VCU College of Engineering

Project CS-25-321 Virtual Reality Space Game

Design Report

Prepared for

NASA/ASU

By

Quinton Jones, Ava Shilling, Akshara Rajesh, Peter Nguyen

Under the supervision of

Rodrigo Spinola

Date: 12/9/2024

Executive Summary

The NASA Psyche mission is designed to explore a metal-rich asteroid, believed to be the exposed nickel-iron core of an early planet. This asteroid presents a unique opportunity for scientists to study the foundational elements of terrestrial planets like Earth. Psyche's composition could provide valuable insights into the processes that shaped planets through violent collisions and accretion during the early formation of the solar system.

As part of our capstone project, a virtual reality (VR) game is being developed to raise public awareness about the NASA Psyche mission. The game is designed for students from elementary to high school and will be showcased at promotional events to engage a general audience.

The primary goal of the project is to create an immersive VR experience that offers users an engaging and realistic space environment. The game will feature simple and intuitive controls to ensure ease of interaction while allowing users to interact with specific objects within the environment. The design will provide multiple modes of interaction, enabling flexibility and enhancing the user experience.

The game will feature a navigable map with five interactable rooms, designed to function like an escape room with puzzles and clues for users to solve. We will rigorously test the design to ensure it meets expectations and is fully playable. The design will follow established guidelines, including prototypes and adherence to time constraints to ensure project completion within 3-4 months. The game will be developed using Unity to ensure compatibility with all major VR headsets, such as Meta Quest 2 & 3 and Apple Vision Pro. The game will offer two modes: a 30-60 minute main storyline and a shorter event mode with a playtime of 2-3 minutes.

Prototypes, project outlines, and other updates will be regularly delivered to both the project sponsor and the advisor, with deliverable dates aligned to sponsor meetings for effective communication. Additionally, academic deliverables will be submitted throughout the project timeline and evaluated by our CMSC451 professor as part of the course requirements. Our deliverables section provides more specific information and dates.

Key accomplishments include the completion of the project proposal, team contracts, initial communication with sponsors, and the development of the game’s overall storyline. A project timeline has also been established, which is detailed in Appendix 1.

Table of Contents

Section A. Problem Statement

The Psyche mission aims to explore a unique, metal-rich asteroid, believed to be the exposed nickel-iron core of an early planet, located between Mars and Jupiter. This asteroid offers a rare opportunity to study the building blocks of terrestrial planets like Earth, as metallic cores are typically hidden beneath rocky mantles. Scientists speculate that Psyche's composition could help reveal the processes that shaped planets through violent collisions and accretion during the solar system's early formation (Psyche). Arizona State University leads the mission, with NASA's Jet Propulsion Laboratory managing operations, while spacecraft development is led by Maxar Technologies. The mission's scientific objectives include determining Psyche's structure, topography, and elemental composition using advanced instruments such as a multispectral imager, magnetometer, and gamma-ray spectrometer (Psyche).

Asteroid Psyche's mass, approximately 220 billion billion kilograms, is composed of up to 95% nickel and iron, making it an important subject for planetary science (Mann). It is hypothesized that Psyche could be the remnant of a protoplanet whose outer layers were stripped away through collisions billions of years ago. This asteroid, which is significantly smaller than Earth's moon, is considered an ideal candidate for studying planetary cores, which are otherwise inaccessible beneath a planet's surface (Mann). Scientists will analyze Psyche's magnetic and gravity fields to test theories about its formation and structure (NASA's Psyche Mission..).

Once the spacecraft reaches the asteroid in 2029, it will spend approximately two years mapping its surface and analyzing its composition (Mission). The spacecraft's state-of-the-art payload will include instruments to investigate Psyche's internal structure, magnetic fields, and elemental makeup, providing unprecedented insights into the asteroid's origins (Psyche Spacecraft). Additionally, the mission will test new laser communication technology that could revolutionize data transmission from deep space (Psyche Spacecraft). This groundbreaking exploration of Psyche is expected to enhance our understanding of planetary formation and the violent processes that shape celestial bodies (NASA's Psyche Mission).

NASA's Psyche mission presents an opportunity to educate and inspire public interest in space exploration. Virtual reality (VR) is increasingly popular among children, making it a good choice for promoting the Psyche mission at public events and demos. There is an unmet need for a VR experience that can introduce children and the general public to space science and exploration in an engaging, immersive way. There needs to be a continued interest in the mission over five years, requiring an engaging way for people to learn about the mission.

Our capstone project aims to develop a VR game to raise awareness about NASA's Psyche mission. The game is targeted at students from elementary to high school and will be played at promotional events for the general public. The game is designed as an escape room on board a futuristic craft going to Pysche after a successful first mission. The overall storyline follows the craft having a breakdown and the user navigating through the spacecraft to find the "code" that will fix the issue. Although not directly connected to the Psyche mission, it draws inspiration from space exploration environments.

The project is a collaboration between NASA Psyche Mission, Virginia Commonwealth University (VCU), and Arizona State University (ASU). Primary stakeholders include NASA, educational institutions, students, and the general public.

The game must provide an immersive experience, featuring realistic environments with dynamic and interactive objects. We face challenges as we are new to VR game development, and need to learn VR design and 3D environment creation. We also need to model the game to be accessible for people who are not used to VR technology, such as children or older interested parties.

While existing educational games on space exploration are available, most are in traditional 2D formats. The project aims to elevate existing educational games by transitioning them to VR, providing a more interactive and immersive experience. This project advances current technology in educational games by offering a VR escape room experience, allowing players to engage with space environments in a more meaningful way.

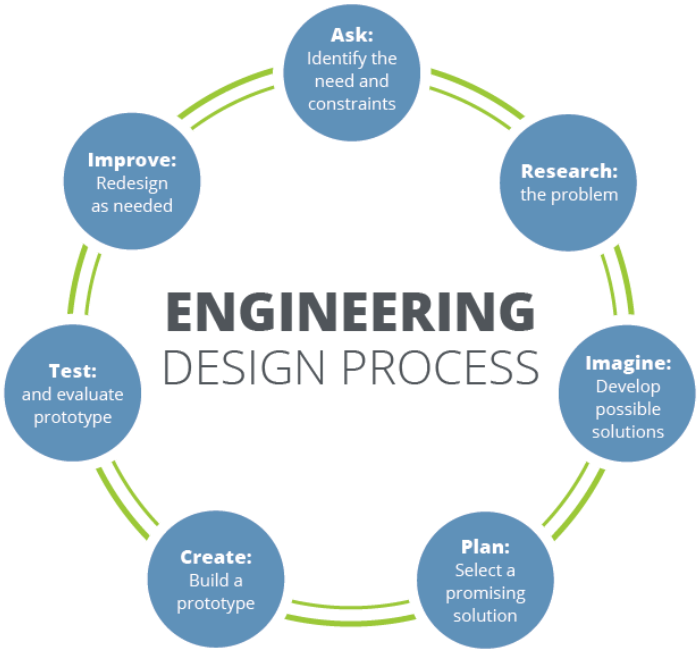


Figure 1. The iterative nature of the engineering design process [2].

