HAULLELUJAH! A SOLUTION TO PACKING A U-HAUL!

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1 Introduction

1.1 Objective

People are constantly moving. Whether it is a short journey from home to school or a long journey from vacationing overseas to flying home, people are always on the move. More specifically, people are always finding a new place to call home during their lifetime. This home could be temporary like a college dorm or permanent like a house to start a family. In America alone, roughly 35.5 million (about 13%) Americans move each year at least once [1]. Reasons like moving/relocating into a new and better home as well as people trying to establish their own household are just the top two reasons in a long list on why people chose to move [1]. These statistics do not even include people moving in and out of the United States as well as people moving worldwide. According to a UN study, in the year 2017 alone, there were a total of 238 million persons migrating from country to country [2]. As you can see, people are always on the move. One of the most difficult tasks in moving is finding a safe and efficient way to store and transport your belongings. In America, people moving their items by renting out moving trucks is the second most popular moving technique right behind people using their own personal vehicle to carry their belongings [1]. Companies like U-Haul offer consumers a variety of different sized trucks to rent to transfer your belongings. However, how do consumers know which truck size is ideal for them given their size and number of belongings? Far too many times people will go for the cheapest size to lower costs or tell themselves they do not have a lot of belongings. Many times, people will end up stuffing their items into the truck or squeeze things into it to ensure everything fits without realizing they could be damaging other items in the process. None of these options work well when you get to your destination and have to deal with the aftermath of having to move out all the cluttered items squeezed into the truck. Wouldn't it be nice if there was a solution that not only tells the consumer what size truck they need, but also gives them step-by-step instruction on what and where their belongings need to be placed in order to efficiently maximize the space?

Our goal for our project is to effectively and efficiently help make the process of moving one's belongings into and out of the transport vehicle easier. To make this process easier, our project aims to answer the previously mentioned questions of finding a solution that tells consumers exactly what size moving truck they need as well as how they should load their belongings to efficiently maximize the space. To accomplish this feat, it is simply done with a digital tape measure and a mobile application. The tape measure will be used to record and transmit the data containing the dimensions and sizes of the boxes holding the consumer's belongings. Using Bluetooth connectivity, the data from the tape measure will be transferred to our mobile application that will not only calculate the ideal size moving truck needed to hold all the belongings, but also give visual instructions to the user on where and how the boxes should be placed into the truck to efficiently maximize the truck space. Additionally, the mobile application would provide the user a nice interface that allows the user to keep track of which items are in each box as well as if the box contains fragile items or not.

1.2 Background

There are a few solutions that exist in the market today that help minimize and solve the problem proposed above in making the process of packing in items in a moving truck more efficient and easier. These solutions include a digital tape measure, other mobile applications, and professional moving companies. In many popular hardware stores like Menards, Lowes, and Home Depot, consumers can find digital tape measures. As you may have guessed, digital tape measures give consumers the ability to receive digital measurements from the items they are measuring. However, many consumers do not know or have the time to figure out what to do with the received dimensions or how it can be applied in the context of moving. In addition, there are other mobile applications existing in app markets today, but many of them revolve around giving users cosmetics that will make the entire process of moving easier. Specifically, apps like Wunderlist and Sortly give users the ability to make lists and take inventory of what items go in each box, but neither tells the users where they should pack the boxes in the moving truck efficiently nor give ideal rental size truck suggestions [3]. Additionally, other moving labeled apps like TaskRabbit and MagicPlan aim to assist users to decorate and manage their new home upon arrival. Neither of these apps help in the moving process at all [3]. Finally, there are professional moving companies on the market as well. However, this option is both expensive and causes liabilities. According to a report, moving companies charge by the hour for each worker with each hour charge ranging from $25 to $60 an hour [4]. This cost is for one worker alone and without a moving truck too [4]. The total average cost of moving would easily be over $1000 with all things considered. Prices also rise based on the distance needed to travel to get to the destination [4]. As you can see, hiring movers becomes an expensive option fairly quickly. Additionally, some companies charge consumers extra when handling fragile items [4]. This statement insinuates that if consumers did not choose this option, workers may not properly handle a person's belongings with care which can cause liabilities for the consumer.

