MOONSHOTS: Moonshooters

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1 Introduction

MOONSHOTS ‘24 was an initiative by the Netherlands Space Office (NSO) and astronaut André Kuipers. It challenged 250 students in the Netherlands to develop bold ideas to improve space missions or life on Earth. Over ten months, a 100 teams worked on their projects, supported by astronaut mentors. The program included exclusive events, expert guidance, and a kickoff at the European Space Agency – European Space Research and Technology Centre (ESA – ESTEC). Here, we had to pitch our ideas. After months of research, brainstorming, and development, we refined our concepts and presented them to astronauts and other students. This led to the idea of creating a video game for astronauts to play in space.

Space travel can be a stressful and isolating experience for astronauts. Long missions with limited social interaction and repetitive daily routines can affect their mental well-being [1]. The feelings of isolation possibly lead to stress, anxiety, fatigue, sleep problems, irritability, mood swings, negative emotions, and emotional distress [2][3]. Therefore, our project tries to address this issue by creating an interactive game designed specifically for astronauts aboard the International Space Station (ISS). We aim to create a game specifically tailored for astronauts in space to assist with improving their mental health by providing them with a playful and engaging distraction. During astronaut' downtime, it can be beneficial for their mental well-being to relax [4]. A systematic review of multiple studies suggests that video games can help in relaxation and in reducing stress and anxiety [5]. Providing a new form of entertainment and relaxation in the form of a video game might therefore help improve astronauts' mental health [4].

Astronauts have repeatedly reported enjoying looking at the earth from space. When astronauts look at Earth from space, they often feel deep emotions and a strong connection to our planet. This experience, known as the "Overview Effect", changes their perspective [1][6]. Many struggle to describe the experience but return with a greater desire to protect Earth. In some cases, the Overview Effect helps astronauts stay mindful during their missions. It reduces stress and improves focus in the challenging space environment [7]. The game for this project is intended to make use of the actual space environment that can be seen when looking out the windows of the cupola of the ISS. The objective is to shoot as many asteroids as you can before losing all lives. Aside from simply playing the game, being surrounded by the view and seeing Earth can further provide a sense of calm and mental relief. In short, the final concept is a game where astronauts engage with asteroids while looking through the cupola windows. This combines entertainment with the space environment, making the experience unique to life on the ISS.

This report describes the development of the prototype of an interactive game designed to help astronauts relax in space. This game is a space shooter game incorporated into the real environment. In this report the main concept and the research process before the implementation of the game are explained. Furthermore, this paper explains the intended technical implementation, as well as, the game design and development, and the challenges we faced along the way. It also covers user feedback, and future developments and improvements of the game. To conclude the entire process of the moonshots project, we reflect on the process, how it relates to Media Technology, and what we learned.

2 From Research Insights to Project Concept

The idea for this project developed through many discussions, brainstorming sessions, and research. As part of MOONSHOTS '24, we were encouraged to think big and come up with ideas that were not necessarily feasible. Due to this, we explored many different ideas at first. We considered practical solutions for space travel, tools for astronauts, and ways to improve communication with Earth and staying connected to loved ones. These ideas were worked out during weekly meetings and documented on a shared Miro board. However, after reviewing various options, we decided to focus on astronaut mental health.

Space travel is mentally and physically demanding. Astronauts experience long periods of isolation, high stress, and a lack of personal space. As discussed earlier, over time, this can lead to emotional distress, fatigue, and sleep problems. To support astronaut well-being, we looked into recreational activities and their impact. Studies suggest that video games can help people relax and reduce stress. This led us to the idea of creating a game specifically designed to be played aboard the ISS.

In general, video games can be played everywhere and by everyone as long as they have a gaming console or a phone. On top of that, many video games exist, including space shooter games. Therefore, a challenge for this project was finding a unique approach that went beyond a standard video game to make it innovative and suitable for a space project. To make the game truly unique to the actual space exploration experience, we wanted to use the real space environment. Since astronauts already enjoy looking out from the ISS cupola, we decided to build a game that would merge the beauty of space with interactive gameplay.

Before settling on a final game concept, we first needed to understand the equipment available to astronauts on the ISS. This included examining the Cupola's layout and the amount of space inside it. Understanding these factors was essential for deciding how the game would be controlled. There were multiple options, ranging from traditional hand-held controllers to gesture-based systems. We explored different control methods, including motion gestures, pointer devices like a Wii controller, standard game controllers, and sensor-equipped gloves. The main priorities were comfort, ease of use, and functionality in microgravity.

