Wilderness Information Link Device

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***Abstract* — This paper details the objectives, research, and implementation concerning the Wilderness Information Link Device (W.I.L.D.): a communication device capable of transmitting a texted ASCII message between another of the same device. Using long-range wireless transceivers, communication across distances measuring several miles in an outdoor environment and several hundred feet when indoors is expected. It is also understood that this device serves the purpose of acting as a simplistic, portable, communication module that can be used when in emergency situations. It would also act as a device capable of providing messaging capability in areas where cellular communication or networks, as well as internet access, may not be readily available.**

***Index Terms* — Wireless communication, transceivers, solar energy**

I. Introduction

In today's technologically-driven world we are more connected than ever. Communication has long been at the center of many emerging technologies. As we continue to advance our ability to communicate with innovations that bring connectivity to the farthest reaches of our big blue planet, there are still some areas that are, quite frankly, hard to reach. The Wilderness Information Link Device seeks to perform the role of a device that will facilitate communication for those who are in these very areas or situations that do not allow for easy and accessible cellular communication. W.I.L.D. aims to be a reliable way for individuals to remain connected without a need for outside networks such as cellular towers or satellite connections. The Wilderness Information Link Device is capable of sustaining operability for long periods of time by collecting its own power via solar panels and is able to maintain a wireless connection over a long range.

There are several different scenarios in which such a device would be useful. One major consideration in this area was for outdoorsmen in rural areas. Whether it be a long section of the Appalachian Trail, the untamed wilderness of Alaska, or even the vast expanse of the Sahara Desert, there are oftentimes scenarios when some form of communication is either vital or at a minimum, very useful in terms of convenience. Maintaining a line of communication also provides an inherent security. Without communication, a minor injury in the wilderness could develop into a life-threatening ordeal, for example. Therefore, the purpose of this project was to develop a wireless communications device capable of transmitting point-to-point (P2P) text messages of, at minimum, sixteen characters across a relatively long distance.

II. Engineering Requirements and Specifications

The engineering requirements most relevant to the Wilderness Information Link Device involve the requirements pertaining to the internal design and functionality of the device. These types of requirements usually do not encompass the requirements relating to the primary customer interaction of the device or the visual aesthetic of the device. These three types of requirements may overlap—however, the engineering requirements at their core mostly deal with how the device will be designed, regardless of usability and visual appeal.

A. Transceiver Frequency Range Between 900-930MHz

Considering the regulations surrounding frequency band usage as well as what is feasibly available to use for the production of W.I.L.D., the frequency band selected for W.I.L.D. was 915 MHz which falls within the approved bandwidth of 902 MHz and 928 MHz A frequency of this magnitude would ensure that the bitrate of the device would be as high as reasonably capable. A frequency of 915MHz provides reasonable obstacle penetration, which would allows for the usage of the Wilderness Information Link Device in non-rural areas.

B. Power Rating within 0.5W-3W

The power rating range selected for the Wilderness Information Link Device was chosen with all relevant materials needed during the production and prototyping of the device, including the solar panel, microcontroller, transceiver, keyboard, display, and other devices used, considered and accounted for. This range of 0.5W to 3W is a key factor in the core functionality of W.I.L.D. as it provides a set limitations to fall within for all devices used to create W.I.L.D. This importance is based on the consideration that there are two main sources of power for the device: solar charging power and USB charging power. Due to the limitations posed by both methods—particularly the means by which the charging methods may be used, as well as when—a power rating range was established and followed to make sure that W.I.L.D., and all relevant parts that make up the final device, are able to function and run as expected.

C. Functioning Keyboard

This requirement exists to ensure that the user is able to properly interface with W.I.L.D. and each advertised function as seen through the display. As this engineering requirement only states that the keyboard must function, there were no limitations posed by this specific requirement that state exactly how this requirement must be met. At minimum, the user must be able to interface with the display using provided keys in order to select their desired function, such as to send a message or to view messages that have been received.

