Portable High Energy Experiment DAQ

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CONCEPT OF OPERATIONS

REVISION – 1
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CONCEPT OF OPERATIONS
FOR
Portable High Energy Experiment DAQ

TEAM <34>

APPROVED BY:

Project Leader Date

Prof. Kalafatis Date

T/A Date

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1	2/10/2023	Ethan Barnes		Draft
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Table of Contents

List of Tables

No table of figures entries found.

List of Figures

1. Executive Summary

This project aims to build a device able to detect the occurrence of low blast (5 lb. charge or smaller) within a 100 ft area. Our device or The Portable High Energy Experiment Data Acquisition System (PHEE DAQ) will continuously gather real time data using a sensor array and subsequently analyze this data within a processor to identify the occurrence of an explosive event. We plan to accurately detect an explosion within 100ft by utilizing acoustic, pressure, and vibration sensors. Since this device is expected to gather data continuously, the design will be self-powered with a chargeable battery. To accommodate real time data acquisition, the microcontroller will capture the rise of the event with sampling at fast rates (2 kHz or higher). The output of the microcontroller will identify whether an explosion has occurred and will be stored onto onboard storage. The main purpose of this device is for the protection of equipment such as weapons and vehicles from the damage incurred after an explosive event.

2. Introduction

The purpose of this document is to propose the design of a device capable of detecting a low blast (5 lb. charge or smaller) within 100ft. This PHEE DAQ is a system capable of gathering and analyzing data to determine occurrence of explosive event in its surroundings by using an array of sensors connected to a microcontroller unit. This system will be portable and will feature removeable data storage so that it can be recovered at any time.

2.1. Background

Terrorism and acts of violence occur daily all over the world. Currently, in places where many US troops are deployed, the risk of bombing is always inherent. Frequently, the size of the explosive charges used in these attacks are not large. However, despite this, the power of these explosives is far greater than we can imagine, and they have the potential to harm many people [1]. To reduce the damage of these explosives, it is advantageous to detect these explosions and minimize their damage.

Sandia National Laboratories aims to design a portable device that can detect explosive charges that are 5 lbs. or less in size from within 100 ft. The working concept of this device is as follows: it gathers data continuously in real time, and the moment it detects a high energy event, it outputs whether it has detected an explosion. Subsequently, this data is saved in onboard storage for reference at any time.

Our team's goal is to design this device. We plan to design a device that can detect an explosive event by selecting the appropriate sensors, designing software that uses sampling, and filters so that the device can analyze the signal in real time as soon as it is detected [2]. This process will require a stable power source, removable storage that can store and utilize sufficient data, and integrate them onto a custom PCB. The portability of this design along with the versatility of its data inputs making it an optimal choice for any type of data acquisition especially high energy experiments.

2.2. Overview

The network used in this device detects the explosion of various sensors (acoustic [3], pressure [4], vibration sensor [5], etc.) connected to the microcontroller. It moves the data to the microcontroller, where the filter is coded and can be sampled in real-time for analysis. This data will be saved continuously on a removable storage device. Developing the GUI for configuring DAQ settings will give the output “quick looks” of data. The Portable High Energy Experiment Data Acquisition System (PHEE DAQ) calculates the time and the weight of the explosive. This allows the user to determine which areas explosions have been detected and pinpoint areas that need to be carefully monitored.

2.3. Referenced Documents and Standards

[1]: Chong S, Long B, Maddry JK, Bebarta VS, Ng P. Acute C4 Ingestion and Toxicity: Presentatio and Management. Cureus. 2020 Mar 16;12(3):e7294. doi: 10.7759/cureus.7294. PMID: 32313735; PMCID: PMC7163342.

[2]: Skotak Maciej, Alay Eren, Chandra Namas, "On the Accurate Determination of Shock Wave Time-Pressure Profile in the Experimental Models of Blast-Induced Neurotrauma" Accessed at https://www.frontiersin.org/articles/10.3389/fneur.2018.00052.

[3]: R. Showen, C. Dunson, G.H. Woodman, S. Christopher, T. Lim, S.C. Wilson, Locating fish bomb blasts in real-time using a networked acoustic system, Accessed at https://doi.org/10.1016/j.marpolbul.2018.01.029.

[4]: Ma, Xuejiao, Deren Kong, and Yucheng Shi. 2022. "Measurement and Analysis of Shock Wave Pressure in Moving Charge and Stationary Charge Explosions" *Sensors* 22, no. 17: 6582. https://doi.org/10.3390/s22176582

[5]: Nguyen, Hoang, Yosoon Choi, Xuan-Nam Bui, and Trung Nguyen-Thoi. 2020. "Predicting Blast-Induced Ground Vibration in Open-Pit Mines Using Vibration Sensors and Support Vector Regression-Based Optimization Algorithms" *Sensors* 20, no. 1: 132. https://doi.org/10.3390/s20010132

3. Operating Concept

3.1. Scope

The Portable High Energy Experiment Data Acquisition System (PHEE DAQ) will determine: (1) if an explosive event occurred, and (2) the general size of the explosive charge in pounds (lbs) as a stretch goal. To accomplish this, various sensors will record an environment and send signals to a microcontroller which will condition and then process the signals in real time. The processed signals will then be analyzed based on an algorithm we will create and then the outputs of this algorithm will be stored locally on the DAQ along with the timestamp of the event. The local storage device will be removable so that the user can see the results.

