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Team 310: Biomedical Monitoring for Astronauts (BMA)

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# Abstract

Spacesuit design is currently an active area of research. Engineers and scientists are always working to improve current and future missions in space. Working in a pressurized suit in outer space presents a range of challenges. These include monitoring the in-suit environment and the astronaut’s health. Team 310 has created a sensor system for monitoring an astronaut’s health and in-suit environment. Our goal was to accurately measure critical metrics for research and safety purposes.

The sensor system consists of three modules. The first of which is a set of environmental sensors for measuring CO2 concentration, ambient temperature, and humidity. To monitor astronaut health, a set of biomedical sensors on the foot is used to measure heart rate, sweat levels, and body temperature. Finally, a main processing unit takes care of reading and interpreting sensor data. The team designed and fabricated a custom printed circuit board to house the processor. The project was a proof-of-concept design that monitors an astronaut’s vital signs and the environmental conditions in a spacesuit.

In general, the device can measure selected variables, store them locally, and transmit the data to an external device. The final deliverable from the team serves as a prototype for a sensor unit that could be used during an extravehicular activity mission.

*Keywords: biomedical, in-suit environment*

# Acknowledgement

We would like to firstly thank Dr. Noroozi for advising and mentoring our team during this project. Dr. Noroozi provided us with the technical expertise that we needed to complete the project. We would also like to thank the rest of our faculty, namely Dr. Hooker and Dr. Chuy for their guidance.

Table of Contents

[Abstract ii](#_Toc164871641)

[Acknowledgement iii](#_Toc164871642)

[List of Tables viii](#_Toc164871643)

[List of Figures viii](#_Toc164871644)

[Notation ix](#_Toc164871645)

[Chapter One: EEL 4914C/4915C 1](#_Toc164871646)

[1.1 Project Scope 1](#_Toc164871647)

[1.2 Customer Needs 1](#_Toc164871648)

[1.3 Functional Decomposition 2](#_Toc164871649)

[1.4 Target Summary 3](#_Toc164871650)

[1.5 Concept Generation 3](#_Toc164871651)

[Introduction 3](#_Toc164871652)

[High-Fidelity Concepts 3](#_Toc164871653)

[Concept 1 3](#_Toc164871654)

[Concept 2 4](#_Toc164871655)

[Concept 3 4](#_Toc164871656)

[Medium Fidelity Concepts 5](#_Toc164871657)

[Concept 1 5](#_Toc164871658)

[Concept 2 5](#_Toc164871659)

[Concept 3 5](#_Toc164871660)

[Concept 4 5](#_Toc164871661)

[Concept 5 5](#_Toc164871662)

[Concept 6 6](#_Toc164871663)

[Low Fidelity Tables 6](#_Toc164871664)

[1.6 Concept Selection 7](#_Toc164871665)

[Comparison Criteria 7](#_Toc164871666)

[House of Quality 7](#_Toc164871667)

[Pugh Chart 9](#_Toc164871668)

[Analytical Hierarchy Process 9](#_Toc164871669)

[Final Selection 10](#_Toc164871670)

[1.8 Detailed Design 10](#_Toc164871671)

[Introduction 10](#_Toc164871672)

[Selected Concept 11](#_Toc164871673)

[Sensor Processing Circuit Card Assembly 11](#_Toc164871674)

[Environmental Sensor Unit 12](#_Toc164871675)

[Biomedical sensor Unit 13](#_Toc164871676)

[Spring Project Plan 14](#_Toc164871677)

[Chapter Two: EEL 4914C/4915C 16](#_Toc164871678)

[Project Definition and Scope 16](#_Toc164871679)

[Final Detailed Design 16](#_Toc164871680)

[2.2 Results: Testing and Validation 17](#_Toc164871681)

[2.3 Operation 26](#_Toc164871682)

[2.4 Discussion of Results 27](#_Toc164871683)

[2.5 Conclusions 27](#_Toc164871684)

[2.6 Future Work 28](#_Toc164871685)

[2.7 References 28](#_Toc164871686)

[Appendices 28](#_Toc164871687)

[Appendix A: Codes and Standards 28](#_Toc164871688)

[Appendix B: Code of Conduct 28](#_Toc164871689)

[Mission Statement 28](#_Toc164871690)

[Team Roles 29](#_Toc164871691)

[Communication 31](#_Toc164871692)

[Appendix C: Functional Decomposition 35](#_Toc164871693)

[Appendix D: Target Catalog 36](#_Toc164871694)

[Appendix E: Engineering Drawings 36](#_Toc164871695)

[Appendix F: Calculations 37](#_Toc164871696)

[Appendix G: Scholarship in Practice 37](#_Toc164871697)

[Austin Roberts’ Scholarship in Practice Submission 37](#_Toc164871698)

[Evan Cloutier’s Scholarship in Practice Submission: 39](#_Toc164871699)

[Dallas Toth’s Scholarship in Practice Submission: 41](#_Toc164871700)

[Appendix H: Risk Assessment 42](#_Toc164871701)

[Appendix I: Operation Manual 42](#_Toc164871702)

# List of Tables

Table 1 - Health Low Fidelity Concepts 6

Table 2 - Environmental Low Fidelity Concepts 6

Table 3 - Circuit Card Design Concepts 7

Table 4 - Concept Comparison Chart 8

Table 5 - Comparison Criteria Chart 9

Table 6 - Spring Work Breakdown Structure 15

Table 7 - Sensors and their associated unit of measurement 18

Table 8 - Testing for Normal Operation of Biomedical Sensors 22

Table 9 - Testing for Normal Operation of Environmental Sensors 23

Table 10 - Testing for Threshold Operation of Biomedical Sensors 23

Table 11 - Testing for Threshold Operation of Environmental Sensors 24

Table 12 - Targets 36

# List of Figures

Figure 1 – Initial Block Diagram of Design 2

Figure 2 - House of Quality 8

Figure 3 - Final Block Diagram of Design 17

Figure 4 - PCB Layout and 3D Rendering 36

# Notation

|  |  |
| --- | --- |
| I2C | Inter-Integrated Circuit |
| SPI | Serial Peripheral Interface |
| BMA | Biomedical Monitoring for Astronauts |

# Chapter One: EEL 4914C/4915C

## 1.1 Project Scope

In our project, we have created a wearable sensor unit that is composed of a set of biomedical sensors and environmental sensors. The end goal was to create a wearable package that could be used inside of an astronaut’s space suit. The sensor unit should monitor data relative to the state of the astronaut, i.e., heart rate, blood O2 levels, etc. Also, the environmental sensors should monitor metrics like CO2 levels, humidity, and temperature within the space suit.

Key Goals:

* Create a device that can measure biomedical and environmental metrics.
* Interface various types of sensors into a single package.
* Process real-time data and output to a display as well as an SD card for storage.

Markets:

* Aerospace Industries
* Biomedical Industries

## 1.2 Customer Needs

Given the unique situation that our team faced, we found out early on that we would not be working with a sponsor. This meant that we were free to create virtually any project that we wanted. Thus, we did not have any customer needs or deliverables.

## 1.3 Functional Decomposition

A diagram of a diagram

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Figure 1 – Initial Block Diagram of Design

This functional decomposition provides an overview of the required functionality of the device. Our design will encompass a life support system for a space suit that will monitor the user’s health as well as their environment. Environmental monitoring metrics include temperature, humidity, pressure, presence or absence of various gases, and alarms when the astronaut’s motion is out of control. Potential biomedical metrics include heart rate, pulse oximetry, EKG, breathing rate, body temperature, and galvanic skin response.

The design will incorporate several sensors to monitor these metrics and once the data is acquired, the sensor noise needs to be filtered and processed. Once processed, the information is then made available through a communication interface. This output interface speed needs to be sufficient for “real-time” monitoring of acceleration and orientation.

The communication interface will transfer the data to an external connected device using the RS422 protocol, as well as possibly a wireless solution such as RFID.

## 1.4 Target Summary

This project is intended to be a proof-of-concept design that measures an astronaut’s vital signs and environment in a spacesuit. In general, the device shall measure selected variables, store the measurements locally, and provide a means of transmitting the data to an external device.

