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EE322
HW5 Due 3/18/14

# Section 1

[Re-iterated from previous report]

The group continued the use of Jeff's idea of a "Biometric Life Shirt" (BLS) for their design project. The goal for the group is to design a cheap, effective, and desirable shirt which is able to interface with the user to measure their heart rate, body temperature, acceleration and other key health measurements to give the user a better understanding of their own body and how the work they're doing affects them. The shirt needs to be cheap enough that anyone can afford it, easy enough for anyone to use, and discreet enough that people will actually wear it.

[What each person did - paragraph form once done]:

- Bluetooth technology [Jeff]
- Low profile battery tech [Jeff]
    - Performance
    - Costs
- Realistic Constraints [Sean]
- Professional and Ethical Responsibilities [Sean]
- Objective Attributes List [Cam]
- Objective Tree [Cam]

| | **Jeff** | **Sean (Leader)** | **Cameron** |
|---|---|---|---|
| Percentage of effort towards this assignment | 40.00% | 30.00% | 30.00% |

# Section 2 - Technical Research

## Bluetooth 'Smart' (v4.0 & 4.1)

Smart protocol, specifically the *Bluetooth Low Energy* protocol, was selected for further research due to the projects low required data throughput and high required standby time. A good overview of Bluetooth can be found here and an overview of Bluetooth low energy here.
Additional articles below:

1. Vancouver Bluetooth 4.0: Low Energy
2. IEEE low-energy WBAN for biotelemetry applications
3. IEEE Performance analysis of an Bluetooth Low Energy sensor system
4. Litepoint WhitePaper
5. Nordic Semiconductors Bluetooth Low Energy overview
6. BLE Arduino Shield

### Comparison between Traditional Bluetooth and Smart Bluetooth (1)

Traditional Bluetooth is oriented around maintaining a connection. A link is constantly maintained even when no data is being transmitted whenever a device is connected. Current draw generally peaks around 25mA. Bluetooth low energy, on the other hand, runs on "a new radio, new protocol stack, new profile architecture and a new qualification regime" (1). This protocol is designed around use for the *Internet of Things*. Maximum current draw for low energy protocols peak around 15mA. Power consumption is designed to be kept low enough that a module would be able to run from scavenged power such as a light sources. This fits very closely with the BLS project plan, though the additional microcontroller would likely tip the team's power consumption over the edge of power requirements of surrounding sources.

Details of these differences will be further discussed in the following sections.

### Bluetooth Low Energy Transmit Strategies (5)

The low energy protocol uses three main strategies to reduce power consumption during transmission. The first strategy is that it uses only three channels to search for other devices and to advertise its presence (as opposed to standard Bluetooth's 32 channels). This reduces powered-up time when scanning for other devices (to between 0.6-1.2 ms). Connection complete time is reduced as compared to standard bluetooth protocols. Specifically, Bluetooth low energy "can complete a connection (i.e. scan for other devices, link, send data, authenticate and "gracefully" terminate) in just 3ms. With Classic Bluetooth wireless technology, a similar connection cycle is measured in hundreds of milliseconds; more time on air requires more energy from the battery" (5).

Its secondary and third strategies employ Gaussian Frequency Shift Keying to employ less stringent RF parameters and to send very short packets (in comparison to *Bluetooth's* longer packets). The long packets require that the transmitter remain on for longer periods of time, thus drawing considerably more power. This naturally shifts the use case of a low energy bluetooth modules to infrequent transmissions of small datasets. Again, this fits in with the use case of the BMS transmitting only limited tables of information back to the parent device (likely a smartphone).

### Integration into Arduino Platform (6)

Although this project is not yet in its integration phase it is worth noting that a bluetooth low energy module is available for prototyping on the Arduino Uno microcontroller. This will be a pivotal part of the Senior Design process, although based on the lack of documentation of this board (along with many of its counterparts) it is likely that a large portion of the integration phase will be interfacing with this board's function set.

