VCU College of Engineering

CS-25-311
VR Tech with GenAI & Emotions
Project Proposal

Prepared for

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Date

Sep 28, 2024

Executive Summary

The executive summary highlights the key points of the document. While your advisor(s) and sponsor are expected to read the document in detail, others may only read the summary looking for a brief overview of the report. Casual readers may look at the summary to decide if they would like to continue reading. Some, more senior decision makers (e.g. executives), may read the summary to help make decisions regarding the future of the project (e.g. continuation, financing, resource allocation, etc.). It is important that all readers get a complete sense of the project, including purpose, primary objectives, design requirements, deliverables, work done to date, and timeline, among other required components provided in a table of contents. Summaries should be considered as "stand-alone" containing a complete account of the essential points of the document in chronological order of the document. Particular focus should be placed on the first sentence in order to draw readers in and should explicitly include the "who, what, and why" of the project. The executive summary is usually between half a page and a full page.

The project focuses on developing a cutting-edge emotion recognition system that utilizes Generative AI to enhance user interactions in various applications, including VR. The primary goal is to create an intelligent and responsive system capable of accurately detecting and interpreting human emotions based on facial expressions and verbal inputs By addressing the current gap in emotion awareness technology, this project aims to revolutionize user engagement and personalization in education contexts.

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Note: The Executive Summary should be updated between major reports as more knowledge is acquired and understanding of the project expands. For example, when submitting Preliminary Design Report in December 2024, make sure you update this page to reflect the progress on the project since the submission of Project Proposal in early October 2024.

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Section A. Problem Statement

Before a design solution is proposed, it is first important to identify, define, and fully understand the problem. Through a significant research effort, provide all relevant background information needed to understand the reasons for doing the project and the **unmet engineering need(s)** being addressed by the project. Assume that the reader does not have existing knowledge of the problem. Some questions that may be addressed by the problem statement include who is facing the problem and why? How widespread (i.e. common) is the problem? How often does the problem occur? What are the potential costs associated with the problem (e.g. economic, environmental, societal, health and safety, etc.)? Who is the project client? Who are the stakeholders? The problem statement should be narrative in nature. It should provide a framework for the project and clearly convey the primary goal(s) of the project.

Discuss the general field of study or industry that the project falls under and how the project contributes to, or advances the current technology in that field. For industry sponsored projects, a brief introduction of the sponsor company and relevant product line(s) is appropriate. For faculty sponsored projects, a description of the laboratory and type of work performed in the lab is appropriate. Put the current project into historical perspective using external references. Determine if the problem, or a closely related problem, has previously been addressed. If so, summarize the results, including any relevant data and/or conclusions, and discuss how this project improves or builds on previous results. For industrial projects, see what non-sensitive information about the process or product line your sponsor will provide. Look for commercially available competitive designs, relevant patents, and alternative design options. For academic studies, search for published journal articles in the field of study. See what papers have been published leading up to the current project. Looking at an article's references may provide additional lines of references. What are the pros and cons of each prior solution attempt?

Figures can often help aid in the discussion and understanding of technical subject matter. Examples of figures may include a labeled, detailed mechanical drawing, 3D rendering, photograph, schematic, process flow chart, etc. All figures should include a figure number and title located below each figure, and a reference number if necessary. The introduction should include a minimum of 5 cited references. More are encouraged. All references should be cited in-text and on a reference page at the end of the report using the APA citation format [1]. Figure 1, illustrating the engineering design process, provides an example of a properly labeled and cited imaged. Given the level of investigative detail required for this design report, it is expected that the introduction will consist of several pages.

Note: The problem statement should be updated between major reports as more knowledge is acquired and understanding of the project expands.

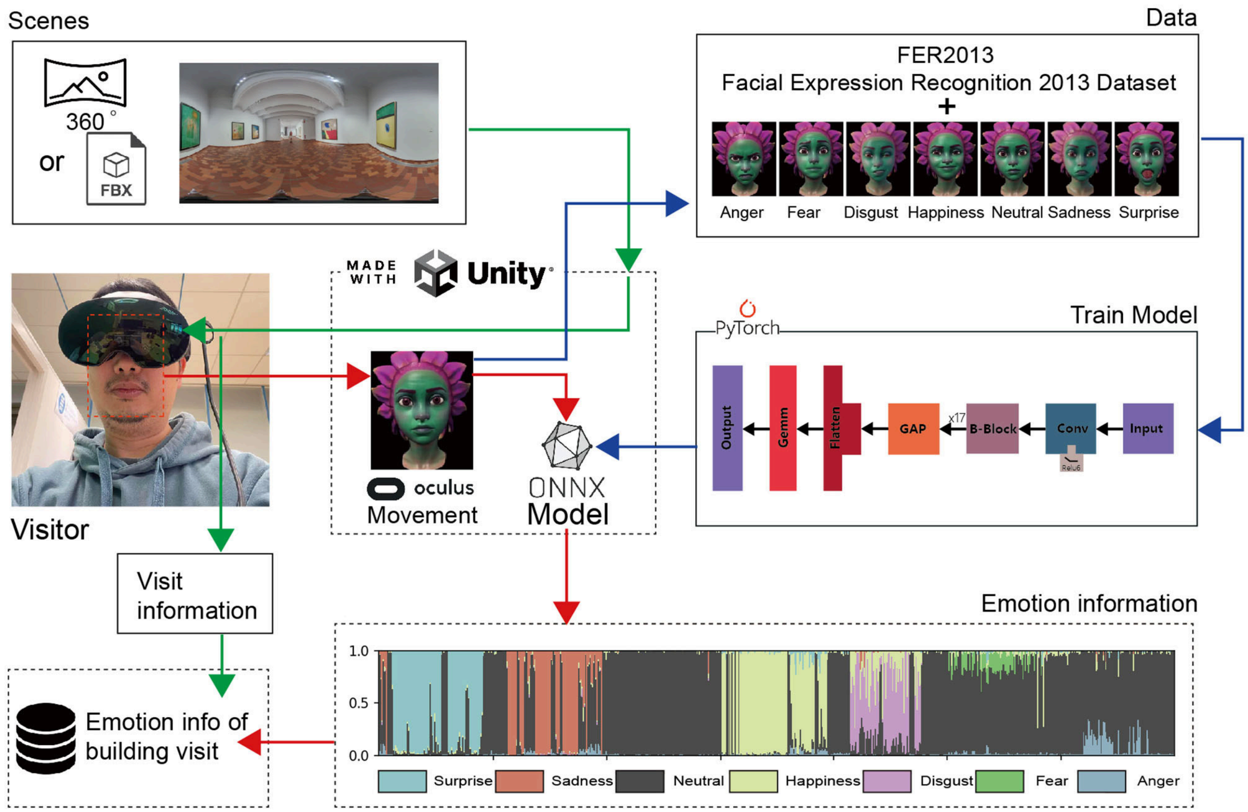


Figure 1. Process of emotion recognition on avatar using VR[2]

Our issue lies in the inability of users in various online domains, such as virtual reality (VR) and web-based applications, to accurately recognize the emotions of others. This problem results from the intrinsic limits of these technologies, which frequently fail to convey non-verbal cues for example body language, facial expressions, and vocal tone. The lack of emotional awareness can become a major barrier, especially when it comes to collaborating and communicating. Users need to be able to read emotions, adjust their communication, and establish connection in order to function effectively in online environments. These tasks are challenging to fulfill in the absence of the conventional face-to-face cues.

