College of Engineering and Architecture

Howard University
Washington, D.C., 20059

First Mid-Term Report

on

Design and Construction of a Prototype Magnetic Levitation System for Seismic Isolator Application

Team Members
Nadine-Marie Bell, Senior, Electrical Engineering
Michelle Chastang, Senior, Computer Engineering
Hakeem Thomas, Senior, Electrical Engineering
Stephen Young, Senior, Electrical Engineering
Jeantelle Francis, Senior, Mechanical Engineering
Sakar Paudel, Senior, Mechanical Engineering
Bibek Ramdan, Senior, Mechanical Engineering
Matthew Shepperd, Senior, Mechanical Engineering

Ph.D Grant Warner, Mechanical Engineering
Graduate Advisor

Dr. Charles Kim
Co-Principal Investigator

March, 2017

Summary:

Today we live in a technology-driven world, where real-time sensing is feasible for a range of applications and environments. The data collected is invaluable, it can be used to improve future designs, enhance security, increase efficiency, assess health, and track performance, to name a few of the potential advantages of embedded sensing hardware. Sandia has many systems that could benefit from real-time monitoring at the system and component level.

This report contains the design and implementation of the multi-sensing device that SANDIA National Labs requested. It shows the process of why the device is needed to be built and the requirements it needs to fulfill, which includes physical and intangible constraints. The solution design contains the timeline of the different designs the group came up with from both departments and how the group decided on choosing the optimal solution. The implementation phase is where this project is currently at due to time limitations. The challenges faced like time, teamwork, etc. will also be expounded on in this project.

Problem Statement:

The groups academic year goal is the same as the long term goal due to the constraint that we only have one year to complete the project. The project goal was to design an integrated sensor device to sense environmental conditions as required by the Sandia Bonanza competition.

The customer (Sandia) needs a small (size specific) and efficient device which operated on low power and responds to its environment when necessary, which will send and provide data on the different environments in which the customer deploys their systems and components.

Design Requirements:

The designed device must sense the environments within the specified ranges, listed in the table below. All sensors should be integrated using a Raspberry Pi Data Acquisition and Controller Pi-Plate card or something with similar capabilities. The sensors can be powered wirelessly or wired. The device must function without supplemental power up to four days. Fit within the mechanical envelope of a ¼ pie piece, with a 14.7 inch diameter and 6.5 inches tall.

This design contains quantitative measures that the customer wants to achieve. These include:

Table 1. Required sensing environments.

Environments	Operating range
Vibration	20 to 5000 Hz
Light irradiation	0 to 1 $W\text{-}m^{-2}$
Temperature	-20 to 70 ^{o}C
Relative humidity	5 to 90 % RH
Linear acceleration	0 to 10 G
Orientation	Orthogonal coordinate frame
Proximity (sense within)	0.028 m^3
Air composition	O, H, CO_2, CO, N
Shock	0 to 10 G

Some other requirements were not needed but were a bonus if done. These were:

Stretch requirements:

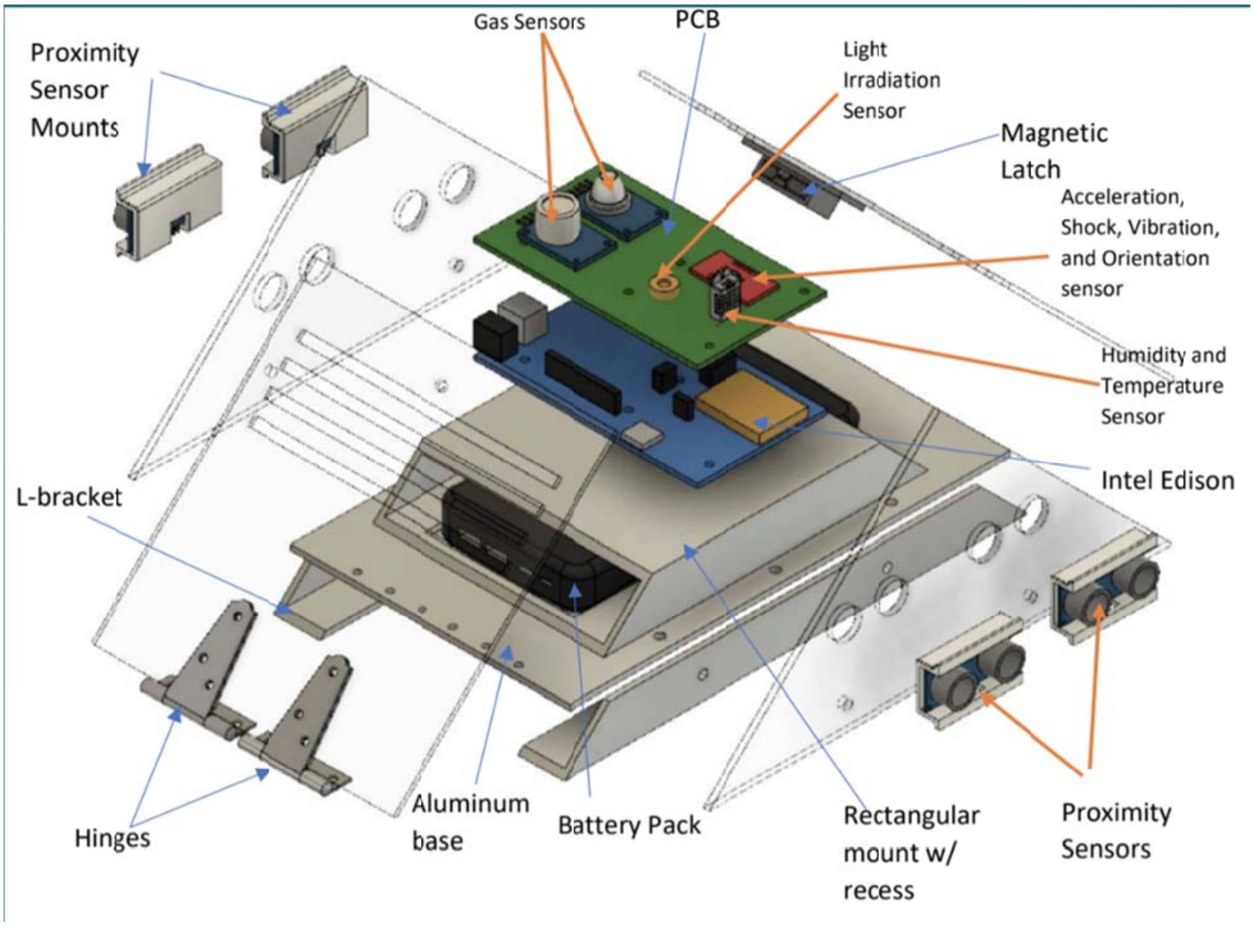
- Actively respond to 1 to 3 of these environments (such as, cool device if it get hot, warmer the device if it get to cold, shading a device if exposed to more 100 $W\text{-}m^{-2}$)
- Sense material changes with time (aging)
- Wireless capability
- Sense pH
- Synchronous sampling and timestamping