Section B. Engineering Design Requirements

Our main goal for this project is to create a VR space game that will be engaging and interactive to the user. Upon our design, there will be certain constraints to consider with precise implementation and requirements. We want to mirror the famous game, escape room into VR to give the user a real-life experience when playing the game. Our requirements will mainly consist of a VR headset and unity for the creation of the game. Furthermore, we will also use assets when needed based on certain developmental parts when designing. Rigorous testing will be applied to ensure that the game works safely and correctly to provide a realistic environment to the user. Considering all of our research and ideas, our expected goal to complete this project will be approximately 3-4 months. The time constraint could be problematic; however, considering the main goal, we will do our best to provide the game with full functionality.

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

Our overall goal is to produce a game in VR that gives the users a cool experience. While we have numerous ideas and directions to take, we must make sure that the event mode that we implement will have a max duration of 2 minutes; however, our story mode will have a duration of 30 minutes to an hour long. Below are goals to keep in mind when delivering our game to the client:

- To provide a realistic space environment allowing users to experience an engaging setting.
- To design user-friendly controls making interaction easy and simple.
- To implement basic interactions with specific objects in the environment.
- To provide multiple modes of interaction to give the user flexibility.

B.2 Design Objectives

Our design process will provide multiple aspects in regard to the creation of the game. Below will describe the main points that the design will do:

- The design will implement a navigable map with five interactable rooms mirroring the functionality of an escape room containing puzzles and clues for the user to explore through VR.
- The design will be tested rigorously by developers and other users to ensure that our design is the outcome we expect with playable functionality.
- The design will follow our guidelines including prototypes and time constraints to complete the project.
- The design will use Unity to provide the game in VR for the user to experience with a decent frame rate playable for around 2 minutes.
- The design will be completed within a period in 3-4 months.
- The design will feature a main storyline with a playtime of 30 minutes to an hour and an event mode with a playtime of 2-3 minutes.
- The design will be playable on all major VR headsets (Meta Quest 2&3, Apple Vision Pro).

B.3 Design Specifications and Constraints

Functional Constraints

Gameplay Flow:

- Requirement: Players must progress by sequentially unlocking rooms via puzzles or minigames.
- Specification: Puzzles in each room must be designed to allow completion within 5 to 10 minutes to ensure a smooth gameplay experience and keep the pacing engaging.
- Objective: Keep player engagement high and ensure logical progression.

Environmental and Physics Constraints:

- Requirement: All movement mechanics must feel realistic given the game's space setting.
- Specification: Movement physics should be adjusted for low-gravity environments, simulating asteroid surface interactions.
- Objective: Provide a realistic, immersive experience while navigating or interacting with the Psyche environment.

Cost Constraints

Development Budget:

- Requirement: Development costs should remain within the allocated $1000 budget.
- Specification: Costs for assets and Unity integrations must not exceed 200 of the budget, leaving room for unexpected expenses.
- Objective: Ensure the project stays financially feasible while delivering high-quality gameplay.

Asset Use:

- Requirement: Leverage readily available Unity assets or free 3D models.
- Specification: At least 70% of game assets (models, textures) should be sourced from existing resources or Unity’s asset store.
- Objective: Keep asset acquisition cost-effective without sacrificing visual quality.

Hardware Constraints

Platform Compatibility:

- Requirement: The game must run smoothly on most compatible devices.
- Specification: Target a minimum of 90 FPS on a system with Intel Core i5, 8GB RAM, NVIDIA GTX 1050 or equivalent.
- Objective: Ensure accessibility for a broad player base, especially those with standard hardware.

Power and Data Constraints (VR and High Fidelity Sections):

- Requirement: Minimize power consumption in VR portions and drone navigation segments.
- Objective: Ensure a smooth experience without overloading VR-capable hardware or causing performance drops.

Maintainability Constraints
Code Modularity:

- Requirement: Each game feature (e.g., puzzles, physics) must be implemented as separate, modular scripts.
- Specification: Ensure by separating functionalities into distinct scripts, making future updates or adjustments simpler.
- Objective: Allow easier maintenance and expandability for future content or features.

Error Logging:

- Requirement: Identify and log bugs or performance issues.
- Specification: Implement Unity's logging system to monitor for critical errors in each game phase.
- Objective: Enhance reliability and track performance issues for timely troubleshooting.

Usability Constraints
Player Control and Navigation:

- Requirement: Controls must be intuitive, especially for complex VR navigation.
- Specification: Implement a tutorial sequence within the first 3-5 minutes of gameplay covering essential movement and interactions.
- Objective: Ensure new players quickly learn controls to avoid frustration and improve retention.

Accessibility Options:

- Requirement: Make the game accessible to players with visual and auditory needs.
- Specification: Provide text-based options and subtitles for all dialogue.
- Objective: Broaden accessibility to improve inclusivity and usability.

Schedule Constraints
Development Timeline

- Requirement: The game must be completed within a 6-5-month timeline.
- Specification: Aim for two major milestones—a playable demo within 6 months and the final version by month 8. Implement bi-weekly sprints to ensure steady progress.
- Objective: Stay on schedule, maintain team motivation, and deliver a polished product within the budget and timeline.

Aesthetic Constraints
Futuristic and Psyche Mission-Themed Aesthetic:

- Requirement: The design must evoke a realistic sci-fi atmosphere aligned with the Psyche mission's objectives.
- Specification: Each room's design must include at least 3 unique mission-relevant elements (e.g., Psyche maps, mineral samples) to reinforce the theme.
- Objective: Increase immersion through consistent visual theming that aligns with the mission narrative.

B.4 Codes and Standards

Standards

NASA Style Guide and Image Policies:

- Standard: Follow NASA's guidelines on image usage, terminology, and branding to ensure an authentic experience.
- Relevance: Maintain consistency with NASA's public image and adhere to their graphic standards, particularly for visuals and any representation of the Psyche mission.

ISO 9241 Ergonomics of Human-System Interaction:

- Standard: This standard includes principles for usability and human-computer interaction, particularly around ease of use and accessibility.
- Relevance: Ensures that game controls, interfaces, and interactions meet ergonomic principles, which is essential for VR and interactive systems.

IEEE 29148-2018 Requirements Engineering Standard:

- Standard: Defines practices for developing and managing requirements, ensuring all functional and non-functional needs are documented and traceable.
- Relevance: Helps document game requirements thoroughly, ensuring all features, constraints, and objectives align with player expectations and are traceable throughout development.

ASTM F3059-14 Standard Guide for Characterization and Performance of Gaming Systems:

- Standard: Establishes guidelines for testing and evaluating the performance of gaming systems, particularly for frame rate, latency, and interaction response.
- Relevance: Provides benchmarks for testing performance in Unity and VR environments to ensure smooth and responsive gameplay for users.

W3C Web Content Accessibility Guidelines (WCAG) 2.1:

- Standard: Offers guidance on making digital content accessible to people with disabilities, including those with visual or auditory impairments.
- Relevance: Ensures that in-game text, AI dialogue, and color-coded puzzles are accessible, expanding inclusivity for players with disabilities.

Codes

NASA Section 508 (Rehabilitation Act) Accessibility Requirements:

- Code: Mandates that all federal digital content and interfaces are accessible to people with disabilities.
- Relevance: Ensures that the game meets accessibility standards similar to those required by federal entities, enhancing usability for all players.

