ETM
ENGINEERING & TECHNOLOGY MANAGEMENT

Development Log

Adaptive Mobility for the Visually Impaired

Exploring what the future of social mobility could look like for the visually impaired community

ETM 547: New Product Development
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Mission Statement:

“Our mission is to leverage existing proximity sensor technology to develop a product to assist visually impaired community to improve their daily mobility, independence, and quality of life.”

Opportunity Identification and Customer Needs:

The development process followed a sequence of steps to conceive, design and commercialized the product. The general development process shown in Figure 1 was the main structure leader to insurance a well-developed product.

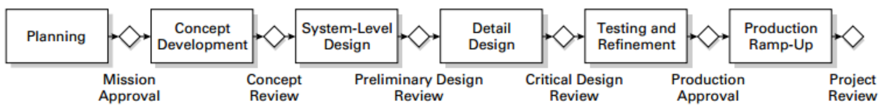

Figure 1 Product Development Process

Our project is primarily a technology-push product, in which we leveraged the advantages of an existence technology called proximity sensor. The team focused on utilizing and matching the appropriate application of the technology with the market needs. Since the technology is proven, the possibility of risks substantially reduced.

The first phase, called “phase zero,” is to identify the opportunity by exploring the market necessities. Our team conducted various types of research to understand the market needs. With personal motives, the team showed the interests to assist the visually impaired community for the freedom and independence with their physical activities.

Prevent Blindness organization, estimated the annual treatment and assisting services for blind people in only the United States is $139 billion. Forecasting and high inclining slope to be $717 Billion by 2050, as shown in Figure 2 Additionally, World Health Organization has estimated “the global number of people of all ages visually impaired to be 285 million, of whom 39 million are blind” [1].

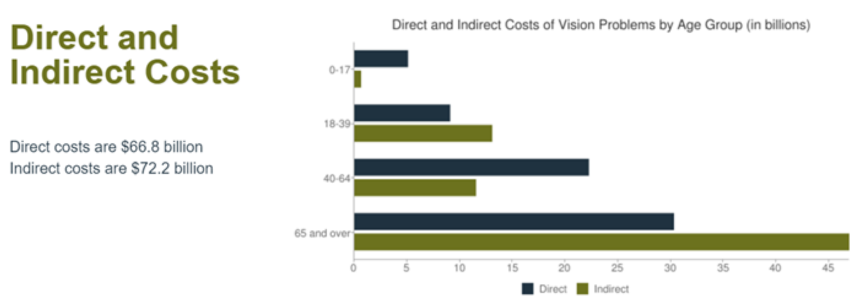

Figure 2 Annual Forecasted budget spent for Visually Impaired Community

The global burden had left nearly 25% of the world population to participate in various activities. Although there are instructors for the blind and visually impaired to assist them and guide them through different activities, there is non-existing technology that can provide them with additional support and assistance. The Projects proposition to improve the daily mobility, independence, and quality of life by helping blind and visually impaired individuals obtaining an opportunity to practice swimming independently. By using the proximity sensor, the device will enable the user to swim at ease without any of their physical disability hampering their activity. The mission could achieve through the feedback that device provide. Alerting with any obstacles, objects or person that might cause an injury by colliding into them. The projects aim to ultimately increase the users confident to swim freely without the need of instructor assistance.

The team is comprised of students from different fields of engineering and science to make the goal achievable. The first assignment is to have a deeper understanding of the common and basic problems faced by the visually impaired individuals and what they expect from our outcome to feel independent in water. The gathered information conducted by the interviews and surveys, through the blind or visually impaired athletes or coaches; survey questions shown in Appendix i.

Oregon Commission for the Blind, Independent Living Resources and Northwest Association for Blind Athletes supported us in our mission by encouraging interaction among the blind individuals. The information gathered from these interviews and surveys serves as essential tools to be used in the design and generating concepts that will address some of the issues faced by the visually impaired or blind while they swim. Table 1, shows few of the customer statements that interpreted into needs.

Customer Statement	Interpreted Need
“ I would like to improve my swimming”	Daily performance improvement data log
“ I can’t swim in deep water”	Notifying the User with pool depth
“ I need steady feedback that I am in the correct straight line while swimming”	Positive reinforcement when swimming in a straight line
“ I need to be aware if someone jumped into my lane quietly”	User feedbacks with sudden changes
“If there is a loud splashing in the pool, it’s hard to know if the person is in my lane or not”	The range of the feedback is controlled
“ I am mostly concern to hit my head by the wall”	Notifying the user before reaching the end of the pool
“ Vibration is my preferred feedback, since pool is usually loud and hard to hear the audio feedback”	Feedbacks should be communicated despite external environment disturbance
“I Prefer the devise to last for long life-time with affordable range”	Reliable and functions well
“I want the vibration feedback to vibrate close to my head on the left when I shift to the left, and vise-versa”	Assist to swim in straight line
“ It is a hustle for me to ask and depend on the safeguard to setup the pool lanes”	Practice swimming without the dependency of surrounding assistance
“ I don’t want anything to interfere with my ears”	Object not covering ears
“It will be a hustle to change the batteries time to time”	Convenient in device maintenance

Table 1 Customer Needs Feedbacks

Creating a high-quality information channel from the customers helped the project to fully identify and understand the most important necessities that required for our product. A priority needs were articulated ranking order from high relevant to low, as shown in Table 2

Need #	Needs	Imp
1	Tracking daily performance	1
2	Pace performance status	1
3	End of pool wall approach alert	2
4	Knowing the pool depth (can stand / deep to stand)	2
5	Positive reinforcement when swimming in a straight line	3
6	Alert when someone is in the pool, specifically in the same lane	3
7	Being able to detect between people in same lane or different lane	2
8	Vibration Feedback to alert user	3
9	Sound Feedback to alert user	2
10	Suitable size	2
11	Worn on the head	3
12	Reliable and functions well	2
13	High quality Product	2
14	Long lasting battery	2
15	Affordable Price	2
16	Vibratory and Direction oriented	2
17	Help/Coach independent	1
18	No hearing interference	3
19	Rechargeable batteries	2
20	Tested in Various Conditions	2
21	Scenario based vibratory volumes	2

Table 2 Priority Ranking Needs

The set of specifications identified by the team integrated into measurable details. The specifications are the reflection of the user requirements in a technical and economic metrics. The sets target specifications, shown in Table 3, will serve as the core factors in the concept drafting and selections.

