<u>**Memorandum**</u>

To: Dr. Tim Titus

From: Cave Gurus (Jason Damp, Yang Du, Cheng Wang, and Taylor Begay)

Date: 06 November 2018

Subject: Technology Feasibility Document

Introduction

It has been a couple of weeks since the team was assembled for the Cave Climate Monitor project. To this point, we have done a fair amount of brainstorming and have placed an order on parts for our first set of prototypes. Although we have not met with our client, Dr. Titus was able to answer the questions we sent to him in our initial client memo. From the project description and answers from our client, we have a solid understanding of how we are going to approach our unique problem. For now, we are going to work on a few core pieces that we know will not change based on client feedback and take it step by step ensuring that we complete tasks before starting new ones. The primary objective of this report is to inform our client about our thought process and define the feasibility of our project. Within this report, we discuss our mind map and brainstorming ideas, define the scope of this project, discuss what type of technologies we plan to use, and explore potential constraints with the devices.

Brainstorming/Mind Mapping

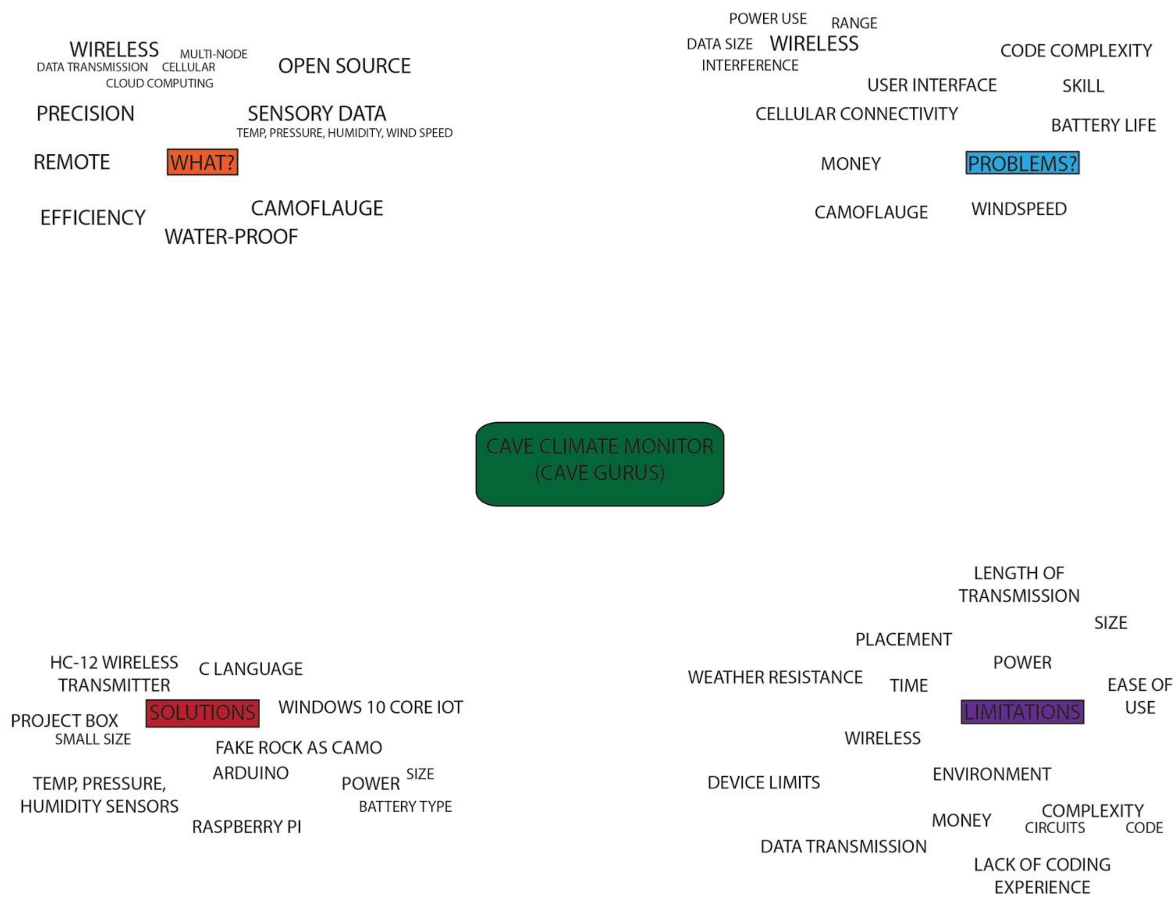

Figure 1: The image above is a snapshot of our mind map. As you see, we address four key points to the overall scope of this project which is first address what is the project, what are problems to this project, what are the solutions to those problems, and what are limitations to the project. We will progress by asking the why and break down tasks from there.

