University of Colorado
Department of Aerospace Engineering Sciences
ASEN 4018

Project Definition Document (PDD)

ASTERIA
(**A**loft **S**tratospheric **T**estbed for **E**xperimental **R**esearch on **I**nfrasonic **A**ctivity)

Approvals

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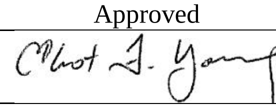
Customer	Eliot Young	Southwest Research Institute		09/15/2014
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1.0 Problem or Need

Infrasound waves are mechanical waves with a frequency of less than 20 Hz that are generated from a number of natural sources[1]. One particular source of interest is bolides, which are meteors that enter the Earth's atmosphere and disintegrate before impacting the surface. The disintegration of bolides creates a large explosion that generates infrasound waves. Due to the low frequency of infrasound waves, they are able to propagate long distances and can be detected by ground-based stations around the world.

The existing Comprehensive Nuclear-Test-Ban Treaty International Monitoring System (CTBT-IMS) network, which is used to detect infrasonic waves on Earth, is currently only capable of sensing approximately 30% of 0.1 kiloton events[2]. The loss is due to the presence of noise, mostly from wind, and to atmospheric ducts that channel infrasound upwards. There exists a need to detect a greater percentage of these events to improve the understanding of the near-Earth object population. There is interest in expanding the current network of detection to include sensors located within the stratosphere. It is proposed that using an infrasonic sensing platform within the stratosphere could reduce sources of noise, permitting more accurate and precise detection of infrasonic events.

The purpose of this project is to develop a high-altitude balloon payload, the Aloft Stratospheric Testbed for Experimental Research on Infrasonic Activity (ASTERIA), which is capable of measuring infrasonic events. ASTERIA will consist of a microphone capable of measuring infrasound waves and a support package to store data, provide thermal control, power, and a structural housing. ASTERIA will be verified for operation in the stratosphere through testing in controlled temperature and pressure environments.

2.0 Previous Work

On February 15th, 2013 a 20-meter wide meteor exploded over Chelyabinsk, Russia. The concussive magnitude of the infrasonic blast was calculated as over 500 kilotons, blowing out windows, causing minor structural damage to the buildings in the town, and injuring over 1500 people[3]. Events such as the Chelyabinsk meteor highlight the global vulnerability to large bolides. Currently, only a few of organizations around the world, such as the United States' National Oceanic and Atmospheric Administration (NOAA), the CTBTO-IMS, and a handful of private stations have the capability of detecting infrasonic waves from ground-based stations.

Although ground-based infrasonic experiments are currently in use, the adaptation of existing infrasound instruments to a balloon platform is novel because it investigates infrasonic detection capabilities from an atmospheric platform. Theoretically, a balloon-borne infrasound sensor array will significantly reduce the noise caused by cross winds[4], permitting more accurate and precise measurement of infrasonic events. This task necessitates integrating a traditionally static sensor into a balloon payload that will then be launched into the stratosphere to provide infrasound measurements.

Infrasound detectors are capable of identifying geophysical and anthropogenic sources of low frequency waves, further extending possible applications of this system. Tornadoes and severe thunderstorm formation, ocean turbulence, volcanic and tectonic activity, and avalanches could all be identified by a near real-time warning system hinging upon atmospheric infrasound detection[5]. Furthermore, man-made sources of infrasound such as nuclear detonations — the original motivation for the development of infrasound technology and the IMS[5] — machinery, and small explosions can be detected and regulated with proper application of infrasonic technology.

3.0 Specific Objectives

The primary project deliverable is a flight-ready payload. Thus, the project must provide a tested and verified high-altitude balloon payload that will: a) Measure infrasound signatures, b) Survive and operate independently from 60,000-100,000 feet[6]. This includes the Instrument Suite as well as the Command & Data Handling, Power, Thermal, and Structural subsystems, and c) Record and store data for local temperature, ambient pressure, and sound pressure.

The success criteria and the levels for success are found in Table 1 below. Meeting the criteria in Level 4 constitutes full success and is what the team will plan to accomplish. Levels 3, 2, and 1 provide "off-ramps" in order to de-scope specific criteria in the event that cost, schedule, or feasibility prevents meeting the Level 4 criteria, where Level 1 is the minimum level of success for the project. Each criterion is considered independent of the others, and de-scoping any of the listed criteria does not affect the other criteria.