We were also given a time constraint of 2 semesters and a budget constraint of $2,000.00.

Solution Design:

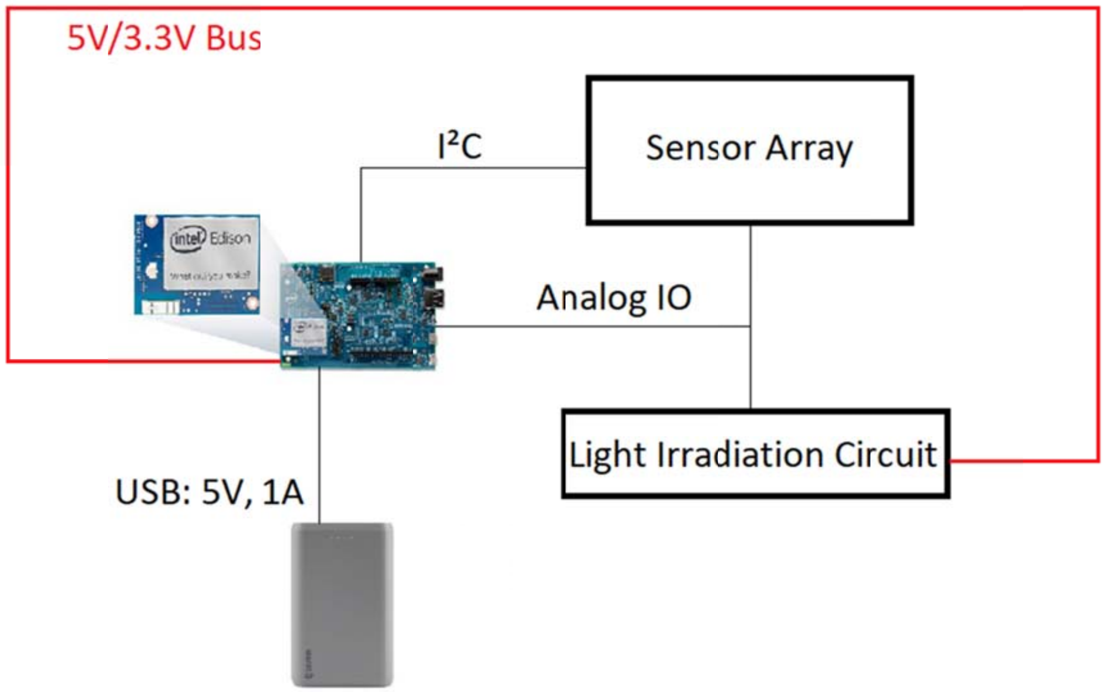
For the solution design, the mechanical engineers and electrical/computer engineers created their designs that will be optimal for the other group's design.

Figure 1. Mechanical Envelope (casing) of the device



The above figure shows the mechanical envelope that fits the border of our space restrictions. The arc of the ¼ pie has been cut out so that the device can have a wide base for increased stability. The 4 sides of the device were made of acrylic and the base is made out of aluminum. These properties were used because they can withstand the environments that the device must go through.

Figure 2. The overall Schematic of the Electrical Design.