#	Needs \ Metric	Smart Phone Application	Speed detector	Distance Measurements	Direction guidance/ Assistance	Sensor detection range	Alert Feedback	Small device size	Swimming Cap Location	Reliability	Rechargeable Battery	Affordable price ($25-$50)	Independency capability	Auto Environment changes compatibility
1	Tracking daily performance	x												
2	Pace performance status		x											
3	End of pool wall approach alert			x										
4	Knowing the pool depth (can stand / deep to stand)			x										
5	Positive reinforcement when swimming in a straight line				x									
6	Alert when someone is in the pool, specifically in the same lane			x										
7	Being able to detect between people in same lane or different lane					x								
8	Vibration Feedback to alert user						x							
9	Sound Feedback to alert user						x							
10	Suitable size							x						
11	Worn on the head								x					
12	Reliable and functions well									x				
13	High quality Product									x				
14	Long lasting battery									x				
15	Affordable Price											x		
16	Vibratory and Direction oriented				x									
17	Help/Coach independent												x	
18	No hearing interference								x					
19	Rechargeable batteries										x			
20	Tested in Various Conditions													x
21	Scenario based vibratory volumes													x

Table 3 Target Metric Specifications

Achieving a commercial success and compete in the marketplace, the target specification terms were used as critical factors to compare between other benchmark competitors. A benchmarking chart constructs with the competitor's names versus the list of metrics. To successes in the marketplace, the project tends to cover most of the metrics and exceed the features that the competitors can offer. Table 4, shows the benchmarking Matrix.

				Benchmark		
Metric #	**Need #'s**	**Metric**	**Unit**	**Samsung**	**IPRO 310**	**Project**
1	**1**	Smart Phone Application	dB	X	X	X
2	**2**	Speed detector	ft/sec			X
3	**3,4,6**	Distance Measurements	feet			X
4	**5,16**	Direction guidance/ Assistance	dB		X	X
5	**7**	Auto Sensor detection range	mb/s			X
6	**8,9**	Alert Feedback	ft/sec	X	X	X
7	**10**	Small device size	--	X		X
8	**11,18**	Swimming Cap Location	in^3	X		X
9	**12,13,14**	Reliabilty	in.	X		X
10	**19**	Rechargeable Battery	dB			X
11	**15**	Affordable price ($25-$50)	$$			X
12	**17**	Independency capability	--			X
13	**20,21**	Auto Environment changes compatibility	$$			X

Table 4 Benchmarking Matrix

Concept Generation, selection and Testing

The concept development phase of the NPD (New Product Development) process can almost be quantified as an evolving process versus a one-time definition. Once the underlying concept of a product is establish in terms of core technology, working principles and the form, the features, functionalities and services rendered by the product must still be open to evolutionary changes. Such as was our experience during the concept generation phase. Luckily concept generation is one of the cost-effective item in the development phase. The level of relaxation in modifying the initial concept through user feedback isn't as binding in terms of resources. As such we were fortunate to see our initial concept evolve through class participation and most effectively through ***face-2-face*** survey and concept testing participation from led users (WSSB and Oregon Blind Commission).