D. Display ASCII Characters from Keyboard Input

Following along with the requirement to have a keyboard that is deemed functional, an additional requirement relating to the keyboard was to make sure that input provided from the user by way of the keyboard appears on the display of W.I.L.D. in the form of ASCII characters. For the purposes of the Wilderness Information Link Device, the selection of ASCII characters includes the alphanumeric characters most commonly seen in the North American English language. Although alternative configuration can easily be reconfigured depending on the desired target audience, it should be mentioned that displaying the alphanumeric characters most commonly seen in North American English was also a limitation on who may reasonably use W.I.L.D. for wireless and self-sufficient communication.

E. Status LEDs

In order to properly communicate to the user the current status of the Wilderness Information Link Device, it was a requirement that status LEDS be used to ensure that the user may at all times know the current actions being performed by the device. It is important that the user be able to effectively and efficiently understand the current state of the device in order to limit the customers need to view the display to see the state and the quickly ascertain the status of W.I.L.D. by using a simple glance instead of continuous physical effort which would result in increased battery use in the long run.

F. Software Design for Low-Power Use

Ensuring that the Wilderness Information Link Device is equip with software designed for low-power use was a requirement that posed limitations and expectations on primarily the software side. By using low-power mode states available to the microcontroller as well as creating efficient code that would allow the device to run and perform all tasks without expending any unnecessary power, the device is able to fulfill this requirement as needed to ensure that W.I.L.D. is able to efficiently and consistently perform in the target environment.

G. 16 Character Limit for Sent and Received Messages

The requirement for W.I.L.D. that the device must be able to send and receive a message that is limited to sixteen characters must be clarified. The initial limit set in place for the device to be limited to sixteen characters was the standard target value. The ability to institute a design that exceeds a sixteen-character limit was prioritized despite the sixteen-character limit, as this alteration was seen as no threat to the other requirements for W.I.L.D.

H. Withstand Drop or Impact Present at 3ft

As the Wilderness Information Link Device has a target usage environment of outdoor, mostly rural locations and is by nature handheld, there is a requirement established that ensures that W.I.L.D. will be able to withstand drops or impacts that would occur after being released from a height of three feet. This type of drop resistance provides considerations for the device being dropped from a height of three feet onto varying surfaces, including concrete and grassy terrain.

I. 1W Generation from Solar Panel

This requirement states the minimum power generation expected from the solar panel seen on the Wilderness Information Link Device in order to ensure that all functionality of the device is adequately powered and maintained for continued and sustained use when using solar power as the source of charge. Core elements of W.I.L.D. that are directly influenced by this requirement include the display, the keyboard, status LEDs present on the device, as well as the battery used to provide power to all components connected. This is a requirement that can be expanded upon in order to potentially provide more power to the device; however, any alterations to the capabilities of the solar panel desired for use must not infringe upon any of the other requirements in a way that would further restrict or lessen the overall capabilities of W.I.L.D.

J. Software Conforms to Microcontroller Code Space

This engineering requirement for W.I.L.D. pertains mostly to the capabilities of the software. All software used to enable the functionality of the core components of W.I.L.D., including the display, status LEDs, and keyboard were thoroughly optimized to perform as expected within the established confines of the microcontroller's code space. The created code must not exceed what is allowed and able of the microcontroller in order to ensure that all required specifications relevant to the Wilderness Information Link Device performs as expected and as presented.

III. MICROCONTROLLER

As the Wilderness Information Link Device was created with the purpose of being low-power and self-sustaining, one of the most important considerations in choosing project components was choosing a microcontroller that would provide the lowest operating current. Assuming that the MCU is active and not operating in a low-power mode, the microcontroller chosen emphasized low-cost, low-power, and energy efficient performance which most fell in line with the project's expectations of efficient, low power operation. The MSP432P401R by Texas Instruments was chosen to be the brain of the Wilderness Information Link Device. Its operating current when in Active mode reaches 80 µA and is based around 32-bit ARM architecture. Due to the various outside modules that come together to form W.I.L.D., the MSP432P401R needed to have a generous amount of GPIO pins—this TI MCU provided 84 GPIO pins for use [1].

