Modular Solutions for Next Generation Safety and Rescue Helmets

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***Abstract* — A combination of well researched technologies into a singular alpha prototype product that can be used for non-professional search and rescue operations. The Search and Rescue Helmet for Enhanced Situational Awareness (SARHesa) is a combination of three modules: 1) an Augmented Vision (AV) module, 2) a Communications module, and 3) a Localized Location module. The objective of the system is to create a single product that can complete three tasks: enhance vision in low light areas, establish a reliable means of communication, and communicate the localized location of the helmet back to a base station. This system aims to enhance situational awareness and has applications in civilian, military, and first response markets.**

Index Terms — Digital audio aroadcasting, power integrated circuits, base Stations, radio transceivers, GPS tracking, Nnght vision, DC-DC power converters, passive noise reduction

I. Introduction

Search and Rescue (SAR) is the action of locating, stabilizing, and extracting persons in distress or immediate danger by professionals or well-trained volunteers. SAR personnel face common challenges such as: poor vision due to low light, lack of reliable means of communication, and lack of means for broadcasting location to members of the team. The SARHesa aims to provide the solutions to these specific challenges. In practice, this mobile device and its peripheral attachments are to be worn on the user as auxiliary pieces of equipment.

II. Problem Statement

What follows is a brief overview of the problems that the SARHesa aims to solve: 1) poor visibility, 2) lack of reliable means of communications, and 3) lack of communicating one's localized location. This design aims to enhance situational awareness, which is the ability to identify, process, and comprehend information about one's surroundings, in order to navigate SAR operations.

In scenarios where vision is impeded, such as foggy conditions, structural and natural hindrances, or low-light conditions, the AV module aims to provide a solution to the problem of poor visibility. In these types of situations, it is possible for SAR personnel to miss an incapacitated person who is in their direct line of sight. In these extreme situations, conventional flashlight or even red-light flashlights on their own may not be enough for the situation. The AV module is comprised of five main pieces of equipment: a camera sensor, Infrared (IR) illuminator, IR beacon, a display screen, and a Raspberry Pi 3B+. Utilizing the IR technology, the AV module will be able to detect and track bodies that are high in IR radiation such as open flames. The AV module will also be able to provide visual tracking to "friendly" helmets also equipped with an activated IR beacon. When the AV module detects either high IR radiation or another SARHesa device, it will put a visual indicator on the LCD screen that will alert the user. In addition, the LCD screen can display the latitude and longitude of the user.

The Communications module aims to solve the problem of unreliable communication. Situations where SAR personnel are too far apart or in too noisy of an environment can impede communications between team members. The ability to communicate effectively and clearly in potentially hazardous situations is a mission critical objective, and compromised communication lines can lead to the difference between life and death. Communication between SAR personnel encompasses both voice communications and data communications. This feature is not only for the benefit of the operation, but for the safety of the SAR personnel as well.

The Localized Location module aims to broadcast Global Positioning System (GPS) data from the helmet to a corresponding base station. This mission critical module works in conjunction with the Communications module and uses radio frequency as a channel to wirelessly communicate the user's latitude and longitude to the base station.

Finally, the Power module is the power source for the SARHesa. A system of power rails connected to the primary battery provide power to the individual components. A battery charging circuit monitors the battery life in addition to recharging the batteries.

III. Project Goals and Objectives

This section outlines the immediate goals of the SARHesa. It is organized in the following order: AV module, Communications module, Localized Location module, and Power module.

The immediate goals of the AV module are as follows: to be able to stream a video from the Near-Infrared (NIR) camera to a mounted screen, to clearly view and work with images at five meters, to record the streamed video on a data storage device, and to have visible IR beacons for others with the same hardware to locate within ten meters. The extended goals of this module are to extend the viewing range from ten to twenty meters, to be able to identify an IR beacon at twenty meters, and to identify and track targets.