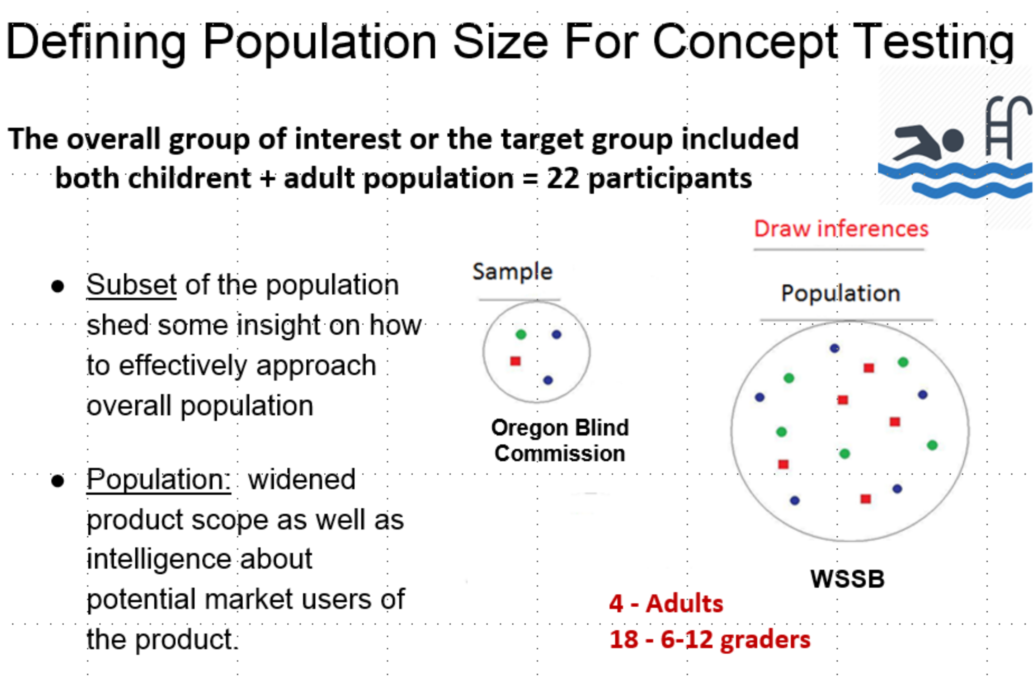

Figure 3 Defining Population Size for Concept Testing

Identifying the need and clarifying the need

The need for Concept Generation 1 came about while one of our team members was engaging in his usual swimming workout routine. The thought of wondering how blind or visually impaired individual swim became a poignant curiosity. As with any bright ideas, they often die when not followed through. Luckily, through the experience enrolling into the NPD course this idea was meant to be explored. Our initial concept was to develop a swimming cap through which auditory feedback can be communicated to the swim via signal, voice, or vibration, called ***Nema***.

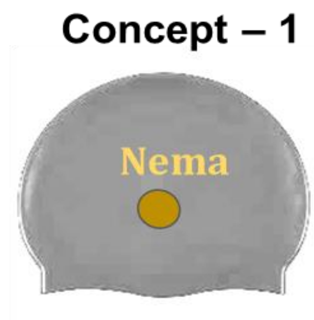

Figure 4 Vibratory Swimming head cap (Directional warning Indicators)

In order to clarify that this need exist and that it warrants a product solution, it was critical to engage with our potential users and or markets. We contacted the Oregon Blind Commission in Portland for assistance. With limited time we were able to establish contact and engage with approximately 3 blind individuals in evaluating their interest in a product of this nature.

To solidify the need and or our problem statement we it was crucial to leveraged ***face-2-face*** interview tool to capture other angles of the need we may have failed to look capture. We developed a series of survey questions to assist us in digging deeper with Group-1 of our survey. Some of those questions entailed:

1. *Are there any recreational and/or physical activities you participate in? If yes, please list activities.*
    - *What other recreational and/or physical activities would you want to participate in, in the future?*
    - *If swimming is not on their list of recreational and/or physical activities, why not?*
2. *Do you like to swim?*
    - *What kind of swimming (structured lanes? Unstructured Ocean or pool? etc)*
    - *If swimming **in lanes** isn't one of your preferred activities, why do you think this is?*
3. *Would you be comfortable using technology to assist you in your physical activities? Please explain.*
    - *If **yes**, what part of your body would you prefer to wear this technology?*
    - *If **yes,** are you currently using any technology to assist with physical activities?*

Our sample of participation were small in number however, they yielded significant feedback and interest in the product-solution. We were startled to learn that the visually impaired and the blind community would actually utilize our initial product concept if it was available on the market. We were also astonished to learn how much the blind community rely on technology to improve their way of life. Most importantly, their feedback also revealed other ways we can expand our original concept idea into various applications. Applications such as running and wearables such as wrist vibratory sensor.

This was a fantastic revelation and gave us a boost in confidence in terms of moving forward with the idea. We took their feedback and shared it with the class. We leverage our class as Expert sample survey participants in addition to our lead users. Through class participation feedback and our sample ***face-2-face*** feedback, a new and secondary concept was birth, the ***Nema Wrist Sensor.***

Concept - 2

Figure 5 Vibratory bracelets for both wrists

Suddenly, our initial product idea was decomposed into or evolved into multiple concepts that could potentially serve dual purposes. *Exciting!* During the class participation, our professor also reveal another level of thinking we could possible take the product. He eluded to the possibility of combining both products into one. Basically, this would mean a 3^{rd} concept birth was in the making. We were focused to explore the second concept but now with a 3^{rd} concept on the horizon were even more ecstatic that these concepts could serve multiple purposes.

Concept – 3

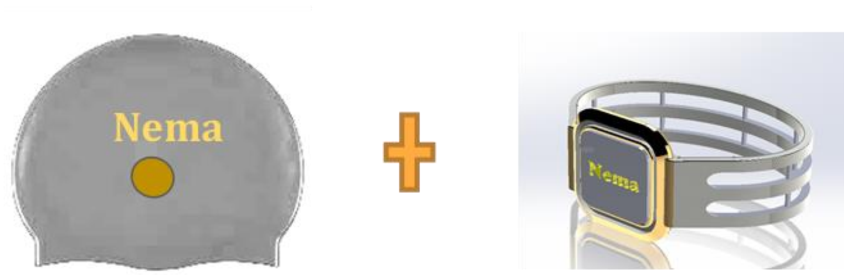

Figure 6 Swimming cap and bracelet

The team reconvene at the PSU library and began brainstorming features and functionalities we could embed into all three concepts to enhance the product eco-system. This process of establishing product specifications is what I call 'bringing life and form" into the product concept. We also conceptualize the various levels of applications and usages. Additionally, we also conduct an external research for competitive product that may have already be on the market. We found several comparable products such the Samsung xxx and the IPRO 310 however, none were exact match to our product initial concept and functionality.

Selected Final Product Concept(s)

Once we established these concepts and the product specifications it was time to finalize our concept and begin concept testing phase with a larger sample size of ***face-2-face*** participation with another set of lead users (WSSB – Washington State School for the Blind). Group-1 in particular were much younger in terms of age than the previous sample, Group-1. They were also more engaging in terms of physical activities such as swimming, running and other types of aerobic workout. Lead user participation survey played significant role in our deliberation of what the final concept(s) should be. It was essential to allow the "voice of the customer" play a role in our decision making since they serve as the beneficiary of the product. The process of selecting the final product concept(s) were achieved partly due to Group-1, Group-2 and our Expert class feedback.

