1. **Design Constraints**

The Zotikon system is comprised to two subsystems - the athlete-worn device and the trainer station. The athlete-worn device collects the essential indicators about the athlete in real-time and transmits it to the trainer station for monitoring purposes. The Zotikon system assists athletes and trainers by providing real-time data monitoring on athletes while they perform. This allows for more adaptive workouts and finely-tuned recovery periods. This section details the constraints that will define the Zotikon system. The section is comprised of two sections. Section 2.1 describes the technical design constraints that serve to constrain the hardware and software performance of the Zotikon system. Section 2.2 describes the practical design constraints which detail realistic engineering standards that must be met to ensure the Zotikon system will perform under real-life conditions.

* 1. **Technical Design Constraints**

Table 2.1 contains the five technical design constraints that the Zotikon system conforms to.

**Table 2.1. Technical Design Constraints**

|  |  |
| --- | --- |
| **Name** | **Description** |
| **Transmission Range** | The Zotikon system must be able to reliably transmit data to at least 70 meters. |
| **Max BPM** | The max BPM the athlete-worn device must be able to measure is 220 BPM. |
| **Simultaneous Users** | The monitoring station must be able to receive data from 11 athlete-worn devices simultaneously. |
| **Runtime** | The athlete-worn chest unit must be able to operate continuously for no less than 4 hours. |
| **Skin Temperature Measurable Range** | 15℃ - 47℃ with 0.125℃ accuracy. |

* + 1. **Transmission Range**

The Zotikon System must be able to transmit data accurately to at least 70 meters. Our System must meet range requirements for most common indoor low contact sports such as volleyball, tennis, basketball, soccer, etc. The largest field among these popular sports is the soccer field. According to the United States Soccer Federation, for a profession court, the recommend size is 60.1 meters by 26 meters [10]. The diagonal from this dimension is around 65 meters.

* + 1. **Max BPM**

According the Centers for Disease Control and Prevention, a person’s typical maximum heart rate is defined by subtracting the person’s age from 220 [12]. Given that 220 BPM sets the upper limit, Zotikon must be able to accurately read a heart rate up to that rate. A typical minimum resting heart rate for an athlete is about 40 beats per minute. Given the nature of athletic monitoring, it is unlikely that any athlete would be near their resting heart rate in a competitive situation, so a more reasonable lower limit that Zotikon must be able to attain should be 60 BPM.

* + 1. **Simultaneous Users**

Zotikon must be able to support enough simultaneous users to allow the trainer to track all active athletes at one time. Zotikon will be able to support 11 simultaneous users. There will be at most 11 athletes on the field for a team at one time in the NCAA. This will ensure that all active athletes’ vitals are relayed to the trainer’s device.

* + 1. **Runtime**

A four hour minimum runtime allows for continuous data collection from athletes playing in common American sports. The average NCAA football game lasts for approximately three hours and twenty-four minutes [7], and one of the longest college basketball games lasted for three hours and forty-six minutes [6]. A four hour minimum runtime would accommodate athletes for both of these popular sports by providing continuous data collection for at least the average duration of the respective games. Four hours would also provide ample time for collecting training data during exercise or drills.

* + 1. **Skin Temperature Measurable Range**

The skin temperature is a valuable measurement meant to help trainers prevent athletes from becoming overheated. According to Freitas [8], the skin is the largest organ in the body and is crucial for maintaining a healthy core temperature of 37℃. In order to effectively measure skin temperature, the sensor must be able to detect temperatures between 0℃ and 64℃ with a reasonable accuracy of 0.25℃. Based on medical research from Freitas, the average skin temperature is 32-35℃ [8]. Another research, Bean, has recorded cases of the lowest skin temperatures reaching approximately 25℃ on the toes [9]. Even though this device is not intended to be worn on the toes and the lowest record skin temperature in the chest region is 32℃, the data measurement range is sufficient to capture all possible skin temperatures on any part of the body. The 0.125℃ accuracy ensures that small increases in skin temperature are observed and reported which provides trainers with the best data to make decisions about their athletes.

* 1. **Practical Design Constraints**

Table 2.2 contains the five practical design constraints that the Zotikon system conforms to.

