Child Location Monitoring Device

Group 9

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March 16, 2022

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II. Executive Summary

Parents generally have a keen interest in knowing where their children are physically located. This is evident with the rise in popularity of applications such as “Life360”, where anyone with a phone can know other trusted members’ locations. However, without the benefit of a phone, parents don’t have a great solution for keeping tabs on their younger children. There are a few products on the market aimed at solving this problem for families, though they lack the durability and utility most parents desire for their younger ones. Specifically, around the ages of two years old to ten years old, children are not only mobile, but also rough with what they are wearing and where they are going. Current products are simply not engineered to stand up to the wear and tear of daily childhood existence while also delivering the location tracking services parents want in an affordable, comfortable form factor.

In order to prove out a design concept to meet these goals, the team gathered requirements from parents: the most important requirements were “child proof”, “easy to put on but difficult for child to take off”, “tracks child”, “does not burn child”, “minimum 5-day battery life”, “non-irritating / non-toxic”, “parent interface”, “rugged”, and “zero risk of strangulation or choking”. These are translated into functional requirements that the engineering team can put towards a realizable design. To this end, the team creates a House of Quality to determine the most important features and how they might be implemented or designed. Succinctly, the most important features are UL safety certification, providing a range of fit sizes, being comfortable to wear, and providing accurate location data. With requirements nailed down, the engineering team uses a handful of ideation and selection methods to determine the most important aspects of the design for a low-fidelity prototype. These include Morphological Charts and Good Ol’ Blue-Collar Intuition.

These design tools inform the desired functionality of the device, but before the team dives into specific implementation, a patent search is conducted to understand prior art and to avoid (or be aware of) patent infringement. To this end, six patents are found that pose a risk of infringement, and the team works to come up with clever ways of navigating them (such as integrating “device removal detection” into the wristband of the device instead of the body).

With all design work prepared, the software team begins prototyping with some off-the-shelf BLE and GPS development boards to integrate with a smartphone application. In parallel, the electrical and mechanical teams work on the physical device – PCB layouts are generated and designed to fit into custom enclosures designed by the mechanical team. The mechanical team designs a custom latching mechanism that is easy to fasten but difficult to un-fasten by a child and 3D-prints a custom, flexible band for form-factor visualization.

To understand how this prototype compares to existing products, the team conducts some preliminary tests: the software team creates a simple smartphone app to test the Bluetooth functionality and range compared to a competitor’s product. Preliminary results show that the team’s low-fidelity prototype comes within 70% or meets the competitor’s product, while still well exceeding consumer requirements. Similar experiments around mechanical life of the proposed latching mechanism are also performed using Finite Element Analysis.

Moving forward, the team wants to put the device in the hands of some parents to gather preliminary feedback. In addition, the team will prove out the GPS functionality and benchmark it against existing products. The team will begin the miniaturization process as well, moving from development boards to integrated circuits on a proper PCB.

III. Nomenclature

PCB (Printed Circuit Board) -- a thin board made of fiberglass, composite epoxy, or other laminate material through which conductive pathways are etched or "printed" onto board, connecting different components.

UWB (Ultra-Wide Band) – a low-energy radio communication technology for short-range, high bandwidth device to device communication.

BLE (Bluetooth Low Energy) – a low-energy variant of Bluetooth designed for low-bandwidth device to device communication.

GPS (Global Positioning System) – a navigation system which synchronizes localization, velocity, and altitude of a receiver by connecting to multiple satellites.

1. Introduction and Background

In general, parents are concerned for their child or children's safety. This protective instinct is useful in many ways, though the constant mental load associated with worrying over children can eventually have negative effects that out-weigh the positives. One such worry is knowing where their child is during the day, especially when the child is going to a new location or somewhere with lower levels of adult supervision than the parent is traditionally comfortable with. Currently, in most of these situations, parents are helpless, relying on good-word or blind trust in those that are responsible for their child. And while most caregivers are worth trusting, the incidences that keep parents up at night are the instances where there is a lapse in attention or judgement of a caregiver (or the child), leaving the child stranded or abducted. Few parents can imagine a worse scenario for their child. In fact, after interviewing over sixty parents of kids between the ages of two and ten years old, the fear of losing a child or child abduction rates in most parents' top five fears with their children, especially when they're not under their parents' watchful eye.

In parallel, several successful companies have built out tracking options to help people find things. Notable products/companies include Life360, Apple Air Tags, Tile, Apple Find My, and Samsung Find My Mobile. The democratization of these products has laid the groundwork other types of tracking products to hit the market, making integrating a GPS, Bluetooth, Cellular, etc. a straightforward proposition. As such, a couple of products have heard the cry of parents and are aiming to solve some of these issues. Most notable in this category are Jiobit by Life360, Angel Sense, and Gizmo Watch 2 by Verizon. Each of these incorporates GPS tracking into a physical device with a mobile app. However, none of these options seems to have captured a substantial share of the potential market, and most are poorly reviewed by consumers. Many parents reported having considered these options but did not purchase them for various reasons.

What exists now is too general. For example, Verizon's Gizmo Watch 2 is a miniaturized, cheaply manufactured version of popular smart watches like the Apple Watch. This means there are features beyond what parents care about and the watch itself lacks the durability needed to work well with young kids. Devices that have done better with robustness still lack some fundamental pieces of value: the Jiobit is well made and tracks well, though its method of attachment is limited to a clip or a fabric-piercing device. This makes the device more accessible to a broader market outside of kids alone, but severely weakens its own value proposition when applied to young children who are masters at taking things off themselves.

Therefore, there is clearly an interest in an accessible, easy to use devices that keeps track of kids' location (as evidence by the few products already in this space); however, there also exists opportunities to do it better. Parents are interested in a GPS tracking solution that is robust, low-profile, and will stay on their kids. This team is working to develop a modular, durable electronic system geared specifically towards GPS tracking. Initial feedback from parents has indicated that a simple wrist wearable device that is difficult for a child to remove is a great first step in this direction. In addition, the team wishes to explore other form factors as the miniaturization of the electronics package occurs.