The immediate goal of the Communications module is to provide clear, reliable voice and GPS data communications. In order to achieve the goal, the Communications module must have a reliable input and output method, a transceiver that is capable of transmitting and receiving data at an appropriate channel that, for the purposes of this project, abides by the Federal Communications Commission (FCC) regulations for non-licensed radio uses, and can provide reliable connections from one device to another.

The immediate goal of the Localized Location module is to track the location of the SARHesa by sending GPS coordinates from the helmet to an assigned base station. The extended goal is to make a failsafe in the case that the GPS loses connection using a Micro-Electro Mechanical Systems (MEMS) device. The MEMS device will transmit accelerometer, gyroscope, and magnometer data to the AV and Communications modules in lieu of the missing GPS data.

There are two immediate goals of the Power module. The first is to provide power to the other modules for at least 3.8 hours. It will do this by sending the correct amount of current to the other modules via a system of rails. The second is to charge the batteries via a battery charger. It will recharge the lithium ion batteries within 99% of its total capacity.

IV. Hardware

This section outlines the major hardware components of each module, transmit and receive schemes for the Communications module, and board design considerations.

A. Major Components - AV Module

There are two types of cameras often called IR cameras. The first is known as the IR camera or thermal camera. This camera picks up light waves emitted in the infrared spectrum. The other type of camera is called the NIR camera. This camera picks up light that falls in between the visible light and infrared light spectrum. The chosen camera for this project is the NIR camera. Many security and night vision cameras use the NIR camera due to its lower cost and better image resolution. NIR cameras can be used during high light and low light level conditions. In high light level conditions, it will output a colored image. At low light level conditions, the image will shift to a gray scale image. Furthermore, in low light level conditions, the wavelengths that the NIR camera receives falls in a very narrow band. The gray scale image is still transmitted in one of the color data types. The color data type used by the camera is the Blue-Green-Red (BGR) data type.

The camera selected is a small USB camera designed with an NIR cut filter and a clear lens. This allows the controller to switch between normal daylight filter and a lens that allows NIR light in when visible light is no longer strong enough to show a quality image. The camera is always kept in NIR mode; so, the mechanical switch is removed from the filter, keeping the NIR cut-off filter off the sensor.

The Raspberry Pi is the control unit of the NIR camera. It is a complete computer measuring 85.6 mm by 56.5 mm. The Raspberry Pi is optimized to work with the Raspbian desktop. The Raspbian operating system is a Linux distribution, which allows easy version control across hardware. The screen attached to the Raspberry Pi is a Thin-Film-Transistor (TFT) display that displays in color.

B. Major Components - Communications Module

The Communications module is broken down into two sub-systems: voice communications and data communications. The goal for the Communications module is to provide both voice communications between two SARHesa units and broadcast their GPS locations back to a base station. The voice communications sub-system consists of one Arduino-based Microcontroller Unit (MCU) utilizing the ATMEGA2560 chip, and the nRF24L01+, which is a 2.4 GHz radio. The data communications sub-system consists of one Arduino-based MCU utilizing the ATMEGA328P chip, RFM69HCW radio functioning at 915 MHz, and a bi-directional logic converter. These mission critical sub-systems must be independent of one another. This design redundancy is a failsafe in case of communication failure.

Special considerations for choosing components for the voice communications sub-system were the processing capabilities of the MCU and the operating frequency of the radio. Due to a limited budget and FCC regulations on radio operators, the voice communications sub-system utilizes an Arduino-based MCU with the ATMEGA2560 chip and the nRF24L01+ 2.4 GHz radio. The reason the ATMEGA2560 chip is used is due to its processing capabilities, its market availability, and its cost-effectiveness. One important consideration to choosing the appropriate MCU is its processing capabilities, specifically whether or not it is equipped with an Analog-to-Digital Converter (ADC) that can handle the sampling for a walkie-talkie style device. A pro to the ATMEGA2560 chip is that its ADC is able to handle sampling audio at 8KHz, which is needed to produce telephone-quality speech. It comes equipped with a 16-channel, 10-bit ADC. For this line of MCUs, the estimated time it takes to read an analog input is 100 microseconds, with a max sampling rate of 10,000 times a second. The sampling rate is sufficient for the purposes of this project. Other advantages of the ATMEGA2560 chip is that it has dedicated Serial Peripheral Interface (SPI) ports needed for communications with the nRF24L01+ 2.4GHz radio. It has enough digital input/output pins and analog input pins needed for a walkie-talkie style circuit.

