# **1. DESIGN REQUIREMENTS/CONSTRAINTS**

Highway safety hardware, such as guardrails and crash cushions, are made to save lives. However, to save lives and prevent injury, they are often damaged or destroyed. As a result, roadside infrastructure employees must drive across the region to check for damage. This time-consuming process costs taxpayers for the gas and labor consumed in the process. Additionally, it can be months between trips to check for damage, leaving the broken guardrails at risk for further car accidents. Wireless roadside emergency collision kinetic sensor (WRECKS) is a device that attaches to the terminal end section of a guardrail to alert customers whenever the asset is hit. WRECKS allows faster response times to reach accident victims as well as to repair damaged guardrails. It also saves the customers the resources used while sending a driver to check for damage. The design team’s sponsor, Atwood Fence Company, is a guardrail manufacturing company. They have provided some of the design constraints and technical standards presented in this document.

## **1.1 Technical Design Constraints**

The technical constraints for WRECKS are listed in Table 1.

Table 1.1. Technical Design Constraints

|  |  |
| --- | --- |
| **Name** | **Description** |
| Battery Life | The battery lasts two weeks without charging. |
| GPS Data | WRECKS uses a GPS that is accurate within 8 meters. |
| Sensor Data | The IMU sensor has a margin of error of 1%. |
| Sampling Rate | The device samples IMU data at 50 Hz. |
| Communication | The WRECKS system alerts customers to damaged safety assets via web and Android applications, as well as email and MMS messaging. |
| Latency | Notifications from WRECKS reach the customer no later than thirty seconds after a crash occurs. |

The technical constraints listed above are explained in detail below.

### **1.1.1 Battery Life**

While WRECKS includes a solar panel for passive power, it has a battery that lasts two weeks. This amount of time is adequate to keep WRECKS powered in the case of prolonged insufficient sunlight.

### **1.1.2 GPS Data**

The crash alert includes the accident’s location. WRECKS features a GPS that is accurate within 8 meters. With the average terminal end section being about 4 meters in length, this accuracy allows the customers enough detail to see which end of the rail is hit.

**1.1.3 Sensor Data**

WRECKS utilizes an Inertial Measurement Unit (IMU) to record motion data. It includes an accelerometer and gyroscope to record within a 1% margin of error [1]. This degree of accuracy is sufficient to be able to detect when the safety assets are hit and notify the customers. For our application, 1% accuracy can be considered while writing the software.

**1.1.4 Sampling Rate**

The sampling rate of the microcontroller is 50 Hz. This means the IMU data is examined 50 times per second to ensure rapid reaction to the collision [2].

### **1.1.5 Communication**

Customers receive crash notifications that can be accessed via web and Android apps. These applications are user-friendly. These notifications can also be sent via email or MMS messaging.

**1.1.6 Latency**

When a crash occurs, a signal travels from the device to the customer. This entire process takes place in less than thirty seconds, so that the customer can respond to a crash in a timely manner.

## **1.2 Practical Design Constraints**

The practical design constraints for WRECKS are listed in Table 1.2.

Table 1.2. Practical Design Constraints

|  |  |  |
| --- | --- | --- |
| **Type** | **Name** | **Description** |
| Safety | Notifications | The device is able to contact emergency services in the case of a crash. |
| Environmental | Waterproofing | The device survives storms and flooding. |
| Environmental | Temperature | The device functions in both hot and cold severe weather conditions. |
| Economic | Price | The device is priced less than one hundred dollars. |
| Sustainability | Lifespan | The device is designed to last five years. |
| Manufacturability | Attachment | WRECKS is attached to the guardrail using adhesive pads. |
| Manufacturability | Size | The entire device is no larger than one hundred millimeters wide, one hundred millimeters long, and fifty millimeters tall. |

### The practical design constraints are discussed and elaborated below.

### **1.2.1 Notifications**

WRECKS is capable of sending notifications to customers including departments of transportation and emergency response units. This feature can save lives, ensuring a quick response to car crashes.

### **1.2.2 Waterproofing**

Because WRECKS is attached to guardrails, it is permanently placed outside. Thus, it has to encounter and withstand heavy rain and dirt, protecting the electronics inside. Often, many guardrails exist on bridges, which are commonly in flood zones. WRECKS can withstand full submersion if flooding should occur.

### **1.2.3 Temperature**

The temperature range in which the device can normally operate is between -29 and 54 degrees Celsius. This range is the average lowest to average highest temperature in the continental United States [3]-[4].

**1.2.4 Price**

To remain economically friendly to customers, the price of the WRECKS device is below one hundred dollars. This price remains affordable enough to be mass-produced while remaining desirable to customers.

**1.2.5 Lifespan**

In a meeting, our sponsor Atwood Fence Company said that the average terminal end section of a guardrail lasts five years before being replaced. Often, they are damaged and need to be replaced before the five-year replacement window. WRECKS lasts five years to match the lifespan of the guardrail. The purpose of WRECKS is to send a notification when a collision occurs. Thus, it is durable enough to survive the collision and send crash data to the customer.

**1.2.6 Attachment**

The device is attached to the guardrail with an adhesive pad. Adhesive pads offer the best method of attachment without compromising the engineered structure of the terminal end section. Any holes drilled into the guardrail could alter its crumpling effect, causing a safety issue.

### **1.2.7 Size**

WRECKS’ dimensions do not exceed 100 millimeters in width, 100 millimeters in length, and 50 millimeters in height. These dimensions ensure that the device can be mounted discreetly on the guardrail. These specifications were requested by Atwood Fence Company in a meeting.

**1.3 Engineering Standards**

Some of the listed constraints are related to specific engineering standards. The corresponding standards are listed in Table 1.3.

Table 1.3. Appropriate Engineering Standards

| **Specific standard** | **Standard document** | **Specification / application** |
| --- | --- | --- |
| IP Rating | IP-67 | WRECKS meets the specifications for an IP-67 rating. |
| Communication | FCC 01-158 | WRECKS uses the LoRa protocol, which utilizes the 915 MHz ISM band. |
| Communication | IEEE Std 802.16m | WRECKS also uses the 4G/LTE network for the communication. |
| Global Positioning System | IEEE 2030.101-2018 | WRECKS app utilizes GPS technology to pinpoint the detected collision. |

### The standards introduced above are discussed below.

### **1.3.1 IP Rating**

The enclosure protecting WRECKS’ internals meets requirements to achieve an IP rating of 67. This rating states that the device is “protected from total dust ingress” and “protected from (liquid) immersion between 15 centimeters and 1 meter in depth” [5]. This allows WRECKS to survive floods as well as debris from the road.

**1.3.2 Communication**

Industrial, Scientific, and Medical radio (ISM) bands are free to use. WRECKS specifically uses the 915 MHz ISM band for primary communication between the sensor and the server.

**1.3.3 Communication**

Not all locations have LoRaWAN coverage. Thus, WRECKS also utilizes the 4G/LTE network for extended coverage situations [6].

**1.3.4 GPS**

WRECKS uses GPS to upload the latitude and longitude coordinates of the collision. These GPS coordinates allow the customers to know where the damaged rail is located. GPS can also be used to set WRECKS’ internal clock to ensure accurate collision time is reported [7]. The GPS standard allows for location information with a margin of error within 8 meters as well as time synchronization within 30 nanoseconds [8].

## **References**

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