The key goal is to develop a prototype for a sensor unit that could be used during an extravehicular activity (EVA) mission. The device shall also transmit the collected and interpreted data. Note that long-range wireless data transmission would be handled by a separate system that interfaces with the device, the implementation of which is beyond the scope of the project. The device shall be powered from the existing power source used by the life support system. The project description and targets have been determined solely by Team 310, as the original sponsor is no longer providing the project definition.

## 1.5 Concept Generation

## Introduction

There are several techniques for concept generation, including the morphological chart, biomimicry, crap shoot, forced analogy, anti-problem, and battle of perspectives. The primary method of choice for Team 310 is the crap shoot technique.

## High-Fidelity Concepts

### Concept 1

The spacesuit sensing unit shall be composed of two main units, one internal and one external. The internal unit shall be a wearable stocking (high-rise sock) that the astronaut will have on under their base suit. The external unit shall be a small device that is able to be attached to the outside of the suit or somewhere on the astronaut’s backpack. These two devices shall be able to wirelessly transmit data to an external control system (a laptop/desktop for our purposes) so that the condition of the astronaut can be closely monitored. The internal unit shall contain an array of different sensors that can accurately monitor the astronaut’s body temperature, blood O2 levels, heart rate, sweat levels, as well as the pressure within the suit. The external sensor shall also contain a variety of sensors that shall monitor the environment surrounding the astronaut. The critical metrics that will be monitored include the angular acceleration of the astronaut, the ambient temperature and humidity, the presence of various gases, as well as the presence of various types of radiation that the astronaut is being subjected to.

## Concept 2

Integrate a set of gloves and socks that communicate via RFID and contain heart rate, blood pressure, core body temperature, and Galvanic skin response (GSR) sensors that use RFID to report data back to a PCB containing an MCU and memory for processing and storage. The gloves can be environmental sensors and the socks can be internal sensors, or vice versa.

### Concept 3

Create a wearable sock with a heart rate sensor, on-toe pulse oximeter, thermometer, and Galvanic skin response sensor. External to the sock, shall be a suite of environmental sensors, including a CO2 sensor, pressure sensor, humidity sensor, and an accelerometer. If multiple sensors are utilized for one particular measurement, the data collected will be taken as best average. The sensor data shall be sampled, timestamped, and logged in CSV format for transmission to another device via either a wired serial connection or RFID.

## Medium Fidelity Concepts

### Concept 1

Create a pair of underwear that contains heart rate, blood pressure, core body temperature, and GSR sensors that use RFID to report data back to a PCB containing an MCU and memory for processing and storage.

### Concept 2

Create a belt containing heart rate, blood pressure, core body temperature, and GSR sensors that use wired serial connections to report data back to a PCB containing an MCU and wireless communication chip for processing and exporting said data.

### Concept 3

The design shall be a wearable sleeve for the arm that contains heart rate, blood pressure, temperature, and GSR sensors connected via a cable to a printed circuit board that processes, stores, and transmits the data over a serial connection or RFID to a PCB containing an MCU.

### Concept 4

The final design shall be an ankle monitor that contains heart rate, blood pressure, temperature, and GSR sensors that utilize Bluetooth connectivity to transmit and analyze the data.

### Concept 5

Create a wearable vest containing the sensor suite. The vest shall measure all of the standard metrics such as heartbeat, temperature, and contains on board MCU and RFID components to collect, interpret, and send off real-time data.

### Concept 6

Create a piece of wearable clothing that can be worn on any limb of the body that contains heart rate, blood pressure, core body temperature, and GSR sensors that use RFID transmitters/readers to report data back to a PCB containing an MCU and for processing and exporting said data.

## Low Fidelity Tables

Each low fidelity concept was organized into a table based on one of three categories: monitoring astronaut vital signs, monitoring the in-suit atmospheric environment, and the circuit card/hardware design.

|  |  |  |  |
| --- | --- | --- | --- |
| **Monitoring Health in Spacesuit** | | | |
| **Microcontroller** | **Data Output** | **Data Logging** | **Mounting Components** |
| MSP430FR5994 | SPI | EEPROM | Breadboard |
| Arduino Nano | I2C | SRAM | Perforation board |
| Raspberry Pi Pico | RS-232 | FRAM | Printed circuit board |
| STM32 | RS-422 | Flash |  |
|  | RFID |  |  |

Table 1 - Health Low Fidelity Concepts

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Monitoring Environment Around Suit** | | | | |
| **Monitor Body Temp** | **Monitor Blood Pressure** | **Blood O2 & Heart Rate** | **Sensor Apparatuses** | **Other Health Variables** |
| In-ear thermometer | Inflatable cuff | Wearable finger pulse oximeter | Glove | EKG |
| Forehead thermometer | Arterial tonometry | Heart rate sensor | Arm sleeve | Breathing rate (chest strap) |
| Oral/nasal thermometer |  | In-ear heart rate sensor | Sock | Hydration |
| IR thermometer |  | Wrist wearable | Leg sleeve | Galvanic skin response |
| Sensor(s) integrated into fabric |  |  |  | Bone density |
| Network of Temperature Sensors |  |  |  | DEXA scan |

Table 2 - Environmental Low Fidelity Concepts

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Circuit Card Design** | | | | | |
| **Monitor Angular Acceleration** | **Monitor Radiation** | **Monitor Ambient Temperature & Humidity** | **Monitor gas concentrations** | **Monitor Ambient Pressure** | **Monitor Humidity** |
| Singal Inertial measurement unit | UV exposure patches | Embedded temperature sensors | Non-dispersive IR sensors | barometer | Absolute, relative, and specific |
| Network of IMUs | Gamma ray detector | Wireless temperature sensors | MOS sensors | Mechanical gauges | Via hygrometer |
| Accelerometer (spin) | Ionizing radiation sensor | Capacitive hygrometer (humidity) | Ammonia detection |  |  |
| Gyroscope |  |  | Psychrometer |  |  |
| Magnetometer |  |  | CO2 sensor |  |  |
|  |  |  | non-dispersive Infrared sensors (NDIR) |  |  |

Table 3 - Circuit Card Design Concepts

## 1.6 Concept Selection

## Comparison Criteria

Once the concept generation process was completed, the high-fidelity concepts were compared and evaluated according to a set of comparison criteria decided by the Team and described in Table 1 below. Each column describes the relative importance of the labeled criterion to the other criteria listed on the left column. For example, *cost* is classified as being 0.5 times as important as *size*. For clarity, *sample rate* refers to the frequency with which sensor readings are taken and logged; *ease of application* refers to ergonomics.

## House of Quality

With the comparison criteria determined and quantified, the next step was to organize the criteria into the house of quality in Figure 1. The house of quality is used to help prioritize criteria and determine the extent to which certain criteria affect other criteria. Although we have no true customer, the house of quality was created assuming customer needs that were imposed by the Team.

A screenshot of a computer

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Figure 2 - House of Quality

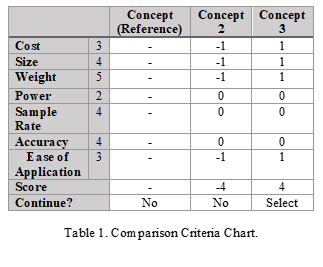


Table 4 - Concept Comparison Chart

Pugh Chart

The Team then created a Pugh chart to compare the three high-fidelity concepts first described in the concept generation process to identify the best design choices. The Pugh chart, displayed in Table 2, uses Concept 1 from the preceding section as the reference concept and compares it with the other two concepts in each of the seven chosen comparison criteria. The Team determined that Concept 3 was equal or better than Concepts 1 and 2.

## Analytical Hierarchy Process

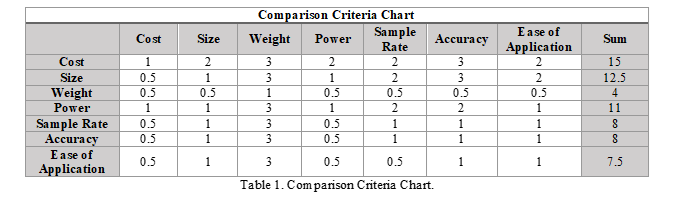


Table 5 - Comparison Criteria Chart

Team 310 has made the careful decision to not include an analytical hierarchy process (AHP) analysis in the concept selection process. The primary reason for this exclusion is the extenuating circumstances surrounding the project definition. As our sponsor informed us that we would no longer be able to complete the project as originally proposed, and the previously envisioned modified version of the original project was deemed overly simplistic and unfitting for a senior design capstone project, the Team elected to invent a completely new project definition—in essence, we act as our own customer. Unfortunately, this iterative process consumed much of the available time in the semester, leaving us with the difficult decision to streamline certain design processes to ensure that the Team meets essential deadlines. This included excluding AHP from the concept selection process.