IV. MICROCONTROLLER PERIPHERALS

Our device must have proper input and output components such that the data communication between the microcontroller and transceiver may be established by a user. With respect to the input and output functionality, a few important modules will be discussed. These components will consist of: a keyboard as the main means of input; a liquid crystal display serving as the main output; two light-emitting diodes; a cursor; and a power switch. The use of embedded programming will be utilized in conjunction with these relevant components such that proper input and output communications may be developed.

A. Keyboard Module

Concerning the main input aspect of our device, after thorough research, it was agreed upon to implement a type of miniature keyboard. The keyboard opted for is the BlackBerry Q10. This module consists of thirty-five keys, of which twenty-eight contain special characters. There is also backlighting for this module, which operates at 3.3 volts, and a current of approximately 40 milliamperes.

The interfacing of this module consists of a complex, thin, flexible cable. On this cable is a male-type connector, consisting of exactly twenty-eight pins. A receptacle, the 'Hirose BM14-B,' was determined such that proper interfacing could be structured. The proper pinout for the connector found on this flex was attained the experience of prior hobbyists [2]. Utilizing the Hirose connector footprint, a simplistic breakout PCB was designed such that prototyping could begin. It is imperative that this circuit board be designed, as the module could otherwise not be programmed and tested. Figure 1 shows the design of the breakout for the Q10.

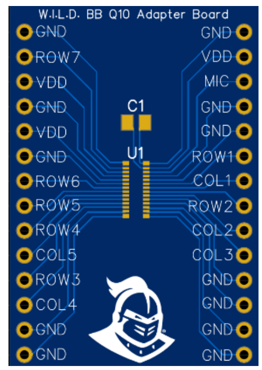

Figure 1. An adapter board for the Hirose BM14, with traces following to through-holes for convenient soldering

B. Cursor Module

The secondary input component consists of a five-way directional cursor, i.e. forward, backward, left, right, and down (enter). This module, the 'SKQUCAA010 ALPS' is meant to serve a user through menu navigation. The mechanical dimensions of the part are ideal in relative comparison to the enclosure of our hardware. With respect to the ergonomics, the cursor has an appreciable feel whilst accurately guiding a user toward the direction they desire. Prototyping with this has served to be a straightforward task, as a breakout PCB was designed. Considering the specifications, the cursor has a voltage rating from 1-12 volts, and a current rating from 10 µ – 50m amperes.

C. Power Switch

A rocker switch was incorporated into the enclosure such that the component acts as a gateway into supplying power to the main PCB and relevant components. Ideally, this switch helps in reducing power consumption when the device is properly turned off. Along with implementation of a programmed hibernation mode, the switch also efficiently keeps the battery from unnecessary drainage.

D. Liquid Crystal Display

The main output module consists of a 20 character by 4-line display screen, which is the 'SunFounder LCD2004'. A character-based display screen was chosen for the ease of programming the component. Sixteen pins are affiliated with the 'backpack' of this screen, which contain the typical signals that are interfaced with. The most important pins consist of the anode and cathode for backlighting, chip enable, data bits, supply voltage and ground. This module was chosen to operate at a potential of 3.3V in conjunction with the single-rail power supply.

E. Status Indicators

The secondary output module consists of two RGB-type light emitting diodes. Also denoted as status indicators, these will help convey a type of standing into the miscellaneous progress functionality. Aside the typical red, green, and blue colors contained within the crystals of the component, it is understood that further colors could diversify the selection. In order to do this, programming pulse-width modulation is necessary. The duty cycle must be configured such that a different type of color will be outputted.

V. Hardware Testing

Our device was tested to ensure that there is functionality pertaining to the relevant modules and the power supply. Many of the testing stages were conducted in the senior design laboratory. Equipment such as oscilloscopes, function generators, digital multimeters, and circuit components were used during this process. The following subsections below will cover the various testing stages in greater depth.