Children's Online Privacy Protection Act (COPPA):

- Code: Requires that online games do not collect personal data from users under 13 without consent and restricts in-game communication to prevent data sharing.
- Relevance: If the game is accessible to children, this code ensures no personal information is collected, and in-game communication remains private.

NASA Psyche Brand Guidelines:

- Code: Provides guidelines on branding, logo usage, and content standards related to NASA's Psyche mission.
- Relevance: Ensures that the game remains true to NASA's branding requirements, particularly for visuals and references to Psyche mission-related content.

Occupational Safety and Health Administration (OSHA) VR Safety Requirements:

- Code: Although primarily for real-world applications, OSHA has guidelines on VR development to prevent user discomfort or harm.
- Relevance: Ensures VR minigames adhere to safety standards, such as minimizing motion sickness risks and maintaining comfort for prolonged use.

Section C. Scope of Work

C.1 Deliverables

During this project, many prototypes and planning/outline deliverables will be delivered to the project sponsor and advisor to follow along with progress. The deliverable dates will generally line up with sponsor meeting dates for optimal communication among all parties. This list will also include academic deliverables that have been assigned throughout the school year and will be graded by the CMSC451 professor and labeled as academic milestones. Below are the project deliverables listed in order, from the first semester of Senior Project Design to the second semester of Senior Design II and the end of the project and the final project submission:

First semester:

- **General idea outline:** Completed before sponsor meeting to propose project idea. Gives a general outline of the game, a visual reference, and an idea of how the story will progress.
  September 30th

- **Project Proposal** (academic):
  October 11th

- **Detailed plan of event room:** description and written plans for event room
  October 23rd

- **Fall Design Poster (academic)**
  November 15th

- **Blockout of event room:** Unity block out of the first event room, featuring a usable character and the general shape of the room
  November 18th

- **First prototype (event room):** prototype of the event room featuring wall designs, a story, and a few interactable objects, mostly to practice working together and test what features work, make sense, are too easy/hard, etc.
  December 2nd

- **Preliminary Design Report (academic)**
  December 9th

Second Semester:

- **Test report of first prototype**: after testing the first prototype on people we know with various levels of VR and game knowledge, we'll report what we learned about the player experience and what changes we can make for the future. The report will feature sections: User feedback (overall experience, likes, dislikes, rated difficulty and points of struggle,

and suggestions), and Developer Report (what we need to change, how we'll use their feedback, and what we overall learned from having the game played)
January 17th

- **Storyline and plan of the full game**: A detailed storyline for the main game, including storyboards, scene layouts, description of main puzzles to be made, and split of work between teammates.
  January 31st

- **Full Game Prototype:** A playable prototype of the full game room with at least 50% of implemented functionality.
  February 24th

- **Full Game prototype 2:** Second prototype of full game with testing and implementation of more elements, about 75%
  March 17th

- **Full Game Final:** Full game with all playable functionality, completed a few weeks before the EXPO to allow for testing and tweaking, as well as a small time cushion in case anything runs long and to prepare our EXPO presentation
  April 7th

- **Final Design Report (academic)**
  Unknown

- **Capstone EXPO Poster and Presentation (academic)**
  Unknown

Our project requires all developers to learn a new software and programming language, along with creating a highly creative storyline and game elements that may evolve. As a result, we anticipate a learning curve, which introduces potential risks to the project's completion and delivery. There may be additional risks associated with the completion and delivery of the project in relation to access to physical resources and accessing the source code simultaneously for the project (which cannot safely be done on Unity and Github). Below we explain these risks and our plan to mitigate complications.

- **Virtual Reality headset access for developing and testing:** There is a Virtual Reality lab at VCU with many headsets to test on, and we will make a schedule of team and individual usage with our advisor when we begin development of the prototype. If this poses too much difficulty we may purchase our own headset to be stored safely and passed between group members on a schedule. Buying one of the more popular and cheap headsets (such as the Meta Quest) is in our project budget and would make sure publicly available headsets are tested on and usable.

- **Unity and Github scene conflicts:** Unity scenes can only be worked one by one person at a time or the work will overlap and cause conflicts. Because of this, we will be sectioning off the work into main rooms and also have thorough communication between ourselves about who is working at what time. This way, work is mostly separated but also heavily communicated when it overlaps thus mitigating overlap issues.

- **Asset creation**: None of the team members have knowledge of asset creation or 3D modeling, so this is a setback in addition to a lack of knowledge of Unity. Because of this, we will be using a simple and less realistic art style, as well as purchasing many of our assets from the Unity Asset Store. If necessary, one of our developers can learn basic 3D modeling (likely Blender) for specific assets.

C.2 Milestones

Milestones are major project phases or tasks that need to be completed in order to ensure the project deliverables. Most major deliverables from above have at least one milestone that we should be working towards to aid us in learning Unity, and keeping us on track so that we get everything done in an efficient manner.

- **Personal Unity environment practice:** block out of personal Unity environments to practice using Unity and learn the software
  October 2nd

- **Unity Github Repository setup:** connect the event room repository and set all file systems for all team members to access and edit
  November 11th

- **Create a test report form** for users to fill out during each prototype test
  January 15th

- **Full Game rooms Blockout:** Blockout of the main game based on storyline and puzzle report, to aid in our prototype development.
  February 24th

- **Full Game Prototype 2 testing report:** Report of testing the full game prototype on others (people we know, members of the project team not associated with the development of the game).
  March 3rd

The project approach will be a mixture of waterfall and agile development. Our program is split into 2 major sections; the first semester of Senior Design and the second semester. The first semester is focused on this report, planning, and designing. The second semester will be focused on building and finalizing our final product. This setup follows a more sequential waterfall-like approach, but we will also be utilizing some agile methodologies in the following ways:

- **Deliverables for each major element of the project are no more than 4 weeks apart**, with milestones for each longer stretch in the middle. This gives us something similar to 2-week sprints where we will be making major progress and then assessing the work and our project direction.
- **We will start by working on the event room**, which is a smaller version of the full game to get a handle on controls and our workflow. Then there will be *3 major iterations* of the full game, ending a few weeks early to allow for finalization. This allows the team to brainstorm new ideas as we're creating and developing and always be thinking about creating the best experience possible.
- **Weekly meetings and frequent communication as needed.** The group meets for 30 minutes to an hour every week to talk about major deliverables coming up, our progress, and work on assignments together.
- **Testing feedback loops**. After every prototype, we will be testing the product on others and having them fill out a testing survey, then making our report of what we will do with this feedback and implementing it into the next iteration.

C.3 Resources

Resources needed for this project are mostly free software online and thus can be learned and used without any purchasing or complicated acquisition. We will be using version control software to save, document, and collaborate on our code, in addition to many types of software for game development and modeling. Key resources include:

Hardware:

- Multiple VR Headsets: We will need access to multiple different types of VR headsets to develop and test our game on, especially the Meta Quest 3. We can access these headsets and controllers from VCU's VR lab, and if necessary can use our budget to purchase one.
- High-performance computers: computers or laptops capable of handling VR development and rendering. These are either already owned or can be used at VCU's computer lab facilities.

