NIGHTWING

KNIGHTWING AI TRANSCRIBE

Divide and Conquer Document

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1. Executive Summary (Not a part of D&C)

2. Project Description

2.1 Project Background

In today's rapidly evolving world, it is important to continuously adapt to modern technologies to have competitive innovations. That is why our senior design project focuses on integrating cutting-edge technologies to face specific challenges in cyber security and real-time data processing. The project involves integrating an edge-computing AI chip with a software-defined radio (SDR) and designing a custom printed circuit board (PCB) with Bluetooth communication. The goal is to create a compact, discrete device that provides real-time translation and transcription in areas without Wi-Fi, with outputs displayed on a handheld device.

Our project is sponsored by Nightwing, a company committed to advancing national security through innovative cybersecurity solutions. Although the project itself is not intended for direct commercial sale, it will serve as a valuable demonstration of Nightwing's technological capabilities. This project is designed to serve as a tool for Nightwing, to demonstrate proof-of-concept designs to defense industry clients during customer presentations. By showing this project, Nightwing aims to highlight their creative approach and commitment to solving complex problems in cybersecurity.

2.2 Motivation

Senior design projects are very important in electrical and computer engineering education. It gives students a chance to apply the concepts taught theoretically to real-life projects. This project should help our team develop both technical and non-technical skills. These skills can be directly applied when we enter the engineering industry. These skills include team building, project and time management, creativity and understanding corporate design flow. Throughout the hands-on part of the experience, we will improve our understanding in circuit design, advanced coding, artificial intelligence (AI), machine learning, hardware interfacing, power designs, and real-world design constraints.

Our sponsor is highly motivated to ensure that we have a successful and advanced senior design project. They have committed to fully funding the project and providing technical mentorship and design reviews. Recently divested from Raytheon Technologies, Nightwing is focused on repositioning itself as a leader in the cybersecurity industry. By sponsoring our project, Nightwing hopes to improve their community outreach. They also hope this sponsorship will allow other University of Central Florida students to learn more about their company and decide if they are interested in a career at Nightwing.

We are privileged to have Bayardo Payan as our mentor for this project. With over 22 years of experience in custom hardware and electronic circuit card assembly design, Bayardo provides us with invaluable industry knowledge. Being an alum from UCF (University of Central Florida) he is passionate and excited about mentoring us on this project. His experience that is specific to our project includes developing his own software-defined radio (SDR) and creating custom printed circuit boards from the proposal to the deliverable product. Bayardo’s mentorship will provide us with realistic design reviews and insights into industry standards, which will help us gain a better understanding of professional practice. Nightwing also has offered to refer us to other employees within the company if we have specific questions outside of Bayardo’s expertise.

Through this project, we aim to push the boundaries of technology and innovation, aligning with Nightwing’s goals and providing us with a comprehensive learning experience. This project's successful execution will demonstrate our ability to handle complex engineering challenges and showcase the potential of integrating advanced technologies to solve real-world problems.

2.3 Goals and Objectives

The main goal of this project is to develop a device that captures and translates radio signals in real time, then sends the translated data to an Android phone via Bluetooth, all without needing an internet connection. Our overall and stretch goals are listed below as well as our objectives.

2.3.1 Basic Goals

- The device will be able to capture and process radio signals using a Software-Defined Radio.
- Implement real-time signal processing to translate radio wave signals into readable text using the Jetson nano.
- The device will connect the Software-Defined Radio to the Jetson through the peripherals on the PCB.
- The device will be able to translate and transcribe in real time from Spanish to English.
- The device will have a Bluetooth module.
- The device will connect to an Android app that shows the translated speech-to-text in real-time.
- The device will be able to recognize key words.

2.3.2 Stretch Goals

- The device can scan multiple channels simultaneously.
- The SDR can receive and transmit signals.
- The Jetson AI will create a deepfake version of the voice from the captured audio.
- The device can translate more than one language.

2.3.3 SDR Objectives

- Capture and demodulate a radio wave signal.
- Output digital signal values.
- Interface with Jetson for data transfer and processing.