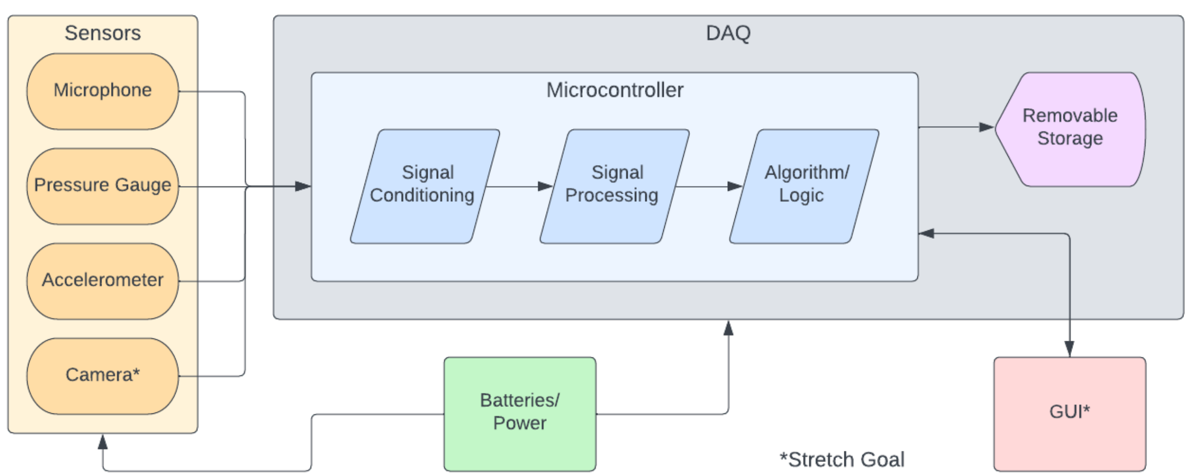
3.2. Operational Description and Constraints

The PHEE DAQ will be used for explosives testing in controlled outdoor environments. The DAQ and its sensors will be placed in close proximity to an explosive charge where it will remain until after the explosive event occurs.

The PHEE DAQ has specific constraints specified by Sandia National Laboratories:

- It will be used in ideal environments where the only phenomenon that occurs is a single explosive event.
- The sensors on the DAQ will be at a maximum of 100 ft away from the explosive charge and at a minimum adjacent to the charge. In the case where the DAQ itself might be damaged by the explosive event, long wires will be used to connect the sensors to the DAQ which will be out of range of and protected from the blast.
- The processor on the DAQ should be capable of sampling at a rate of 2 kHz or higher.
- The processor on the DAQ also must be able to classify if an event is explosive in real time.
- A signal conditioner must be integrated into the design.

3.3. System Description



The PHEE DAQ will consist of sensors, a microcontroller, and a removable storage device all integrated on a custom PCB which will be powered by batteries through a power supply. A GUI that can be used to receive data from and change settings on the DAQ may be added to the system if time and resources permit.

Sensors: Data will be acquired by our system through sensors that will measure the following:

- Audio: We will use a microphone that can pick up high-amplitude sound adequately to record the sound of the blast. Frequency will be important in determining if an explosive event occurred, but amplitude will be a more valuable metric considering how loud explosions are compared to other phenomena.
- Pressure: We will use either a diffusion silicon pressure sensor or a ceramic pressure sensor to measure the pressure of the air from the blast and shock waves due to the explosion. The blast wave produced from explosions, which consists of highly pressurized air, is a defining characteristic of explosions. We will use the pressure sensor to measure the high pressure from the shock front of the blast wave and the dynamic pressure of the air behind the shock front.
- Vibrations: We will use either an inertial measurement unit (IMU) or an accelerometer to measure vibrations from the blast wave. This sensor will be able to gather data on the force due to the high pressure of the shock front.
- Camera: A stretch goal may be using a camera to record video of the explosive event and using computer vision to analyze the light emitted from the explosion.

Signal Conditioning/Processing and Detection Algorithm: The data acquired through our sensors will then be sent to a microcontroller where we will use digital signal conditioning to enhance the signals by amplifying and filtering them. Then we will use digital signal processing to extract useful information from the signals to make them easier to analyze. Once our signals are in a format that is easy to understand, we will develop an algorithm that will analyze each metric in relation to time and decide if an explosive event occurred at that specific time.

Microcontroller: The microcontroller will be the brain of the entire system. We will program it to interact with the sensors, removable storage, and possibly the GUI. All our signal conditioning/processing and detection algorithm code will be run on this microcontroller and will be sent to the removable storage device and possibly the GUI. The removable storage device we will use is an SD card, so an SD card reader will be integrated into the circuit so that data can be written to it from the microcontroller.

Custom PCB: One option is that there will be a main PCB interfacing the microcontroller, sensors, and removable storage device reader and then another PCB for the power supply, power management. The other option is that there will be one PCB where all the previously mentioned components will be integrated together.