2. Existing Products and Applicable Patents

There exist a handful of existing products aimed at meeting this need – some products have been discontinued since the middle of the pandemic, citing chip shortages as a primary reason. Others, such as "Kiddo" seem to be in the research-and-development stage. Fundamentally, most of the products are not built well for young kids. Most lack the robustness and durability parents long for inside a package that will stay on their child without their worry.

2.1 Toddler Proximity Sensing Devices:

Gizmo Watch 2 – $99 plus activation cost and monthly fee - The Gizmo watch is a device designed for children to wear around their wrist. The watch is connected to 4G LTE through the Verizon network and provides location information to the parent's smartphone. The watch enables children to text up to ten contacts. It also includes step count, notifications, and calls. Many of the reviews claim that the watch has a poor build quality, does not change, and that the battery dies very quickly. Overall, the watch is not reliable and seems to be marketed towards older children who are often away from their parents.

Monkey KID Sensor – $39 - Strictly a proximity sensor that will send a notification to the user's phone when the sensor has gone past a user specified range. Claims to allow the user to choose a perimeter between 15 and 150 feet. The product cannot currently be purchased. On the website it says that the product is sold out and on amazon it says it is currently unavailable. The reviews from when the device was available are also extremely low, claiming that the device does not accurately monitor distance.

Kiddo – price unknown – Strictly a health monitoring device. Marked to children aged 2-10 and claims to monitor temperature, blood oxygen, pulse, and stress. The device has recently received FDA approval. An article about the product claims that the company plans to work with hospitals to provide children with wearable devices.

My Buddy Tag - $35 – The My Buddy Tag is wristband that provides proximity detection to alert the parent when the child wanders outside of a range, and it will provide data on the child's last seen location. It also gives water safety alerts if a child falls into a water body or pool. This device contains no health monitoring technology, and instead is a very bare minimal wristband with a nice one-year battery life but poor aesthetic quality. The reviews for the device are average with some saying that it is unreliable and gives too many false alarms. The company has also stopped selling wristbands, citing the supply chain issues and chip shortage.

Jiobit - $90 + $9/month fee – The Jiobit is a clip-on GPS tracking tool marketed at kids, pets, and seniors. It takes advantage of lower-cost-to-use 2G and 3G towers to communicate location data captured using GPS and additionally saves power by using Bluetooth Low Energy when in-range (a unique technical solution compared to other offerings). Jiobit interfaces with Life 360, taking advantage of the same back-end and has a similar app interface. Jiobit has no ability to communicate two-ways. This is the highest rated and recommended tracking device, though it has little promise of staying on young kids and can provide no biometric data.

Angel Sense - $59 + $33.33/month fee – The Angel Sense is a small wearable GPS tracker and 2-way communication device marketed at parents of kids with special needs and elderly people with memory problems. The Angel Sense device requires a cellular plan and does not have the capability to use Bluetooth which tends to limit its battery life substantially. The Angel Sense device comes with a few different methods of attachment that cannot be easily removed by a child. Its primary value add is the form-factor additions and continuous GPS monitoring. The company recently came out with a smaller version (this year) that aims to compete more head-to-head with Jiobit.

2.2 Applicable Patents

The information disclosure statement in Appendix 1 gives a list of all applicable patents that the device could infringe upon. The disclosure contains both utility patents claiming different mechanical aspects of a wearable tracking device as well as method patents which claim different means of capturing and sending location data. Although this list was acquired in an intensive search, it is not exhaustive.

In 2016, Christopher DePascale patented a wearable personal locator device with a removal indicator [1]. This patent details a similar device (one that the team could not find on the market) which is intended for use with groups of children. Interestingly, Christopher identified a similar pain point to the team's interview feedback: parents or guardians want to know if the wristband has been removed. Our device will also perform this action, but in a different way from this patent; instead of using a frangible circuit placed on adhesive on the back of the device, our device will use a small circuit running through the band. This is a more robust and repeatable method of removal detection. Additionally, our device will utilize a unique fastening mechanism which is easy to fasten but difficult to unfasten with one hand. These two significant differences should facilitate procurement of a patent, though paying patent royalties is a very real possibility even after these changes. Adopting other form-factors (other than wrist-wearables) would also help significantly to avoid patent infringement.

Other prior art includes a wearable that contains electronics in both the display and the band of the wearable that communicates when the two components are connected [2]. There is also a utility patent on a wearable that integrates its battery into its band to conserve space in the top of the device [3]. Both patents have claims that could be important in the final design of this tracking device, but there are clear ways to avoid infringing upon these patents though unique mechanical design. Also included is a wearable device that comprises biometric and environmental sensors, which could be relevant in a future version of our device [4]. Overall, the PomDot device will have a combination of features, some unique, that no one patent includes and will therefore be patentable. Licensing from companies who own the patent to certain features might be needed if commercialization is pursued.

Since most of the functionality of this device comes from the design of the software and electronics, it is important that investigation any prior art in this area as well. A patent that was submitted by a potential competitor (Jiobit) claims a method of selecting a location tracking category based on a series of parameters and using that location tracking category to determine the location of a given device [5]. Their patents include a device that contains up to three location tracking categories. The method used to select between Bluetooth and cellular location categories could infringe on this patent. Jiobit also has a similar patent pertaining to the method of indicating which location category is currently being used and communicating that information back to a parent device [6].

3. Customer Requirements and Engineering Design Specifications

Parents want a reliable, durable device with a long battery life that stays on their child and can let them locate their child instantly and effortlessly. To this end, Appendix A1.1 shows the functional requirements developed to meet this goal. These functional requirements mesh well with the House of Quality shown in Appendix A1.2, which takes those requirements and passes them through an importance filter, to yield the areas of the product most crucial to implement optimally.