Due to FCC regulations, there are limited amounts of operating frequencies that non-licensed radios can operate on. Choosing the proper transceiver meant abiding by FCC regulations that limits which non-licensed frequencies can transmit voice. This is why a design for a digital walkie-talkie was favorable. The digital transmission over analog meant greater flexibility in choosing an unlicensed operating frequency. The nRF24L01+ 2.4GHz radio was selected due to its market availability and price point. Other advantages are its Industrial, Scientific, and Medical (ISM)-band operating frequency and decent operating range, which is at 60 meters with clear line of sight. Its reliability and many readily available online resources make it a popular choice among amateur radio enthusiasts. FCC regulations on radio operation, specifically for voice transmission and receiving, are strict. The FCC often designate certain frequencies to emergency personnel and first responders. For the purposes of the SARHesa, the 2.4 GHz frequency, although quite susceptible to interference due to a number of other devices using the same frequency, is acceptable for the short-range voice communications demonstration.

Transmission of GPS data, latitude and longitude, to the base station is one of the project's mission critical objectives. The transceiver must be reliable and robust. It must be under the sub-1 GHz frequency. It must be equipped with strong signal lock capabilities and range. The MCU must have fast processing capabilities and have enough ports for the integration of both the location module components and data communications components.

An Arduino-based MCU utilizing the ATMEGA328P chip was selected due to its market availability, price point, and ability to process the necessary data. Its high performance, coupled with low power consumption made it a good choice as the MCU for the data communications sub-system. Advantages to the Arduino ATMEGA products are the amount of readily available online documentation and its strong online support community.

The RFM69HCW is a sub-1 GHz radio available at a wide frequency range. The radio module is available in 315 MHz, 433 MHz, 868 MHz and 915 MHz license-free ISM band. The 915 MHz range was chosen due to its availability for use in the United States for passive data transmission. Several of the key features about this transceiver are its high receiver sensitivity at -120 dBM at 1.2 kbps (kilobits per second), high power output capability at +20 dBM at 100 mW, and high dynamic Received Signal Strength Indicator (RSSI) range at +115 dB. The high receiver sensitivity, ultra-low power, and high RSSI range make it an ideal radio to send out GPS coordinates at predetermined intervals back to base station. Passively sending data means that considerations were taken to make sure that its power consumption was fairly low, since it will be utilizing the same battery pack as the Localized Location module, AV module and voice sub-system. Since the receiver on this transceiver is quite sensitive, it also meant that its RSSI range would be high. The RSSI value is indicative of how much power is being received by the radio factoring all the associated losses accompanying wave propagation. A higher range equates to a strong power signal. 5V is needed to power the Arduino-based MCU that the RFM69HCW is connected to. However, the radio is quite sensitive and any voltages above 3.3V will cause the radio to break. The function of the bi-directional logic converter is to act like a transformer to step down the voltage from 5V to 3.3V so that the radio can function properly.

C. Major Components - Localized Location Module

The goal of the Localized Location module is to provide coordinate data of the SARHesa user to the Communication and Augmented Vision modules. The main components of the Location module are the NEO-6M GPS module and the ATmega328P microcontroller, shared with data communications. GPS is the chosen location technology for the SARHesa, because it is the most reliable and cost effective for SAR operations. GPS receivers have accurate time and position, because of the process of trilateration that uses the GPS' network of approximately 30 satellites orbiting the Earth[7]. Using Wi-Fi, which uses a network of devices, would not be reliable for SAR team members, who perform operations in buildings with failing infrastructures and outdoors due to the Wi-Fi access points requiring power to operate. Using Beacon technology would reduce power consumption and have good data speeds. However, it would be ineffective because multiple beacons would have to be stationed in specific spots at the time of SAR operations with sensors that would pick up the beacon signals. Using Radio Frequency Identification (RFID) technology is expensive, is for short range use, and often requires user interaction to operate. Using Near Field Communication (NFC), though inexpensive, is very short range only[6].