### Power Consumption Estimation (4)

The entire purpose of developing the Bluetooth low energy platform is to decrease power consumption. The following table (developed by Litepoint) displays representative values for current draw of a low energy module:

| Peak Current | Idle Mode Current | Average Current |
|---|---|---|
| tens of mA | tens of nA | ~ µA (assuming <1% duty cycle) |

While peak current draw is key under high data transmission loads, the reality of this team's application is that the transmitter will be under an extremely light duty cycle, with very short bursts. As such, the idle mode current and the average current assuming a light duty cycle of <1% are key to this device's performance on the system. A draw on the order of tens of nA is consistent with the very low energy draw required by the limited battery space available, and the average current (assuming that same low duty cycle) in the microAmp range aligns with an average use case that can be expected for a >1 day product battery lifetime (see Low Profile Battery Technologies section for additional details). Note that these estimates are only valid to their order of magnitude and vary per implementation.

low energy bluetooth modules are capable of low energy consumption because of the shift in power management to the controller, allowing the device to sleep for longer periods of time. Additionally, the duty cycle of a low energy bluetooth module can be reduced further than a standard bluetooth module down to as low as 0.1%. This low duty cycle behavior takes advantage of the fact that the bluetooth module is only responsible for very short range communication, and that a network device with access to a WAN is nearby.

## Low Profile Battery Technologies

Due to the nature of the BLS' proximity to the human heart it is important to minimize device profile. The power source will take much of the device's required volume. It is therefore critical to minimize size of the device by maximizing battery energy density.

The team was inspired by batteries by PowerStream to seek these low profile batteries.

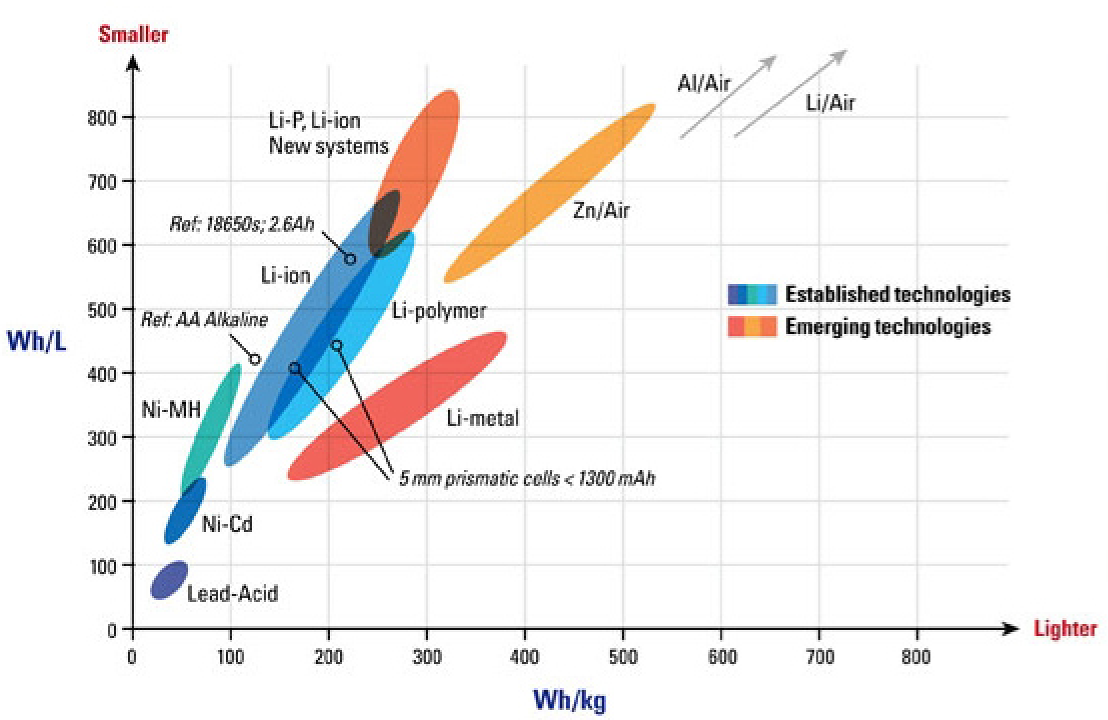
- IEEE Rechargable litium polymer electrolyte batteries