## Final Selection

After careful deliberation, the Team decided to proceed with Concept 3 as the final design. This concept was selected because it performed exceptionally well per the comparison criteria. It also appears to be feasible to implement while containing certain manageably challenging aspects, such as fitting biomedical sensors into a textile for the foot and adequately logging and transmitting sensor data. The primary issue with the previous project definition was the lack of substance to the project, given that the project sponsor is no longer providing the IMU, and the form/fit/function specifications as originally intended. This new project concept presents a similar engineering challenge—that is, acquiring, processing, and transmitting sensor data—while having an interesting and engaging application: spacesuits.

## 1.8 Detailed Design

## Introduction

 This section describes the final product produced by Team 310, including modifications as necessary to meet time constraints. Our focus from this point forward is creating a suitable demonstration which showcases as much of the functionality we completed as possible. This project is a proof-of-concept design that can read from a variety of sensors for potential use by an astronaut.

# Selected Concept

The chosen design shall contain two main monitoring suites. The first of which is a set of biomedical sensors capable of monitoring an astronaut's vital signs and spacesuit environment during EVA missions. The suite shall be incorporated within a wearable sock that is able to transmit the sensor data to the main communications system, implemented in C++, via a serial interface, I2C.This suite shall feature a heart rate sensor, on-toe pulse oximeter, thermometer, and Galvanic skin response sensor to monitor the internal vitals of the wearer.

The second of which will be a set of in-suit environmental sensors that will live external to the sock. This set of sensors will include a CO2 sensor, pressure sensor, and humidity sensor. The sensor data shall be sampled, timestamped, and logged in CSV format for transmission to another device via a wired serial connection.

# Sensor Processing Circuit Card Assembly

The sensor processing board’s main function shall be to receive any data from the sensors, analyze and display it in an organized format, to be sent to the LCD display that shall show pertinent information in real time. The processing unit contains the microcontroller, and SD card reader, as well as all other connections to the sensors. The microcontroller shall process the data being sent to the unit from the environmental sensors and biomedical sensors. This data shall then be converted to I2C format to be inputted into the microcontroller. The data shall then be stored onto the SD card inserted into the SD reader. It should be noted that for the final processing unit, our team has constructed a custom PCB containing an STM32 microprocessor.

The data received from the sensors shall be processed and analyzed through the Sensor Processing Circuit Card containing the STM32 microcontroller, SD Card reader, and I2C connectors and displayed in a meaningful way for accurate reading and response. The program shall be implemented in C++ developed in Code Composer Studio. The program shall sample the sensor data with timestamps, log and display real-time readings from each sensor in graphical format and detect when abnormal levels are reached from any sensor to then trigger a visual and auditory alert to the wearer and their supervisor.

# Environmental Sensor Unit

The environmental sensing dynamics of the sock include a multitude of sensors. These sensors include CO2, pressure, and humidity sensors with the direct intention of monitoring the astronaut’s isolated environment within their spacesuit. It is self-evident that the environment shall be monitored at all times while the device (sock) is in use. There were multiple sensors up for selection that underwent scrutiny amongst the team; two to three sensors were researched and selected as candidates for their respective categories. The selection process included elements such as price, sampling rate, I/O interface(s), power consumption, data format, etc. In addition, applicability and lead time was another critical element that is considered. All of the dictating elements were used in the selection process for determining which of candidate sensors would be chosen as the utilized sensor in the design.

For the first of the environmental sensors was the CO2 which consisted of 3 candidates: the USEQGSEAC82180, T6793-5K, and PASCO2V01BUMA1 CO2 sensors. Each of them met the requirements for I/O output (I2C) and the power consumption rates. The dictating factor for the chosen sensor was the range of how much CO2 was in the system it operated in; options 1 and 3 both worked in the 250-4000 ppm range while option 2 was capable of ranges from 0-5000ppm of CO2. This was the deciding factor for its selection, additionally its short lead time of 3 weeks compared to its respective counterparts.

The barometric air pressure sensor proved to be difficult in finding a small-scale application that fitted the requirements of the design. However, after researching, two candidates were looked at and underwent the decision process: The Bosch BMP280 and the AITRIP pressure sensors. After decision making process the BMP280 sensor was selected due to its capability to be integrated with an I2C connection as well as the voltage operation range. The counterpart was very similar in regard to performance however lacked the I2C attribute thus its rejection in use for the project.

Lastly the humidity sensor selection was conducted and consisted of two options that gave promising potential. The SHT85 and the CC2D33S-SIP humidity sensors were very similar with respect to performance – they both had I2C I/O interfaces, digital outputs, power consumptions, and physical size. The deciding factors were lead time and output data rates; the chosen sensor was the SHT85 which has 16-bit output at 8 sec/sample with an 8-week lead time versus a 14-bit output at 7 sec/sample with a 13-week lead time.

# Biomedical sensor Unit

The biomedical sensor suite shall be comprised of a pulse-oximeter, thermometer, and galvanic skin response sensor. Each of these sensors shall be integrated into the sock and have each of their signals conglomerated into one connection so it can be exported outside of the internal pressure suit. Each type of sensor had multiple contenders for our project. We selected each sensor based on their price, sampling rate, I/O interface(s), power consumption, and data format.

The first biomedical sensor, the pulse-oximeter, had an extremely small pool to select from. The sensor we chose was the MAXREFDES117. The advantage of this sensor is that it is a highly integrated small-size sensor, non-chest based, and ultra-low power consumption. The small board size of 12.7mm x 12.7mm is useful for this wearable sock application where size is a crucial factor.

The second biomedical sensor, body temperature reader, was the most expensive sensor in our project. The sensor chosen is the MAX30205. This device converts the temperature measurements to digital form using a high-resolution, sigma-delta, analog-to-digital converter (ADC). The accuracy of this sensor meets clinical thermometry specification. The sensor has a 2.7V to 3.3V supply voltage range, low 600µA supply current, and an I2C compatible interface that make it ideal for medical applications.

The third biomedical sensor, the galvanic skin sensor, was chosen for its I2C interface. The sensor chosen is the MIKROE-4500. This sensor’s main features include low-noise analog front end, highly accurate GSR acquisition, blood pressure measurements, long operating period and more.

## Spring Project Plan

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Tasks**​ | **Description**​ | **Assigned to**​ | **Start**​ | **Due Date**​ |
| Updated BOM​ | Include additional items needed to the BOM and send to Dr. Hooker for purchasing.​ | Evan Cloutier, Austin Roberts​ | 1/8/2024​ | 1/15/2024​ |
| Abstract​ | Create an abstract discussing motivations and goals of the project​ | Evan Cloutier, Austin Roberts​ | 1/22/2024​ | 2/2/2024​ |
| VDR 4​ | Update of Fall progress & future work.​ | All​ | 1/22/2024​ | 2/9/2024​ |
| PCB Design & Ordering​ | Design a PCB that can house all sensors and connections.​ | Landon Hicks, Nicholas Billmire​ | 2/5/2024​ | 2/22/2024​ |
| VDR 5​ | Initial prototype presentation​ | All​ | 2/12/2024​ | ~3 weeks​ |
| Interfacing sensors with MCU​ | Create an initial prototype of sensor connections and gather data.​ | Austin Roberts, Jada Davis​ | 2/1/2024​ | 3/1/2024​ |
| Software design​ | Write the software for our design and format parameters like threshold values, alarms, and display values.​ | Jada Davis​ | 2/12/2024​ | 3/1/2024​ |
| Testing Documentation​ | Create testing documentation. This will enable efficient and thorough​ testing of our design.​ | Dallas Toth, Evan Cloutier​, Nicholas Billmire | 2/19/2024​ | 3/1/2024​ |
| Integrate sensors in the sock​ | Synthesize the final, wearable design as described in our scope.​ | Landon Hicks​ | ?​ | ?​ |
| Begin Testing Procedures​ | Complete testing procedures per standards given in the documentation.​ | Dallas Toth, Evan Cloutier​ | 3/1/2024​ | ?​ |
| Create Website​ | Create website to demonstrate our project​ | Evan Cloutier​ | 2/1/24​ | ?​ |
| Final Presentation​ | Prepare and present a final product that solves our problem.​ | All​ | After VDR 5​ | ?​ |
| Final Demonstration​ | Provide a technical demonstration of our design to faculty involved in the project. ​ This will be the last thing that we do.​ | All​ | 4/26/2024 | 4/26/2024 |