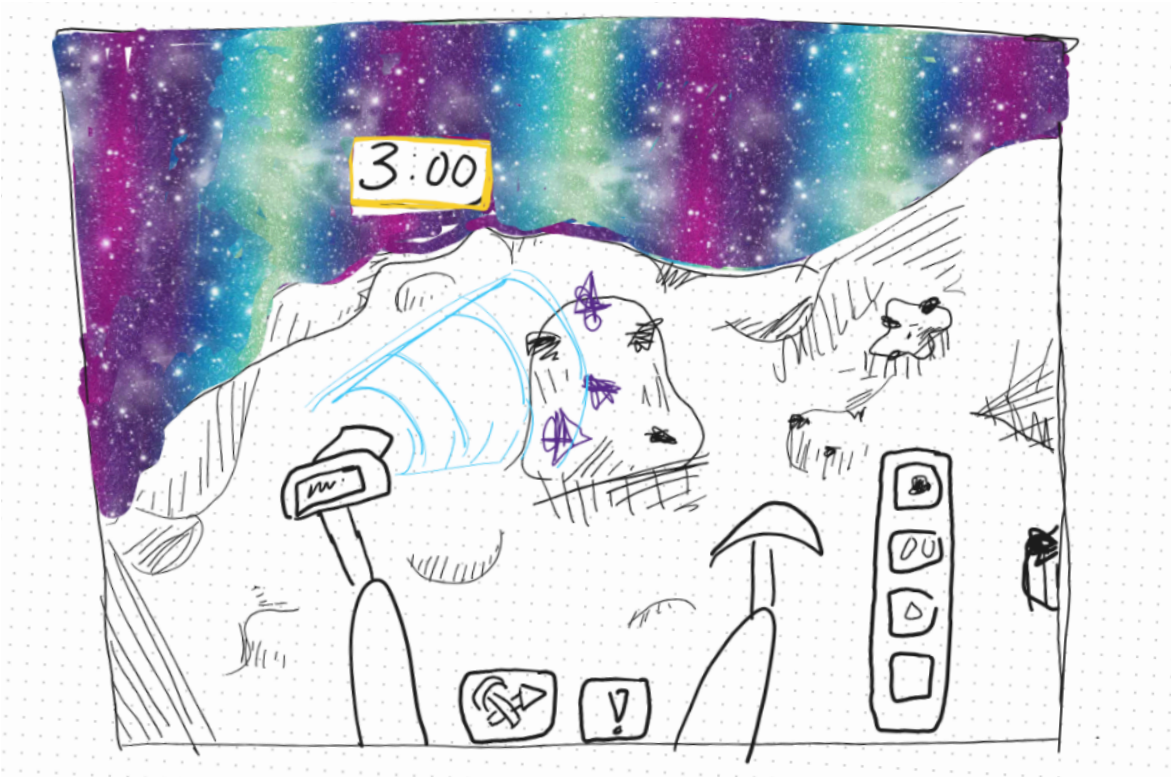
Software:

- Unity: This will be our primary game engine. It is free to use and has many assets in its store, making it a crucial resource for new developers. We will also be making use of the Unity asset store. Unity has a wide variety of free and paid assets including models, textures, and sound effects that we will purchase and use to make our game more realistic and immersive.
- 3D Modeling Software: Depending on our workflow, we may be making our assets for this project. If so, we will use Blender to create 3D assets.
- Version Control:
    - Git and Github: Necessary for collaborating, tracking changes made and by who, and managing the development process effectively. We may be making use of GitLFS (Large File System) to store and work with large files while developing.

Section D. Concept Generation

We made concept sketches of many different ideas and brainstorming types of games. Below are the 3 concepts that we explored in depth and measured against each other to decide which was best suited for our project based on our abilities and the sponsor's requirements.

Concept 1: Space mining game



Our first idea was a mining game set on the surface of Psyche. It would feature the player having a few tools, like a pickaxe, scanner, and crafting bench. They would complete simple tasks like collecting a few samples of certain ores, making objects, and delivering the samples. The samples and items would be of those one might find or use on Psyche (Iron, Nickel, and tools one would use on a space mission) for educational purposes and accuracy. The design concept features an inventory, and buttons to open the crafting and goals menu to keep track of progress.

Pros:

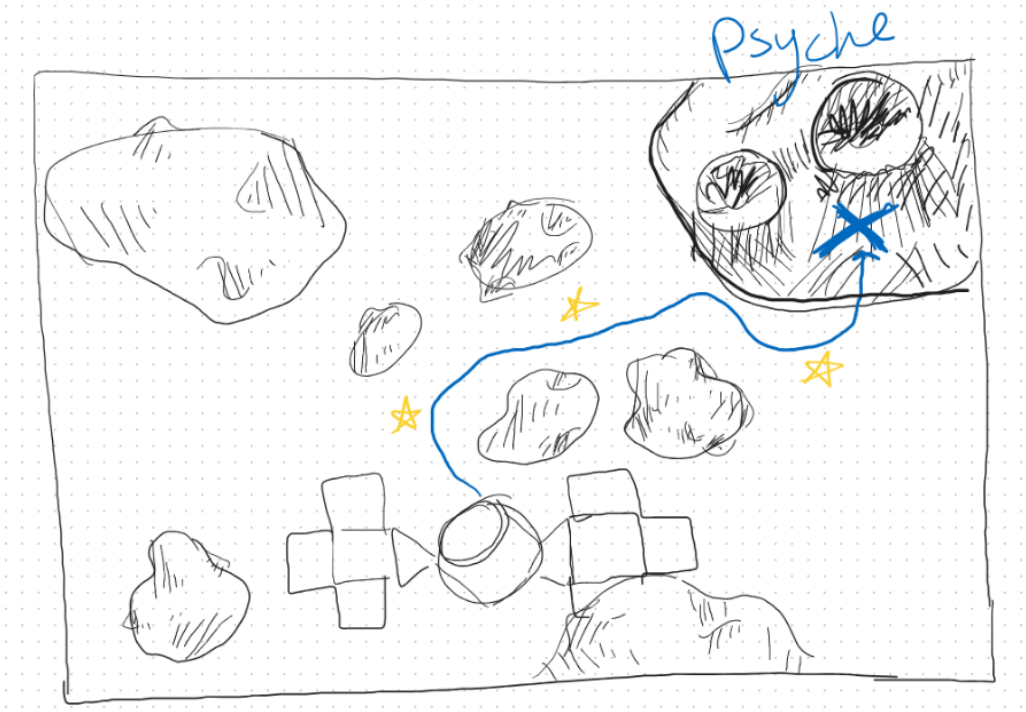
- Educational, features real items and materials from the Psyche mission
- Scalable, could be given any time limit and amount of tasks based on needs

Cons:

- Ores would likely be identified by color and shape, which isn't the most accessible people with color or vision disabilities

- Complicated mechanics (scanning, mining, crafting, completing tasks), a lot to explain in 2-3 minutes
- Not the most accurate/realistic since the Psyche mission doesn't involve surface sampling

Concept 2: Asteroid aversion flying game



This game would feature a flying minigame where the player controls the spaceship and flies through asteroid obstacles in order to get to Psyche's surface or orbit. There would be a limit of 2-3 minutes, and the player would use the controllers and various buttons or hand movements to maneuver the ship, maybe using the orbit of other planets to get there (like in the actual Psyche mission).

