1. PROBLEM STATEMENT

Senior citizens are one of the highest-risk groups in the world for falls and cognitive disorders. These elders are facing a lack of oversight and safety in their households and outside. Modern monitoring devices are expensive or do not monitor certain aspects of the environment which might affect the patient. There is a gap in the market for monitoring the elderly and affordability.

1.1. Need Statement

The demand for caretakers for those who require extra aid is higher than ever, especially in age groups of 65 or older [1]. An example of this is in the state of Maine, where over "11,000 hours of personal care are going understaffed" [2]. These caretakers cannot be omnipresent, yet patients cannot be left unmonitored, and this technology can help provide a stopgap. The caretaker role is currently facing not only staffing shortages but also a lack of commercially available technology that can help ensure patients are never alone.

1.2. Objective

The SafeStep shoe addresses this personnel shortage to ensure people who require monitoring, such as those who are at risk of being exposed to dangerous temperatures or falling, are kept safe. The SafeStep shoe is footwear designed to be noninvasive while providing a constant environmental monitoring system, ensuring that the wearer does not stray from the location and contacts the caregiver if a fall occurs. The SafeStep allows the caretaker to receive and monitor the environment of the wearer without physically being beside them.

1.3. Background and Related Work

The premise of the product is to create a wearable environmental monitoring system for patients that sends notifications to their assisted living workers. This product is implemented by integrating an array of sensors into a shoe and sending the data received from the sensors to an app that the caretaker monitors. There are several anticipated limitations when developing the design, including the need for the shoe to detect falls, the sensors to provide accurate readings, the battery life to last for 24 hours, and the radio module to maintain communication with the app while within range. Currently, no commercially developed smart shoe is designed to monitor the user's environment, although smartwatches and smart shoes can monitor the user's vitals and location. No wearable environmental monitoring systems are currently patented, even though all smart shoes and watches that monitor vitals and user athletic activity are patented.

2. DESIGN REQUIREMENT SPECIFICATIONS

The design team's product is designed to improve the safety of those requiring certain accommodations due to mental or physical conditions, such as age-related cognitive disorders. The SafeStep shoe becomes a part of the user's day-to-day life and is comfortable and suitable for daily use. This product features an array of sensors to monitor the environmental risks that the user faces. This data is forwarded to the caretaker or holder of the SafeStep's accompanying smartphone application to provide a sense of security for the caretaker. This document is divided into three major sections involving the requirements, constraints, and standards of the product.

2.1. Requirements

This portion of the document details the various types of requirements, constraints, and engineering standards that the SafeStep accomplished. The following sections detail the requirements met by the SafeStep.

2.1.1. Marketing Requirements

The SafeStep marketing requirements address the needs of the product and the team. The marketing requirements are as follows:

1. Product detects if the user has fallen.
2. Product monitors the local environment of the user and notifies the app in the event of a harsh environment.
3. Product stores emergency contact information that can be easily accessed.
4. Product has at least a 24-hour battery life.
5. Product fits within a standard-sized shoe.
6. Product maintains a real-time communication link with the user's smartphone.
7. Product is rechargeable via a USB-C connector with a wall outlet.
8. Product is water resistant.

In Figure 2-1, the objective tree for the project is presented.