As seen in Appendix A1.1, the most important functional requirements revolve around child safety – parents want to feel confident that this device will never cause their child distress or harm. Therefore, requirements such as "non-choking", "does not burn child", and "child proof" are considered immensely important.

These requirements begin to outline some fundamental constraints on the solution set. Appendix A1.1 lists these constraints. The constraints largely fall under two main categories: Physical Constraints and Technological Constraints. Physical Constraints include things like using non-toxic or irritating materials, ability to use a charging deck, and interoperability with a partner app. These constraints focus on the customer-facing requirements; for instance, many children are allergic to nickel and cannot wear something that would irritate their skin. Technological constraints are more closely tied to the state-of-the-art and underlying physics; for instance, there is currently not a cost-effective method of communicating GPS data over large distances (> 2 miles) other than using existing cellular networks. This is a fundamental constraint on solving the technical portion of this product.

After identifying all customer requirements, defining all functional requirements, ranking their importance, and naming constraints, the team pushed forward towards developing a rigid set of preliminary design goals.

Design Concept Ideation

After determining the customer requirements, the mechanical design team began ideating potential avenues to solve the problems presented. These ideas are represented in Appendix A2.1 in the mechanical design space. The primary starting point for most of the designs stemmed from analogs to current technologies or methodologies. When looking at ways to make the device adjustable to fit a growing child, the team considered something akin to a watch strap which provided discrete intervals that would fit the child as they grew. In a different direction, elastic/silicon bands that could be removed and replaced as the child grew was also an idea that could provide more customizability to the device. Velcro and adjustable straps like that found on a helmet were also toyed with to provide a more continuous fit adjustability.

Keeping the device on the child and deterring or making it impossible for the child to remove the device was imperative. Some childproof mechanisms considered were a magnetic lock that could be powered on and off by only the parent or authorized guardian. In a similar vein, a lock and key mechanism was also an idea developed where only authorized adults could remove the device from the child. Another idea focused more on making doffing process "tortuous" for the child. By making the clipping mechanism very difficult to remove for the child, then ideally it would serve as a potent deterrent from removing the device themselves. Similarly, making the doffing mechanism require two or more hands to remove would also increase the difficulty of removal.

To keep the device "hidden in plain sight" and seamlessly integrated into the child's life and clothing, designing the device to be like a common accessory or clothing article that children wear is the prevailing design theory. Working removal detection into the overall design is also very important, hence the continuous wire that would detect if the device has been cut. Magnetic clip opening detection follows a similar principle that would let the authorized parent or guardian know when the device was removed.

The issue of power generation and storage fell into two schools of thought. One set of ideas focused on using the environment or natural use to generate power using solar power or kinetic energy generated through daily movement and use. On the other hand, a bigger battery would also prolong battery life. Including a charger for the device to use periodically was also a viable way to power the device.

4. Concept Selection and Justification

Appendix A2.2 shows a morphological chart of different system design and design options. The three main concerns for system design are Method of Local Wireless Communication, Method of Global Wireless Communication, and Method of Locating the Device. For each, there exist several well-established protocols and supporting hardware, so the correct choice therefore lies within the ability to choose which option works most effectively while being seamlessly integrated into the customer's life. This idea of "seamless integration" immediately rules out a few options since the team decided to initially focus on using a partner app on a customer's phone which means that the solution must take advantage of existing phone hardware.

Most phones are well equipped to deal with the Bluetooth Classic, Bluetooth Low Energy (BLE), and WiFi protocols out of the box. This quickly rules out anything that cannot take advantage of these protocols (such as ZigBee, LoRa, or Radar). MQTT works well over WiFi, and this option will be explored in further prototyping. For privacy reasons, most phones do not allow an app to maintain a continuous classic Bluetooth connection as a background process. In addition, Bluetooth classic requires more power and a larger software stack to implement on an embedded device. These two constraints make BLE an attractive option since it requires minimal code, very little power, and can be run in the background with most phone operating systems. WiFi meets some of these criteria, but WiFi consumes much more power than BLE[7]. Therefore, BLE makes the most sense for local data communication. For global communication, the only protocol/interface that most phones implement is cellular, therefore that decision is straight-forward.

Positioning is interesting, since most phones have a few reasonable options available. The tightest constraints here are around topology. GPS works close to everywhere in the world, since it relies on satellites which orbit the earth. Ultra-Wide Band (UWB) and BLE require other UWB or BLE enabled devices to act as "anchors" to localize objects. This is great for fine-grain resolution in crowded areas, but this ceases to work at all in more remote areas. Therefore, to track a child, GPS makes the most sense.

The current selected design for adjustability is the discrete elastic bands combined with a clipping mechanism. This design was chosen in to minimize prototyping time to output a low fidelity prototype. Outputting the prototype was imperative to getting an idea for the physical model and understanding the fit for further iterative design.

Childproofing the device is currently designed around making the unclipping mechanism very difficult to remove. Magnetic locks have too much power draw in a device that is trying to optimize the length of the battery life. Keys can be lost in the lock and key system, and it isn't the most ethical practice to lock a tracker on a child. The two-handed unclipping is enveloped by the complex unclipping mechanism and helps increase the difficulty of removal.

The seamless integration choice was a bracelet. Bracelets are generally gender neutral and don't require a screen which increases the durability of the device as decreases the power draw. They also only allow one hand of the wearer to be involved in taking it off, so making the unclipping process require both hands work best with a bracelet. However, the small electronics package that is being developed would ideally be translatable into being applied to necklaces, scrunchies, belt buckles, and anklets as well. Seamlessly integrating a wire to detect removal is also the best method of implementing that feature.

After analyzing the power budget, the best method of powering the device so far would be the pogo-pin charger. Solar and kinetic power harvesting don't provide enough of a power generation to keep the device operational. A large battery begins to encroach on the volume constraints of the device for aesthetic purposes.

