

# Final Project Report: Mixed Reality Alien Shooter

**Team Members:** Bhanu Chandra Pachipala, Zhiyu Lan, James Davis

**Github:** [https://github.com/PinYin-Software-Developers/CS5097-Mixed\\_Reality.git](https://github.com/PinYin-Software-Developers/CS5097-Mixed_Reality.git)

## Introduction

The team built a mixed reality game where players shoot virtual aliens in a real world environment. The game uses the Meta Quest 3's cameras to display the player's physical room with their real furniture and other objects in the surrounding scene. It adds virtual elements: aliens, lasers, and other effects.

Players first scan the room, then the game begins with aliens that come through a virtual stargate portal with musical accompaniment. The player fights the aliens with a virtual laser gun that maps to the physical right hand-controller.

## Key Features and Highlights

- **Room Scanning System**

Players are prompted to scan their physical space using Meta Quest 3's sensors before gameplay begins. Using Meta's scene tools, we generate a 3D mesh (Effect Mesh) of walls, furniture, and obstacles. This mesh allows aliens to avoid passing through real objects and determines where fixed elements such as the Infinity Stone can relocate by re-spawning. If players move to a new room, the game automatically asks them to scan again and to map the new game boundary before the game begins.

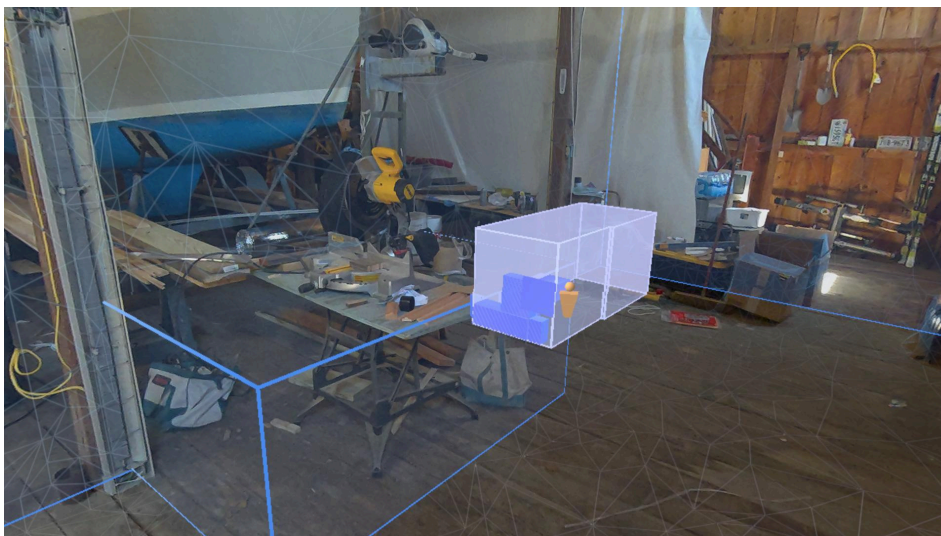


Figure 1: Room Scanning at the beginning of the game

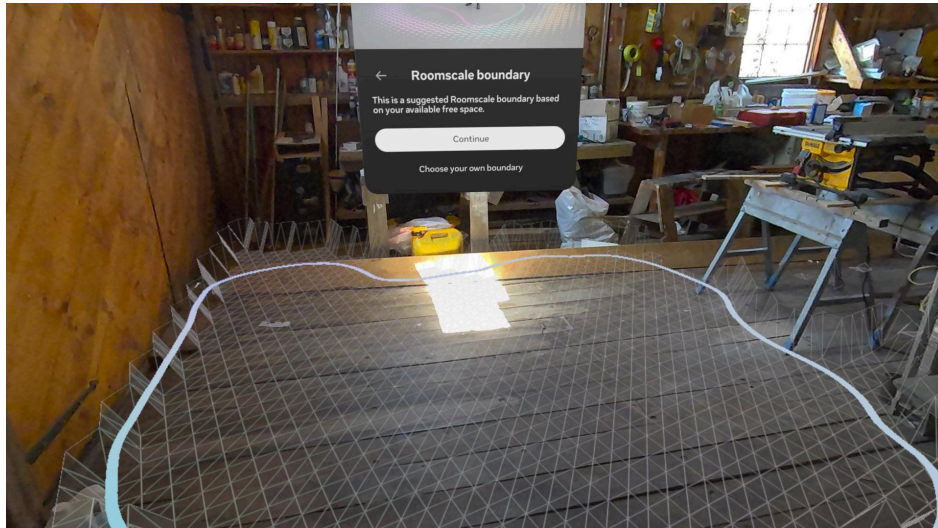


Figure 2: Boundary Mapping at the beginning of the game

- **True Free Movement**

Unlike traditional VR games that restrict movement, our game uses the player's entire scanned space. Players can walk around freely, duck behind real furniture, or use walls as cover. Both aliens and the Infinity Stone can appear anywhere within the scanned area, making each session unique and reinforcing the illusion that the game is taking place inside the player's actual room.