The Localized Location Module uses a Neo-6M module. The Neo-6M module runs on 2.6V to 3.6V, which is within the range of most readily available batteries. This has an advantage over other GPS receivers that operate at higher voltages, which would need more power infrastructure to step up the voltage. The National Marine Electronics Association (NMEA) protocol baud rate is 9600 bps for the Neo-6M module when CFG_COM0 and CFG_COM1 are both set to 1. The Localized Location module needs to lock an accurate localized location in as little time as possible during a SAR operation. The Neo-6M accomplishes this; with a hot start of 1s with a sensitivity of 156dBm, and a cold start of 27s with a sensitivity of 147dBm. It has three configuration pins and 1-time pulse[1].

The ATmega328P microcontroller is used for Localized Location module of the SARHesa. The Neo-6M connects to four pins on the MCU: GND, 3.3V, and two pins for Transmit and Receive . Reference designs for the Arduino Uno microcontroller board were used to create an Arduino with the capabilities needed for this project. For example, an external 16MHz crystal oscillator is used to set the clock frequency of the MCU.

Another note for hardware for the Localized Location module, is that the Future Technology Devices International (FTDI) is used to configure the Neo-6M module.

D. Major Components - Power Module

The battery pack will serve as the power source for the SARHesa. The battery type chosen for this project is the Lithium-ion (Li-ion) battery chemistry. It is very important to choose a battery chemistry that is well suited for embedded type of applications. The Li-ion battery chemistry has a higher self-discharge rate when compared to its chief competitor, the Nickel Metal Hydride (NiMH) battery chemistry. Due to its higher self-discharge rate, it is well suited for the low current applications needed to power the devices on the SARHesa. The Li-ion is also smaller and can deliver higher voltages per cell. This is due to its recharging cycle being four times faster than NiMH batteries. The Li-ion battery is more resistant to varying temperatures ranging from cold environments to much hotter ones. Lastly, Li-ion batteries have a higher energy density, meaning that it carries more charge per gram than a NiMH battery of the same weight.

The SARHesa is meant to be worn by the user so weight and size are very important factors. In addition, the product was designed to be as user friendly as possible. It is intended for the batteries to be interchangeable. The 18650 Li-ion Battery was chosen because it is so common and easily found from reputable vendors on the Internet. The 18650-battery type takes approximately four hours to charge and varies very little across manufacturers.

The battery charger will charge the battery. Battery chargers work in three phases. The first phase occurs when the battery is critically undercharged. This is when the battery must trickle charge until it is within the acceptable range for the second phase to kick in. The second phase is the constant current phase. The current being applied to the battery should be half of the current the battery can deliver. This corresponds to the discharge rate, 0.5C, of the batteries current. This means that one cell will charge or discharge in two hours. The constant current phase charges the battery to 70-80%.

It is important to note that some battery chargers advertise that their products can charge twice as quickly as their competitors. This is only because their products have a constant current mode and only charge to about 70-80% of the total charge. In order to get the full charge out of a battery, there must be a constant voltage mode. This cycle is done in order to preserve the longevity of the batteries. It is also important to note that Li-ion batteries need to be charged to within 0.1% of their total charge. Overcharging can damage the battery, potentially causing it to blow up. Ultimately, a constant current and constant voltage battery charger would be the better choice compared to just a constant voltage charger.

The selected battery charger for the SARHesa is the BQ25606. It is a battery module that will charge the battery with 92.5%-charge efficiency. It is designed to be used with Li-ion single cell batteries. It works in conjunction with the 18650 single cell Li-ion batteries used in the SARHesa. It supports USB On-The-Go (OTG) applications. It also has a high battery discharge rate.