Key Features	Concept 1	Concept 2	Concept 3
WiFi		√	√
BT		√	√
NFC			
Proximity	√	√	√
Accelerometer			
CMOS	√	√	√
Tone		√	√
Vibratory	√	√	√
Voice	√		
Elastic/rubber	√	√	√
Cloth		√	√
Metallic		√	

Table 5 Concept Testing -Final Concept

The process of concept generation can be fallacious if it's not done right. From an empirical perspective, formulation of the concept must be influenced by understanding of the customer needs with several key inputs considered. Our team implemented some aspects of the five-step method in a sort of topsy-turvy manner. The five-step method details a stepwise approach beginning with clarifying the problem. As we began to conduct interviews with live persons suitable for our product various angles of the problem we were trying to solve were illuminated from the feedback we received. Upon returning to the drawing board it was germane to decompose the problem we were attempting to solve into several sub problems. Some of the sub problem we had to take into consideration included user preferences w.r.t features and product interaction due to their physical limitations. While we were attempting to improve the visually impaired and the blind way of life it was essential to consider that our product doesn't become a problem in itself.

In considering the degree in which to satisfy our potential customer's needs, several concepts for our product were considered upon interviewing select lead users. In order to finalize our concept selection in terms meeting our customer needs, we had to explore several alternatives.

Industrial Design:

What is Industrial design? Creation and development of concepts and specifications aimed at optimizing the functions, value, and appearance of products, structures, and systems [3]. Industrial Design as it applies to our system:

- **Small size and weight**
  - Bracelets are lightweight and no more obtrusive than smartwatches or fitness trackers.
  - Swim cap is comparable at first sight to a less obtrusive water polo cap and is extremely lightweight.
- **Performance Features**
  - Waterproof bracelets house tiny vibratory motor
  - Swim cap ear covering feature slim design allowing for simultaneous
    - audition and
    - space for a speaker (tonal alerts)
- **Superior Ergonomics**
  - Bracelets are soft rubber for superior comfort
  - Swim cap is as comfortable as a standard water polo cap
- **Durability**
  - Bracelets are made of rubber that is tear proof, waterproof, and slightly elastic
  - Swim cap is made of durable nylon. It is waterproof, easy to clean, is affixed with convenient ties of the same tough but comfortable material.
- **Material**
  - Bracelets are made of recycled rubber that can be traded in and re-recycled as newer versions are released. Our first release will white and red, and secondary releases' color will be determined by reported demand.
  - Swim cap is made of durable nylon. It is easily stretched and tied to fit a wide range of individuals.
- **Appearance**
  - Bracelets are white and red, suggesting safety and positivity reminiscent of a pool's life preserver or lifeguard color template
  - Swim cap is all white to be both versatile and suggestive of
    - A walking stick that grants ease in accessibility
    - New, clean, bright technology
- **Utility**
  - Bracelets provide safe, simple to use, and effective features that communicate clearly to the user.
    - They vibrate once unilaterally to alert the user when they are too close to an obstruction, allowing the swimmer to veer and correct their course.

        - They vibrate in one quick burst bilaterally to alert an obstruction requiring a full halt, such as a swimmer or object directly ahead.
        - They vibrate in one long slow alert to affirm an impending wall, indicating a pivot to complete the lap.
    - Swim Cap can be utilized to
        - Alert the user with set of tones
            - Unilateral tones will alert the user when they are too close to a wall or obstruction, allowing the swimmer to veer and correct their course.
            - Bilateral quick tones will alert of an obstruction requiring a full halt, such as a swimmer or object directly ahead.
            - One long slow bilateral tone will affirm an impending wall, indicating a pivot to complete the lap.
        - Audition feature can be disabled, according to individual user preference with the click of a button.
        - The swim cap allows the user reasonably unimpeded hearing, comparable to a common water polo cap in either scenario.
- **Ease of Maintenance**
    - The bracelets are nearly maintenance free, with daily battery life lasting 18 hours, charging cords included, and warranties covering manufacturer defects for six months. We estimate the total battery life to be several years, by which time we plan to offer a new version release.
    - The swim cap has equally long life, as all parts will be protectively encased in the waterproof cap. Similar products tend to last 2-5 years, so we predict ours will as well. Occasional washings might be preferred if user maintains long hair, similar to the maintenance of a common swim cap.
- **Moderate Cost**
    - Bracelet pair will 186.64, which is lower than the market average for a single new fitness tracker. Since our initial product has far more limited features than the suite of capacities in a modern fitness tracker, the cost will reflect this.
    - Swim Cap will be$72. We will keep prices moderate to widen the availability of accessibility.
    - The set together will be priced at $258.64, at which is 75% profit.

- **Communication**
    - Bracelets will communicate with the swim cap proximity sensor via Bluetooth, unless research development which will be further qualified here.

Total Expenditures Predicted

- We predict, based on textbook Exhibit 11-2 that our device will be on par with handheld medical equipment, requiring nearly 30% of our total expenditures towards industrial design and requiring around $3,000.

  (Include chart in Appendix)

Industrial Design Process

1. **Investigation of Customer Needs**
   a. Fulfilled by composing and administering questionnaires
   b. Compiling metadata
2. **Conceptualization**
   a. Initial ideas tailored and new concepts introduced.
      i. For example, we knew at this point we needed to include auditory and vibratory functionality, as the visually impaired persons interviewed had notably strong preferences in all studies investigated, and the preferences were nearly equally divided in halves.