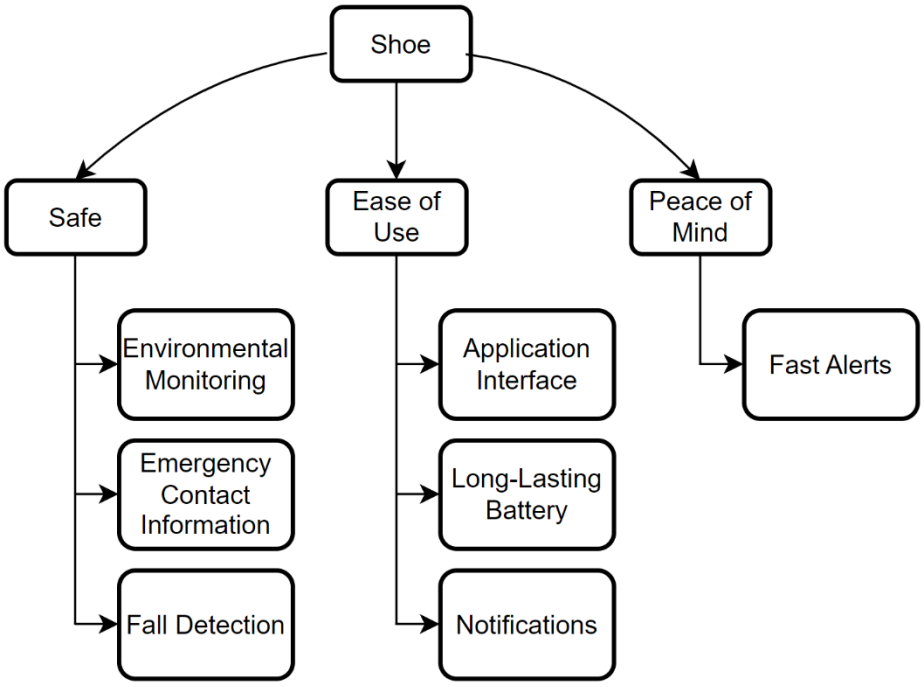

Figure 2-1: Objective Tree for the SafeStep

In the above chart, the marketing requirements are organized into three primary groupings. The groups, safe, ease of use, and peace of mind, demonstrate the primary goals of the SafeStep.

2.1.2. Engineering Requirements

Engineering requirements are the primary things in the project that guide the SafeStep project. These requirements are presented in Table 2.1.

Table 2.1: Engineering Requirements

Marketing Requirements	Engineering Requirements	Justification
1	The device detects when the wearer falls.	Falls are the leading cause of over 90% of hip and wrist fractures in America [3].
2	The device detects and reports exposure to temperatures of <65 °F or >75 °F for over 30 minutes.	This temperature range was chosen because, according to research, people aged 65 years, or more are at risk after exposure to these temperatures for half an hour [1].
3	The device sends emergency contact information to smartphones within 9 cm of the Near Field Communication sensor.	The Near Field Communication (NFC) sensor standards state that the operational range of NFC sensors is approx. 10 cm [4].
4	The device can remain in use for 24 hours.	The device can function a full day of use without having to be recharged.
5	The device fits within a standard size 14 athletic shoe.	This device is contained within the shoe for accurate sensor data.
6	The device is charged using wall outlet receptacles and a USB-C port.	The device contains a recharging port that is capable of interfacing with standard United States outlets of 120 V, 60 Hz.
7	The device features an IP rating of 67.	The device is protected from damage caused by environments in which it may interact. This rating includes penetration by dust and temporary submersion within water.

The SafeStep features an array of sensors to accomplish environmental monitoring. The shoes detect falls as well as reporting environmental temperatures that are lower than 65 Fahrenheit and greater than 75 degrees Fahrenheit. These two requirements concern the sensor packages. The requirements are designed to give the sensors an accurate rate of responding to hostile or unsafe environments for the wearer.

The SafeStep features a power system that can recharge and store power. The requirements of the power system necessitate that the shoe features a 24-hour battery life for use throughout the day and the ability to recharge the shoe using wall receptacles. These two requirements were set in place for ease of use on the

wearer as a 24-hour battery life allows the wearer peace of mind in that the shoe will not fully discharge during normal daily activities. The device is charged via a standard Universal Serial Bus - C (USB-C) port that allows it to be compatible with other chargers such as those used on the iPhone or a Google Pixel.

The SafeStep shoe features an Ingress Protection (IP)-67 rating for the safety of the wearer. This requirement states that the electronics of the device remain dust-free and resistant to temporary submersion in liquids. [5] This requirement was chosen to provide safety for the user if they encounter puddles and rainy weather.

2.2. Constraints

The design constraints of the project are presented in Table 2.2 below.