## Profile Concerns

Bulk batteries or batteries in remote locations are not viable for wearable electronics. The barrier for entry to wear the product must be incredibly low, or else the end consumer will likely not use it. Extending this idea, the battery must be tightly integrated into the system, and offer the energy density necessary to power all sensors, transmitters, and the microcontroller. Standard lithium ion and lithium polymer batteries offer no flexibility, and are often too thick for applications near the human body. Previous battery technologies such as nickel cadmium, while potentially acceptable in terms of energy storage depending on microcontroller power requirements, are far bulkier and less suited to low profile applications. The resulting focus on battery technologies with a flexible substrate follow these concerns.

## Energy Density

The following is an overview of modern battery technologies and their respective energy densities (Source).




It can be (generally) stated that, from bottom left to upper right, price also goes from low to high. So, although a Ni-Cd battery would be relatively inexpensive, its lower energy density and larger profile make it unsuitable for the team's applications. Once a sensor suite has been selected for use a suitable battery technology (and accompanying profile) can be selected as well.

# Section 3

## [Realistic Constraints]

*Economic*

One of the driving forces behind the development of the BLS is the desire to provide high quality , high accuracy, and cheap wearable tech. The economic feasibility of the BLS is of the utmost concern. It is also one of the most susceptible to design changes and considerations. There are many components that need to be designed, manufactured and installed in a final BLS production. The batteries, microprocessor, shirt, sensors, and development costs need to be closely monitored to prevent any sort of runaway cost build up. The batteries, as discussed above need to be able to supply power for a long amount of time, but they also need to be thin and barely noticeable. This secondary requirement makes it so that the batteries need to be carefully selected to fit the BLS and the person wearing it. The microprocessor component is an integral part of the BLS. Without it, all the project would be is a shirt. The microprocessor does not need to be the most expensive component, but it needs to be dependable, safe, and relatively cheap.

The shirt component of the BLS needs to be developed in such a manner that people will actually want to wear it. It needs to be relatively "hip" while not taking anything away from the person using it. Some of the possible implementations of the BLS will require special E-textile components which are new and could possibly drive up the price of the shirt. A significant balancing act will be needed to make sure that the shirt is both fully functional and cheap at the same time. There are a number of sensors on the BLS. The group cannot allow the sensors to be inaccurate. They also cannot allow the sensors to be a significant portion of the development costs. The sensors are important, and there are a lot of them but budgeting has to allow for a greater emphasis on some of the more novel problems and considerations.

*Environmental*

Environmentally speaking the BLS is fairly harmless. The only real environmental concerns arise from the use of the battery and what happens to the sensors and other hardware after they've started to wear out. The battery itself will be nothing special so any concerns dealing with that can be solved using general battery recycling guidelines. There are no emissions from the shirt itself, it is a fairly self contained system without much interaction outside of the shirt, person, and their phone. One item of possible concern is what happens to the shirts and their new E-textile components.

*Health and Safety*

The BLS is being developed to assist in monitoring and improving the user's health. The most important health and safety consideration is to make sure that actually wearing the BLS does not harm the user. There are a few health and safety concerns that need to be addressed and prioritized during the design of the project. The most concerning aspect of the BLS for some users would most likely be the use of the battery built into the shirt. Without the battery the BLS is useless, but batteries don't always work according to plan. The group needs to consider ways of minimizing any damage that the battery could do to the user if it were to overheat, explode or otherwise break down. On the flip side, the group needs to be certain that the measurements being made by the BLS are accurate. Inaccurate readings could give people a false understanding of the work they think they're doing. Additionally, false temperature or acceleration readings could improperly cause  the wrong warnings or otherwise enable incorrect signals.

*Manufacturability*

Manufacturing the BLS will be a somewhat major concern for the group. The BLS has a few major manufacturing concerns which will need to be addressed. The group will need to be able to mass produce the shirts cheaply. The shirts will need to be able to include the E-textiles without too much additional cost. A large component of adding the E-textiles will deal with how to properly place them and where to route them throughout the shirt. The E-textiles will need to be located in such locations that the user doesn't feel uncomfortable due to their presence and in a way so that no possibly dangerous connections are made. The sensors and microcontroller themselves will not be difficult to manufacture. The team will most likely buy the components from other vendors instead of trying to reinvent the wheel. The group will also take the same approach when it comes to the batteries.