The Cupola is a small observatory module on the ISS (Figure 1). It consists of seven windows. These windows provide astronauts with a panoramic view of space [8]. This area is often used for observational tasks, but astronauts also spend time there to enjoy the view. For this project, we wanted to use the view of the Cupola as part of the game experience to take advantage of the space environment. To make the game fit the conditions of space better, it is intended to work with the existing surroundings. In order to do this, the initial idea was to project the game directly onto the Cupola windows. This would allow astronauts to interact with the game while still seeing space through the window. However, this came with challenges. The brightness of Earth and the reflection of light could interfere with the projection. On top of this, when using a projector, it needs to be ensured that the player does not block the projection on the window while playing the game. There were also concerns about how well projections would work on the glass. Multiple alternatives were considered such as using special projection-friendly glass, transparent screens placed over the windows, or even transparent OLED displays. Each of these options had its own advantages and limitations in the ISS environment. Although the idea for the MOONSHOTS '24 project did not need to be feasible to implement, we still wanted it to be a realistic possibility. Therefore, after having discussed multiple options with astronaut Andrew Feustel, we decided to shift the display method to AR glasses instead of a projection. Andrew Feustel mentioned that they already use AR glasses on the ISS. Based on this, we decided it would be more practical to incorporate technology that astronauts are already familiar with, and is already aboard the ISS. The game will still be based on the real view outside the Cupola but is now intended to be visible through augmented reality. This way, astronauts can play without requiring physical modifications to the ISS. The AR system should detect when they look at the Cupola window and display the game elements onto their field of vision.

Figure 1: A photo of the Cupola. This is an observatory module of the International Space Station (ISS) [8].

3 Technical Implementation

The game was developed using Unity for creating the game and Blender for 3D modeling of asteroids. With these tools we could create a functional prototype with animations, sound effects, and scoring. Since astronauts experience microgravity, the game had to be designed in a way that did not require a stable surface or fixed positioning. The prototype was built with inspiration drawn from an online tutorial for the environment. The different game mechanics and elements were implemented by ourselves.

The prototype was built to eventually potentially be implemented into AR glasses. The AR glasses are supposed to create an interactive experience that takes advantage of the space environment. To implement this game into AR glasses, several technical components would be required. The AR system would need to detect when an astronaut is looking at the cupola window and overlay the game elements accordingly. This could be achieved using computer vision and spatial tracking. Computer vision is a technology that allows AR glasses to recognize objects and environments. It would help the system detect the cupola window and understand where the astronaut is looking. Spatial tracking allows virtual objects, like asteroids, to stay in place even when the astronaut moves. It would allow for accurately overlaying virtual content onto the actual environment the astronaut is in.

To interact with the game, different control methods were considered:

- **Eye tracking**: the astronaut aims by looking at an asteroid. Blinking multiple times or a head movement could trigger a shot.
- **Hand gestures**: the system detects simple hand movements, like pointing, to fire at targets.
- **Small controller**: a (handheld) device or glove with sensors could be used for extra control.

For this project, we decided that using an arcade-style controller with a simple joystick and buttons would be the most fitting. This is because it would provide a reliable and familiar control method that is easy to use in such little space since the cupola is small. Gesture-based controls could be imprecise in weightlessness, and eye tracking may cause strain over time or could be too complicated to control. A joystick with buttons setup ensures accurate input while keeping the experience simple and engaging. An example of such a controller can be seen in Figure 2. The joystick can be used for looking around and aiming, and the button for shooting at asteroids. For the prototype, we simply used the computer keys "A" and "D" to avoid asteroids. The computer mouse can be used for looking around and shooting projectiles.
Since we only intended to create a demo of the game without implementing it in AR, we did not run into a lot of technical difficulties. The main challenges were to create a 3D model of an asteroid in blender, and to

Figure 2: An example of an arcade joystick controller intended for the final prototype [9].

ensure an animation would play if an asteroid collided with the spaceship or got shot. This was especially difficult since neither of us had any experience in working with blender or 3D animations. Besides these challenges, we also ran into some programming issues. It was hard to ensure aiming of projectiles worked correctly. Furthermore, it was challenging to detect collision between asteroids and a projectile since the asteroids were part of a particle system. However, after a lot of trial and error, we managed to figure it out.