- Enable functionality for receiving signals.
- Ensure seamless integration of the SDR with the PCB.

2.3.4 Jetson Objectives

- Implement edge computing to run AI algorithms for real-time signal processing.
- Develop and integrate models for translating and transcribing a radio signal.
- Optimize AI models for efficient performance on Jetson.

2.3.5 PCB Objectives

- Design and fabricate a custom PCB to integrate and connect all components.
- The device will be able to power the Jeston, SDR, and other parts reliably through the PCB.
- Include peripherals to connect the Jetson and SDR.
- Optimize the layout for compactness and efficiency.
- Provide power management for low power mode and battery monitoring.
- The device will be housed in a case to keep all the components together.

2.3.6 Android Phone Objectives

- Develop an app to display the translated signal data in real-time.
- Ensure reliable Bluetooth connectivity for data reception.
- Design a user-friendly interface for visualization of data.

2.4 Features and Functionalities

Our senior design project integrates a Jetson Nano development kit with a custom-built PCB, Bluetooth connectivity, and a software-defined radio (SDR) to receive data and translate walkie-talkie signals in real-time. This solution is designed to outperform existing products by combining edge computing with advanced signal processing in a compact, portable format.

2.4.1 NVIDIA Jetson Nano

The NVIDIA Jetson Nano is a compact and versatile platform tailored for diverse applications, especially in artificial intelligence (AI) and machine learning. There have been many different projects that have used Jetson's AI capabilities that we will use in our project. We use Jetson for its capability of edge computing which allows for local data processing, eliminating the need to rely on a central server. It is crucial for our application that demands real-time decision-making without internet access. Additionally, the Jetson Nano will convert raw signal data into a readable format by interpreting signals from the SDR and translating them into human-readable information. It will also facilitate the running of speech-to-text algorithms, transcribing spoken words into text. Furthermore, the Jetson Nano will implement custom algorithms and natural language processing (NLP) techniques for analyzing signals, including noise reduction, meaningful data extraction, and recognition of specific signal patterns.

2.4.2 Jetson Nano versus existing SBCs

Compared to other single-board computers (SBCs) like the Raspberry Pi or BeagleBone, the Jetson Nano offers superior AI and machine learning capabilities.

Raspberry Pi 4 Model B:

Processing Power: The Raspberry Pi 4 features a quad-core ARM Cortex-A72 CPU and up to 8GB of RAM. While powerful for general-purpose computing and some light AI tasks, it does not match the Jetson Nano’s GPU capabilities. It is less suited for intensive real-time processing and AI tasks due to its limited parallel processing capabilities.

AI Capabilities: The Raspberry Pi relies on external AI accelerators or libraries (like TensorFlow Lite) for AI applications. It lacks built-in support for CUDA or other GPU-accelerated frameworks, making it less optimal for tasks requiring extensive neural network computations.

Connectivity: The Raspberry Pi offers built-in Bluetooth and Wi-Fi connectivity, which is useful for the wireless communication part of this project. However, for interfacing with specialized components like SDRs, you might still need additional adapters.

Power Consumption: The Raspberry Pi 4 typically consumes around 3-7 watts. While lower than the Jetson Nano, it may require additional power for peripherals and AI accelerators.

BeagleBone Black:

Processing Power: The BeagleBone Black features a single-core ARM Cortex-A8 CPU and 512MB of RAM. Its processing power is lower than that of both the Raspberry Pi and Jetson Nano. This limitation can be a significant drawback for real-time processing and AI applications where higher computational power is needed.

AI Capabilities: The BeagleBone Black does not have built-in support for advanced AI frameworks or GPU acceleration. It is designed more for general-purpose computing and interfacing with hardware rather than for intensive AI tasks.

Connectivity: Similar to the Raspberry Pi, the BeagleBone Black includes GPIO, I2C, SPI, and UART, which are useful for hardware interfacing. It does not include Bluetooth, which would require additional modules for wireless communication.

Power Consumption: The BeagleBone Black typically consumes around 2-5 watts, making it one of the lower-power options among the three. This can be beneficial for applications where power efficiency is critical.