3. **Preliminary Refinement**
   a. Instead of just a swim cap or just bracelets, we decided to honor the strong preferences of our divided potential market and offer a system utilizing both in symbiotic harmony.
   b. We leave it up to the user to choose to
      i. Wear the cap, but not the bracelets, utilizing the tonal function without vibratory feedback.
      ii. Wear the cap with the bracelets, utilizing both the tonal function in the cap and the vibratory function in the bracelets.
      iii. Wear the cap with the bracelets utilizing the vibratory function in the bracelets but disabling the tonal function in the cap, allowing for completely uninterrupted regular audition.
   c. Bracelets were deemed the user-preferred method of vibratory feedback, leaving the swim cap's function as
      i. The location of the proximity sensor and
      ii. Location of speakers for tonal signal

4. **Further Refinement and Final Concept Selection**
   a. Here we chose materials, from exterior waterproof recyclables to interior circuitry and connectivity.

5. **Coordination with engineering, manufacturing, and external vendors**
    a. We will have prototypes developed at quality overseas vendors in an attempt to fund more iterations of our product and have something safe, effective, and thoughtfully designed released to market.

There are two types of products, Technology Driven and User-Driven. We consider our product **User-Driven for the following reasons**:

- **Identifying Customer Needs**: We will need to work closely with marketing to identify customer needs. We require focus groups and/or one to one interviews to better identify these needs for continuing improvement.
- **Concept Generation and Selection**: We generated multiple concepts and designs as encouraged by process flows in customer feedback.
- **Concept Testing**: We will create models to be tested with customer by marketing.
- **System-Level Design**: We narrow down the concepts and refine the most promising approaches
- **Detail Design, Testing, and Refinement**: We will finalize the design with marketing, manufacturing, and engineering.

How We Assess the Quality of our Industrial Design:

1. **Quality of the User Interface**
    a. The features of the product will effectively communicate their operation to the user. The manual will be auditory and re-playable at will, though all functions work with a few clicks.
    b. The product is intuitive.
        i. One quick click on the cap turns it on, enabling the proximity sensor and tonal alerts (a tone followed by a higher tone).
        ii. One longer click to the cap turns off the tone (a double tone will sound).
        iii. One shorter click to the cap turns the device off completely (a tone followed by a lower tone).
        iv. The bracelets are powered on and off with a single click (they vibrate bilaterally once when device is activated and twice upon deactivation).
    c. The product is safe, utilizing waterproof exteriors
    d. The potential users and uses of the product have been considered. Without their feedback the design would have been impossible.
        i. The swim cap and bracelets are comfortable
        ii. The power switches are easily located by touch

   iii. The functions are easily understood either by quick trial and error (concise functionality means less margin of error for users), or can be learned in a clear one minute audio tutorial or braille instructions, both provided in box upon purchase.

2. **Emotional Appeal**
   a. The product is attractive and minimally invasive
   b. The product expresses quality
   c. The images that come to mind are designed to inspire feelings of nautical safety (white and red color scheme reminiscent of life preservers and life guards' uniforms)
   d. The product instills pride of ownership with a sleek exterior and superior functionality
   e. The cap is comfortable and durable, the bracelets and stretchy and soft. Both allow freedom of movement without feeling restricted.
3. **Ability to Maintain and Repair the Product**
   a. The maintenance is easy and obvious, with easily found charging locations
   b. There is nothing to dissemble, so no assembly is required.
   c. Total battery life should last years, so no hardware change is necessary. We plan to release a new updated product by then, offering trade-up recycling incentive discounts.
4. **Appropriate Use of Resources**
   a. All our resources will be used to satisfy customer requirements.
   b. The material selection is appropriate, satisfying tough yet comfortable waterproofing needs at a reasonable price
   c. The product is minimalist, but appropriately designed
   d. Environmental and ecological factors were considered. The product will be made from mostly recycled materials that can be upcycled for a discount on new product releases.
5. **Product Differentiation**
   a. To those who have seen the product in advertisements, it will be easy to distinguish without being visually busy or overly conspicuous.

Design for Environment and Manufacture:

What is Design for Environment? Product design philosophy that aims at generating minimal waste during product's cradle-to-grave life cycle during production, marketing, distribution, use, and disposal [4]. Selecting a recyclable material and package is key to prevent further global warming. For more information see Appendix i.

What is Design for Manufacture? Is the method of design for ease of manufacturing of the assortment of parts that will form the product after assembly .Design for Manufacture (DFM) is primarily concerned with reducing overall part production cost and minimizing the complexity of manufacturing operations. [5] DFM help facilitate the informed decision making during the product design and sourcing process, as shown in Appendix i. DFM typically happens concurrently with the design, rather than as a separate step. As design engineers develop the product all the way from the functional specification through brainstorm, sketching and Industrial Design, they are constantly applying DFM principles appropriate for the project. The design engineering process is rarely straightforward, but by applying DFM principles throughout the design process, design engineers can develop a product in a way that balances cost, manufacturing considerations, function, features and product usability.

We've done a number of small prototype runs that have allowed us to verify the design and the tooling, as well as test a number of different sample materials from our supplier. The next step is a pre-production run where we will produce a significant number of parts in a manufacturing environment under manufacturing control. This is a critical move towards successfully launching the baskets. Quick determination of the relative contribution of variable costs, fixed operating costs, and capital depreciation to the total product costs allows cost-reduction efforts to be focused on those cost components that are likely to be most significant. As shown in Tables 5, 6 and 7 below, is a pre-production cost estimate the first year at lower volume for the wearable head cap and bracelet.