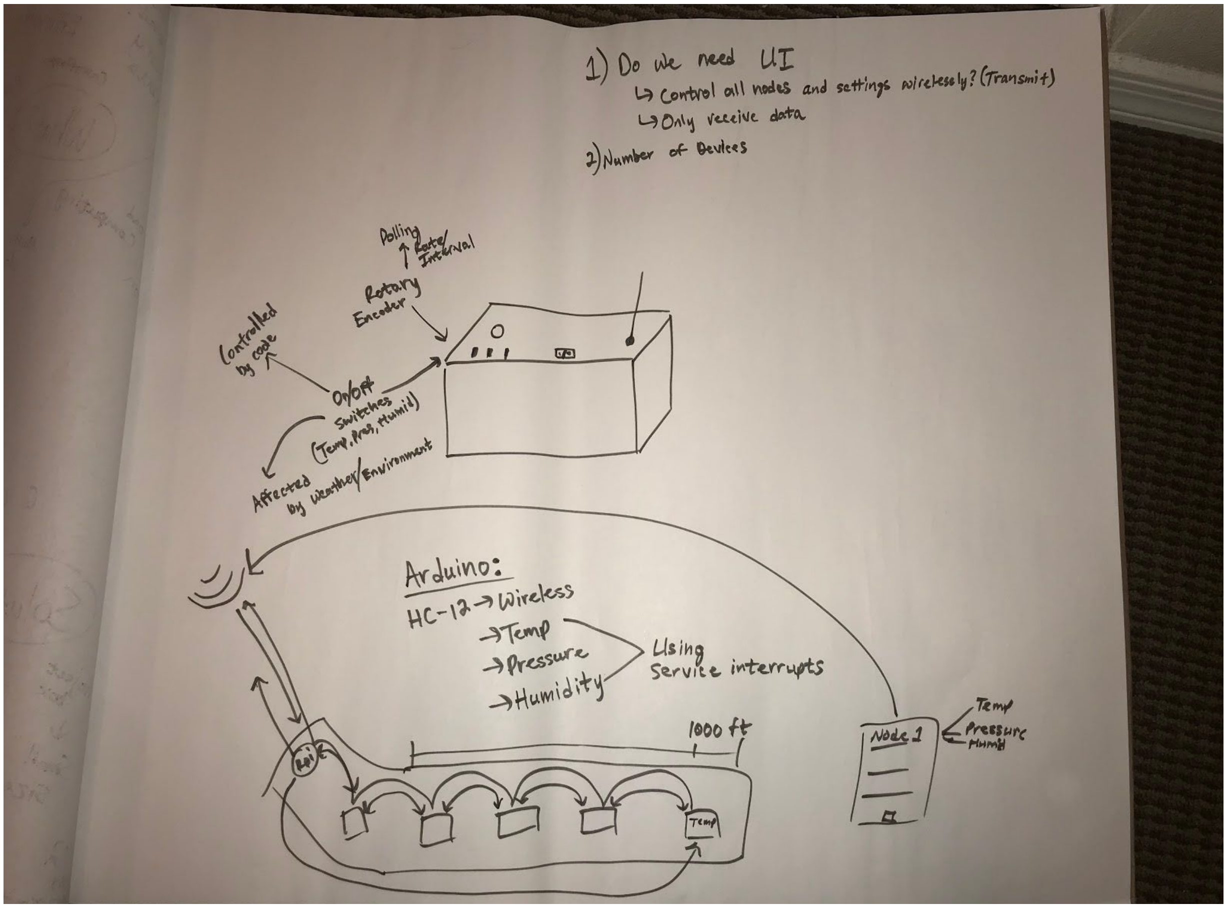

Figure 2: The image above is a very rough diagram of how we expect our nodes to communicate and interface in order to transmit information outside of the cave. Also pictured is a rough sketch of how our final device may turn out. Our design will definitely evolve as time goes on and we run into various complications and design changes. Explaining in more depth, the five device boxes you see at the bottom of the chart are nodes. Each node will be spaced an X amount of distance away from each other. We have a lead node and that is the one node that will transmit the data to the cloud for a user to view the data that is calculated from the sensors of the embedded systems. The drawing at the middle of the poster is a device box and that will house our circuits inside. We understand that it has to be camouflage and that is one constraint we are going to have to solve since we may need some sensors to stand above to better collect data.

