpenAI even has a disclaimer saying “ChatGPT may give out false information about people, places, or facts.” To illustrate these shortcomings, we will provide three examples.

For the first example, one of our members asked ChatGPT, “Please tell me how the Pepper Robot can be helpful for the positive development for children with autism.” It listed various ways it can be helpful, such as emotional recognition, social interaction, and reducing anxiety. With each point listed, it elaborated with long explanations of what each point meant and how the robot provides that. For example, it listed customized learning as something the Pepper robot can provide. It explained that, “Pepper can be programmed to cater to the specific needs and interests of individual children, providing a customized learning experience that is tailored to their requirements.” While true, these are explanations given without examples. It does not cite studies, articles, or stories of the Pepper robot helping autistic children. In fact, when asked to provide an example, ChatGPT provided a hypothetical scenario where the Pepper robot helps an autistic child. It told the story of Alex, a nine year old autistic boy who found social interaction, communication, and expressing emotions challenging. In this story, Alex's therapist suggests using the Pepper robot to teach them how to effectively communicate and participate in social activities. This robot was able to incorporate Alex's interests, like drawing or playing games, into the activities. With time, Alex's confidence improved and he was able to participate in social situations. While this scenario is plausible, it is merely a hypothetical scenario. ChatGPT did not cite any studies or articles, so whether or not ChatGPT really knows what it is talking about is still unknown. Meanwhile, our team has read studies on the Pepper Robot and learned how effective it is at helping children with autism. Not only have we read and understood it, but we also have observed some unexpected actions that ChatGPT probably would not have considered. One of these actions was when a child tried to give the Pepper Robot hair using a rubber snake. It was an act of playfulness that neither we, nor ChatGPT would have thought of. While ChatGPT can certainly write, and admittedly write well, it lacks the knowledge one needs to actually write effective essays. It cannot read or cite sources unless prompted to. Even if our team did give the studies to ChatGPT and told it to write our paper for us, it would likely regurgitate what the studies said without offering its own thoughts or opinions.

The second example of the limitations of ChatGPT is evidenced by an experience one of our members had when trying to code using ChatGPT. Our member, Zachary Larson, had a programming assignment for his Operating Systems class. This programming assignment required that he try to get ChatGPT to create a round robin scheduler in Python. Zach decided that for this assignment, he would approach the topic step by step. He would first ask ChatGPT if it knew what a Round Robin Scheduler was. If it did, he would ask it to write a basic version of the scheduler, then add on more features to fit the assignments requirements. It took him three attempts to get a functioning code whose output was at least close to being correct. The first time he tried, the scheduler kept giving the wrong outputs. No matter how many prompts he gave, no matter how many times he pointed out the mistakes in its code, ChatGPT would not fix the code. In the second attempt he tried again. In this attempt, he first asked ChatGPT to write a basic program in Python that would print the phrase “Hello World.” The purpose of this was to guide ChatGPT to first understand what Python is, then try building the Round Robin Scheduler. After proving that it understands the basics of Python, he then asked ChatGPT what a Round Robin Scheduler is. ChatGPT answered correctly. After that, he tried to get ChatGPT to write another round robin program, but much like before, it failed to give the correct outputs. Frustrated, he tried a third time. This time he wanted to build the round robin scheduler, but use ChatGPT as a helper. Although he did rely on ChatGPT for drafting the initial part of the code, he modified the program so that it could work correctly according to the assignment requirements. However, there was one flaw in the code that he could not figure out. He knew what the flaw was and how it was affecting the output, but he did not know how to fix it. He tried asking ChatGPT multiple times to fix the error, but it did not produce a solution even when it said it found a solution. Ultimately, Zach concluded that ChatGPT was no replacement for real coders. While it can be useful for creating initial code and can make coding faster, an experienced and knowledgeable programmer is still required to make the code the best it can be.

The third example of ChatGPT's limitations is the number of times ChatGPT has written wrong information as outputs. ChatGPT itself even refuses to answer questions about public figures in the current year because its training data includes written text written up to 2021. OpenAI's disclaimers clearly state that ChatGPT can often get information wrong on multiple topics. OpenAPI has also described its dissemination of false information as "hallucinating" and "making up facts."[16] For example, a Purdue University study explained that out of five hundred and seventeen software engineering questions, ChatGPT got fifty two percent of the questions wrong and seventy two percent of the questions verbose [21]. Ironically, ChatGPT is often used to help people write code and understand Computer Science Concepts. Zach Larson, a computer engineering major, admits that he has used ChatGPT a few times to help with programming assignments. However, he has also noted that ChatGPT is not always correct. The same Purdue study also states that at least thirty nine percent of people rely on ChatGPT for software-related inquiries. In another incident, a journalist for Insider, named Samantha Delouya, asked ChatGPT to write a news article [18]. The article was about a Jeep factory in Illinois whose production was struggling due to the cost of producing electric vehicles. Despite being written quickly and seeming convincing, it contained fake quotes from the CEO. Vincent Conitzer, a Carnegie Mellon professor of computer science remarked that "These models are trying to come up with text that is plausible according to their model. Something that seems like that kind of thing that would be written. They're not necessarily trying to be truthful."[18] Thus, our team feels that we cannot fully entrust ChatGPT with writing our paper for us, since it regularly writes wrongful information.

