Feb 15, 2016

Dr. Andrew Rawicz
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Re: Functional Specification for AlarmSense System

Dear Dr. Rawicz

Attached you will find the document 'Functional Specification for AlarmSense System', which outlines the functional requirements for our ENSC 440W project. Our goal is to design a system protocol to allow workers in noisy industrial settings to remain safe and work efficiently while protecting their hearing.

The functional specification outlines the requirements of headphone units, a charging station, and a mobile app. Safety is the number one priority for the AlarmSense System, and the requirements for safety have been integrated throughout the functional specification. The specification also include usability, cost, technical, and environmental requirements.

Ekho Systems is composed of four fourth year engineering students: Russell McLellan, Taylor Robson, Gordon Ho, and Adrian Tanskanen. If you have any questions or concerns, please contact us my email at rmclella@sfu.ca.

Sincerely,
Russell McLellan
Ekho Systems

Functional Specification for AlarmSense System

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Executive Summary

Workplace safety is becoming one of the biggest, if not the biggest, concern for the men and women working in the trades and resource industries. Ever present are the endless rules and safety regulations, which while necessary, can be cumbersome and often cause new issues to arise. We at Ekho Systems seek to make dangerous workplaces safer and more efficient by allowing for seamless communication between workers, while ensuring that important emergency signals never go unheard.

We intend on developing a system that integrates hearing protection, advanced communication, and modern functionality into a single unit, with the unique benefit that allows for emergency signals to bypass the hearing protection. All of these functions will be a part of the AlarmSense System developed by Ekho Systems. Development of this project will be conducted over the course of the next few months according to the requirements listed in this document.

The most essential requirement of the system is the selective noise cancelling feature of the headset. Active noise cancelling will attenuate industrial noise, but certain frequencies corresponding to worksite alarms will be passed through. The frequencies of the alarms will be selected by the user of the AlarmSense System to allow for its use across all worksites.

In addition to passing through alarms, the AlarmSense System will allow the users to communicate to each other as easily and intuitively as in a quiet environment. A microphone attached to the headset will record and send speech from worker to worker, improving the cohesiveness of the worksite. This communication will also allow an injured worker to quickly request help, even if the injury leaves the worker immobile or unable to signal with visual cues.

Lastly, the functionality of the whole system will be tied together through use of a smartphone app as well as a single charging station for all headset units. The users will be able to select the desired alarms to filter out, simply by inputting commands easily found on both the charging station as well as the smartphone app.

Safety is not our only concern here at Ekho Systems. Environmental factors and sustainability are also a part of every project we develop. The AlarmSense System will be constructed in such a way as minimize any negative environmental factors typically caused by the large scale electronic manufacturing.

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Glossary

Term	Meaning
Alarm	An auditory alert of a specific frequency present in a worksite
AlarmSense System	The complete product, including the unit, briefcase, and app
App	A smartphone program used for managing the AlarmSense System
Briefcase	A portable charging station for AlarmSense System units
Foreman	A manager of industrial workers responsible for safety
PPE	Personal protective equipment, including hearing protection
Unit	The part of the AlarmSense system worn by every worker, including headphones, a microphone, and a microcontroller
Worker	An individual using an AlarmSense System unit
Worksite	An area where loud industrial work is carried out

Classification of Requirements

The following table is used in this document to represent functional requirements.

Requirement Number	Description	Related Requirements
[Rn-p]	A functional requirement	[Rn-p]

The requirement number is made of three parts: **R**, which stands for requirement, **n**, which is an identifying number, and **p**, which gives the priority in one of three values. The values for the priority are given below.

I - The requirement applies to a proof-of-concept system with only one unit
II - The requirement applies to a prototype system with multiple units
III - The requirement applies to the production system only

The related requirements column listed requirements from other sections which directly relate to the requirement stated. Requirements from within the same section are not listed, as they are assumed to always be related.

1. Introduction

The AlarmSafe System is a product designed to increase safety and efficiency in loud industrial settings. In loud worksites, such as construction sites, manufacturing plants, or saw mills, hearing protection must be worn. Unfortunately, wearing hearing protection has a side effect that auditory alarms and communication from co-workers is also cut off, which can often have devastating consequences. The AlarmSafe System is designed to block out harmful industrial noise while allowing both alarms and worker speech through. The system is comprised of individual units worn by workers, a central charging station, and a smartphone app used for the monitoring and control of the system.

