Problem Statement and Goals
Audio360

Team #6, Six Sense
Omar Alam
Sathurshan Arulmohan
Nirmal Chaudhari
Kalp Shah
Jay Sharma

Table 1: Revision History

Date	Developer(s)	Change
2025-09-22	Nirmal, Sathurshan, Omar, Kalp, Jay	Initial Write-up
2025-09-29	Jay	Update goals and stretch goals
2025-11-20	Sathurshan	Update Extras
2025-12-12	Omar	Address TA feedback for goals and stakeholders.

1 Problem Statement

1.1 Problem

Individuals who are deaf or hard of hearing tend to have difficulties with staying situationally aware, generally leading to increased risk of injury. Many safety cues such as "the sounds of a tea kettle, the warning beep as a fork lift backs up, and the engine of an oncoming car may be missed". [1] General sound cues such as someone calling their name, or a phone ringing, may also be missed, often leading to miscommunication and elevated frustration. With 1 in 10 Canadians being impacted by hearing loss [2], there are over 4 million individuals in Canada dealing with these struggles every day.
While existing assistive technologies such as hearing aids, smart glasses with speech transcription, and home alert systems address some aspects of this problem, they leave critical gaps. Hearing aids amplify sounds but do not assist profoundly deaf individuals or provide visual directional cues. Transcription glasses focus solely on speech and ignore environmental sounds. Home alert systems are stationary and predetermined, lacking portability and real-time directional awareness. None of these solutions provide real-time, wearable, directional localization of environmental sounds, leaving individuals vulnerable to missing important safety cues such as approaching vehicles, warning beeps, or emergency alerts.

1.2 Inputs and Outputs

The high level input of the system is the audio from the surrounding environments, with the output being a visual indication of the direction of audio sources and what the identified source of a sound is (e.g. car horn, dog bark).

1.3 Stakeholders

The primary stakeholder identified for this project are individuals whom are deaf or hard of hearing. The project will be designed with their needs in mind and they will benefit the most from increased situational awareness.

Secondary stakeholders identified include individuals who have their ears covered for any reason. The brain exploits how the human ear shape changes waveforms hitting the eardrum from various directions to localize sound direction. Placing covers on ears such as noise cancelling headphones severely degrades the brain's ability to localize sound in addition to very little sound being transmitted through noise cancelling headphones. The same reasoning applies for construction workers who have to wear large ear muffs to protect their hearing [3].

Other tertiary stakeholders may include smart glasses and noise cancelling headphone manufacturers who may be interested in implementing the resulting technology from this project.

1.4 Environment

The project is expected to perform adequately in indoor and outdoor environments. The hardware utilized will be a compact micro-controller to allow future integration into a wearable device form factor. The processor will be connected to a microphone array over a suitable communication interface that is able to accommodate multiple audio streams with adequate latency.
The software developed to be run on the hardware will adhere to real-time constraints, most likely utilizing a real-time operating system (RTOS) designed to execute on embedded micro-controller targets.
The user facing hardware display is expected to be a pair of smart glasses with an embedded display that the user can see. This display will be connected to the project hardware with a wired connection for prototyping purposes.

2 Goals

- Capture real-time audio from a microphone array with synchronized sampling.
- Accurate spatial analysis and real-time processing of audio sources surrounding the user.
- Estimate the angular direction of multiple audio sources relative to the user, providing reliable localization for practical use cases.
- Develop a minimal and easy to understand user interface that overlays on top of what the user sees without being intrusive.
- Meaningfully improve the situational awareness of primary and secondary stakeholders by means of the project with minimal effort required by end-users.
- Minimize the power usage of the software to extend the battery life of the host wearable. This will allow end-users to use the product for longer.

3 Stretch Goals

- Classify sounds using audio fingerprinting with useful accuracy, allowing the system to recognize and differentiate between common sounds.
- Display audio classification, localized direction and transcription (when applicable) on smart glasses, supporting real-time and user-friendly interaction.

- Test the project with members of the hard of hearing community to obtain valuable actionable feedback and improve the user experience.

4 Extras

1. Price + Hardware Selection Report
2. Theory Report (DOA + Sound Classification with pyroom simulation integration)

Appendix — Reflection

1. What went well while writing this deliverable?

   Omar Alam: I think all members of our team were proactive and genuinely interested in the project presented which made it easier to delegate and expect high quality work.