1.3 High-Level Requirements List

· Mobile application algorithm must accurately and effectively determine the size of moving truck needed for the user based on incoming user measurement data in under 2 minutes.

· Mobile application must display a visual interface detailing how users should load their belongings into the moving truck to efficiently maximize space through step-by-step instructions.

· Bluetooth module attached to digital tape measure (equipped with two buttons, two status lights, and a power ON/OFF mechanism) must accurately and effectively transmit the data to the mobile application in a timely manner (seconds).

2 Design

2.1 Functional Overview

For our design to be successfully operational in satisfying our project problem, it needs to be comprised of four subsystems: control unit, pre-existing tape measure, power supply, and mobile application. Each subsystem is a vital component to the overall design and when combined together builds a product we believe will solve our problem statement. The power supply contains the necessary items to adequately power our microcontroller, which will in turn power the Bluetooth module to transfer the measurement data to our mobile application. The control unit subsystem will house our microcontroller, Bluetooth module, and a few cosmetic items like buttons and LEDs. The goal of this subsystem is to receive user inputs from the buttons as well as receive measurement data from the pre-existing digital tape measure. Finally, this subsystem will output the measurements received via Bluetooth to the mobile application. The pre-existing tape measure subsystem contains an already existing digital tape measure on the market today, which we will use to "hack" into its digital display to pipeline the measurement data into our control unit. The mobile application subsystem is comprised of a mobile app that will use the phone's Bluetooth connection to receive the measurement data and perform an algorithm that will correctly determine the size of truck need for the user. This subsystem will also provide the user with a visual interface of where they should place their belongings as well.

