Design of an IoT-Based Marine Transportation Accident Rescue and Detection System by Using Solar Panels as an Energy Source

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***Abstract* - The use of sea transport is a means of mobility between islands that is often used by the Indonesian people. Data on shipping accident investigations by the KNKT in 2018-2021 show that the number of victims who died / disappeared was 342 people. The purpose of this design is to reduce the number of victims of sea transportation accidents. This design uses a quantitative experimental method. The stages carried out include secondary data collection, product design, manufacturing, testing, and product evaluation. This design is a bracelet equipped with an airbag and GPS module and uses the LoRaWAN network as data communication. The results of data communication testing, it can be concluded that the range of LoRa data communication reaches a distance of 2 km. Based on the test results, it is also concluded that the average error on the NEO-6MV GPS module ranges as far as 1.82 meters from the actual position. The airbag capacity test shows that the airbag used as a buoy can be used by victims with a body weight of up to 86 kg. The results of the power calculation in this design show that the battery discharge and charging time are about 27 hours and 7 hours, respectively.**

Index Terms: **Investigation, LoRaWAN, Error, GPS, Realtime**

I. INTRODUCTION

Indonesia is the largest archipelago in the world, with a sea area of 5.8 million km^2 and 17,504 islands [1]. Therefore, the use of sea transport is a means of inter-island mobility that is often used by the people of Indonesia. In 2020, the number of sea passengers was 12.58 million passengers with departures and 12.70 million passengers with arrivals [2] .The use of sea transport as a means of inter-island mobility has its own dangers including bad weather, natural disasters, and human negligence. According to data from the investigation of shipping accidents by the KNKT in 2018-2021, the number of victims who died / disappeared was 342 people [3].The large number of dead/missing victims tends to be caused by the slowness of the SAR team in finding the victims. The vastness of the ocean and the waves at sea are believed to be contributing factors. In general, life jackets are provided as a safety system for victims at sea. However, it will be dangerous if the victim is not found immediately. Because victims can only survive without food and water at sea within 3-7 days and depends on the health and fitness of the victim at that time [4] .In its development, a rescue and detection system has already been designed, namely a rescue bracelet by utilising GPS and temperature sensor lights. This bracelet is equipped with a water sensor light strip, this light turns on when there is contact with water. This facilitates the search for victims by the SAR team, because the victim is wearing a luminous bracelet [5]. In addition, a Chinese company called Shenzhen Dowins Tech Limited has successfully designed and produced a system in the form of an anti-drowning survival bracelet that can help a person to float when in water. The bracelet is equipped with a compass, whistle, CO_2 cylinder, and airbag. The way the bracelet works is that the user only needs to pull the lever next to the CO_2 cylinder and the airbag will inflate quickly [6] .Therefore, it was inspired to develop an Internet of Things-based marine transport safety system with solar panels as an energy source. This product is a wristband equipped with an airbag, and a GPS module. The product is designed to respond when the lever is pulled by the victim, which automatically fills the airbag with carbon dioxide gas from the gas cylinder. The LoRa sender is in charge of sending GPS location information to the LoRa receiver, which will be integrated into a database and smart phone application.

II. LITERATURE REVIEW

A. *Environmental Conditions*

Environmental conditions, especially in oceans that have unfavorable climate change and internet network signals that are difficult to obtain, are a challenge for the rescue team in searching and rescuing victims of sea transportation accidents. To overcome these problems, this bracelet design uses the LoRaWAN network as data communication. This type of communication can work with a distance of 5 to 15 kilometers [7]. This can happen because the LoRaWAN network uses wireless sensor network technology that supports the need for two-way remote data communication from machines that are the object of IoT.

B. *Microcontroller*

The use of a microcontroller in this design is used to process data. The data processed includes GPS reading data in the form of position coordinates (latitude and longitude). In addition to processing data, the microcontroller is also used as a sender or data link from the sensor to LoRa. The microcontroller used is ESP32. The results of the implementation of multi-node sensor data transmission using the master slave method on LoRa communication using this type of microcontroller show that the largest percentage of packet loss is found in data transmission from sensor node 2 to the gateway which is about 200 meter away and the highest average latency at a testing distance of 100 meter [8].

C. Tracker System

The tracking system in this design serves to detect the coordinates of the victim's location. The tracking system used is a GPS module. The GPS module works by capturing and processing signals from navigation satellites. Data from GPS readings are position coordinates (latitude and longitude). The type of GPS module used is the NEO-6M GPS module.