The primary individuals affected by this problem are users of digital platforms, particularly those involved in professional remote work, online education, and multiplayer virtual worlds. In these settings, collaboration and teamwork are key, yet the inability to perceive emotions often leads to misunderstandings, frustration, and reduced productivity. Emotional recognition is a critical aspect of human interaction, providing feedback necessary for understanding the intent behind words, adjusting communication strategies, and fostering empathy. Without it, these online environments become less effective, and in some cases, dysfunctional. This is a problem faced by a broad and growing range of people who rely on digital platforms for daily interaction, not just a niche group.

This issue is widespread and increasingly relevant as digital platforms dominate work, education, and entertainment. The COVID-19 pandemic accelerated the shift toward remote work and online collaboration, pushing millions of people to rely on web-based applications and virtual environments. Similarly, the rise of virtual reality as a tool for education, professional training, and gaming has highlighted the need for better emotional communication. Whether users are participating in virtual team meetings, attending online classes, or playing multiplayer games, the emotional disconnect they experience in these digital spaces affects their ability to collaborate effectively. This makes the problem one of significant relevance across industries, age groups, and geographic locations.

The problem occurs frequently, particularly in environments where communication is central to the user experience. Remote workers, for example, may struggle to interpret their colleagues' emotions during virtual meetings, which can lead to misunderstandings or misaligned goals. Students in online learning environments may find it difficult to gauge their instructors' feedback, while players in virtual reality games may miss important social cues that foster collaboration. Each of these examples highlights the recurring nature of the issue, as emotional communication is an essential part of any interaction where teamwork is required.

The potential costs associated with the inability to recognize emotions in digital environments are numerous. Economically, companies relying on remote teams may face reduced productivity and costly delays if emotional miscommunication leads to project failures. Training costs may also rise, as organizations seek to improve digital communication skills among their employees. From a social and psychological perspective, users may feel isolated or frustrated by the lack of emotional connection in online spaces, decreasing satisfaction and increasing stress. In more critical environments, such as virtual healthcare training or emergency response simulations, miscommunication due to poor emotional recognition can result in dangerous decision-making errors, affecting health and safety.

The clients for this project are the Virginia Commonwealth University (VCU) Department of Kinetic Imaging and associated academic divisions focused on the intersection of digital media, virtual reality, and communication. These clients are particularly interested in exploring ways to improve communication in immersive media environments. Their goal is to push the boundaries of how digital tools are used for interaction and ensure that users can engage with these technologies in ways that mimic or enhance real-life emotional communication.

The stakeholders involved in this project are diverse, ranging from end-users of these technologies to developers, educators, and healthcare professionals. End-users, including remote workers, students, and gamers, are directly impacted by the emotional recognition gap and would benefit the most from a solution. Developers of virtual platforms and online applications also have a vested interest in improving emotional communication to enhance user experience. Educators and trainers who rely on virtual environments for instruction are stakeholders as well, as they need to convey and interpret emotions to teach effectively. Lastly, professionals in critical fields like healthcare and emergency response, where virtual reality is used for simulations, would benefit from improved emotional communication to make these tools safer and more effective.

The field of study this project falls under is Human-Computer Interaction (HCI), with a focus on virtual reality, web-based applications, and digital communication. Within this domain, the project aims to advance technologies related to emotional communication and user interaction in virtual spaces. Emotional recognition in digital environments is a complex challenge, and this project seeks to contribute to solving this problem by exploring new methods or enhancing existing technologies to bridge the gap between real-life interactions and virtual experiences.

Human-Computer Interaction research has long focused on improving how users interact with machines, particularly in virtual and augmented reality. Emotional recognition plays a vital role in making these interactions feel natural. For VR to serve as a viable alternative to face-to-face communication, users must be able to express and experience emotions in real-time. The current project aims to improve existing technologies by potentially integrating machine learning algorithms and natural language processing (NLP) to enhance emotion detection from both physical cues and verbal interactions.

In the past, there have been numerous attempts to solve this problem. Early efforts relied on textual cues like emoticons or simple avatars, but these were limited in their ability to convey the full range of human emotion. More recent solutions have included facial tracking technologies that mirror the facial expressions of users in virtual environments. Companies such as Meta (formerly Facebook) and Microsoft have explored using avatars to convey emotional states in VR, with systems that track body movement and facial expressions. One such example is Meta's Horizon Workrooms, which offers virtual spaces for meetings that simulate body language and eye contact. However, these systems still fall short of fully replicating the nuances of real-life emotional communication.

A key area where this project can build on prior work is by addressing the limitations of existing solutions. Facial tracking technologies, while promising, often face challenges in accuracy under poor lighting conditions or in capturing subtle expressions. Haptic feedback systems can simulate physical interaction but are generally expensive and cumbersome, making them unsuitable for everyday use. AI-driven emotion recognition has shown promise in interpreting emotions based on both text and tone, but there are still significant barriers to its accuracy, particularly in cross-cultural contexts where emotional expression can vary. This project could improve on these technologies by exploring less invasive, more user-friendly solutions that are affordable and adaptable across various cultural contexts.

In addition to technological improvements, this project aligns with ongoing academic research in the VCU Department of Kinetic Imaging. The department focuses on integrating digital media with human creativity, exploring fields like virtual reality, sound design, and digital interaction. The current project fits well within the lab's work, contributing to the broader academic discourse on how immersive technologies can better replicate real-life human experiences. Prior studies have explored aspects of emotional communication in VR, but there is still significant room for improvement, particularly in enhancing user immersion and emotional connection.

Section B. Engineering Design Requirements

This section describes the goals and objectives of the project, as well as all **realistic constraints** to which the design is bound. It is meant to provide a structure that helps to formulate the problem. Design requirements are often derived from client or stakeholder needs. They may consider benchmarking against or improving on currently available solutions, providing novel techniques or design solutions, integration with existing components, systems, or equipment, required codes and standards, general observations of the problem space, etc. Describe how the requirements provided below were researched and decided upon. Common design requirements often include considerations of the design efficacy, cost, safety, reliability, usability, and risk, among others.

Note: The deign requirements should be revisited between major reports to ensure that the design objectives and constraints still accurately reflect the client needs and project goals and to make sure that the team is on track to meet all goals and objectives.

