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HydroBand: The Continuous Hydration Monitoring System

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Introduction

After researching the health and fitness market, it was determined that a convenient way to properly monitor one's hydration level was not available. Dehydration during exercise is defined as the dynamic loss of body water that is associated with an increase in core body temperature, an increase in cardiovascular strain, and decreases in blood sodium levels and stroke volume (Volpe). In the article *Estimation of Pre-practice Hydration Status of National Collegiate Athletic Association Division I Athletes* from the Journal of Athletic Training, "Appropriate hydration is an important but often overlooked aspect of proper training and competition" (Volpe). Early signs of dehydration include dry mouth, fatigue, poor elasticity of the skin, decreased urine output, headaches, and dizziness. If left untreated, dehydration can potentially lead to fever, low blood pressure, rapid heartbeat, rapid breathing, delirium, and unconsciousness ("Dehydration").

Hydration levels in athletes should be monitored in order to prevent dehydration before, during, and after exercise. The HydroBand™ device works by calculating dehydration levels in terms of water loss and alerts the user as to how much water is needed to combat dehydration. If the user's temperature reaches dangerous levels, the user will be alerted as well. These values are calculated using an IR temperature sensor that is positioned across the user's chest. The infrared (IR) sensor constantly records the user's core body temperature and relates the change in temperature to water loss. The mission statement for the HydroBand is as followed: "HydroBand is devoted to being involved in people's well-being by empowering them to control their fitness ambitions."

Dr. Otterstetter, our primary client, provided additional guidance for this project. Dr. Otterstetter is an associate professor in the Department of Sport Science and Wellness Education at The University of Akron. With the help of Dr. Otterstetter, other hydration measuring devices will be used in testing protocols and the labs in the Exercise Science department will be utilized. By combining Dr. Otterstetter's expertise on body physiology and the team's education on engineering core concepts, the HydroBand solves the unmet medical need of dehydration in athletes.

Background Information

There are numerous other ways to measure dehydration besides changes in core body temperature. These range from blood analysis, urine analysis, weight loss, skin elasticity tests, pH levels in sweat, and the osmolality in saliva. An IP search was performed on existing products on the market that related to this medical need. Product technicality, functions, and any patents that existed were researched and noted in the project binder. The fitness wearables market in the United States is showing steady growth with no signs of a decline. According to WinterGreen Research, Inc., the sports and fitness performance wearable market was valued at $3.5 billion in 2014, with a projected market value of $14.9 billion by 2021 (Market Reports Hub, web). The wearable devices shipment revenue itself is currently valued at $20 billion (Hunn, web). Numerous existing devices on the market track the user's temperature, however none of them apply the mathematical relationship between core temperature and hydration level that will be implemented in the HydroBand.

One of HydroBand's leading competitors on the market is a smart baseball cap. The Spree Smartcap uses biosensors to measure the user's skin temperature at their forehead. It also records heart rate, pace/cadence, and distance covered during the workout. The smart cap is also supported by Bluetooth Smart© for corresponding smartphone app functionality. Most athletes either find wearing hats impractical or are not allowed to wear one during competition. Another product discovered during the IP search was the CorTemp® Ingestible Core Body Temperature

Sensor. This small capsule contains a sensor that wirelessly transmits core body temperature as it travels through the digestive tract. One of the major disadvantages with this pill is that it is not reusable and is expensive. The popular Fitbit and similar wrist watch devices take the skin temperature at the user's wrist while tracking and displaying other health factors. The VitalSense® Dermal Temperature Patch is a disposable sensor patch for wireless skin surface recordings. The Polar© Heart Rate Chest Belt takes the skin temperature at the chest while also calculating the user's heart rate during exercise.

The only device found that relates the temperature reading to hydration is the Cosinuss Technology wearable in-ear device that continuously monitors core temperature via the tympanic membrane. If the temperature rises to a dangerous level that indicates dehydration, a corresponding "warning light" will display. HydroBand differs from what is on the market because it serves as the only device that will input the temperature reading and convert this into a specific amount of liquid that needs to be consumed to return the user to a healthy and hydrated state during strenuous exercise. Since many sports prohibit wearing wrist bands, headbands, and other outside equipment, the chest band provides a convenient and appropriate location for a larger variety of athletes. A complete functional and system block diagram and description of how the HydroBand device works is explained in Appendix A: Functional Requirements.

Project Objectives and Goals

The majority of all project objectives stem from the design process outlined in Biomedical Engineering Design I and II class and through the assigned textbook, *Tools and Tactics of Design* (Kinzel et al.). Original objectives included brainstorming different unmet medical needs, filtering through ideas, identifying a client, patent and research searches, and eventually devising solutions to solve these unmet needs. All of these objectives were reached in the fall semester and have been thoroughly recorded. This documentation is shown in the project binder in the form of Coggle brainstorming charts, patent and research searches, decision matrices, and meeting minutes from each client and team meeting. After developing solutions, the objectives for this project started to gear more towards establishing ways to build a prototype and how this would be accomplished. After an initial alpha prototype was created, the functionality was evaluated and all issues were addressed in order to begin transition into the working beta prototype. The end objectives of this project included maintaining a project notebook, maintaining professional relationships with all mentors, clients, and teammates involved, writing quarterly reports and presentations, and outlining all design process requirements. A Development Plan that outlines how the project transpired is included in Appendix E.

At this phase in the project, the end goal is simple: devise a working beta prototype that alerts the user of their hydration needs. In order to meet this goal, there were a series of other goals that had to be accomplished along the way. The first of these goals was to create a working alpha prototype using a breadboard and Arduino Uno system incorporated with an IR temperature sensor (all parts used are further explained in the Methods and Manufacturing section and outlined in the working budget). With the utilization of research and data sheets, the product development team completed the alpha prototype. The second goal for the alpha prototype was to implement wireless transmission. After a few snags, the alpha prototype testing and debugging was pushed back from February 2016 to March 2016. At this point, the functionality of the prototype was evaluated and further design iterations were brainstormed and illustrated through the use of mechanical drawings. Design modifications were made and the beta prototype construction began. In order for the beta prototype to work seamlessly and to complete functionality documentation, additional testing must be completed on a variety of individuals under different working conditions (discussed in testing procedures). The Beta prototype and the second phase of testing will be completed by the last week of April. An updated Gantt chart as of April 4th, 2016 is included in Appendix C. As evident from Gantt Chart updates since first semester, the alpha and beta prototypes took longer than expected, but are still subject to be completed on time. To wrap up the design process, a written final report and oral presentation will be given at the beginning of May to the Design I and II class. The purpose of this final report is to draw conclusions and outline all important phases of this project.

Methods, Procedures, and Manufacturing

Jeff Schrieber and Chris Bender of HydroBand lead the circuit and coding design of the product. The initial steps before construction of the concept device were to seek consultation from Electrical Engineering professors and graduate students at The University of Akron during December of 2015. Using the advice and knowledge from a series of consultations, the HydroBand team approved the use of Arduino microcontrollers, which will control the concept device. At the beginning of January, the first round of parts were ordered to start the first phase of the alpha prototype. Appendix D includes an up-to-date spreadsheet on all purchases made thus far as well as a breakdown of the $500 budget. The initial construction included testing the components with Arduino architecture and the software language C++. The second stage of alpha construction consisted of debugging the hardware and software. This was completed during the month of February along with Testing Phase 1. The beta prototype and the next set of testing began in the middle of March. Karina, Catherine and Ryan will lead testing Phase 1 and 2, which is explained below in Performance Testing. All testing will be completed by the end of April.