Architectural choices and compact power and memory make this GPS module ideal for battery-operated mobile devices with tight power and space constraints [9]. The results of designing a motorbike location tracking system using the U-Blox Neo 6mv GPS module and GSM Sim800l show that the accuracy of the GPS module coordinate data is 98% with comparison data, namely Google Maps coordinate data [10].

D. Wireless Sensor Network

The use of a wireless sensor network in this design serves as a data collector and sender to a server for data processing. Therefore, WSN is widely used in data collection, security monitoring and code tracking processes. Ade and others have completed the use of WSN as an air quality monitoring system [11].

In this design, the wireless sensor network used is LoRa-based. The LoRa module used is the LoRa SX1276 module with a frequency of 915 MHz and a range of approximately 2 km. The way the LoRa module works is the sensor node, the reading data will be sent to the node header so that it can be displayed in the android application. The sensor node referred to earlier is the GPS module.

E. Energy Source System

The mechanism of how the energy source system works in this design includes solar panels converting solar energy into electrical energy. The charger module will charge the battery according to its capacity.

The output voltage value of the charger module of 3.7 volts will be increased to 5 volts using a voltage amplifier module so that the voltage can be accepted by the microcontroller. Himsar and Halim succeeded in making battery charger technology using solar energy in Petangguhan Village, Galang District, Deli Serdang Regency to overcome the increase in electricity tariff prices from PLN [12].

F. Interface and Database System

The use of a database in this design is used to store the GPS module reading results. The reason for using this type of database is because when the data changes, the application connected to firebase will be automatically updated through every device, both website and mobile. Ilham successfully completed the creation of an android mobile-based "E-Tilang Smartphone" application using firebase real-time database [13].

G. Buoying System

The float system in this design uses several materials, namely needle valves, levers, airbags and 12gram carbon dioxide gas cylinders. As a result, gas will flow from the gas cylinder to the airbag. Furthermore, the airbag will expand and is ready to be used by the victim. The size of the airbag used is 40x50 cm so that it is safe to use by users who weigh no more than 100 kg.

III. METHODOLOGY

The research stages in the design of an IoT-based marine transportation accident victim detection and rescue system by using solar panels as an energy source are shown in Figure 1.

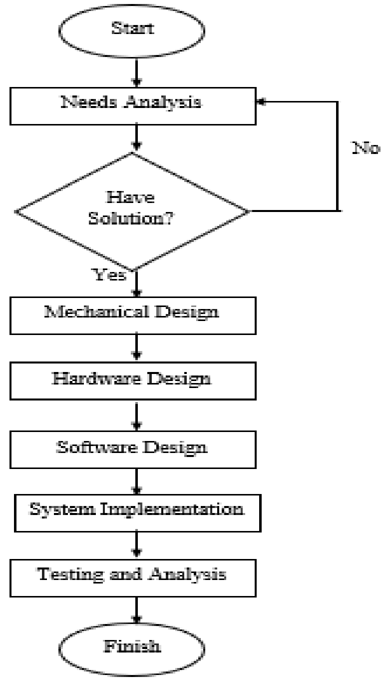

Fig. 1. Flowchart of Marine Transport Safety System Development Research

The quantitative experimentation method was used as the method for testing the design. This method of activity systematically describes how to implement the design when in the water and measure the effectiveness of the design [14]. Testing this design consists of direct observation and retrieval of results for data analysis. The process of making this design consists of several stages, namely needs analysis, mechanical design, hardware design, software design, system implementation, and testing with analysis.

A, Needs Analysis

In making this product, mastery of mechanical design, hardware design and software design is essential. In mechanical design, an understanding of the materials used is required to produce a solid and waterproof product body and lid. Hardware design involves knowledge of cable security, the use of microcontrollers, GPS modules, and LoRa SX1276 modules. The system also uses the LoRaWAN network at a frequency of 915 MHz, as well as 18650 3.7v 6800 mAh lithium batteries and 5v 5w 1000 mAh solar panels as power sources. In the software design, there are two main components: microcontroller programming and smartphone application. The ESP32 microcontroller is used to control various components, such as GPS and LoRa. The collected data is sent via LoRa to the database with the help of a Wi-Fi module. On the other hand, the smartphone app provides a user interface that displays the victim's location with data retrieved from the Firebase database that serves as an intermediary between the microcontroller and the app.