Wearable Head Cap Cost Estimate		
Variable Cost		
Material	0.15 lb Regular Grade Silicone at $50.00/lb	$ 7.50
Processing (Molding)	500 units/hr at $85	$ 5.88
Fixed Cost		
Tooling for Molding	$1,250/tool 300K units/tool (lifetime)	$ 0.004
Machine Tools and Fixture	One-time NRE	$ 10.00
Total Direct Cost		**$ 23.39**
Overhead charges		$ 15.20
Total Unit Cost		**$ 38.59**

Wearable Bracelet Cost Estimate		
Variable Cost		
Material	0.10 lb Regular Grade Silicone at $50.00/lb	$ 5.00
Processing (Molding)	1000 units/hr at $65	$ 15.38
Fixed Cost		
Tooling for Molding (Main and wrist straps)	$2350/tool 300K units/tool (lifetime)	$ 0.008
Machine Tools and Fixture	One-time NRE	$ 20.00
Total Direct Cost		**$ 40.39**
Overhead charges		$ 26.26
Total Unit Cost		**$ 66.65**

Table 6 Wearable Bracelet and swimming cap Pre-Production Cost Estimate

Proximity Sensor Cost Estimate		
Variable Cost		
Material	BUZZER PIEZO, 5Vp-p,80dB, 4 kHZ,5mA, PIN CONTACTS LED, RED, 643NM, T-1 3/4 75MCD, 2.2V, V/A25 POT, 3/8"SQ.CERMET, 1/2W, 10K OHM SINGLE-TURN, THRU HOLE, TOP ADJ IC, LM358N, DIP-8, OP-AMP DUAL 0-70DEG C RES, CF, 100 OHM, 1/2 WATT, 5% BREADBOARD, SOLDERABLE PC, 400 PTS,1.9x3x1/16", .042"HOLE/.1"C RES, CF, 220 OHM, 1/2 WATT, 5% RES, CF, 10K OHM, 1/4 WATT, 5% LED, IRFRD EMITTER, 940nm, T13/4 1.6Vf @ 20mAIf, T1-3/4, 90mW PHOTOTRANSISTOR, INFRD,WTR CLR T1-3/4,940nm, Vr=30,useW/106526 LED, INFRD, WTR CLR, EMIT, T1-3/4 940nm, 1.2Vf@20mA, 8mW@20mA	$ 6.09
Processing PCB Fabrication	200 units/hr at $105	$ 1.90
Processing PCBA Layout	200 units/hr at $30	$ 6.67
Fixed Cost		
PCBA Assembly Fixture	$500/tool 300K units/tool (lifetime)	$ 0.002
Total Direct Cost		**$ 14.66**
Overhead charges		$ 9.53
Total Unit Cost		**$ 24.19**

Table 7 Proximity Sensor Pre Production Cost Estimate

The bill of material (BOM) is a comprehensive list of parts, items, assemblies and sub-assemblies required to get a product ready to sell. The BOM cost estimation is fundamental to DFM, because it help keeps the materials within the finished good (FG) BOM organized. A bill of materials explains what to buy, how to buy and where to buy, and includes instructions for how to assemble the product. The BOM guides positive results from business activities like parts sourcing, outsourcing and manufacturing, so it is important to create a BOM that is well organized, as shown in Table 8 below.

Finish Good (FG) Bill of Material (BOM)									
Component	**Manufacture PNs**	**Quantity**	**Purchased Materials**	**Processing (Machine + Labor)**	**Assembly (Labor)**	**Total Unit Variable Cost**	**Tooling and other NRE Cost**	**Total Unit Fixed Cost**	**Total Cost**
Wearable Head Cap	30000					$ -			$ -
Silicone Mold Injection Head Cap Tool	50000	1		$ 50.00		$ -	$ 1,250.00	$ 10.00	$ 10.00
Silicone Mold Head Cap	21000	1	$ 17.53		$ 2.00	$ 17.53			$ 17.53
Wearable Bracelet	30001					$ -			$ -
Silicone Mold Injection Bracelet Tool	50001	1		$ 50.00		$ -	$ 1,550.00	$ 10.00	$ 10.00
Silicone Bracelet main sensor Housing	21001	1	$ 7.50		$ 0.75	$ 7.50			$ 7.50
Silicone Mold Injection Wrist Band Tool	50002	1		$ 50.00		$ -	$ 800.00	$ 10.00	$ 10.00
Silicone Adjustable Wrist Band	21002	2	$ 2.00		$ 0.75	$ 4.00			$ 4.00
SS Fasteners	10000	4	$ 0.10			$ 0.40			$ 0.40
Proximity Sensor	30002					$ -			$ -
BUZZER PIEZO, 5Vp-p,80dB, 4 kHZ,5mA, PIN CONTACTS	2098523	2	$ 0.50			$ 1.00			$ 1.00
LED, RED, 643NM, T-1 3/4	333973	10	$ 0.12			$ 1.20			$ 1.20
75MCD, 2.2V, V/A25									$ -
POT, 3/8"SQ.CERMET, 1/2W, 10K OHM SINGLE-TURN, THRU HOLE, TOP ADJ	43001	3	$ 1.25			$ 3.75			$ 3.75
IC, LM358N, DIP-8, OP-AMP DUAL 0-70DEG C	23966	3	$ 0.39			$ 1.17			$ 1.17
RES, CF, 100 OHM, 1/2 WATT, 5%	661263	10	$ 0.10			$ 0.99			$ 0.99
BREADBOARD, SOLDERABLE PC, 400 PTS,1.9x3x1/16", .042"HOLE/.1"C	2125051	2	$ 2.50			$ 5.00			$ 5.00
RES, CF, 220 OHM, 1/2 WATT, 5%	661343	10	$ 0.10			$ 0.99			$ 0.99
RES, CF, 10K OHM, 1/4 WATT, 5%	691104	10	$ 0.10			$ 0.99			$ 0.99
LED, IRFRD EMITTER, 940nm, T13/4 1.6Vf @ 20mAIf, T1-3/4, 90mW	2162548	4	$ 0.49			$ 1.96			$ 1.96
PHOTOTRANSISTOR, INFRD,WTR CLR T1-3/4,940nm, Vr=30,useW/106526	2129385	3	$ 0.35			$ 1.05			$ 1.05
LED, INFRD, WTR CLR, EMIT, T1-3/4 940nm, 1.2Vf@20mA, 8mW@20mA	106526	10	$ 0.19			$ 1.90			$ 1.90
Total Direct Cost			$ 33.22	$ 150.00	$ 3.50	$ 49.43	$ 3,600.00	$ 30.00	$ 79.43
Overhead charges					$ 5.00			$ 45.00	$ 50.00
Total Cost									$ 129.43