The first meeting was conducted with Dr. Nghi Tran, Assistant Professor of Electrical and Computer Engineering, regarding wireless communication due to his expertise in relay networks and MIMO systems. Dr. Tran does not have an extensive background in analog circuits, but recommended his current graduate student, Ardalan Alizadeh for help using ZigBee nodes. ZigBee nodes consist of low-cost and low power wireless networks that use IEEE 802.15.4 radio specifications and operate in unlicensed frequency bands. The meeting with Ardalan provided a better understanding on coding the device based on his previous projects.

Dr. Arjuna Madanayake, an Associate Professor in Electrical and Computer Engineering, was also consulted due to his broad background in circuitry. Dr. Arjuna suggested implementing microcontrollers into the design due to its small form factor, low power and ability to fulfill the requirements for the design. Microcontrollers are simply a small computer with memory, RAM, I/O connections, and a processing unit. His last suggestion was to speak with Dr. Forrest Bao of the Electrical Engineering Department for his advice on using the Arduino hardware. Dr. Forrest Sheng Bao, Assistant Professor in Electrical Engineering at The University of Akron, explained how simple Arduino boards could be implemented using tutorials and videos found online. There are an abundant amount of accessories, such as simple RF transmitters and receivers, temperature sensors, and many others, that are compatible with Arduino architecture. After the series of consultations with Electrical Engineering professors, the team decided to implement Arduino microcontrollers into the alpha design based on its low cost and simplicity.

To help guide the design process, a thorough list of customer and engineering requirements was created before prototype construction began (Appendix B). The customer requirements focus on basic principles Dr. Otterstetter outlined. The engineering requirements were then generated based on the customer requirements, current product specs, FDA product requirements, and HydroBand team goals. All components of the alpha and beta units were designed to meet all engineering requirements. Testing procedures were also generated based on this list and will be addressed in more detail in the testing section.

Jeff Schreiber and Chris Bender conducted HydroBand prototyping. The first step of the development process was to get familiar with the programming language and hardware. This step was done by completing online tutorials to gain knowledge on how the Arduino system performs. After the team was familiar with Arduino setup, testing of the TMP007 sensor was next. The TMP007 is an infrared thermopile sensor that can measure the temperature of an object without contact. The HydroBand team researched various types of IR sensors before finally deciding on the TMP007 and the MLX90614 infrared thermometer because their applications included skin/body temperature and had low power consumption (low power consumption is one of the listed engineering requirements found in Appendix B). The prototype team had success in wiring the TMP007 to the Arduino microprocessor and installing the code for the device. The installed firmware allowed them to display the temperature readings in both Celsius and Fahrenheit onto a computer screen.

Following the success of the IR sensor test, displaying the readings onto a seven-segment display was desired. A seven-segment display was included within the Arduino Uno starter kit. These displays are commonly used in digital clocks, electronic meters, and basic calculators. After several attempts of developing a working code for the display, the prototype team was unable to successfully send the data from the sensor to translate onto the seven-segment display. Rather than spend more time trying to troubleshoot the seven-segment display, a team decision was made to implement the use of a LCD screen for the alpha unit based on its simplicity. The wireless capability with the LCD display was completed in February.

The next phase of the alpha unit included testing the wireless communication between the two microcontrollers. A 433MHz transmitter and receiver were used to communicate between the two microcontrollers, (Arduino Pro Mini and Arduino Uno). However, programming the Arduino Pro Mini proved difficult with the lack of a connector. The team was able to get around this issue by using a small breadboard and jumper wires to serve as a connector. Following several debugging issues, the program was successfully installed. The Arduino Pro Mini wirelessly transmitted a message to the Arduino Uno, which then received the message and displayed it on the computer. Testing procedures for the alpha unit focused on verifying the display readings on the LCD screen, implementing the equation for water loss due to body temperature changes, on/off functionality, and finally evaluating the complete system with the use of wireless communication.

With the completion of the alpha unit, testing was performed to compute the range of the wireless transmitters and the accuracy of the TMP007 IR sensor. Testing verified the functionality of the circuit design and coding, but the tests were not meeting the engineering requirements for accuracy, range, size and mobility. For accuracy testing, Chris and Jeff took turns measuring the temperature of their palms every four seconds with the TMP007 sensor. The data were compared to a calibrated infrared gun that was given to the team by the client, Dr. Otterstetter. The measurements obtained from the TMP007 were a few degrees off from the infrared gun. These results prompted the team to purchase a new IR temperature sensor, the MLX90614. The same test was performed for the newly installed IR sensor, and the data collected proved more accurate and consistent. Chris and Jeff also tested the wireless range of the 433MHz transmitters. The initial range only proved to be about five feet. The transmitters did have an option for external antennas to help add to the range, so copper wire was soldered to them. The external antennas helped the range improve up to 35 feet. This was still significantly less than the engineering requirements. The antennas also took away from the size and mobility requirements as well. In short, alpha testing helped to improve the functionality of the system and lead to design iterations to be used in the beta unit. A complete system block diagram and functionality of the alpha design is available in Appendix A. These diagrams help explain in more detail how the prototype performs.

Careful planning and consideration was taken when deciding how the team would meet the engineering requirements and improve upon the alpha prototype. First, new transmitters were found, the nRF24L01+, a 2.4GHz transceiver with a range of 200 feet, (meets the engineering requirement). To improve the mobility and condense the size, the Arduino Uno was replaced with another Arduino Mini Pro. With the switch to a smaller Arduino board implemented, the 5V output from the Uno was replaced. However, the Arduino Pro Minis and the LCD screen are powered using 5 volts. This issue was solved with the use of a charge pump, which boosts an input voltage of 3V to an output voltage of 5V. The batteries themselves were also modified from the alpha to the beta prototype by originally using two AAA batteries to now only using one lithium battery. This switch was also needed in order to help save space and keep the design as condensed as possible. The final additional feature added to the beta unit was a slide switch used to turn the device on and off. This switch was required in order to help extend the battery life.

Upon the completion of the circuit design, the project went from a breadboard in the alpha unit to a PCB board beta unit. The PCB was selected to allow the circuit to be a more permanent fixture, to keep the electronics soldered in place, and to eliminate errors due to bad connections. This also fulfilled section 1.7 of the Customer Requirements: to create the small form factor for a wearable device. The PCB also improved the layout by shortening the wires so the circuit was easier to follow. Once the beta prototype generates acceptable test results, the design will have a more practical and smaller layout. This will be completed by only using necessary parts. These parts include a microprocessor rather than an entire Arduino circuit, switching all resistor and capacitors to a smaller ceramic design, and getting rid of protoboards by using actual footprints for integrated circuits. A two layer PCB could then be etched with the circuit design and be massed produced.

With the completion of the circuitry, SolidWorks was utilized to model a custom casing part to house all of the sensor components. This includes a base and top lid that screws in place so that the electrical components can be accessed if needed. The team approved the final design and will be 3D printing the housing parts using ABS. Within the next week or two the final beta unit will be completed by placing all of the components in the casing and by connecting elastic bands to the housing unit (to strap around the user's chest). Final beta testing is outlined below in performance testing and will be completed no later than the end of April.