B. Mechanical Design

The mechanical design of this product uses AutoCAD software. The material used for the casing of the box containing the components and airbag is Filament PLA. The use of this material was chosen because it has very high strength properties and because this material is more environmentally friendly. In addition, the material used in the manufacture of airbags is Thermoplastic Polyurethane (TPU). The process of creating the mechanical design of this product will involve the use of a 3D printer.

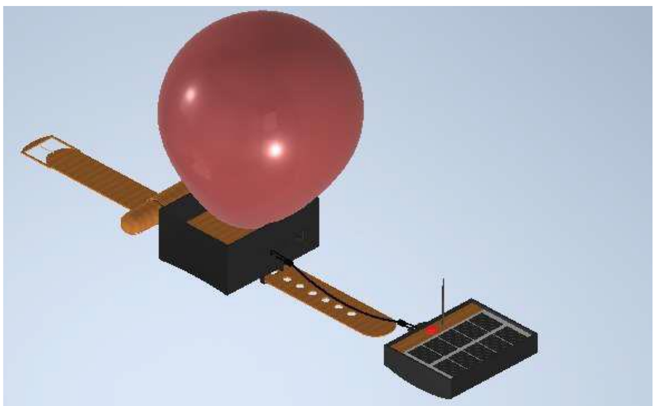

Fig. 2. Mechanical Design of Marine Transport Safety System Development Research

The dimensional size specifications of this product involve various aspects that need to be considered. The size of the component holder is 151 mm long, 114 mm wide, 30 mm tall, and 3 mm thick. Meanwhile, the body of the product has a different size, which is 111 mm long, 61 mm wide, 52 mm tall, and 3 mm thick.

C. Hardware Design

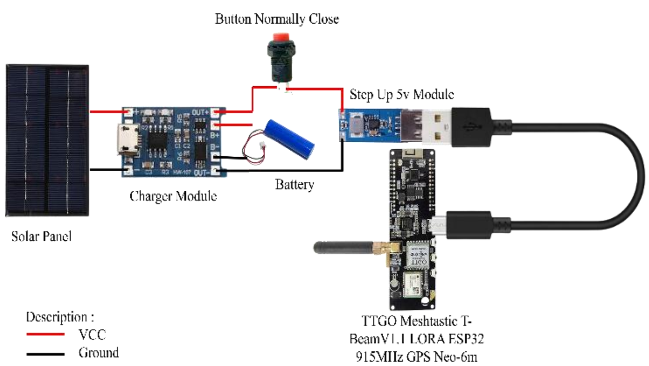

Fig. 3. Hardware Design of Marine Transport Safety System Development Research

The hardware mechanism in this product works, for instance, when the solar panel converts sunlight into electrical energy. The charger module will charge the battery according to its capacity. Furthermore, there is a normally closed button actuator as a breaker and connector for the flow of electrical energy. The output voltage value of the charger module of 3.7 volts will be increased to 5 volts using a voltage amplifier module so that the voltage can be accepted by the microcontroller. When the microcontroller receives electrical energy automatically, the GPS Neo 6M module reads the location coordinates, and the LoRa 915MHz module acting as a sender sends the readings to the receiver LoRa module.

D. Software Design

Software design is related to the overall working mechanism of the product. When the victim pulls the lever, the needle valve automatically presses the carbon dioxide canister so that the carbon dioxide gas will make the airbag inflate and is ready to be used by the victim as a life preserver. In addition, the normally close push button will connect electrical power between the power supply circuit and the microcontroller. When the microcontroller receives electrical power, the GPS module will immediately process the reading of the victim's current location coordinate data and the LoRa transmitter will send the GPS reading results to the LoRa receiver and will be forwarded to the database then to the smartphone application. Furthermore, the smartphone application user will receive a notification that the bracelet is being used when the application is opened according to the bracelet code, the coordinate point of the location of the victim or bracelet user will be displayed. When the application user presses the display track, we will be redirected to Google Maps to detect the location of the victim so that the victim can be found immediately. The flowchart of the overall product work mechanism can be explained in Figure 4.