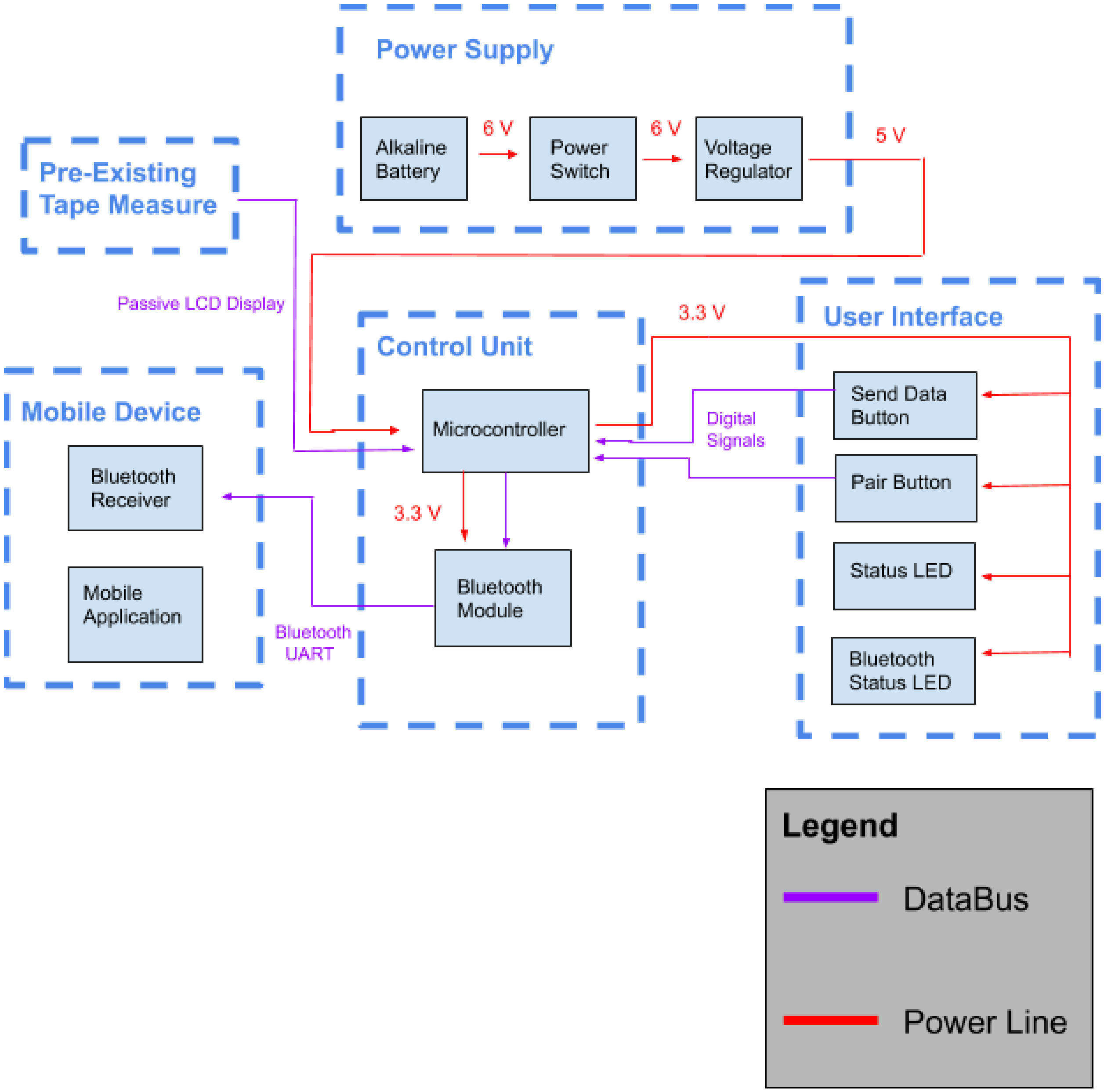

Figure 1. Block Diagram

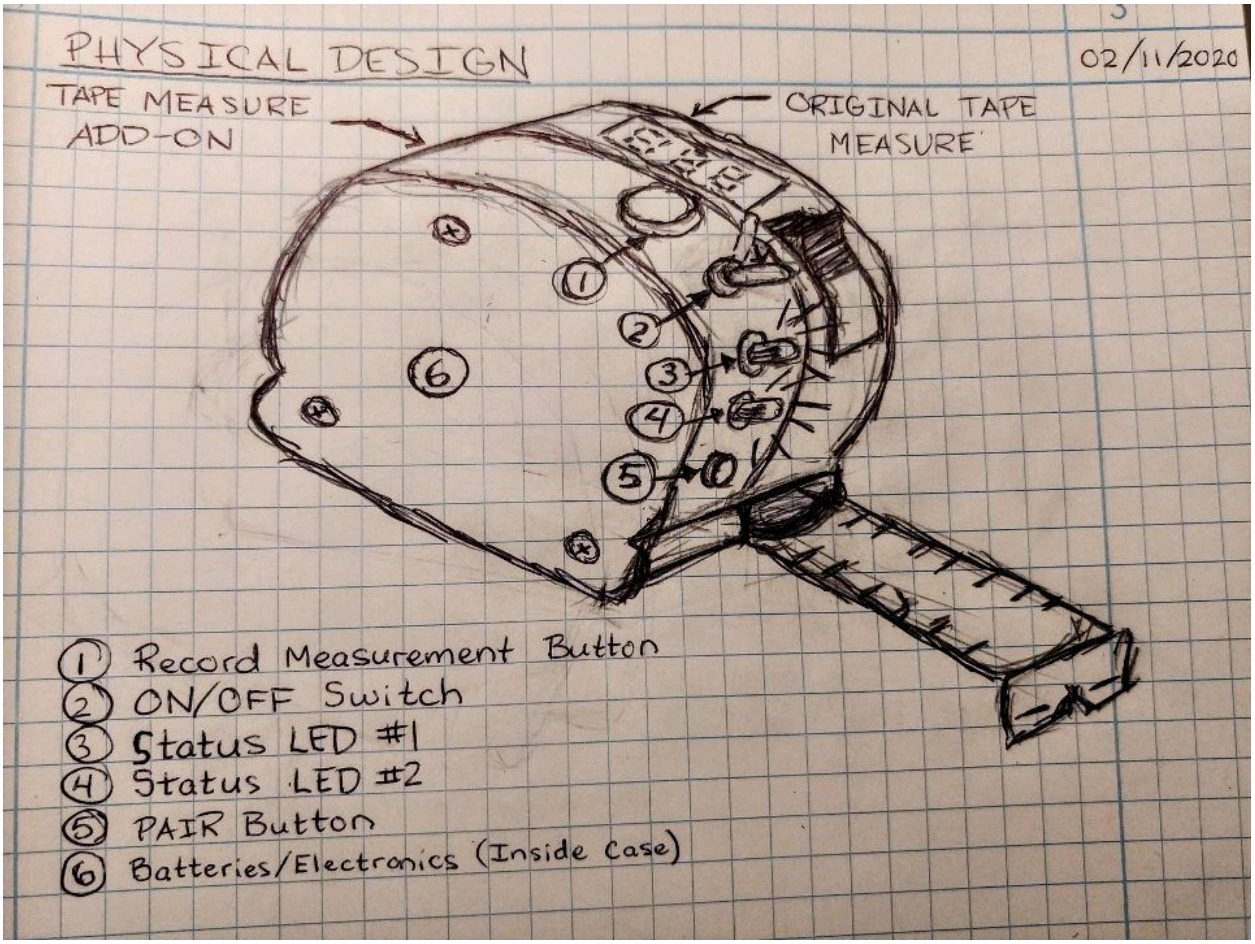

Figure 2. Physical Design

2.2 Power Supply

There are various components being added to the tape measure which require power to operate. These include the microcontroller, the Bluetooth module, lights, and buttons. With this being said, it is necessary for us to design a power supply which will power these things. The power supply will be made up of the following: alkaline batteries, power switch, and voltage regulator.

2.2.1 Alkaline Batteries

Ultimately, everything powered in the control unit will be powered by batteries. The batteries we pick need to have a high enough voltage to keep everything powered, and they need to have enough capacity to keep the digital tape measure operating for an extended amount of time. Battery voltage will be applied to a voltage regulator, so it is okay for the total voltage coming from the batteries to exceed the voltage needed for the microcontroller/Bluetooth module.

Requirement: Batteries must be able to supply 5-9.5VDC to the voltage regulator.

Requirement: Batteries must be able to last more than 1 hour of normal use by the control unit.

2.2.2 Power Switch

To keep the batteries lasting as long as possible, a small switch (likely, a slide switch) will be used to enable the user to turn on and off power to the voltage regulator, and thus, the control unit.

Requirement: Must successfully disconnect power from voltage regulator when switched OFF and successfully connect power to the voltage regulator (<0.1V drop) when switched ON.

2.2.3 Voltage Regulator