Note: The codes and standards section is not required for the Project Proposal, but is required for all subsequent reports. This section should be comprehensive and thorough, requiring a significant research effort.

B.1 Project Goals (i.e. Client Needs)

Describe the overall goals of the project from the point of view of the customer or client. Goals should be derived from the specified needs of the project and *do not explicitly describe what the design will do*. They should be short, concise, and achievable. Bulleted lists are a good way to present key points and draw the reader's attention to those points. Note that a few sentences should be included at the beginning of any section using a bulleted list to introduce the content of the section and lead into the upcoming list. Some general examples of project goals are as follows:

- To produce an improved method for achieving some function
- To design a smaller, cheaper, faster, etc. device that performs some function
- To perform an experiment to produce data to gain a better understanding of some phenomena
- To produce a model that more accurately predicts some physical behavior

-The project aims to boost user engagement by creating a system that makes interactions more personal and engaging based on users' emotions, while also improving learning outcomes. It will support mental health by implementing therapeutic VR applications that adjust in real-time to users' emotional needs, and increase safety in high-stress training scenarios by establishing protocols that adapt to trainees' emotional states. Ultimately, this initiative seeks to transform how users interact with virtual environments, fostering a more responsive and enriching experience across various applications.

B.2 Design Objectives

List the key objectives of the design that you will produce. Objectives describe *what the design will do*, not how it should do it. Objectives should be SMART – Specific, Measurable, Achievable, Realistic, and Time-bound. Each objective will ultimately be linked to a design specification/constrain during the design process. Again, lists are nice if applicable.

- The design will…be specific.
- The design will…make sure the objective has the ability to be measured.
- The design will…make sure the objective is achievable given your resources.
- The design will…make sure the objective is realistic.
- The design will…make sure you have a reasonable time to achieve the objective.

-The design will create and validate algorithms for emotion recognition. During the process, we will ensure the highest accuracy of at least 90%. Our team has access to existing datasets and tools for developing and testing algorithms. This objective is achievable within six months, given our expertise and resources, and it is realistic based on current benchmarks in the field. By the end of this period, we will measure our success through comprehensive testing and validation against standard datasets, ensuring that we meet our target accuracy before proceeding to the next phase of development.

B.3 Design Specifications and Constraints

For the Virtual Reality system focused on Emotion Recognition and Generative AI, the design specifications and constraints need to ensure the system functions effectively while also adhering to technical, functional, and regulatory requirements. Below are specific design specifications and constraints organized by relevant categories.

- **Functional Constraints:**
    - **Emotion Recognition Accuracy**: The emotion recognition model must achieve at least 90% accuracy when predicting emotions based on facial expressions and verbal inputs.
    - **Latency in Emotion Detection**: The system must process emotional data in real-time with a maximum delay of five seconds or less to ensure seamless interaction between the user's emotional state and the virtual world.
    - **VR Game Integration**: The emotion recognition system must integrate smoothly with the VR game, synchronizing emotional responses within five seconds or less of emotional input.
    - **Emotion Classification**: The system must identify at least six core emotions (happiness, sadness, anger, fear, surprise, disgust) and, if necessary, more complex emotions to enhance gameplay.
    - **Platform Compatibility**: The system must be optimized for use with VR hardware, specifically the Meta Quest Pro headset, and fully integrated into the Unity platform for seamless deployment.
- **Data Constraints:**
    - **Audio Input Requirements**: The system must process audio input with a sample rate of 16kHz to ensure high-quality speech emotion detection.
    - **Facial Data Requirements**: The system must process facial landmarks captured by the VR headset at a minimum rate of 30 frames per second to ensure accurate emotion recognition.
- **Interoperability Constraints:**
    - **API Integration**: The system must provide an API for easy integration with third-party applications, supporting compatibility with RESTful services and data formats such as JSON or XML.

A list of design specifications and constraints include all limitations, restrictions, and requirements of the design. They are firm limits that must be met for a design to be acceptable and are ultimately used to measure the success of a design. Each specification or constraint should map to one or more design objective(s) and explicitly state *how the design* will meet the objectives. Specifications and constraints should be specific and are often numerical. They must be measurable or testable to prove that the design has met all of the design objectives. Numerical metrics may include qualifying statements such as "at least," "at most," "between," "exactly" or include a set of discrete values. Avoid subjective, untestable constraints (e.g. "environmentally friendly", "user friendly", "nice looking", etc.).

Realistic constraints can come take on a variety of forms including accessibility, aesthetics, codes, constructability, cost, ergonomics, extensibility, functionality, interoperability, legal considerations, maintainability, manufacturability, marketability, policy, regulations, schedule, standards, sustainability, or usability. Examples of physical constraints might include numerical limits or ranges on overall size envelope, weight, pressures, stresses, flow rates, voltages, current, power consumption, hardware limitations, data constrains, interoperability, etc. Other constraints might include production unit cost, expected part/device life, or maintenance requirements.

Some general examples of constraints are as follows:

- Design must integrate with existing equipment or process (Functional constraint) – examples include specific piping or electrical connections, available size envelope, power requirements, etc.
- Design must not exceed some overall weight (Functional constraint) – specify weight limits or range
- Design must not exceed some power consumption or operate at some efficiency (Functional constraint) – examples include current, voltage, power requirements, mechanical or electrical efficiency
- Must be cheaper to produce than currently available designs (Cost constraint) – provide specific cost limit or range
- Design must be made from readily available materials (Manufacturability constraint) – provide exact materials
- Design must operate for so many hours without requiring maintenance (Maintainability constraint) – provide exact time or range
- Design must operate within some hardware with specifications up to certain values (Hardware constraint) – provide exact hardware specifications
- Design must operate within some constrains on data collection and processing (Data Constrains) – provide exact guidelines or restrictions
- Design must operate within a set of systems or platforms requiring compatibility with specific protocols or APIs (Interoperability Constrains) – provide specific systems of platforms.

B.4 Codes and Standards

- **ISO/IEC 27001:2013 – Information Security Management Standards**
  - **Relevance to Design:** This standard provides guidelines for managing sensitive information, particularly user data such as facial expressions and audio inputs. It ensures that all data collected and processed in the emotion recognition system adheres to rigorous security protocols, which is crucial for protecting user privacy in therapeutic and training scenarios.
  - **Application:** The design must include encryption methods and access controls to secure user data, meeting the requirements set by ISO 27001.
- **IEEE 802.11 – Wireless Communication Standard**
  - **Relevance to Design:** This standard governs wireless communication protocols. In VR environments, wireless data transmission is essential for sending and receiving real-time emotional data between the VR headset and the processing system.

- **Application:** The system must ensure compatibility with Wi-Fi protocols to enable seamless data transmission between hardware components in real-time, minimizing latency in emotional responses.

