Go Baby Go: Adherence Sensor Requirements

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**Introduction**

Disabilities tremendously impact people's abilities to move, interact with others, and complete daily activities. Besides these physical changes, mobility disabilities can influence social development. Understanding and addressing these deficits can promote equality and justice for all.

One potential solution for assisting those with physical disabilities is to provide tools and devices that assist disabled people in gaining access, including wheelchairs, walking canes, and hearing aids [6]. Mobility devices like wheelchairs and walkers benefit older children and adults with disabilities. However, they are inaccessible for disabled babies and toddlers who do not have the coordination or strength to move their body weight. Over 1.3 billion people worldwide are born with disabilities, and despite this, few devices help disabled babies and toddlers navigate their environment and develop independence [2].

In January 2019, Trexo Robotics created Trexo Home, a therapeutic mobility device that assists children in developing a proper gait pattern [6]. It features a tablet that can monitor the mobility device's speed, data, and child's progress. Families can purchase the Trexo product for just under $40,000 or lease it for about $1,200 monthly [25]. This product is expensive and insufficient for toddlers who can barely hold their body weight or move their legs. For this reason, an assistive device should be made for toddlers with little bodily control to promote independence and development.

Permobil, a company created to help provide advanced mobility technology for individuals with disabilities, created the Explorer Mini cart. The cart supports children ages 12-36 months old and has been safety tested and FDA-approved in 2020. The cart is unavailable for the general market; families need to get a pediatrician's prescription even to get one. These carts are then adjusted to fit each child's individual disability needs. The cart has a customizable chair that allows the child to sit comfortably and dangle their legs. Attached to the chair is a table with a joystick in the middle that the child can use to move the cart in the direction they want. The entire chair is supported on a platform with four wheels [26]. The Permobil Explorer Mini was listed in TIME Magazine's "Top 100 Best Inventions of 2021" [1].

For our 2023-2024 capstone project, we are collaborating with Go Baby Go Oregon and Oregon Health and Science University to improve a device that attaches to the back of the Explorer Mini. The previous year's capstone team created the initial prototype for the device. We are motivated to improve the current capabilities of the cart to help shape the future of people with disabilities and the medical field. While the current product is functional, these changes will improve system accuracy, efficiency, and cost. Most importantly, these changes will enhance the experiences of disabled children, parents, and clinicians.

A picture containing indoor, case

Description automatically generated

*Figure 1: Overhead view of the circuitry in the device*

Figure 1 displays the blue accelerometer on the top left, connected to the red real-time clock module below. A 1000-ohm resistor and yellow wires are soldered into the board, connecting the hardware components. The white rectangular component at the top of the device is the 3.7V lithium-ion battery that powers the ESP32 Microcontroller (not shown), which records the data from the real-time clock and accelerometer. These functionalities are programmed into the microcontroller using the Arduino programming language [27]. The entire circuit is kept in a plastic container that can be attached to the back of the Permobil Explorer Mini cart with Velcro.

**Product Overview**

A diagram of a battery charger

Description automatically generated

*Figure 2: Data and power flow of the device*

Figure 2 displays the major communicative and electrical interactions between the various components of the device.

Shown above as “Triple Axis Accelerometer Breakout”, this sensor detects the motion of the cart. When the accelerometer detects movement, it will signal to the microcontroller to grab a timestamp to mark the beginning of a movement. When the accelerometer no longer detects movement, it will signal to the microcontroller to grab another timestamp to mark the end of that same movement. When the device is in energy-saving mode, it will only leave energy-saver mode if the accelerometer detects motion.

Shown above as “ESP32 Microcontroller”, this component will serve as the central processor. The controller is primarily responsible for accepting accelerometer motion data, along with real-time clock timestamps, and writing them to the SD card or remotely to a text file via Bluetooth (indicated with a forward-slash and bolded “W”). The controller is also responsible for turning on and off LEDs that indicate various statuses of the device (shown as LEDs 1, 2, and 3). The board will turn on each of these lights under unique conditions. The microcontroller will turn on LED 1 when the device is powered on and ready to collect data. The microcontroller will turn on LED 2 when the device has entered energy-saving mode. The microcontroller will turn on LED 3 when the device has a low battery.