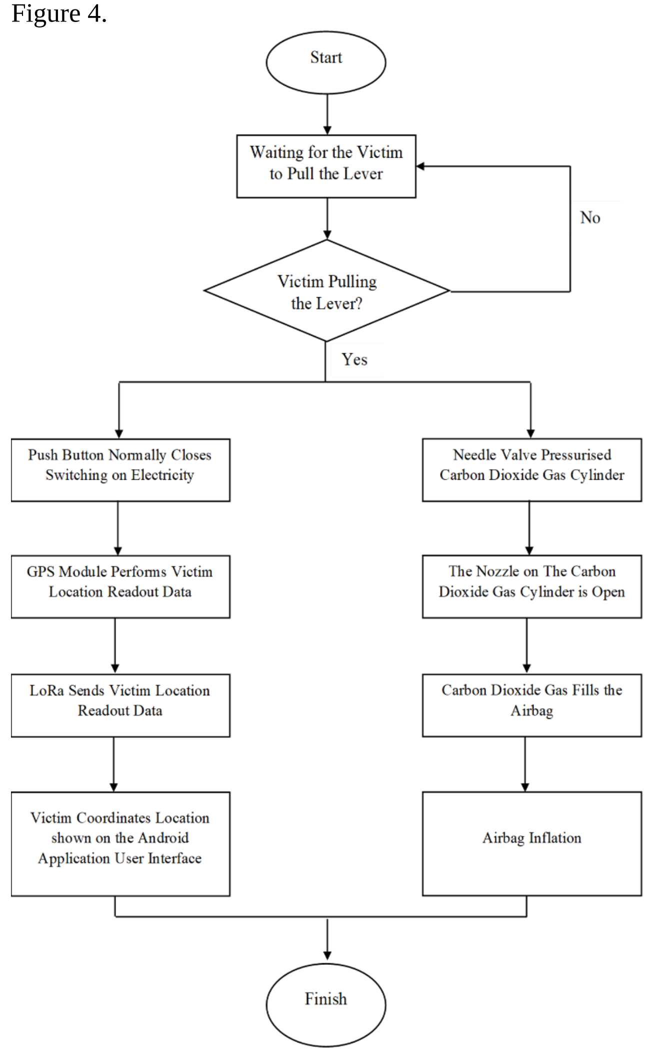

Fig. 4. Flowchart of the Overall Product Work Mechanism

E. System Implementation

The system implementation process starts with printing the mechanical design using a 3D printing machine. When the printing of the mechanical design is complete, then the laying and wiring of electrical components is carried out. In addition, this product also requires an application that can be operated on a smartphone device. This application will receive the coordinate point of the victim and display it on the smartphone screen for further evacuation process.

F. Testing and Analysis

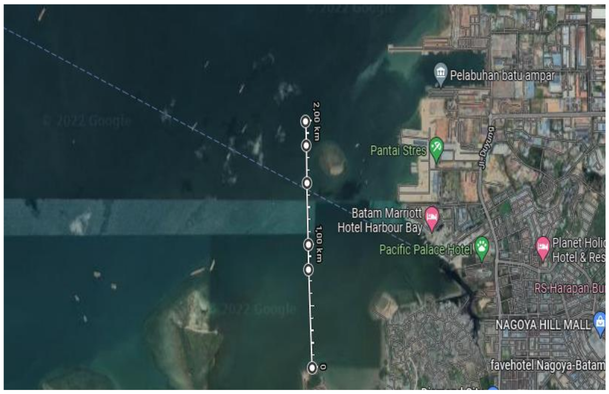

Fig. 5. Maps Testing the Effect of Distance on LoRa Communication

Some aspects that will be tested on the product include the effect of distance on the RSSI value in LoRa communication which is done by communicating data based on several adjusted distance parameters, testing the accuracy of the U-Blox Neo 6MV GPS module which is done by comparing the latitude and longitude readings on the U-Blox Neo 6mv GPS and Google Maps, and testing the airbag capacity which is done by using an airbag as a float with several adjusted body weight parameters. In addition, power calculations were also carried out to obtain battery discharge and charging times. Meanwhile, testing of this design was carried out on the beach of Tanjung Tritip beach, Tj. Uma, Kec. Lubuk Baja, Batam City, Riau Islands Province on 8 September 2022 for 1 day.

Fig. 6. Testing Location

Some of the tools used in testing this design are an ESP32 microcontroller board equipped with a 915MHz LoRa module and Neo-6m GPS, airbags, Google Maps applications, cameras, and stationery.

IV. RESULTS AND DISCUSSION

A. Functional Products

The following are the results of the functional product design "Design of an IoT-Based Marine Transportation Accident Rescue and Detection System by Using Solar Panels as an Energy Source".