Power: To power the PHEE DAQ, we will design a PCB that will enable battery charging and distribute the power from that battery to the microcontroller and sensors that need power. This will require voltage level regulation, load management, and adjusting the charging rate of the batteries.

GUI: The GUI will display data received from the MCU onto a smartphone or laptop. This data will be in the form of waveforms or a summary of the data so the user can develop a general understanding of the data that has been gathered over a period of time. The GUI will also allow the user to configure settings to change how the data is sampled.

3.4. Modes of Operations

The default mode of operation for the PHEE DAQ will require that the DAQ is turned on by the user and placed in a suitable location relative to the explosive charge. The DAQ will run automatically without further interaction from the user until the user decides to remove the storage device.

The second mode of operation is a stretch goal for this project. This mode would include a GUI to allow the user to: (1) configure the necessary number of channels for optimum data sampling, and (2) select different channels to display a small sample of the data (e.g., a waveform or summary of data such as maximum, minimum, and average data points).

3.5. Users

The target users of our system are researchers and engineers from government agencies, industry, and academic institutions with focuses on explosives testing and defense technology. Because the target users of our system have all the following knowledge and training, we expect our target users to have very few problems with setting up and operating our system given a user manual:

- Users of our system should have previous knowledge of how DAQs work, but our system will be simple to set up and activate with minimal technical training.
- If the GUI is implemented, the user is expected to have knowledge of high shock and explosive events so that they can adjust the DAQ's settings accordingly.

3.6. Support

A user manual will be created to specify how to operate the PHEE DAQ. It will include how to set up the DAQ and its sensors, gather data from the storage device, and interact with the GUI. Any code written for the microcontroller will be commented and README files will be included in the repository to further explain the purpose of the code.

4. Scenario(s)

4.1. #1 Sensing Explosive Events for Defense Mechanisms

The portability of the high energy DAQ system enables its use in a wide variety of applications that require the sensing of events with extreme decibel levels, vibrations, and overpressure. This includes its use as a part of military defense systems that require the sensing and detection of explosive events. In addition to the DAQ system's portability, its rapid sampling rate of real-time data makes it useful for systems that require immediate action to be taken based on the event that is sensed. More specifically, it can be used as a part of a larger system that will deploy defensive mechanisms to protect equipment or personnel from the onset damage of an explosion in the event that one had been detected.

#2 Characterization of Explosive Event (Stretch Goal)

The high energy DAQ system's number and variety of data inputs enable it to not only detect the occurrence of an explosive event, but also characterize such an event based on the estimated size of the charge. The system will be able to compare the gathered data and differentiate explosive events on the order of a few grams to tens of pounds. This data can also potentially be used to analyze the different metrics to aid in explosive weapons research. The acoustics data gathered by the system can also be valuable in research related to any type of extreme decibel-level event such as ballistics or natural disasters.

5. Analysis

5.1. Summary of Proposed Improvements

The list of improvements that the high energy DAQ system offers includes the following:

- The system will be portable and self-powered allowing it to be used in any environment without danger to the user in the context of explosive event detection.
- The sensing devices will be multi-directional allowing it detect events of interest in a wide area and without line-of-sight of the event occurring.
- With on-board memory the DAQ system will be able to store its decision regarding a detected event of interest and the time associated with it, giving the user the ability to access the recorded data at any time.
- The DAQ system will feature highly durable temperature and shock resistant sensing devices that can withstand explosions directly adjacent to them.
- The wide variety of data gathered by the system along with the on-board data and signal processing offers modularity for use in many other applications.
- As a part of the stretch goals for this design, the DAQ system will be able to not only make decisions on identifying events of interest but display data metrics on the event of interest in real-time.

5.2. Disadvantages and Limitations

The limitations associated with the high energy DAQ system includes the following:

- The design must include sensing devices that are separate from the processing unit since the processing unit vulnerable to damage, limiting the compactness of the system.
- The sensing devices being separated from the processing unit also requires the use of long cables which are vulnerable to damage and contaminating the data with noise.
- The system's accuracy in sensing and identifying events of interest is reliant on certain explosive metric thresholds derived from previously recorded data of explosions. This may leave the system vulnerable to mis-identifying explosive events.
- To ensure data is acquired accurately, a mount will be designed to hold the sensors steady and position them correctly relative to the explosive event. As a result, the system is vulnerable to bad readings if the sensors are not mounted properly.

5.3. Alternatives

Several alternatives to the high energy DAQ system include the following:

- Use security cameras with computer vision to decide if an explosive event has occurred.
- Thermal imaging could be used to detect significant changes in temperature to identify explosions within a certain environment.
- A break trigger could be placed adjacent to an explosive charge so that an explosive event can be detected when the electrical signal through the trigger is interrupted.