Shown above as “microSD”, this component will plug into the microSD socket embedded in the microcontroller. This is where the motion data will be written by the microcontroller. This data can be manually moved from the microcontroller into any compatible computer for further processing.

Shown above as “Real Time Clock”, this component will send time stamps to the microcontroller that are accurate to the centisecond [10].

Shown above as “LED 1 Power On”, this component will turn on when the device is powered on and stay on until the device is powered off.

Shown above as “LED 2 Power Saving Mode”, this component will turn on when the device has entered power saving mode and turn off when the device is no longer in power saving mode.

Shown above as “LED 3 Low Battery”, this component will turn on when the external battery life is below 20%.

Shown above as “Lithium Ion 3.7V External Battery”, this component is an extra power storage unit for the device. An internal battery exists on the microcontroller (shown as: “Internal Battery”), but an external, rechargeable battery is required to record data over a four-to-six-week period [3].

Shown above in the yellow box as “External Battery Charger”, this three-part component is responsible for charging the external battery. This includes a USB-A Wall Charger, a USB miniB/A 3-foot cord, and a USB miniB LiPoly battery charger. This charger can plug into any wall socket to charge.**Functional Requirements**

*LED Light Status Indicators*

Device Power-On LED: As a parent or guardian I need to see that the device is on so that I can know that the device is tracking my child’s movements in the cart (5 person hours)

Battery Life Indication LED: As a parent or guardian I need to see when the device has low battery (below 20%) so that I can charge the battery (5 person hours)

Energy-Saving Mode LED: As a parent or guardian I need to see when the device has entered energy-saving mode so that I can decide whether to turn the device off because of a lack of use (5 person hours).

*Data Storage and Transfer*

SD Card Excel Datasheet: As a healthcare professional, I need to see the data in an Excel file format that algorithmic software can easily read (6 person hours).

Bluetooth Compatibility: As a healthcare professional, I need to have a stable Bluetooth connection between my computer and the device to ensure that all data transfers are complete (7 person hours).

Bluetooth Data Transfer: As a healthcare professional, I need to have the data transfer from the device to my computer so I don’t need to access the device’s internal hardware to retrieve the data (10 person hours).

Correct Timestamps: As a healthcare professional, I need to see when the child has used the cart (10 person hours).

*Data Security and Encryption*

Motion Data Encryption: As a researcher or healthcare professional, I need the stored motion data to be encrypted so the data cannot be compromised (10 person hours).

Motion Data Decryption: As a researcher or healthcare professional, I need the encrypted data to be decrypted so the data can be input into an analytical algorithm (10 person hours).

**Non-Functional Requirements**

Making the device less intimidating and confusing for parents/guardians is one of our client's priorities. Our team believes adding a set of LEDs to indicate the different states of the device (power on, power-saving mode on, low battery) is the best way to communicate the demands of the device. Therefore, the parent/guardian will not be surprised when the device powers down from a lack of energy.