While the Raspberry Pi and BeagleBone are both advanced SBC’s, they lack the Jetson Nano’s specialized GPU for edge computing, crucial for real-time signal processing and NLP tasks. Its superior GPU performance and native support for AI frameworks make it more suitable for handling complex algorithms and real-time data processing. While the Raspberry Pi and BeagleBone Black are more versatile for general-purpose tasks and lower power consumption, they fall short in terms of AI capabilities and real-time processing power. The Jetson Nano’s combination of high performance and edge AI capabilities makes it the optimal choice.

2.5 Prior Related Projects

2.5.1 “Deploy Whisper on NVIDIA Jetson Orin for Real time Speech to Text”

This project explores deploying real-time speech-to-text (STT) systems on the NVIDIA Jetson Orin. They focus on integrating Whisper, a highly accurate deep learning-based STT model, and NVIDIA’s Riva conversational AI framework. By leveraging Jetson Orin’s powerful GPU, CPU cores, and hardware acceleration, they aim for low-latency, real-time STT processing directly on the device, eliminating the need for constant network connectivity. They also compared the inference speeds of Whisper and Riva on the Jetson Orin, enabling the development of efficient and robust STT applications for various domains.

This project uses Jetson for similar functionalities like how it uses real time speech-to-text models. It gives us insights on which STT models (Whisper and Riva) worked for their project and compares the two which is beneficial to our research and implementation of the Jetson. Riva, known for its advanced AI-driven speech recognition and natural language processing, empowers users with real-time transcription, translation, and analysis of spoken conversations. Whisper is an automatic speech recognition (ASR) system trained on 680,000 hours of multilingual and multitask supervised data collected from the web. Moreover, it enables transcription in multiple languages, as well as translation from those languages into English. We can implement both Riva and Whisper into our Jetson because Riva accomplishes the speech recognition functionality and real-time transcription, and Whisper has the functionality to translate different languages into English.

This project utilizes a **reSpeaker** USB microphone for capturing audio, rather than a Software Defined Radio (SDR). The reSpeaker is specifically designed for voice interaction and audio processing, offering a direct digital audio stream to the NVIDIA Jetson. This setup simplifies the process of capturing and processing voice data, making it well-suited for applications like speech-to-text.

In contrast, an SDR captures a wide range of radio frequencies and requires additional steps to convert these signals into a digital format. This involves complex signal processing tasks such as demodulation and decoding. Consequently, the Jetson's method of handling audio data differs significantly depending on whether it is using the reSpeaker for direct voice input or an SDR for broader radio signal analysis.

2.5.2 "How to Run a ChatGPT-Like LLM on NVIDIA Jetson board"

This project aims to demonstrate a ChatGPT-like language model running on an NVIDIA Jetson board. The setup includes a ReSpeaker USB microphone array, the NVIDIA Jetson board, and a Bluetooth speaker. The microphone captures audio, which is processed by the Jetson to generate text responses. These responses are then sent to the Bluetooth speaker to be converted back into speech. This entire process occurs locally on the Jetson board, ensuring privacy and reducing latency by eliminating the need for an internet connection.

This project is relevant to ours because it incorporates similar functionalities that we aim to implement. It leverages the Jetson's ability to process audio and generate text responses, and it transmits this text to a device via Bluetooth, which aligns with one of our objectives. Additionally, this project uses Automatic Speech Recognition (ASR) technology, which converts spoken language into written text, enabling the voice assistant to interpret the user's speech. They created the ASR with Vosk API. Since we also need to integrate this ASR functionality for our project, knowing which API they used helps deciding and researching how we want to implement this objective. The system avoids using the internet by performing all necessary operations—speech recognition, text generation, and Bluetooth—locally on the Jetson board. This approach ensures that data remains within the device, maintaining privacy and reducing latency.

However, much like the last project, it captures audio from the user through a microphone. Our project will be more complex since it captures the audio input from the SDR radio frequency waves. This project takes another step to convert the generated text into speech. After the chatbot language model generates a response, the text-based output is converted into spoken words using a Text-to-Speech system.