A. Q10 Keyboard Testing

A variety of different tests were conducted relating to the keyboard. The male connector from the flex cable of the Q10 properly connected to the BM14-B which was soldered to the breakout PCB. It was found that the operating voltage for the keyboard is exactly 3.3 volts which effectively turns on the backlighting of the keys. It was also desired to see if the individual keys are acknowledged when pressed. Utilizing a digital multimeter, it was seen that when a particular key was pressed, it was effectively grounded based on the row and column to which it belonged

Each character and number allowed for the user to choose from the keyboard corresponds to a specific pin on the microcontroller. The distinction between row and column pins allows the software to tell when a key is being pressed by checking the state of the row and column pins in junction, in order to receive a singular reading for the value inputted by the user.

Once the supply voltage was provided to the adapter board, the backlighting for the keys turned on as mentioned earlier. It was found that the keyboard draws a current of roughly 40 milliamperes. Figure 2 depicts the keyboard and the illuminating backlights.

Figure 2. Interfacing the BlackBerry Q10 keyboard with the adapter PCB in lab

B. Liquid Crystal Display Testing

Further testing was performed for the liquid crystal display we chose. A supply voltage of 3.3 volts was provided to the backpack of the LCD using a bench power supply. The backlighting for the screen then properly illuminated. Proper connections between pin signals were made to a developer board for the microprocessor, where further tests on coding could be made. Figure 3 demonstrates the functionality of this module.

Figure 3. LCD screen with character display and custom icon implementation

C. Power Supply Testing

Two revisions of the PSU have been constructed and tested. Over the course of this testing, it has been determined that the PSU works well for charging the battery from either the USB or solar input; in addition, the DC-DC converter keeps a steady 3.3-volt rail regardless of charging inputs or reasonable loading.

VI. Enclosure

The mechanical dimensions of the enclosure were set to be approximately 5"x5"x1.5". A complication regarding this revolves around the keyboard; the geometrical architecture for this component is relatively complex, thus making 3D printing a viable option. For the material, ABS was the optimal choice over PLA, with an infill of approximately sixty percent. This material was chosen for its superior durability over PLA, allowing it to sustain greater environmental damage.

VII. Power Supply Unit

As with all electronic devices, a Power Supply Unit (PSU) was required for device operation. Given that this is a mobile (and thus battery-powered) device, it is of the utmost importance that the PSU be as efficient as possible; in addition, the PSU needed to be compact so as to be able to fit inside of the case for the device, and all while still being capable of wicking the heat generated during operation. To this end, it was decided that a single voltage rail with a current capacity capable of running the entire device was ideal – and thus a tuning of the rest of the device so that it could be run on a single voltage rail was performed. As it happened, the only changes required to accommodate this requirement was a changing of LCDs and current-limiting resistors on the status-indicator LEDs. The supply potential chosen was 3.3 volts, as there are many things (including the chosen MCU and XCVR) that natively support that supply voltage, thus making it easier to run the entire device off of a single rail.

A Lithium-Ion (Li-Ion) battery was chosen as the energy storage medium for the device. Due to their high energy density and lack of memory, they make for high-quality batteries for mobile applications (hence their prevalence in mobile phones). A Li-Ion was chosen over a Lithium-Polymer (LiPo) because of the rigidity offered by Li-Ion batteries – thus making the device safer in the event of a drop or crush event, which is what may happen in some wilderness scenarios. A battery with a nominal voltage of 3.7 volts and a charge capacity of 2200mAh was chosen.

For charging the device, it was determined that the ability to charge the battery quickly was of the utmost importance; however, the ability to charge the device "in the field" while in wilderness scenarios was also deemed important. As such, two different charging methods were employed: charging via a USB-C port, and; charging via an external solar panel that connects through a 2.1mm barrel jack. Both charging methods are limited to 500mA of current; while the battery chosen could potentially charge at a maximum of up to 1A, 500mA was chosen so as to provide a comfortable safety margin. In addition, it is unlikely that the solar input would even be reaching 500mA in current, given most portable panels the user could potentially connect to the device.