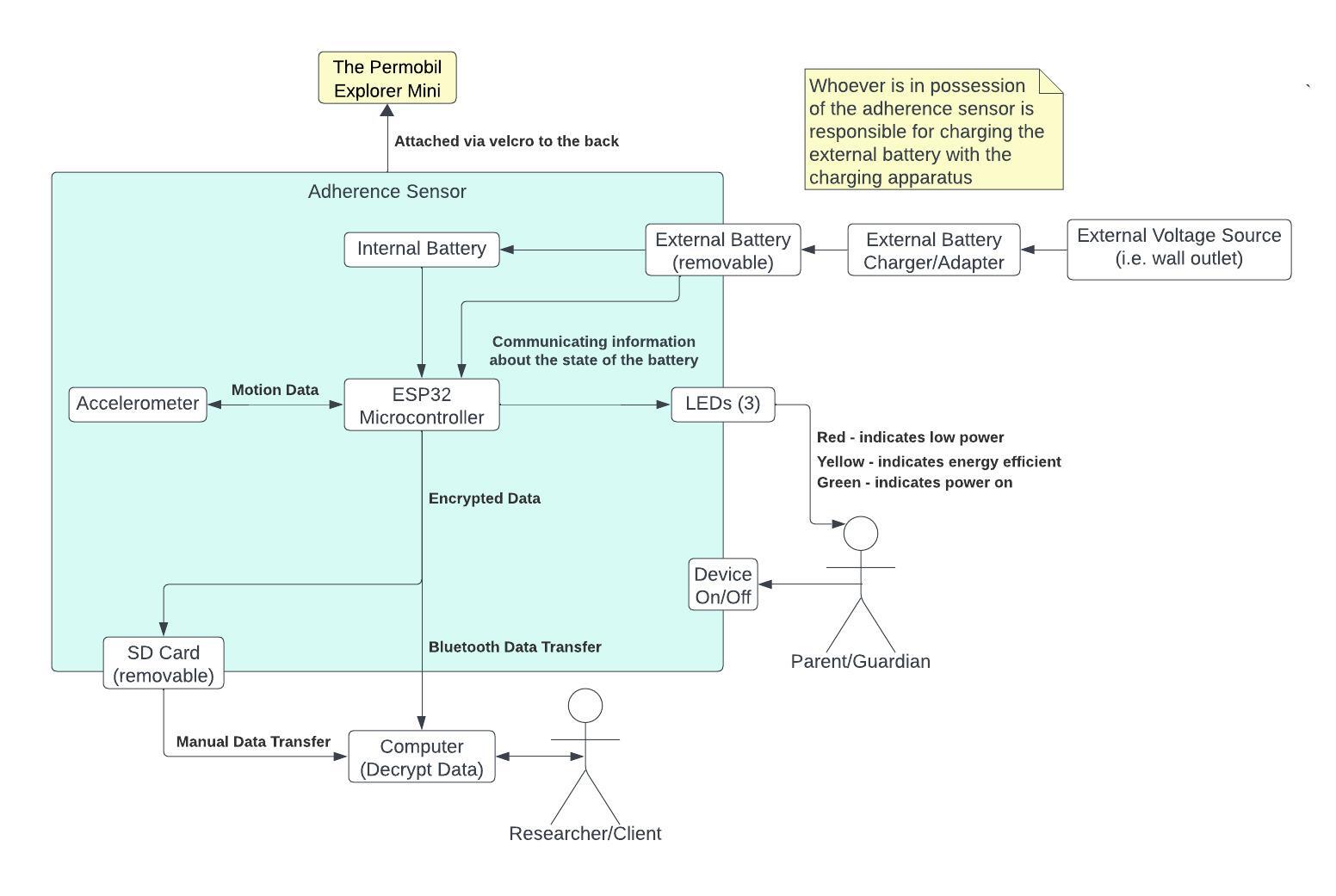
The battery for the device has a limited lifespan, so we would like to add a power-saving mode so the device will run out of power less frequently than the previous prototype. Implementing a power-saving mode would decrease the number of recharges the parent/guardian would need to do, making the device more accessible for parents and guardians. Charging the device is difficult; the primary charging component is small and delicate, about the size of a quarter [13]. If we decrease the number of times parents/guardians need to charge the device, we can reduce the risk of damage to the battery or charger.

The client expressed difficulty in handling the data. The data currently consists of tracking start times, stop times, and directional data. The client uses this data to calculate the time the child uses the cart. We should simplify this process by having the ESP32 handle those calculations. Additionally, the client was interested in utilizing the directional data to understand how a child uses the cart: Are they moving forward and around? Or are they only moving backward? Are they understanding how to operate the cart? Extracting more meaningful data from the accelerometer and processing these calculations on the ESP32 will provide clinicians with more valuable data and answer those critical questions.