- **ISO 9241-910:2011 – Ergonomics of Human-System Interaction**
  - **Relevance to Design:** This standard addresses usability and ergonomics for virtual environments. It helps ensure that the VR application provides a comfortable and accessible user experience by accounting for human factors like motion sickness, interface design, and ease of use.
  - **Application:** The design must follow these guidelines to make the VR system ergonomic and user-friendly, reducing fatigue and enhancing user engagement.
- **GDPR (General Data Protection Regulation) – European Data Privacy Law**
  - **Relevance to Design:** GDPR establishes legal requirements for data privacy and user consent, particularly for European users. Since the system collects sensitive personal data such as facial expressions and voice recordings, it must comply with these regulations to ensure data privacy.
  - **Application:** The design must include user consent features and anonymization processes for collected data, as well as mechanisms to allow users to delete their data, in compliance with GDPR requirements.
- **W3C WCAG 2.1 – Web Content Accessibility Guidelines**
  - **Relevance to Design:** These guidelines help ensure accessibility in digital platforms, including VR applications. It emphasizes features such as text-to-speech, alternative input methods, and adaptable interfaces for people with disabilities.
  - **Application:** The VR system must adhere to these accessibility standards to ensure that it can be used by people with physical, visual, auditory, or cognitive impairments.
- **OSHA 29 CFR 1910.133 – Eye and Face Protection**
  - **Relevance to Design:** OSHA standards ensure safety in workplace environments, specifically requiring eye and face protection when using devices that could pose a risk of injury. This applies to VR environments, where prolonged use of headsets could cause strain or injury.
  - **Application:** The design must consider ergonomics, minimizing eye strain and discomfort from prolonged use of VR headsets, in compliance with OSHA safety standards.
- **NIST SP 800-63-3 – Digital Identity Guidelines**
  - **Relevance to Design:** This standard provides guidelines on secure digital identities, including authentication and access control, which are crucial for securing access to the VR system and protecting user data.
  - **Application:** The system must implement secure authentication methods, such as multi-factor authentication, to comply with NIST digital security standards and ensure only authorized access to sensitive emotional data.

These standards and codes are crucial to ensure that the VR system is safe, secure, ergonomic, interoperable, and compliant with legal and industry best practices.

List all specific codes and standards that are relevant to the design providing specific details of each as they relate to the design. While the terms codes and standards are often used interchangeably, there are in fact important differences in their definitions that should be understood. **Standards** are documents that provide a set of technical definitions, instructions, rules, guidelines and/or characteristics of a product, process, or service meant to provide consistent and comparable results (e.g. performance requirements, dimensions, testing procedures, file formats etc.). They allow for interchangeability of components and system interoperability and are typically produced by industry or professional organizations such as ASME, ANSI, ASTM, IEEE, ISO, ACM, IAPP, AIS, etc. Standards are meant to help ensure quality, reliability, and safety.

Codes are laws or regulations that specify the methods, materials, components, etc. required for use in a certain product, process, or structure. Codes have been *codified* into a formal written policy or law and can be approved at the local (municipal), state, or federal level. While standards provide sets of guidelines, codes are constraints that *must* be met in accordance with the law. It is, however, common for codes to reference or require the use of one or more standards. Some common code producers include the EPA, OSHA, DOTs, and the NFPA. Codes help set minimum acceptable levels in order to protect public health, safety, welfare.

Codes and standards are often listed by their producer followed by an identifying numerical code. They often contain hyphens or periods which may help reference specific parts of a larger code/standard or provide the year of the latest revision. Some general examples in a list of codes and standards are as follows:

- ASME Standard No. xxx – design must consider some specific fatigue failure criteria
- IEEE Standard No. xxx – design components must not exceed some maximum current limit
- ISO Standard No. xxx – design components must adhere to some standard thread size
- OSHA Code No. xxx – operators of design must wear appropriate eye and face protection
- IRTF Standard No. xxx – design must consider internet communication protocols
- W3C Standard No. xxx – design must adhere to some HTML/CSS standards
- NIST Standard No. xxx – design must consider some specific data security standards

Note: Relevant codes and standards should be incorporated into the design specifications and constraints listed above.

Section C. Scope of Work

The project scope defines the boundaries of the project encompassing the key objectives, timeline, milestones and deliverables. It clearly defines the responsibility of the team and the process by which the proposed work will be verified and approved. A clear scope helps to facilitate understanding of the project, reduce ambiguities and risk, and manage expectations. In addition to stating the responsibilities of the team, it should also explicitly state those tasks which fall *outside* of the team's responsibilities. *Explicit bounds* on the project timeline, available funds, and promised deliverables should be clearly stated. These boundaries help to avoid *scope creep*, or changes to the scope of the project without any control. This section also defines the project approach, the development methodology used in developing the solution, such as waterfall or agile (shall be chosen in concert with the faculty advisor and/or project sponsor). Good communication with the project sponsor and faculty advisor is the most effective way to stay within scope and make sure all objectives and deliverables are met on time and on budget.

C.1 Deliverables

1. Trained Emotion Recognition Model

- **Description**: The core deliverable is a machine learning or deep learning model that recognizes emotions based on facial landmarks. This model could be either trained by the team using relevant datasets or adapted from a pre-trained model.
- **Components**:
    - **Dataset**: A collection of facial landmark data labeled with corresponding emotions.
    - **Training Process**: The steps, tools, and techniques used to train the model (e.g., TensorFlow, Keras, OpenCV for facial landmark extraction).
    - **Model Accuracy**: Performance metrics such as accuracy, precision, recall, and confusion matrix to demonstrate how well the model predicts emotions.
- **Integration**: The model should be exportable in a format (e.g., ONNX) that can be integrated into Unity for real-time emotion recognition.

2. Unity Integration

- **Description**: The Unity environment will use the trained model to project facial landmarks onto an avatar, which will mimic the user's facial expressions and display recognized emotions.
- **Components**:
    - **Unity Engine**: The team will develop or customize the VR experience within Unity, a popular game engine that supports 3D graphics, real-time interaction, and VR integration.
    - **Model Integration**: The model should be able to run within Unity and interact with real-time data from the VR headset.
    - **Real-Time Emotion Detection**: When the user's face is captured through the VR headset (Meta Oculus Quest Pro), the system will map the face to an avatar and detect emotions in real-time.
    - **Avatar Animation**: The avatar will mimic the user's facial expressions based on the input facial landmarks. This includes synchronizing emotions with facial movements.