Sometimes, it is difficult for batteries to maintain a certain voltage over an extended period of time. If certain components require steady voltage levels, it isn't ideal to rely on batteries to accomplish this feat. Additionally, it isn't always possible to pick out battery combinations which meet certain voltage requirements (for example, AA batteries are rated at 1.5V; trying to produce a voltage level which isn't a multiple of 1.5V becomes difficult). Therefore, the concept of voltage regulators becomes useful. In our project, we will be powering a microcontroller and a bluetooth module which will likely require specific voltage levels which are different than the batteries we pick. By using voltage regulators, we can supply the correct voltages to these components even though our batteries may not exactly match these same voltages.

Requirement: Voltage regulator must supply voltages within +/-1V of the operating voltages of both the microcontroller and the Bluetooth module.

2.3 Control Unit

The control unit will use an Arduino BT which uses an ATmega328P Microcontroller to receive values from our pre-existing Tape Measure's Passive LCD Display, receive inputs from the user through buttons, display states to the user through LEDs, as well as send data to the mobile device through bluetooth UART.

2.3.1 Microcontroller

We plan on using an ATmega328P Microcontroller. It can be powered by 2.5V to 12V which gives us a lot of options for the power source [8]. It has 32kB of flash memory which should be more than enough to store our code [8]. The Arduino BT shows us that its ATmega328P microcontroller easily and reliably pairs with its Bluegiga WT11 module to give it bluetooth capability which would be a great starting place for us to get bluetooth working [8]. The Arduino BT also contains 14 digital pins and 6 analog pins for us to use which is sufficient for our LEDs and Buttons as well as translating the Passive LCD Display from the Tape Measure [8].