Table 1. Specific Objectives and Levels of Success

Criteria	Level 1 (minimum success)	Level 2	Level 3	Level 4 (full success)
Detect infrasound signatures				
Detection Criteria	Detects TBD large amplitude infrasonic signatures and noise in TBD bandwidth at low resolution	Completes Level 1 and measures background infrasonic noise in TBD bandwidth at high resolution	Completes Level 2 and measures background infrasonic noise in TBD narrow bandwidth at high resolution	Completes Level 3 and filters background noise to identify TBD low amplitude infrasonic signatures
Survive and operate in stratospheric environment				
Microphone	Detects infrasonic signals on the ground	Detects infrasound signals at stratospheric temperatures	Retains structural integrity at stratospheric pressure	Collects pressure data at stratospheric pressure and temperature
Integrated System	Operates in ground conditions	Continues to operate at stratospheric temperatures	-	Continues to operate after structural tests
Record and store data				
Data Collection Duration	Collects and stores data for the duration of a specific event as well as two hours before and after	-	-	Collects data for maximum duration of balloon flight

4.0 Functional Requirements

4.1 Functional Block Diagram

The orange box in Figure 1 is the designed infrasound detection payload. A microphone on board the payload measures propagating infrasound waves, producing an analog signal. This analog signal is conditioned and converted to a digital output, which is stored in on board memory. All of these components require both power to remain functional and thermal control to stay within their operational temperature ranges. The thermal control is based upon onboard temperature readings of the various components.

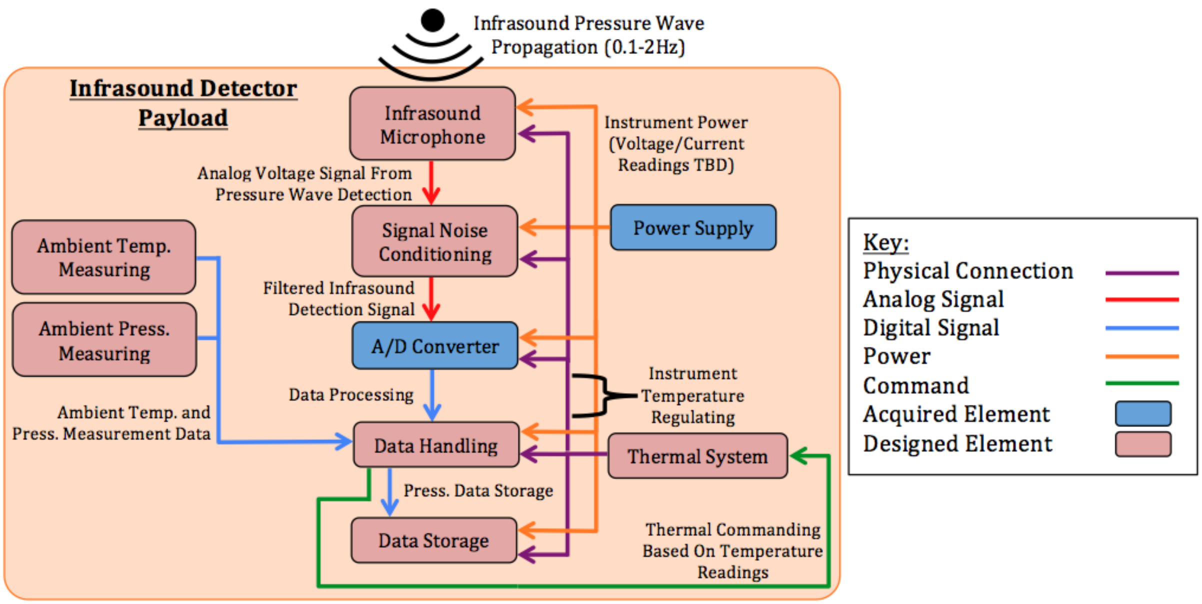

Figure 1. Functional Block Diagram of Payload

4.2 Concept of Operations

The scope of this project encompasses the building and testing of an infrasound sensor balloon payload, and ground test equipment for the infrasonic sensor. Figure 2 illustrates the goal of the current project as well as the intended uses of the infrasound payload.