3. Functional VR Application

- **Description**: The deliverable is a fully functional VR application that captures facial landmarks through the Meta Oculus Quest Pro headset, processes the data using the trained model, and projects the detected emotions onto an avatar.
- **Components**:
    - **User Interface**: A simple, intuitive interface within the VR environment to allow users to interact with the system.
    - **Avatar Customization**: Users may have the ability to select or modify avatars in the VR space, enhancing engagement.
    - **Emotion Feedback**: The system will provide real-time feedback about the emotions it detects on the avatar's face, which users can compare to their own expressions.
    - **Possibility of Emotion Deduction from Other Avatars**: A stretch goal could be to recognize the emotions of avatars other than the user's own, where facial landmarks are not directly accessible but estimated based on facial patterns.

4. Documentation

- **Project Report**: A comprehensive document outlining the following:
    - **Problem Definition**: A detailed explanation of the emotion recognition task and its importance in VR.
    - **Design and Development**: A step-by-step description of how the model was trained, how data was collected, and how it was integrated with Unity.
    - **Challenges**: Potential challenges faced during model training, performance limitations, VR integration, and how they were addressed.
    - **Performance Metrics**: Quantitative evaluation of the model's emotion recognition capabilities.
- **User Guide**: Instructions for using the VR application, including:
    - How to set up the Meta Oculus Quest Pro and connect to the application.
    - How to interact with the avatar and interpret its emotion feedback.
    - Troubleshooting and tips for optimizing the experience.

POTENTIAL ISSUES:

- hardware requirements
- compatibility issues with hardware (VR headsets)

C.2 Milestones

Milestone	Task Description	Timeframe	Completion Date
1. Project Planning	Define project scope, goals, and deliverables. Meet with the advisor to confirm project expectations.	1 week	September 4th
2. Research and Data Collection	Gather information on emotion recognition models, VR hardware, and facial landmarks. Identify datasets.	3 weeks	Still working
3. VR Hardware Setup	Set up the Meta Oculus Quest Pro and ensure integration with Unity for real-time data acquisition.	1 week	October 10th
4. Dataset Preparation	Acquire or generate facial landmark datasets labeled with emotions. Clean and preprocess the data.	2 weeks	Still working

5. Model Development	Build or fine-tune the emotion recognition model using AI techniques (CNNs, facial landmark processing).	3 weeks	TBD
6. Model Testing & Validation	Test the model on the training dataset. Fine-tune for accuracy and performance.	2 weeks	TBD
7. Unity Integration	Integrate the trained model with Unity. Set up the VR environment to project facial landmarks onto avatars.	2 weeks	TBD
8. Avatar Design & Animation	Create or import avatars in Unity that mimic facial expressions using facial landmark data.	1 week	TBD
9. Prototype Completion	Complete the initial prototype of the VR application with basic emotion recognition functionality.	2 weeks	TBD
10. Extended Emotion Recognition	Explore emotion recognition from other avatars without direct access to their facial landmarks.	3 weeks	TBD
11. Testing & Optimization	Test the complete system. Gather user feedback and refine model/VR integration. Optimize performance.	2.5 weeks	TBD
12. Final Deliverables Preparation	Prepare the final report, user guide, and presentation materials. Review with the advisor/sponsor.	2 weeks	TBD
13. Presentation Rehearsal	Rehearse the presentation and live demonstration for the Capstone EXPO.	1 week	TBD
14. Final Presentation & Submission	Submit final deliverables and present the project at the Capstone EXPO.	-	TBD

C.3 Resources

Resources needed for project completion should be listed at the proposal stage. These resources can either be purchased within the Project Budget, or provided by the project sponsor. Some examples are: hardware such as HPCs or servers, software such as IDEs, data analysis platforms or version control systems. Access to cloud computing services may also be necessary to scale certain procedures. Additionally, databases containing operational data for testing, as well as libraries or APIs relevant to predictive analytics and machine learning may be required.

Some resources required for this project include: the High Performance Research Computing Core (HPRC), virtual reality headsets such as the Meta Quest Pro, access to

Section D. Concept Generation

A number of methods can be used to help generate design concepts from simple reflection and brainstorming, to working the problem backwards, using reverse thinking techniques, and looking to nature for inspiration (i.e. biomimicry). Existing solutions, or components of existing solutions, can be substituted, combined, adapted, modified, put to other uses, eliminated, or rearranged to meet new design objectives and specifications. A minimum of 3 overall design concepts is required for this section although more are welcome. Provide a brief description of how each design concept addresses the design problem. Discuss the potential pros and cons, including and potential risks of failure, of each of these concepts.

It is likely that each design concept may consist of several components. In this case, one or more of these components may offer a sub-problem that can be further explored, modified, or otherwise improved upon. These sub-problems may lead to the addition of several additional design concepts and may require the inclusion of a design concept chart or matrix to organize all ideas and potential solutions.

Provide any initial design sketches, drawings, 3D renderings, or conceptual models such as dataflow diagrams, process flows, etc. developed during the concept ideation phase. All hand drawings should be drawn to scale using basic engineering drafting tools (i.e. ruler, protractor, and compass). Geometric stencils can also be used to help produce quality hand drawings. Drawings should be presented in a profession manner, preferably done on engineering graph paper and using a high-quality scan. All sketches should be labeled to identify major components and different drawing views or projections if applicable. Basic dimensions should be provided to give a general sense of scale. Label each sketch or drawing with the name of the team member responsible for the sketch, the date it was drawn, and the drawing scale.

Section E. Concept Evaluation and Selection

Using a systematic decision-making process, evaluate each of the design concepts and choose the one that is most likely to succeed in meeting the design objectives and constraints. A Decision Matrix, or Pugh Matrix, helps to analyze alternatives, eliminate biases, and make rational decisions through thought and structure. First, work to develop a set of selection criteria for which to evaluate the previously generated design concepts. Selection criteria often include concepts of performance, cost, safety, reliability, risk, etc. Note that the selection criteria developed here will likely be more general than the project design objectives. As with the design objectives, conversations with the client help define appropriate selection criteria.

In many cases, the client may value the selection criteria differently, preferring that more emphasis be placed on some than others. In this case, weighting factors may be used to place more or less importance on the various criteria in the decision making process. Again, conversations with the client can be used to define criteria weighting factors. Often times, these conversations must be analyzed and interpreted by the team to determine which criteria are more important to the client and by how much. Feel free to discuss the assigned weighting factors with the client to see if they seem accurate.

Next, define an associated metric to represent each criteria. Metrics should be specific and quantifiable, providing numerical values that quantify the often vague concepts of the selection criteria. Metrics can be obtained, generated, or estimated through a number of methods including simple background research, preliminary design calculations, or basic analyses. Note that these metrics do not need to specifically align with the design specifications although there may be some commonality between the two. Provide a brief discussion of the rationale for selecting each of the assigned metrics.

Using the defined metrics, evaluated each design concept against all selection criteria by filling out a Decision Matrix. Design concepts can be compared by using simple rank scoring, raw scoring, or weighted scoring techniques and design concept with which to move forward can be selected. This type of process provides a meaningful, unbiased means for choosing a preliminary design concept prior to moving forward with more comprehensive, detailed analyses as provided in the design methodology section below. The results of this process should be discussed with the project client prior to moving forward with the selected design. Table 1 provides an example of a simple decision matrix.

