# **1. DESIGN REQUIREMENTS/CONSTRAINTS**

Highway guardrails are made to be destroyed. WRECKS (wireless roadside emergency collision kinetic sensor) is a sensor that attaches to the terminal end section of a guardrail to alert customers whenever a car hits a guardrail. This allows for a faster response time to repair damaged guardrails and saves the expensive resources wasted in routine checks. Outlined in this document are some of the technical and physical constraints of the project, guided by engineering standards.

## **1.1 Technical Design Constraints**

The technical constraints for WRECKS are listed in Table 1.1.

Table 1.1. Technical Design Constraints

|  |  |
| --- | --- |
| **Name** | **Description** |
| Battery Life | Battery capacity lasts 2 weeks without solar charging. |
| GPS Data | GPS accuracy is within 6 meters. |
| IMU Data | The IMU sensor has an accuracy of ±1%. |
| Sampling Rate | The device samples IMU data at 50 Hz. |
| Application | The WRECKS system alerts users via a web app and an Android application. |
| Latency | Notifications from WRECKS reach users no later than 30 seconds after a crash occurs. |

### **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].

### **1.1.2 GPS Data**

Upon receiving the crash alert, the customer will need to locate where the accident occurred. WRECKS features a GPS that is accurate within 6 meters, allowing the customer to receive precise location information with the crash alert. This information shows the location of the accident accurately enough to show which end of the rail has been hit.

**1.1.3 IMU Data**

WRECKS utilizes an Inertial Measurement Unit (IMU) to record motion and position data. It includes an accelerometer and gyroscope to record crash data within ±1% accuracy.

**1.1.4 Sampling Rate**

The sampling rate of the microcontroller is 50 Hz. This ensures the IMU data is quickly captured to ensure rapid reaction to a collision [2].

### **1.1.5 Application**

Users receive crash notifications that can be accessed via a web app and an Android app. These applications are user friendly and allow convenient management and updates.

### **1.1.6 Latency**

When a crash occurs, a signal travels from the device to the user. This entire process takes place in less than 30 seconds, so the user can respond to a crash in a timely manner.

## **1.2 Practical Design Constraints**

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

Table 1.2. Practical Design Constraints

|  |  |  |
| --- | --- | --- |
| **Type** | **Name** | **Description** |
| Environmental | Waterproofing | The device can survive storms and flooding. |
| Economic Factors | Durability | The device can survive when the guardrail is hit. |
| Environmental | Temperature | The device functions in both hot and cold severe weather conditions. |
| Sustainability | Lifespan | The device is designed to last 5 years. |
| Safety | Attachment | WRECKS is attached to the guardrail using adhesive pads. |
| Manufacturability | Size | The entire device is not larger than a standard brick. |

### **1.2.1 Waterproofing**

Because WRECKS is attached to guardrails, it is permanently placed outside. This means that it encounters and withstands heavy rain and dirt, protecting the electronics inside. Even when the device is splashed by passing cars, the internals survive.

### **1.2.2 Durability**

The purpose of WRECKS is to send a notification when a collision occurs. Thus, it is durable enough to survive a guardrail collision and send crash data to the customer.

### **1.2.3 Temperature**

The temperature range in which the device can normally operate is between -20°F to 130°F. This range is the average lowest and highest temperatures in the continental United States, where the device will be marketed [3, 4].

**1.2.4 Lifespan**

According to Atwood Fencing, the average terminal end section of guardrail lasts 5 years before being replaced. Often, they are damaged and need to be replaced before the 5-year maintenance window. WRECKS lasts 5 years to sufficiently match the lifespan of the guardrail.

**1.2.5 Attachment**

The device is attached to the guardrail with an adhesive. Adhesive offers the best method of attachment without compromising the meticulously engineered structure of the terminal end section.

### **1.2.6 Size**

WRECKS’ dimensions do not exceed 92 mm in thickness, 57 mm in height, and 203 mm in length. These are the dimensions of a standard brick and are provided by the customer.

**1.3 Engineering Standards**

Some of the 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** |
| --- | --- | --- |
| Ingress Protection | IP-44 | The electronics inside of WRECKS are protected from splashes and foreign objects. |
| Effective Use | IEEE/IEC 82079 | The product comes with an effective use guide showing how to be correctly utilized. |
| FCC 915 MHz | P1451.5.5 | WRECKS uses the LoRa protocol as the primary method of communication between the sensor and the server. |
| GPS | IEEE 2030.101-2018 | WRECKS’ app utilizes GPS technology to pinpoint the detected collision. |

### **1.3.1 IP Rating**

All electronics involved in WRECKS are enclosed in a waterproof case. This follows the IP-44 standard, which allows for protection against objects at least one mm in size as well as waterproofing against splashes [5].

**1.3.2 Effective Use**

Understanding how to effectively use a product is essential for the customer. A document with standard principles and product use is included with WRECKS, following the IEEE Effective Use standards [6].

**1.3.3 FCC 915 MHz**

ISM bands are free to use. WRECKS uses the 915 MHz ISM band to communicate between the sensor and the server, providing collision detection packets.

**1.3.5 GPS**

WRECKS uses GPS to upload the latitude and longitude coordinates of the collision. This allows for the customer to know where the damaged rail is located. GPS is also be used to set WRECKS’ internal clock to ensure accurate collision time is reported [7]. The GPS standard allows for less than 8 m margin of error as well as time synchronization within 30 ns [8].

## **References**

[1] Skilling, Tom. “Ask Tom: What Is the Longest Stretch without Sunshine?” Chicagotribune.com, Chicago Tribune, 22-May-2019. [Online]. Available: https://www.chicagotribune.com/weather/ct-wea-0131-asktom-20170130-column.html. [Accessed: 12-Feb-2022].

[2] G. Shi, C. S. Chan, W. J. Li, K.-S. Leung, Y. Zou, and Y. Jin, “Mobile human airbag system for fall protection using MEMS sensors and embedded SVM classifier,” *IEEE Sensors Journal*, vol. 9, no. 5, pp. 495–503, 2009.

[3] J. Masters, “Death Valley, California, breaks the all-time World heat record for the second year in a row " Yale climate connections,” *Yale Climate Connections*, 27-Jul-2021. [Online]. Available: https://yaleclimateconnections.org/2021/07/death-valley-california-breaks-the-all-time-world-heat-record-for-the-second-year-in-a-row/. [Accessed: 12-Feb-2022].

[4] “Average Temperature by State,” *Average temperatures by state 2022*. [Online]. Available: https://worldpopulationreview.com/state-rankings/average-temperatures-by-state. [Accessed: 12-Feb-2022].

[5] Degrees of Protection Provided by Enclosures (IP Code). International Electrotechnical Commission, 2013.

[6] IEEE/IEC International Standard for Preparation of information for use (instructions for use) of products - Part 1: Principles and general requirements. IEEE: IEEE, 2019.

[7] “GPS.gov: Timing Applications,” Gps.gov, 2019. https://www.gps.gov/applications/timing/. [Accessed: 12-Feb-2022].

[8] Global Positioning System Standard Positioning Service Performance Standard. Washington, DC: United States Department of Defense, 2020. [Online]. Available: https://www.gps.gov/technical/ps/2020-SPS-performance-standard.pdf [Accessed 12-Feb-2022].