5.4. Impact

There are several safety, ethical, and national security concerns associated with use of the high energy DAQ system:

- Its suitability to military defense systems designates it a technology that would be in the best interest of national security to prevent other nations or foreign threats to gain access to.
- The DAQ system gathers data that is useful for research in explosives and ballistics testing. Because of the dangerous nature of this type of research there are safety concerns that must be considered when using this system.
- Users must be properly trained on the optimal safety conditions when using this system for sensing explosives or any type of high energy event.
- The damage caused by explosive testing can be harmful to the environment if not properly contained.
- Because the DAQ system will utilize portable batteries there is a risk for batteries to explode and become a hazard to the environment

Portable High Energy Experiment DAQ

Ethan Barnes
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FUNCTIONAL SYSTEM REQUIREMENTS

REVISION – Draft
22 February 2023

Functional System Requirements
for
Portable High Energy Experiment DAQ

Prepared by:
Group <34>

Author Date

Approved by:

Project Leader Date

John Lusher, P.E. Date

T/A Date

Change Record

Rev.	Date	Originator	Approvals	Description
-	22/2/2023	Sang Hoon Chung		Draft Release

Table of Contents

List of Table

List of Figures

1. Introduction

1.1. Purpose and Scope

The project aims to create a device that detects explosives within 100 feet. This device uses acoustic, pressure, and vibration sensors to create a process for receiving real-time data of the detected explosion. This explosive detection device, or the Portable High Energy Experiment Data Acquisition System (PHEE DAQ), recognizes that an explosion has occurred and allows you to protect equipment and personnel within that range more carefully. Since this device is expected to gather data continuously, the design will be self-powered with a chargeable battery. For accommodating real-time data acquisition, the microcontroller will capture the rise of the event with sampling at fast rates (2 kHz or higher). The microcontroller's output will identify whether an explosion has occurred and will be stored in onboard storage.

This document shows the technical requirements for the sensors and items used in the project and the systems being developed. It presents the products used in the flow diagram shown in CONOPS and specifies more detailed requirements.

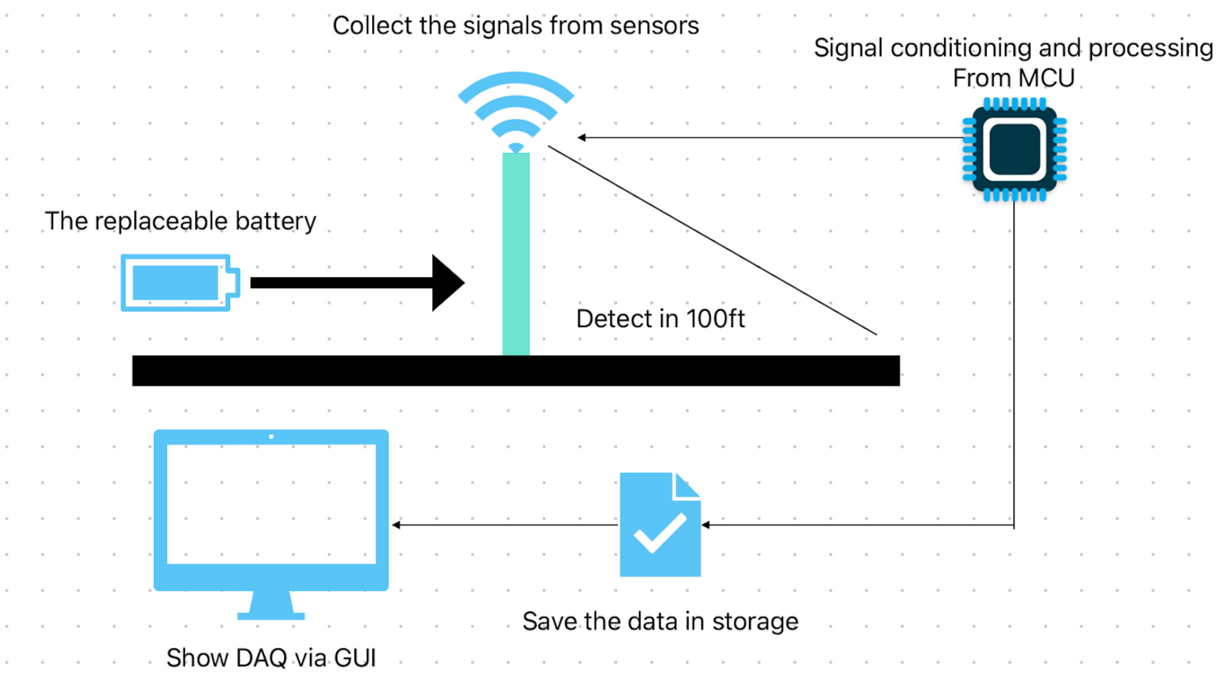

Figure 1. Project Conceptual Image

The following definitions differentiate between requirements and other statements.

Shall:	This is the only verb used for the binding requirements.
Should/May:	These verbs are used for stating non-mandatory goals.
Will:	This verb is used for stating facts or declaration of purpose.

1.2. Responsibility and Change Authority

This project is divided into three main items: a microcontroller that makes decisions based on the sensors' input, a power supply on PCB with chargeable batteries, and a PCB to integrate the microcontroller with signal processing. The team leader, Ethan Barnes, will verify all project requirements are met. These requirements can only be changed with the approval of the team leader and Professor Stavros Kalafatis.