Table 1. Example of a Decision Matrix.

	Design Concept A	Design Concept B	Design Concept C	Design Concept D
Criteria 1				
Criteria 2				
Criteria 3				
Criteria 4				
Criteria 5				
Total Score				

Note: Weights can be assigned to each criterion if desired.

Section F. Design Methodology

Provide a detailed explanation of the methods that will be used to help evaluate, improve, and evolve the design through the iterative engineering design process. Consider that ultimately, the final design must be verified and validated to ensure that it meets all of the previously developed and listed design objectives and specifications. Verification ensures that the design meets all specification, while validation confirms that the design functions as intended such to meet the client's needs. While it is common for initial design concepts to first be evaluated using simplified design criteria and metrics, the chosen design should be advanced, and later verified, using engineering calculations, computational models, experimental data, and/or testing procedures.

Use this section to describe any underlying physical principles and mathematical equations that govern the design. Provide details of any computer-aided modeling techniques used to evaluate the design including the software used, prescribed boundary conditions, and assumptions. Include a detailed description of any experimental testing methods including required testing equipment, test set-up layout, data acquisition and instrumentation, and testing procedures. If one or more prototypes is to be produced and tested, provide a detailed description of how each will be evaluated.

Note: The contents of this section are expected to vary from project to project. Subsections may be appropriate for providing details of analytical, computational, experimental, and/or testing methods. Some potential subsections that may be included in this section are provided. While critical design equations may be provided here, lengthy mathematical derivations may be included in an appendix. Validation procedures are critical and all projects should address such topic.

F.1 Computational Methods (e.g. FEA or CFD Modeling, example sub-section)

F.2 Experimental Methods (example subsection)

F.3 Architecture/High-level Design (example subsection)

F.5 Validation Procedure

Describe how the design team will validate that the final design meets the client's needs. This section should include a plan to meet with the client towards the end of the project to discuss final design details and demonstrate a prototype, experimental test, and/or simulation results. Provide a relative time frame for this validation to occur (e.g. "mid-March" or "early-April"). Include a brief discussion on how client feedback will be captured, such as a formal survey, interview, or observation notes of the client using the prototype. It may also include plans to solicit feedback from other stakeholders and/or potential users.

Section G. Results and Design Details

Use this section to highlight the major results of the design methodology described above including important analytical, computational, experimental, modeling, assembly, and testing results. This section should be one of the most substantial sections of the report showcasing all of the hard work and effort that went into the completion of the final design and delivery of the project deliverables. Show how the identified problem was solved.

Highlight the prominent features of the final design through analysis results, modeling, drawings, renderings, circuit schematics, instrumentation diagrams, flow and piping diagrams, etc. to show that the design functions as intended and meets all design objectives and constraints. Overview designs such as dataflow diagrams, process flow, swim lane diagrams, as well as presentation-layer designs (e.g. storyboards for front-ends) should be included here. Detailed designs such as database designs, software designs, procedure flowcharts, or pseudocode should be included here. Support computational and experimental results with key plots and figures. All supporting figures should be clearly labeled and annotated to highlight the most important points of the figure (i.e. explicitly point out what the reader should focus on or understand about the image).

Note that while all results should be used to help inform design decisions, not all results may be necessary to include in the main body of the report. Extraneous supporting results (e.g. graphs, data, design renderings, drawings, etc.) that are not necessary for presenting the fundamental findings can be placed in one or more appendices. Detailed documentation of each program module can be provided as appendix.

G.1 Modeling Results (example subsection)

G.2 Experimental Results (example subsection)

G.3 Prototyping and Testing Results (example subsection)

G.4. Final Design Details/Specifications (example subsection)

Note that while the design constraints and specifications may have provided minimum or maximum values, or ranges or values, that the design needed to meet, the final design specifications should be listed here showing that the required design values were met. A list of final design details can also be included demonstrate fulfillment of the design objectives.

Note: Preliminary results should be included in the Preliminary Design Report to show the progress made of the selected design concept to-date. This section should be updated for the

Final Design Report to include documentation of all of the work that was completed on the project throughout the entirety of the academic year.

Section H. Societal Impacts of Design

In addition to technical design considerations, contemporary engineers must consider the broader impacts that their design choices have on the world around them. These impacts include the consideration of public health, safety, and welfare as well as the potential societal, political/regulatory, economic, environmental, global, and ethical impacts of the design. As appropriate for the project design, discuss how each of these considerations influenced design choices in separate subsections. How will the design change the way people interact with each other? What are the political implications of the design? Does the technology have the potential to impact or shift markets? Does the design have any positive or negative effects on the environment? Don't forget to consider unintended consequences such as process or manufacturing byproducts. What impacts might the design have on global markets and trade? Are there any ethical questions related to the design?

While it is hard to forecast the various impacts of a technology, it is important to consider these potential impacts throughout the engineering design process. When considered during the early stages of the design phase, consideration of these impacts can help determine design objectives, constraints, and specifications and help drive design choices that may mitigate any potential negative impacts or unintended consequences.

Note: A minimum of 4 of these design considerations, including the consideration of public health, safety, and welfare, are required for the Preliminary Design Report while a section for all considerations must be included in the final design report.

H.1 Public Health, Safety, and Welfare

Provide a list of all design safety features and provide a brief description of each. Discuss the potential effects the design may have on public health, safety, and welfare. References to the codes and standards previous provided and the organizations that produced them may be summarized or referenced here.

H.2 Societal Impacts

H.3 Political/Regulatory Impacts

H.4. Economic Impacts

H.5 Environmental Impacts

H.6 Global Impacts

H.7. Ethical Considerations

Section I. Cost Analysis

Provide a simple cost analysis of the project that includes a list of all expenditures related to the project. If an experimental test set-up or prototype was developed, provide a Bill of Materials that includes part numbers, vendor names, unit costs, quantity, total costs, delivery times, dates received, etc. Do not forget to include all manufacturing costs incurred throughout the completion of the project. If the design is expected to become a commercial product, provide a production cost estimate including fixed capital, raw materials, manufacturing (including tooling and/or casting), and labor costs to produce and package the device. Note that this type of detailed cost analysis may be listed as a project deliverable.

Note: The Preliminary Design Report should include all costs incurred to date. It is expected that this section will be expanded and updated between the preliminary and final design reports.