The clinician must remove the SD card from the device and insert it into a computer to transfer the motion data. However, this means that our client must drive to a family, pick up the device, and drive back to upload the data to their computer. The ESP32 is Bluetooth-capable, so utilizing that function makes collecting data more manageable for the client and other clinicians. However, there is a risk in sending this data via Bluetooth; it may be intercepted by those with bad intentions. Therefore, on top of encrypting the data hosted on the microSD card, we will also encrypt data that is sent via Bluetooth. Additionally, we will create decryption software so that data can still be read by clinicians after the data transfer.

**User Interactions**

The child will not interact directly with our device; the child only interacts with the joystick embedded into the cart. Due to FDA regulations, we cannot connect our device to any systems inside the cart; our device is only attached to the outside of the cart.



*Figure 3: User Interactions with parts of the device*

Figure 3 demonstrates the various interactions the parent/guardian and researcher/client will have with the device.

The parent/guardian has two primary interactions with the device: turning it on and off and charging it. The parent/guardian will turn on the device from an external switch, and LEDs will indicate when the device is on, in power-saving mode, or is low on power. The parent/guardian will charge the 3.7V LiPo battery using the LiPo Battery charger. The parent or guardian will connect the LiPo battery charger to the USB Mini-B end of a USB A to Mini-B power cord. The parent/guardian will then plug the USB-A end of the power cord into a USB-A wall charger. The parent will finally connect the 3.7V LiPo Battery to the LiPo battery charger. The parent/guardian will insert the USB-A wall charger into a powered wall plug, and the LiPo battery will receive enough power to collect data for four to six weeks on a full charge [3].

The clinician interacts with the collected motion data after the child has finished using the cart over one or several sessions. Currently, the data is stored on an SD card, which is inserted into a computer to transfer the data to the client. With encryption, the client must run files through a decryption algorithm before accessing the data. Implementing Bluetooth data transfers simplifies the data transfer process. The client connects their laptop to the device via Bluetooth and receives the encrypted data wirelessly.

**Preliminary Sprint Schedule**

*Sprint 1 - Team Lead: Anna Yrjanson*

|  |
| --- |
| Create Team Charter |
| Initial Meeting with Industry Advisor |
| Schedule Regular Meetings with Industry Advisor |
| Kick Off Presentation |
| Requirements Document Drafting |

*Sprint 2 - Team Lead:* *Margo Brown*

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| --- |
| Final Requirements Document to Client/Industry Advisor |
| First & Second Drafts of Reference Guides |
| Arduino Code Clean-Up – Re-Commenting Existing Code Base (FinalAdSensor.ino) |
| Project Demonstration – Encryption & Decryption of a Sample Data File |
| Submit Budget and Item Requests for Approval |
| Obtain Previous Prototype |

If the previous prototype and ordered items are received:

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| --- |
| Duplicate Previous Prototype (without alterations) |
| Alter Duplicate Prototype – Replace LIS3DH Accelerometer with KX134 Accelerometer |
| Alter Duplicate Prototype – Add Energy-Saver Mode LED (Non-Functional) |
| Alter Duplicate Prototype – Add Battery Level Indicator LED (Non-Functional) |

*Sprint 3 - Team Lead:* *Kaylee Mock*

|  |
| --- |
| Finalize Individual Reference Guides |
| Semester 1 Project Poster Draft |
| Duplicate Previous Prototype (without alterations) |
| Alter Previous Prototype – Add Energy-Saver Mode LED (Non-Functional) |
| Alter Previous Prototype – Add Battery Level Indicator LED (Non-Functional) |
| Alter Previous Prototype – Fix Real Time Clock to Display Correct Time |
| Project Demonstration – Print Accelerometer Data in Text File on microSD card |
| Project Demonstration – Prototype 1.0 |

*Sprint 4 - Team Lead: Anna Yrjanson*

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| Semester 1 Final Project Poster |
| Project Demonstration – Encrypt Motion Data on the ESP32 Microcontroller |
| Project Demonstration – Decrypt Motion Data on Computer |
| Energy Saver Mode LED – Corresponds with Energy-Saver Mode Activation |
| Low Battery Level Indicator LED – Corresponds with Energy-Saver Mode Activation |