The unit is worn by all workers in the worksite, and is shown in Figure 1. It is composed of a microcontroller, earmuffs containing headphones, and a microphone. The earmuffs actively cancel the industrial noise, while the embedded headphones broadcast sounds directly into the worker's ear. The microcontroller picks up ambient noise, filters out the sound from certain alarms, and passes it to the headphones. The frequencies of alarms are set by the foreman of the worksite using either the briefcase or the mobile app.

Figure 1. A unit

Additionally, the microcontroller takes in signals containing the speech of other workers and sends it through the headphones. This communication system is designed to be much more natural than a standard walkie talkie. The microcontroller will attenuate incoming voice signals based around how loud the sender is speaking and how far away they are. For example, if one were to speak quietly into the microphone, the speaker's voice would only be received by nearby units. If the same person were to then yell into the microphone, their voice would then project to all units. This communication protocol mimics a worksite with no industrial noise or hearing protection, where workers are free to talk normally to one another. It also ensures that should the user become injured, they need only yell for the whole work site to hear their distress call.

Communication between different units will be done wirelessly. We will likely implement this communication using Bluetooth technology, however several other avenues of integration such as sending these signals via WiFi or through other radio frequency signals. Regardless of the method, the incoming signals will all be processed by the system microcontroller to allow for its unique functionality.

The specific requirements for the units are given in Section 2.

A briefcase will be provided with the AlarmSense System to allow multiple units to charge simultaneously. The briefcase will also allow alarm frequencies to be added and removed from sets of units. A model of the briefcase full of units is shown in, and its specific requirements are given in Section 3.

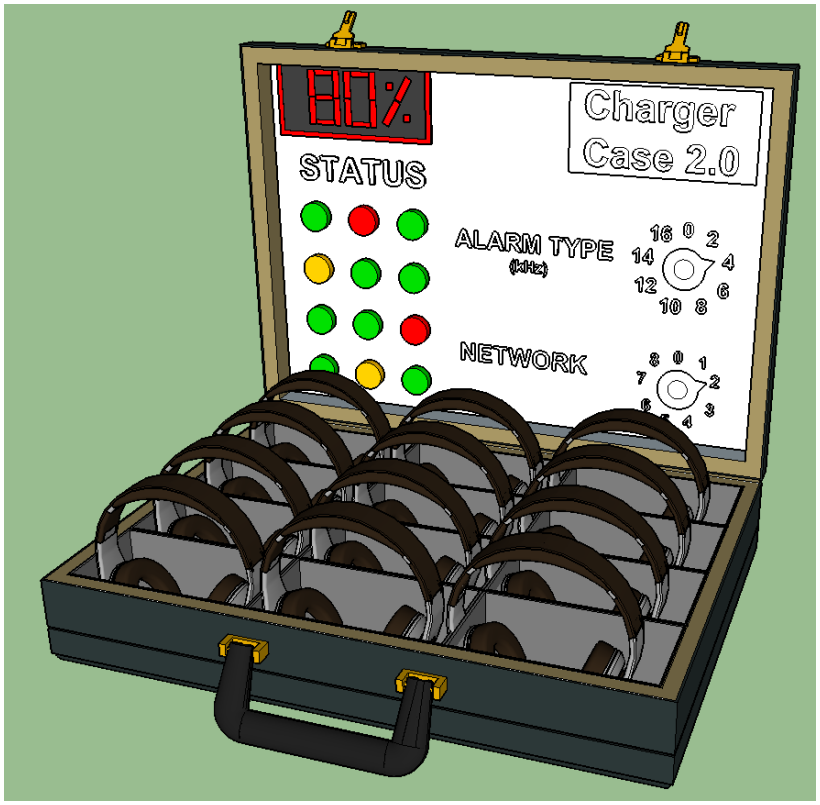

Figure 2. The briefcase

The AlarmSafe System can also be controlled by a smartphone. We intend on developing a simple to use smartphone app that allows the foreman to easily tune the whole AlarmSafe System to certain alarm frequencies. The app will also display the status of all units on the network, which includes the connection status and battery life. The home screen, alarm addition screen, and alarm deletion screen of the app are shown in Figure 3. The specific requirements for the app are given in Section 4.