If the game were fully developed for AR glasses, additional challenges would need to be addressed. Head tracking and spatial stability could be unreliable in microgravity, as unintentional movements might cause objects to shift in the astronaut's view. Detecting the cupola window accurately could also be a challenge. The system would need to recognize when the astronaut is actually looking at the window rather than just glancing in its direction. If the tracking is too sensitive, the game might appear at the wrong times. If it is not sensitive enough, the game might not activate when intended or could suddenly stop while playing.

4 Game Design & Prototype

The game is a simple space shooter where players control a spaceship, and avoid and shoot asteroids. The goal is to destroy as many asteroids as possible before losing all three lives. A scoring system tracks performance where hitting an asteroid earns you 5 points. The three hearts indicate remaining lives. If a heart is grayed out it means that life has been lost. When an asteroid hits the spaceship, the player loses a life. If all lives are lost, the game ends, displaying a game over screen with the final score. If a player hits an asteroid when shooting a projectile, or if a player gets hit by an asteroid, an animation gets played where you can see the asteroid breaking.

For the prototype, the background simulates space and a spaceship window is displayed. Asteroids are flying around in space. The game also includes sound effects for shooting, asteroid destruction, and taking damage to make the experience more immersive. We did not implement background music or sound effects for flying around, to ensure the game remained simple and relaxing instead of becoming overwhelming. To add an extra layer of motivation, we implemented a score. A leaderboard feature is intended to be added for the actual AR game. This would allow astronauts to compare their scores with each other or even with astronauts who had previously played the game that are no longer aboard the ISS. The idea is to encourage a friendly sense of competition while keeping the focus on relaxation and distraction. The created prototype demonstrates the core mechanics of the game.

The game design itself was kept simple and easy to understand. The game is meant to be relaxing but still engaging, so the difficulty had to be balanced. The design was intended to be intuitive to make it easy to understand for astronauts of different ages and gaming experiences. The hearts were chosen to represent lives because they are a familiar symbol in many games, making it clear how many chances the player has left. For non-gamers hearts are still universal icons that are associated with lives. The score is displayed at the top left, and the lives are shown at the top right. This was done to keep important information easily visible without distracting from gameplay. For the prototype, we used basic mouse controls to move the aim and click to shoot. In the future AR version, a joystick and button controller will be used to keep controls straightforward. This is to hopefully ensure astronauts can play comfortably in a small environment and without complicated controls.

Below, screenshots of the prototype can be found. The game starts with a simple starting screen that can be seen in Figure 3. This screen displays the title of the game and the start button. Figure 4 shows the player flying around in space while shooting at asteroids. The obtained score is displayed at the top left of the screen. On the right, the hearts show how many lives the player has left. Figures 5 and 6 show the animation that gets played once a player hits an asteroid or gets hit by an asteroid. Once a player has lost all three lives, they are game over as can be seen in Figure 7. After this, the player gets directed to the game over screen (Figure 8) where the final obtained score is displayed, and where the player can restart the game.

Figure 3: Starting screen of the prototype.

Figure 4: Prototype interface where the player is flying around in space and shooting at asteroids.

Figure 5: Prototype interface where the player successfully shot an asteroid.

Figure 6: Prototype interface where the player was hit by an asteroid.

Figure 7: Prototype interface where the player lost all lives and is game over.

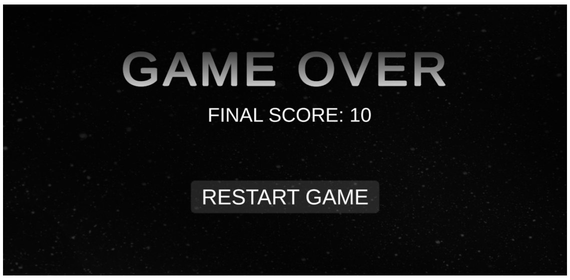

Figure 8: Game over screen of the prototype.