Each of the charging circuits was given its own integrated circuit (IC): the USB charging circuit, the MCP73831T-2ATI/OT from MicroChip; the solar charging circuit the BQ24210DQCT from Texas Instruments. Each of these devices is optimized for charging Li-Ion batteries with chemistry that yields a maximum voltage of 4.2 volts; this matches with the chosen batteries.

Followed by this is a DC-DC converter (TPS63001DRCR) for converting the voltage at the battery to 3.3 volts. The chosen battery has a minimum voltage of 3 volts and a maximum voltage of 4.2 volts; both of these voltages are within the range that the DC-DC converter can work within the convert to 3.3 volts. Included in Figure 4 and Figure 5 are renders of the power board.

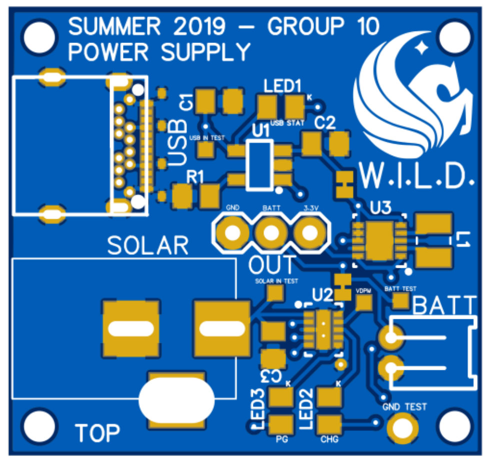

Figure 4. Top of the PSU board

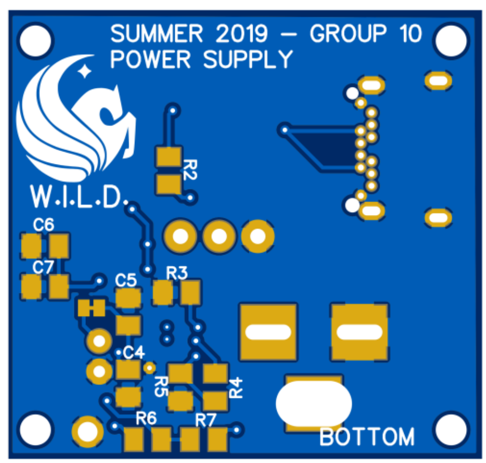

Figure 5. Back of the PSU board

VIII. Mainboard

It was determined to be desirable that only two PCBs with parts be used in the final design; a third PCB is present in the final design, but it serves purely as a mounting point and breakout board. As such, most everything that was not placed on the PSU board would need to go on the mainboard. The mainboard includes: the MCU, the XCVR, the status indicators and their control MOSFETs, as well as all their associated headers and passives. It was determined that, for the sake of ease in configuring custom ribbon and other connection cables, that 2.54mm (0.1 in) would be desirable for the headers on the board. In addition, it was determined that – although the MCU is capable of 48MHz operation – a 16MHz timing crystal and its associated capacitors would suffice for the relatively computationally-inexpensive operations that are being performed here. Dual-package N-channel enhancement-mode MOSFETs were chosen so as to minimize the footprint of the RGB LEDs that constitute the status indicators; the same MOSFETs were used to control the backlights for the LCD and keyboard as well. Figures 6 and 7 show renders of the mainboard.