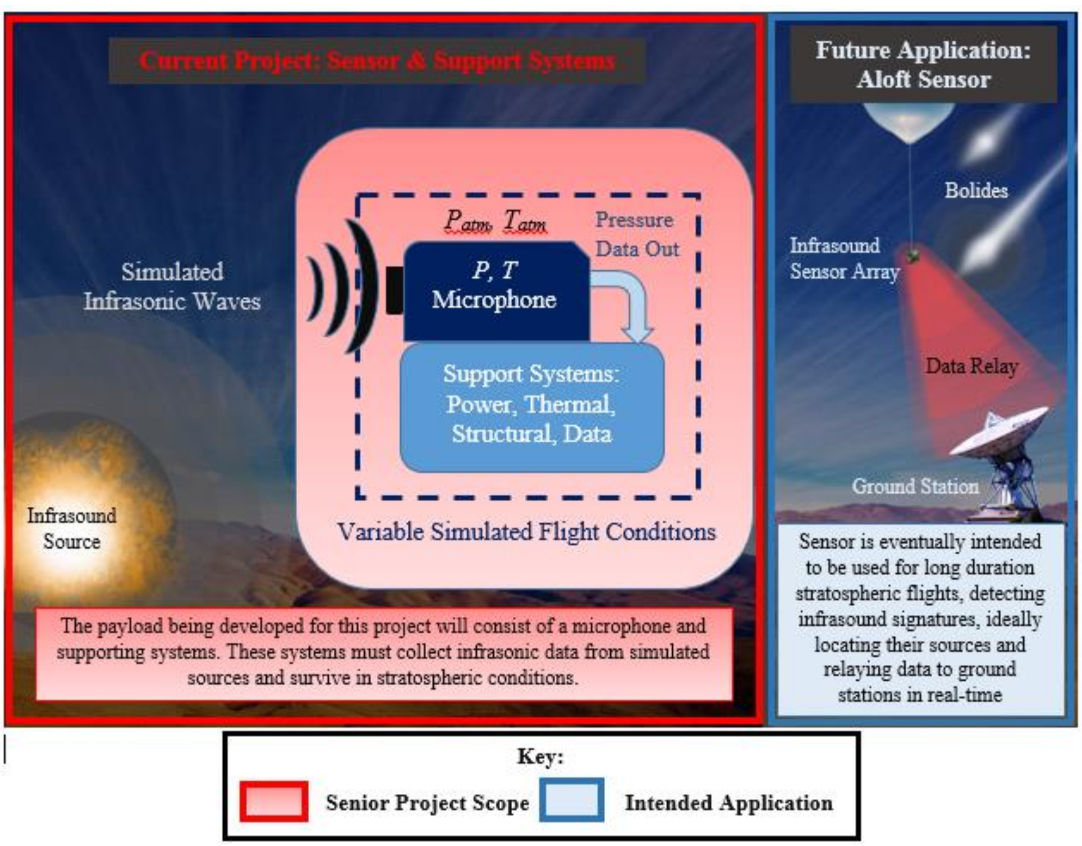

Figure 2. Concept of Operation for functioning payload

This project requires a microphone capable of detecting simulated infrasonic signals during testing, which will be done by recording voltages produced due to a pressure differential. The microphone must also be capable of surviving in the harsh environment of the stratosphere. Thus supporting systems will provide thermal regulation, power, structural support, and data storage capabilities. When operating, the payload will be a self-contained unit, collecting and saving data with no outside support.

Eventually the payload will be modified to monitor infrasound signatures for longer durations, collecting data for extended flights and relaying this data instead of simply storing it. While the initial payload itself will save data to solid state memory, the future payload would be modified to contain a communications system so that information and instructions can be transferred between the payload and ground stations. The aloft sensor's intended purpose is the detection of bolides through their infrasound signatures. This purpose could be expanded to explore other significant sources of infrasound in the upper atmosphere, gather data on the propagation of infrasound waves above the atmospheric boundary layer, and fully validate whether an upper atmospheric bolide detection platform provides better infrasonic data than their counterparts on the ground.

5.0 Critical Project Elements

5.1 Stratospheric Survivability of Payload

It is essential that the payload be able to survive in the stratospheric environment in which high-altitude balloons operate. In order to do this, the payload as a whole must be designed to withstand the extreme temperatures, low pressures, and structural loads present during the balloon flight. It must also provide power to on-board electronics for the duration of the flight. The survivability of the payload will need to be verified by environmental testing in a vacuum chamber with thermal capabilities. Designing the payload to withstand these conditions will be technically difficult because many commercial pieces of hardware are not rated for extreme temperatures or low pressures. The testing might be logistically and/or financially difficult depending on the team's ability to schedule, and, if necessary, pay for the use of vacuum chambers with thermal capabilities.