5. Engineering Analyses and Experimentation

Sizing

The desired user of this product will be children aging 2-10 years of age. Because this is an age group that has a wide range of wrist sizes, the adjustability of this device is a crucial functional requirement. After looking at statistics for children in this age range, it has been determined that the circumference of the band needs to be able to adjust for a wrist circumference between 5 in and 6.5 in. This will add a significant amount of complexity to the mechanical design because there will need to be some sort of expandable section while continuing to be durable and comfortable. The sizing diagram used in this design is shown in Appendix A1. It can be assumed that the overall shape of the wrist scales uniformly, but the design will need to have some play to account for irregular wrist shapes. Wrist size will also play a role in the design of the electronics package as well as the clip mechanism. Since the curvature of the wrist will change as it gets bigger, it is important to design these components to account for this. This can be done by adding air gaps in the cavity where the electronics package is held so that the silicon band is able to flex around the wrist, but also continues to hold the electronics package securely.

Material Testing – Fatigue Analysis

For the purposes of a low fidelity prototype, the components are 3D printed in different photopolymer resins on Form Labs Form3 printers. The band is printed in Flexible 80A resin, which has an ultimate tensile strength of 1290 psi, can be elongated 120% before breaking [8]. Furthermore, this resin is soft to the touch and comfortable to wear, making it a viable lo-fi prototyping material for developing the band. The electronics package is encapsulated in Tough 1500 resin which has an Elastic Modulus of 218 ksi. Tough 1500 is meant for parts to be printed that will be withstanding high impacts and rugged use, thus making it great to use when simulating a child's activities' effects on its ability to withstand impacts [9]. The final materials used in the manufacture of the device have yet to be finalized, but for the purposes of rapid prototyping, these materials will provide a good alternative.

Power Analysis

On the electrical side, power analysis was performed to find the average power consumption of the device and figure out the required battery size and plausible device run time. This analysis was performed by creating a power budget where the major power consumption devices' typical current draw, operating voltage, and duty cycle were considered. The values for the operating voltage were found in the components' datasheets and the current draw was determined by using calculators from the manufactures as well as the datasheets. As seen by the power budget in Appendix A4, the estimated average power draw for this device is 25 milliwatts. The duty cycles for the components were estimated by accounting for how often a component would be required for use and the typical amount of time a child spends away from their parents in each day for data transmission related components. This metric is important as when the child is near the parents, location data can be transmitted through the Bluetooth Low Energy (BLE) protocol. BLE requires far lower power for operating compared to cellular thus would save power. If this device uses a 1.1 Wh battery (comparable to the Jiobit), then the run time would be nearly 44 hours. The results of this analysis helped push the team to investigate ways to reduce the power consumption further. It was found that methods such as eDRX and PSM can be used to reduce the frequency of cellular connectivity. Also, an accelerometer was added to determine whether the child is in motion so that the device can be put to sleep when the child is not in motion as the location will not change. In the future, real-world power analysis will need to be performed to measure how much power is consumed by the device as there are so many variables that cannot be properly accounted for in a power budget.

Adding energy harvesting technologies such as solar, thermoelectric, and kinetic were considered to prolong the run time of the device after a single charge, but it was determined that the packaging and costs of the thermoelectric and kinetic energy harvesting technology were too large and high to be practical. Small solar cells from Anysolar Technologies' IXOLAR lineup seemed useful to integrate as the sizes of their cells were extremely small and can provide a peak supply current of 25 milliwatts which would significantly extend the device run time. Solar power generation analysis was performed to confirm how much power would be generated by adding these solar cells by modelling the amount and intensity of various light sources the device would be exposed to throughout the day. The greatest source of power generation in the solar cells is when they are exposed to sunlight as the power density is almost 1000 $\frac{W}{m^2}$, whereas most indoor environments with artificial lighting only have a power density of about 30 $\frac{W}{m^2}$. With children and most people only spending limited time outdoors, the power generation from the solar cells throughout the day on average was determined to be around only 3 milliwatts. Although this additional power to the device would extend the device run time, the additional costs and space requirements from the solar cells, maximum power point tracker IC, and power control IC would be too great to be justifiable.

In the future, antenna analysis will need to be performed to ensure the antennas are receiving and transmitting signals as intended along with impedance analysis to get the proper antenna matching circuitry. Within the antenna analysis, the location accuracy, BLE distances in a variety of environment, and indoor GPS signal quality will all need to be verified. On the impedance analysis side, the antennas being used for BLE, cellular, and GPS all have an inherent impedance of 50 Ohms, and to avoid signal reflections, the total impedance between the cellular chipset and each of the antennas must also be 50 Ohms. Keysight's Advanced Design System software will be used to analyze the impedances from the PCB traces, vias, and the antenna switches. After this is performed, the necessary capacitors and inductors to get the total impedance to 50 Ohms will be added into the circuit for the remaining impedance matching.

6. Initial Drawings, Patent Claims, and Fabrication Package

Electronics Package

The device is planned to have a modular design where the main electronics package is within a rectangular prism-like shape and can be attached into various assemblies such as a wristband or even something such as a scrunchie. The initial product will be the main electronics package assembled with a wristband to become a wearable. As children's wrists are small, the goal is to make the main electronics assembly as small and lightweight as possible. Given these requirements, the initial proposed electronics packaging and layout, as seen in Appendix A3.1, would be three separate PCBs that are stacked vertically to reduce the surface area of the device. A 3D model of the PCB stack and electronics package is shown in Appendix A3.2. It is currently expected that all the electronics can be packaged within three PCBs that each have a length of 1.5 inches and a width of 0.75 inches.