**Table 2.2. Practical Design Constraints**

|  |  |  |
| --- | --- | --- |
| **Type** | **Name** | **Description** |
| **Economic** | Cost | The athlete-worn device will cost less than $150 per unit. The monitoring station software package, or trainer station, will cost less than $1,500. The total cost of a system with 10 measurement units and 1 monitoring station will be less than $3,000. |
| **Manufacturability** | Size | The athlete-worn device must have maximum dimensions of 152mm x 152mm x 38mm. |
| **Environmental** | Physical | The athlete-worn device will be IP64 compliant and able to operate in temperatures between -40℃ and 85℃. |
| **Sustainability** | Longevity | The athlete-worn device must be easily rechargeable. The software for the trainer’s station must be capable of software updates over time. |
| **Health and Safety** | Safety | Must protect an athlete from electrical shock or other physical harm. |

* + 1. **Economic**

The Zotikon system is comprised of two components, the athlete-worn device and the monitoring station software package. From market research, the common system package includes 10 athlete-worn devices and 1 monitoring station software package. This common system is how the Zotikon system is compared for competitive analysis in the market. The objective is to ensure the Zotikon system, as a whole, will be price-competitive with other vendors, such as those referenced in Section 1.2. Competitive vendors offer systems that range from $1,600 to over $10,000 with most of the widely-used products being at the higher end of that range. To make the Zotikon system competitive, the system will cost $3,000 or less. The athlete-worn devices will cost $150 per unit and the monitoring station software package will cost $1,500. While this goal does not place the Zotikon system as the [cheapest] option, the features that Zotikon provides are only offered by vendors at the high-end of the price range. The primary selling point is that the Zotikon system offers the functionality of the high-end product at a competitive cost with the low-end products.

* + 1. **Manufacturability**

The player-worn device must be designed so that it can be manufactured in bulk without an excessive amount of labor due to the volume of units that may be required. In order to keep the player-worn device usable, it must be manufactured to fit under a jersey or uniform without causing the wearer noticeable discomfort by impeding their normal athletic activity. According to First In Architecture, the average shoulder width for women is around 395 mm [11]. We chose the size for women because the size for men is larger. Our wearable must be at least half that size on length and width so it will fit comfortably on the area just below the sternum. The device must not at the most 38mm thick so it can be concealed under a uniform and still be comfortable.

* + 1. **Environmental**

The athlete-worn device is subjected to a variety of environmental conditions where the device must continue to operate properly. According to Secure Systems & Technologies, “The IP code or Ingress Protection ratings are defined in international standard EN... They are used to define levels of sealing effectiveness of enclosures against intrusion from foreign matter (tools, dirt etc) and moisture.” (Secure Systems & Technologies, 2017). Per the IP standards, the athlete-worn device should meet IP64 standards which requires the device to be totally protected against dust and protected against splashes of water from all directions. This requirement ensures that the device will continues to operate when affixed to a sweating athlete. The device must also be able to operate in the commercial temperature range of -40℃ to 85℃. This is based on the Altera standard for commercial and industrial operating temperatures (Altera.com, 2017). Commercial standards specify a range of 0-85℃ which is insufficient for the athlete-worn device because there may be occasions where athletes train or compete in temperatures below freezing. Due to this, the minimum temperature was expanded to -40℃ which is the specified minimum temperature for industrial components. These constraints should adequately constrain the design to ensure the athlete-worn device is functional in all possible training environments.

* + 1. **Sustainability**

A rechargeable athlete-worn device frees the user from needing to buy a new set of batteries for the device every four hours. With a rechargeable battery that comes with the device, the design for the device does not need to take into account the availability of consumer batteries. The size, shape, and energy density can be left to the designer of the device. If multiple devices are owned by a user, once device can charge while the other can be used, giving more freedom to the user.

The software included in the Zotikon system for the trainer’s station must be maintainable and able to be updated. As the needs of the user mature, the system must be able to adapt by the improvement of features and elimination of bugs. With the ability to update the software, features provided by new hardware can be incorporated into the Zotikon software. Algorithms for data analysis can be finely- tuned and grow in number.

* + 1. **Health and Safety**

The Zotikon system must be able to safely measure the heart rate of the athlete. The wearable devices will have electrical leads that will be exposed to the chest of the athlete. The athlete must be safe from electrical shock and burns. The wearable device must be small enough to be worn underneath a jersey. These devices must be worn without posing harm to the athlete wearing it or any other athletes. There can be no sharp edges that could pierce the skin of an athlete.

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