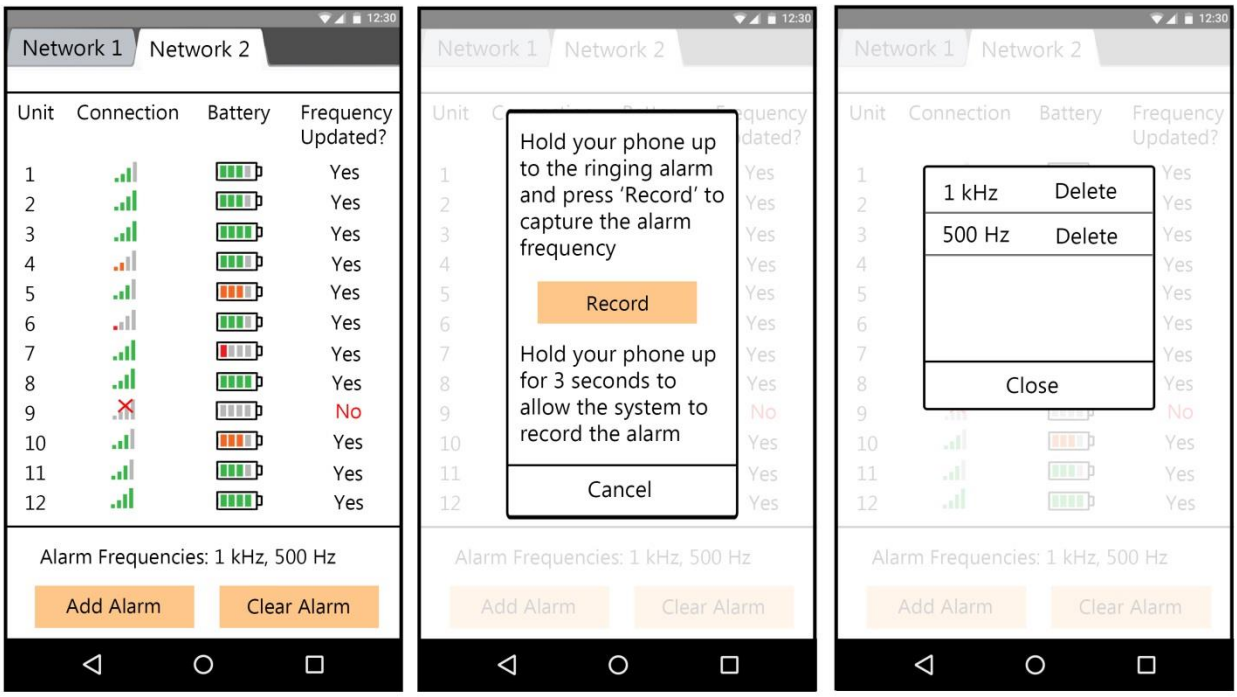

Figure 2. Example app displays for the home screen, alarm addition screen, and alarm deletion screen

2. Unit Requirements

2.1 Mechanical Requirements

2.1.1 Safety Requirements

As the Selective Noise Canceling headphone system is for use as safety equipment in industrial settings, safety requirements are paramount. Industrial noise must be reduced to avoid long term hearing damage in accordance with standards. Much of the system is electrically powered, but as safety equipment should have levels of redundancy, the Selective Noise Canceling Headphone system must perform to the safety standards in the event that electrical power is lost. The safety standard used is the Canada Labour Code, Part II, Canada Occupational Health and Safety Regulations, Section 7.4(1)(b) [1].

Table 1. Safety requirements

Requirement Number	Description	Related Requirements
[R1-II]	Without electrical power the device should reduce all noise up to 115 dB to below 85 dB	[R17-I]

2.1.2 Durability Requirements

The personal headphone/microphone system must be carried by workers in industrial environments. The physical form of the device must be conducive to work in these varied environments, with small dust particles, varied temperatures, and heavy rain. The device must also continue to function after being dropped, as industrial workers are tired at the end of a workday when removing their PPE, and may not be careful with it. To make AlarmSense worth the purchasing price, the system must last for several years.

Table 2. Durability requirements

Requirement Number	Description	Related Requirements
[R2-II]	The casing shall be waterproof	
[R3-II]	The unit shall be dustproof	
[R4-II]	Operates between temperatures of -30C and 50C	
[R5-II]	The unit must remain operational after a drop from a height of 3 m to hard concrete	
[R6-III]	The unit must have a minimum lifetime of 5 years	

2.1.3 Ergonomic Requirements

Industrial workers will often be wearing heavy work gloves on the job. All controls must be operable with this restriction in mind.