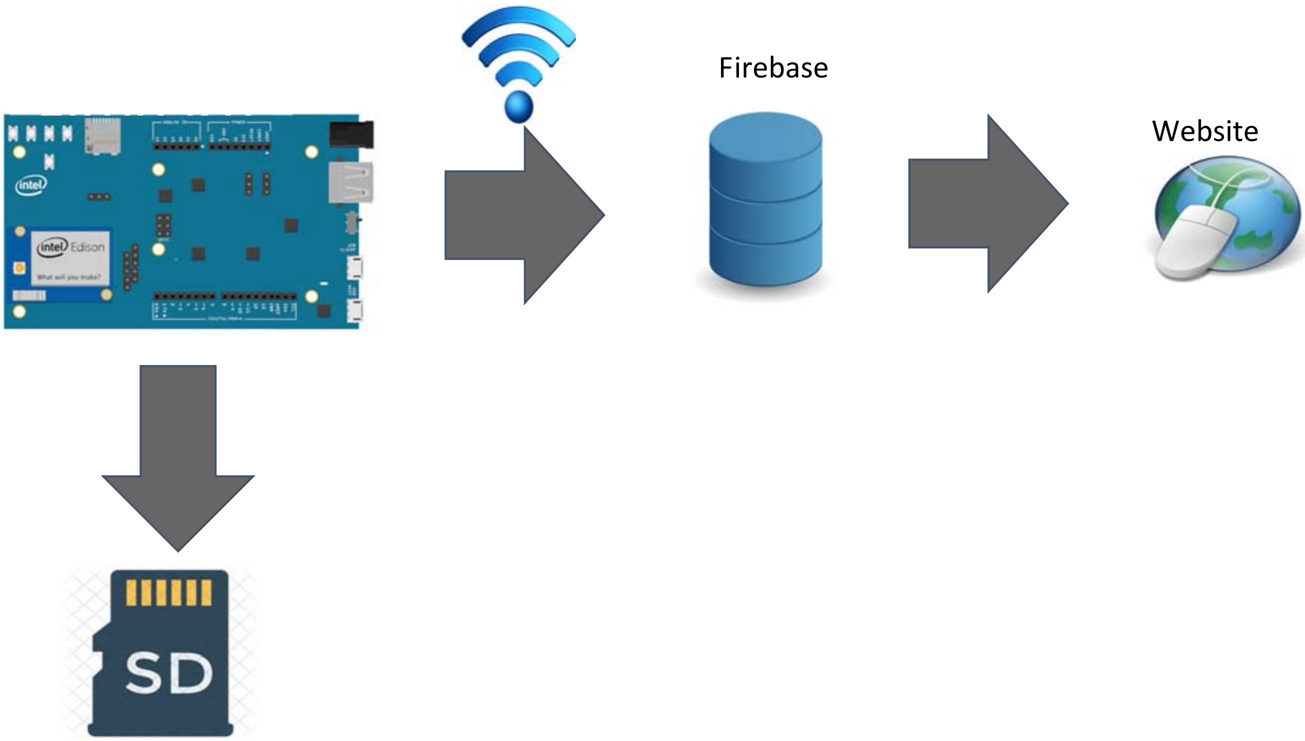


The total power of the microcontroller (Intel Edison) and the sensing elements were calculated at their highest frequency via the datasheets and the total power consumption for four days came up to 28,450 mAh. Knowing that we were using the microcontroller in lower power mode which can reduce its power consumption by 2/3, the power-bank chosen of 26,800 mAh suffices. The brain of the operation (microcontroller), the Intel Edison with Arduino Expansion Board was chosen. This is due to the Arduino IDE which the group has familiarity with, external memory capability, Wi-Fi capability, and lower power consumption than its peers. The sensing elements communicates with the microcontroller via:

Vibration	- I2C
Light Irradiation	- Analog IO
Temperature	- Analog IO
Relative Humidity	- Analog IO
Linear Accelerometer	- I2C
Orientation	- I2C
Proximity	- Digital IO
Air Composition	- Analog IO
Shock	- I2C

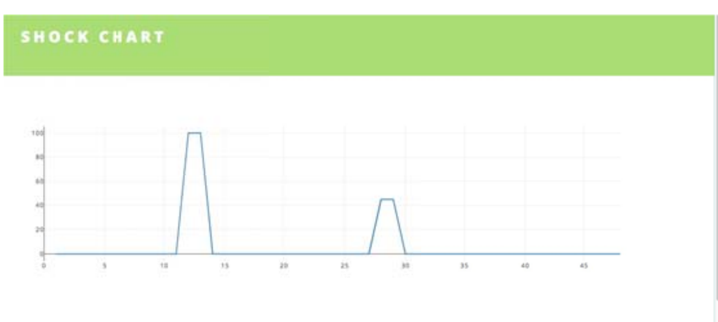
Flow of Data:

Figure 3. the flow of data via SD card and Wi-Fi



This diagram shows how the data would be stored. The Edison would write data to the data and also transmit the data via wifi to our website. The data is stored on Firebase and then updated on the website in real time.

Figure 4. Graph of one of the environments that was required to sense.