Looking towards future years, in order to mass-produce the HydroBand product, an outside manufacturer must be utilized. A manufacturer will be selected based on costs, reliability, and how quickly they can manufacture the product. The entire HydroBand team will meet at the end of the project to discuss future directions.

Performance Testing

After the creation of the alpha prototype in late February, an initial round of general testing on the overall functionality of the HydroBand was completed. The general operations, listed in the table below, of the HydroBand system were tested and passed verification within the team.

General Functionalities	Pass/Fail
Chest-piece with temperature sensor powers on successfully	Pass
Chest-piece with temperature sensor powers off successfully	Pass
Water bottle portion powers on successfully	Pass
Water bottle portion powers off successfully	Pass
Data is wirelessly sent between chest-piece and water bottle portion	Pass
Output on the water bottle portion is clear and readable	Pass
Data is automatically collected at the proper times (according to the code)	Pass
The HydroBand system is user-friendly (Based on a survey and general-use log completed by test subjects)	Pass

An infrared non-contact laser temperature gun (acquired from Dr. Otterstetter) was used to obtain baseline palm temperature values. Thirty baseline temperatures were taken from the palm of the first test subject (one of the HydroBand team members). Immediately following the IR gun temperature collection, the temperature sensor on the HydroBand was used to collect thirty palm temperature values from the same test subject. The baseline temperature values and the HydroBand temperature values were compared against each other. The standard deviations between the IR gun readings and the HydroBand readings were then calculated. The standard deviations were acceptable based on customer and engineering requirements. A complete table of the results from this initial testing can be seen in Table 1F of Appendix F.

With the beta unit approaching creation, the HydroBand team enters the second phase of testing in the upcoming weeks. Table 2F in Appendix F outlines specific tests that will be performed and verified based on the engineering requirements. Urine test strips (obtained from Dr. Otterstetter) will be used to collect the initial baseline data for hydration values. Various test scenarios will be outlined (e.g. in the morning before food/drink, immediately before exercise, immediately following exercise, etc.) and hydration levels will be read from the urine test strips from one member of the HydroBand team for each scenario. Then, the HydroBand will be tested and the hydration value outputs will be compared to the levels obtained from the urine strips.

An observation log will be compiled throughout all testing which will contain general findings, possible functional or feature improvements, and any inconsistencies or outliers. This log, along with the data collected, will be used as the core foundation for any necessary changes and adjustments leading up to the Beta prototype.

A third round of testing will then be performed on the Beta prototype. Two volunteer test subjects (acquaintances of the HydroBand team members) will undergo the testing. In the same manner as before, general functionalities, core temperature collection, and hydration level collection will be obtained using both baseline values and the HydroBand's output. The HydroBand will be tested in different scenarios that correspond to a specific engineering requirement. The test subjects will perform testing in both Dr. Otterstetter's exercise science lab and in outdoor environments in order to determine any environmental differences or factors that may affect performance. Data from the tests will be compiled, analyzed, and approved as acceptable according to the functional specifications and requirements. The test subjects will also complete a thorough log with general notes, feature requests or improvements, ease of use, and any problems or troubles that were encountered. This log will be used for any final adjustments necessary before product completion.

Presenting and Implementing the Design (Future Directions)

With the completion of testing the beta prototype, HydroBand will begin the presentation phase in the middle of April. All research, designs, test data and analysis, progress documents, company information, and marketing documents will be compiled into the final revision of this report. A presentation of the completed design process will be conducted to the 2016 Biomedical Engineering Senior Design class and guests, along with a demo of how the HydroBand solves the medical need of dehydration in athletes.

Challenges and Recommendations

The team faced several challenges as the HydroBand project progressed. Most of the major challenges were related to issues with the electronic components. None of the team members had prior experience in this area. The team also encountered issues with timelines and deadlines, and with scheduling team meetings and consultations with outside resources.

If the HydroBand device continues to be improved and modified in the future, all group members would be responsible for familiarizing themselves with electrical wiring, and for finding a more compact set-up that was more suitable for real world application. If the project were repeated, a stricter schedule would be followed.

References

Amtel Corporation. *Atmega48P.* 2016. Web. 08 February 2016.

<www.atmel.com/images/atmel-8271-8-bit-avr-microcontroller-atmega48a-48pa-88a-88pa-168a-168pa-328-328p_datasheet_complete.pdf>

"Arduino - ArduinoBoardProMini." Arduino - ArduinoBoardProMini. N.p., n.d. Web. 08 February 2016. <www.arduino.cc/en/Main/ArduinoBoardProMini>

"Arduino - ArduinoBoardUno." Arduino - ArduinoBoardUno. N.p., n.d. Web. 08 Feb. 2016. <http://www.arduino.cc/en/Main/ArduinoBoardUno>.

"Dehydration." *Mayo Clinic*. Mayo Foundation for Medical Education and Research, 2015. Web. 04 December 2015.

"Download MLX90614 Datasheet PDF (Single and Dual Zone Infra Red Thermometer in TO-39)." N.p., n.d. Web. 08 Feb. 2016.

<http://www.datasheetspdf.com/PDF/MLX90614/798825/1>

"Dr. Forrest Sheng Bao." *Individual Faculty Profile : The University of Akron*. N.p., n.d. Web. 06 Feb. 2016.

"Dr. Nghi Tran." *University of Akron College of Engineering*. N.p., n.d. Web. 6 Feb. 2016.

Madanayake, Arjuna. "Bio." *Advanced Signal Processing Circuits (ASPC)*. WordPress, n.d. Web. 06 Feb. 2016.

Hunn, Nick. "The Market for Smart Wearables 2015 – 2020: A consumer centric approach." *WiForce Wireless Consulting.* March 2015. Web. Accessed 21 April 2016.

<http://www.nickhunn.com/wp-content/uploads/downloads/2014/08/The-Market-for-Smart-Wearables.pdf>

Kinzel, G., Freuler, R., Demel, P. G., Labaugh, D. M., Labaugh, W. M. “Tools and Tactics of Design.” *Wiley.* 2000. ISBN-13: 978-0471386483.