A power switch is necessary for a device running off of batteries, but the switch should not be able to be pushed accidentally during a workday.

Different workers will have more or less sensitive hearing, as well as louder or quieter voices. Controls for incoming and outgoing volume will allow workers to compensate for this variance.

The important internal states of the unit are the battery life and connection status. These states should be communicated clearly to the worker. The displays for these states must be durable, therefore LEDs are chosen over fragile screens.

The unit must be comfortable for all workers, or they will not wear it. The unit cannot be excessively heavy, and the headphones must adjust to various head sizes.

Lastly, any loose wire attached to the unit can be a safety hazard in an industrial setting. The device must be compact.

Table 3. Ergonomic requirements

Requirement Number	Description	Related Requirements
[R7-II]	The controls of the unit shall be large enough to be operated in heavy gloves	[R31-II]
[R8-II]	The unit power switch shall not be easily pushed	
[R9-I]	Incoming headphone volume control	
[R10-I]	Outgoing microphone volume control	
[R11-II]	The unit shall have an indicator LED to give connection status	
[R12-II]	Battery life shall be displayed on LEDs when a button is pushed	
[R13-II]	The unit cannot weigh above 500 g	
[R14-I]	The headphones shall be of adjustable size	
[R15-II]	The unit shall have no loose wires	

2.2 Software Requirements

2.2.1 Operational Requirements

The software on the AlarmSense System must run in soft real time. While the software can crash in extreme circumstances, the noise processing software must be able to work reliably.

Requirement [R1-II] is the bare minimum that hearing protection must achieve for safety levels. To give a more comfortable, and therefore productive, environment the AlarmSense system should attenuate ambient noise to a lower threshold. A comfortable noise level attainable by active noise cancelling hearing protection is stated in CSA standard Z94.2-14, and will be the functional target [2]. As the single-unit proof of concept will be using predesigned libraries, this standard may not be met until the mulit-unit prototype.

One of the main improvements of the AlarmSense System is its ability to let alarms bypass the hearing protection. As different work sites all use different alarm frequencies, the frequency must be tunable by an external controller and remotely sent to every device on the network. In addition to alarms, the speech transmitted by other units must be passed through the hearing protection.

Human hearing works in the range up to 16 kHz, so that is the frequency the processor must be able to output [3].

Table 4. Software operational requirements

Requirement Number	Description	Related Requirements
[R16-I]	Processing must be done in soft real time to have an output of up to 16 kHz	[R27-I]
[R17-II]	Reduce all incoming noise by an additional 30 dB when electrically powered	[R1-II]
[R18-I]	Pass arbitrary alarm frequencies through the headphones	[R39-II], [R44-I]
[R19-I]	Pass worker communication through the headphones	[R24-I], [R27-I]
[R20-I]	Alarm frequency can be updated during operation from mobile app	[R44-I]

2.2.2 Network Requirements

The units comprising the AlarmSense System must belong to a network in order to allow workers to communicate with each other. While a physical hub or mobile app will be used for the setup of the devices, the network should function when the central hub is removed.

As the purpose of the network is to send speech wirelessly to increase worker efficiency, the speech transmitted needs to be as understandable as ordinary speech.

Table 5. Network requirements

Requirement Number	Description	Related Requirements
[R21-I]	The unit must work without a central hub	
[R22-II]	The unit must be able to differentiate between other devices	
[R23-I]	The speech transmitted over the network must be intelligible	[R19-I]

2.3.3 Proximity Attenuation Requirements

In order to recreate the effect of worker to worker communication with no background noise, there must be a roll-off of sound level based on the distance that workers are from each other. Conversational sound levels are taken from the Engineering Toolbox [3], and these levels form the basis of the following requirements.

Table 6. Proximity attenuation requirements

Requirement Number	Description	Related Requirements
[R24-I]	Proximity sensor begins rolling off at 5 m	[R37-I]
[R25-I]	Once attenuation begins, doubling the distance between two units attenuates the broadcast noise by 6 dB	[R37-I]

2.3 Hardware Requirements

2.3.1 Operational Requirements

The hardware of unit must be able to run the software described in Section 2.2.

As given by the Engineering Toolbox [4], people cannot hear each other shouting at much longer than 40 m. The transmitters should have an effective distance which is longer than the maximum human voice range in case of obstructions. Worksites contain many walls, and sound should transfer through these walls.