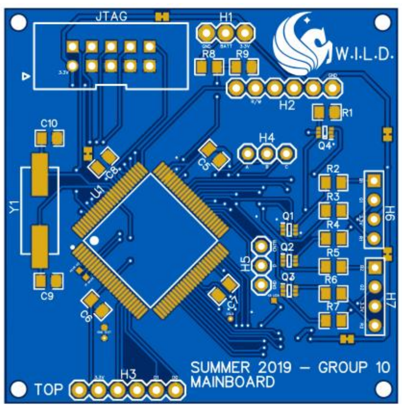

Figure 6. Top of the mainboard

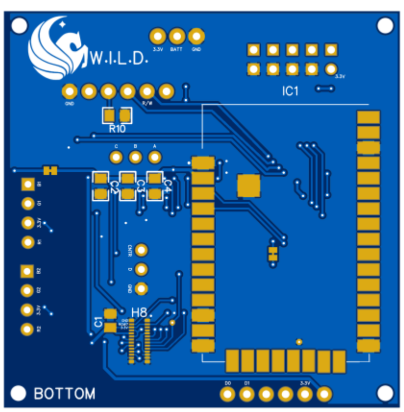

Figure 7. Back of the mainboard

IX. Range of Operation

The range of the Wilderness Information Link Device was one of the most important considerations in choosing design constraints and long-term project objectives. This distinction was due to the fact that the range was one of the most variable factors in the building and use of our device. While the power usage can be expressed as a clear maximum, for instance, the minimum expected range can vary greatly due to the large number of varying environmental conditions. The best range for most wireless communication devices is attained when performing in an area with clear line of sight and little to no interference. Line of sight is simple to define and thus easy to predict—wherein line of sight can be explained as a path where the view of the selected target is obstructed and free of obstacles. However, with the range that we wanted to achieve in this product, there were a number of factors that affected the LOS (line of sight) range. Interference was comparatively more difficult to predict. This is partially due to the fact that interference is defined differently for different technologies. The only way to plan for this factor was to assume for the worst-case scenario when testing the device. The power rating of the device that enables W.I.L.D. to function as a communications device was considered as well. Because we wanted this device to function for long periods of time without an external power source, we needed to select a technology that was capable of functioning at the ranges that we desired without consuming inordinate amounts of power. While researching all the parts for this product, we found that in nearly all cases, the communications portion of the device consumed the most power when the device was at maximum power consumption. Additionally, it should be noted that cost was also an important factor. With a development budget of near $1100, we needed to ensure the communications device that enables W.I.L.D. fit within that budget.

Outside of power rating and cost, was determining the specific frequency to use. Radio frequencies cover a very large range, from about 3Hz to 3TH—although not all frequencies in this range have well developed technologies. In most countries, including the United States, these frequencies are highly regulated. Some frequencies are reserved for government use, while others are reserved for specific uses, such as cellular networks or broadcast television. It was extremely important for the success of our project to select a frequency that was open for our use. Additionally, there are regulations that specify the maximum peak amplitude for devices transmitting on these frequencies. This would greatly impact not only the range of our devices but also the power usage.

Range and power use, it so happens, are tied very closely to the physical properties of the frequency used. The major two trade-offs are range in open areas, and the ability to penetrate obstacles, such as buildings or terrain features like a hill or forest. While researching the different open RF bands, we determined that at a frequency as low as 2.4ghz (a common WiFi band), we would not achieve a range that was acceptable, even in an open space. Another factor was the bitrate. As you lower the frequency of the transmission, the data bitrate drops accordingly. Because of this, we needed to ensure that the technology we chose would fit within our bitrate requirements. We determined that the overall package size was in the range of a few Kbs. The data sent through W.I.L.D. is fairly small, consisting of a string of ASCII characters and some provisions for transmission acknowledgements. Based on these considerations, we arrived on two frequencies that seemed to fit our requirements well. These two RF bands were the 435MHz and 915MHz bands. These two bands had a number of pros and cons for each. Ultimately, either of these bands would have worked for our project, however after thoroughly comparing the two bands, we determined that the 915MHz band more closely fit our design requirements.

When considering the 915MHz band, there were several advantages. There were a number of existing product lines that seemed to support what we intended to do with this project. The maximum range for this technology was well above the range specified for our project, and the cost was fairly attractive as well. While the range would vary depending on the specific communications-enabling device, the devices in this frequency band seemed to all have ranges that either exceeded our requirements, or greatly exceeded them. Not only did this mean that selecting a product would be much simpler, it also meant that when it came to power usage, we could lower the power usage, which in turn would lower the maximum range, while staying inside our design specifications. This gave us a great amount of flexibility for later stages of the development of the Wilderness Information Link Device. The 915MHz band also featured slightly better obstacle penetration than that of the 435MHz band. Because of this increase, we expected our finished device to function with the specified requirements, even in a worst-case scenario such as a busy urban area with greater amounts of interference and a greater number of obstacles.