*Sprint 5*

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| --- |
| Receive Device from OHSU and Receive Critiques |
| Working Bluetooth – Serial Connection between ESP32 and Computer |
| Bug Fixing – Refining Accuracy of Energy-Saver Mode and Battery Level Indicator LEDs |
| Bug Fixing – Refining Accuracy of Distance Data on microSD card |

*Sprint 6*

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| Working Bluetooth – Text File Transfer between ESP32 and Computer |
| Project Demonstration – Collecting Data and Text File Transfer |
| Excel File – Convert Sample Data to Excel File |
| Decryption – Successfully Decrypt Text Data on Computer |

*Sprint 7*

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| Prototype - Transfer Encrypted Text Data via Bluetooth to a Computer |
| Excel File – Convert Collected and Decrypted Data to Excel File |

*Sprint 8*

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| Testing and Refinement – Bluetooth Data Transfer |
| Project Demonstration – Live Data Collection, Encryption, Data Transfer, & File Conversion |
| Final Project Poster |
| Final Project Design Report |
| Send to OHSU for Testing Over Summer Break |

**High-Level Technical Specifications**

We plan to improve an existing product by adding several status-indicating LEDs, encrypting the data, and implementing Bluetooth data transfer. We will modify and create our current prototypes; Shiley School of Engineering has granted us access to the electrical engineering lab to use the soldering tools. Regarding software, we will improve existing code written in the Arduino Programming Language from last year. We will be using the Arduino IDE to develop this software.

**Budget**

*Project Materials/Supplies (Individual Items Under $500)*

|  |  |
| --- | --- |
| Adafruit LIS3DH Triple-Axis Accelerometer (x2) [8] | $9.90 |
| SparkFun Triple Axis Accelerometer Breakout – KX134 (x2) [9] | $43.90 |
| SparkFun Real Time Clock Module – RV-8803 (Qwiic) (x2) [10] | $35.00 |
| Lithium Ion Polymer Battery – 3.7v 2500mAh (x2) [11] | $29.90 |
| Tenergy Fire Retardant LiPo Bag (Set of 2) [12] | $11.99 |
| USB Lilon/LiPoly Charger – v1.2 (x2) [13] | $25.00 |
| Amazon Basics USB-A to Mini USB 2.0 – 3ft (x2) [14] | $12.64 |
| microSD Card – 1GB (x2) [15] | $11.00 |
| YETLEBOX Waterproof Electrical Box with Mounting Plate (x2) [16] | $35.98 |
| SparkFun IoT RedBoard – ESP32 Development Board (x2) [17] | $59.90 |
| LED – RGB Addressable, PTH, 5mm Diffused (5 Pack) (x2) [18] | $7.00 |
| LED – Assorted (20 Pack) (x2) [19] | $3.95 |
| TUOFENG 24 awg Wire Sold Core Hookup [20] | $14.99 |
| Qwiic Cable – Grove Adapter (x10) [21] | $16.00 |
| USB Wall Charger, GiGreen Dual Port Electrical Cube 5V (Set of 3) [22] | $13.99 |
| Gikfun Solder-able Breadboard Gold Plated Finish Proto Board (Set of 5) [23] | $11.98 |
| E-Projects 10EP5121K00 1k Ohm Resistors (Set of 10) (x2) [24] | $10.82 |

Subtotal: $352.94

*Miscellaneous*

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| --- | --- |
| Shipping Total Cost | $15.79 |
| Cost Overage | $75.00 |

Subtotal: $90.79

Estimated Total: $443.73

*Budget Justification*

The previous capstone team had an estimated budget of $470.32 and underestimated their costs by around $100. Our team will purchase enough items to create two prototypes: one prototype that will remain at the University and another that can be tested by researchers at OHSU. Each of these prototypes can be produced for around $150 each. The University of Portland will be handling the costs of any necessary parts.

**Facilities**

We have access to the Shiley 306 electrical engineering lab, which provides us with the tools to work on the hardware of the cart (soldering, testing, etc.). We will not use the lab for our development; most meetings will be held in computer science classrooms. We do not anticipate needing any other facilities.