Requirement: The microcontroller must be able to accurately reproduce measurement data from the tape measure's display and transmit this data via Bluetooth to a paired device.

2.3.2 Bluetooth Module

The Arduino BT uses a Bluegiga WT11 bluetooth module that we can use while prototyping and hopefully implement in our pcb. This bluetooth module will be responsible for receiving data from the ATmega328P Microcontroller and sending it to the Mobile Device. It has an operating voltage of 2.7 to 3.6 V which is well within the window we want [9]. Also, it has a range of 350 meters line-of-sight which is more than enough since the user will have their smartphone most likely less than 5 meters from the bluetooth module [9].

Requirement: Bluetooth module must be able to send measurements to the smartphone accurately with a transfer speed of at least 2 Mbps.

2.3.3 Send Data Button

This button will be responsible for grabbing the current measurement from the pre-existing tape measure, and when pressed will signal to the bluetooth module to send measurements to the smartphone.

Requirement: When pressed, the send data button must signal the bluetooth module to send data, and the bluetooth module must not send data otherwise.

2.3.4 Pair Button

This button will be used to pair the bluetooth module to a device the first time. After we use this button to pair the bluetooth the first time, the user will not have to press this button to connect to the device.

Requirement: When pressed, the bluetooth module must appear to smartphone devices in their bluetooth setting. Multiple presses should not do anything differently.

2.3.5 Status LED

This LED will be lit while the device is powered on and not lit while the device is turned off.

Requirement: Must be lit while the device is on and not lit while the device is off.

2.3.6 Bluetooth Status LED

This LED will be solid lit while the bluetooth module is connected to a mobile device, not lit while the bluetooth module is not connected to a mobile device and not looking for a mobile device, and blinking while the bluetooth module is waiting to be paired to a device (after we press the pair button, but before we connect it to a mobile device).

Requirement: Must be solid lit while bluetooth module is connected, blinking while bluetooth module is searching for a mobile device, and not lit otherwise.

2.4 Mobile Device

The control unit will send data through Bluetooth UART to the mobile device. This device will receive values, store them in a mobile application, input them into an algorithm, and display them in a visual for the user to know where to store their items and how much space will be required.

2.4.1 Bluetooth Receiver

The user will have an existing smartphone that will be able to pair to our bluetooth module in our control unit.

Requirement: N/A since the user will already have this device.

2.4.2 Mobile Application

Our mobile application will receive values from the bluetooth receiver, store them in the app, run an algorithm that looks for the best places to store the boxes in the truck, tell the user what size truck is required, and show a visual of where to store the items in the truck.

Requirement: The algorithm to decide where items must be placed must take less than 2 minutes to compute.

Requirement: The algorithm must display one solution for the most efficient way to pack the truck and report the smallest possible size truck to store the items.

2.5 Pre-existing Tape Measure

Our application needs objects' dimensions in order to calculate the best way to pack items in a confined space. These dimensions, ultimately, will be entered in by the user of our application. The quicker the user can figure out dimensions of the things he/she is moving, the more useful our application will be to him/her. Our solution to minimize the amount of time for this process is to use a pre-existing digital tape measure, to "steal" measurement readings from it, and then to send this data over Bluetooth to our application.

Requirement: Tape measure must have "accessible" data signals which can be used by our control unit.

Requirement: The number of data signals used by the tape measure should be less than or equal to the number of inputs available on our microcontroller.

2.6 Risk Analysis

The implementation of the Bluetooth module poses the greatest risk in order for our project to be completed successfully. Not only would we need to build the casing for the module to withstand both indoor and outdoor environments (discussed more in-depth in the Safety and Ethics section), but we also need to successfully have this module be attached on either an already existing digital tape measure or one we built ourselves. In the scenario we use the former route, we need to make this module easily attachable and functional to a variety of digital tape measures out on the market today. From a hardware standpoint, we need to take the casing material into account as we would need to deconstruct the existing digital tape measure in order to successfully attach our PCB Bluetooth module with the existing electronics then choose a satisfiable casing for the module that works well with the rest of the product and eases safety concerns [7]. If we decide to go with the latter choice and construct our own digital tape measure, we would need to design our PCB to contain components that not only include Bluetooth connectivity but also feature the functions of a digital tape measure. From a hardware aspect, we would need more components on our PCB, and we would also need to ensure our board is of compact size to ensure the product after casing is of equal size to existing digital tape measures to make it viable on the market. In either situation, the hardware surrounding the Bluetooth module will require us to attune our PCB with either more components or compatible with existing electronics.