After reading about incidents of ChatGPT failing and experiencing its shortcomings ourselves, we conclude that ChatGPT cannot be totally relied on to write our paper or our code for us. While we may use it to draft initial versions of our paper and write initial drafts of our code, we still need to extensively edit the outputs to ensure that they meet our expectations. The problem with relying on ChatGPT extensively is that it produces well written but uninformed opinions of topics, produces code that only functions after careful editing, and often produces misinformation. These shortcomings seem to be a key design flaw that results from its original purpose: to be an artificial intelligence that successfully mimics human language. It can certainly mimic human language in an incredibly convincing fashion, but only because it considers which words and which phrases are most likely to be used after certain words or according to a prompt. As stated before, its goal is not to be correct or knowledgeable, its goal is to write text that can pass as human. Therefore, we conclude that the best use of ChatGPT for our purposes is to prompt it to write initial drafts of code and papers for us, and then help us edit them after we have modified them to suit our purposes. By employing ChatGPT in this manner, we can ensure that our work is honest, informative, and well written while also allowing us to be more efficient and work faster.

In addition to using ChatGPT, we have been using Google to research our project. Google has been an excellent platform for finding researching materials that can aid in our project. It has an incredibly large variety of resources and is excellent at choosing the most relevant resources first. It has provided us with studies to demonstrate that our project has potential. When we were first researching our project idea, we needed to find studies of similar projects to see if the idea had any merit. We asked Google to find us articles or research on social robots and it gave us several that were exactly what we needed. These studies discussed multiple social robots, affirmed that their use in therapy was effective, and provided examples of downsides of each robot. After finalizing our project idea and finishing our preliminary research, we needed examples of other social robots to understand their strengths and weaknesses. So, we searched on Google for other related robots and found numerous examples. One of the robots we found was called Moxie, a small, cute robot that can have conversations with children and recognize faces. It is designed to be a friend to young children and can teach them important social skills. We used this robot as one of our inspirations as we learned what it is capable of, how exactly it helps its users, and what downsides it has run into. We hope to create a social robot that not only has the same advantages, but also improves upon its disadvantages. However, Google has not always been able to provide direct answers to all our questions. For example, one of our members wanted to look for robots that can teach young children consent and boundaries. He knew that, if implemented, such a feature can make our robot unique among many of the other social robots. However, he wanted to research to see if other robots implemented this feature and, if so, how it was implemented. Unfortunately, Google's results did not include articles or studies of robots teaching users consent. It instead linked to more articles about the previously mentioned Moxie robot. Ultimately, while Google can provide sources and can better understand search queries, unlike ChatGPT, it cannot always provide direct answers to questions. Nonetheless, this team will research what it can and learn all that it can in order to design the best possible social robot.

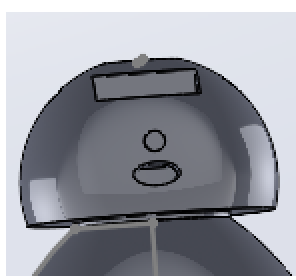
Section 6: Hardware Design

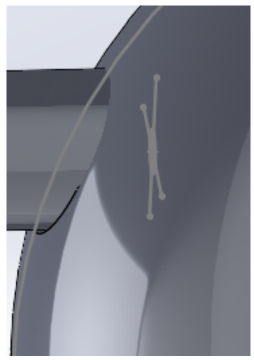
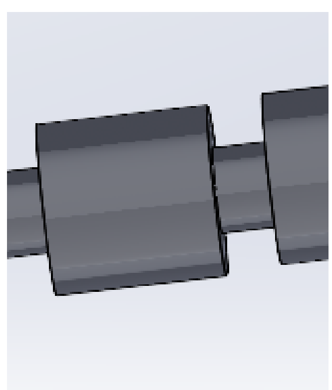
Relationship Matrix

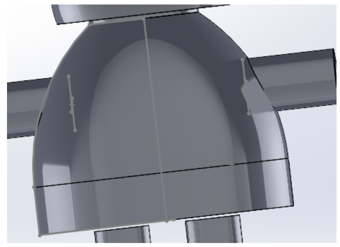
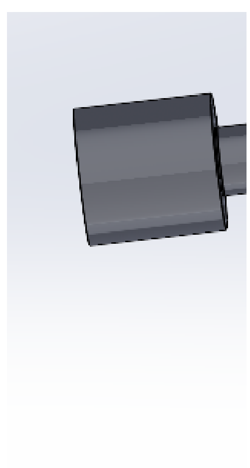
Engineering Requirements	User Needs and Wants	Resemble a stuffed bear and be visually appealing for children to be comfortable around	Low cost	Robot is attentive and keeps child engaged	Helps child learn emotions	Responds to child's words or actions appropriately	Easy to use/interact with	Safe	Helps child express emotions and soothes child	Capable of giving the child a hug
Expresses different emotions through LCD screen eyes and body movements				High	High	Medium	Medium		High	
Mobile through track system, controlled by remote control				Low		Low	High			Low
Detects user stress and responds accordingly				High	Medium	High	Medium		High	Medium
Withstands indoor/outdoor temperatures								High		
Withstands moderate humidity								Low		
Appealing to children and parents		High		Medium		Low				
Remain upright and maintains balance								Medium		High
Low cost			High							
Motion tracking through camera				Medium	Medium	Medium	Medium	Medium	Medium	
Must be durable			Medium					High		Medium
Soft exterior, no sharp edges		High						High		High
Capable of head and neck movement				Medium	High	Medium			High	Low
Capable of shoulder, arm, and hand movements				Medium	High	Medium		High	Medium	High
Able to talk or say phrases appropriate to user's needs or situation		Medium		High	Medium	High	High		Medium	
Lightweight		Low						High		High
Must be durable					Low			Medium		Medium
Capable of verbal greetings		Medium		Medium		Low			Medium	
Easy to setup							High	Medium		