Table 6 - Spring Work Breakdown Structure

# Chapter Two: EEL 4914C/4915C

## Project Definition and Scope

The key goal is to develop a prototype for a sensor unit that could be used during an extravehicular activity (EVA) mission. The device shall also transmit the collected and interpreted data. Note that long-range wireless data transmission would be handled by a separate system that interfaces with the device, the implementation of which is beyond the scope of the project. The device shall be powered from the existing power source used by the life support system. The project description and targets have been determined solely by Team 310, as the original sponsor is no longer providing the project definition.

## Final Detailed Design

Team 310 has designed a proof-of-concept space suit sensor system. This sensor system has two main systems which will measure the astronaut’s vital signs as well as the in-suit environment of the spacesuit. This system of sensors will be incorporated into a wearable sock that the astronaut will wear. The environment sensors include CO2, pressure, and humidity sensors to monitor the astronaut's environment within their spacesuit. The biomedical sensors will incorporate a pulse-oximeter, thermometer, and galvanic skin response sensor together to monitor the health of the astronaut. These sensor readings were processed by a microcontroller. The data will be outputted to an LCD display and stored on an SD card.

A diagram of a circuit board

Description automatically generated

Figure 3 - Final Block Diagram of Design

## 2.2 Results: Testing and Validation

**1. Introduction**

* The project is based on the application of a sensor package applicable for astronautical use in the form of a sock. It includes two primary systems which measure both the vital signs of the user and their surrounding ambient environment within the space suit. Many sensors are built onto this design including CO2, pressure, humidity, pulse oximetry, body temperature, and galvanic skin response. The combination of the sensors will be connected to a microcontroller where the readings and associated data are assessed.

**2. Equipment and Materials**

* Equipment required includes a laptop running Windows with the STMcube IDE to update/ change any software, and to conduct the test. Additionally, the sensor package in both the raw and completed states (i.e. not attached to sock or attached), Logic analyzer, oscilloscope, and DMM.
* Specific requirements for equipment calibration or maintenance include inspecting the sensor package to be sure if there are any defects to the device, these include but are not limited to electrical shorts, frayed connections, broken pins, or any apparent defects that would require the test operation to be stopped. Calibration is expected to be stout from the manufacturer but still verified in the development of the sensor package.

**3. Data Standards**

* Collected data will be measured in the manufacturer's designated units. Data transmission for the sensor package and any external information system are specifically designed to i2C protocols i.e. all sensors and external displays operate on the i2C protocol to and from the MCU.
* The design was for the LCD display, SD card, and RFID tag systems and their communication protocol is over SPI.
* Referring to the block diagram and table below for respective flow of data and designated units of measurement.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Sensor** | Pulse Ox | Heart rate | GSR | CO2 | Pressure | Temp. | Humidity |
| **Unit** | SpO2 % | Beats/min | Ohms | Ppm | atm | Centigrade | Relative (%) |

Table 7 - Sensors and their associated unit of measurement

**4. Safety Precautions**

* The sensor package is built well however it is better to conduct proper safety behavior and be mindful of instances of electrostatic discharge, wet environments, and electrical shock cases.
* It is the responsibility of the test operator, test engineer, and test subject to be always vigilant in the matter of safety and required to stop the test if there is any possible case of a concern.
* In case of emergency, remove power from device and call emergency services.

**5. Responsibilities**

* For the test the following roles are present: test operator, test engineer, test subject, quality personnel (if applicable) and any observers.
* The responsibilities of the test operator are to take into account the safety of the environment, verify test is ready to begin, strictly follow the test procedure nor deviate from it in any circumstance unless to stop the test, and remain vigilant for any errors, faults, or other instances of failure that may occur.
* The responsibilities of the test engineer are the following: work in relation to the test operator, walkthrough the test procedure with test operator, overlook well-being of test subject, consistently be aware of test environment, verify the results and determine if within the pass/fail specifications.
* Test subject is a voluntary role which includes of simply wearing the sensor package sock and following all instructions from test operator and test engineer.
* Quality personnel are responsible for monitoring the authenticity and qualities of the test procedure & data collection. They serve no purpose in conducting the test itself but are required to watch over and be sure the testing isn’t deviating from the instructions.
* Observers are welcome but not required to sit on tests, their role is to spectate the test and remain out of the way during the procedure.

**6. Procedures**

* 6.1. Preparation:
  + - Setup of both the Biomedical and In-Suit Environmental sensors
    - Preparation of materials
    - Calibration of equipment (if applicable)
* 6.2. Execution / Threshold
  + - Step-by-step instructions for conducting the test.
    - Parameters to be measured or observed.
    - Control measures to ensure accuracy and repeatability.
* 6.3. Data Collection
  + - Recording of observations and measurements
    - Documentation of any deviations or unexpected occurrences
* 6.4. Analysis (if applicable)
  + - Data analysis procedures
    - Interpretation of findings / results
* 6.5. Reporting
  + - Compilation of results
    - Generation of test reports
    - Communication of findings to relevant stakeholders

**7. Test Cases and Functionalities**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Test Writer:** Evan Cloutier & Nicholas Billmire & Dallas Toth | | | | | | | |
| **Test Case Name** | | Normal Operation – Biomedical Sensors | | | | Test ID #: | 0001 |
| **Description** | | This test procedure is used to ensure the biomedical sensors are operating as they should in a normal situation. | | | | Type | Functionality |
| **Tester Information** | | | | | | | |
| **Name of Tester** | | Dallas Toth | | | | Date | 4/10/24 |
| **Hardware/Software Ver.** | | 1.0 | | | | Time | 4:00 pm |
| **Setup** | | Power on device and make proper connections so that outputs may be observed. | | | | | |
| **Step** | **Actions** | **Expected Results** | **Pass** | **Fail** | **N/A** | **Comments** | |
| 1 | H.R. -  Make skin contact with the HR sensing unit and observe the printed results. | In the normal case, the HR sensor should report a resting heart rate value of between 60-100 bpm. |  | Reading of about 150 bpm. |  | According to the Mayo Clinic, the normal resting heart rate for adult’s ranges from 60 to 100 bpm. | |
| 2 | SpO2 -  Blood O2 % |  | Reading of 82.5% - good enough |  |  | According to the CDC, oxygen saturation around 90% is normal for healthy adults. | |
| 3 | G.S.R. -  Make skin contact with the electrode pads | In the normal case, the wearer should have low sweat levels. This should correspond to low skin conductivity. | Reading of about 37 across electrodes on the user. |  |  | The sensor reads skin conductance and gives a reading of an integers between 0 and 63 – 0 being very conductive and 63 being very resistive. | |
| 4 | Body Temp. | In the normal case, the body temperature should be around 37 C. | Reading of about 74 F on the user's skin. |  |  | According to the Mayo Clinic, the normal average body temperature for adults is about 37 C or 98.6 F. | |
| **Overall Test Result** | | | Pass |  |  |  | |