Solution Implementation Plan:

Table 2. Main tasks to accomplish

Tasks	Primary Responsibility
Finalize Parts & Power Calculations	Hakeem
PCB Design	Stephen
Make Invoices	Group
Flowchart	Nadine & Michelle
Order Parts	Group
Configure Intel Edison	Stephen
Reading sensor data	Hakeem
Merging code and adding auxiliary functions	Stephen
Transmitting data	Nadine
Displaying real time data on our website	Michelle

These were the main tasks that the EE group needed to get done for the semester. The tasks were divided to the persons who are the most proficient in the areas. Everyone was responsible know and help for every task at hand.

Solution Implementation Process:

The first task to implement the solution design was to create a flowchart to show how our device would register data from the environment.

Figure 4. Flowchart of the device.

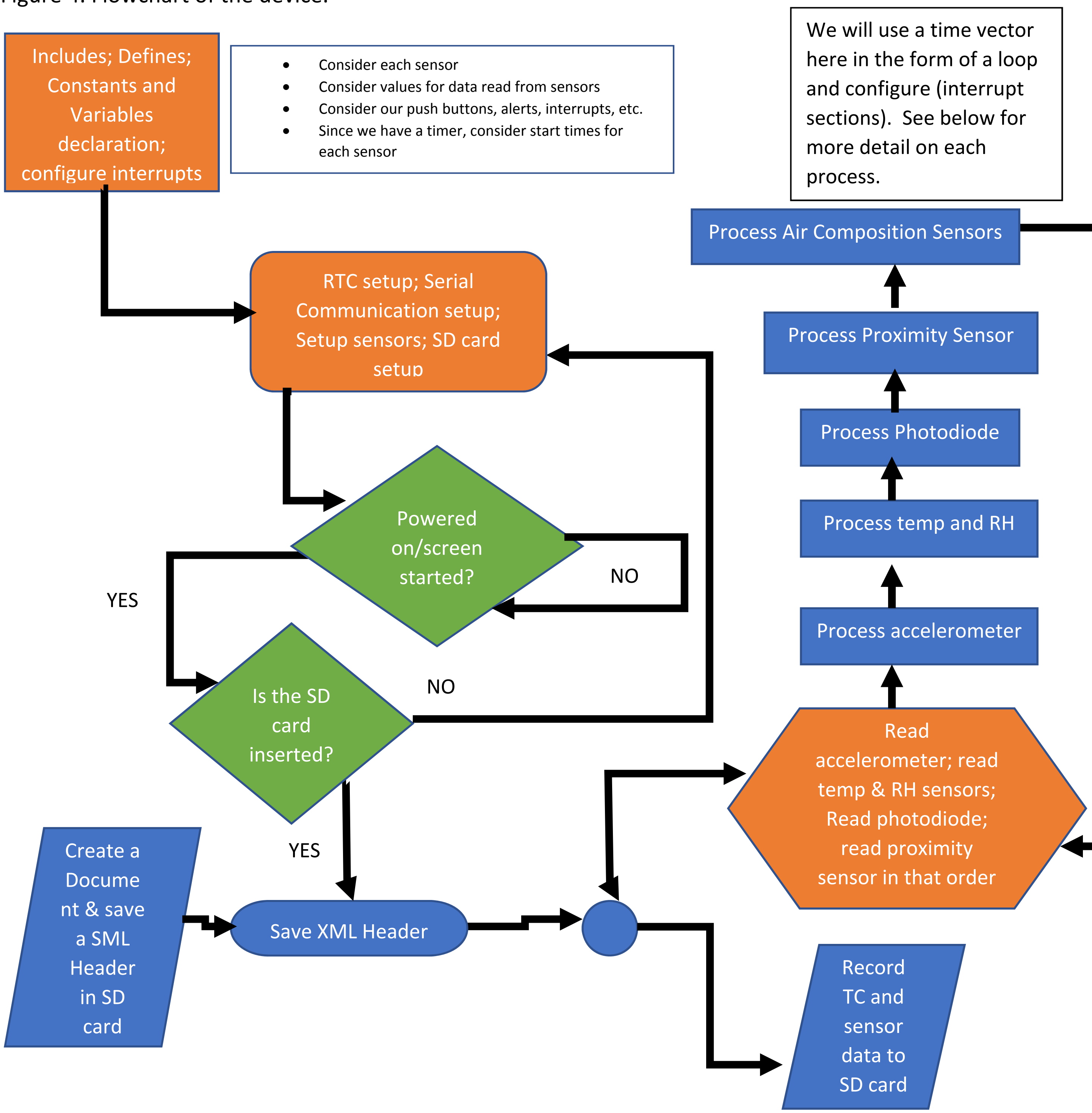
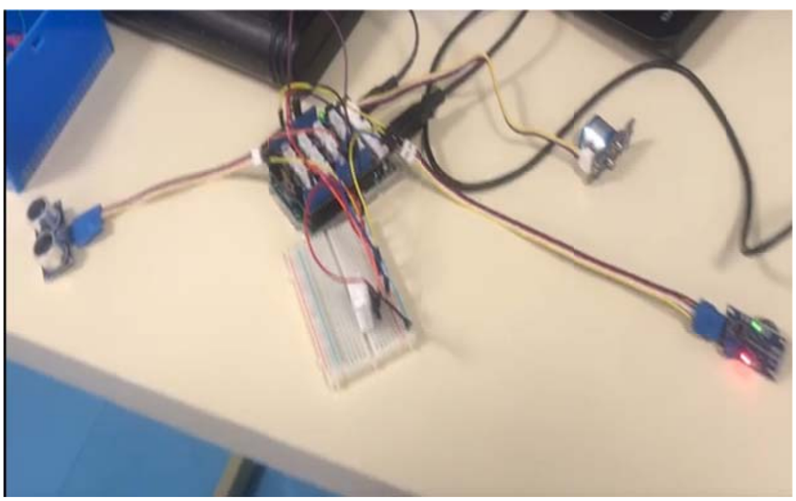