Subsystem	Responsibility
Power Create power supply PCB capable of recharging the batteries	John Sabra
Microcontroller Create main PCB which integrates I/O with the microcontroller	Ethan Barnes
Signal Processing Create software to condition and process input signals	Sang Hoon Chung
GUI	TBD (Sang Hoon Chung)

Table 1: Responsibility and Change Authority

2. Applicable and Reference Documents

2.1. Applicable Documents

The following documents, of the exact issue and revision shown, form a part of this specification to the extent specified herein:

Document Number	Revision/Release Date	Document Title
a1310510	Oct 2009	Experimental response of an optical sensor used to determine the moment of blast by sensing the flash of the explosion
0957-4174	Nov 2021	DeepShip: An underwater acoustic benchmark dataset and a separable convolution based autoencoder for classification
382-392	May 13, 2020	Research on piezoelectric pressure sensor for shock wave load measurement
s22176582	Aug 29 2022	Measurement and Analysis of Shock Wave Pressure in Moving Charge and Stationary Charge Explosions
s20010132	Dec 24, 2019	Predicting Blast-Induced Ground Vibration in Open-Pit Mines Using Vibration Sensors and Support Vector Regression-Based Optimization Algorithms
DS10693	Rev 10, 22-Jan-2021	STM32F446xC/E Datasheet
DB3871	Rev 6, 26-Nov-2021	STM32CubeIDE Data brief

Table 2: Applicable Documents

2.2. Reference Documents

The following documents are reference documents utilized in the development of this specification. These documents do not form a part of this specification and are not controlled by their reference herein.

Document Number	Revision/Release Date	Document Title
10.3389	Feb 6, 2018	On the Accurate Determination of Shock Wave Time-Pressure Profile in the Experimental Models of Blast-Induced Neurotrauma
10.1016	Jan 29, 2018	Locating fish bomb blasts in real-time using a networked acoustic system
PMC7163342	Mar 16, 2020	Acute C4 Ingestion and Toxicity: Presentation and Management
20030571	Jan 2005	Mining Publication: Detonation Wave Propagation in Underground Mine Entries

Table 3: Reference Documents

2.3. Order of Precedence

In the event of a conflict between the text of this specification and an applicable document cited herein, the text of this specification takes precedence without any exceptions.

All specifications, standards, exhibits, drawings or other documents that are invoked as “applicable” in this specification are incorporated as cited. All documents that are referred to within an applicable report are considered to be for guidance and information only, except ICDs that have their relevant documents considered to be incorporated as cited.

3. Requirements

This section defines the minimum requirements that the development item(s) must meet. The requirements and constraints that apply to performance, design, interoperability, reliability, etc., of the system, are covered.

3.1. System Definition

The PHEE DAQ system will be used to determine if a recorded event in an environment was an explosive event or not. The system will use a pressure sensor, accelerometer, and microphone to measure pressure, vibration, and sound respectively. The analog data captured by these sensors will be sent to a microcontroller where they will be converted to digital signals using a DAC. These signals will then be conditioned and processed. The data from the processed signals will be used to classify a measured event as either explosive or not explosive. The classification and the exact time of classified event will be saved onto an SD card which can be removed from the system so that the user can view its contents.

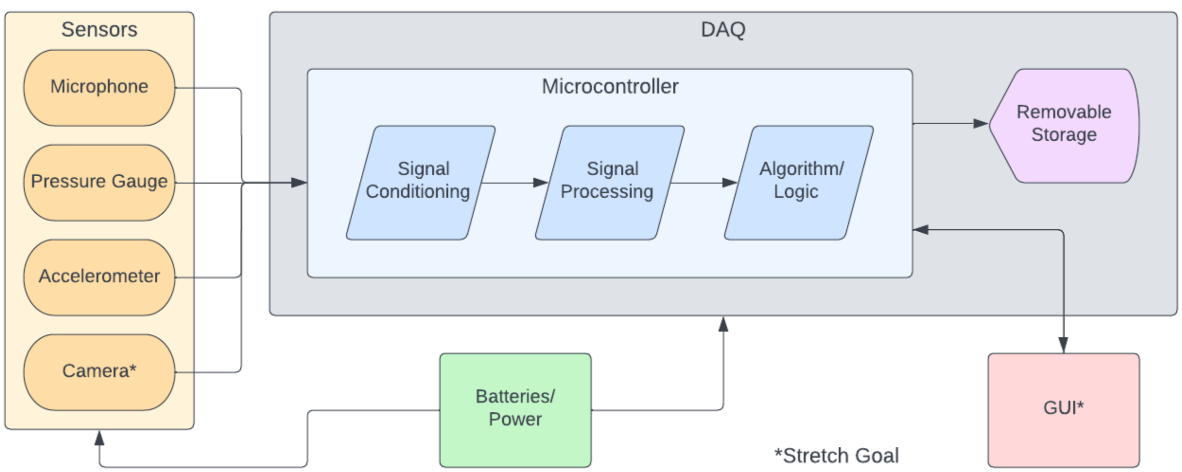

Figure 2. Block Diagram of PHEE DAQ System

The PHEE DAQ system will be divided into three main subsystems: power, microcontroller, and signal processing.