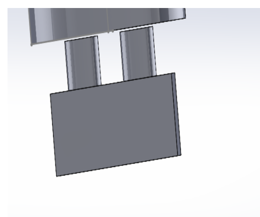
FUNCTION		
Engineering Requirement	Target Values or Acceptable Range	Plan to Validate Performance
Must resemble a stuffed bear and be visually appealing for bonding.	Ears resembling bear ears, round torso, bear nose, exterior painted to appear like a bear(which kind TBD)	Visual inspection and feedback from interactions.
Emotions with 5 - 10 programmed emotions with expressive visuals and body language.	BearMax as an SEL tool will be able to execute stated emotions for help in teaching how to perceive emotions.	Test runs of each emotion movement program, then a test runs to see if BearMax responds with correct movement.
Move well with a track system easily navigable with remote controls.	Speed = TBD Able to move forward backward and change directions.	A test course involving carpet and wood flooring to test the track system for BearMax.
Must be able to detect stress in persons with camera	CS team details, outside of ME/CE scope	Verify that BearMax is identifying stressed people correctly.

PERFORMANCE/MAIN DETAILS		
Engineering Requirement	Target Values or Acceptable Range	Plan to Validate Performance

Weight of Body and Frame	Maximum 20-30 pounds	Weight scale measurement
Height of Robot	Maximum 3 feet	Inspection (use measuring tape)
Width of Robot	Maximum 2 feet	Inspection (use measuring tape)
Material of Frame	Composed of PVC, 3D printed PLA parts for the rigid structures, Elastic 50A resin shell, and a cloth covering	Inspection each material satisfies each purpose
Number and List of Components	Head, neck, body shaft, 2 hands with digits, 2 lower arms, 2 elbows, 2 upper arms, 2 shoulders, torso, base, tracks	Inspection
Manipulators	Electrical motors	Inspection
Type of Manipulators	Servo Motors Designate torque and power for each motor	Inspection and testing each movement to ensure load requirements are met by motors
Head and Neck Motion System	 Neck is capable of bending forward, backward, and side to side to express emotions. Neck is also capable of 180 degree yaw rotation.	Verify neck and ears move through proposed range of motion, evaluate by inspection.

	Ears are capable of rotating forward and backward to help with emotional expression.	
Shoulder and arm motion system	 Shoulder joint is capable of rotating forward 180 degrees and sideways rotating 90 degrees. Inward rotation of 90 degrees. Arm limb will be connecting to the elbow joint	Verify shoulders move through proposed range of motion, evaluate by inspection.
Elbow joint and forearm	 Elbow joints will be capable of 90 degree rotation toward the body.Elbow joint will be connected to the forearm	Verify elbows move through proposed range of motion, evaluate by inspection.

	which will be connected to digits.	
Torso	 Inner torso will be a rotational rod able to support the upper structure that connects into the track platform. Rod will be able to yaw 180 degrees. Outer shell will then cover the rod to retain the goal of teddy bear appearance. BearMax 2.0 will have a screen on the torso to display emotion for the game. Design will be similar to BearMax 1.0	
Digits		Verify digits move through proposed range of motion, evaluate by inspection

	Our hand design will consist of 2 large fingers and a thumb. Each finger will be capable of 90 degree inward rotation at 2 different points, while the thumb will be capable of 90 degree downward rotation.	
Platform/Track	 BearMax will have a track system for movement which is adjustable with the app. The track system was decided because of the prevalence of carpet in living rooms which BearMax would likely be positioned in. The carpet surface would make tracks more suitable because it is a softer surface.	Test track system on course similar to family home and or classroom which would include carpet and tile flooring.

BearMax is able to play two distinct games (stretch goal have more) and greet the person interacting(“Hello”, with wave) 1.Rock Paper Scissors 2. How is BearMax feeling today? Identify the right emotion.	BearMax waves and greets correctly. BearMax is able to correctly be prompted into either game and identify when it has lost or won. BearMax will display different emotion options on the torso screen and the child will select the perceived emotion BearMax is making.	Testing each game and greeting to confirm BearMax is operating properly.

OPERATING ENVIRONMENT		
Engineering Requirement	Target Values or Acceptable Range	Plan to Validate Performance
Temperature Requirement Must withstand indoor/outdoor temperature range.	Per ASHRAE Orlando design conditions 2021 concerning dry bulb temperatures, temperature does not normally exceed 99.6 degrees fahrenheit and does not drop below 32.2 degrees fahrenheit.[25] Comfortable indoor range per ASHRAE is listed as roughly 75 degrees averaging both winter and summer conditions.[26]	Full test including emotion movements/displays and linear movement on track system.