Figure 5. Code for SD card storage.

```
#include <SD.h>                      //To communicate to the SD card.
void setup()
{
Serial.println("INITIALIZING CARD");   //Prints the line in serial monitor
pinMode(CS_pin, OUTPUT);              //Sets CS pin as output
pinMode(pow_pin, OUTPUT);             //Sets pow pin as output
digitalWrite(pow_pin, HIGH);          //Turns on the SD card for being written to
if(!SD.begin(CS_pin))
{
  Serial.println("CARD FAILED!");     //Prints "CARD FAILED!" to the serial monitor if card fails to detect or is not inserted
  return;
  }
  Serial.println("CARD READY!");      //Prints "CARD READY!" to the serial monitor if card is all set to be written
}
void loop()
{
float dataString = float(cel);        //Writes the data to datastring to be written to the SD card
File dataFile = SD.open("SANDIA.txt", FILE_WRITE);  /*Creates a .txt file named SANDIA in the SD card and initializes it to be
                                                      written onto*/
```

Figure 6. Integration of sensors



This picture here shows the combination of a Proximity(HC-SR04), Oxygen and Hydrogen (ME2-02 & MQ2), Temperature and Relative Humitiy (DHT22) sensors.

Sensor Sampling:

Figure 7a.

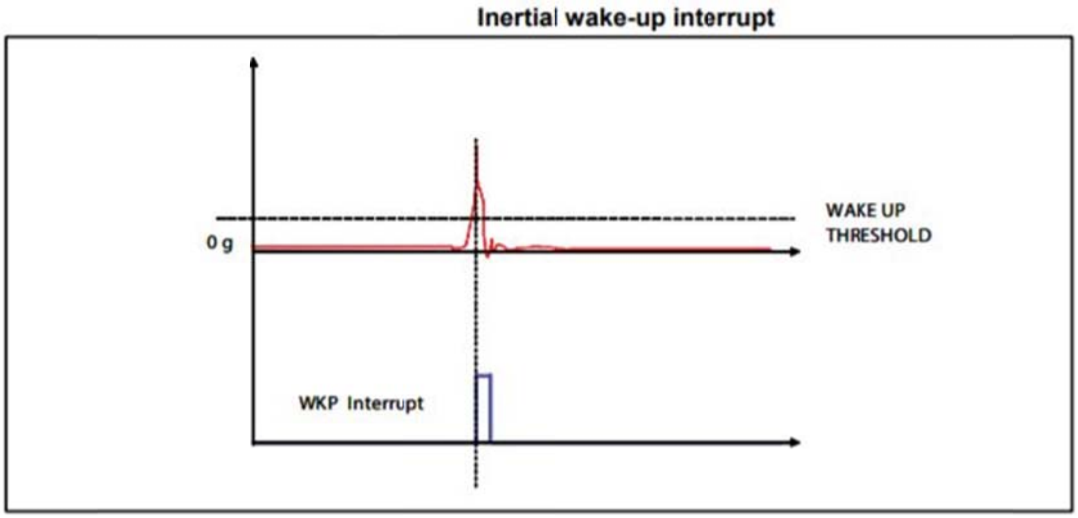
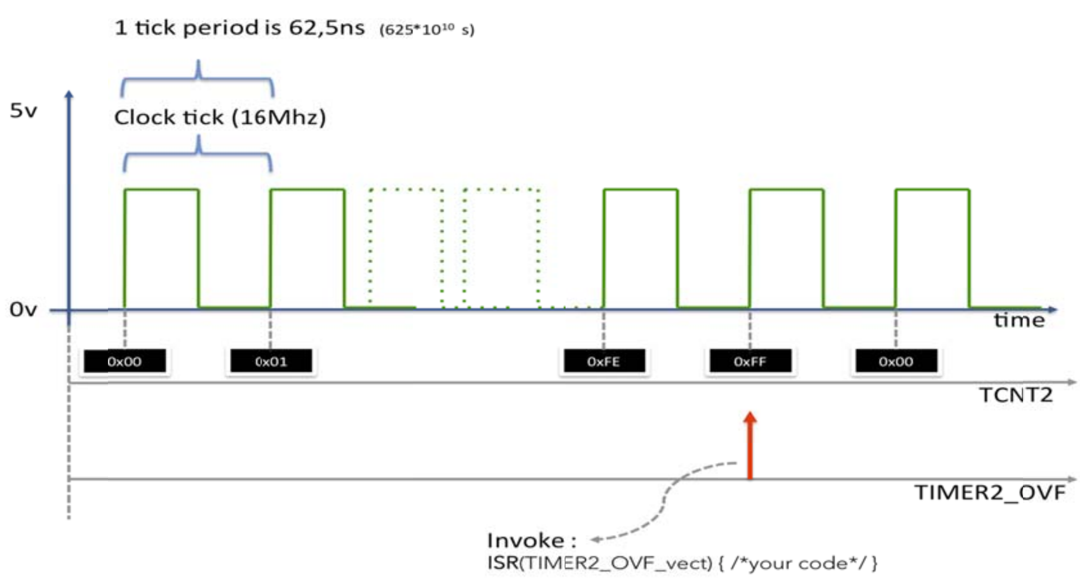


Figure 7b.