The power subsystem will be designed to power the microcontroller, sensors, SD card reader, and any other component that will need a stepped-down supply voltage. It will also be designed to recharge the batteries used as the supply. This will be implemented on a PCB that will be connected to the main PCB and the sensors.

The microcontroller subsystem will consist of a microcontroller, sensor inputs, and an SD card reader integrated on a PCB. The microcontroller will be programmed to read the sensor input, write its output to an SD card and run the firmware from the signal processing subsystem.

The signal processing subsystem will be designed to condition (clean up and amplify), and process (extract useful information) the digital signals read by the microcontroller using firmware that we will create. Other firmware in the form of an algorithm we will create will then use the information gathered from the signals to determine if those signals indicate the occurrence of an explosive event or not. These results will be saved onto an SD card along with the exact time at which the event occurred.

3.2. Characteristics

3.2.1. Functional / Performance Requirements

3.2.1.1. Data Storage Requirement

The PHEE DAQ system will save results to a removable storage device.

Rationale: This is a requirement specified by our sponsor.

3.2.1.2. Classification Accuracy

The PHEE DAQ system shall meet a threshold objective of 90% accuracy.

3.2.1.3. Classification Speed

The PHEE DAQ system should generate the result in real time.

Rationale: This is a requirement specified by our sponsor.

3.2.1.4. Battery Operating Time

The PHEE DAQ system should operate for at least twelve hours and also have power for a predictable amount of time. With an estimated working current of around 25 mA and a capacity ranging from 1000 mAh to 3000 mAh for the battery options that are currently under consideration, the battery operating time is expected to be at the minimum 40 hours and a maximum of 120 hours.

Rationale: The system should be able to be on standby, therefore a specified battery operating time would allow users to predict when the batteries must be charged.

3.2.2. Physical Characteristics

3.2.2.1. Mass

The mass of the PHEE DAQ system shall be less than or equal to 1 kilogram.

Rationale: This is a requirement specified by our sponsor to consider portability.

3.2.2.2. Volume Envelope

The volume envelope of The PHEE DAQ system shall be less than or equal to 15 cm in height, 15 cm in width, and 15 cm in length.

Rationale: This is a requirement specified by our sponsor to consider portability.

3.2.3. Electrical Characteristics

3.2.3.1. Sensor Inputs

The PHEE DAQ system will take inputs from a pressure sensor, accelerometer, and microphone.

Rationale: This is a requirement specified by our sponsor.

3.2.3.1.1 Power Consumption

With an estimated operating time of 120 hours, the maximum peak power of the system shall not exceed 11.1 watts.

3.2.3.1.2 Input Voltage Level

The input voltage level for the microcontroller from the power supply shall be between 1.7 VDC and 3.6 VDC.
The input voltage level for the microcontroller from the signals shall be between -0.3 VDC and 5.5 VDC.

Rationale: STM32F446RET6 specification, STM32F446xC/E Datasheet.

3.2.3.1.3 External Commands

The PHEE DAQ system may be controlled by an interactive GUI from either a smartphone or a laptop to configure the necessary number of channels for optimal data sampling.

Rationale: This is a stretch goal specified by our sponsor.

3.2.3.2. Outputs

3.2.3.2.1 Data Output

The PHEE DAQ system shall output the results of the event classification and the time at which the event occurred.

Rationale: This is a requirement specified by our sponsor.

3.2.3.2.2 GUI Metrics Display

The GUI should select different channels to display a small sample of the data either by waveform or summary of data collected.

Rationale: This is a stretch goal specified by our sponsor.

3.2.3.3. Connectors

The PHEE DAQ shall use external connectors compatible with the sensors provided by the sponsor.

Rationale: The sensors provided by our sponsor have specific connector types.

3.2.3.4. Wiring

The PHEE DAQ system shall follow the guidelines outlined in Figure 3 of STM32F446xC/E Datasheet.

Rationale: Conform to STM32 standard.

3.2.4. Environmental Requirements

The PHEE DAQ system shall be designed to withstand and operate in environments specified in the following section.

Rationale: This is a requirement specified by our sponsor due to constraints of the system in which the PHEE DAQ is integrating.

3.2.4.1. Ideal Environment

The PHEE DAQ system shall operate in an ideal environment (no explosive event, no extreme weather, no existing fires, normal atmospheric pressure, normal temperature).

3.2.4.2. Environment with Explosive Event

The PHEE DAQ system shall operate in an explosive event with extreme pressure and heat.

3.2.4.2.1. Pressure

The PHEE DAQ sensors shall be able to withstand and work properly in an environment with high pressure.

Rationale: The pressure generated by explosives of 5 lbs or less reaches about 150 kPa.

3.2.4.2.2. Thermal

The PHEE DAQ sensors shall be able to withstand and work properly in an environment with high temperature.

Rationale: This range includes the environment of the place and the maximum temperature when the explosive happens. When the 5 lbs of TNT explodes, the temperature reaches 5000 °F within 100ft.

3.2.5. Firmware Specification

The PHEE DAQ system shall arrange the signals and give rapid results for customers who use this system.

3.2.5.1. Microcontroller

The PHEE DAQ system shall have a microcontroller that is adequate for the requirements in this section.