Pros:

- Very interactive and makes full use of virtual reality capabilities (hand movement controls and fully immersive)
- Great replayability for events - achievable goal that's easy to understand quickly
- Cost efficient - not many assets in the environment, just various asteroids and the ship

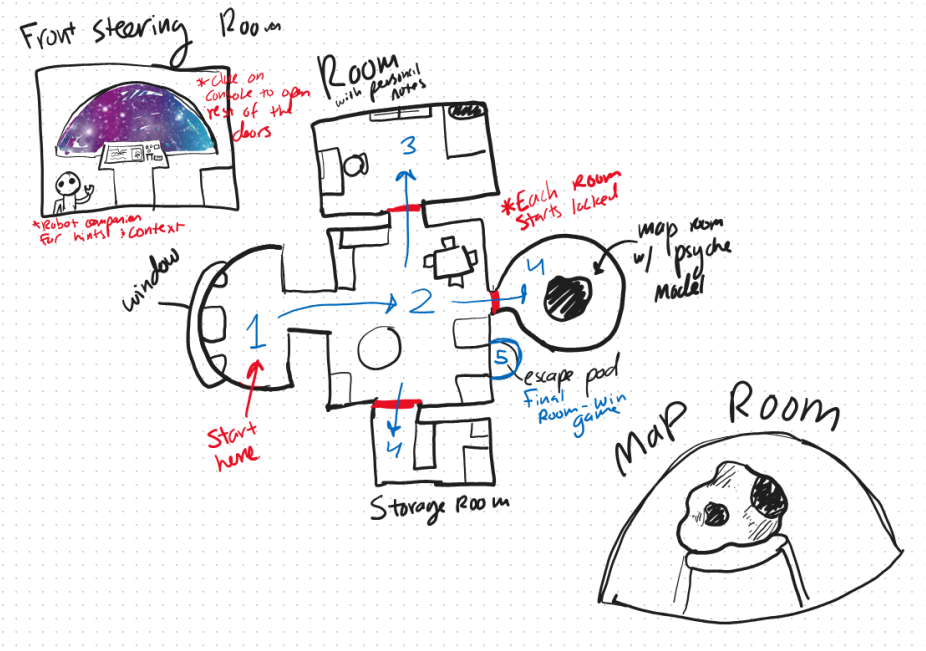
Cons:

- Complicated controls, would feature multiple buttons to move in all directions and control acceleration, or more complicated hand movements to cut back on button usage.

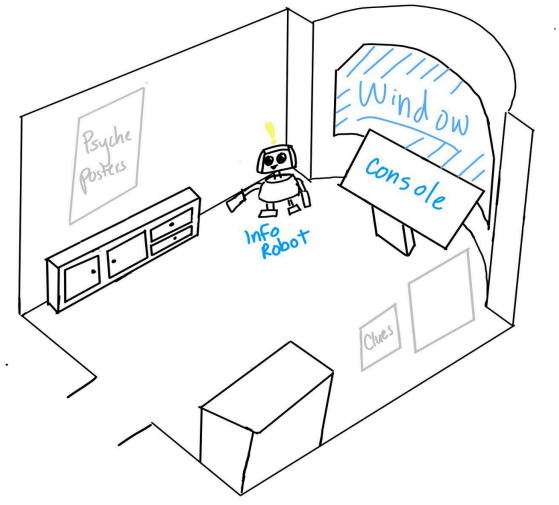
- Very active, could be bad for users who are more sensitive to motion or virtual movement in VR
- Less educational, mostly for fun

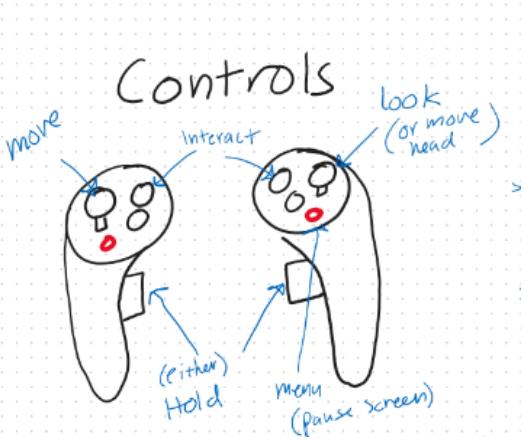
Concept 3: Escape room ship with event room

Original map:

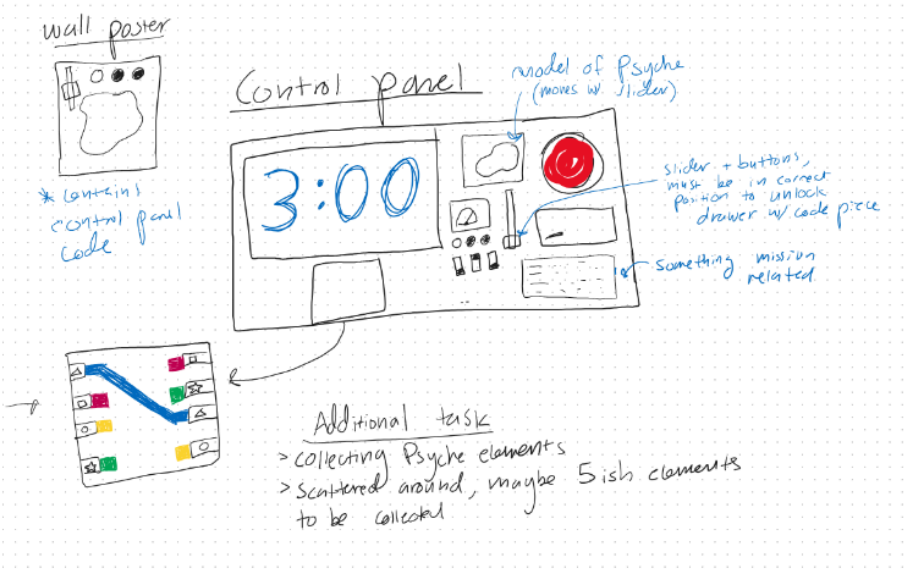


Event room map and controls description:





Puzzle ideas:



This design will feature a single isolated event room of 2-3 minutes of length, as well as a 3-5 room story mode playable for 20-60 minutes. Both modes will follow the same general storyline of a future Psyche mission following the successful first mission that revealed lots of useful materials on the Psyche asteroid, sending a crewed ship that includes the player. They'll go through a series of puzzles and challenges before finding a full landing code to initiate the ship landing on the surface. It will have escape room themes such as many interactable objects that can be picked up and looked at, as well as posters on the walls with clues, and small puzzles to put together to solve a bigger mystery.

Pros:

- Easy to understand. Simple controls and storyline
- Educational, can be easily tied into Psyche facts and details
- Accessible, features a hint mechanism for younger or less experienced players and easily adaptable to not rely on colors or fast movements

Cons:

- Not cost efficient, many assets to make/buy to make an interactive room
- Lots of story/exposition and concept explanation for a 2-3 minute experience

Overall, we came up with many ideas that would meet the Psyche team's needs to varying degrees. Many of these designs were inspired by the web based game portal on the Psyche website, offering a more immersive experience to the games that have already been thought out

and enjoyed. Below is a breakdown of each of the important categories is explained, and each design is scored by these features.

Section E. Concept Evaluation and Selection

This section explores the ideas above in more depth, going over the criteria that we decided to rate them with. We chose these as a basis from our conversations with the Psyche team, our sponsor, and the documentation provided to us about the VR specifications. Each design will be given a rating 1-10 in each category. We've also rated the category 1-3, with categories rated 1 being the most important and 3 being less important. This will be reflected in our rating process by having varying weights for each category based on importance. The final score will then be computed by applying the weight to each score, then adding them all up for the final.