The device sampled data under 2 conditions, one periodic based on internal clock configuration on the Intel Edison, the other was under special inertial change considerations. The clock tick interrupt on the intel Edison is a software interrupt, this was configured using the TimerOne.h library. The accelerometer was configured to generate interrupts when the acceleration changed by 1G in either the x, y or z plane. We configured this by writing values to the Threshold register, enable registers and configuration register listed below by I2C communication.

Figure 7c.

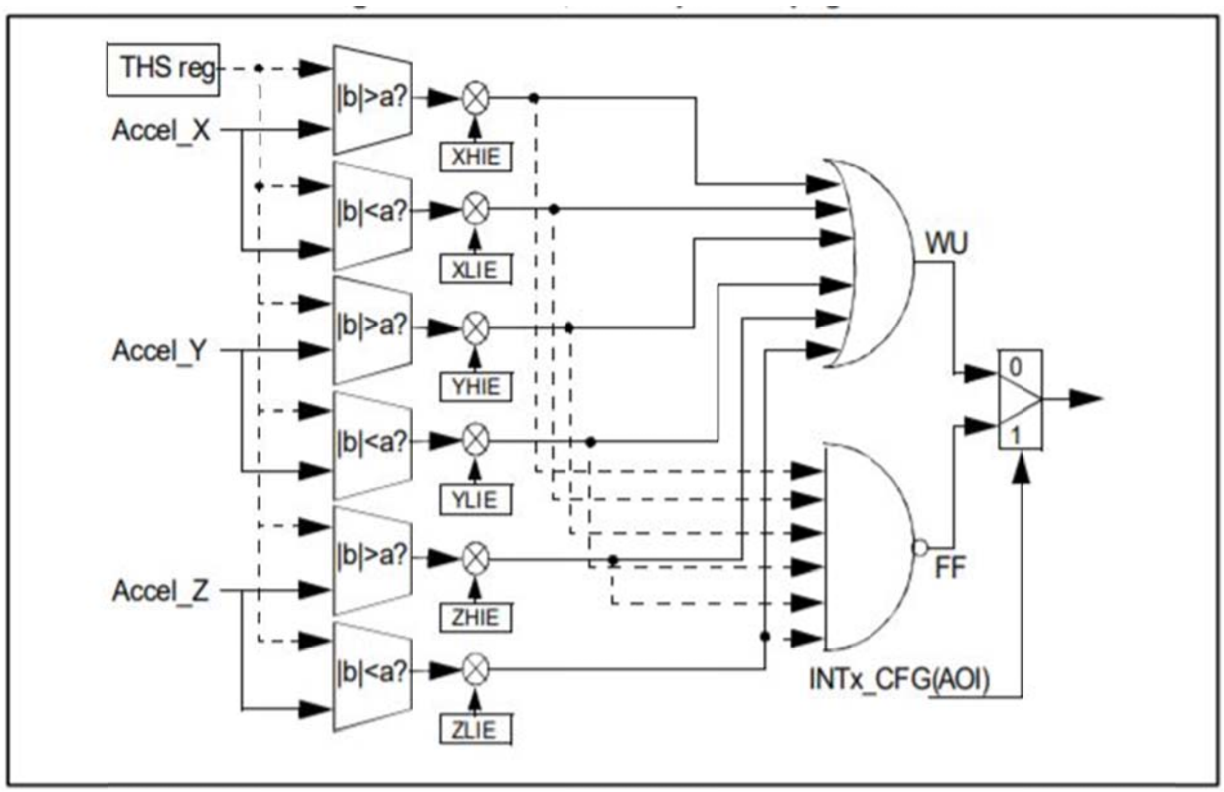
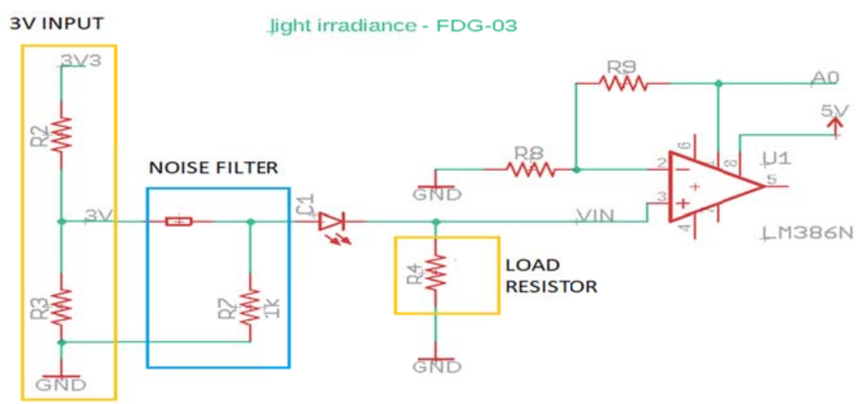
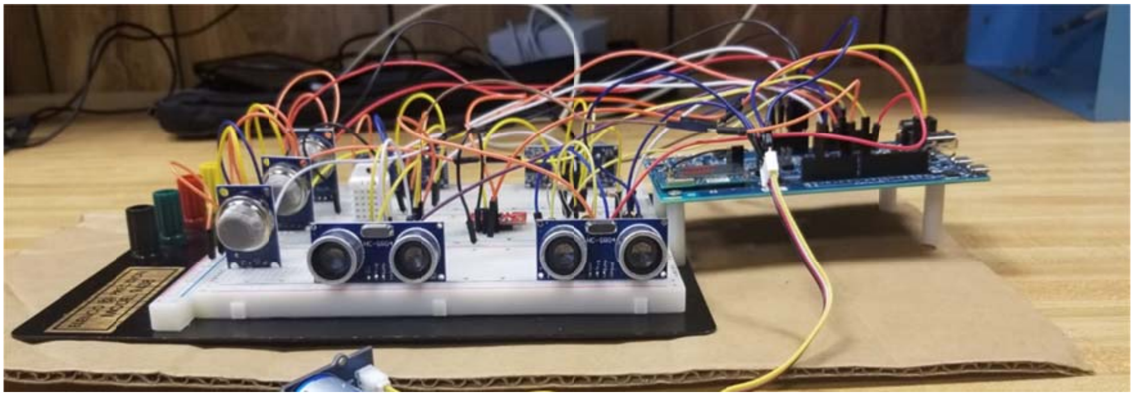