3.2.5.1.1. Programming Language

The firmware for the PHEE DAQ system shall be written in C or C++.

> Rationale: STM32 Cube IDE specification, page 2 of STM*STM32CubeIDE Data brief*.

3.2.5.1.1. RAM

The PHEE DAQ system shall have at least 40 kB of RAM to run the firmware.

> *Rationale: This is a requirement based on the volume of data that we are getting from a sensor and the size of the firmware we will develop.*

3.2.5.2. Signal Processing and Conditioning

The PHEE DAQ system gets the signals from the sensors. After getting the signals, MCU starts to operate using the filter and sampling the signals.

3.2.5.2.1. Specific Filter Design

Each sensor measures a different type of signal, so each input signal needs a specific type of filter.

3.2.5.2.2. Sampling Rate

The PHEE DAQ system shall sample signals at 2 kHz or higher.

> *Rationale: This is a requirement specified by our sponsor.*

4. Support Requirements

The Portable High Energy Experiment Data Acquisition System is equipped with all the parts required to successfully collect and process a signal. After storing the data that is conditioned and processed, GUI will display data received from the MCU. The system to collect the signal consists of (1) an acoustic sensor, (2) a vibration sensor, (3) a pressure sensor, (4) a replaceable battery, and (5) removable storage. The control unit consists of (1) microcontroller, and (2) custom PCB design.

Appendix A: Acronyms and Abbreviations

SPI	Serial Peripheral Interface
GUI	Graphical User Interface
Hz	Hertz
ICD	Interface Control Document
kHz	Kilohertz (1,000 Hz)
LCD	Liquid Crystal Display
LED	Light-emitting Diode
mA	Milliamp
mAh	Milliamp Hour
W	Watt
PCB	Printed Circuit Board
RMS	Root Mean Square
TBD	To Be Determined
USB	Universal Serial Bus
DAQ	Data Acquisition
DAC	Digital-to-Analog Converter
MCU	Microcontroller
RAM	Random Access Memory
kB	Kilobyte(about 1,000 bytes)

Appendix B: Definition of Terms

Microcontroller: A small computer on a single integrated circuit chip that contains a processor, memory, and input/output peripherals.

Sampling: The process of measuring or recording a continuous analog signal at discrete time intervals.

Data acquisition: The process of measuring or acquiring data from physical or digital sources, such as sensors, instruments, or computer systems.

Firmware: A type of computer software that is embedded in non-volatile memory chips, such as ROM, EPROM, or flash memory, that are part of electronic devices or systems.

Accelerometer: A sensor that measures acceleration, including both linear acceleration and changes in orientation. It typically consists of a small device with one or more sensing elements, such as piezoelectric crystals or microelectromechanical systems (MEMS), that detect changes in motion and convert them into electrical signals.

SD card: A type of removable flash memory card used for storing digital data. (Secured Digital card)

Real time: Less than one second (TBD)

Portable High Energy Experiment DAQ

Ethan Barnes
Sang Hoon Chung
John Sabra

INTERFACE CONTROL DOCUMENT

REVISION – Draft
22 February 2023

INTERFACE CONTROL DOCUMENT
FOR
Portable High Energy Experiment DAQ

PREPARED BY:
Group <34>

Author Date

APPROVED BY:

Project Leader Date

John Lusher II, P.E. Date

T/A Date

Change Record

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-	22/2/2023	Ethan Barns		Draft Release

Table of Contents

List of Tables

List of Figures

1. Overview

This document provides detailed interfaces for the three subsystems of this project. The ICD will include physical descriptions of the various elements and each sensors' electrical interface, power, and placement. The document will also explain how the subsystems will interface to achieve the goals and requirements mentioned in the FSR and ConOps documents.

2. References and Definitions

2.1. References

Refer to sections 2.1 and 2.2 of the Functional System Requirements document.

2.2. Definitions

mA	Milliamp
mW	Milliwatt
kHz	Kilohertz (1,000 Hz)
MHz	Megahertz (1,000,000 Hz)
kB	kilobyte (1,000 bytes)
MB	Megabyte (1,000, 000 bytes)
TBD	To Be Determined
psi	Pounds per Square Inch
kPa	Kilopascal
dB	decibel
G	Gravitational force equivalent
GUI	Graphical User Interface
PCB	Printed Circuit Board
SPI	Serial Peripheral Interface
VDC	Voltage Direct Current

3. Physical Interface

3.1. Weight

3.1.1. Main Control Unit

Component	Weight	Number of Items	Total Weight
Microcontroller	0.34 g	1	TBD
PCB	TBD	1	TBD
Micro-SD card reader	TBD	1	TBD

Table 1: Main PCB Weight

3.1.2. Sensor Unit

Component	Weight	Number of Items	Total Weight
Pressure Sensor	TBD	1	TBD
Accelerometer	TBD	1	TBD
Microphone	TBD	1	TBD

Table 2: Sensor Unit Weight

3.1.3. Power Supply

Component	Weight	Number of Items	Total Weight
Batteries	80 g	1	TBD
PCB	TBD	1	TBD

Table 3: Power Supply Weight

3.2. Dimensions

3.2.1. Dimensions of Main Control Unit

Component	Length	Width	Height
Microcontroller	10 mm	10 mm	N/A
PCB	TBD	TBD	TBD
Micro-SD card reader	TBD	TBD	TBD