*Sustainability*

Sales and development of the BLS should be extremely sustainable. None of the components are very complex or unique. As sales pick up people will most likely want to purchase additional shirts so that they can wear them more often while they go about their day. As updates are pushed out it is not unreasonable that people will upgrade their devices to new iterations to obtain lighter, faster, or more accurate BLS iterations. There are no real specialty markets that need to be specially primed for the BLS release except for possibly the E-textile field, but that has yet to be seen. E-textiles may not be used in the final design - it is still too early to tell.

## Professional and Ethical Responsibilities

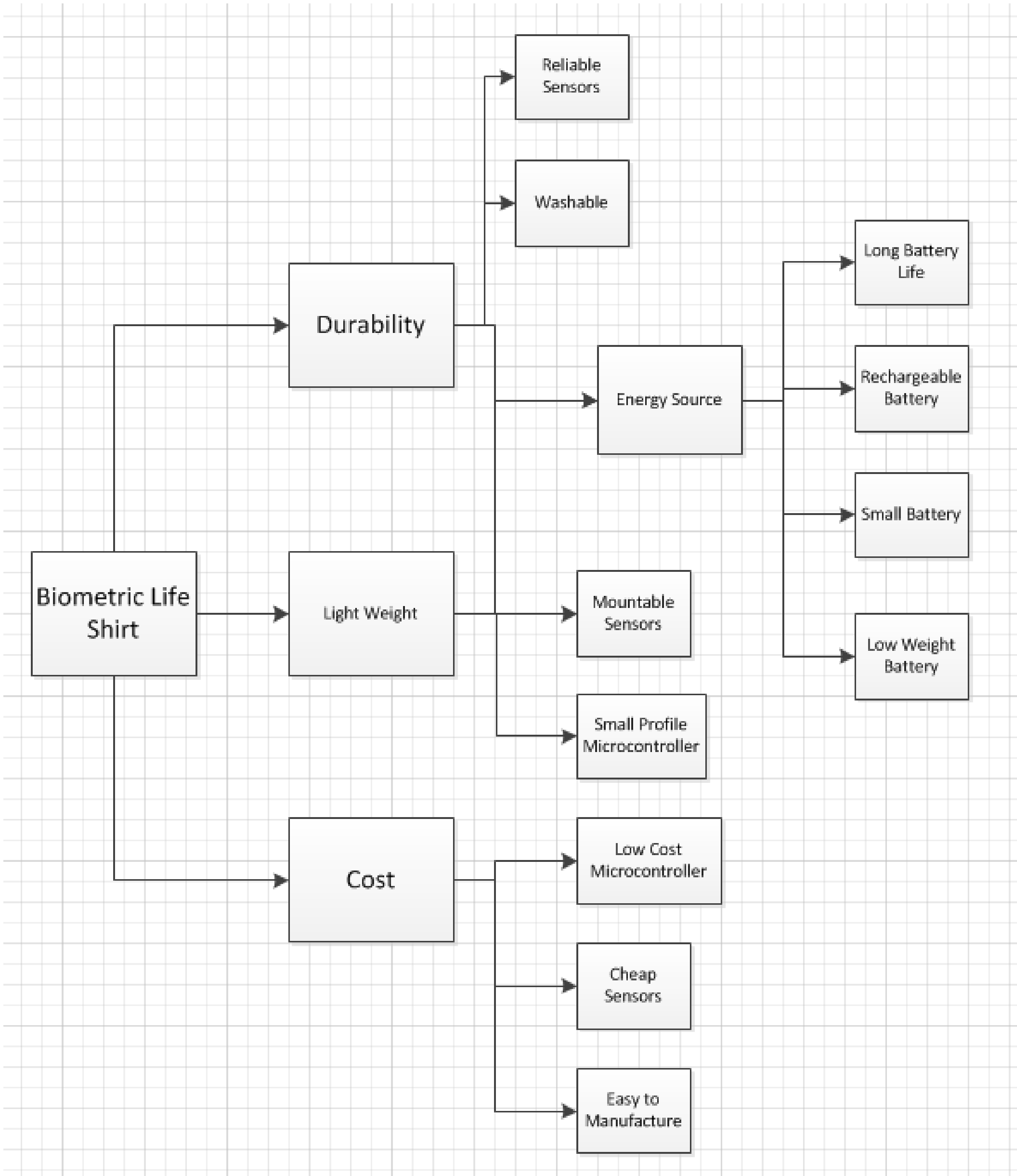
It is the group's goal to do the right thing in order to assure that the consumers are getting a highly accurate, high quality, and inexpensive product. That desire needs to be balanced against the group's need to reduce the cost by as much as is possible to prevent the cost from being too significant. The group will need to obtain materials from reputable sources to assure high quality devices and productions. The group would like to make certain that the users know where every component is coming from and how it was produced. The BLS will hopefully be made using local materials from producers in the local area. The work force will be fairly compensated and will be freely able to advance through the ranks.