2.6 Existing Products

In evaluating our senior design project, it is important to compare it with existing products on the market. Several notable products have attempted to address similar challenges but differ in their approaches and features. One of the features of our project is to have a portable system that can allow for real-time translation and transcription to a handheld device without requiring an internet connection. For example, **Kynamics**, based in Mountain View, CA, has developed a portable, standalone system for automatic language detection and updates but with internet connectivity. Funded by the Department of Homeland Security and currently in Phase 3, this system depends on an internet connection for updates, which in comparison ours does not. In the cyber security world, it is important to be able to be discrete and not have to connect to the internet.

Similarly, **myLanguage**, located in San Jose, CA, is making an online and offline voice-to-text system for use in rugged handheld devices. Also funded by the Department of Homeland Security and in Phase 3, myLanguage uses machine learning and artificial intelligence for speech recognition and translation. While this product does offer an offline feature, it does not provide real-time translation and transcription.

Another stretch goal and feature would be able to have our project translate and transcribe multiple languages. **Honeywell's Pick Up & Go (PnG)** is another relevant product. This speech recognition system offers speaker-independent recognition that requires no user training. However, it requires an internet connection and is limited in its multilingual capabilities unless you pay for licensing, making it less versatile than our project.

Another feature in our project is that the SDR will be picking up the radio wave frequencies for these translations. The **Ectaco Military SpeechGuard GI-5** is designed for high-risk environments and provides hands-free, eye-free communication with pre-recorded phrases and translations. It is effective for issuing situational commands in extreme conditions because it offers real time translations and can perform offline, which is a feature in our project. However, it does not integrate with an SDR, it instead uses pre-recorded phrases.

Pocketalk Translator offers real-time translation between multiple languages in a handheld device. Although it does offer the feature of real-time multiple language translation, it relies on internet connectivity for accurate translations and does not incorporate an SDR.

Travis Touch Plus is another real-time voice translator designed for travel and communication. Like Pocketalk, it depends on internet access and lacks SDR capabilities.

Our project is significant and unique because of its integration of a software defined radio to receive data of walkie-talkie signals and its ability to deliver real-time, accurate translation and transcription without relying on internet connectivity. This combination of SDR technology, real-time processing, and offline functionality makes our project particularly valuable for defense and other high-stakes environments where immediate, reliable, and discrete communication is required.

2.7 Engineering Specifications

Engineering Specifications	Description	Values
Power	Amount of electrical power required for operation	Shall not exceed 15W
Weight	Total Weight of the Device	Shall not exceed 10lbs
Size	Dimensions of the device (L x W x H)	Shall not exceed 20in x 14in x 8in (typical backpack measurements)
Battery Life	Duration the Device the device operates on a single charge	At least 8 hours

Temperature Range	Operating temperature of the device	50°F - 100°F
Cost	Estimated cost of production	Shall not exceed $3000
Latency of translate and transcribe	Time taken to translate and transcribe signals	Less than 1 second
Error per words	Average error rate in the transcription and translation process	Less than 5%
Bluetooth Connectivity	Connection range from the computing device to the handheld device	30 ft

Table 1: Engineering Specifications

Note: These specifications are estimations based on the anticipated requirements and capabilities of the device. The values provided represent the maximum expected performance levels to ensure the device meets its intended functionality.

The highlighted values in the table represent the estimated specifications and the demo specifications shown during the demonstration of the final product Additional demo features encompass Bluetooth connectivity with a demo phone, accurate translation and transcription of Spanish speech, and seamless integration with the SDR for effective data signal reception