From a software aspect, both situations of using an existing digital tape measure or building our own for the Bluetooth module poses similar risks. In the situation of using an existing digital tape measure, our Bluetooth module would need a way to "hack" the existing electronics to receive the incoming measurements and transmit them to our mobile application. This would likely be done by "stealing" the output to the digital tape measure's display. Additionally, we need this datapath to our module to be fast enough to transmit the data efficiently to our mobile application so users can receive feedback once they have finished all their measurements. In the former situation, building our own digital tape measure, we would need to implement our own software that will act similar to already existing digital tape measures. Specifically, we would need to record measurements and then use some time of notification or alert to tell the user measurements are being read like an LED. In addition, once again, we would need to also route a datapath containing these measurements to our Bluetooth module to ensure the mobile application receives all the necessary measurements. We also need to make sure our Bluetooth module can transmit the data received fast enough to our mobile application to ensure users do not have any long delays. Both situations require us to implement software features to our Bluetooth module to transmit and receive measurement data effectively.

The Bluetooth module is essential to our design. This interface connects both the digital tape measure and mobile application together. Additionally, it is responsible for transmission of measurement data used by our algorithm to determine what size of moving truck users will need and how they need to place their belongings in such a space. From both a hardware and software aspect as well as in either situation of using an existing digital tape measure or building our own, the Bluetooth module will require crucial handling to ensure our project is a success.

3 Safety and Ethics

There are a few safety and ethical concerns that reside with our project. One of the main safety concerns comes from the lithium-ion batteries used by our digital tape measure. These batteries can explode if they become overcharged or reach an extreme heat temperature [5]. Additionally, these batteries should not be charged in extreme cold temperatures either as they can deteriorate and leak chemical acid [5]. To ensure safety, we will adequately test and monitor the battery cell temperature to ensure its overall quality and performance.

Another safety concern stems from the enclosed Bluetooth module attached onto the digital tape measure. Since the tape measure can be used in both indoor and outdoor environments, the Bluetooth module should be encased in material in such a way no moisture or water can short the circuit. For our specification, the casing material will adhere to IP67 standards ensuring it will withstand up to 1 meter of water.

An ethical concern our project raises involves the containment of private user data. Within our mobile application, users will be able to store their own private data that is kept hidden from other users. This issue raises the concern of possible data leaks or piracy that can take place through malicious software attacks focused on app or phone data. These issues go against the IEEE Code of Ethics #9 - to avoid injuring others, their property, reputation, or employment by false or malicious action [6]. To mitigate this issue, we will have a notification appear to users recommending popular security applications to install if they are not installed already.

Since the mobile application calculates the needed amount of space to hold one's belongings, our project raises concern of taking advantage of the given measurement data and suggesting the biggest size truck possible. This concern violates the IEEE Code of Ethics #3 - to be honest and realistic in stating claims or estimates based on available data [6]. To avoid violation, we want to construct and develop an algorithm that does not just estimate the space from the given user measurement data, but one that calculates the entire dataset and concludes a total amount of space needed for the user. Then using this number, the algorithm would recommend to the user what size truck they should get given the user measurement data.

Finally, to avoid violation of IEEE Code of Ethics #1 - hold paramount the safety, health, and welfare of the public, to strive to comply with ethical design and sustainable development practices, and to disclose promptly factors that might endanger the public or the environment [6]; we accept responsibility for our design. Our project aims to ensure the safety of its users and while we hope to test all possible scenarios there are a billion more that may occur. Therefore, we accept responsibility for faults in our design and ensure we take appropriate action to ensure user safety when these faults occur.

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