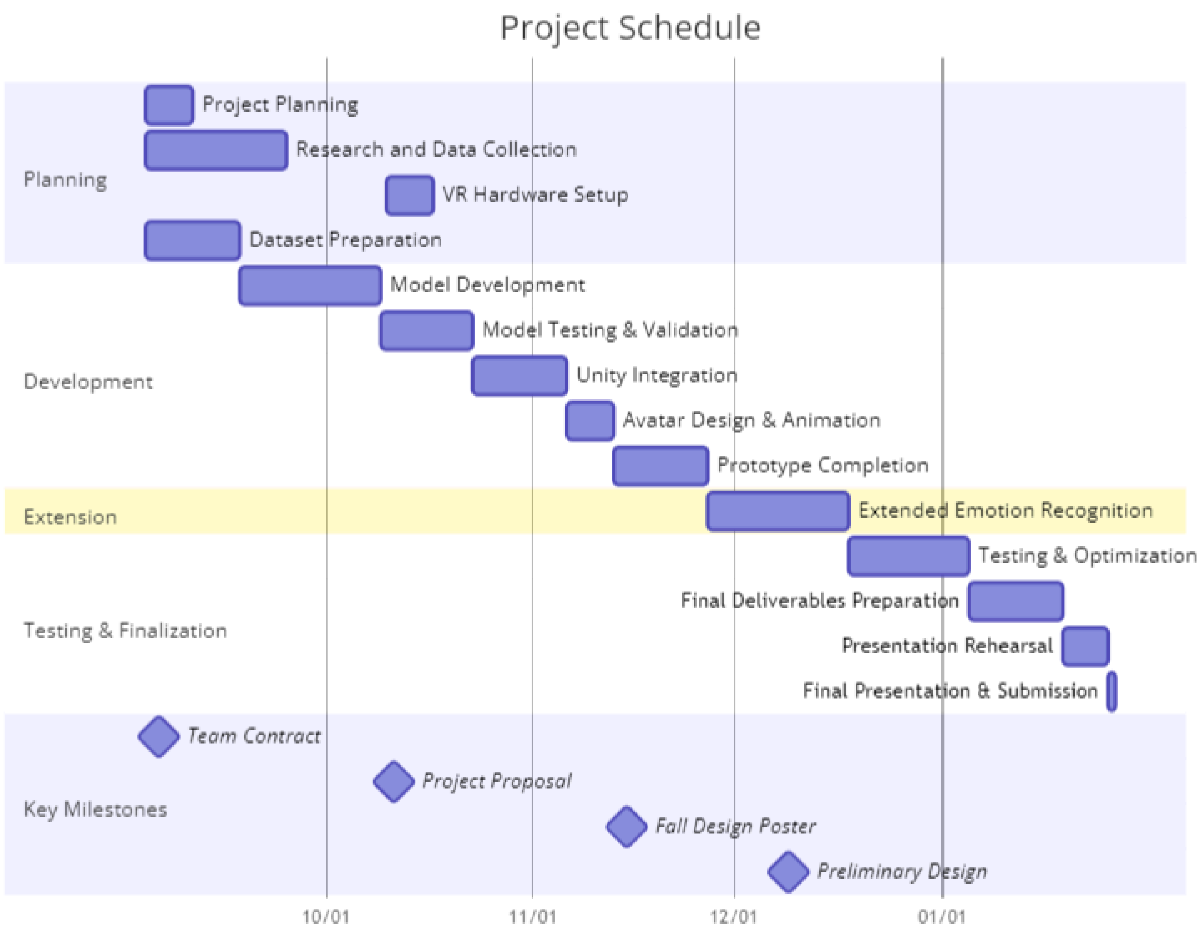
Section J. Conclusions and Recommendations

Use this section to summarize the story of how the design team arrived at the final design. Focus on the evolution of the design through the use of the engineering design process including lessons learned, obstacles overcome, and triumphs of the final design. Revisit the primary project goals and objectives. Provide a brief summary of the final design details and features paramount to the function of the design in meeting these goals and objectives.

A discussion may be included to discuss how the design could be further advanced or improved in the future. If applicable, summarize any questions or curiosities that the final results/design of this effort bring to mind or leave unanswered. If this project might continue on as a future (continuation) senior design project, detail the major milestones that have been completed to date and include any suggested testing plans, relevant machine drawings, electrical schematics, developed computer code, etc. All relevant information should be included in this section such that future researchers could pick up the project and advance the work in as seamless a manner as possible. Documents such as drawings, schematics, and codes could be referenced here and included in one or more appendix. If digital files are critical for future work, they should be saved on a thumb drive, external hard drive, cloud, etc. and left in the hands of the project advisor and/or client.

Appendix 1: Project Timeline

Provide a Gantt chart of similarly composed visual timeline showing the start and end dates of all completed tasks and how they are grouped together, overlapped, and linked together. Include all senior design requirements including design reports and Expo materials (i.e. Abstract, Poster, and Presentation). All major milestones should be included in the timeline.



Appendix 2: Team Contract (i.e. Team Organization)

Copy and paste the content from the completed Team Contract here starting with Step 1 of the Team Contract and including all content following the 'Contents' list.

Step 1: Get to Know One Another. Gather Basic Information.

Task: This initial time together is important to form a strong team dynamic and get to know each other more as people outside of class time. Consider ways to develop positive working relationships with others, while remaining open and personal. Learn each other's strengths and discuss good/bad team experiences. This is also a good opportunity to start to better understand each other's communication and working styles.

Team Member Name	***Strengths each member bring to the group***	***Other Info***	***Contact Info***
Gokul Chaluvadi	*Problem-solving, creative, hard working*	*Enjoy learning new things and implementing them in my projects.*	*chaluvadig@vcu.edu*
Kshitij Kokkera	*Communication and problem-solving*	*I enjoy being a part of a team and meeting new people.*	kokkerak@vcu.edu
Natalia Tondi	Planification and organization, creative ideas, problem-solving	I enjoy working on teams and on projects that involves problem-solving	tondin@vcu.edu

Zanika Hossain	Bring unique ideas, analytical, communicative, persistent.	I like learning about different things.	hossainzt@vcu.edu

Other Stakeholders	***Notes***	***Contact Info***
Faculty Advisor & Sponsor	*Alberto Cano - College of Engineering*	*acano@vcu.edu*

Step 2: Team Culture. Clarify the Group's Purpose and Culture Goals.

Task: Discuss how each team member wants to be treated to encourage them to make valuable contributions to the group and how each team member would like to feel recognized for their efforts. Discuss how the team will foster an environment where each team member feels they are accountable for their actions and the way they contribute to the project. These are your Culture Goals (left column). How do the students demonstrate these culture goals? These are your Actions (middle column). Finally, how do students deviate from the team's culture goals? What are ways that other team members can notice when that culture goal is no longer being honored in team dynamics? These are your Warning Signs (right column).