2.8 Hardware Block Diagram

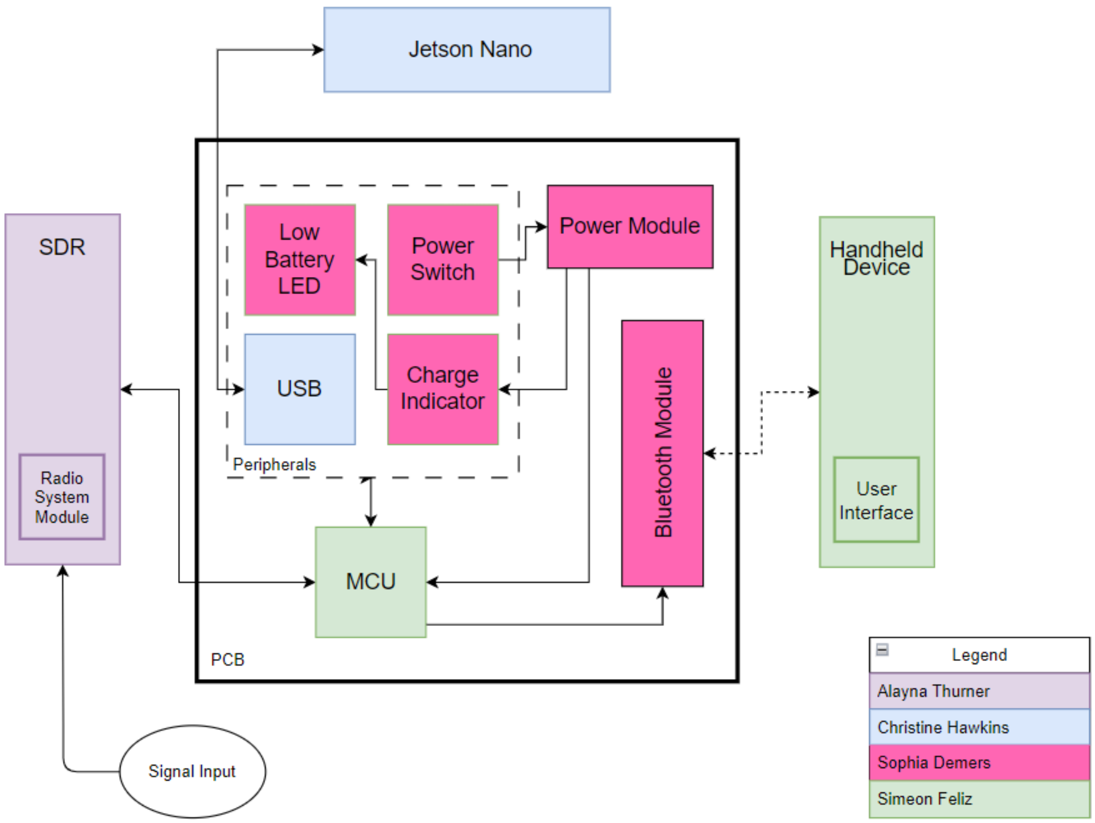


Figure 1: Hardware Block Diagram

2.9 Software Diagram

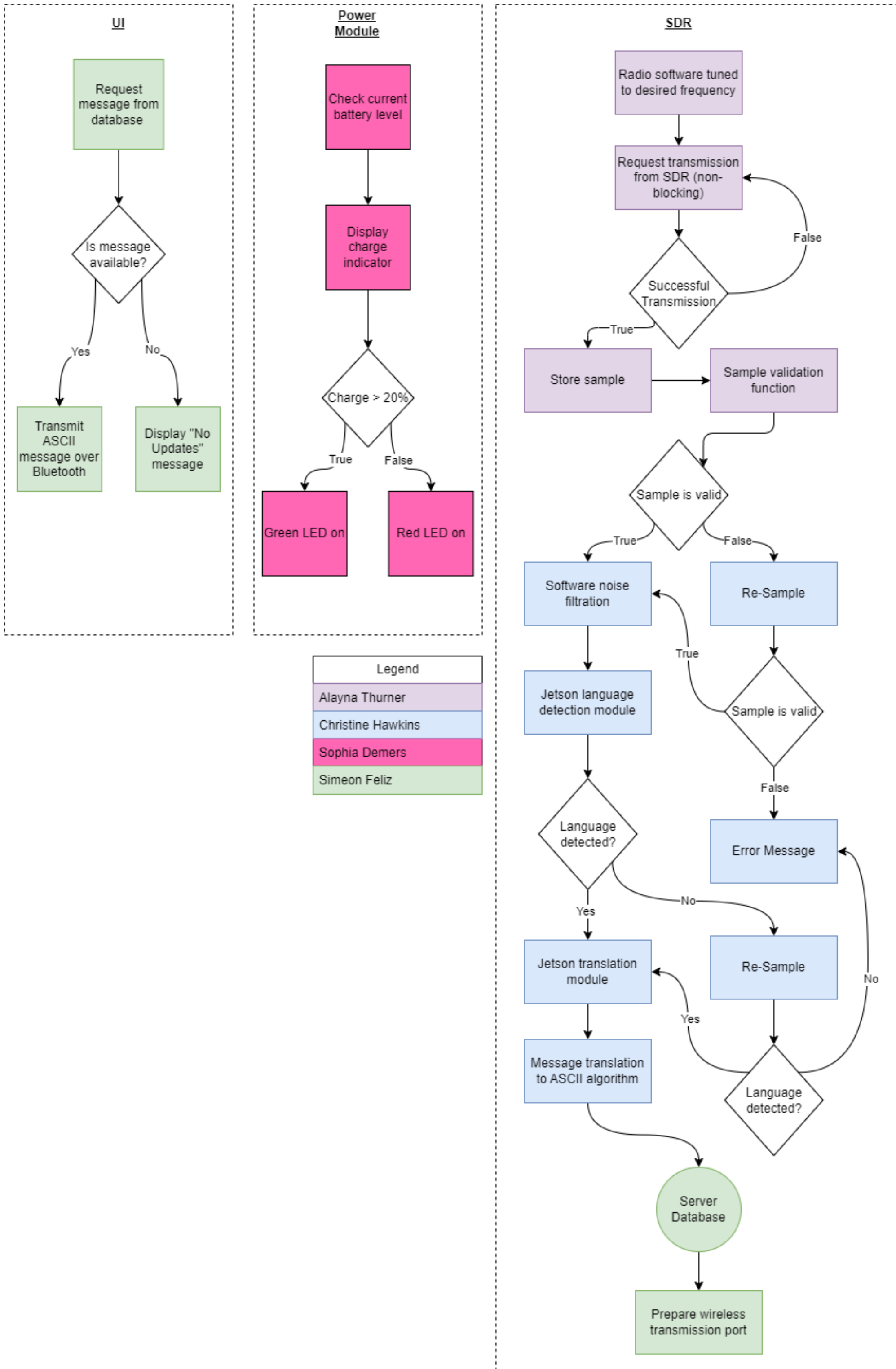
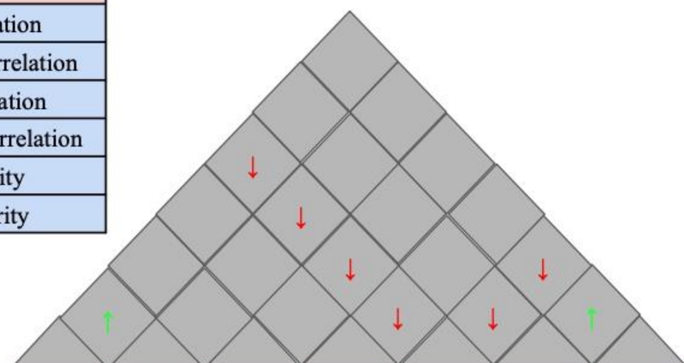


Figure 2: Software Flowchart

2.10 House of Quality

The house of quality is a matrix that shows the relationship between the engineering requirements and the marketing requirements. This allows us to see the tradeoffs between the two and to understand the needs of the customers while also taking the design into account. By taking note of this, we can make more educated decisions when it comes to implementation of our design as far as what features we may need to prioritize as well as compromises that may need to be made to get the most balanced design both on the customer and engineer side.