V. Transmit and Receive Scheme - Voice Communications

The transmit and receive scheme for voice communications uses the output of the microphone circuit to feed as an input to one of the analog pins on the MCU. The signal travels through the MCU, first going through the ADC, then travelling into the SPI ports. The SPI ports are how the ATmega2560 communicates to the nRF24L01+. The carrier signal will be at 915 MHz and will have an input signal imposed upon it. The input signal is the analog voice signal being input from the analog pin A0.

The process of modulation for this device is using Gaussian Frequency Shift Key (GFSK). First, the signal travels through the GFSK filter to smooth out the transition from analog to digital [10]. This process reduces the sideband power and decreases interference with nearby channels [10]. GFSK modulation differs from Frequency Shift Key (FSK) due to the passing of the signal through the GFSK filter [10]. This smoothing process limits the spectral width of the signal [11]. This spectral width limiting is called pulse shaping [11]. Pulse shaping is advantageous in telecommunications because it helps transmitted signals to better fit the communication channel that they are being transmitted on [11]. This reduces the effective bandwidth of transmission.

On the receiving end, the electromagnetic waves captured by the antenna are fed into the radio. The radio demodulates the signal and feeds it into the SPI pins of the Arduino. The signal is then processed through the Digital-to-Analog converter (DAC), and gets filtered through the Inductor-Capacitor (LC) filters before being outputted into the speakers on each ear.

VI. Transmit and Receive Scheme - Data Communications

The data communications sub-system consists of an Arduino-based MCU using the ATmega328P, a bi-directional logic converter, and the RFM69HCW radio. The transmit and receive scheme on the data communications sub-system is similar to that of the voice communications sub-system. GPS data will be fed into the MCU and the information passed into the SPI ports, which will then travel to the radio, where FSK modulation will occur.

VII. Board Design Considerations- Filtering and Amplification for Voice Communications

Two passive low pass LC filters are used to aid in the rejection of noise for voice communications. The reason why passive low pass filters are used is due to their simplistic design, noise reduction capabilities, and that they do not need to be powered. During testing of voice communications, several filter designs were used to try to remove the noise being heard on the receiving end. Passive low pass Resistor–Capacitor (RC) filters and active low pass RC filters were implemented during the prototyping phase but did not reduce the noise, and therefore, were not implemented.

VIII. Board Design Considerations – Impedance Matching

In order for impedance matching to occur, the impedance of the source, load, and transmission line must all be the same. This is very important in any Radio Frequency (RF) system because it allows maximum power transfer to occur. Maximum power transfer is important so that the emitted signal from the radiator is strong. The idea is that the more power transferred from the source to the load, the stronger the signal becomes. In order to get a strong signal, the impedance of the source and load must be the same, and the transmission line carrying the signal from the source to the load must be able to carry the signal with little to no losses. A strong signal is very important especially when using RF, due to the RF signal being particularly lossy. The signal can experience attenuation due to a number of sources like atmospheric conditions (i.e. rain, bad weather) and physical structures (i.e. buildings) in between the transmission point and receiving point [9].

An application of maximum power transfer in the Communications module involves the antenna. The antenna's impedance must match the transmitter output impedance in order to receive maximum power transfer. To transfer the signal effectively, the transmission line impedance must have equal characteristic impedance of 50Ω as the source and load impedance. This 50Ω is an RF transmission standard and was taken into consideration when creating the trace that connected both radios from their respective MCUs on the Printed Circuit Board (PCB) [9].

IX. Software

This section outlines the major software components of each module, transmit and receive schemes for the Communications module, and board design considerations.

A. Augmented Vision

The software for the AV module uses the OpenCV library. OpenCV is a popular software library for image analysis of both still images and video feeds. OpenCV can be implemented using C++, Java, and Python. Python was chosen because of the ease of implementation. Using OpenCV in conjunction with the camera creates processed images on screen and a video that can be saved on in the memory. These processed images consist of highlighting high NIR saturations. Video images are stored as arrays with each pixel having several bytes worth of data. OpenCV is designed to quickly process different reads or modifications to this array in order to process the picture or video frame quickly. This allows for real time video processing that can be displayed.