	BearMax will almost always be operating indoors but we can confirm it will still function under these conditions.	
Humidity Requirement	Comfortable relative humidity of indoor conditions per ASHRAE range from 30% to 60%. Outdoor Orlando humidity can approach 100% on extremes. BearMax will likely only be outside if children/clinician find it comfortable that day so these extreme conditions are not restricting so we should assume mainly indoor conditions.	Full test including emotion movements/displays and linear movement on track system.
Pressure Requirement.	Standard atmospheric pressure.	Full test including emotion movements/displays and linear movement on track system.

EMOTIONAL BODY LANGUAGE		
Engineering Requirement	Target Values or Acceptable Range	Plan to Validate Performance
Emotion: happy/excited	BearMax displays a happy face and eyes on screen in addition to raising arms/shoulders/elbows and thumbs up. Torso screen displays	Visual inspection

	emotion.	
Emotion: sad	BearMax displays a sad face and eyes on screen in addition to slumped shoulders/tilting head down. Torso screen displays emotion.	Visual inspection
Emotion: angry	BearMax displays an angry face and eyes on screen in addition to balling up hands, straightening arms and nodding forward. Torso screen displays emotion.	Visual inspection
Emotion: confused	BearMax displays a confused face and eyes on screen in addition to tilting head to side. Torso screen displays emotion.	Visual inspection
Emotion: shock	BearMax displays a shocked face/eyes in addition to raising hands to face and bending elbows. Torso screen displays emotion.	Visual inspection
Emotion: fear	BearMax displays a frightened face/eyes in addition to covering head with hands and looking down. Torso screen displays emotion.	Visual inspection

Emotion: tired	BearMax displays a tired face/eyes in addition to tilting head to side. Torso screen displays emotion.	Visual inspection

GEOMETRY/PHYSICAL		
Engineering Requirement	Target Values or Acceptable Range	Plan to Validate Performance
Specific length/width/height of Torso skeleton	TBD	Measurement via CAD software and confirmation with measuring tape
Specific length length/width/height of Neck/head skeleton	TBD	Measurement via CAD software and confirmation with measuring tape
Specific length/width/height of track system/platform	TBD	Measurement via CAD software and confirmation with measuring tape
Specific length/width/height of shoulders, elbows, hands skeleton	TBD	Measurement via CAD software and confirmation with measuring tape
Specific length/width/height of outer plastic shell covering skeleton	TBD	Measurement via CAD software and confirmation with measuring tape

COMMERCIAL/SAFETY		
Engineering Requirement	Target Values or Acceptable Range	Plan to Validate Performance
Cost	<500$ to manufacture	Sum of cost related to parts
Tip risk and countermeasures if needed	Identify risks of tipping over and insert counterweights/redesign if needed.	TBD
Appeals to market(clinicians/parents)	Using benchmarked traits from competitors, ensure BearMax has major abilities that meet industry standards.	Confirm feature in relationship matrix
Ensure low risk of laceration	Avoid exposed sharp corners or edges	Visual inspection

ELECTRICAL/COMPUTER SYSTEM		
Engineering Requirement	Target Values or Acceptable Range	Plan to Validate Performance
Battery voltage power supply	Maximum of 12 volts, step down converter will be used to lower to 6 volts	Confirm via multimeter
Battery current	TBD	Confirm via multimeter
System resistance	TBD	Confirm via multimeter
System operating power requirements	TBD	Confirm via multimeter
Computer/head operating system power requirements	TBD	Confirm via multimeter
Run time	When plugged in, as long as they want. When not plugged in, a goal of 20 minutes to an hour.	Confirm with stopwatch
Speaker System	Must be loud enough to say simple greetings. Estimated around 50-60 decibels based on CDC guidelines for conversation volume measurements	Confirm with volume measuring app
Microphone System	Able to detect spikes in volume, range from 50-80 debels to determine a “normal range” and a “loud range”.	Ensure it could pick up volume from these ranges with testing verification of normal and yelling conversations.
Camera system	Each LCD eye will have minimum resolution of 320x240 pixels, size of LCD could range from 4x4 inches to 6x6 inches	Quality verification.

ACTUATOR SYSTEM		
Engineering Requirement	Target Values or Acceptable Range	Plan to Validate Performance
Actuation	Electrical	Servos motors, possibly DC motors
Motor size	TBD but must fit within size parameters	Measurement verification
Motor Power	Can operate within 1-6V range	Measurement verification
Motor RPM	Must be able to turn joints as specified	Measurement verification