Each PCB in the vertical stack has a role. The bottom layer houses the battery along with the power management IC and the external pogo pin connectors for the charging wire to plug into. The middle layer contains the chips needed for processing, memory storage, cellular connectivity, GPS, and BLE operations along with an eSIM and an accelerometer. The top layer is dedicated to the antennas along with their keepout areas and the required impedance matching circuitry, filters, and low noise amplifiers. The PCBs will have electrical connections between each other using SMD vertical PCB stack connectors. There will likely also be mechanical standoffs used in the corners to distribute weight evenly and keep the PCBs evenly together.

The height of the overall package will be determined once the battery height is known. The current design provides a somewhat small area for the battery as the battery should not be located under the areas containing the antennas as it can cause electromagnetic interference. Due to this restriction, the battery height will likely need to be raised to compensate. Another potential approach is to include another battery portion or the entire battery itself within in the wristband.

An initial bill of materials has been created, as seen in Appendix A5, and the current single unit cost for the required electronics is approximately $65. Based off prices for a thousand units of each of the electronics, the price for all the electronics for each location tracker will drop to about $38. These prices do not account for the costs of the required capacitors, inductors, resistors, pogo pins, SMD vertical stack connectors, and PCBs. With these parts included, the electronics cost per unit for a thousand-unit scale will likely be around $50. Assuming further economies of scale can be applied, the electronics and its packaging per device could end up being under $45. The current vendor for all the electronics is expected to be DigiKey except for the rechargeable LiPo battery. This battery will likely be sourced from the battery manufacturer Grepow as they can produce custom sizes for these batteries are often used in other wearables.

Band

The current band is designed to be slim and comfortable. Unlike the typical smartwatch band, which consists of two arms that connect to a central electronics package, this design will consist of one individually molded band that contains a cavity for the electronics package to fit and lock into. The current prototype is shown in Appendix A3.3, and an exploded view is shown in Appendix 3.4. This design will allow for easy removal of the electronics package and provide comfort due to only one material contacting the skin. The current design is 1.0 inch wide and 0.4 inches thick at its widest section. It is possible that these dimensions could change if the electronic components change or if they can be packaged in a smaller volume. The method of attaching the band to the clip mechanism is also an important component. Using a small metal rod to hook the two pieces together was considered for attaching the clip mechanism to the band. The design for this prototype consists of an interlocking feature where the band has a bulb shape that the clip slides around. They are held together by friction. It is important to note that in this first prototype, the design is relatively simple to prove functional capabilities, but in future interactions the plan is to improve the industrial design and aesthetics of the device drastically to make it more appealing to customers.

Clip Mechanism

There are currently clip designs for both a child proof and non-child proof mechanism that are being implemented into the first prototype. Both designs are included in the initial drawings in Appendix A3.4 and Appendix A3.5. The first, a child proof design, is a two-part design that contains a latch mechanism that is similar to what one would see in a common side release buckle but is opened by moving the arms of the buckle outward rather than pinching them inwards. This will make it very difficult for the child to open the clip with only one hand and will therefore require a second person to take it off. The design utilizes a compliant mechanism in both arms, and therefore must be made of a material that can withstand a high amount of fatigue. This design also includes a magnetic connecting mechanism for easy application. Ideally, the mechanism will snap together with ease, requiring little effort by the parent of the child that is putting on the device.

The second clip design in not intended to be child proof and is included for those who do not want to put a child proof mechanism of their child’s wrist. This design consists of a simple slot and groove mechanism that allows the “male” end of the clip to interlock into the “female” end. An image of this mechanism is also shown in the appendix. The clip mechanism attaches into the band of the device by keying into a positive groove which corresponds to a negative groove on the clip. It is most likely that ABS plastic will be used for the final production model of both clip mechanisms because it is durable, long lasting, and easily molded.

Patent Claim

“Disclosed is a locating tracking device that will continuously monitor the location of an electronics package containing location tracking modules. This continuously tracked location data will be transmitted back to a receiver device, and accurately communicate to the receiver device user said location. The electronics package will include both Bluetooth and Cellular location tracking capabilities so that the device find location within both Bluetooth range and cellular range. The electronics package will be housed in a variety of wearable devices including a wrist band, scrunchie, ankle band, or necklace. The device will include capabilities that can detect when the device is removed from the user as well as being able to communicate that information back to the receiver device. The device will have a method of ensuring it to be child proof so that a person between the age of 2-10 will not be able to remove the device without the help of another person.

We claim:

1. A location tracking device comprising: an electronics package that is capable of tracking location using a plurality of location tracking methods and communicating location data to a receiver; a fastening device that houses and provides a durable outer shell for the electronics package; a means of fastening the electronics package to a wearer and a means of preventing the wearer from removing the device.
    2. The location tracking device of claim 1, wherein the fastening device that houses the electronics package is selected from the group consisting of: a wrist band, a scrunchie, an ancle bracelet, a necklace, or a belt.
    3. The location tracking device of claim 1, wherein the location tracking methods include Bluetooth and Cellular, and the location tracking methods can be independently used in the device depending on what is desired.
    4. The location tracking device of claim 1 further comprising a means of detecting if the location tracking device has been taken off the wearer and transferring that data to a receiver device.
    5. The location tracking device of claim 1 and claim 2, wherein the fastening device is made of a rubbery material that provides comfort to the wearer.
    6. The location tracking device of claim 1, wherein the fastening device is a wrist band containing a wrist strap with a means of adjusting to the wrist circumference of the wearer.
    7. The location tracking device of claim 1 and claim 6, further comprising a clip mechanism that prevents the wearer from removing the device without the help of a third party.