The microphone of the unit should pick up all sounds in the human hearing range. As it would be pointless to rebroadcast all industrial noise through the hearing protection, the microphone must filter out all ambient noise to the same levels as given in [R7-II]. The microphone should not require a button press to record, as the many times workers will have both hands full and still need to communicate. A

hands-free only operation may be disruptive in worksites with many workers, as it will rebroadcast all sounds made by all workers. Therefore, a push button option shall be included.

Table 7. Hardware operational requirements

Requirement Number	Description	Related Requirements
[R26-I]	The headphones must output sounds at up to 16 kHz	[R16-I]
[R27-I]	The hardware must be able to run the software in real time	[R16-I]
[R28-I]	The transmitters must be able to broadcast at up to 100 m	[R43-I]
[R29-I]	Must be able to transmit through 20 cm thick steel stud walls	
[R30-I]	The microphone should pick up frequencies up to 16 kHz	
[R31-II]	Microphone is hands-free or push button operated	[R7-II]
[R32-I]	Input microphone filters ambient sound to the same level as set out in [R17-I]	[R17-I]

2.3.2 Battery Requirements

Workers in industrial setting typically work in 8 hour shifts, with a maximum of 12 hours. The battery life of the device should last for an entire shift. At the end of a shift, workers should be able to pass their device to another worker who is starting their shift. It is therefore important to have the batteries interchangeable, so that the next worker can use the device while the battery used by the first worker charges.

Table 8. Battery requirements

Requirement Number	Description	Related Requirements
[R33-II]	16 hour battery life	
[R34-II]	Runs off of a rechargeable battery	
[R35-II]	Battery must recharge in 1-2 hours	
[R36-II]	Battery must be removable	

2.3.3 Proximity Sensor Requirements

The sensors used for the proximity based roll-off should be accurate.

Table 9. Proximity sensor requirements

Requirement Number	Description	Related Requirements
[R37-I]	The proximity accuracy should be ±1 m	[R25-I], [R26-I]

3. Briefcase Requirements

A network of units all need to charge at one time. To aid in organization and use less wall outlets, a briefcase will be provided with the AlarmSense System with multiple charging stations for individual units. As all units are placed into the briefcase, the briefcase also is a natural place to allow alarms frequencies to be keyed in.

Table 10. Briefcase requirements

Requirement Number	Description	Related Requirements
[R38-II]	The briefcase shall allow up to 12 devices to charge at one time	[R18-I]
[R39-II]	The briefcase shall allow manual tuning of the alarm frequencies of all connected devices through a dial	
[R40-II]	The briefcase shall allow many different networks of units, each with their own alarm frequencies	
[R41-II]	The briefcase shall display the battery charge level of each connected device	
[R42-II]	The briefcase shall be powered from a 15A/120V wall socket	

4. App Requirements

To allow a foreman to quickly and easily set alarms for his work crew, a mobile app will be created. The foreman of a worksite is not trained as an engineer, therefore the app must be easy to understand and operate. The foreman is not expected to know the frequency of the alarm system, therefore the main function of the app will be to measure the frequency of an incoming sound and set it as the alarm frequency. The foreman will simply trigger the alarm, hold up the app, and the units will all be updated to use the alarm frequency.

As the app is already wirelessly connected to the network of units, other diagnostic information can be displayed here to give the foreman information about the system.

A foreman may want to have several networks of units, each with their own alarm frequency. The app should support this functionality.

Table 11. App requirements

Requirement Number	Description	Related Requirements
[R43-I]	The app shall wirelessly connect to units within 100 m	[R29-I]
[R44-I]	The app shall support the adding and removing of alarm frequencies	[R20-I]
[R45-I]	The app must measure dominant frequency of sound above 90 dB	
[R46-II]	The app shall display the connection status of all units on the network	
[R47-II]	The app shall display the remaining battery life of each unit on the network	
[R48-II]	The app shall support an arbitrary number of independent networks	
[R49-I]	All functions on the app must be clearly understood by an untrained user	
[R50-III]	The app shall be available on iOS and Android	

5. General Requirements

In addition to technical requirements, the system must satisfy environmental and pricing requirements. The price of the system should not be significantly higher than the cost of current PPE designed for hearing protection and communication. The current prices range from $300 to $600 [5, 6]. The system must also not damage the environment unnecessarily. The specifics of this requirement are given in Section 6.