Figure 8. Light Irradiation Circuit



This circuit was designed due to not having a light irradiation sensor. A photodiode was used with an op amp to get a desired range to get good data to calculate. A noise filter was used and the irradiation circuit is used to detect IR radiation.

Figure 9. Breadboard design.



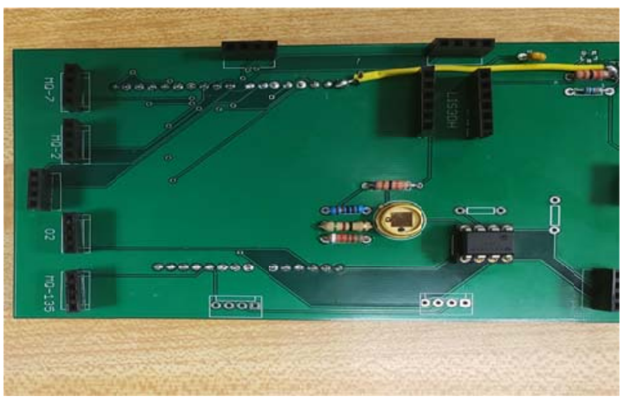
The breadboard design consists of 11 sensors which includes:

- 4 proximity sensors
- 4 gas sensors
- Temperature and relative humidity sensor
- Triple axis accelerometer
- Photodiode

This design was not feasible for the design due to several reasons.

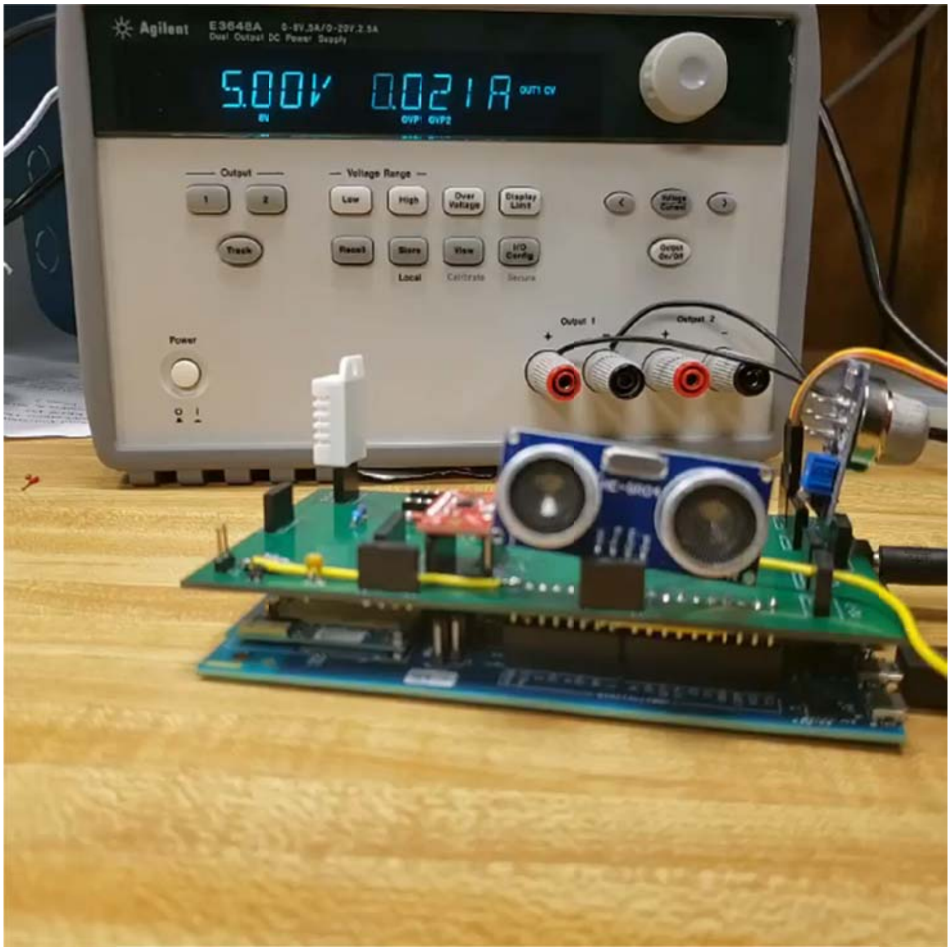
1. The wires would not be completely secure in the breadboard/sensors so the forces the device would be put it through would not be optimal.
2. The breadboard design was too big for the design.