“Smart Sports and Fitness Wearables Market to Hit $14.9 Billion by 2021.” *Market Reports Hub*. 21 September 2016. Web. Accessed 2 February 2016. <http://www.prnewswire.com/news-releases/smart-sports-and-fitness-wearables-market-to-hit-149-billion-by-2021-528461241.html >

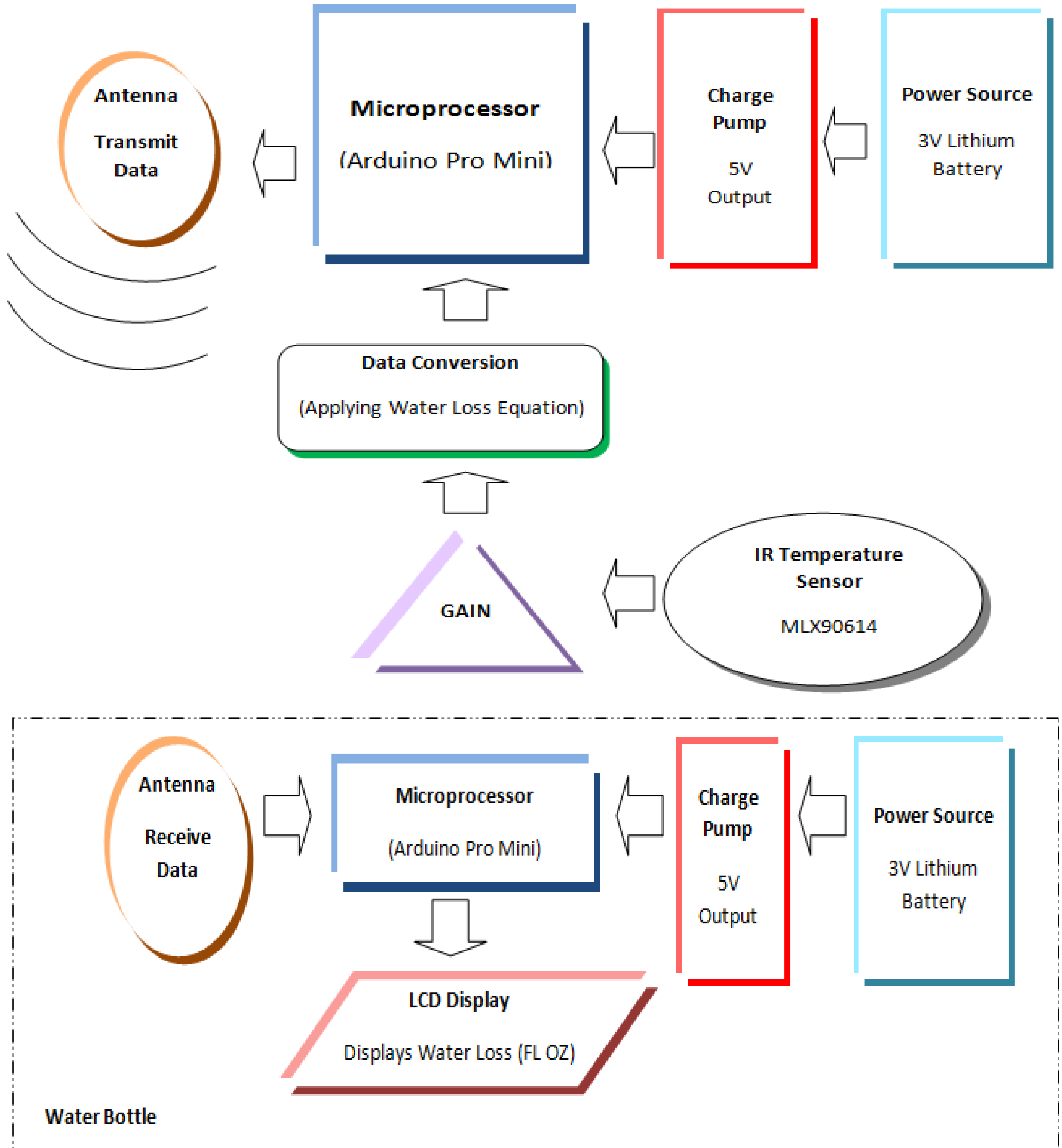
Texas Instruments Incorporated. *Infrared Thermopile Sensor with Integrated Math Engine* (n.d.): n. pag. Web. www.adafruit.com/datasheets/sbos685.pdf

Volpe, Stella L., Kristen A. Poule, and Erica G. Bland. "Estimation of Pre-practice Hydration Status of National Collegiate Athletic Association Division I Athletes." *Journal of Athletic Training*. The National Athletic Trainers' Association, Inc, n.d. Web. 04 December 2015.

"ZigBee® Wireless Standard." *Digi International*. N.p., n.d. Web. 07 Feb. 2016.

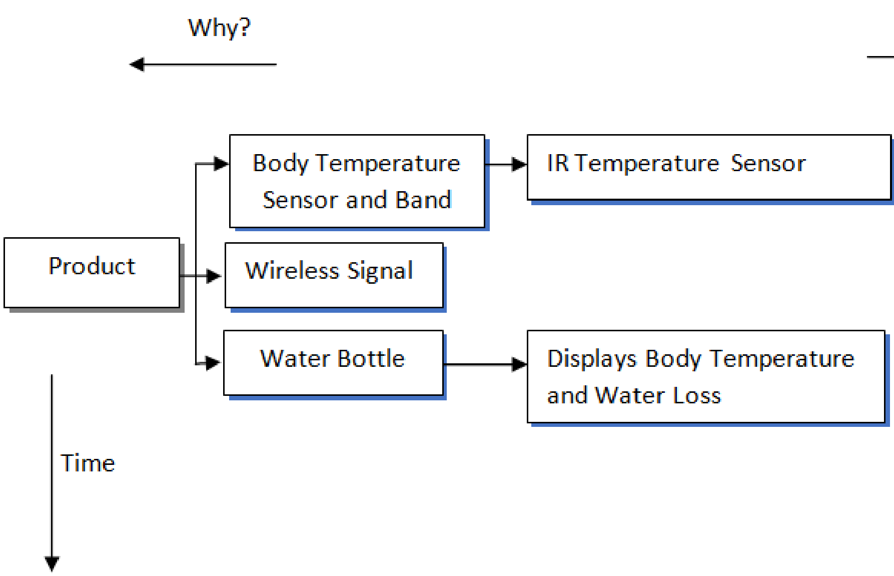
Appendices

Appendix A: Functional Requirements

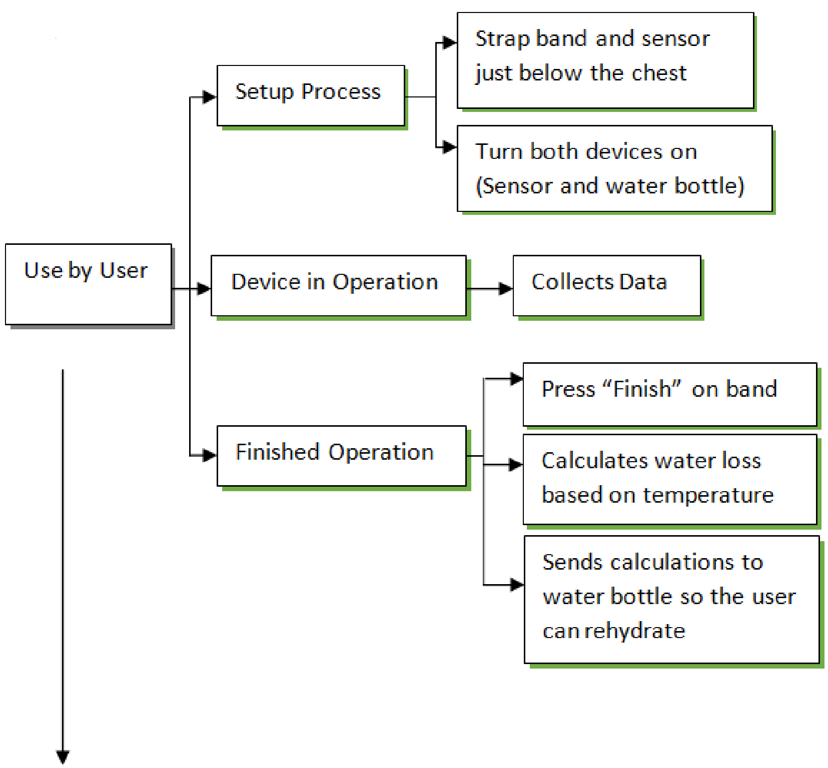


(Figure 3.1 System Block Diagram)