5 User Testing & Results

The game prototype was tested in two different settings. The first test took place at the final Moonshots event on October 2, 2024 at the Leiden Instrument Maker School (LiS). Our target users are astronauts. Since it is difficult to approach astronauts and ask them to participate in testing a prototype, this event was the perfect opportunity to get feedback from actual astronauts. Here we presented an early version of the game, and pitched our entire idea. The presentation was held by Christina Irakleous, Annelies Vaandrager, and us since we started out this project together. The presented prototype version allowed players to fly around and dodge asteroids. However, projectiles had no effect when hitting an asteroid. The audience included university and applied sciences students, applied sciences teachers, and astronauts Bill McArthur and Michael Fossum. Figure 11. shows a photo of us at the moonshots event with Bill McArthur and Michael Fossum. The feedback from this test focused on the overall concept rather than usability. The responses from the entire audience were very positive, especially from Bill and Michael. The astronauts suggested adding a scoring system and leaderboards to encourage competition among astronauts to make it more fun. During the presentation we mentioned a multiplayer function even though we realized it would be very difficult to implement. Bill and Michael confirmed the difficulties of implementing a multiplayer mode due to the communication delay between the ISS and Earth.

The second test was conducted with 10 family members and students in the week of February 3, 2025. 2 of them did not have any gaming experience, and the ages of the users ranged between 22 and 55. They played the game while we observed the usability aspects we had set beforehand (Figure 9). Participants played the updated version of the game, which now included functional shooting mechanics, asteroid destruction animations, a scoring system, sound effects, and a game-over screen. After playing, they were interviewed about their experience. A few more adjustments were made to the prototype after the second evaluation to make the game run more smoothly and allow for better aiming of projectiles.

Usability Attribute	Measurement	Metric Unit	Worst Possible Score	Worst Acceptable Score	Target Score	Best Possible Score	Results (average)
Learnability	Time to learn controls	Seconds	∞	30	15	0	17
Functionality	Score obtained in first playthrough	score from 0 to ∞ (increments of 5)	0	5	15	∞	14.5
Familiarity	Number of mistakes in using controls	# of errors	∞	4	1	0	1.3
Engagement	Players wanting to replay the game	% of testers	0%	50%	75%	100%	80%
Usability	System Usability	Score from 1 to 10 (interview)	1	5.5	7.5	10	8.2

Figure 9: Usability specification with the worst possible scores (red), the worst acceptable scores (yellow), the best possible scores (light green), and the target scores (green) for each usability attribute and metric. The measurement column shows what was measured to evaluate the usability attribute. The metric unit column shows what metric unit was used to measure the usability metric. Result averages of the usability attributes measured during the user evaluations are highlighted in purple.

The usability test results are visible in Figures 9 and 10. Figure 9 shows the predefined usability specifications and the average results of all the tests for the second evaluation. Figure 10 shows the results of every single tester for each usability attribute. The results show that players learned the controls fairly quickly, with an average learning time of 17 seconds. The average number of mistakes when using the controls was 1.3 per player. Most players adapted to keyboard controls with minimal errors. Unfortunately, both averages are slightly above the target score we were aiming for. On a positive note, both are still above the worst acceptable scores we had set. However, since the controls of the tested prototype were on the computer, it can't be fully compared to the intended controls with a controller within the AR environment. Scores in the first playthrough varied, but we noticed that most players improved in their second attempt. This shows that the game mechanics were easy to learn and get used to. However, players did report that they thought the asteroids and spaceship were moving too fast. This caused some frustration in a few users due to not being able to hit more asteroids. Therefore, we decided to make it a little easier

	Time to Learn Controls (s)	Score in First Playthrough	Mistakes in Using Controls	Wants to Replay (yes/no)	System Usability (1-10)
User 1	18	10	1	yes	8
User 2	4	15	0	yes	9.5
User 3	25	5	3	no	7
User 4	9	20	0	yes	9
User 5	22	10	2	yes	7.5
User 6	10	15	1	yes	9
User 7	15	20	0	yes	8.5
User 8	25	10	1	yes	7.5
User 9	12	25	1	yes	9
User 10	30	5	4	no	7

Figure 10: Results for each usability attribute for every user tester.

after the user evaluation. Engagement was also high, with 80% of participants expressing a desire to replay the game. At the end, we asked the users to rate the usability of the game on a scale from 1 to 10. With usability, we mean how usable the game is, meaning how easy the game is to understand, navigate, and play without confusion or frustration. The average usability rating from participants was 8.2 out of 10. This suggests a positive experience. Players mentioned they appreciated the simplicity of the game. They also mentioned the game was engaging without being too stressful. The score feature was well received, with several testers mentioning that they liked the competitive element. There were no relations found between the users' ages, level of gaming experience, and their performance within the game.