7. Summary and Next Steps

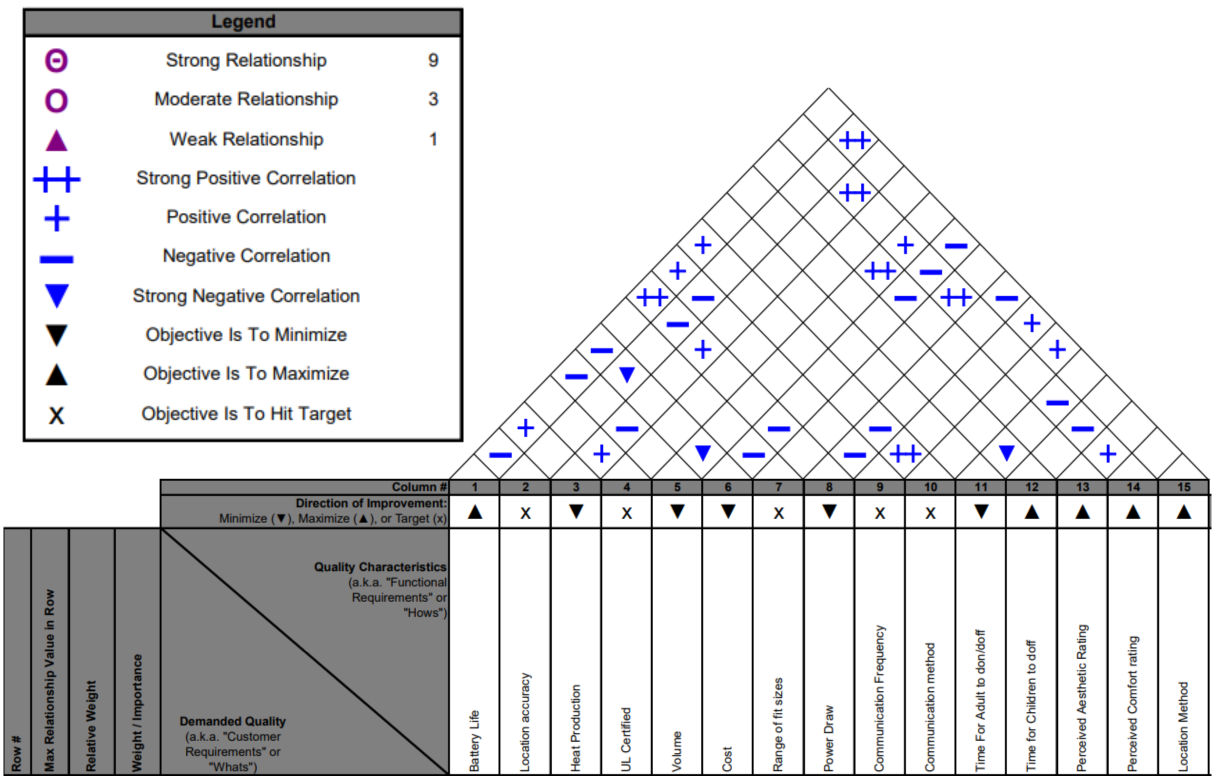
On the electrical side, the major accomplishments include figuring out all the required electrical components for performing all the operations needed for a location tracking device, finalizing the specific parts that will be used, performing power budget analysis, and creating a preliminary layout and packaging design. The next steps will involve creating all the electrical schematics and then make the board layouts for the PCBs. The initial manufactured board will likely be a development board style where the team can upload code, test out the operations, check the signals and antenna communications, and ensure everything works as intended. Once this goes well, the end goal PCB stack design will be manufactured and integrated into the mechanical design.

The timelines and schedule for the rest of the semester can be seen in the Gantt chart as seen in Appendix A6.

8. Appendix A1

Customer Requirements	Constraints
Child Proof	Communicating GPS data
Comfortable	Form Factor
Easy to put on but difficult for child to take off	Battery Life
Tracks child	Interoperability with partner app
Does not burn child	Ability to use a charging dock
Minimum 5-day battery life	Non-toxic or irritating material
Non-Irritating / Non-Toxic	
Parent Interface	
Rugged	
Zero Risk of Strangulation or Choking	
Charging capability	

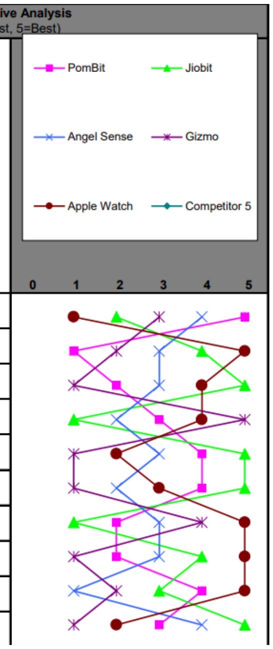
House of Quality:



Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x) / Quality Characteristics (a.k.a. "Functional Requirements" or "Hows") / Demanded Quality (a.k.a. "Customer Requirements" or "Whats")	Battery Life	Location accuracy	Heat Production	UL Certified	Volume	Cost	Range of fit sizes	Power Draw	Communication Frequency	Communication method	Time For Adult to don/doff	Time for Children to doff	Perceived Aesthetic Rating	Perceived Comfort rating	Location Method
				Direction of Improvement	▲	x	▼	x	▼	▼	x	▼	x	x	▼	▲	▲	▲	▲
1	9	7.8	5.0	Hard for Child for Remove						▲	▲				O	Θ	▲	▲	
2	9	6.3	4.0	Easy for Parent to Remove						▲	▲				Θ	O	▲	▲	
3	9	10.9	7.0	Comfortable			Θ		O	▲	Θ						▲	Θ	
4	3	15.6	10.0	Non-Choking				O	▲										
5	9	15.6	10.0	Safe to Wear			O	Θ		▲								▲	
6	3	10.9	7.0	Durable						O	▲						▲	▲	
7	9	14.1	9.0	Location Tracking	Θ	Θ				O		Θ	Θ						Θ
8	9	12.5	8.0	Easy access to data		▲							▲	Θ					▲
9	9	1.6	1.0	Aesthetically Pleasing	▲				Θ	O	O						Θ	▲	
10	9	4.7	3.0	Adjustability					▲		Θ				▲		O	Θ	
				Target or Limit Value	7 days	5 meters	Contact Temp under 75 degrees F	Certification	8 cm^3	$100	Ages 2-10	6 mW	Optimized	Optimized	< 5 seconds	> 30 minutes	> 4/5	> 4/5	Optimized
				Difficulty (0=Easy to Accomplish, 10=Extremely Difficult)	10	3	6	5	6	4	2	10	3	1	3	7	4	6	1
				Max Relationship Value in Column	9	9	9	9	9	3	9	9	9	9	9	9	9	9	9
				Weight / Importance	128.1	139.1	145.3	187.5	67.2	120.3	170.3	126.6	139.1	112.5	84.4	89.1	64.1	182.8	139.1
				Relative Weight	6.8	7.3	7.7	9.9	3.5	6.3	9.0	6.7	7.3	5.9	4.5	4.7	3.4	9.6	7.3

Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x) / Quality Characteristics (a.k.a. "Functional Requirements" or "Hows") / Demanded Quality (a.k.a. "Customer Requirements" or "Whats")	PomBit	Jiobit	Angel Sense	Gizmo	Apple Watch	Competitor 5
Hard for Child for Remove	5	2	4	3	1	
Easy for Parent to Remove	1	4	3	2	5	
Comfortable	2	5	3	1	4	
Non-Choking	3	1	2	5	4	
Safe to Wear	4	5	3	1	2	
Durable	4	5	2	1	3	
Location Tracking	2	1	3	4	5	
Easy access to data	2	4	3	1	5	
Aesthetically Pleasing	4	3	1	2	5	
Adjustability	3	5	4	1	2	

Competitive Analysis (0=Worst, 5=Best)



Information Disclosure Statement:

U. S. PATENT DOCUMENTS					
Examiner Initials*	Cite No.[1]	Document Number Number-Kind Code[2] *(if known)*	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
		US-9508241B2	24-02-2014	Christopher DePascale	
		US-9471102B2	14-08-2015	Townsend, et al.	
		US-20150333302A1	15-05-2015	Johns, et al.	
		US-10537245B2	28-12-2015	Miller, et al.	
		US-9980087B2	01-12-2017	Renaldi, et al.	
		US-10064002B1	30-04-2018	Renaldi, et al.	

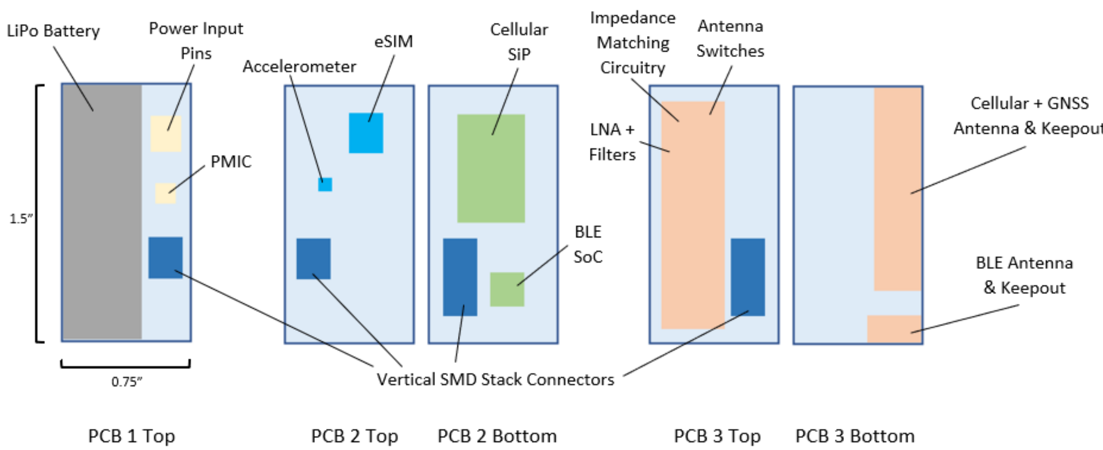
9. Appendix A2

Adjustable	Watch Strap	Elastic/Silicon Strap	Helmet Clip	Velcro	
Child-proof	Magnetic Lock	Lock and key system	Complex clipping pathway	Two-handed unclipping	
Aesthetic/Seamless implementation	Bracelet	Anklet	Necklace	Belt	Scrunchie
Charging	Solar Power	Kinetic Energy harvesting	Long-lasting Battery	Pogo-Pin charger	
Removal Detection	Continuous embedded Wire	Magnetic separation detection in Clip			

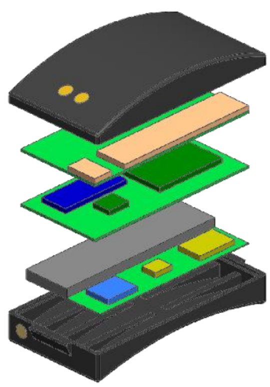
Local Wireless Communication Method	Bluetooth Classic	Bluetooth Low Energy	MQTT	LoRa	zigbee	Radar	WiFi	Nothing
Global Wireless Communication Method	Cellular	Low Frequency Radio	Satellite	Nothing				
Positioning Protocol/Specification	GPS	Ultra Wide-Band	Bluetooth Low Energy	Nothing				