B. Localized Location Module and Data Communication Sub-Systems

The software for the Localized Location module sends GPS data from the NEO-6M module to the ATmega328P, then from the ATmega328P to the RFM69HCW radio. For the RFM69HCW radio, the NETWORKID is set to 0, MYNODEID is set to 2, and the TONODEID is set to 1. The frequency of the radio is set to 915MHz. ENCRYPT is set to “true,” ENCRYPTKEY is created, and USEACK is set to “true.” The LED is defined as pin 9 and GND is defined as pin 8. Lastly, a library object is created for the radio module. For the GPS receiver, the RX pin is set to 4 in the code, while the TX pin is set to 3 in the code. The speed of communication of the channel (baud rate) is set to the NEO-6M’s NMEA protocol baud rate, 9600bps.

In the function void setup(), the rate of the serial monitor is set to 9600bps for the serial data transmission. In the function void loop() , the void gpsTX() function is run every five seconds. First, the void gpsTX() function gets the latitude and longitude. If the data is valid, it is transmitted to the ATmega328P, then transmitted to the “home base” data communication sub-system[2].

C. Voice Communications

Code for voice communications takes advantage of the Arduino loop system and is in constant receive mode until a push-to-talk button is pressed. The radio is first set up by defining the Chip Enable (CE) pin which activates the Transmit (TX) and Receive (RX) modes. The SPI Chip Select (CS) pins are also defined, and the program sets the transmission channel to 0. The channel must match in order for both radios to transmit and receive to one another. A Standard Template Library (STL) container, rfAudio, then initializes the audio driver and an interrupt is defined. The instruction attachInterrupt() sets the interrupt to check if the push-to-talk button has been pressed. This instruction is important because its check on the interrupt will either put the sub-system in TX or RX mode.

In the function void setup(), the volume is set, and the baud rate is set to 115200 bps. The container, rfAudio.receive(), sets the default state of each radio to receive mode. In void talk(), the if-statement checks to see if the interrupt is engaged. If so, the sub-system is in transmit mode, otherwise, it will default to receive mode.

X. Software Interfaces

What follows is a detailed overview of how the software of the different modules work.

A. Augmented Vision

The software for the AV module uses the OpenCV library. The camera is first set up and initialized by OpenCV in order to capture the video stream. After the camera video stream is started, OpenCV takes each frame and resizes the image to twice the resolution of the video screen being used. This is to reduce the load on the processor while still allowing a higher quality filter. The optimal resolution to use is two to three times the resolution of the output screen. Less than two times the resolution results in filters that did not capture enough data. More than three times the resolution did not increase the quality of the output noticeably but did increase the amount of work the processor had to do. These two values were found by hand testing difference resolutions and watching for noticeable camera response times. Once the screen is resized, the color scheme that the data is stored in is switched to gray scale. This further reduces the data used without reducing the quality since the image being inputted is already a gray scale video feed, but is stored as BGR. After the color scheme has been corrected, a mask is generated. Once the mask is generated, the mask is used to create an identification mark, such as a box, around the identified objects. This box is drawn on the gray scale image and the mask is not drawn. Once the box is drawn, the gray scale image is then sent to the screen.

If the user decides they wish to see their GPS coordinates, they will push the GPS button. The GPS button sends an interrupt to the Raspberry Pi to stop video processing and to request the GPS coordinates from the Localized Location module. The returned GPS coordinates are then displayed on the screen. After ten seconds, the screen will go back to the video feed with the tracking software running.

B. Localized Location

The code for the Localized Location module takes in the longitude and latitude from the GPS device and transmits it through the data communication sub-system to the home base.

The Arduino IDE is an Integrated Development Environment (IDE) that was used as the software development tool for the ATmega328P MCU. The libraries used are: TinyGPSPlus library, Software Serial library, RFM69 library, RFM69_ATC library, and RFM69registers library. The TinyGPSPlus library is a NMEA protocol-based library used for parsing the GPS data. The Software Serial library is an Arduino IDE library used for displaying information to the Serial Monitor. The RFM69, RFM69_ATC, and RFM69registers libraries are used to communicate from the RFM69HCW radio to the ATmega328P MCU.