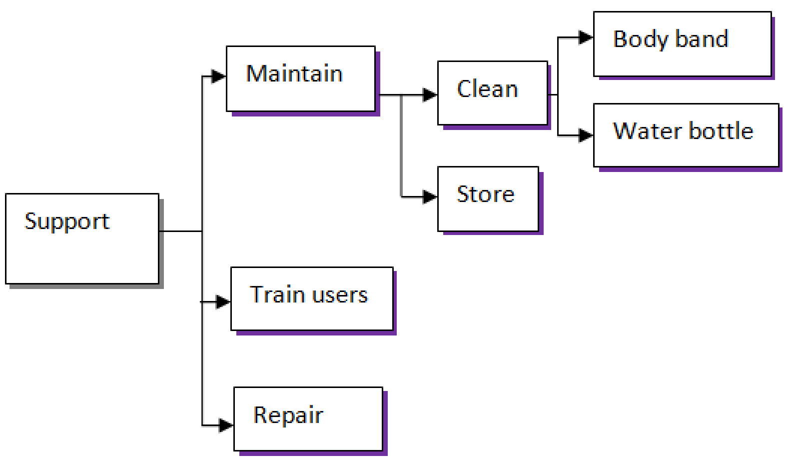
Functional Analysis Diagram



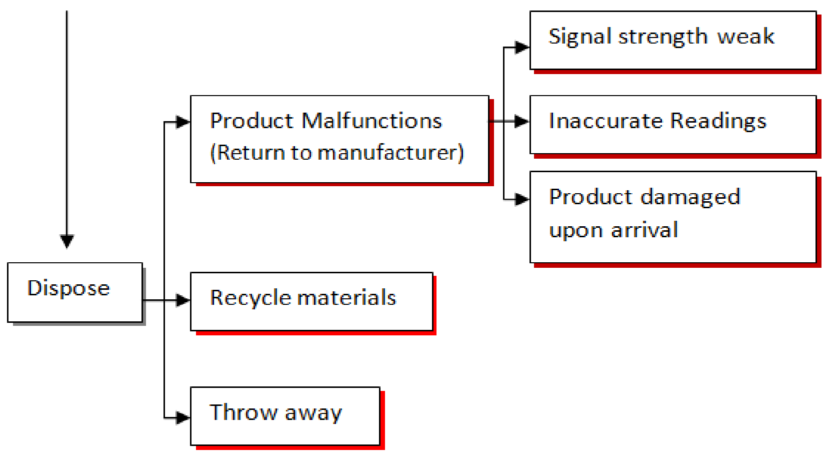
Weight of Sensor	Less than 1lb
Weight of Water Bottle?	1-2lbs
How much?	$45.00
Power type?	1 Lithium Battery
Battery life?	2-3 years
Signal strength?	200 Feet
Sensor Accuracy?	**Highly** Accurate



How often does it collect data?	Every 15 min
Does it store data?	Temporarily
Can user set how often/long they want data collected for?	No
Can the user strap the band to other areas of the body?	Yes but closer to the core the better the accuracy.
Is there an alarm if user is reaching dangerous temperatures?	Not available for present version, could be a future feature
Do both devices need to be on for system to work?	yes



How to wash the body band?	Can be washed in washing machine, air dry.
How to wash water bottle?	Remove band around water bottle, dish washer safe.
Is water bottle BPA free?	yes
How can the user learn how to use the device?	Instruction Manual
How is it stored?	-4F-120F or -20C-49C
What happens if a part breaks?	**Replacement parts can be bought and** replaced.



Is there tech support?	Yes
What happens when the user sends their device in?	They will receive a new device, or refund depending on customer wants.
What parts are recyclable?	Water bottle and batteries.
Is it safe to throw broken electronics?	**Yes devices are** lead free.

Important Functions	Why It Is Important	Uncontrolled parameters
Wireless Signal	A poor signal could result in data loss	User goes outside of wireless range unknowingly
Sensor Placement	Bad placement of the sensor could result in accurate data	User measures body temperature further away from core
Water Bottle	Displays how much water the user has lost during exercise or physical labor	
Cleaning Band	So the user can have good hygiene.	User ignores instructions, band gets damaged from dryer
Cleaning Water Bottle	It is important to be able to clean and disinfect the water bottle to prevent illness.	User forgets to remove Display band from water bottle, electronics become damaged.

Appendix B: Constraints and Limitations

When determining the constraints & limitations of a device it is important to take into consideration the requirements of the customer. Customer Requirements are a more general idea of what is expected while Engineering Requirements are more quantitative. Although Engineering Requirements are measureable values they do not state exactly how the device will achieve the requirement. Additionally, all Customer Requirements are addressed by Engineering Requirements to ensure that they are achieved. To ensure that all requirements are addressed the Engineering Requirements are broken into different sections. These sections include regulatory, technical, performance, sales, manufacturing, packaging, and environmental requirements.

For this design the requirements were set so that an athlete would be able to use the device during a workout to track how much water was lost. Not only does the device have to be able to accurately transmit the data but it also has to be able to withstand any forces it may experience over the course of the workout. Other requirements were determined by comparing the device to those currently on the market in order to stay competitive.

Section 1: Customer Requirements

Section 1: Customer		
Number	Comment	Source
1.1	Temperature Measurement: Temperature sensor must take accurate readings of the core temperature.	Dr. Otterstetter
1.2	Data Collection: Sensor must take multiple readings throughout the workout.	Dr. Otterstetter
1.3	Data Collection: Water bottle must tell the user how much water to consume.	Dr. Otterstetter
1.4	Chest band must not become loose or be too tight on the user.	Dr. Otterstetter
1.5	Data Collection: Sensor must have a range greater than the length of the field.	Athlete
1.6	Power: Battery must last longer than the length of practice.	Athlete

1.7	Device Weight: Device must be light enough to not interfere with athletic performance.	Athlete

Section 2: Regulatory and Statutory:

Section 2: Regulatory and Statutory		
Number	Comment	Source
2.1	Basic User Safety Standards	Standards Review
2.2	This device must not cause harmful interference.	Part 15 FCC Rules
2.3	Material: Material must comply with ISO standards (Electronic components and elastic band)	FDA recognized consensus standards. Standards Review.
2.4	Testing: All electronic components are subject to to meet ASTM standards	Standards Review
2.5	This device must accept any interference received, including interference that may cause undesired operation.	Part 15 FCC Rules

Section 3: Functional Requirements

Section 3: Technical		
Number	Comment	Source
3.1	Power: Chest band will require the power of at least 5 volts.	Investigational Reports
3.2	Temperature Measurement: Must measure temperatures ranging from 14-122 degrees F	Competitor Average
3.3	Water resistance must be at least 15 ft.	Competitor Average
3.4	Operating Humidity: Can be used in totally dry or totally immersed environments (0-100% humidity)	Investigational Reports