Criteria:

- (1) Performance: The design must be compatible with standard consumer-grade VR equipment with an FPS of at least 90, as is necessary for VR games to feel smooth. Any slower would feel choppy, and can cause the player to be uncomfortable. Long loading times would slow down events playing our game, so performance is important. A design with high performance rating is one that won't be constantly loading in new things or that's likely to have the highest performance.

- (1) Ease of use: The design must be easy to understand, have simple controls, and be playable for most audiences, including children and new VR players.

- (1) Accessibility: The design must be as accessible as possible to all players. It should feature visibility/audio assistance such as captions for any speaking, rely on texture and shape rather than just color, and use snap camera rotation to minimize discomfort/dizziness in motion sensitive players. A high rating on this category means the features of the design will be able to be made in a way that is accessible, as some games have mechanics that are hard to change.

- (2) Edutainment: Psyche VR games are supposed to be on the "edutainment" spectrum, therefore should either feature some learning aspect or at least offer an immersive experience that will teach players about Psyche in some way.

- (2) Cost: The design should be cost efficient and fit within the capstone budget, since 50% of the budget will be spent on the VR headset itself. This is less important to the sponsor as it doesn't affect the final project as much as the others. A design will have a high rating if we don't anticipate buying many assets/music/software during its creation

- (2) Engagement: Games with more immersive/engaging stories and components will generally be more appealing for the public playing the game for short periods of time. This includes things like: an exciting environment, interactive components, and

fast-paced gameplay/storyline.

- (3) Scalability: Since some of our designs could be scaled up to a larger "story mode" for non-event players, they will also be rated in this category; it is much less important for the designs intended use.

Design concept matrix:

	Weight	Concept 1 (Space mining)	Concept 2 (Asteroid aversion)	Concept 3 (Escape room)
Performance	20%	9	6	10
Ease of Use	20%	8	7	9
Accessibility	20%	9	7	9
Edutainment	15%	10	7	9
Cost	10%	8	10	7
Engagement	10%	9	10	8
Scalability	5%	5	9	8
Total score		8.65	7.5	**8.85**

Escape room is the chosen concept with a rating of 8.85/10. It has slightly lower ratings on things like engagement and cost than the other two concepts, but these are weighed lower, and it wins over the higher categories like a capability for high performance, easy controls and storyline and high possibility for an immersive and educational experience.

The other designs would have lower cost and slightly more engaging gameplay for the short term, but have lower scores in things like performance as the asteroid game will possibly have longer load times due to large rendering objects, and accessibility as the asteroid game will also feature lots of fast player movement and turning. Additionally, both the asteroid game and the mining game will have more difficult controls/concepts and therefore will be harder to understand and explain with limited time in an event setting.

Section F. Design Methodology

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

The design process utilized computer-aided modeling to simulate and evaluate the Control Room's layout and functionality. Key computational tools included:

- **Unity Game Engine**: Served as the primary platform for modeling and implementing the Control Room environment, ensuring seamless interaction between the player and terminal interface.
- **Assumptions and Boundary Conditions**: Simulations ensured that the asteroid view and terminal interactions were both visually immersive and functionally responsive.

F.2 Experimental Methods (example subsection)

Prototypes will be iteratively developed and tested to improve functionality and user experience:

- Testing Equipment and Setup:
    - User feedback will be collected via playtesting sessions conducted remotely.
    - A Google Form survey will be distributed to collect detailed feedback on gameplay, puzzles, and immersion.
- Testing Procedures:
    - Participants will navigate the Control Room, interact with the terminal, and complete puzzles or minigames.
    - Specific testing goals included:
        - Validate the accessibility of terminal mechanics.
        - Ensuring that the asteroid view will contribute to immersion
        - Assesses the clarity of instructions provided by the AI robot.

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

The level design centers on the Control Room as the game's focal point, integrating functional elements:

- **Control Room Design:**
    - Central terminal provides access to puzzles and minigames.
    - Observation window offers a dynamic, real-time view of the Psyche asteroid.
- **Gameplay Flow:**
    - Players complete sequential tasks via the terminal, culminating in mission-critical objectives.
    - Tasks include entering codes, analyzing asteroid data, and recalibrating equipment.
- **Interactive Elements:**
    - AI robot guides the player, offering hints and narrative context.
    - Holographic displays enhance both functionality and visual appeal.

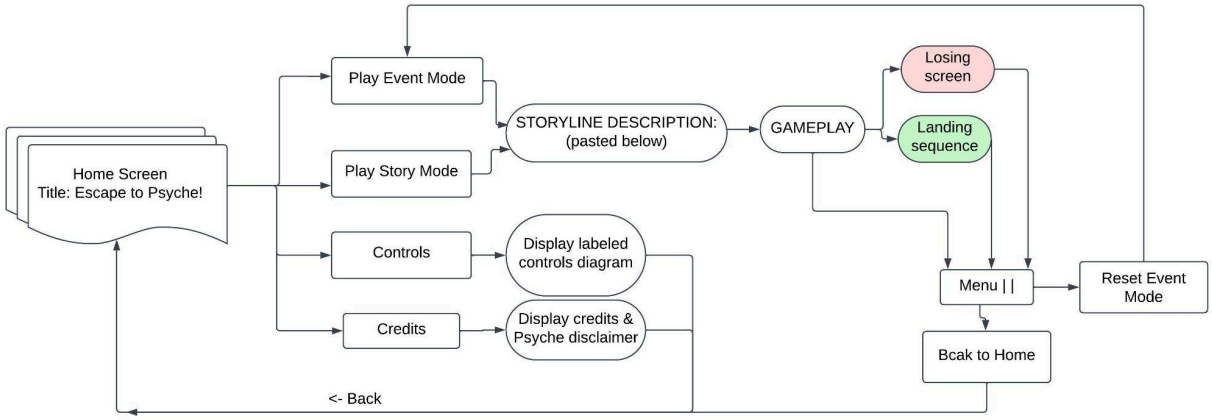
F.3 Validation Procedure

The design team will implement a validation plan to ensure the final design meets all objectives and user needs:

- **User Feedback Collection**:
    - Participants provided feedback via structured Google Form surveys.
    - Key focus areas included:
        - Clarity and intuitiveness of gameplay mechanics.
        - Immersion and realism of the Control Room environment.
        - Overall satisfaction with the game's narrative and interactive elements.

Section G. Results and Design Details

Flowchart of menu/scene design:



Storyline description: "It is the year 2076, you are an astronaut aboard Psyche 2, the second mission to the metal-rich asteroid Psyche following the first mission that found lots of valuable and interesting minerals on the surface. Your goal is to find the final section of the code to initiate the landing sequence onto Psyche's surface. Look around the room for clues and figure out the code, then type it in on the console. Collect anything that seems interesting along the way, and talk to your AI assistant if you need help. Good luck!"