Table 8 - Testing for Normal Operation of Biomedical Sensors

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Test Writer:** Evan Cloutier & Nicholas Billmire & Dallas Toth | | | | | | | |
| **Test Case Name** | | Normal Operation – In-suit Environment Sensors | | | | Test ID #: | 0002 |
| **Description** | | This test procedure is used to ensure the in-suit environment sensors are operating as they should in a normal situation. | | | | Type | Functionality |
| **Tester Information** | | | | | | | |
| **Name of Tester** | | Dallas Toth | | | | Date | 4/10/24 |
| **Hardware/Software Ver.** | | 1.0 | | | | Time | 4:00 pm |
| **Setup** | | Power on device and make proper connections so that outputs may be observed. | | | | | |
| **Step** | **Actions** | **Expected Results** | **Pass** | **Fail** | **N/A** | **Comments** | |
| 1 | CO2 | The CO2 levels in the environment should be reported and displayed. | Readings were at about 1000ppm and they increased when the sensor was exhaled on. |  |  | If CO2 levels exceed 1000ppm alarm | |
| 2 | Ambient Temp. | The ambient temperature of the environment should be reported and recorded. | Readings of around 74 degrees. |  |  |  | |
| 3 | Ambient Pressure | The ambient pressure should be reported/displayed | Readings of about 101394 Pa which is about 1 atm. This is what we expected. |  |  | The sensor operating range is 300 hPa to 1100 hPa, or about 0.296 atm to 1.08 atm. Generally, a spacesuit needs 32.4 kPa (324 hPa) pressure, but older spacesuits operate at 20.7 kPa, which is about the level of commercial jet pressurization. | |
| 4 | Humidity | The humidity level (%) of the environment should be reported. An expected value of around 30-50% should be observed and recorded. | Readings of about 29% which is accurate given the testing environment. |  |  |  | |
| **Overall Test Result** | | | Pass |  |  |  | |

Table 9 - Testing for Normal Operation of Environmental Sensors

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Test Writer:** Evan Cloutier & Nicholas Billmire & Dallas Toth | | | | | | | |
| **Test Case Name** | | Threshold Operation – Biomedical Sensors | | | | Test ID #: | 0003 |
| **Description** | | This test procedure is used to ensure the biomedical sensors trigger proper alarms/messages when certain threshold conditions are met. | | | | Type | Functionality |
| **Tester Information** | | | | | | | |
| **Name of Tester** | | Dallas Toth | | | | Date | 4/10/24 |
| **Hardware/Software Ver.** | | 1.0 | | | | Time | 4:00 pm |
| **Setup** | | Power on device and make proper connections so that outputs may be observed. | | | | | |
| **Step** | **Actions** | **Expected Results** | **Pass** | **Fail** | **N/A** | **Comments** | |
| 1 | Heart Rate  Make skin contact with the HR sensing unit and observe the printed results. | A reading of the test subjects' heart rate should be displayed and provide a refresh on the reading. If the reading falls out of the ranges specified, then an alarm is triggered. |  |  |  |  | |
| 2 | G.S.R. | Reading the galvanic skin response value (in ohms), the value is expected to remain constant but if the skin is too sweaty then a warning is triggered |  |  |  |  | |
| 3 | Body Temperature. | Expected results include triggering a notification or alarm if the test subject's temperature is too hot or cold. |  |  |  |  | |
| **Overall Test Result** | | |  |  |  |  | |

Table 10 - Testing for Threshold Operation of Biomedical Sensors

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Test Writer** Evan Cloutier & Nicholas Billmire & Dallas Toth | | | | | | | |
| **Test Case Name** | | Threshold Operation – In-suit Environment Sensors | | | | Test ID #: | 0004 |
| **Description** | | This test procedure is used to ensure the in-suit environment sensors trigger proper alarms/messages when certain threshold conditions are met. | | | | Type | Functionality |
| **Tester Information** | | | | | | | |
| **Name of Tester** | | Dallas Toth | | | | Date | 4/10/24 |
| **Hardware/Software Ver.** | | 1.0 | | | | Time | 4:00 pm |
| **Setup** | | Power on device and make proper connections so that outputs may be observed. | | | | | |
| **Step** | **Actions** | **Expected Results** | **Pass** | **Fail** | **N/A** | **Comments** | |
| 1 | CO2 | Show and result the CO2 reading and trigger an alarm if the CO2 levels exceed the specified value. |  |  |  | Per MIT Climate portal the value for CO2 levels sustainable for humans are within 280 - 350ppm | |
| 2 | Ambient Temp. | The ambient temperature within the suit is expected to be shown and recorded in degrees Fahrenheit, if the value is too cold or too hot an alarm is displayed. |  |  |  | Per NASA, a spacesuit is designed to insulate its user from temperatures ranging from –249F to 250F | |
| 3 | Ambient Pressure | If pressure of in-suit environment is less or greater than 3.5 psi alarm should trigger |  |  |  | Per NASA, 3.5psi is the internal pressure of a spacesuit environment | |
| 3 | Humidity | The humidity sensors are required and expected to display the percentage of relative humidity within the suit, triggering an alarm if the percentage exceeds 60% humidity (ideal range for electronics) |  |  |  |  | |
| **Overall Test Result** | | |  |  |  |  | |

Table 11 - Testing for Threshold Operation of Environmental Sensors

**8. Quality Control**

* The procedure for the test's quality assurance is to have the present quality engineer (if applicable) verify the collected data.
* If the quality engineer is not present, then the sake of quality falls upon the test engineer and test operators to verify the test procedure's quality.
* All results, records, and other information collected are expected to be taken as is and not skewed whatsoever to provide a passing test. This is the primary purpose of the quality engineer, to observe if this malpractice is conducted as well as maintain the authenticity of the test.
* Any changes to the testing procedure must illustrate a valid reason, changing the passing requirements requires a reason such as updates to hardware, software, etc. rather than for the sake of getting tests to pass or to overlook failing aspects.

**9. Documentation and Record-Keeping**

* All documents relating to pass/fail of the test are to be filled out on the designated testing forms provided from the ECE department.
* All failures of test should be recorded and the reason for such failure.
* Recording the test procedures is conducted in the documents associated with the sensors and their associated observers.
* All test results and readings are to be kept for future reference, additional recordings that are not written in the testing procedure such as debugging or monitoring outlying product behavior is to be recorded and documented as well.

**10. Validation & Verification**

* Validation of the test is composed of making sure that the specified parameters of the test are followed and not changed/overwritten to assure a forced-passing test. This section is in conjunction with the previous (Doc. and record keeping)
* Validation includes checking the process of checking the product meets the requirements per customer, or design specifications.

**11. Approval**

* For the test to be approved, the test operator, test engineer, and quality control personnel must sign off and agree to approve the test and respective results.
* The approval's main purpose is recording who conducted the test and responsibilities.

## 2.3 Operation

The biomedical monitoring for astronauts sensing sock is easy and intuitive to use.

1. The first step is to put the sock onto the astronaut’s foot. Ensure that the sensors sewn into the sock align with the toes of the foot. Be careful not to damage any cabling or sensors while putting on the sock.
2. To operate the device, begin by powering it up by connecting a battery. The device runs on five AA batteries. The microcontroller will automatically power on and begin taking sensor readings.
3. Sensor data will be displayed on the LCD screen and any anomalous readings will be reported in the form of an audible alarm.
4. To obtain the readings wirelessly please connect the RFID reader to a computer. Install compatible software that works with the RFID reader and use the software to interrogate the onboard RFID chip. Any RFID reader and software supporting the appropriate frequency range will work.
5. Data is also written to the attached SD card automatically. No further configuration is required to use the device. If required, the device may be reset by pressing and holding the reset button briefly.

## 2.4 Discussion of Results

It should be noted that the project design is incomplete. We are still working on interfacing all the sensors with the custom PCB processing unit. Once this is done, we will incorporate our threshold conditions and alarms in our software and will be able to test threshold conditions.

## 2.5 Conclusions

All in all, our design was successful in interfacing various types of sensors to a single processing unit. Additionally, the sensor data that was read was processed to be able to be understood by the user. However, our team faced some issues with a couple of sensors, primarily the heart rate and pulse oximeter sensor, thus the results from these sensors were not successfully read at the end of the semester.

## 2.6 Future Work

In the future, work would continue with creating and implementing software to process and monitor the sensor data. This would be used to create alarms to notify the user of any concerning values, e.g., high levels of CO2 inside the suit. Additionally, the overall package of the design would be improved so that it is all encompassed in a low profile, wearable design.

## 2.7 References

There are no sources in the current document.