3.5	Operating Temperature: Can be used from North Pole to Equator (-40 to 40 C)	Investigational Reports
3.6	Power: Battery must last at least 6 hours per day.	NCAA Practice Report
3.7	Device Weight: Wearable Device must weigh under 4 ounces.	Competitor Average
3.8	Minimum length of band must be 24.17 inches.	Competitor Average
3.9	Maximum length of band must be at least 68.11 inches.	Competitor Average
3.10	Power: Battery Life must exceed 2 years.	Competitor Average
3.11	Wearable Device must be smaller then 2x1x1 in.	Competitor Average

Section 4: Performance Requirements

Section 4: Performance		
Number	Comment	Source
4.1	Object Interference: Measure temperature accurately within 2% if an object disrupts IR beam.	Competitor Average
4.2	Both devices must connect within 5 seconds when turned on.	Company Requirement
4.3	Data Collection: Accuracy of temperature sensor read up to the hundredths place.	Focus Group Report
4.4	Servicing: Should operate successfully for 100 uses between servicing intervals.	Focus Group Report
4.5	Data Collection: LCD screen to tell user how much water to consume within 2 seconds of sensor read.	Focus Group Report
4.6	Data Collection: Temperature sensor must read every 2 minutes.	Focus Group Report
4.7	Data Collection: Device communication must be at least 100 meters.	Focus Group Report

Section 5: Sales Requirements:

Section 5: Sales		
Number	Comment	Source
5.1	Selling Price: Not to exceed $75 with production cost under $55.	Marketing Requirements
5.2	Color: Colors can be customized to match a team's colors.	Marketing Requirements
5.3	Sales: Sell 450 units by the end of 2016.	Marketing Requirements
5.4	Sales: Implement device by the end of 2016 year.	Marketing Requirements
5.5	Sales: Increase number of unit sales by 40% next year.	Marketing Requirements

Section 6: Manufacturing		
Number	Comment	Source
6.1	Cleaning: Device needs to be cleaned post manufacturing.	
6.2	3-D printed material must not cause bodily harm.	
6.3	Calibration: A calibration test needs to be done post assemble to ensure the device's accuracy.	
6.4	Device must disassemble for user to change battery.	

Acceptance Requirements:

Section 7: Packaging and Transportation:

Section 7: Packaging and Transportation		
Number	Comment	Source
7.1	Drop Test: When packed the device should withstand a drop from a height of 5 feet.	ASTM D5276
7.2	Instructions for Use: Each box will contain one set of instructions.	MDD-FDA
7.3	Shelf Life: The shelf life for the package is to be 5 years.	ASTM F1980
7.4	Packaging Dimensions: The box will have a footprint of 6x3x3 in.	Packaging Office
7.5	Labeling: Labels must abide to the code of federal regulations for labeling, good manufacturing practices and general electronic products	CFR Part 801 CFR Part 820 CFR Part 1010
7.6	Vibration: Packaging must be able to withstand a vibration test to simulate transportation	ISO 8318 ASTM D4728
7.7	External Packaging: Packaging must be able to complete a water spray test to ensure device won't be harmed due to environment	ISO 2875

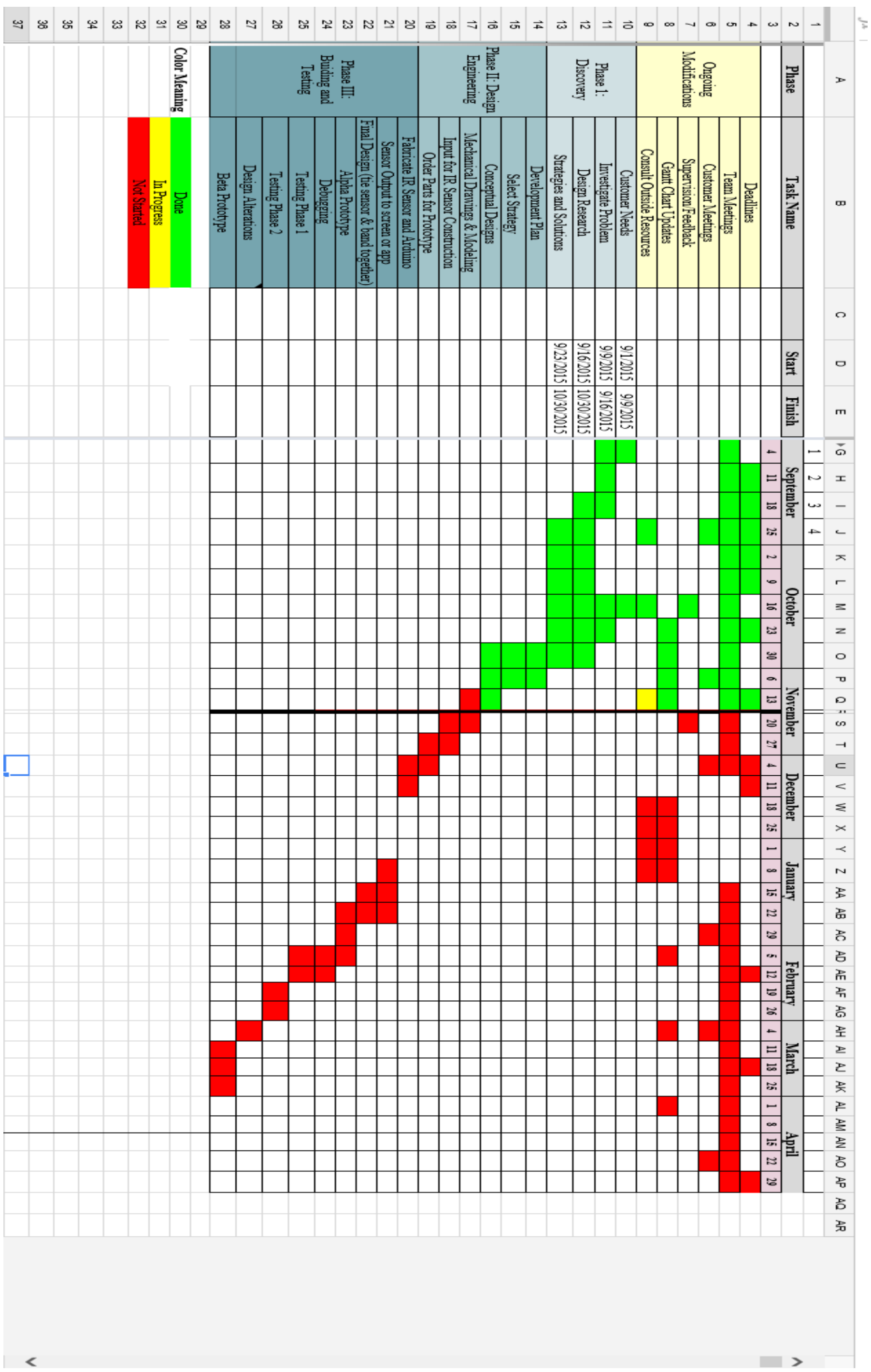
Section 8: Environmental Requirements:

Section 8: Environmental		
Number	Comment	Source
8.1	External Packaging: All external packaging to be recyclable.	Focus Group Report
8.2	Disposal: Device must be returned back to supplier for proper disposal.	Focus Group Report