5.2 Microphone Design & Construction

The payload must include a microphone capable of detecting infrasound waves. It is anticipated that the design or modification of such a microphone will be technically, logistically, and potentially financially difficult. Commercial microphones used for ground-based infrasound detection are designed to work at surface-level conditions. In order to perform infrasonic measurements at stratospheric conditions, modifications to commercial microphones must be made or a custom microphone must be designed and constructed. The cost of a commercial microphone or materials to build one will potentially be expensive for the project budget, and logistics for lead time and shipping must be taken into account.

5.3 Infrasound Generation & Test Equipment

Testing of the infrasonic microphone is required in order to verify its design and functionality. Infrasound wave generation is not trivial. While current technology can produce high frequency infrasonic waves, the desired frequencies are typically only produced by natural phenomena. It will be technically, logistically, and potentially financially difficult to design a method of infrasound generation and the related test equipment for the lower range of infrasound frequencies.

5.4 Microphone Sensitivity Model

One of the objectives of the project is to deliver an instrument that would collect data under atmospheric conditions. However, it is not feasible to test the functionality of the microphone with infrasonic waves in a low-pressure environment. This model will provide confidence in the ability of the microphone to detect infrasonic frequencies without actual test data. It will be technically and logistically challenging since it requires extensive research, especially for a unique microphone design.

6.0 Team Skills and Interests

Critical Elements	***Team Skills/Interests*** (S) = Skill (I) = Interest
Stratospheric Survivability of Payload	-Thermal modeling: Michael (S), Martin (S) -Environmental testing: Kerry (I), Kyle (I), Emma (S) -Manufacturing: Connor (S), Kyle (I), Ian (I) -Mechanical design: Connor (S), Kerry (I), Emma (S) -Circuit design: Courtney (S), Martin (I), Connor (I) -Software: Michael (S), Emily (I), Ian (S)
Microphone Design & Construction	-Atmospheric modeling: Michael (S), Emily (I), Martin (I) -Manufacturing: Courtney (S), Kerry (I), Connor (S) -Wave modeling: Michael (S), Martin (S), Connor (I) -Mechanical design: Ian (S), Kyle (I), Emma (I) -Circuit design: Courtney (S), Martin (I), Connor (I) -Software: Michael (S), Emily (I), Ian (S)
Infrasound Generation Testing Equipment	-Mechanical design: Courtney (I), Connor (S), Kerry (I) -Manufacturing: Michael (I), Connor (S), Courtney (S) -Wave modeling: Michael (S), Martin (S), Connor (I) -Circuit design: Courtney (S), Martin (I), Connor (I) -Software: Michael (S), Emily (I), Ian (S)
Microphone Sensitivity Model	-Software: Michael (S), Emily (I), Ian (I)

7.0 Resources

In addition to the capabilities and knowledge of the team members, the team will also be able to rely on access to other resources that will aid in the development of this project, listed in the following table in tandem their respective critical project elements.

Critical Elements	***Resources***
Stratospheric Survivability of Payload	JANA vacuum chamber NOAA Facilities – Expertise of Dr. Al Bedard
Microphone Design & Construction	NOAA Facilities – Expertise of Dr. Al Bedard Expertise of Trudy Schwartz & Bobby Hodgkinson Expertise of Matt Rhode
Infrasound Generation Testing Equipment	NOAA Facilities – Expertise of Dr. Al Bedard Expertise of Trudy Schwartz & Bobby Hodgkinson Expertise of Matt Rhode
Microphone Sensitivity Model	NOAA Facilities – Expertise of Dr. Al Bedard Knowledge of Aerospace Department Faculty Existing models

8.0 References

[1] Nave, R., "Infrasonic Sound," Georgia State University Department of Physics and Astronomy – HyperPhysics, 2014, [http://hyperphysics.phy-astr.gsu.edu/hbase/sound/infrasound.html. Accessed 09/04/2014]

[2] Young, Eliot et al. "Infrasound Detection From Balloon-Borne Platforms." Southwest Research Institute, Boulder, CO. 26 Aug. 2014.

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[4] Bedard, A. J. "Sources of Atmospheric Infrasound and Detection Techniques." National Oceanic and Atmospheric Administration, Boulder, CO. 10 Sep. 2014.

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[6] Smith, I. Steve. "Low Cost Access to Near Space." Southwest Research Institute, San Antonio, TX. 11 Sep. 2014.

[7] Aerospace Engineering Sciences Senior Design Projects, University of Colorado at Boulder, n.d., [http://aeroprojects.colorado.edu/archive.shtml. Accessed 09/09/13.]