Figure 8: Initial conceptual CAD model of Version 2 BearMax

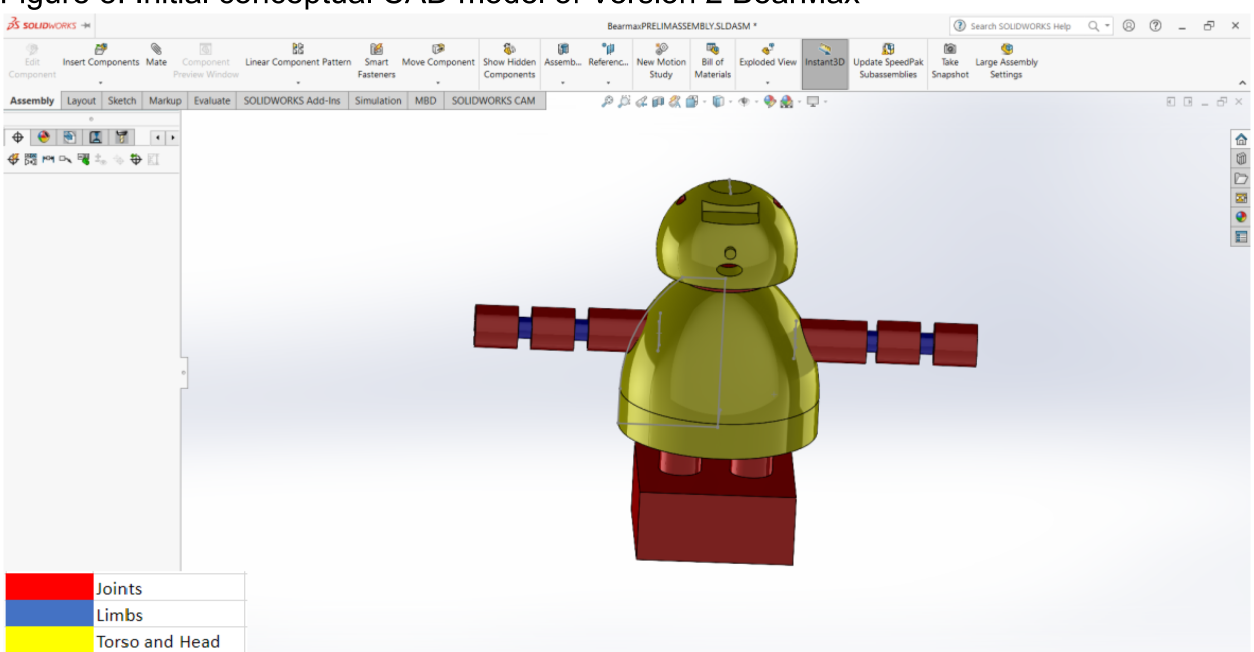


Figure 9: Initial CAD close up of conceptual head of Version 2 BearMax

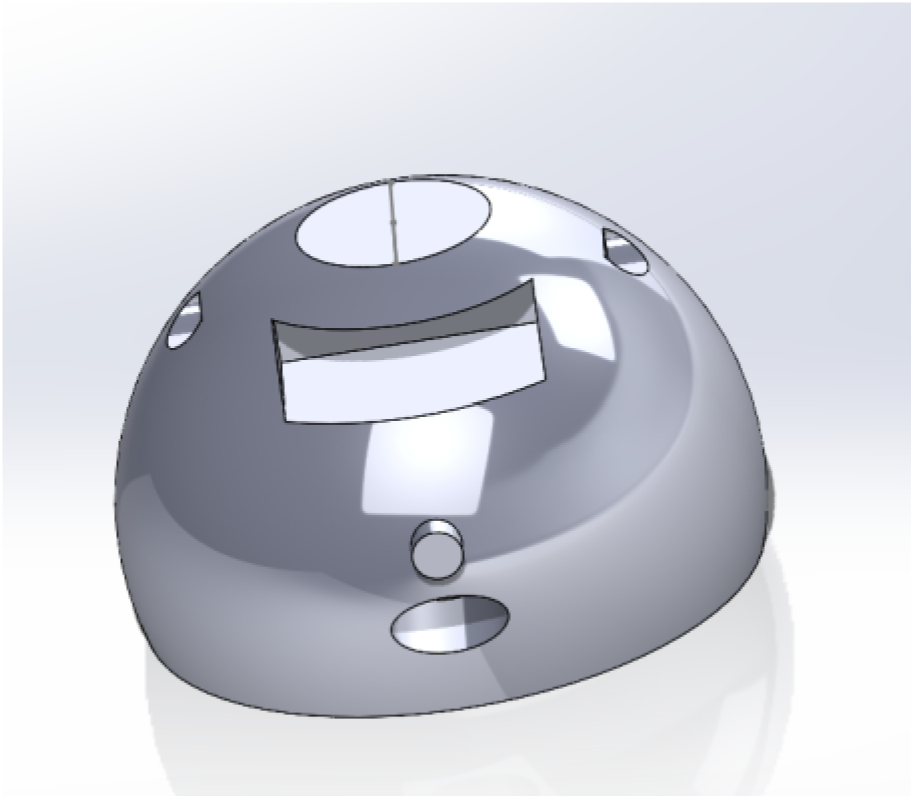