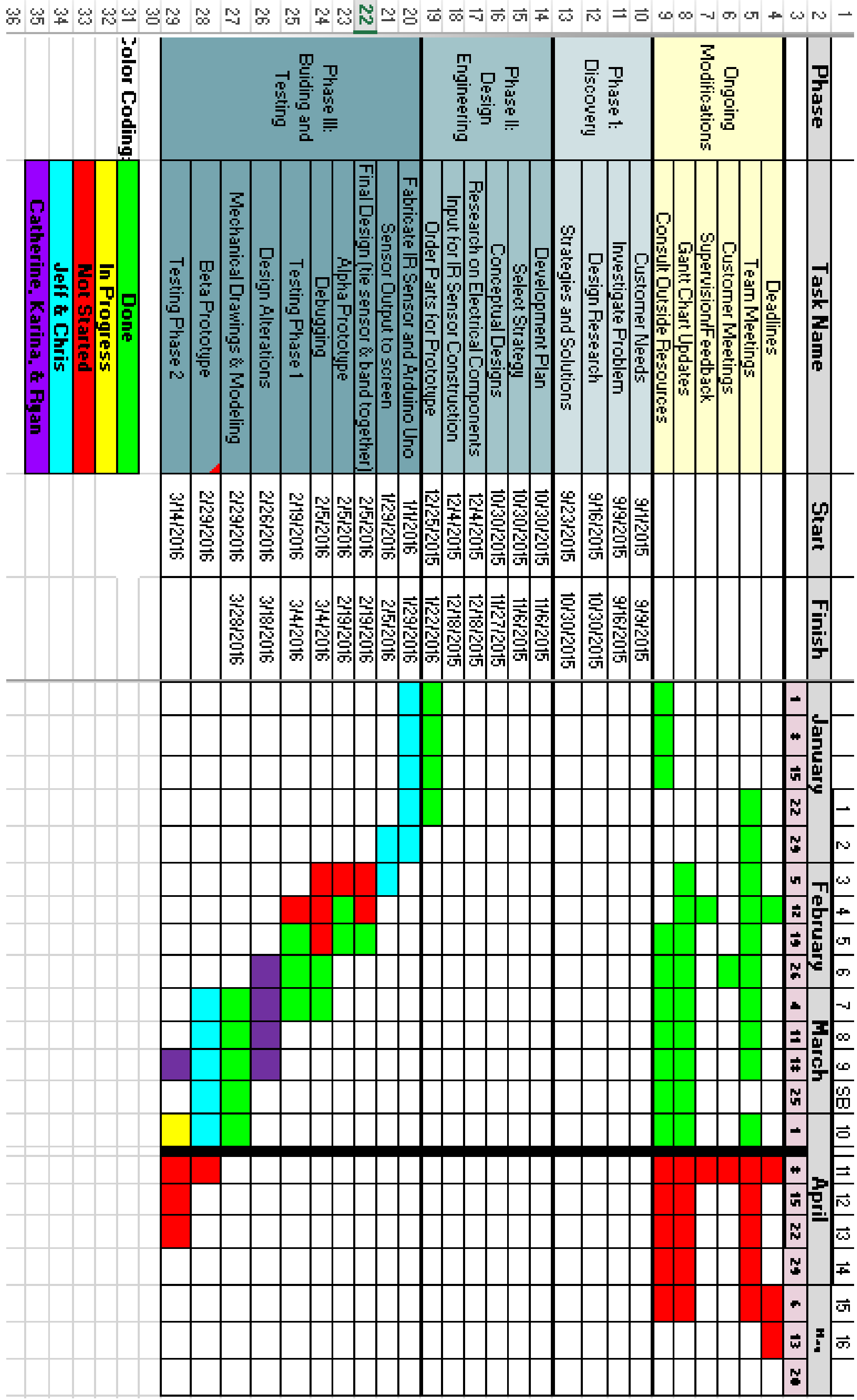
8.3	Servicing: By-products of servicing to be disposed of meeting the requirements of relevant standards.	Standards Review
8.4	Sterilization: Device should be able to be cleaned with everyday cleaning products.	Focus Group Report
8.5	Interference: Device must withstand interference from other wireless devices that use the 2.4 Ghz band.	ANT Wireless Comm. Protocol
8.6	Device must be at least 65% recyclable	EPEAT
8.7	Sleep mode for the device must power less than .2 Watts	Energy Star

Appendix C: Timeline

Gantt Chart as of 11/16/15 (1st Semester Completed Timeline):



Second Semester Gantt Chart: Updated 4/4/2016



Appendix D: Budget Specs (Subject to Change)

Name	Description	Receipt Printed	Cost + Shipping	Running Total
Chris Bender	KT003 Arduino Uno starter Kit	No	$24.41	$24.41
Chris Bender	Resistor Kit	No	$7.99	$32.40
Chris Bender	Capacitor Assortment Kit	No	$6.49	$38.89
Jeff Schreiber	TMP007 IR Thermopile Sensor	Yes	$12.50	$51.39
Jeff Schreiber	MLX90614 IR Sensor	Yes	$22.85	$74.24
Jeff Schreiber	Arduino Pro MINI MCU	Yes	$5.27	$79.51
Jeff Schreiber	433MHz Transmitter	Yes	$0.74	$80.25
Jeff Schreiber	433 MHz Receiver	Yes	$0.71	$80.96
Jeff Schreiber	10K ohm potentiometer	Yes	$1.18	$82.14
Jeff Schreiber	LCD Display	Yes	$19.50	$101.64
Jeff Schreiber	DHT11 multi-function sensor	Yes	$12.89	$114.53
Jeff Schreiber	Battery Holder	Yes	$18.27	$132.80
Jeff Schreiber	Slide Switch	Yes	$1.90	$134.70

Jeff Schreiber	Arduino Pro MINI 328 - 5V/16MHz	Yes	$19.50	$154.20
Jeff Schreiber	Protoboard SMT	No	$5.28	$159.48
Jeff Schreiber	Lithium Battery 3V	No	$23.46	$182.94
Chris Bender	Protoboard PCB	No	$22.01	$204.95
Chris Bender	Audrino Mini Port	No	$6.30	$211.25
Chris Bender	Universal Cables	No	$6.72	$217.97
Chris Bender	nRF24L01+ Transmitters	No	$14.45	$232.42
Chris Bender	ABS Spool	No	$35.94	$268.36
Chris Bender	nRF24L01+ Transmitters	No	$17.46	$285.82

Total Money Spent as of 4/4/2016: $285.82

Currently $215 of the budget is still available for the completion of the beta prototype. This allows the team to make additional modifications as needed. Most of the Beta prototype components have been purchased, so additional expenses will only be utilized if parts become damaged or design iterations are needed. Additional funds have been set aside for the purchase of the elastic band for the beta unit. In total, the beta prototype will consist of a plastic casing to house the sensor, an attached band, and the water bottle display. Even with these design features, the HydroBand project will still be under budget at the completion of this project.