Resources: More information and an example Team Culture can be found in the Biodesign Student Guide "Intentional Teamwork" page (webpage | PDF)

Culture Goals	***Actions***	***Warning Signs***
Being on time to every meeting	- *Set up reminders through discord* - *Letting people know when you can't make it on time*	- *Student misses first meeting without notice, warning is granted* - *Student misses meetings afterwards – issue is brought up with faculty advisor*
Proactively communicate any anticipated delays in completing tasks	- *Stay up to date with each other's project responsibilities* - *Set reasonable deadlines and note when an extension is needed*	- *Student shows up for weekly meeting with no considerable work done* - Student misses the deadline

Safe environment	*-Ask questions right away.* *-Propose any idea*	*-Not willing to ask questions* *-Seeming lost* *-Not contributing*

Step 3: Time Commitments, Meeting Structure, and Communication

Task: Discuss the anticipated time commitments for the group project. Consider the following questions (don't answer these questions in the box below):

- What are reasonable time commitments for everyone to invest in this project?
- What other activities and commitments do group members have in their lives?
- How will we communicate with each other?
- When will we meet as a team? Where will we meet? How Often?
- Who will run the meetings? Will there be an assigned team leader or scribe? Does that position rotate or will same person take on that role for the duration of the project?

Required: How often you will meet with your faculty advisor advisor, where you will meet, and how the meetings will be conducted. Who arranges these meetings?

See examples below.

Meeting Participants	***Frequency*** ***Dates and Times / Locations***	***Meeting Goals*** ***Responsible Party***

Students Only	*As Needed On Discord Voice Channel*	*Update group on weekly challenges and accomplishments* *(Natalia will record these for the weekly progress reports and meetings with advisor)*
Students Only	*Every Friday either on Discord or In-Person.*	*Actively work on project* *(Gokul will document these meetings by taking photos of whiteboards, physical prototypes, etc, then post on Discord and update Capstone Report)*
Students + Faculty advisor	*Every wednesday at 12:15 in Engineering Research building*	*Update faculty advisor and get answers to our questions* *(Kokkera will scribe; Gokul will create meeting agenda and lead meeting)*
Project Sponsor	*VCU College of Engineering*	*Update project sponsor and make sure we are on the right track (Zanika will scribe; Natalia will create meeting agenda and lead meeting; Kokkera will present prototype so far)*

Step 4: Determine Individual Roles and Responsibilities

Task: As part of the Capstone Team experience, each member will take on a leadership role, ***in addition to*** contributing to the overall weekly action items for the project. Some common leadership roles for Capstone projects are listed below. Other roles may be assigned with approval of your faculty advisor as deemed fit for the project. For the entirety of the project, you should communicate progress to your advisor specifically with regard to your role.

- **Before meeting with your team**, take some time to ask yourself: what is my "natural" role in this group (strengths)? How can I use this experience to help me grow and develop more?

- **As a group,** discuss the various tasks needed for the project and role preferences. Then assign roles in the table on the next page. Try to create a team dynamic that is fair and equitable, while promoting the strengths of each member.

Communication Leaders

Suggested: Assign a team member to be the primary contact for the client/sponsor. This person will schedule meetings, send updates, and ensure deliverables are met.

Suggested: Assign a team member to be the primary contact for faculty advisor. This person will schedule meetings, send updates, and ensure deliverables are met.

Common Leadership Roles for Capstone

1. **Project Manager:** Manages all tasks; develops overall schedule for project; writes agendas and runs meetings; reviews and monitors individual action items; creates an environment where team members are respected, take risks and feel safe expressing their ideas.

   Required: On Edusourced, under the Team tab, make sure that this student is assigned the Project Manager role. This is required so that Capstone program staff can easily identify a single contact person, especially for items like Purchasing and Receiving project supplies.
2. **Logistics Manager:** coordinates all internal and external interactions; lead in establishing contact within and outside of organization, following up on communication of commitments, obtaining information for the team; documents meeting minutes; manages facility and resource usage.
3. **Financial Manager:** researches/benchmarks technical purchases and acquisitions; conducts pricing analysis and budget justifications on proposed purchases; carries out team purchase requests; monitors team budget.
4. **Systems Engineer:** analyzes Client initial design specification and leads establishment of product specifications; monitors, coordinates and manages integration of sub-systems in

the prototype; develops and recommends system architecture and manages product interfaces.

5. **Test Engineer:** oversees experimental design, test plan, procedures and data analysis; acquires data acquisition equipment and any necessary software; establishes test protocols and schedules; oversees statistical analysis of results; leads presentation of experimental finding and resulting recommendations.
6. **Manufacturing Engineer:** coordinates all fabrication required to meet final prototype requirements; oversees that all engineering drawings meet the requirements of machine shop or vendor; reviews designs to ensure design for manufacturing; determines realistic timing for fabrication and quality; develops schedule for all manufacturing.

Team Member	***Role(s)***	***Responsibilities***
Gokul	*Project Manager*	Manages all tasks; develops overall schedule for project; writes agendas and runs meetings; reviews and monitors individual action items; creates an environment where team members are respected, take risks and feel safe expressing their ideas.
Kokkera	Systems Engineer	Analyzes Client initial design specification and leads establishment of product specifications; monitors, coordinates and manages integration of sub-systems in the prototype; develops and recommends system architecture and manages product interfaces.

Zanika	Logistics Manager	Coordinates all internal and external interactions; lead in establishing contact within and outside of organization, following up on communication of commitments, obtaining information for the team; documents meeting minutes; manages facility and resource usage.
Natalia	Test Engineer	Oversees experimental design, test plan, procedures and data analysis; acquires data acquisition equipment and any necessary software; establishes test protocols and schedules; oversees statistical analysis of results; leads presentation of experimental finding and resulting recommendations.

Step 5: Agree to the above team contract

Gokul Chaluvadi: *Signature: Gokul Chaluvadi*

Kshitij Kokkera: *Signature: Kshitij Kokkera*

Team Member: *Signature: Natalia Tondi*

Team Member: *Signature: Zanika Hossain*

Appendix 3: [Insert Appendix Title]

Note that additional appendices may be added as needed. Appendices are used for supplementary material considered or used in the design process but not necessary for understanding the fundamental design or results. Lengthy mathematical derivations, ancillary results (e.g. data sets, plots), and detailed mechanical drawings are examples of items that might be placed in an appendix. Multiple appendices may be used to delineate topics and can be labeled using letters or numbers. Each appendix should start on a new page. Reference each appendix and the information it contains in the main text of the report where appropriate.

Note: Delete this page if no additional appendices are included.

References

Provide a numbered list of all references in order of appearance using APA citation format. The reference page should begin on a new page as shown here.

[1] VCU Writing Center. (2021, September 8). *APA Citation: A guide to formatting in APA style.* Retrieved September 2, 2024. https://writing.vcu.edu/student-resources/apa-citations/

[2] Teach Engineering. *Engineering Design Process*. TeachEngineering.org. Retreived September 2, 2024. https://www.teachengineering.org/populartopics/designprocess