Figure 10: Initial CAD close up of conceptual torso of Version 2 BearMax

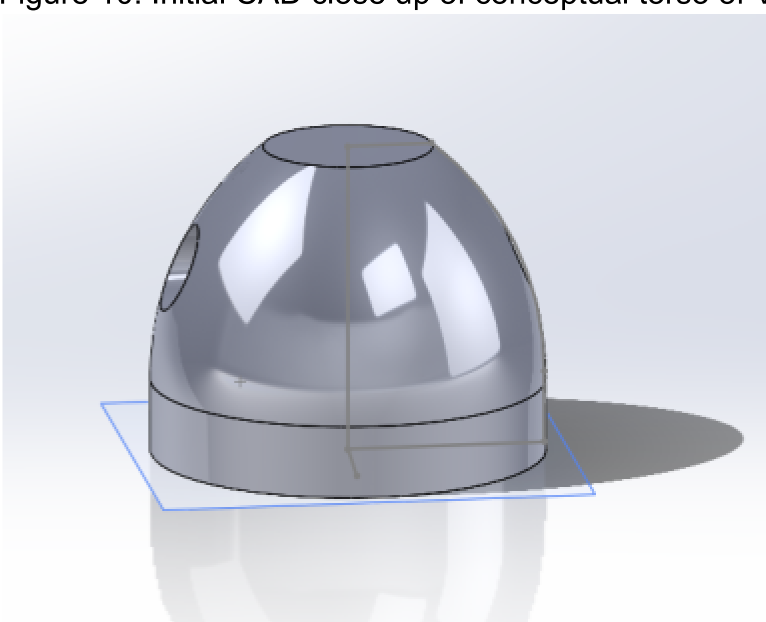
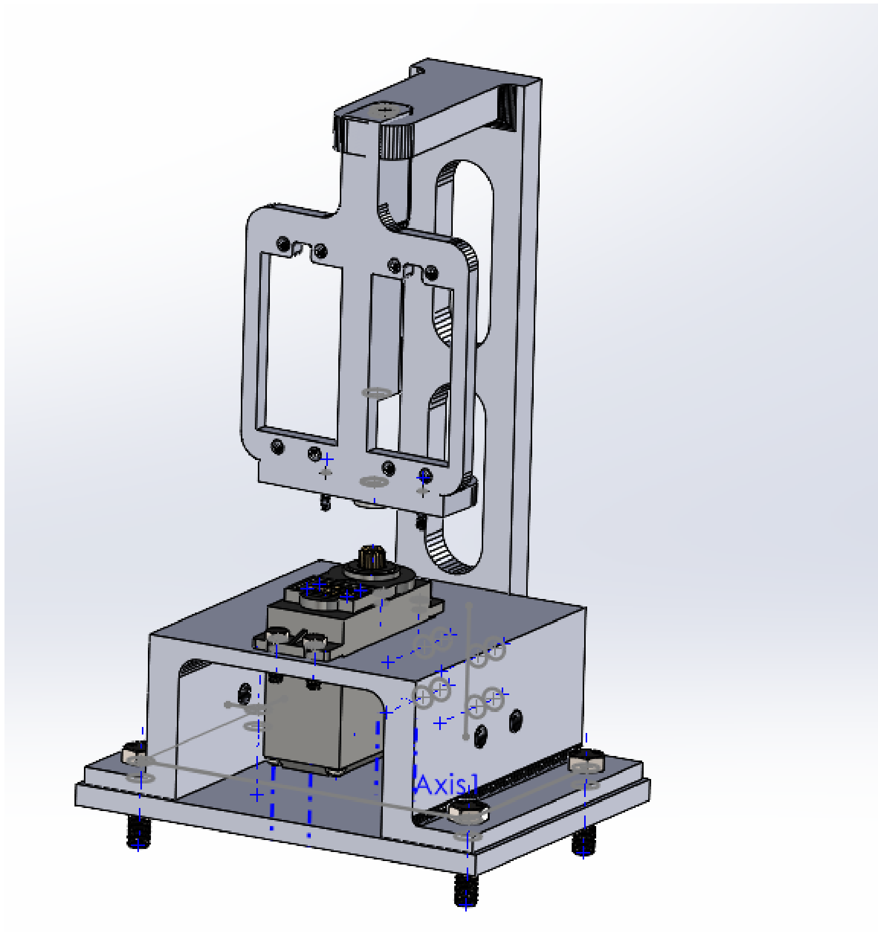


Figure 11: Initial CAD of further specified Neck Design



Section 10: Administrative Content

Estimated Budget:

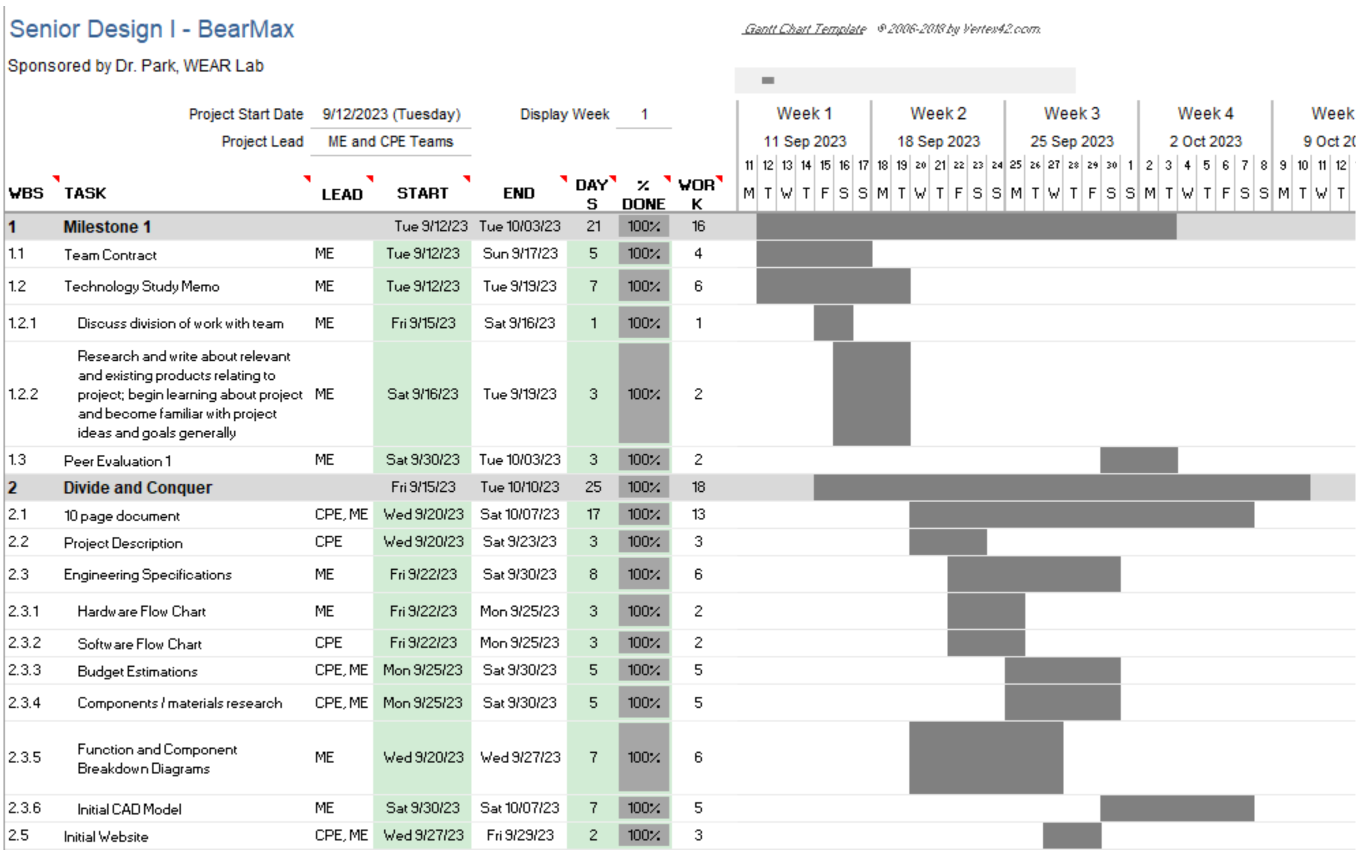
The previous version of this project proposed a budget of 250 to 300 dollars. We estimate that the 250 to 300 dollar budget will be sufficient.

Project Milestones:

- 9/20/23- Form a Divide and Conquer committee and decide which member will do which task
- 9/28/23- Divide and Conquer version 2
- 11/3/23- Complete a 60 page draft of the research report for this project
- 12/5/23- Complete the final research document for the project
- 3/28/24- Complete the final report

Gantt Chart:

Template retrieved from:
https://www.vertex42.com/ExcelTemplates/excel-gantt-chart.html