**Ethical Considerations**

U.S. Food and Drug Administration (FDA) regulations prevent our team from accessing the internal circuitry of the cart, so we cannot compromise the cart's safety. Our priority is the safety of the data within the device. Currently, a microSD card stores all the data; while it does not contain sensitive medical or location data, it will be used in research and within medical settings. This data will be subject to the security restrictions of internal review boards and medical associations. Therefore, we intend to encrypt the data to protect the data from being compromised or accessed by ill-intended actors.

**Conclusion**

These carts have served as invaluable tools, empowering numerous disabled children to explore and engage with their surroundings in ways they may have otherwise been unable to. We recognize our responsibility to improve a product that helps clinicians facilitate and analyze movement in disabled children. We aim to enhance the functionality of these carts to offer users, children, parents, and clinicians valuable insights that can contribute to their well-being. By fostering innovations and sharing these advancements, we hope to contribute to a more accessible and inclusive environment for disabled children nationwide.

**References**

[1] Charlton, Haley. "Plummer, Permobil’s Explorer Mini Recognized in TIME Magazine’s Top

100 Best Inventions of 2021." Belmont Unviersity News & Media. Belmont University,

April 8, 2022. https://news.belmont.edu/plummer-permobils-explorer-mini-recognized-in-time-magazines-top-100-best-inventions-of-2021/#:~:text=The%20Explorer%20Mini%20was%20listed,that%20positively%20impact%20the%20world.

[2]"Disability." World Health Organization. WHO, March 7, 2023. https://www.who.int/news-room/fact-sheets/detail/disability-and-health#:~:text=Key%20facts,earlier%20than%20those%20without%20disabilities.

[3] "Go Baby Go - Design Document (Ver. 1.0)." Microsoft Word. Microsoft, April 25, 2023. <https://upedu-my.sharepoint.com/:w:/r/personal/petersot24_up_edu/_layouts/15/Doc.aspx?sourcedoc=%7BCEB0018C-C5F9-4FEC-A064-951111659539%7D&file=Go%20Baby%20Go%20-%20Design%20Document%20(ver.%201.0).docx&action=default&mobileredirect=true>.

[4] "Go Baby Go." Go Baby Go Oregon. Go Baby Go, April 25, 2023. <https://gobabygooregon.org/home>.

[5] "Modified Ride-on Toy Car User's Manual." Google Docs. Google, Accessed September 28, 2023. https://docs.google.com/document/d/1YicK4\_H787xEOGDYQX43jDBuXEcOHK2fsZFHY6uRAy8/edit.

[6] Nikitina, Dina. "Trexo Home Puts Kids on Their Feet and Helps Them Walk." Abilities. Trexo Robotics, Accessed September 25, 2023. <https://www.abilities.com/community/trexo.html>.

[7] "Pediatric Adaptive Equipment." Adaptive Specialties. Adaptive Specialties. https://www.adaptivespecialties.com/pediatric-adaptive-equipment.aspx.

[8] "Adafruit LIS3DH Triple-Axis Accelerometer (+2g/4g/8g/16g)." Adafruit Industries, Unique & Fun DIY Electronics and Kits. Adafruit, <https://www.adafruit.com/product/2809>.

[9] "SparkFun Triple Axis Accelerometer Breakout - KX134 (Qwiic)." SparkFun Electronics. SparkFun, Accessed October 5, 2023. https://www.sparkfun.com/products/17589.

[10] "SparkFun Real Time Clock Module - RV-8803 (Qwiic)." SparkFun Electronics. SparkFun, Accessed October 5, 2023. https://www.sparkfun.com/products/16281.

[11] "Lithium Ion Polymer Battery - 3.7v 2500mAh." Adafruit Industries, Unique & Fun DIY Electronics and Kits. Adafruit, Accessed October 5, 2023. https://www.adafruit.com/product/328.

[12] “Amazon.com: Tenergy 2 Pack, Fire Retardant Lipo Bags, Battery Bags for Charging and Storage, 5.5x3.5x2 inches Each, material tested to meet UL94 Standard.” Amazon, Amazon.com. <https://a.co/d/41Whqd9>.