C. Communications Protocol.

There are three types of communication protocols used in the SARHesa: UART, I2C, and SPI.

Universal Asynchronous Receiver/ Transmitter (UART) is asynchronous, which means it does not have a clock. Therefore, all the devices must have the same baud rate and the same signal changes to compensate for a lack a clock. The baud rate is between 1200 to 115200 bps. UART cannot have multiple devices on the UART bus. UART is also significantly slower than SPI. However, UART is a little bit more versatile than SPI in sending information to multiple devices. UART bus starts and stays at idle, until a start bit is sent. Next, the data is sent. A parity bit can be sent to check for errors. Lastly, a stop bit turns the UART bus back to idle mode. The UART protocol is used for communications between the NEO-6M module and the ATmega328P MCU, and the ATmega328P MCU and the AV module[3].

I2C consists of two wires that allow a master device to communicate to multiple slave devices, using 7-bit addressing. The Serial Data (SDA) is the data carrier and the Serial Clock (SCL) syncs data transfer between the master and slave from the master. An active low voltage is put across both lines. The data sequence is sent in 8-bit sequences. First the master sends the data to the slave it is addressed to. The slave device acknowledges whether the data from the master was received, with one bit. The internal register address then sends a data sequence until all the data is sent. The stop condition is the 8-bit that determines reading or writing. I2C is the protocol used for communication between the MEMS and the ATmega328P MCU[4].

SPI consists of three wires and one chip select wire. The Master Out Slave In (MOSI) wire sends data to the slave device. The slave then sends data back using the Master In Slave Out (MISO) wire. First, the chip select is set on the slave device that is being used. A command is sent to send out the data. Then, the decision is made to read or write data. The device that the master is communicating with is turned to active high. The disadvantage of using SPI is having one chip select line per device; multiple devices cannot simultaneously communicate with the master. SPI is the protocol used for communication between the ATmega328P MCU and both onboard radios[5].

XI. Possible Project Enhancements

This section is dedicated to what enhancements can be made to the SARHesa for future developments.

The SARHesa is an alpha prototype. This iteration is a minimum viable product ready to be used by outdoor hobbyists. Later iterations of this project can be used by first responders and military personnel. Major upgrades would need to be implemented in order for it to be mission critical ready. For example, the camera used for the AV module would be upgraded to an IR camera with better resolution. Also, standards for fireproofing, waterproofing, and impact resistance would need to be implemented and rigorous testing must be done. If the above standards were implemented in earlier iterations of the design the cost of the SARHesa would be costly. Moreover, military grade encryption for radio transmissions would need to be implemented for military applications. Lastly, the FCC supplies specific frequencies for first responders. For example, in Orange County, Florida first responder frequencies range from 453Hz to 465Hz [8].

XII. Conclusion

The intent of the SARhesa is to be an integrated solution purposed to aid SAR personnel in their operations. Currently, this alpha prototype may only be used for non-professional hobbyists. It consists of 1) an AV module, 2) a Communications module, and 3) a Localized Location module. These three modules work together to enhance the user's situational awareness. This proposed modular system merges well researched technology with proven, reliable solutions to provide an enhancement to existing equipment. Its modular design not only means potential cost-savings for client, but also has capabilities for more modules for further system integration.

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The Engineers

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Harriet Medrozo is graduating from the University of Central Florida in May 2019 with a Bachelor's degree in Electrical Engineering. After graduation, she will be working as a hardware communications engineer in the aerospace industry. She has experience in both power distribution systems and wireless communication systems. Her professional interests are in radio frequency, communications systems, and remote sensing. She plans on pursuing a Master's degree in Electrical Engineering with a focus on communications systems.

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Jacob Anthony is graduating from the university of central Florida in August 2019 with a Bachelor's degree in electrical engineering. After graduating ,Jacob intends to work in the space industry or in a field where he can do Advanced Research.

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