G.1 Modeling Results

The game design focuses on a single, centralized **Control Room** to streamline the player experience while maintaining immersion and narrative depth. Key features of the updated model include:

Control Room Layout:

- **Center Terminal**: Serves as the primary interactive hub for the player, integrating gameplay mechanics such as puzzle solving, minigames, and mission-critical operations.
- **Observation Window**: Offers a dynamic view of the Psyche asteroid, enhancing immersion and reinforcing the connection to the mission theme.
- The astronaut character interacts with the terminal to complete tasks.

Environment Design:

- Futuristic Control Room modeled with realistic space textures and Psyche-themed elements.
- Integrated screens and displays present mission objectives.

G.2 Experimental Results

Other similar VR games were tested so that the team could get an idea on what we wanted out of a VR space escape room game. Some of the games tested included past capstone psyche VR games, one included mining for materials and sorting them out in space while others were more focused on actual VR escape rooms. Some of us who haven't experienced VR up until that point got a good feel for what a VR should look and feel like.

G.3 Prototyping and Testing Results

Control Room Prototyping:

- The Control Room layout will be iteratively refined for intuitive navigation and interaction.
- Terminal interaction mechanics should be prototyped to allow seamless access to puzzles and mission objectives.

G.4 Final Design Details/Specifications

The final design consolidates gameplay into the Control Room while ensuring it remains engaging and meets educational and interactive goals. Key specifications include:

- **Control Room Design**:
    - **Terminal**: Central hub for all gameplay mechanics, presenting puzzles, minigames, and narrative progression in an integrated interface.
    - **Observation Window**: Real-time asteroid visuals enhance immersion and provide visual context for tasks.

- **Game Mechanics**:
    - **Puzzles and Minigames**:
        - Tasks such as sorting codes for unlocks, mini games or repair games around the ship.
- **Accessibility**:
    - Difficulty modes include:
        - Easy: Full hints and longer timer.
        - Medium: Limited hints and moderate timer.
        - Hard: No hints and strict timing.
- **Graphics and Immersion**:
    - The room features dynamic lighting, and Psyche-themed assets.
    - The asteroid view reacts to gameplay events, reinforcing the sense of progress.

Section H. Societal Impacts of Design

The Psyche VR game design has numerous societal impacts that align with its educational and inspirational goals.

One significant impact is educational outreach, where the game serves as an interactive tool to help teach students and the general public about NASA's Psyche mission in an interesting manner. By incorporating elements about the Psyche mission into an engaging virtual reality experience, the game makes raising education accessible and enjoyable for diverse audiences.

Another important contribution is raising public awareness. During some of NASA's tablings and exhibitions, this VR game will help explain some of Psyche's features and uses to the general public in an interactive way. It will also encourage players to think critically, analyze puzzles, and navigate a new space in order to solve a unique problem. These skills are vital in education and contribute to broader cognitive and analytical development.

This project also plays a vital role in inspiring the next generation of learners and developers. Young students who play this game would be interested in the fact that college students developed this, instead of companies that produce most of the games they have played. This may encourage them to go into the field of technology and/or space, influencing their career path to becoming future leaders in STEM.

Section I. Cost Analysis

When we create our game, we must consider the costs and materials that will be mandatory. The main item that will be required is the VR headset. We will specifically purchase the Meta Quest 3 headset for the creation of our game along with a handheld case for protection. Unity is the main software that we are using and there is an asset store that provides free and paid assets that can benefit specific parts of the game. Based on our ideas, we will incorporate space-theme assets from Unity to make the user experience as realistic as possible. Below is a simple overview of our expenditures and costs for our game.

Meta Quest

- Vendor Name: Amazon
- Parts included: 2 Meta Quests Touch Plus controllers, 2 Wrist Straps, USB-C charging cable, 2 AA batteries, 18w Power Adapter
- Quantity: 1
- Regular Cost: $499
- Manufacturing Cost: $391
    - Mainboard (RAM/ROM, chips, Bluetooth, etc.): $148
    - Sensors (IMU,PCB, etc.): $40
    - Optics (Pancake, LCD-screen, etc.): $130
    - Structure of Meta Quest 3: $16
    - Controllers: $32
    - Accessories: $6
    - Build-in Fans and Cooling: $5
    - Headphone Jack: $6
    - Batteries: $8
- Raw Materials: 8GB RAM, Time of Flight Sensors, 2064x2208 LCD panels, Adreno 740 GPU, 400x400px IR Camera, SnapDragon XR2, built-in speakers, 3.7 Lithium Volt Ion Battery
- Delivery time: 11/15/204
- Date received: 11/18/2024

Assets

- Vendor Name: Unity
- Quantity: 7
- Total Costs for all Assets: $45.99
    - Low Poly Sci-Fi Pack - Polyworks: $25
    - Keypad: FREE
    - Low Poly Sci-Fi Station Pack: FREE
    - Deep Space Skybox Pack: FREE
    - Asteroids: $16
    - Cute Robot Assistant: $4.99
    - Crystal and Gem Asset Pack: $16

Carrying Case

- Vendor Name: Amazon
- Quantity: 1

- Regular Cost: $49.88
- Manufacturing Costs: $22
    - Exterior design(zippers, straps, material, etc.): $12
    - Interior design(pockets, dividers, material, etc.): $10
- Raw Materials: felt, polymer, zippers, accessory strap, pockets
- Delivery time: 11/15/2024
- Date Received: 11/18/2024

Above are the simple breakdowns of everything that will be used in the creation of our game. The Meta Quest 3 has the most manufacturing costs out of the others because it will be the main item that will be used and there's a plethora of resources to create the headset. While we have assets as well, there aren't manufacturing costs because the Unity store doesn't provide much detail on how and what was used to create the asset. It makes it very challenging to navigate what was used. The carrying case has very little manufacturing costs as well due to the minimal amount of required items. Therefore, this concludes all of the costs that we will use when creating the game.

Section J. Conclusions and Recommendations

The design of the Psyche VR game evolved significantly through the iterative use of the engineering design process, incorporating continuous improvements and addressing challenges to achieve the project's goals. From initial concept to final implementation, the team focused on creating an engaging, educational, and user-friendly experience aligned with the objectives of promoting public awareness and inspiring interest in NASA's Psyche mission.