Table 8 Pre Production Finish Good, Bill of Material Cost Estimation

The main functions of the BOM is to ensure that the product is built right, it is best to include specific pieces of product data in the BOM record. Creating a bill of materials is not only a necessary step in the product development process, it is also what makes your product design a reality. Therefore determining the contribution of variable costs, fixed operating costs, and capital depreciation to the total product costs allows cost-reduction efforts to be focused on these cost components that are likely to be most significant. As shown in Table 9, 10 and 11 below, is a post-production cost estimate, year two and beyond at higher volume for the wearable head cap and bracelet.

Wearable Bracelet Cost Estimate		
Variable Cost		
Material	0.10 lb Regular Grade Silicone at $50.00/lb	$ 5.00
Processing (Molding)	5000 units/hr at $1500	$ 3.33
Fixed Cost		
Tooling for Molding (Main and wrist straps)	$2350/tool 300K units/tool (lifetime)	$ 0.008
Machine Tools and Fixture	One-time NRE	$ 20.00
Total Direct Cost		**$ 8.34**
Overhead charges		$ 5.42
Total Unit Cost		**$ 13.76**

Wearable Head Cap Cost Estimate		
Variable Cost		
Material	0.15 lb Regular Grade Silicone at $50.00/lb	$ 3.00
Processing (Molding)	2500 units/hr at $850	$ 2.94
Fixed Cost		
Tooling for Molding	$1,250/tool 300K units/tool (lifetime)	$ 0.004
Machine Tools and Fixture	One-time NRE	$ 10.00
Total Direct Cost		**$ 5.95**
Overhead charges		$ 3.86
Total Unit Cost		**$ 9.81**

Processing PCB Fabrication	2500units/hr at $950	$ 2.63

Table 9 Proximity Sensor Pre Production Cost Estimate

PCBA Assembly Fixture	$500/tool 300K units/tool (lifetime)	$ 0.002
Total Direct Cost		**$ 5.80**
Overhead charges		$ 3.77
Total Unit Cost		**$ 9.57**

Table 10 Proximity Sensor Post Production Cost Estimate

All cost-reduction was driven through simplifying the designs, minimizing components through modularity and volume. As shown in Table 12 below, is the post production FG BOM cost.

Finish Good (FG) Bill of Material (BOM)									
Component	Manufacture PNs	Quantity	Purchased Materials	Processing (Machine + Labor)	Assembly (Labor)	Total Unit Variable Cost	Tooling and other NRE Cost	Total Unit Fixed Cost	Total Cost
Wearable Head Cap	30000					$ -			$ -
Silicone Mold Injection Head Cap Tool	50000	1		$ 50.00		$ -	$ 1,250.00	$ 10.00	$ 10.00
Silicone Mold Head Cap	21000	1	$ 2.00		$ 0.15	$ 2.00			$ 2.00
Wearable Bracelet	30001					$ -			$ -
Silicone Mold Injection Bracelet Tool	50001	1		$ 50.00		$ -	$ 1,550.00	$ 10.00	$ 10.00
Silicone Bracelet main sensor Housing	21001	1	$ 1.50		$ 0.17	$ 1.50			$ 1.50
Silicone Mold Injection Wrist Band Tool	50002	1		$ 50.00		$ -	$ 800.00	$ 10.00	$ 10.00
Silicone Adjustable Wrist Band	21002	2	$ 0.50		$ 0.10	$ 1.00			$ 1.00
SS Fasteners	10000	4	$ 0.10			$ 0.40			$ 0.40
Proximity Sensor	30002					$ -			$ -
BUZZER PIEZO, 5Vp-p,80dB, 4 kHZ,5mA, PIN CONTACTS	2098523	2	$ 0.01			$ 0.02			$ 0.02
LED, RED, 643NM, T-1 3/4	333973	10	$ 0.05			$ 0.50			$ 0.50
75MCD, 2.2V, V/A25									$ -
POT, 3/8"SQ.CERMET, 1/2W, 10K OHM SINGLE-TURN, THRU HOLE, TOP ADJ	43001	3	$ 0.05			$ 0.15			$ 0.15
IC, LM358N, DIP-8, OP-AMP DUAL 0-70DEG C	23966	3	$ 0.05			$ 0.15			$ 0.15
RES, CF, 100 OHM, 1/2 WATT, 5%	661263	10	$ 0.05			$ 0.50			$ 0.50
BREADBOARD, SOLDERABLE PC, 400 PTS,1.9x3x1/16", .042"HOLE/.1"C	2125051	2	$ 0.06			$ 0.12			$ 0.12
RES, CF, 220 OHM, 1/2 WATT, 5%	661343	10	$ 0.06			$ 0.60			$ 0.60
RES, CF, 10K OHM, 1/4 WATT, 5%	691104	10	$ 0.08			$ 0.75			$ 0.75
LED, IRFRD EMITTER, 940nm, T13/4 1.6Vf @ 20mAIf, T1-3/4, 90mW	2162548	4	$ 0.09			$ 0.34			$ 0.34
PHOTOTRANSISTOR, INFRD,WTR CLR T1-3/4,940nm, Vr=30,useW/106526	2129385	3	$ 0.16			$ 0.48			$ 0.48
LED, INFRD, WTR CLR, EMIT, T1-3/4 940nm, 1.2Vf@20mA, 8mW@20mA	106526	10	$ 0.08			$ 0.80			$ 0.80
Total Direct Cost			$ 4.83	$ 150.00	$ 0.42	$ 9.31	$ 3,600.00	$ 30.00	$ 39.31
Overhead charges					$ 1.50				$ 1.50
Total Cost									$ 40.81

Table 11 Post Production Finish Good, Bill of Material Cost Estimation

Comparing the pre and post production costs, there was a 31% overall cost savings. The key learning to this cost saving was mainly simplicity and volume. Optimizing cost reduction gives the company confidence in meeting their 60% margins and enables a lot headroom for research and development.