X. Digi XBee Chipset

Digi XBee is a product line created by Digi encompassing an expansive array of radio communication modules relevant from home to professional use. The XBee products include communication modules that we considered for use in W.I.L.D. that feature ranges going up to 105km (approximately 65 mi.). The data rates were anywhere from 10kb/s up to 250kb/s which was well within the needs for our device. Even in urban non-LOS applications, we saw that we might exceed the range requirement noted in our requirements specifications. The software for this product was the most comprehensive that we had seen. Not only did XBee support configuration on the end device, it also had a development suite that allowed configuration of the chips through a USB development board with a pluggable socket. This feature allowed us to use the chips in a testing environment prior to installing them in the end device. We were also able to become more familiar with the commands used to control the chip and test the range before we fully developed the end product. The software also contained discrete support for mesh networking capabilities. The inclusion of the networking protocol for mesh networking in the chipset itself meant that the software development process could focus more on the core functionality that we required rather than getting caught up in the details of the backend. This chipset also has the UART communication standard. The only drawback that this line of products had, was that the prices seemed to be a bit higher than other chipsets. We determined that this price was mostly due to the much better documentation and addition features that were available. Additionally, there were a wide range of different versions for this product, which meant that we were able to select a device that more closely fit the use case for our project.

XI. User Interface

The user interface, consisting of a 4x20 character-based display, accurately and effectively displays all information necessary for the user to operate the device. The user interface has been designed to operate with ease using the input methods available to the user. Using both the keyboard module as well as the five-direction cursor, the user is able to use these tools to navigate the menu. All interface pages were designed with hardware limitations of the character-based keyboard as well. With a maximum number of characters on one line being 20, minimizing extraneous information was extremely important to ensure clarity and efficiency of use.

The main menu consists of roughly four options. These four options are: ‘Show Messages’, ‘Send Message’, ‘Options’, and ‘Information’. The ‘Show Messages’ menu allows the user to read messages that have been sent from the device. The number of messages available will be limited by the programming constraints and the hardware limits of the available memory provided by the microcontroller. The top menu for this portion of the device shows the number of new messages, if any, that the device has received and that have not been viewed. The Send Message section allows the user to send a message to another device. This menu also has built in options that are deemed necessary for each message. One such setting is specifying whether the device will receive a read acknowledgement from the destination device. Due to the emphasis on using this device in potentially dangerous or emergency situations, the user might need to know that the message has been read; or the user might wish to save the battery power required to send and receive additional information.

The third menu is the Settings menu. This menu is used to set global settings that are to be used during the full duration that the device is powered. Finally, the Information Menu offers information on the device such as the device ID, version information, and usage statistics. When a user proceeds through the Show Messages menu, they are greeted with a page showing the first message in the list. Messages are ordered as received with messages that are unread being indicated as so. By pressing the forward or back buttons the user is able to select a different message. By pressing the select/enter button (by for example, pressing down on the cursor), the user is able to view the message.

The Send Message menu starts by displaying a prompt to enter text. The user can either begin typing a message or press enter. When the user begins typing the message a cursor appears to guide the user's input. The user is able to erase characters or use the arrow keys to move the cursor to another letter in the display. The cursor functions similarly to the cursor in a text processor that uses the insert function. Any letter that is selected will be over written and then the cursor will move to the next letter on the display.

ACKNOWLEDGEMENT

The authors and creators of the Wilderness Information Link Device would like to express gratitude to the professors who have taken the time to review our project. We would also like to kindly thank Dr. S. M. Richie and Dr. Lei Wei for the assistance provided in helping us to develop and complete W.I.L.D.

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THE TEAM BEHIND W.I.L.D.

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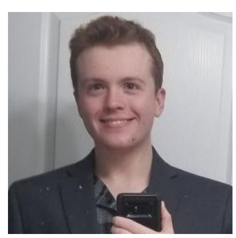

Justin Tuggle is a 21-year-old Electrical Engineering student from the University of Central Florida. He intends to pursue an entry-level job in control systems while preparing for graduate school in 2020.