   Jay Sharma: We aligned quickly on the problem and split responsibilities in a way that played to each person's strengths. Our LaTeX/Git workflow came together smoothly, which helped us iterate fast on the documents.

   Kalp Shah: I think we all had a good understanding of the project after discussing it in detail during the write up for the development plan. Due to this, everyone was able to quickly contribute to the problem statement and goals without much difficulty.

   Sathurshan Arulmohan: I focused on writing the Extras section of this deliverable. Since these items were pre-approved by the course instructor during the project approval stage, the writing process was straightforward and required minimal revisions.

   Nirmal Chaudhari: I think our team worked well when dividing up the tickets, and assigning reviewers for each PR. Moreover, we had frequent sync ups to discuss and reach out to our stakeholders, and determine the scope of our overall project.

2. What pain points did you experience during this deliverable, and how did you resolve them?

   Omar Alam: Since the project idea incorporates glasses with displays that are visible to the user, we had to do a significant amount of research to figure out if it was feasible in the time that we have. We resolved this by developing a contingency plan that would allow us to still allow us to develop the core algorithms without the display glasses.

   Jay Sharma: Our main pain point was deciding on the hardware that we would use for the project. We had to spend a significant amount of time researching the different options and their feasibility.

   Kalp Shah: I think we did end up spending a lot of time exploring the scope and feasibility of the project while writing the development plan which caused us to spend less time writing the problem statement and goals. We ended up writing it all on the day before the deadline which was not a problem (as mentioned above - we already knew what to write), but cause a bit of stress.

   Sathurshan Arulmohan: My main contribution to this deliverable was reviewing pull requests. The challenge was understanding the expected quality and depth since it is the team's first submission. To address this, we used Pull Requests to exchange feedback and propose improvements. This process helped the team establish documentation standards and align on expectations.

Nirmal Chaudhari: Based on discussions with our supervisor, MVM, we were told it won't be easy to find a cheap solution that has 4 ADCs. To remain consistent with our project goals and requirements, having one ADC for each microphone was crucial for real time audio recognition. Our supervisor was very helpful in helping us overcome this challenge as he suggested a couple options from which Omar investigated further. We later met as a team and decided that we will only know if its compatible or not after actually buying hardware.

3. How did you and your team adjust the scope of your goals to ensure they are suitable for a Capstone project (not overly ambitious but also of appropriate complexity for a senior design project)?

   Omar Alam: My team and I spent a significant amount of time researching the feasibility of the project. Since the team does not have much experience with signal processing, we decided to consult with Dr. Mohrenschildt to get his opinion on the project. He provided us with valuable feedback on how to constraint our project goals to ensure that we can complete the project in the time we have.

   Jay Sharma: We started by mapping the problem space, did feasibility analyses, and set criteria around impact, difficulty, and time. We also checked in with Prof. Mohrenschildt to advise the direction of our project and keep the scope focused for the capstone timeline.

   Kalp Shah: A lot of what we did for defining the scope of the goals was done through research and consulting with Dr. Mohrenschildt and Dr. Smith. Dr. Mohrenschildt helped us better understand the expected time and resource costs of the project since he has experience with similar work and confirmed with us that our scope is neither too simple nor too ambitious for a Capstone project.

   Sathurshan Arulmohan: During the project proposal stage, the scope of the project was large. We had many features in mind, and we were not aware of the software and hardware complexities of achieving our vision. To refine this, each member shared their desired learning outcomes and technical interests. Through this discussion, we narrowed the scope of features and goals that balanced feasibility with sufficient challenge.

   Nirmal Chaudhari: Our team decided to go with the iterative approach for this project. During our first meeting with MVM, we discussed the feasibility of this project and our supervisor mentioned we should research each part individually first. This ensures that we can validate our project goals early on, and adjust as needed.

References

[1] E. Masterson, "Measuring the impact of hearing loss on quality of life," *NIOSH Science Blog*, 2016.

[2] Healthing.ca, "Hearing loss in canada: Stats, impact and resources," *Healthing.ca*, 2025.

[3] H. A. S., B. M., N. S., S. MR., and S. AA., "The effects of hearing protection devices on spatial awareness in complex listening environments," *PLoS One*, no. 1, 2023. [Online]. Available: https://doi.org/10.1371/journal.pone.0280240