Fig. 7. Rescue and Detection System Functional Products

The production of products is a very important thing. Of course, the product has a function in accordance with the design that has been made since before the product manufacturing activities are carried out. The resulting product functions as a rescuer which is a buoy system that can accommodate the user's body weight, an interface and database system that can display the location of the victim to application users in real time, a tracking system that can detect the whereabouts of the victim, a data communication system that is able to communicate even in conditions of unstable climate change and difficult internet networks, and an energy source system that can generate electrical power so that the product can work for one full day.

B. User Application Design of Rescue and Detection System

As an IoT-based product, this product is equipped with an application with a user interface that displays the victim's location point. The application will display a login page where the application user will enter an email and password. However, before entering some data required for registration. Next, the welcome page will display the application user name followed by the selection of the ship.

Then the bracelet selection page, where each bracelet button contains a code. For example, 1.1 means that the bracelet is on ship 1 with serial number 1. The application will display the coordinate points of the product user in the form of latitude and longitude, commonly referred to in English as latitude and longitude. Furthermore, the application that has received the coordinate point will be forwarded to the Google Maps application so that the location and route from the application user to the product user can be known.

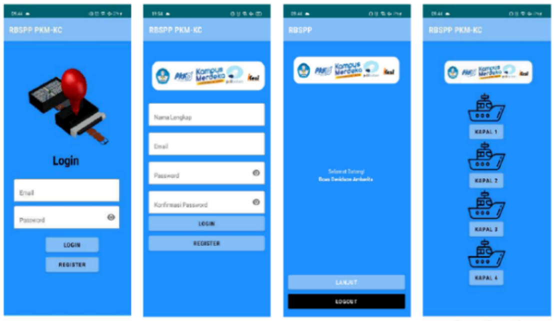

Fig. 8. Initial Application Display

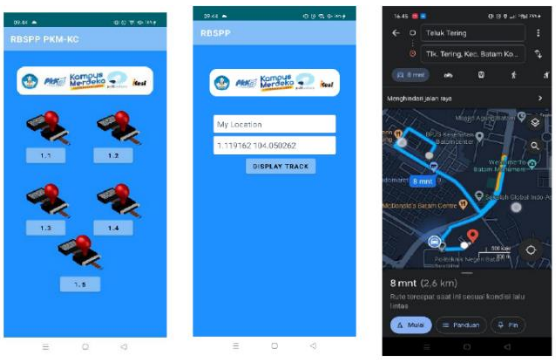

Fig. 9. Final Application Display

C. Effect of Distance on RSSI Value in LoRa Communication

Received Signal Strength Indicator (RSSI) is a unit of signal strength received by a wireless device [15]. The results of LoRa communication testing with RSSI value parameters can be seen below:

TABLE 1
Table of RSSI Value Testing Results on LoRa Communication.

No	Range (m)	RSSI (dBm)
1	100	-96
2	200	-100
3	300	-105
4	400	-110
5	500	-112
6	800	-113
7	1000	-115
8	1500	-117
9	1800	-119
10	2000	-122

LoRa communication test results at a distance of 100 m showed an RSSI value of -96 dBm. Furthermore, LoRa communication testing at a distance of 1000 m shows a reduced RSSI value of -115 dBm. However, the LoRa communication test at a distance of 2000 m, showed a decreasing RSSI value of -122 dBm. Based on the test results of LoRa communication, it can be concluded that distance has a big influence on the RSSI value in LoRa communication. The greater the distance between the sending LoRa and the receiving LoRa, the less the RSSI value obtained [16]. This also shows that the LoRa module in the product can communicate data up to a distance of 2 km.

D. Testing the Accuracy Level of the Tracking System

The tracking system used in this design is the Neo-6Mv GPS module. Architectural choices and compact power and memory make this GPS module ideal for battery-operated mobile devices with tight power and space constraints. The results of testing the accuracy level of the Neo-6Mv GPS module can be seen in the table below:

TABLE 2
NEO-6MV GPS Module Accuracy Testing.