Symbol	Description
↑	Positive Correlation
↑↑	Strong Positive Correlation
↓	Negative Correlation
↓↓	Strong Negative Correlation
+	Positive Polarity
-	Negative Polarity



Engineering Requirements		Weight	Dimensions	Battery Life	Temperature Range	Cost	Latency of Translate and Transcribe	Error per Word
Marketing Requirements		-	-	+	+	-	-	-
Portability	+	↑↑	↑↑	↓		↓		
Accuracy	+			↑	↑	↓	↓	↑↑
Speed	+				↑	↓	↑↑	
Power Efficiency	+			↑↑	↑	↓	↓	
Affordability	-	↓↓	↓↓	↓↓		↑↑	↓	
Targets for Engineering Requirements		< 10 lbs	L: 20 (in) W: 14 (in) H: 8 (in)	>= 8 Hours	50-100 Degrees Fahrenheit	<= $3000	< 1 Second	< 5%

Table 2: House of Quality

2.11 Budget and Financing

Item	Options	Estimated Cost Range	Notes
Software Define Radio	LimeSDR PlutoSDR RTL-SDR	\$300 - \$500 \$150 - \$250 \$20 - \$50 Overall \$20-\$500	The SDR cost varies based on performance. The LimeSDR and PlutoSDR are higher end options while RTL-SDR is more budget friendly but has fewer capabilities. The selection will depend on final budget approval from sponsor because they may want to have additional future capabilities outside this project's scope.
Jetson Development Kit	NVIDIA Jetson Nano	\$500-\$1000	With each development kit costing around \$500 the total cost for two would be \$1000.
Custom PCB and Components		\$100 - \$1000	The cost depends on the complexity of the board and the components used. We are proposing an extensive range because we have not developed the design for this yet.
Demo Phone	Any android phone with Bluetooth capabilities	\$50 - \$300	Like the SDR, the cost varies depending on how many additional capabilities our sponsor may want.
Additional Considerations		\$0 - \$200	Software Licensing and enclosure for the final product

MAX BUDGET ESTIMATE	$3000

Table 3: Budget

2.12 Senior Design 1 Milestone

Start Date	Due Date	Description
08/19	**08/23**	Group Formation and Project Idea Brainstorming
08/23	**08/30**	Project Idea and Sponsor finalized
08/30	**09/06**	Write Divide and Conquer Document and finalize Review Committee
09/09	**09/09**	Meet with SD Coordinator for Divide and Conquer
09/09	**09/13**	Trade study: Select key components and look at lead times
09/13	**09/16**	Start ordering components
09/16	**09/27**	Update and upload D&C report onto group website and start working on 60-page D&C Draft
09/27	**10/11**	Continue work on 60-page D&C Draft
10/14	**10/16**	Check-in progress with Nightwing
10/16	**10/25**	Revise and submit 60-page D&C
10/28	**10/30**	60-Page Report Group Meeting
10/30	**11/08**	Upload 60-page report onto group website and start 120-page document
11/08	**11/18**	Continue work on 120-page report and have a Preliminary Design Review
11/18	**11/26**	SD1 Final Report & Mini Demo Video

Table 4: Senior Design 1 Milestone

2.13 Senior Design 2 Milestone

Start Date	Due Date	Description
01/06	**01/10**	Update 120-page document as needed
01/10	**01/17**	Start work on the SDR and the Jetson Separately
01/17	**01/24**	Begin work on PCB
01/24	**02/07**	Continue Work on PCB, SDR, Jetson
02/07	**02/14**	Integrating the hand-held device

02/14	**02/21**	Start integrating components together
02/21	**02/28**	Testing stage
02/28	**03/07**	Research Solutions to any Malfunctions
03/07	**03/14**	Implement Solutions to Test New Protype
03/14	**03/17**	Test New Protype
03/17	**03/22**	Spring Break
03/22	**03/28**	Optimize Protype
03/28	**04/04**	Prototype should be fully functional
04/04	**04/11**	Go over Project Presentation
04/11	**04/18**	Demonstrate Project to SD Coordinators

Table 5: Senior Design 2 Milestone

2.12 Citations and Resources

Citations

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