Appendix E: Development Plan

1. *REQUIREMENTS*

Design and Development Planning

- The team must develop a design following the design process
- Design is limited to a budget of $500
- The project must all deadlines set by the instructor

2. *DISCUSSION AND POINTS TO CONSIDER*

Design and development planning is done to ensure the design process is correctly completed. The plans must be consistent with the customer and engineering requirements. The following elements are addressed in the design and development planning:

- The goals and objectives of the design
- Identification of the major tasks, deliverables for each task, and individual responsibilities for completing each task
- Scheduling of major tasks to meet overall time constraints
- Progress meetings with advisors to help improve on the design
- Design binder maintained with all design documentation
- Weekly meetings held to work as a team

Planning increases the success of the design and development process by clearly communicating procedures, and goals to members of the team. Design activities should be specified at the level of detail necessary for carrying out the design process. The extent of design and development planning is dependent on the size of the development team and complexity of the product being developed. Since our team only has five members it will limit the amount that will be able to be completed.

ORGANIZATIONAL RESPONSIBILITIES

To ensure that the design process is properly documented a binder will be consistently updated with all design documentation. This contains information on all aspects of the design including concept drawings and part data sheets. Additionally weekly meetings will be held to ensure that all members of the team are on the same page and meeting minutes will be taken to keep track of what was accomplished. Finally progress meetings will be held with advisors to help mentor the team to successfully complete the design.

TASK BREAKDOWN

A Gantt chart is used to help plan out all of the major tasks that need to be accomplished as well as provide an estimate of the amount of time that will be required for each task. As development proceeds, the plan will evolve to incorporate more and better information. The Gantt chart is separated into the three different phases of the design process as well as a section for ongoing work. For each section all of the major tasks are listed with date they should be started. Below is a segment of the Gantt chart that shows how all of the tasks are broken down. To see the current progress of the tasks refer to the most updated copy of the chart.

Phase	Task Name	Start	Finish
Ongoing Modifications	Deadlines		
	Team Meetings		
	Customer Meetings		
	Supervision/Feedback		
	Gantt Chart Updates		
	Consult Outside Resources		
Phase 1: Discovery	Customer Needs	9/1/2015	9/9/2015
	Investigate Problem	9/9/2015	9/16/2015
	Design Research	9/16/2015	10/30/2015
	Strategies and Solutions	9/23/2015	10/30/2015
Phase II: Design Engineering	Development Plan	10/30/2015	11/6/2015
	Select Strategy	10/30/2015	11/6/2015
	Conceptual Designs	10/30/2015	11/27/2015
	Research on Electrical Components	12/4/2015	12/18/2015
	Input for IR Sensor Construction	12/4/2015	12/18/2015
	Order Parts for Prototype	12/25/2015	1/22/2016
Phase III: Building and Testing	Fabricate IR Sensor and Arduino Uno	1/1/2016	1/29/2016
	Sensor Output to screen	1/29/2016	
	Final Design (tie sensor & band together)		
	Alpha Prototype		
	Debugging		
	Testing Phase 1		
	Design Alterations		
	Mechanical Drawings & Modeling		
	Beta Prototype		
	Testing Phase 2		

Appendix F: Testing Data

Table 1F: Data of the initial test on the general temperature functionality of the alpha prototype.

Initial Test					
Product:	Alpha unit				
Date:	Mar 15, 2016				
Description:	Test of palm temperature reading from MLX90614 sensor on the alpha unit versus the IR gun.				
Data:					
Chris's Palm			Jeff's Palm		
IR Gun	MLX90614		IR Gun	MLX90614	
Temperature (\`F)	Temperature (\`F)	Standard Dev.	Temperature (\`F)	Temperature (\`F)	Standard Dev.
96.4	96.39	0.005	89.6	92.71	1.555
96.8	96.24	0.28	89.6	92.57	1.485
96.6	96.53	0.035	90.5	92.97	1.235
97.5	96.78	0.36	90.6	92.68	1.04
97.3	96.93	0.185	90.8	92.57	0.885
96.9	96.93	0.015	91	92.57	0.785
97.1	97.18	0.04	91	92.82	0.91
97.7	97.25	0.225	91.2	92.5	0.65
97.5	97.25	0.125	91	92.17	0.585
97.7	97.25	0.225	91.2	92.82	0.81
97.8	97.36	0.22	91.8	92.5	0.35
94.6	96.93	1.165	92.1	92.17	0.035
95.0	97.11	1.055	91.7	92.89	0.595
94.2	97.25	1.525	92.3	93.51	0.605
95.3	97.54	1.12	92.6	92.43	0.085
95.9	97.32	0.71	92.6	92.79	0.095
96.2	97.65	0.725	92.8	93.36	0.28
96.4	97.39	0.495	92.8	93.33	0.265
95.9	97.68	0.89	93	93.58	0.29
96.4	97.79	0.695	93.2	93.79	0.295
96.8	97.75	0.475	93	93.76	0.38
95.5	97.39	0.945	92.6	93.61	0.505
95.3	97.36	1.03	91.7	92.71	0.505
95.9	97.5	0.8	92.1	94.05	0.975
95.3	97.54	1.12	92.8	93.76	0.48
95.7	97.75	1.025	93	93.79	0.395
95.9	97.47	0.785	93.3	94.84	0.77
96.6	97.47	0.435	93.3	93.72	0.21
96.4	97.65	0.625	93.2	94.44	0.62
96.4	97.75	0.675	93.5	94.98	0.74

96.9	97.54	0.32	93.5	93.25	0.125
			93.3	94.01	0.355
			93.7	93.87	0.085

Table 2F: HydroBand Test Plan based on Engineering Requirements.

Test	**Corresponding Eng. Rqmts.**	**Description of Test:**
Temperature Measurement	1.1, 1.2, 3.2, 3.5, 4.1, 4.3, 4.6	Test range of core temperature compared to IR gun. Does the temperature read up to the hundredths place?
		Test range of core temperature compared to IR gun. Is the temperature reading within 1% of the comparable temperature?
		Wear the temperature sensor for a period of 10+ minutes. Using a stopwatch, record the entire test session. Was the temperature data sent/read every 2 minutes?
		Allow the temperature sensor to sit/perform in a hot room/cold room environment. Did the sensor work correctly without any issues?
		Find a comparable object temperature at 14 degrees F. Test the HydroBand temperature sensor on the object. Did the product successfully read 14 degrees F? Repeat with an object at 122 degrees F and test the temperature sensor. Did the product successfully read 122 degrees F?
Water bottle display	1.3, 4.5	Using a stopwatch, time how long it takes for the LCD to display the water consumption after a temperature reading. Is it within 2 seconds?
Battery life	1.6, 2.4, 3.1, 3.6, 4.0, 4.2, 4.4	The test subject (athlete) will use the HydroBand generally throughout an entire length of practice. Does the device work without issue for the duration of practice?
		The test group will attempt to power the device with power of less than 5 volts. Verify that the device does not power on.
		Allow the device to sit, idle, but powered on, for at least 6 hours of the day. Check the device regularly. Verify that the battery stayed charged and powered on for a full 6 hours. (3.6) Now perform regular use of the device for 6 hours, and verify that the battery stayed charged and the device stayed powered on for 6 hours.
		Turn the device on and start a stopwatch. Do the devices connect within 5 seconds?
Cosmetic specifications	3.7, 3.8, 3.9, 3.11	Weigh the device. Is it under 4 ounces?
		Measure the band. Is the band in between the range of 24.17 - 68.11 inches?
		Does the device meet the size specifications?
Range	4.7	Measure a distance of 100 meters from the chest band to the water bottle portion. Are the devices able to communicate at this distance?