Table 4: Dimensions of Main Control Unit

3.2.2. Dimensions of Sensor Unit

Component	Length	Width	Height
Pressure Sensor	TBD	TBD	TBD
Accelerometer	TBD	TBD	TBD
Microphone	TBD	TBD	TBD

Table 5: Dimensions of Sensor Unit

3.2.3. Dimensions of Power Supply

Component	Length	Width	Height
Batteries	18 mm	34 mm	50 mm
PCB	TBD	TBD	TBD

Table 6: Dimensions of Power Supply

3.3. Mounting Locations

The PHEE DAQ will be placed in a normal environment with no special circumstances (explosive event, extreme weather, existing fires, abnormal atmospheric pressure) within a range of 100 ft. It is assumed that explosives may be present in this area.

4. Thermal Interface

Because the PHEE DAQ system is portable and required to use batteries as its main source of power, it may require a heatsink or some type of cooling system to mitigate the effects of heat buildup. Additionally, since it is possible for it to operate continuously for 120 hours, heat buildup may be so intense that the system may require air circulation.

5. Electrical Interface

5.1. Microcontroller Specifications

Model	STM32F446RET6
SRAM	128 kB
Flash Memory	512 GB
Processor Frequency	180 MHz

Table 7: Microcontroller Specifications

5.2. Primary Input Power

The PHEE DAQ system will be powered by a 3.7 V rechargeable lithium ion battery. The battery will have a capacity of 3000 mAh and ,with an expected working current of 25 mA, it is expected to last up to 120 hours. The power supply will have a maximum charging voltage of 4.2 V and estimated cycle life of 300 cycles where cycles represent the amount of times the battery can be charged and discharged until it reaches 80 % of its capacity.

5.3. Signal Interfaces

5.3.1. Sensor

The interface of the sensors is TBD.

Sensor	Output Voltage	Voltage Supply
Pressure Sensor	3.3 VDC - 5 VDC	TBD
Accelerometer	3.3 VDC - 5 VDC	TBD
Microphone	3.3 VDC - 5 VDC	TBD

Table 8: Signal Interfaces

5.4. User Control Interface

The user control interface may be a GUI that is displayed on a smartphone or a laptop. It may be used to display data captured by the PHEE DAQ or configure channels on the PHEE DAQ.

6. Communications / Device Interface Protocols

6.1. Wireless Communications (WiFi)

If WiFi is used, data will be transmitted and received using one of the IEEE 802.11 standards. If Bluetooth is used, data will be transmitted and received using the IEEE 802.15.1 standard.

6.2. SD card Reader Interface

The MCU will transmit data to the SD card reader using SPI.

Portable High Energy Experiment DAQ

Ethan Barnes
Sang Hoon Chung
John Sabra

SCHEDULE AND VALIDATION PLAN

REVISION – Draft
22 February 2023

Schedule:

Task	Deadline	Owner	Status
Write FSR, ICD, Milestones, Validation Plan	Feb 22, 2023	All	Complete
Present Midterm presentations	Mar 8, 2023	All	Pending
Present the status update presentation	Mar 29, 2023	All	Pending
Present the final presentation	Apr 19, 2023	All	Pending
Perform final demo	Apr 28, 2023	All	Pending
Decide on microcontroller	Feb 19, 2023	Ethan Barnes	Complete
Interface I/O with microcontroller	Apr 19, 2023	Ethan Barnes	Pending
Design main PCB	Apr 28, 2023	Ethan Barnes	Pending
Identify battery type for power supply	Feb 19, 2023	John Sabra	Complete
Identify voltage regulation method	Feb 19, 2023	John Sabra	Pending
Decide on integrated PCB design or separate power supply	Feb 19, 2023	John Sabra	Complete
Begin power supply PCB design	Apr 28, 2023	John Sabra	Pending
Pick types of sensors for design	Feb 19, 2023	All	Complete
Write signal conditioning code	Apr 28, 2023	Sang Hoon Chung	Pending
Write the code for	Apr 28, 2023	Sang Hoon Chung	Pending

signal processing			
Write detection algorithm	Mar 8, 2023	Sang Hoon Chung	Pending
Order Parts	Feb 24, 2023	All	Pending
Receive Sensors form Sandia	Mar 5, 2023	All	Pending

Validation Plan:

Test	Owner	Status
Able to read digital signals from sensors	Ethan Barnes	INCOMPLETE
Able to write to SD card	Ethan Barnes	INCOMPLETE
Sample signals at least 2 kHz	Ethan Barnes	INCOMPLETE
Algorithm is 90% accurate	Sang Hoon Chung	INCOMPLETE
Signal to noise ratio above 40 dB	Sang Hoon Chung	INCOMPLETE
Results print once per second	Sang Hoon Chung	INCOMPLETE
Power supply can convert input voltage to 3.3 V and 5 V	John Sabra	INCOMPLETE
Batteries will recharge	John Sabra	INCOMPLETE
Power supply should last for at least a full day	John Sabra	INCOMPLETE