Table 12. General requirements

Requirement Number	Description	Related Requirements
[R51-III]	The AlarmSense System price must be under $150 per unit	
[R52-III]	The AlarmSense System must be produced in an environmentally sustainable way	

6. Environmental Sustainability

Electronic waste, or E-Waste, a subject that was seldom talked about only several decades ago, has become one of the most pressing issues of modern society. In Canada alone, over 725 metric tonnes of E-Waste is generated each year, and this number is only increasing [7].

Sustainability is a vital component of the AlarmSafe System. This section highlights the efforts into ensuring that the manufacturing of our product is enviornmental and that the product is sustainable.

6.1 Innovative Design

We intend on refining our design by removing as many unecessary parts as possible. The final design will be as simple, with only one large screw on each earmuff holding together the internal electronics. The single screw assembly will allow for the user to easily replace any broken parts, rather than being required to replace the whole headset when a small part breaks. We believe that this innovative design is absolutely necessary for the physical environments that safe alarm will be used for [8].

Figure 4. Simple design to allow parts to be replaced [8]

6.2 Sustainably Sourced Materials

E-Waste is a prominent issue because most plastics are not biodegradable. To remedy this problem, the plastic parts of the Safe Alarm system will all be constructed using starch-based completely biodegradable polymers (SCBPs). SCBPs are a widely used for applications in biomedical and environmental instruments due to robustness [9]. This robustness makes it the perfect material for our applications in heavy industrial settings. Table 13 documents the materials used in our design as well as the environmental considerations behind these parts [8].

Table 13. Materials used in product manufacturing

Part	Materials	Enviornmental Considerations
Screw	Aluminium	Made from recylced metals
Housing	SCBP Plastics	Completely biodegradable
Microcontroller and Circuitry	Various Metals and Plastics	Recyclable
Speaker	SCBP Plastics	Completely biodegradable
Cushion and Fabric	Polyester	Made from recylced polyester
Headphone connector	SCBP and Various Metals for Interconnect Circuitry	Completely biodegradable, Recyclable
Microphone	Various Metals and SCBP Plastics	Completely biodegradable, Recyclable
Outer Casing	SCBP	Completely biodegradable

6.3 Manufacturing Considerations

For the electronics that are to be purchased for the microcontrollers as well as for any of the other electronics, Ekho Systems will be purchasing products reviewed the Electronic Product Environmental Assessment Tool (EPEAT), to ensure that the enviornemntal impact is minimal. Additionally, we will be seeking an EPEAT Gold ranking before mass producing our product [10].

6.4 Disposal

Due to the innovative and simple design detailed earlier, disposing of the product will be simple. The buyer need only remove a single screw and recycle the interior electronics and any polyester fabrics. The rest of the product is made of starch-based completely biodegradable polymers and thus will quickly degrade in any landfill.

7. Conclusion

The AlarmSense System will be designed to the functional requirements laid out in this document. The full production system will allow for multiple networks of units, each with independent alarm frequencies. The system will be charged through a portable briefcase and controlled by the foreman either through the briefcase or the mobile app.

Safety is the chief goal of the AlarmSense System, therefore the hearing protection requirement is paramount. Regardless of battery power or connection status, a unit must act as certified hearing protection as per the Canada Labour Code.

The chief advantage that the AlarmSense System has over standard hearing protection is that some sounds will be allowed through to a worker's ears. These sounds are auditory alarms and the speech of other workers. A worker wearing an AlarmSense System unit should feel as though there is no industrial noise, but should not feel that their sense of hearing is compromised with regard to safety or communication.

The AlarmSense System should be easy to set up and use. A foreman at a worksite has many responsibilities, and may not want to add the responsibility of setting up and managing a sound system. Having the management on an app allows a foreman to quickly and easily set up and monitor the status of the system withou the need for specialized hardware. If a foreman happens to not have a smartphone, the basic set up can be performed through the briefcase. The usability requirements also extend to the workers, as a proximity and loudness based roll off allows for an intuitive understanding of how the sound system works.

All components of the AlarmSense System can be produced either from recyclable or biodegradable material. Ekho Systems is committed not only to workers safety, but to environmental safety. By designing the unit in a modular way, workers and foremen can easily replace a damaged part with a new one, which will save on waste products. As all components of the AlarmSense System are environmentally friendly, disposal of damaged components can be done in a green way.

Designing the three components of the AlarmSense System to the requirements listed in this document will allow Ekho Systems to create a usable, functional, environmentally safe product.

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