Senior Design I - BearMax

Sponsored by Dr. Park, WEAR Lab

Project Start Date: 9/12/2023 (Tuesday) Display Week: 1

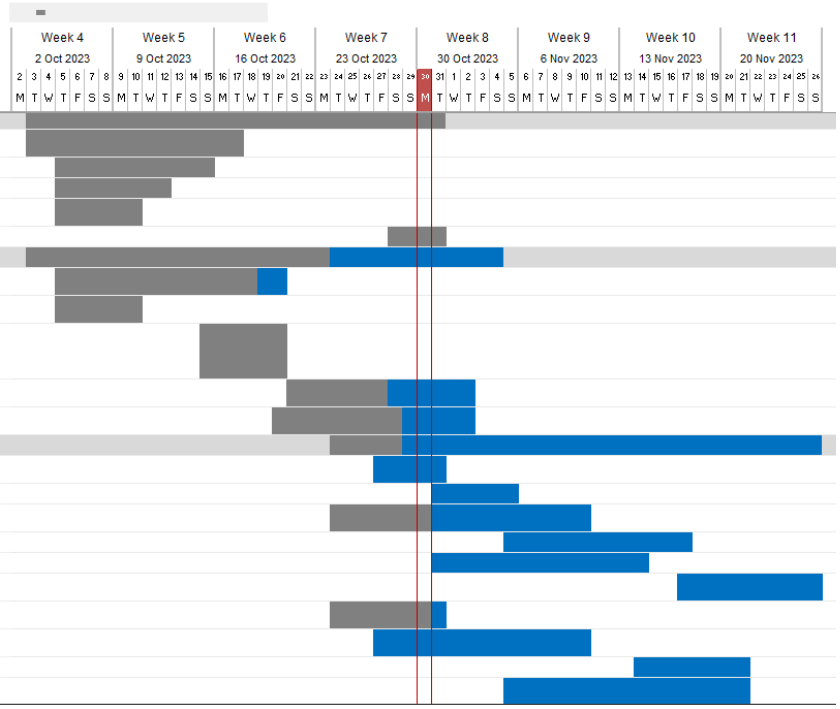
Project Lead: ME and CPE Teams

WBS	TASK	LEAD	START	END	DAYS	% DONE	WORK
1	**Milestone 1**		Tue 9/12/23	Tue 10/03/23	21	100%	16
1.1	Team Contract	ME	Tue 9/12/23	Sun 9/17/23	5	100%	4
1.2	Technology Study Memo	ME	Tue 9/12/23	Tue 9/19/23	7	100%	6
1.2.1	Discuss division of work with team	ME	Fri 9/15/23	Sat 9/16/23	1	100%	1
1.2.2	Research and write about relevant and existing products relating to project; begin learning about project and become familiar with project ideas and goals generally	ME	Sat 9/16/23	Tue 9/19/23	3	100%	2
1.3	Peer Evaluation 1	ME	Sat 9/30/23	Tue 10/03/23	3	100%	2
2	**Divide and Conquer**		Fri 9/15/23	Tue 10/10/23	25	100%	18
2.1	10 page document	CPE, ME	Wed 9/20/23	Sat 10/07/23	17	100%	13
2.2	Project Description	CPE	Wed 9/20/23	Sat 9/23/23	3	100%	3
2.3	Engineering Specifications	ME	Fri 9/22/23	Sat 9/30/23	8	100%	6
2.3.1	Hardware Flow Chart	ME	Fri 9/22/23	Mon 9/25/23	3	100%	2
2.3.2	Software Flow Chart	CPE	Fri 9/22/23	Mon 9/25/23	3	100%	2
2.3.3	Budget Estimations	CPE, ME	Mon 9/25/23	Sat 9/30/23	5	100%	5
2.3.4	Components / materials research	CPE, ME	Mon 9/25/23	Sat 9/30/23	5	100%	5
2.3.5	Function and Component Breakdown Diagrams	ME	Wed 9/20/23	Wed 9/27/23	7	100%	6
2.3.6	Initial CAD Model	ME	Sat 9/30/23	Sat 10/07/23	7	100%	5
2.5	Initial Website	CPE, ME	Wed 9/27/23	Fri 9/29/23	2	100%	3

Senior Design I - BearMax

Sponsored by Dr. Park, WEAR Lab

Project Start Date: 9/12/2023 (Tuesday)
Display Week: 4
Project Lead: ME and CPE Teams



WBS	TASK	LEAD	START	END	DAYS	% DONE	WORK
3	**Milestone 2**		Tue 10/03/23	Tue 10/31/23	28	100%	21
3.1	Requirements Definition		Tue 10/03/23	Tue 10/17/23	14	100%	11
3.1.1	3 Column Table		Thu 10/05/23	Sun 10/15/23	10	100%	7
3.1.2	Relationship Matrix		Thu 10/05/23	Thu 10/12/23	7	100%	6
3.1.3	Competitor System Benchmark		Thu 10/05/23	Tue 10/10/23	5	100%	4
3.2	Peer Evaluation 2		Sat 10/28/23	Tue 10/31/23	3	100%	2
4	**60 Page Document**		Tue 10/03/23	Sat 11/04/23	32	66%	24
4.1	Technology Comparision	CPE, ME	Thu 10/05/23	Fri 10/20/23	15	90%	12
4.2	Standards and Design Constraints	CPE, ME	Thu 10/05/23	Tue 10/10/23	5	100%	4
4.3	Official Standards/Guidelines from UNICEF, ASME, etc.	CPE, ME	Sun 10/15/23	Fri 10/20/23	5	100%	5
4.4	CAD model of select components	ME	Sat 10/21/23	Thu 11/02/23	12	60%	9
4.5	Chat GPT Comparision	CPE, ME	Fri 10/20/23	Thu 11/02/23	13	70%	10
5	**Milestone 3**		Tue 10/24/23	Sun 12/03/23	40	14%	29
5.1	Motivation and Solution Approach	ME	Fri 10/27/23	Tue 10/31/23	4	10%	3
5.2	Needs Analysis	ME	Tue 10/31/23	Sun 11/05/23	5	0%	4
5.3	Technology Assessment	ME	Tue 10/24/23	Fri 11/10/23	17	40%	14
5.4	System Requirements	ME	Sun 11/05/23	Fri 11/17/23	12	0%	10
5.5	Concept Generation and Selection	ME	Tue 10/31/23	Tue 11/14/23	14	0%	11
5.6	Preliminary Engineering Analysis	ME	Fri 11/17/23	Thu 11/30/23	13	0%	10
5.7	Gaant Chart and Major Deliverables	ME	Tue 10/24/23	Tue 10/31/23	7	90%	6
5.8	System Concept Evaluation Plans	ME	Fri 10/27/23	Fri 11/10/23	14	0%	11
5.9	ABET Matrices	ME	Tue 11/14/23	Tue 11/21/23	7	0%	6
5.10	Failure Modes and Effects Analysis	ME	Sun 11/05/23	Tue 11/21/23	16	0%	12

References

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