No	Module GPS Neo-6Mv	Google Maps	Accuracy (Meters)
1	1.132351,103.992305	1.132343,103.992312	1.00
2	1.132708,103.991023	1.132698,103.991026	1.14
3	1.133799,103.988887	1.133789,103.988885	1.19
4	1.134301,103.987605	1.134283,103.987613	1.34
5	1.134970,103.985526	1.134951,103.985544	2.15
6	1.135585,103.983643	1.135576,103.983665	2.15
7	1.136186,103.982287	1.135570,103.983663	2.20
8	1.136878,103.980814	1.136843,103.980846	2.40
9	1.137770,103.979112	1.137756,103.979131	2.20
10	1.138071,103.977326	1.138051,103.977348	2.45
Average (Meters)			1.82

Based on the test results in the table above, it shows that the average error on the NEO-6MV GPS module is around 1.82m from the real time position. The test also shows that the detection module used in the product has a fairly low error rate.

E. Testing the Airbag as a Buoy

The float system in this design uses several materials, namely a needle valve, lever, airbag and 33gram CO_2 gas cylinder. As a result, gas will flow from the gas cylinder to the airbag. Furthermore, the airbag will expand and is ready to be used by the victim. The size of the airbag used is 260x80 mm so that it is assumed to be safe to use by victims who weigh no more than 100 kg. This test aims to determine the exact specifications of the airbag capacity of the product. The results of the airbag capacity test with body weight parameters can be seen in the table below:

TABLE 3
Airbag Capacity with Body Weight Parameters

No	Weight (Kg)	Description
1	55	Works
2	60	Works
3	68	Works
4	75	Works
5	86	Works

Based on the table above, it shows that the airbag used as a float in the product can be used by victims with a body weight of up to 86 kg.

F. Calculation of Battery Discharge Time

The calculation of the battery discharge time aims to find out how long the battery can work assuming that the solar panel has not received sunlight so it cannot charge the battery. The calculation of total battery power consumption can be seen below:

TABLE 4
Calculation of Total Battery Power Consumption

No	Load	Current (A)	Voltage (V)	Power (W)
1	Ublox NEO-6M Module	0,045	3,6	0,162
2	LoRa SX1276 Module	0,134	3,7	0,496
3	Step Up G5177C Module	0,00007	3.7	0,00026
4	Charger TP4506 Module	0,0005	5	0,0025
5	Microcontroller ESP32	0,5	5	0,25
Total Daya (W)				0,91076

The battery specification used in this product is 3.7 volts with a capacity of 6.8 Ah, then the calculation is as follows:

Battery Power (P) = V x I x h
= 3.7 Volt x 6.8 Ampere x h
= 25,16Watt Hour
Battery discharge time

$$= \frac{\text{Battery Power } (P)}{\text{Total power consumption } (P)} x 1 \text{ hour}$$

$$= \frac{25,16}{0,91076} x 1$$

= 27,62 hours

So, it can be concluded that the battery can work in full condition will run out after approximately 27 hours of use.

Calculation of Battery Charge Time

The calculation of battery charging time aims to find out how long it takes to charge the battery assuming that the solar panel are receiving sunlight and producing lyrical power in maximum condition.

The use of solar panels in this design is used as power plant which will then be flowed to the TP4506 charger module TP4506. The battery is charged by the TP4506 charger module with a charging current of 1 A and a charging voltage of 3.7 volt charging current of 1 A and charging voltage of 3.7 volts.

The battery specification used in this product is 3.7 volts with a capacity of 6.8 Ah. capacity of 6.8 Ah, then the calculation of battery discharge time is as follows:

$$\text{Battery charge time} = \frac{\text{Battery power}}{\text{Battery charge capacity}}$$

$$= \frac{(6.8 \text{ Ah}) (3.7 \text{ v})}{(1 \text{ A}) (3.7 \text{ v})}$$

= 6.8 hours
= 7 hours

V. CONCLUSION

The manufacture and testing of this design has been completed. This design is in the form of a bracelet equipped with an airbag and GPS module. This design consists of a sender and a receiver. As data communication, this design uses the LoRaWAN network. The workings of this design include when the victim pulls the lever, the airbag will expand because it is filled with carbon dioxide gas and the normally close button will send electrical power from the power supply circuit to the ESP32 microcontroller circuit. When the ESP32 microcontroller receives the input power, the Neo 6M GPS module will track the victim's location. Furthermore, the sending LoRa will send the reading results in the form of latitude and longitude data to the receiving LoRa. Then, the receiving LoRa will forward the reading results to Firebase to be stored. The reading data stored on Firebase will be displayed on the application user interface so that the victim can be evacuated immediately.

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