# Appendices

## Appendix A: Codes and Standards

Our project, while not particularly intensive regarding codes and standards, makes extensive use of the I2C and SPI serial communication protocols, as well as utilizing RFID as a means of data transmission. These protocols ensure efficient communication with the microcontroller, sensors, data storage device(s) and transmission devices. We are committed to following all appropriate codes and standards as required by professional organizations and law.

## Appendix B: Code of Conduct

### Mission Statement

Team 310 is committed to developing a highly effective circuit card assembly for interfacing with a multi-axial angular sensor. Each member of this team will contribute their full effort toward creating a safe and productive work environment by treating one another with respect and acting with integrity. Everyone is expected to contribute equally to the project while upholding the highest standard of quality, ethics, and professionalism. This team is committed to delivering a solution that reflects positively on Florida State University, Florida A&M University, and project sponsor L3Harris Technologies.

### Team Roles

Each team member is delegated a specific role based on their experience and skillsets and is responsible for all here-within:

**Project Manager: Evan Cloutier**

The project manager is responsible for the team as a whole. Their responsibilities include developing a plan and timeline for the project, delegating tasks among group members according to their skillsets, finalizing all documents, and providing input on other positions where needed. The project manager is responsible for promoting synergy and teamwork. When a problem arises, the project manager shall act in the best interest of the project. They keep the communication flowing, both between team members and the project sponsor. The project manager is generally expected to plan and organize meetings. They are additionally responsible for producing minutes for the meetings. Finally, the project manager is responsible for overall project plans and progress.

**Test Engineer: Dallas Toth**

The test engineer will play a critical role in ensuring the quality and reliability of the circuit card interface. Their responsibilities include designing, implementing, and executing test plans, as well as documenting defects when redesign is needed. Their contributions will be vital in delivering software solutions that meet or exceed customer expectations and industry standards.

**PCB Design Engineer: Landon Hicks**

The printed circuit board (PCB) design engineer shall design the physical circuit card, including the circuits themselves (when appropriate), their placement and routing.

**Digital Communications Engineer: Nicholas Billmire**

The digital communications engineer shall implement the sensor system output in the proper message format. This includes assisting the PCB design engineer with proper connections and hardware configuration.

**Embedded Software Engineer: Jada Davis**

The embedded software engineer is responsible for designing and maintaining embedded software implemented in the project, as delegated by the project manager.

**Signal Processing Engineer: Austin Roberts**

The signal processing engineer is responsible for the processing of data from the angular sensor, as delegated by the project manager.

**Agreement Among Team Member:**

- Work on assigned tasks for the project

- Prepare themselves in advance for meetings and presentations

- Invest themselves into the project and its success

- Learn new skills and technologies to deliver at the highest standard

- Have curiosity about new possibilities

- Operate at all levels, paying close attention to details

- Exercise good judgment, seeking advice from others when warranted

- Listen and contribute constructively

- Openly challenge decisions when they disagree, without compromising for social cohesion.

- Commit to final decisions once they are determined

- Communicate effectively and conscientiously

- Respect the roles and ideas of others

- Act as the owner of their part of the project

- Consider the long-term and avoid making sacrifices for the short-term

### Communication

Communication shall be facilitated primarily through Microsoft Teams and secondarily through text messaging. In-person team meetings will be held weekly on Friday at 10:45am unless otherwise noted. Email shall be a secondary form of communication for issues that are not time sensitive. Files and presentations shall be stored and shared through Microsoft Teams.

Each team member shall have a working email, phone number, and personal computer. Members shall check their emails at least twice a day for important information and updates from the group. Meeting dates and pertinent information from the sponsor shall be communicated through Microsoft Teams.

If a meeting must be canceled, an email and a message via Teams or text message shall be sent to the group at least 24 hours in advance.

**Attendance**

Any team member that cannot attend a meeting or needs to leave early shall give at least 2 hours advance notice by formally declining the meeting in the Teams calendar. Sending a text or email is insufficient, except under extenuating circumstances. The reason for absence would be appreciated but would not be required, if personal. Arriving more than 15 minutes late or leaving more than 15 minutes early without 2 hours’ notice or approval from the project manager shall be considered an absence. After two unexcused absences or tardies, the team member shall be contacted by the project manager privately to address the issue. If the issue continues after being addressed by the project manager, the team reserves the right to file a formal complaint with the instructor.

In general, team members are expected to stay for the entire duration of the meeting until adjournment, unless permission to leave early is obtained from the project manager. However, a meeting shall be considered adjourned if it exceeds three hours in length, unless a two-thirds supermajority of the team votes to extend the meeting in one-hour increments. Team members shall not be penalized for leaving the meeting once it has adjourned.

**Team Dynamics**

The students shall work as a team while allowing one another to feel free to make any suggestions or constructive criticisms without fear of being ridiculed or embarrassed. If any member on the team faces exceptional difficulty in completing an assigned task, the member shall ask for help from the other teammates. If any member of the team feels that they have been disrespected or that their ideas were not given fair consideration, the member shall bring it to the attention of the team and, if necessary, the faculty advisor. Emotions shall not dictate the actions of the team. Team members shall act cooperatively in the best interest of the project such that, together, everyone achieves more.

**Ethics**

Team members are required to be familiar with the NSPE Engineering Code of Ethics. They are responsible for their obligations to the public, the client, and the profession. There will be stringent following of the NSPE Engineering Code of Ethics.

**Dress Code**

No dress code is required for regular team meetings. However, the dress for sponsor meetings and group presentations shall be business casual or formal as decided by the team for the event. Business casual typically includes, at minimum, button-down shirts and slacks with an optional jacket. Business formal typically includes a full suit and tie or dress, at minimum.

Videoconferences with the sponsor generally shall not require formal dress, but members should ensure that they appear appropriately presentable. If a team member fails to comply with the dress code, then the team member shall purchase one full pizza for the team, for each offense.

**Weekly and Biweekly Tasks**

Team members shall participate in all meetings with the sponsor, advisor, and instructor. During said times ideas, project progress, budget, conflicts, timelines, and due dates shall be discussed. In addition, tasks shall be delegated to team members during these meetings. Due dates shall be set at least five days in advance. Repeat absences will not be tolerated. If a team member fails to complete two assigned tasks and does not inform the project manager within two days of the task being due, a formal complaint will be filed to the instructor.

**Making Decisions**

Decision making is conducted by a majority vote of the team members. Should ethical/moral reasons be cited for dissenting reason, then the ethics/morals shall be evaluated as a group and the majority will decide on the plan of action. Individuals with conflicts of interest should not participate in decision-making processes but do not need to announce said conflict. It is up to everyone to act ethically in the interests of the project and stakeholders. Below are the steps to be followed for each decision-making process:

* Problem Definition – Define the problem unambiguously.
* Tentative Solutions – Brainstorms possible solutions. Then, discuss which options are the most plausible.
* Data/History Gathering and Analyses – Gather the necessary data to implement the selected tentative solution. Re-evaluate the tentative solution for plausibility and effectiveness.
* Design – Design the tentative solution product and re-evaluate it for plausibility and effectiveness.
* Test and Simulation/Observation – Test the tentative solution and re-evaluate for plausibility and effectiveness.
* Final Evaluation – Evaluate the testing phase and determine its level of success. Decide if the design can be improved and whether time and budget allow for it.

**Conflict Resolution**

In the event of conflict among team members, the following steps shall be employed:

First, communicate points of interest from both parties. Demonstrate active listening through paraphrasing and other tools acknowledging clear understanding. Once the issue at hand is clearly defined and mutually understood, a discussion of the merits and disadvantages shall begin. Once the discussion is completed, a vote shall be administered, favoring majority rule. If a debate becomes prolonged, the discussion may be ended at any time by a supermajority three-fourths vote, at which time the vote regarding the issue will be taken.

In the event of a tie vote, the tie shall be resolved via rock paper scissors. The project manager may call rock paper scissors if one other team member seconds the call to do so, provided that a stalemate has been reached. The rules of rock paper scissors for this purpose are defined on WikiHow. The project manager reserves the right to involve the instructor and faculty advisor in conflict resolution when appropriate, to the extent allowed by this Code of Ethics.

## Appendix C: Functional Decomposition

This functional decomposition provides an overview of the required functionality of the device. The biomedical sensing unit for astronauts monitors critical metrics of the astronaut’s status as well as the status of the in-suit environment. Its primary function is to monitor the overall well-being of an astronaut in a space suit during a long term extra-vehicular mission in space. The design has three main functional components: a set of biomedical sensors, a set of in-suit environmental sensors, as well as the main processing unit.