Table 2.2: Constraints

Type	Name	Description
Economic	Cost	The budget for the team is $1,000.
Manufacturability	Radial Communication Distance	The product sends and receives Bluetooth communications to a user's device within a distance of 10 meters.
Manufacturability	Size	The physical dimensions are 35 cm (L) x 13 cm (W) x 14 cm (H).
Health and Safety	Battery Safety	The product conforms to the battery safety regulations given by the manufacturer.
Health and Safety	Power Supply Safety	The Power source for the product follows International Electrotechnical Commission (IEC) 62680-1-3:2022 standards to prevent possible damage to internal circuitry.
Economic	Time	The project is required to be completed within two academic semesters.

These constraints are expanded upon in the following section. Constraints were chosen to fall within one of three major categories.

2.2.1. Economic

The budget for the SafeStep did not exceed $1,000. This budget is provided by the electrical and computer engineering department to complete all senior design projects.

2.2.2. Manufacturability

The SafeStep utilizes Bluetooth to communicate with the mobile device of the user. The usage of Bluetooth allows for easy interfacing with users' mobile devices. The antenna(s) for this subsystem requires extensive work to guarantee that it works properly.

The SafeStep fits within the size constraints imposed by a standard athletic shoe.

2.2.3. Health and Safety

The SafeStep is safe for wear and usage by all consumers. All electrical components operate safely in the specified environments. Care is taken to ensure the safety of all battery systems, electrical components and sensors. All circuits are built to ensure proper grounding and safe operation.

2.2.4. Time

The SafeStep is completed within two academic semesters. This period includes research, development, design, and testing.

2.3. Standards

The SafeStep utilizes multiple standards in its construction, design, and testing. These standards allow us to guarantee the safety of users, the design group, and all others. The standards that the project utilizes allow the design group to ensure the stability of the design, the validity of our testing, and the accuracy of the data collected by both the project and our testing. If required to alter the design of the product, testing will be conducted to ensure that the device still falls within standards. If the project after modification no longer meets standards, the project will be modified or the usage of the standard in question re-evaluated.

Table 2.3: Engineering Standards

Specific Standard	Standard Document	Specification / Application
IP-67 [5]	This product conforms to IEC Standard 60529.	The SafeStep is dust-tight and can withstand immersion of up to 1 meter in water.
Bluetooth V5.0 [6]	This product follows Bluetooth Core Specification V5.0.	The SafeStep maintains constant Bluetooth connectivity with a user's mobile device.
ASTM E879-20 [7]	During calibration of the temperature sensors, the product is held to the Standard Specification for Thermistor Sensors for General Purpose and Laboratory Temperature Measurements.	The SafeStep requires accurate temperature readings for the measurement of the user environment.
IEC 62680-1-3:2022 [8]	The SafeStep USB interfaces for data and power - Part 1-3.	The SafeStep features a USB-C port to recharge the battery.
FCC Section 15.109 [9]	The SafeStep is designed to the FCC Section 15.	The SafeStep features RF and the device can communicate within 10 meters.

The standards presented above are expanded upon in the following section.

2.3.1. Communications Standards

The SafeStep utilizes Bluetooth Version 5 to facilitate communication between the device and the user's mobile device.

2.3.2. Electronic Standards

The SafeStep is used within multiple inhabited environments: homes, public environments, and assisted living facilities. These environments require the SafeStep to use standards for electromagnetic interference from Federal Communication Commission (FCC) Section 15.109. This standard is necessary because of the large amount of electromagnetic interference caused by modern devices.

The SafeStep utilizes Ingress Protection (IP) 67 resistance standards outlined under International Electrotechnical Commission (IEC) Standard 60529. The implementation of this standard ensures that the SafeStep cannot be penetrated by dust and is able to withstand temporary submersion within 1 meter of water. This standard allows the device to withstand everyday substances that a user can experience.

The SafeStep utilizes a USB-C connector, as outlined in IEC 62080-1-3 for power input to the batteries.

The SafeStep utilizes a thermometer that conforms to the standards outlined in ASTM E879-20. This thermometer allows the unit to measure and monitor environmental temperature.

2.3.3. Testing Standards

The SafeStep will be subjected to testing standards outlined within IEC 60529 for submersion testing. The same standard will be used in testing dust resistance.

The SafeStep will be subjected to electromagnetic testing to meet FCC Class B standards for electromagnetic interference.

References

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