The product development expenses and period has been identified through the analytical table and graphs shown in the Appendix

Intellectual Property (IP) and Conflict of Interest

The criticality of IP when developing new product warrants the need to adequately define IP and an area of IP that could impact our product. By definition, ***intellectual property*** refers to the legal protectable ideas, concepts, names, designs, and processes associated with a new product. IP consist of four main areas including Patent, Trademark, Trade Secret and Copyright. As such we will focus on the Patent and the legal mechanisms necessary to protect the rights of IP owners and how corporate guidelines could influence as inventors of this new product concept from an Intel perspective.

Conflict of Interest

Every year all Intel employees must enrolled and complete the code of conduct training. Part of the training requires Handling of Conflict of Interest. Intel expects all of its employees to act in the best interests of Intel and avoid conflicts of interest any activity that is or has the appearance of a conflict of interest with Intel is frown upon. Here are a few of the guidelines we research in preparation for this product concept launch in order to stay clear of legal ramifications.

- Employees must not use confidential company information, company assets (except as permitted under Intel's Electronic Communications Guideline), or our role or position at Intel for personal gain.
- Employees must avoid situations where our personal, outside business, or family interests could impair our ability to make sound business decisions in the best interest of Intel.
- Conducting any non-company business that interferes with the proper performance of our roles, such as conducting non-company business during working hours; utilizing confidential information or processes gained as a company employee; or using company property or equipment for non-company uses (exceeding reasonable personal use) Using confidential information or processes gained as a company employee for personal gain or to Intel's detriment

Intellectual Property

Intellectual Property Intellectual property rights are crucial to protecting the investments that companies and individuals make in developing new products and ideas. Employees may not copy, reproduce, or transmit protected material, such as writing, artwork, music, video, photographs, movie clips and software unless we have authorization or license.
Employees must use the confidential information of Intel or others only for business purposes and disclose it only to those who are authorized and have a need to know.

Understanding these strict guidelines of IP and Conflict of Interest propelled us to ensure that we don't walk the fine line between violation of IP and Conflict of Interest. If we and when we choose to productize these concepts, we intend to invest our own time outside of normal working hours and utilized resources purchase with our own funds so as to avoid the appearance of IP and Conflict of Interest violation

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Appendix

	first		last	base burn rate
Development	1		3	-10
Testing	1		4	-10
Tooling and Ramp-Up Costs	4		5	-4
Market Introduction	4		5	-5
Ongoing Marketing Costs	5		12	-5
Unit Sales	5		24	100
Unit Price	5		24	0.200
Unit Production Cost	5		24	0.130
Discount Rate (per time period)		2.50%		
**** values are multiple of $1000***				

Table 12 Budget

Period	1	2	3	4	5	6	7	8	9	10	11	12
Development	-10	-10	-10	0	0	0	0	0	0	0	0	0
Testing	-10	-10	-10	-10	0	0	0	0	0	0	0	0
Tooling and Ramp-Up Costs	0	0	0	-3.6	-3.6	0	0	0	0	0	0	0
Market Introduction	0	0	0	-5	-5	0	0	0	0	0	0	0
Ongoing Marketing Costs	0	0	0	0	-5	-5	-5	-5	-5	-5	-5	-5
Production Cost	0	0	0	0	13	13	13	13	13	13	13	13
Product Revenues (wholesale)	0	0	0	0	20	20	20	20	20	20	20	20
Unit Sales	0	0	0	0	100	100	100	100	100	100	100	100
Unit Price	0	0	0	0	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Unit Production Cost	0	0	0	0	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Period Cash Flow	-20	-20	-20	-19	19	28	28	28	28	28	28	28
PV Time Period 0	-20	-19	-19	-17	17	24	24	23	22	22	21	21
Cumul. Disc. Cash Flow	-20	-39	-57	-74	-57	-33	-9	14	36	58	79	100

Table 13 Cash Flow

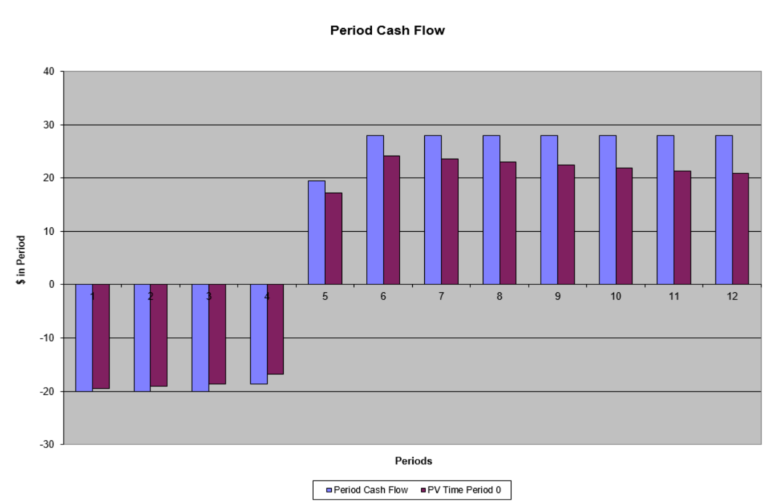

Table 14 Period Cash Flow