Once the data is acquired, the sensor noise needs to be filtered and processed. Once processed, the information is then made available through a communication interface. This output interface speed needs to be sufficient for “real-time” monitoring of the condition of the astronaut and their environment.

## Appendix D: Target Catalog

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **#** | **Function/Need** | **Metric** | **Significance** | **Ideal Value/Range** |
| 1 | Measure environment variables | Temperature, pressure, humidity, CO2 level, acceleration | High | +/- 5% |
| 2 | Monitor astronaut health | Heart rate, body temperature, blood O2, galvanic skin response, EKG | High | +/-5% |
| 3 | Store timestamped health and environment data | Bytes | Low | 1 Gigabyte |
| 4 | Transmit or display processed variable data | Baud rate, transmit or display refresh rate | Medium |  |

Table 12 - Targets

## Appendix E: Engineering Drawings

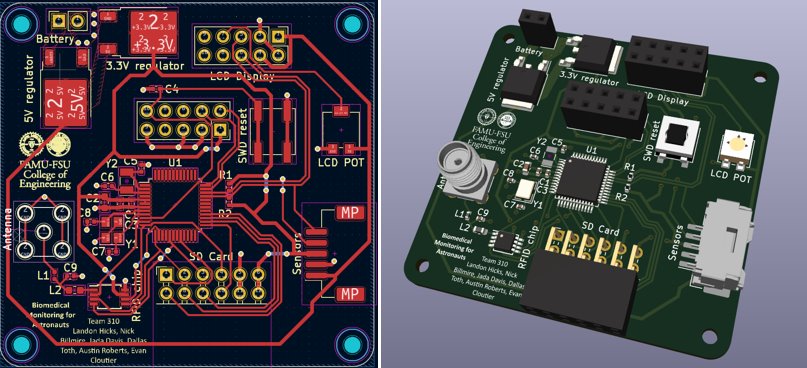


Figure 4 - PCB Layout and 3D Rendering

## Appendix F: Calculations

N/A

## Appendix G: Scholarship in Practice

### Austin Roberts’ Scholarship in Practice Submission

There are two decisions that come to mind for this reflection: the first is using an STM-based microcontroller. There was no strong use case for this microcontroller family over Arduino, other than that we felt we should prioritize using professional tools like the STM32 over microcontrollers built primarily for hobby projects, like the Arduino family. However, this decision had serious practical consequences. Despite its intended use case, the Arduino would have made the implementation of this project much quicker, easier, and more straightforward. The SD card reader, LCD screen, and many of the sensors had libraries built specifically for Arduino, with plug-and-play compatibility. We could have almost completely eliminated my job on the team—sensor integration—with this choice. Instead, I had to manually change the libraries to make them compatible with the STM32. The “standard” choice is not always the best choice. The upside of this is that I have gained considerable experience with the STM32 platform and with debugging code, leveraging the skills I learned in microprocessor-based system design and advanced micro to make the sensors functional. Even so, this was a suboptimal choice.

Perhaps the most pivotal decision in this project was the redefinition of the project objectives to implement something entirely different from the multiaxial angular sensor interface that we were originally asked to create. This decision was made after the team realized that the original project scope, as we understood it, had no obvious motivation or guiding principles which we could apply to make it successful. We were making decisions arbitrarily, in order to make something that we believed would approximate our poor understanding of the original project scope. With no motivation for some of the more peculiar features in particular, such as RS-422 message format, various layers of complexity were sheared away until there was hardly anything left. Had we continued on, we were planning to simply buy an angular sensor with a serial interface, wire it up to the microcontroller, and read its values.

Realizing this collapse of the scope, we knew we had to take action. We could have reinstated some of the peculiar requirements with no understanding of why they are important, or the details of what implementation will make them truly useful, but we ultimately decided to make a completely different project. Clearly, this was a good choice, or at least a better choice than spending nine months on a project that would otherwise take a day. Redefining the project gave us a shot at producing something we could be proud of by choosing the more difficult path—namely, creating our own. However, the final decision to do so came very late in the first semester, which had serious consequences for the remainder of the project. Debate about the new project idea was halted the week of Thanksgiving break, where we made the final decision rather suddenly due to the lack of time. That left us only a few weeks to redo the entire first semester’s work. While not an impossible pursuit, this meant that some corners were cut, especially regarding component selection.

Following the decision to move to biomedical monitoring for astronauts, each team member was assigned a certain functional requirement to research components for and asked to compile several options for. We then met and evaluated the presented options for each sensor and component in order to make the final selection. Unfortunately, this process often ruled out most (or all) of the options that were presented. Due to a lack of time, we had to settle for the suboptimal component selection anyway, rather than go back and research more options.

In the spring semester, the consequences of all this included having insufficient memory on the microcontroller, struggling to implement sensors with limited documentation and support, and the need for several more purchase orders in the final months of the project. Thus, the greatest misjudgment was failing to commit to the new project concept much sooner in the semester. Had we spent more time to identify and implement a high-quality project concept that everyone on the team would be excited about, our project outcome would have likely been quite different. Instead, we struggled to keep the team motivated to work on the project, and the problems compounded.

### Evan Cloutier’s Scholarship in Practice Submission:

Our project was rather unique given the circumstances that our team faced. Early on in the fall semester, we found out that our initially chosen sponsor would be unable to collaborate with us, meaning we were free to do virtually anything that we wanted. This led to the first major decision that our team had to make unanimously: what exactly did we want to do for our design project? It was safe to say that this decision was the most difficult one that we had to make over the course of the two semesters of the senior design course. We had all chosen the initial problem statement as something that we desired to work on, and now it was up to use to define a new project description amongst ourselves. Additionally, we knew that this decision would affect every decision that we would make in the future.

Nevertheless, after a long period of research and deliberation, we were able to all agree on an idea that interested us. From this decision process, it is safe to say that our team learned quite a bit about undertaking a serious engineering problem like this. We learned how important it is to have a clearly defined problem statement and have a solid understanding of what exactly is expected of us. Things can be quite difficult when you attempt to start a project that you aren’t exactly sure of what you should be accomplishing. Looking back, the largest difference that our team would have made would be to make a decision much earlier on and been very clear to each other about what interests that we had. The period of time that it took for us to all find something we agree on is something that set us back quite a while and likely harmed our project the greatest out of any other decision.

Moving on, the second decision that proved most challenging to our project was the component selection process. This is a process that occurred toward the end of the fall semester once we decided we would pursue a wearable, biomedical sensor device for astronauts. At the end of the semester, we were in a bit of a rush to submit a bill of materials so that we could return from winter break and have materials to begin working with. This led to a few of the components that we selected being redundant or unable to actually be incorporated into the project. Additionally, there were things like the microprocessor that would not be sufficient enough to utilize in the final design. These things led to us having to submit a secondary bill for materials later on and wasting a bit of money. If our team had more time to perform sufficient research as to what components we would actually use, we would have saved a great deal of time and money and would have overall benefited us greatly. The lesson we learned is similar to the sentiment of “measure twice, cut once;” meaning spend more time ensuring you are making the right decision on the front end to save yourself from fixing your mistakes on the backend.

### Dallas Toth’s Scholarship in Practice Submission:

Our senior design project has taught myself and my team many important lessons about engineering. We had a unique situation since our original project description that we were planning on completing fell through. This was a challenge that we were not expecting to face but in fact taught us more about managing a project and the process of engineering as a whole.

Our original project given by L3Harris was to help build a multi-axial angular sensor. About 2 weeks into the fall semester, we realized that we would not be working on this anymore and this left our team in a situation that we were not expecting. Our problem was that we did not have a task to complete, which put our team in a tough spot. Through weeks of deliberation and research, we put together our current project by the end of the fall semester. This process taught me how to put together everyone’s ideas and come up with the best project for us. The first problem we ran into was taking too long to decide on a new project. I believe we could have been more decisive and quicker with deciding on the project as a team. If we were quicker to come up with a project we wouldn’t have been behind schedule as we were.