Figure 3: Gameplay with Aliens and gun in the real environment

- **Passthrough View of the Real World**

The game uses the MetaQuest 3's full-color passthrough cameras to show the real world, onto which virtual elements like aliens, portals, and laser effects are layered. The gun moves with the player's hand in real-time, creating a convincing 3D illusion of interacting with both virtual and physical elements.

- **Laser Shooting and Visual Effects**

When players shoot, the laser tracks the gun's orientation and fires in the corresponding direction. When it hits a real-world surface, a visible splatter effect appears at the impact point. When it hits an alien, the alien plays a death animation and disappears. Accompanying sound effects for shooting and hitting targets enhance the feedback and realism.

- **Alien Spawning and Movement**

Aliens emerge from a floating "Stargate" portal and gradually increase in number. They use the scanned room mesh to navigate intelligently, avoiding obstacles while chasing the player. This behavior makes the game more immersive and action-packed.

- **The Infinity Stone – A Win Condition**

To avoid endless gameplay, we introduced a glowing Infinity Stone that moves between different positions in the room. When the player successfully shoots it, it begins to blink and shuts down the Stargate, stopping the alien invasion. This provides a quick way to win the game.

## Background

Mixed Reality (MR) gaming has grown rapidly with the release of devices like the Meta Quest 3, which support full-color passthrough and advanced spatial awareness. These capabilities allow digital content to be layered onto the physical world, creating immersive experiences where virtual elements can interact with real-world environments and objects.

Several MR games and demos inspired our project, especially in how they use room scanning, passthrough vision, and interaction design:

- First Encounters, a demo built by Meta, lets aliens burst through the walls of a player's real room, showcasing how MR can blend physical and virtual spaces in fun, surprising ways.
- Espire 2 MR Missions allows players to sneak around real furniture and use it for cover.
- Demeo: Mixed Reality Mode projects a virtual game board onto real-world surfaces like a table, letting players move naturally around their environment.

Inspired by these examples, we wanted to explore how virtual aliens could navigate a real-world setting with scanned furniture and walls. By prompting the player to walk freely and scan their space, we aimed to demonstrate a true MR experience.

Additionally, Meta's built-in tools—such as spatial mapping, passthrough, and hand/controller tracking—provided a technical foundation for building this experience.

- For room scanning, MR systems can construct a digital representation of the user's physical space. This enables virtual objects to interact with

real-world furniture and boundaries. Meta's **Scene API** supports **scene mesh generation (MetaHorizon, 2024)**<sup>1</sup>, allowing developers to anchor game logic to real-world features.

- For Passthrough, the Meta Quest 3 improves upon earlier models by offering **full-color passthrough<sup>2</sup> with depth information**, making it possible to blend virtual effects with physical surroundings in a convincing way. Prior research by **Julia Woodward and Jaime Ruiz (2023)**<sup>3</sup> shows that high-fidelity passthrough significantly enhances situational awareness and user comfort in XR experiences.
- For interacting with aliens, shooting effects such as **surface splatter**, **beam tracking** were informed by principles from **Multimodal User Experience in Extended Reality: Exploring Hand Tracking, Voice, and Passthrough Interactions**<sup>4</sup> where feedback through visuals and sound strengthens the connection between player and system. The aliens' movement uses **NavMesh-style logic** constrained by the scanned room mesh. This design builds on techniques used in AI pathfinding research (see **Unity AI Navigation Toolkit**<sup>5</sup>).

## Methods

The team used the Unity development environment for Apple silicon and Meta software tools: Meta XR MR, Effect Mesh and NavMesh.

## Tools Used

Our development environment was **Unity**, which we used to design the game logic, implement interactions, and integrate 3D assets. We downloaded 3D models (such as aliens, laser guns, and the stargate portal) from **Sketchfab**, and audio assets (including gunfire sound effects and background music) from **Freesound.org**.

We scripted custom behaviors and interactions in **C#**, defining how models and prefabs move, animate, and respond to player actions. Additionally, we downloaded and integrated various SDKs and plugins from the **Unity Asset Store** and **Meta's developer tools**.

## How It Works

Our game uses several **Mixed Reality (MR) building blocks** provided by Meta to enable key features:

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<sup>1</sup> <https://developers.meta.com/horizon/documentation/unity/unity-scene-overview>

<sup>2</sup> <https://developers.meta.com/horizon/documentation/unity/unity-passthrough>

<sup>3</sup> <https://ieeexplore.ieee.org/abstract/document/9676467/authors#authors>

<sup>4</sup> <https://dl.acm.org/doi/abs/10.1145/3712677.3720459>

<sup>5</sup> <https://docs.unity3d.com/Packages/com.unity.ai.navigation@2.0/manual/CreateNavMesh.html>