While the main mechanics worked well, several possible improvements were mentioned by our testers. Some users found aiming difficult, so we decided to refine the sensitivity of the camera moving, as well as making aiming more accurate with the computer mouse position. Others mentioned that more variety in gameplay, such as different asteroid speeds and sizes, could make the game more engaging. Additionally, they all mentioned they liked the idea incorporating the real space environment with the help of AR glasses on the ISS. They think it could be a good distraction while aboard the ISS that could be considered relaxing.

6 Conclusion & Future Work

During this project we developed a space-themed prototype game designed to help astronauts relax during their missions. The prototype demonstrated key gameplay mechanics, including asteroid shooting, scoring, sound effects, and simple controls. The two evaluations suggest that the game was engaging and easy to learn. Users responded positively to its intuitive design. The feedback gathered will help refine the concept further.
The game's potential impact on astronaut well-being lies in its ability to provide a fun and immersive distraction. By integrating the real space environment in the future with the help of AR, it might offer a unique form of relaxation. The score system could also encourage friendly competition among astronauts. This adds a social element to the experience.

Future improvements could include expanding gameplay features, such as different asteroid types or levels of difficulty. Although multiplayer is not feasible due to ISS-Earth communication delays, local multiplayer between astronauts aboard the ISS could be explored. Since we aimed to simply build a prototype for the computer, AR development is still necessary to ensure smooth gameplay in the actual space environment through the windows of the Cupola of the ISS. Another exciting possibility is integrating real space data, such as space weather conditions. This could make the game more immersive to astronauts' surroundings.

7 Reflection & Final Remarks

This project brought together literature research, technical skills, and interdisciplinary collaboration. This aligns with the Media Technology MSc. The program encourages research through creative output, which was an important aspect of our project. We applied both technical and creative problem-solving skills to develop a prototype of an interactive game for astronauts. We combined research on astronaut psychology with game development.

Through this process, we gained more experience in Unity for game development. Especially since we had to learn how to create 3D animations within unity. Furthermore, we had to learn working with Blender for 3D modeling. Additionally, working on this project strengthened our ability to communicate and collaborate across disciplines. We had to engage with astronauts and experts throughout the Moonshots events. Talking to astronauts and researching online gave us insight into the practical constraints of the environment of the Cupola on the ISS, helping us refine our concept. Not only did we gain information by talking to people from different disciplines, we also learned how to communicate certain technical game development and game design aspects with people who do not have this knowledge.

The project also reflects the Media Technology approach of using different (creative) methods to explore scientific topics. We tried to find a playful solution to a serious problem, and considered real-world constraints while working out a unique interaction concept. Thinking about the design for a microgravity environment and AR concepts further challenged us to think beyond standard game design. In addition, it pushed us to do more research on AR and discuss this with actual astronauts.

Overall, this project allowed us to integrate skills from research, programming, and creative development while exploring an innovative idea. It showed how creative technology can be used to address real-world challenges. Throughout the Media Technology program, we have often incorporated game design or game elements into our projects. We both took the course ''Video Games for Research", which introduced us to the idea that games are not just for entertainment or learning but can also serve as tools for research and problem-solving. This project reinforced that idea by allowing us to design a game with a specific purpose. Developing this game for MOONSHOTS '24 was in line with our interest in games and game development. It gave us the opportunity to apply what we learned in previous projects while expanding our skills. The project challenged us to think beyond traditional game mechanics and consider real-world conditions like microgravity and the use of AR in a confined environment. It also further improved our ability to integrate research and creativity in a possibly meaningful way. This experience added to our master's program trajectory by strengthening our interest in game development as a tool for research and practical applications.

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Appendix

Relevant additional information can be found on:

- The MOONSHOTS website: https://moonshots24.nl/en/
- Our website: https://xristinair.wixsite.com/media-techstronauts
- Our Miro board: https://miro.com/app/board/uXjVNnKZQdw=/?share_link_id=490104227350

MOONSHOTS event:

Figure 11: Christina Irakleous, Michael Fossum, Nikki Rademaker, Yanna Smid, Bill McArthur, and Annelies Vaandrager at the MOONSHOTS '24 final event.