Another big challenge that we faced with coming up with our own project was deciding on the reasonably difficult scope of the project. Our goal was to read the biomedical and environmental sensor values of an astronaut and their space suit. This gave us lots of leniency when it came to how many sensors we would use and how we could process and store the data. Our advising professor recommended that we use RFID to wirelessly store the data from the sensors. This was a good idea, but in my opinion was too complex for the scope of the project given the time we had to complete it. This is the second problem that we came across as we were trying to build our sensor system. A lesson I learned is to keep the scope of the project reasonable and expand on it if time permits. We created a complex project which caused us not to meet all of the original requirements that we had set.

Overall, this project taught me many engineering lessons. Primarily to expect change to happen and be flexible when the scope of your project changes as time goes on. I am glad this happened to myself and my team because of the many lessons that we learned together.

## Nicholas Billmire’s Scholarship in Practice Submission

Regarding the efforts in this project, two of the decisions amongst multiple that I had input on were the choosing of the sensors on the entire sensor-suite package and the decision to vote on changing the project scope. Looking back, if given more time to choose each sensor rather than just have a few days I would have most certainly chosen sensors with datasheets that contained supplemental information such as locations of code libraries and ample specifications rather than leaving my teammates emptyhanded when trying to obtain their values or information due to the insufficiencies on the current datasheets. Simply put, I should have looked at datasheets of the prospective sensors rather than just choosing ones with short lead times and desired specs we wanted.

The change of project scope in all honesty didn’t need to be changed at the time we decided to change it; changing it earlier in the semester such as right when we learned L3Harris had gone silent on us would’ve been more appropriate. Being 8-10 weeks into the first semester and deciding to wipe the slate clean and restart a project and create an entirely new scope was not good engineering practice regardless of what the deliverable was to be nor within the interest of, however, my input was shot down by the other 5 group members and I reluctantly chose to agree in changing the scope thus the current state of the project. My decision, despite being reluctant, to vote on the sensor package seemed most feasible due to the time constraint after starting 10 weeks late compared to other teams. In retrospect I believe the following approaches would have been more appropriate in the development of Team 310’s efforts:

1. Change the project scope weeks earlier & proceed with situation of new scope.
2. Continue the original project scope and add to it for more complexity.
3. Dissolve the team and have faculty distribute each of the 6 members to other teams.

After everything, the choices made cannot be undone and I learned that some people tend to take their best interest over a group and strongarm late term changes in situations as such. My contributions as the communication engineering were quite lackluster with respect to seeing my work up until I was able to implement the LCD display for our project and I do have a sense of fulfilment in the project from it. I also observed that no matter what goes on in a group setting there’s always someone who is not content with what is happening whether it is technical or not. A moment I recall was the random and sudden vote change in the code of conduct to implement a rule that would reprimand group members who were late or absent nor didn’t communicate their circumstances as to why and no clear answer as to why it was. The motives were eventually discovered and explained then amends were made amongst the team to dissolve the issue. Additionally, from that experience I learned that when working in groups that aren’t in agreement there exists an element of tension and resentment towards them due to the decisions made by them or inspired by them. However, due to these experiences my skillsets have grown in working with groups, how to adapt to unsettling events, and the exposure to topics of communication protocols, RFID implementation, and integrating hardware without any standard tutorials or useful datasheets.

The methods of progression during this long-term project were not as what the team thought of, nor me. Given a project scope within my interests and domain of engineering as well as being put in a group of prosperous future engineers all turned out to be a complete disenchantment of what I assumed this project was going to be. Although my expectations were depleted after the first semester, the elements that make up what engineering is were present in every decision that the team had to make regardless of whether it was complete nonsense or absolutely necessary. In hindsight the experience I had is supplemental enough that I’m able to something from it and lean into my future endeavors as an engineer with that knowledge.

### Landon Hicks’ Scholarship in Practice Submission:

This project delivered a bitter taste of the real world from the outset as our sponsor had to stop responding to us due to intellectual property concerns. This left our group the tough problem of designing a brand-new project scope that would be of adequate difficulty (not too hard, not too easy). Our group spent far too long trying to decide on something so the first decision I would critique is the lack of a decision. By the time we finally defined our project scope, the first semester was practically over, and we were always playing catch up from then on. In hindsight I realize that we were far too worried about choosing a project of adequate difficulty and it would have been a much more successful project if we had just chosen something from the outset.

The second decision I am most critical of is our decision to purchase a bill of materials far too early. We purchased a lot of items without fully understanding what the device was or if it would be compatible with the rest of our system. This misstep led to much confusion and frustration trying to find all the data and functionality documentation, only to be disappointed when they were inherently incomplete. This problem would cascade leading to many wasted hours, and more importantly wasted dollars whenever we would conclude that a device would not complete the function we needed it for or wouldn't be compatible with the rest of our system.

One final, specific thing that I would personally do differently actually stems from the problem previously mentioned. We bought a small SD card holder with a pinout with the very first bill of materials, so I designed the PCB to have a female pin connector to hook into the SD card module. There was a far simpler method, design the PCB to just hard the SD card holder on the PCB.

**Jada Davis’ Scholarship in Practice Submission:**

Throughout this project I was responsible for implementing the user interface software. This entailed determining a way to display sensor information and alert the user of any concerning readings internally or in the environment. To satisfy this requirement, I decided to use an LCD to present sensor data and a buzzer system for audible warnings. This decision was sound and justified at the beginning of the project redefinition, but the actual implementation of it proved to be sub-optimal. The LCD that was ordered was the AMC2002CR-I2C model. In choosing this model, I was more concerned that it met the I2C communication requirement, set by our Digital Communications Engineer, and did not measure its simplicity of execution. The datasheet was poorly written and difficult to understand, and the sample code provided by the production company was in a corrupted file and unable to be opened. This led to a lot of guess and check work to get the LCD to display even a simple cursor. Far too late, the group realized that both displays ordered were faulty and would not operate with our project. Before that, it was assumed to be an issue with the software, instead of a hardware matter. This issue probably would have been discovered earlier had a model with a better operational manual been ordered so we could determine what the display should look like upon power up. The LCD was prioritized over the buzzer system therefore most development time went towards trying to figure out how to make the broken displays work, that progress on the buzzer system was not able to advance.

Another decision I was involved in was determining the next course of action in response to our sponsors, L3Harris, reneging on providing guidance and technical expertise on the project scope they assigned to us. A few months were spent idly waiting for some type of response from the sponsors, but after meeting with our advisor, Dr. Noroozi, a few times, he suggested we begin figuring out how to proceed without them. Regardless we had to develop a new project scope, but our options were redefining the scope to one similar to the original L3 definition or create a completely new scope that aligns with the group’s collective interests. After some deliberation and hopeful thinking that L3 would appear mid-semester to help, the group decided to generate a new project. This process took up most of the fall semester, and working out the kinks of our chosen project took a good bit of spring semester, so our time for developing a working prototype in time for Senior Design Day and Final Demonstrations was limited greatly. Despite this setback, I believe we conclusively made the right decision regarding our project, as L3 never contacted us again and the group was able to produce a product that we are proud of.

## Appendix H: Risk Assessment

The only risks that our project entail was encountered during testing. These include minor shocks, cuts, or scrapes from the circuitry used in our design. Overall, our design lacks any source of serious risk if proper care is taken by the user or handler.

## Appendix I: Operation Manual

The biomedical monitoring for astronauts sensing sock is easy and intuitive to use.

* 1. The first step is to put the sock onto the astronaut’s foot. Ensure that the sensors sewn into the sock align with the toes of the foot. Be careful not to damage any cabling or sensors while putting on the sock.
  2. To operate the device, begin by powering it up by connecting a battery. The device runs on five AA batteries. The microcontroller will automatically power on and begin taking sensor readings.
  3. Sensor data will be displayed on the LCD screen and any anomalous readings reported as an audible alarm.
  4. To obtain the readings wirelessly please connect the RFID reader to a computer. Install compatible software that works with the RFID reader and use the software to interrogate the onboard RFID chip. Any RFID reader and software supporting the appropriate frequency range will work.
  5. Data is also written to the attached SD card automatically. No further configuration is required to use the device. If required, the device may be reset by pressing and holding the reset button briefly. That is how our device works.