- **Passthrough Building Block:** We use it to allow players to see their real environment through the Meta Quest 3 headset's cameras. This is essential for merging virtual elements (aliens, effects) with the player's physical space.
- **XR MR Utility Kit:** Used for enabling **room scanning** and scene understanding. It helps the developer to dynamically map the player's physical environment in real-time, generating a mesh of walls, furniture, and obstacles.
- **Effect Mesh Building Block:** Helps display interactions such as lasers hitting surfaces or aliens. These visual cues enhance feedback and immersion.
- **Camera Rig Building Block:** Tracks the player's head and hand movements, syncing the virtual camera with physical motion for realistic viewing angles.
- **Real Hand and Grabbable Building Blocks:** Enables interaction with virtual objects using the hand controllers. The gun, for instance, can be grabbed, aimed, and fired.
- **Destructible Mesh Building Block:** Allows parts of the environment (e.g., fake walls or objects) to break apart when hit by lasers, adding dynamic feedback.
- **NavMesh:** Used to define how virtual aliens move around the scanned room. Aliens can walk around furniture and navigate the environment intelligently by referencing the generated room mesh.

We also relied on tutorials and documentation from Meta's developer portal and Unity's community to guide our implementation. These resources helped us understand best practices for spatial computing, controller tracking, and MR interaction design.

By combining these tools and techniques, we created a fully interactive MR game where digital enemies respond intelligently to the real-world layout and the player's actions.

## Limitations

### Room Scanning Problems

We struggled most to get reliable room scans. First we tried using the Scene API and XML files to load room data, but this often failed with missing walls or incorrect shapes. Next, we tested the XR MR Utility Kit<sup>6</sup> alone to scan the area, collect the data points and render it in Unity, but this proved to be unworkable. Finally, we used Meta's passthrough mode and the XR MR Utility kit with Effect Mesh<sup>7</sup> to interact with the scanned data for the best results. Even then, we needed to perform many tests to handle different room types and lighting conditions.

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<sup>6</sup> <https://developers.meta.com/horizon/downloads/package/meta-xr-mr-utility-kit-upm/>

<sup>7</sup> <https://developers.meta.com/horizon/blog/mesh-depth-api-meta-quest-3-developers-mixed-reality/>

## Alien Navigation Issues

Early versions had aliens getting stuck on furniture or passing through walls. We fixed this by adjusting the NavMesh<sup>8</sup> settings and making sure the scanned room mesh matched the real space properly. Now aliens can navigate freely around most objects.

## Other Project Limitations

All team members use the Mac development platform with Apple silicon. This has some inherent disadvantages relative to the PC in that most VR tools are made for the PC. While the MetaQuest 3 headset and Unity is compatible with the Mac, an important and time-saving test feature is not available for Mac developers, in that the Meta XR Simulator and Meta Link are unavailable for the Mac version of Unity. Hence the team was completely reliant upon downloading compiled code to the headset for all incremental software testing for build and run. Software builds could not be tested on the laptop.

## Future Work

The team had a relatively short amount of time to develop their application but many additional features could be added to the game such as having the aliens follow more complex flight paths, adding new characters and weapons and introducing multiplayer action and scorekeeping.

The team is most excited about integrating AI tools<sup>9</sup> such as computer vision and speech recognition to make future versions of the game more intelligent.

The team believes that MR, AR, and VR has many applications for the professional and consumer markets in addition to video games. The price point of MetaQuest headsets depending on the model (\$260 - \$500) places them well in the range of the latest Sony Playstation, the Microsoft Xbox and the Nintendo Switch game consoles. Currently the more affordable MetaQuest 3S is the top seller on Amazon<sup>10</sup> and approximately 1.5 million units have been sold since the product was announced. Compare this to 231 million iPhones sold<sup>11</sup> in 2023, and it is evident that the market size for VR applications is much smaller by comparison with smart phone applications.

Beyond gaming and entertainment, professional applications for AR and MR visualization in such fields as military training, drone operations, aircraft pilot/ship training, civil engineering, mining and oil exploration, architecture/construction and medical imaging could provide significant opportunities for software developers.

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<sup>8</sup> [https://developers.meta.com/horizon-worlds/reference/2.0.0/navmesh\\_navmesh](https://developers.meta.com/horizon-worlds/reference/2.0.0/navmesh_navmesh)

<sup>9</sup> <https://doi.ieeecomputersociety.org/10.1109/MCG.2025.3548554>

<sup>10</sup> <https://nwn.blogs.com/nwn/2024/02/quest-3-install-base-q4-2023.html>

<sup>11</sup> <https://www.demandsage.com/iphone-user-statistics/#:~:text=Apple%20sold%20151.3%20million%20iPhones,million%20iPhone%20units%20in%202023>

Given the growing interest in MR, AR and VR and the enormous investment<sup>12</sup> made by Meta, Apple, Sony, Nvidia, Google, Microsoft, Qualcomm, Amazon, HTC, Unity Technology and others in the evolving technologies, the market for commercial applications will likely continue to grow.

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<sup>12</sup> <https://aimagazine.com/top10/top-10-vr-companies>