Figure 10. Printed Circuit Board



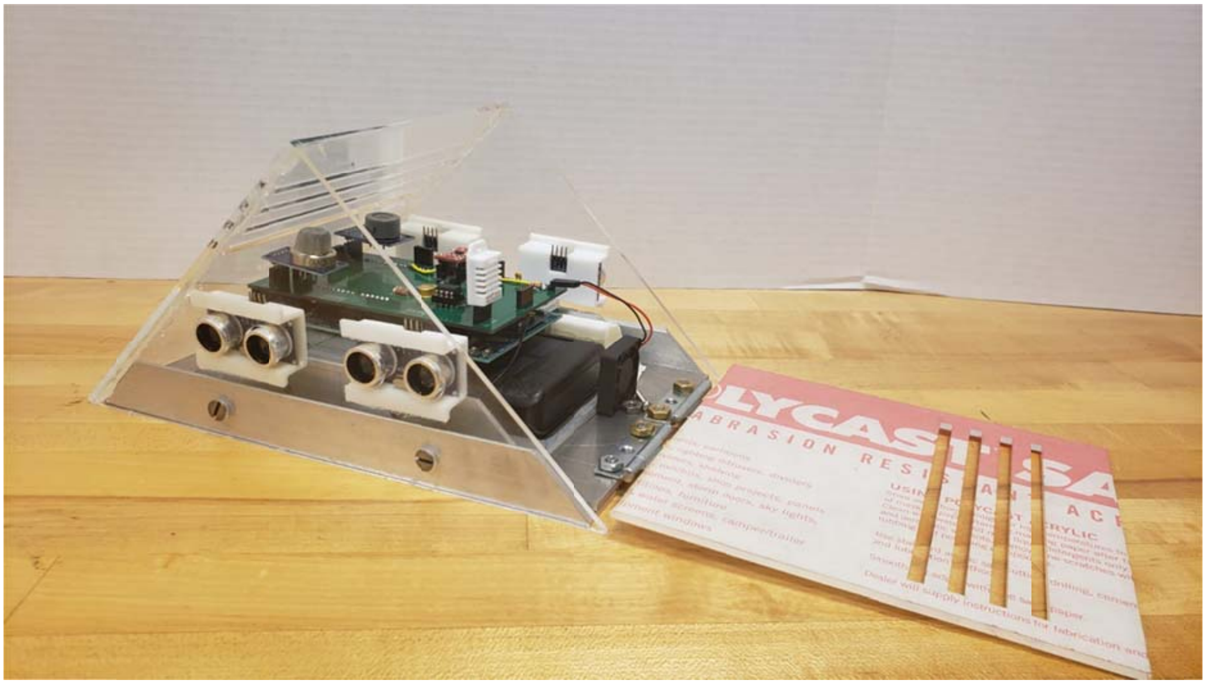
The PCB was the solution to the breadboard. Headers are made to insert the sensors in, the light irradiation circuit was built into the PCB. The PCB also has pins so it can insert onto the Intel Edison as a daughter card.

Figure 11. Power Consumption



This screenshot shows the power consumption of the Edison in low power mode. In this state the current drawn is around 20 mA. When it comes out of power consumption it draws up to 60 mA.

Figure 12. Picture of the entire device.



The electrical components were fully integrated into the mechanical envelope. A fan was implemented into the design via transistor theory. Testing and validation of data would need to be implemented for the next academic year.

Conclusion:

This academic year the Sandia group designed and implemented a multi-sensing device that is used to record data that will be sent to the customer. It shows the process of why the device is needed to be built and the requirements it needs to fulfill, which includes physical and intangible constraints. The solution design contains the timeline of the different designs the group came up with from both departments and how the group decided on choosing the optimal solution. The implementation phase is where this project is currently at due to time limitations. Time was limited so the group did not have time to fully integrate the codes for all of the environments. The PCB had errors with I2C communication which made the triple axis accelerometer unusable for the design. Hopefully the next set of seniors would take the lessons that we learned from this year which we have in great detail in the link in the references so that next year would be a success.

References:

https://drive.google.com/drive/folders/1v0kJ4xQn8kkpJcp7mlFo_R6wcNLuUgqM