Scope

Based on what we have discussed so far, cave exploration requires a lot of knowledge and hands-on support. Over the course of our project, we will need to be constantly learning and adapting to our struggles in order to ensure that we have a final product to demonstrate by April 2019. The primary goal of this project is to collect temperature, humidity, and pressure data since it will be difficult to collect useful and meaningful wind data while remaining camouflaged. Our project will include a Temperature, Pressure, and Humidity module that will be used to collect data. The SD Card module will be used to collect, store and prepare for the next data transmission. A real time clock will be used for timestamping and service interrupts.The Arduino Nano is a small, open-source, ATmega328-based board with a micro USB port. It uses a simple-interface IDE for which most of our project will be coded on. We hope to use the HC-12 for our wireless communication format and for the ideal file format, it was suggested that we use a .csv, because they are easy to use and can be read by both human and machine. Finally, we still need to achieve low power consumption by using a long-lasting battery to achieve a month-long polling time. Our plan is to prototype our device using external power supplies and then when we successfully implement every features, we will add the long-lasting battery. In the next meeting, we still need to talk about the details in order to continuously optimize our project, such as the most effective distance between each node and device.

The process of completing a project always requires constant testing and correction, so there are some alternatives for our design. First, based on the different ways of data transmission, we have two choices. One is that each test node is connected in series, then the final node is connected to the SD card, If a node has a problem, it will be reflected in the entire circuit, and we can easily know the situation. Another choice is that we connect each test node to the SD card, by this way, each test node works independently. Second, regarding the control of the working state of the monitor, we have two choices. The first one is manual operation through the mechanical switch, so that we can really ensure the actual working state of the monitor, but this method is more labor-intensive because a researcher will have to visit the site and turn on switches, the second method is that we control the working state through the code, this method is very convenient, but depends on the wireless control, so we can not fully ensure the synchronization of the code and the actual working state of the monitor.

After reviewing the scope and analyzing, the geological structure and development in the cave has different forms and mechanisms. For the investigator, the cave itself is a source of information and the main basis for the development of the work plan. The purpose of the cave is different, but the cave survey is the common requirement and the primary task. The results accumulated by a long-term cave survey will lay the foundation for the establishment of the national cave resource database, and provide a basis for the selection of cave research bases and cave resource planning, development and construction.

Technologies

After some researching and examination of other code/projects, we have narrowed down a specific set of technologies, sensors, and various other modules to carry out all of the tasks required by our project description memo. For the main brains of our project, we plan to use an Arduino Nano which is based on the Atmega328P Microcontroller Chip. The Arduino Nano is extremely versatile and is capable of controlling all our sensors, keeping time via the Real Time Clock module, storing the data via the SD Card Module, displaying a User Interface via the LCD, and transmitting/receiving data via the HC-12 wireless module. In order to keep our power consumption down, we will be using the RTC (Real Time Clock) to monitor the Arduino's power modes. We have a lot of code to write in order for our project to work seamlessly. Because of the complexity of code, it will be imperative that we work piece by piece and make sure blocks of code are functional before combining them with other tasks and blocks of code. This will make for easier debugging.

As mentioned previously, one of the most crucial modules of our project will be the implementation of a wireless communication system. Our ultimate goal is to have a local network of Arduinos using the HC-12 Wireless module to transmit and receive the timestamp/TPH data. Once the data has been transmitted across the network of nodes, it will be sent to some server or 'cloud' where our client will be able to interface with the data. In order for this all to happen seamlessly, we will need to rely heavily on the local communication between our Arduino nodes which will be spread throughout the cave. To accomplish our goal of a seamless wireless communication system, each Arduino will record data, store it to the SD card, and finally send it to the next node in the series. We were thinking that each node could independently record data on a set interval and once the data was collected it could again, be sent independently down the chain of nodes back to the server. Each node will be its own entity and will only interact with the other nodes as a way of relaying information to the device connected to the server. The HC-12 will rely on the Arduino Nano's built in I2C communication protocol. In order to use I2C with our HC-12, we will need to learn the appropriate libraries and research some other projects or I2C code. All modules except the SD Card module will be using the I2C bus on the Arduino Nano. For example, node 1 will be located furthest away from the entrance to the cave and ultimately should be able to send its data every 5 or so minutes to node 2 which will do nothing but relay the data to the next node, continuing until it reaches the surface node where it will be transmitted to the server. Perfecting the wireless communication system is going to rely heavily on code, but it will also need to work hand-in-hand with our RTC module.

The Real Time Clock is a clock that we will be able to interface with and control for specific tasks. The module operates and keeps time externally through its own low power circuit. It will need to keep track of time in order to control the on/off state of our microcontroller, timestamp our data readings, and be able to time the sending and receiving of data across wireless channels. In order to implement the RTC, we will need to attach it to the same I2C bus as the HC-12 Wireless module. Again, the key piece of making this module work is our code. If our code structure and use is incorrect, it could lead to problems further down the road when we start to combine modules.