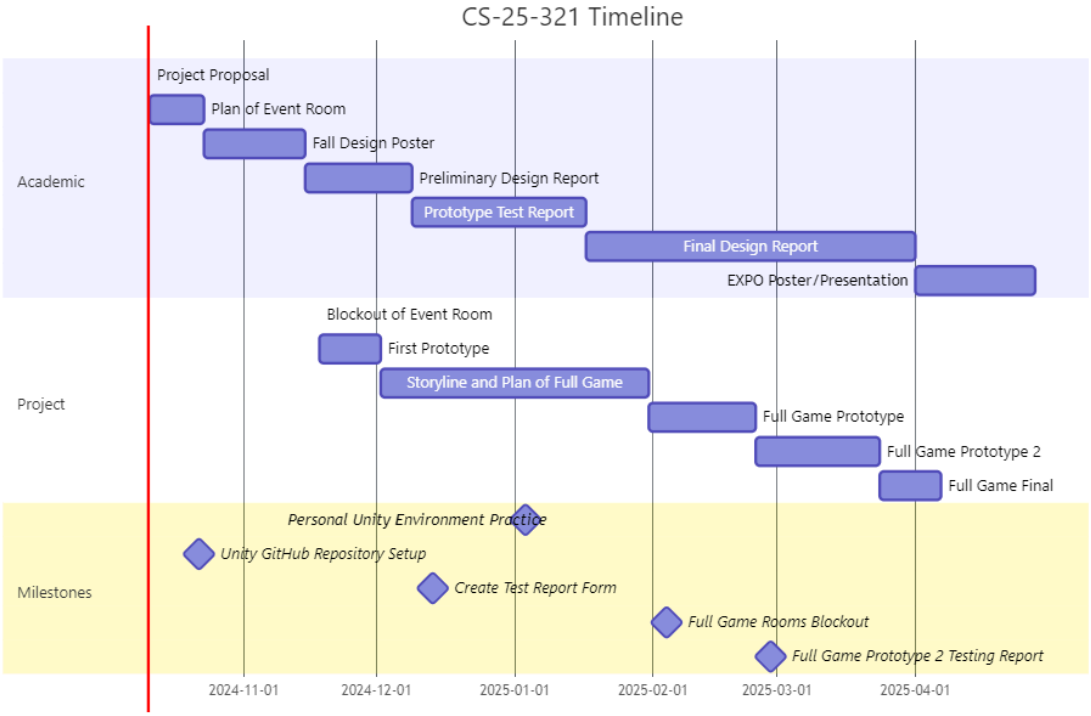
The journey began with exploring the different types of games available to us and basing our inspiration on those before us. After we had established our scope of intent, we then began brainstorming ideas for our game. We wanted our primary goals to be providing a realistic and immersive space environment, fostering critical thinking, and maintaining accessibility across VR platforms. After discussing with our mentors and advisors, we narrowed down our brainstorming to creating a virtual escape room.

Lessons learned during development included the importance of testing early and often to identify potential design flaws and the value of clear communication among team members and stakeholders.

Our final design will be a two minute event room where the player will have to decipher various clues and objects around the room, building on the previous one to figure a way to land the ship safely. After completion, the game can then be reset and passed on to the next person in line. The immersive visuals and engaging gameplay ensures the design will meet its objectives of educating and inspiring users while showcasing the Psyche mission.

Our original idea had a 20 minute story mode, where the player would have to navigate multiple rooms filled with puzzles that connect with each other. This idea was moved to the back burner, as we had to focus on making the event room the main focus. In future continuations, a full story mode would be a great inclusion to our event room.

Appendix 1: Project Timeline



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

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 better understanding each other's communication and working styles.

Team Member Name	***Strengths each member brings to the group***	***Other Info***	***Contact Info***
Akshara Rajesh	Communication, fast learner, and team worker	I enjoy spending time outside, watching TV, and reading new books. I have experience in Java, Python, C++, and SQL.	rajesha3@vcu.edu 703-338-4755
Ava Shilling	Problem-solving, good communication, on time	I like playing games and VR and I chose this project because it sounds very interesting and lines up to my interest. Worked with Java and C, Git and Github.	Shillingar@vcu.edu 540-255-6609
Quinton Jones	Ambitious, leadership qualities, perseverance	I like watching TV shows and anime, I love sports, and I enjoy playing video games, and bowling. Experienced with Java, Python, and SQL with a little experience with front-end development using React.	jonesql@vcu.edu 804-221-2401
Peter Nguyen	Hard worker, determined	I like games, fishing, and cooking. I have experience in Java, C++, python,	nguyenph11@vcu.edu 904-972-4126

Other Stakeholders	***Notes***	***Contact Info***

Rodrigo Spinola - faculty advisor	*Professor at VCU - available to talk/meet Mondays-Wednesday-Friday in the morning*	*spinolaro@vcu.edu*
Cassie Bowman - Sponsor	Associate Research Professor School of Earth and Space Exploration Arizona State University Co-Investigator, NASA Psyche Mission	*cbowman5@asu.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 they 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 cultural goals? These are your Actions (middle column). Finally, how do students deviate from the team's cultural 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 of Team Culture can be found on the Biodesign Student Guide "Intentional Teamwork" page (webpage | PDF)

Culture Goals	***Actions***	***Warning Signs***
Finishing goals on time	- Set up deadlines in a shared calendar - Send a reminder through Discord the day before the due date	- Student misses deadlines consistently - Student misses deadlines afterward – the issue is brought up with the faculty advisor
Informing the group of any delays in completing assignments	- Stay up to date with each other's project responsibilities - Set reasonable deadlines and communicate when an extension is needed	- Student shows up for weekly meeting with no considerable work done - Student consistently does not finish work or communicate – the issue is brought up with the faculty advisor
Keep an organized schedule and workflow.	- Set schedules and dates through Google Calendar - Allocated work/ document of everyone's roles	- Student is disorganized, not fulfilling the correct role - Student is disorganized and does not perform assigned work - the issue is brought up with the faculty advisor

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 the same person take on that role for the duration of the project?

Required: How often you will meet with your faculty 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	*Every Thursday at 5:15 pm*	*Update group on day-to-day challenges and accomplishments*
Students Only	*If needed, meet on discord*	*Update team on unexpected challenges/ revisions*
Students + Faculty advisor + Project sponsor	*Every other Monday (mostly) at 5:30 pm*	*Update faculty advisor and talk to sponsor about current work and expectations*
Students + Faculty advisor	*Every Wednesday at 10 am in his office*	*Update the faculty advisor and get answers to our questions*

Step 4: Determine Individual Roles and Responsibilities

Task: As part of the Capstone Team experience, each member will take on a leadership role ***and*** contribute 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 the 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 the 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 an overall schedule for the 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 Purchasing and Receiving project supplies.
2. **Logistics Manager:** coordinates all internal and external interactions; leads in establishing contact within and outside of the 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 the 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 findings 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***
Akshara Rajesh	Project Manager	✔ Develop a schedule for the team ✔ Review individual action items ✔ Make sure everyone understands what is going on
Peter Nguyen	Financial Manager	● Carries out purchase requests from the team ● Makes sure the team is staying within budget with purchase request
Quinton Jones	Logistics Manager	● Ensures that the team has meeting times documented ● Ensures that information will be gathered for the team ● Ensure that resourced usage is sufficient
Ava Shilling	Systems, Test, and Manufacturing Engineer	- Oversee experimental design and testing - Manage product to meet final prototype requirements

Step 5: Agree to the above team contract

Team Member: Peter Nguyen *Signature:* 

Team Member: Akshara Rajesh *Signature:* 

Team Member: Quinton Jones *Signature:* 

Team Member: Ava Shilling *Signature:* 

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.

Mann, Adam. Stein, Vicky. The Psyche mission: A visit to a metal asteroid. *Space.com.* Retrieved October 7, 2024. https://www.space.com/psyche-mission-metal-asteroid.html

Mission. *Psyche ASU.* Retrieved October 7, 2024. https://psyche.asu.edu/mission/

NASA's Psyche Mission Could Unlock Secrets to How Planets Are Formed. (2024, February 26) *Aerospace*. Retrieved October 7, 2024. https://aerospace.org/article/nasas-psyche-mission-could-unlock-secrets-how-planets-are-formed

Psyche. *Jet Propulsion Labratory.* Retrieved October 7, 2024. https://www.jpl.nasa.gov/missions/psyche/

Psyche Spacecraft. *NASA.* Retrieved October 7, 2024. https://science.nasa.gov/mission/psyche/spacecraft/

[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