All users will be informed about some of the possible repercussions and possibly dangerous effects of using the BLS. While it is unlikely that anything bad will happen to or from the battery, or that the E-textiles will prove dangerous, it would not be fair for the users to be subjected to any danger without being notified beforehand. Users will be shown the possible danger areas and all the tests that the BLS undergoes so that they can get a full picture of the work that is done on the BLS by the group. An additional concern for some users is the possibility that their personal information will be recorded or otherwise shared without their knowledge. A significant portion of the BLS is the fact that recorded information will be communicated to the users personal phone and/or their computer. The group will do all that they can to minimize the probability of interception to such a level that the user does not need to fear for their information's security. The group will not share information that is not theirs to share. To do so would be unforgivable and a breach of the user/design agreement.

The BLS will be an entirely see-through project but it will be protected by reasonable copyrights and other protections. The group will make sure that all subsidiary technologies are properly acknowledged and that anyone who requires fair compensation, will receive it. At the same time however the group will not be trampled underfoot by larger corporations. Their hard work will be rewarded accordingly.

## Section 4 - Objective Review

| | | |
|---|---|---|
| Washable | → | Convenience, promotes sales |
| Low cost | → | Competitive with other products |
| Long battery life | → | Able to last most of a day under use |
| Rechargeable battery | → | Fully chargeable overnight |
| Small battery | → | Requires small profile |
| Low-weight battery | → | Cannot be very noticeable |
| Small-profile Microcontroller | → | Microcontroller must not be too large |
| low cost microcontroller | → | Microcontroller must be cheap to manufacture/purchase |
| reliable sensors | → | Sensors must not significantly degrade over time and must give reasonable readings |
| cheap sensors | → | Must be able to include numerous sensors at low cost |
| Mountable sensors | → | Sensors must be connectable to the human body or the BLS |
| easy to manufacture | → | Entire process must be able to be automated |


Biometric Life Shirt
Durability
Light Weight
Cost
Reliable Sensors
Washable
Energy Source
Long Battery Life
Rechargeable Battery
Small Battery
Low Weight Battery
Mountable Sensors
Small Profile Microcontroller
Low Cost Microcontroller
Cheap Sensors
Easy to Manufacture

## Reference List

1. http://chapters.comsoc.org/vancouver/BTLER3.pdf (Bluetooth 4.0)
2. http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=6177022&tag=1 (A 1V 5mA multimode IEEE 802.15.6/bluetooth low-energy WBAN transceiver for biotelemetry applications)
3. http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=6377634 (Performance analysis of an Bluetooth Low Energy sensor system)
4. http://litepoint.com/whitepaper/Bluetooth%20Low%20Energy_WhitePaper.pdf (Bluetooth low power paper)
5. http://redbearlab.com/bleshield/
6. http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=282028&tag=1 (Rechargeable lithium polymer electrolyte batteries)
7. http://www.nordicsemi.com/eng/Products/Bluetooth-R-low-energy (Nordic Bluetooth article)