[13] “USB Lilon/LiPoly charger – v1.2.” Adafruit Industries, Unique & Fun DIY Electronics and Kits. Adafruit, Accessed October 5, 2023. <https://www.adafruit.com/product/259>.

[14] “Amazon.com: Amazon Basics USB-A to Mini USB 2.0 Fast Charging Cable, 480Mbps Transfer Speed with Gold-Plated Plugs, 3 Foot, Black.” Amazon, Amazon.com. Accessed October 5, 2023. <https://a.co/d/aCNqv4V>.

[15] “microSD Card – 1GB (Class 4).” SparkFun Electronics. SparkFun, Accessed October 5, 2023. <http://sfe.io/p15107>.

[16] “Amazon.com: YETLEBOX Waterproof Electrical Box with Mounting Plate 200x150x100mm, IP67 Junction Box Dustproof Clear Cover Plastic DIY Electric Project Enclosure Box Grey 7.9”x5.9”x3.9”.” Amazon, Amazon.com. Accessed October 5, 2023. <https://a.co/d/4wDrJ3R>.

[17] “SparkFun IoT RedBoard – ES32 Development Board.” SparkFun Electronics. SparkFun, Accessed October 5, 2023. <http://sfe.io/p19177>.

[18] “LED – RGB Addressable, PTH, 5mm Diffused (5 Pack).” SparkFun Electronics. SparkFun, Accessed October 5, 2023. <https://www.sparkfun.com/products/12986>.

[19] “LED – Assorted (20 pack).” SparkFun Electronics. SparkFun, Accessed October 5 2023. <https://www.sparkfun.com/products/12062>.

[20] “Amazon.com: TUOFENG 24 awg Wire Solid Core hookup Wires-6 Different Colored Jumper Wire 30ft or 9m Each, 24 Gauge Tinned Copper Wire PVC (OD: 1.46mm) Hook up Wire Kit.” Amazon, Amazon.com. Accessed October 5, 2023. <https://a.co/d/eGDl9JQ>.

[21] “Qwiic Cable – Grove Adapter (100mm).” SparkFun Electronics. SparkFun. Accessed October 5, 2023. <http://sfe.io/p15109>.

[22] “Amazon.com: USB Plug, USB Wall Charger 3 Pack, GiGreen Dual Port Electrical Cube 5V 2.1A Charging Block USB Outlet Plugs Compatible iPhone 11 XS X 8 7, LG V30 G8, Samsung S20 S10+ S9 S8 Note 9 8, Moto G6.” Amazon, Amazon.com. Accessed October 5, 2023. <https://a.co/d/2o6K0pf>.

[23] “Amazon.com: Gikfun Solder-able Breadoard Gold Plated Finish Proto Board PCB DIY Kit for Arduino (Pack of 5PCS) GK1007.” Amazon, Amazon.com. Accessed October 5, 2023. <https://a.co/d/hW9Bqlz>.

[24] “Amazon.com: E-Projects 10EP5121K00 1k Ohm Resistors, ½ W, 5% (Pack of 10).” Amazon, Amazon.com. Accessed October 5, 2023. <https://a.co/d/8MjtlmN>.

[25] “Trexo Home Pricing.” Trexo Robotics, October 5, 2023. <https://www.trexorobotics.com/trexo-home-pricing/>.

[26] Explorer Mini. Accessed October 6, 2023. https://www.permobil.com/en-us/products/power-wheelchairs/permobil-explorer-mini.

[27] “IOT Redboard ESP32 Development Board Hookup Guide.” IoT RedBoard ESP32 Development Board Hookup Guide - SparkFun Learn. Accessed October 6, 2023. https://learn.sparkfun.com/tutorials/iot-redboard-esp32-development-board-hookup-guide/all.

**Glossary**

Cart: The Permobil Explorer Mini provided by the OHSU team.

Device: the movement sensor and tracker attached to the back of the Permobil Explorer Mini.

ESP32 Microcontroller: a small, specialized electronic component that computes and manages simple devices, making them work by following specific instructions.