The SD Card will be in charge of locally storing data in the case that there is an error in wireless transmission or a malfunction of some sort. As mentioned above, the SD card module is the only module that will not be attached to the I2C communication bus. Instead, the SD card will be using the SPI communication bus header on the Arduino Nano. Again, there is plenty of code and examples when using the SD card module with the Arduino. This is new technology to us, so implementing it in our application will be an obtainable challenge. Most likely, we will be storing data in a .txt or .csv file as they are both universal file types.

As of now, we are planning to implement an LCD screen that will allow the user to control certain settings of our device. The LCD will be implemented using the I2C with the HC-12 and SD Card modules. The LCD will use built in Arduino libraries to control sending/receiving channels, which modules are on and off, and possibly even the estimated amount of battery life. Ideally, we would like to have as low of a power consumption as possible and may have hardwired switches to control the modules and LCD. The LCD may be far fetched with the time we have for this project, but would ideal to allow the support of configuration changes.

The Temperature, Pressure, Humidity module that we will be using is the BME280 and is a complete measurement package. We intend to use libraries and code that is already out there to implement the module into our project. The hardest part about using the module is knowing which format and integer type to store all of the values in. Once our wireless communication system is working properly, the transmission of TPH data will be relatively easily and come naturally.

The absolute hardest part of our entire project will be taking our locally recorded data and transmitting it over a cellular network to the user. As of now, we have not brainstormed possible solutions to this as we have many other mountains to overcome before we accomplish the task of implementing a cellular network. As time progresses and we make progress on other aspects of our project, more time will be spent on solving this piece of the puzzle.

Issues with technologies

Transmitting Data between nodes - As mentioned before and reporting from our client, there was no definitive say on how far each node will be spaced for an X amount of distance from each other. This is a determining factor as we must test how far wireless modules can communicate with each other and to also solve other potential problems. Such as data loss when communicating with each other and how that data may be affected by distance, frequencies, cave curvature, etc. To address this problem, we'll have to run tests on distance to know the boundaries of wave communication.

Transmitting data from nodes to the cloud/user - As you will read under "Developing a local wireless configuration menu" will we discuss the constraint of implementing both tasks.

Power consumption - When considering power consumption, we also have to consider the size of the DC battery cell for each complete embedded system which is to fit into a box of its own, also for 5 systems to fit into a backpack. At the moment, we have considered a Lithium-Ion battery but did not discuss the voltage for the battery. We understand there is a 3.3V, 5V, and V-input for the Arduino Nano. As we progress through with the circuit implementation, we'll have to test power consumption. We understand that these circuits will run on Milli-Amps and possibly Micro-Amps. We wouldn't want to overload the circuits. Now, in terms of milli-Amp-Hours, this will lead us into our next problem of how long will the batteries supply power for the duration of one month. To address, we'll have to record data and observation when we build the prototypes.

Complexity of code and implementing all the necessary functions in their right order - As we researched, we found online resources to help us with this task of coding. Online resources like libraries, Electrical Engineering Project Community Forums, Computer Programming Peers, etc. With past project experiences, it would not be much difficult to program sensors but the challenge we may have trouble comprehending and implementing is the cloud computing function. To address the problem, we'll have to do heavy research on the topic.

Developing a local wireless configuration menu - When the data is computed, we will need a user interface for our researchers to see data and analysis for scientific purposes. As of now, we are still in the talks of real time computing for our outputs. It has not been discussed on what platform we want our users to interfere with to view the data. One proposed idea was the use of a website link to go to and the data could be viewed there. As far as transmitting data from one node to another, we will use transmitter and receiver circuits and that will be in the working prototype of our three selected prototypes.

Closing

As we finish up the thinking process and begin building the prototypes, will we have answered the questions listed in this document and then propose new questions. And by this process, the continuous asking of questions, will we continue to learn more about our project and execute it as planned. As of now, we have three proposed prototype task ideas and each will execute their own objective. One is to store data on an SD Micro Card, second is to transmit and receive data with another node, and third is to record data from the embedded sensors. In the end, each will have to act on each other and work as one complete embedded system. Upon completion, and/or attempted completion of our prototypes, we will present our work and findings to our client, Dr Tim Titus, as well as our GTA, Dina Ghanai. This presentation will be at the end of November and early December. Note that we are not subject to only presenting three prototypes so as a team we discussed that we may add a fourth prototype which is to act as a device box to demonstrate that it is weatherproof.