10. Appendix A3

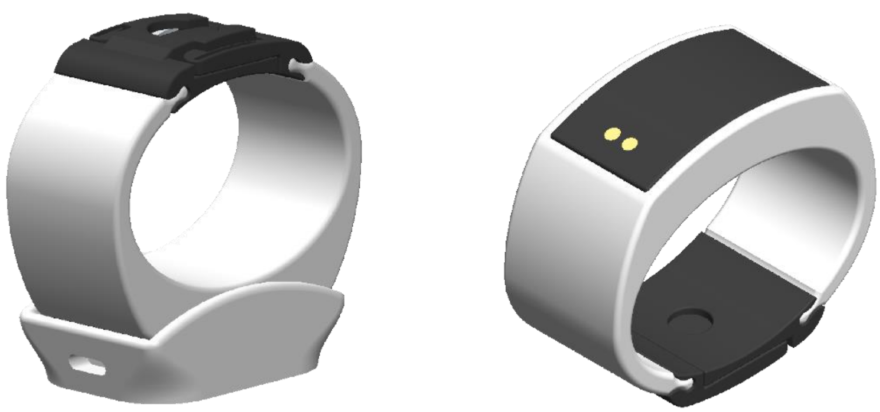
A3.1: PCB Stack Proposed Layout



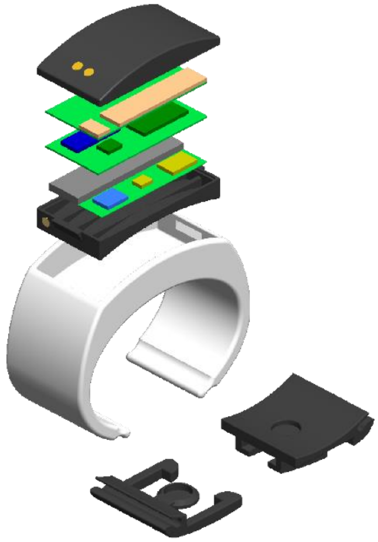
A3.2: Electronics Package



A3.3: Prototype 1 Assembled View (With and without Charging Station)



A3.4: Prototype 1 Assembly (Exploded View)



A3.5: Alternate Clip Mechanism (Non-Child Proof)

11. Appendix A4

Power Budget:

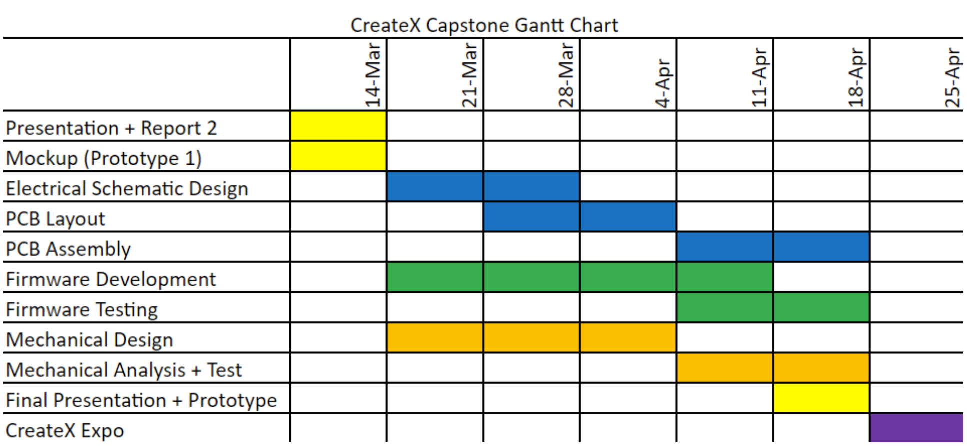
	Part ID	Operating Voltage (V)	Avg Current (mA)	Avg Power (mW)	Duty Cycle	Dimensions (mm)
Power Consumption Components						
MCU + LTE + GNSS + Flash	nRF9160	3 - 5.5				16 x 10 x 1
Cellular Non-BLE		3.7	1.45	5.365	50%	
GPS Non-BLE		3.7	4.5	16.65	50%	
GPS BLE		3.7	2.5	9.25	50%	
BLE + MCU + Flash	nRF52833	3.7	0.15	0.555	50%	5 x 5 x 1
Power Management + Voltage Monitor	ADP5360	3.9	0.01	0.039	100%	3 x 3 x 1
Cellular + GNSS Antenna	NN02-224	3.7	1	3.7	100%	L x 7 x 3
BLE Antenna	2450AT18D0100	3.7	0.2	0.74	50%	8 x 4 x 1
Accelerometer	BMA400	3.6	0.01	0.036	100%	2 x 2 x 1
GNSS LNA w/ Filters	SKY65943-11	1.8	2.9	5.22	100%	3 x 3 x 1
				36.335	**25.275**	
Misc. Components						
eSIM	SIM-E-MFF2-GL-250					6 x 5 x 1
Antenna Switch Module x 2	BGS18GA14					2 x 2 x 1
BLE SAW Filter	SAFFB2G45MA0F0A					1 x 1 x 1
Power Supply						
Battery	Custom					L x (W - 8) x H

12. Appendix A5

Electrical Bill of Materials:

Electrical BOM	Part ID	Vendor	Unit Cost	1000x Unit Cost	Alternatives
MCU + LTE + GNSS + Flash	nRF9160	Digikey	$ 27.11	$ 18.96	AVT9152/RAK8211
BLE + MCU + Flash	nRF52833	Digikey	$ 7.20	$ 3.62	BGM220SC22HNA2
Power Management + Voltage Monitor	ADP5360	Digikey	$ 5.48	$ 2.93	MAX20360, DA9070
Cellular + GNSS Antenna	NN02-224	Digikey	$ 4.55	$ 2.58	0830AT54A2200
BLE Antenna	2450AT18D0100	Digikey	$ 0.67	$ 0.29	
Accelerometer	BMA400	Digikey	$ 1.70	$ 0.96	
GNSS LNA w/ Filters	SKY65943-11	Digikey	$ 3.45	$ 1.73	
eSIM	SIM-E-MFF2-GL-250	Digikey	$ 5.43	$ 2.56	
Antenna Switch Module x 2	BGS18GA14	Digikey	$ 2.20	$ 1.18	
BLE SAW Filter	SAFFB2G45MA0F0A	Digikey	$ 0.23	$ 0.12	
LiPo Battery	Custom	Grepow	$ 5.00	$ 2.60	
			$ 63.02	$ 37.53	

13. Appendix A6



14. References

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