

Gaming Beyond Earth

High-Level Project Summary

Leveraging the unique conditions of microgravity, our project aims to develop a cognitive training device that also functions as an interactive game for astronauts. Our device comprises small, portable LED screens with motion sensors (10cmx10cm). With these screens, we can create various activities such as speed and agility games, reflex challenges, and competitive modes. Depending on the selected game mode, the devices can be used in a specific room or distributed.

To further enhance the physical aspect, astronauts will wear a harness-style vest equipped with an elastic band connected to the wrist, providing resistance to the arms during gameplay. Additionally, the vest will feature a health monitor to track the astronauts' physical condition in real time, ensuring both safety and performance optimization.

By combining mental and physical stimulation in an engaging, competitive format, the device helps astronauts maintain cognitive acuity and physical coordination in microgravity. This innovation is vital as it fosters both mental sharpness and physical fitness, which are critical for astronauts' well-being in space, especially within the unique constraints of microgravity.

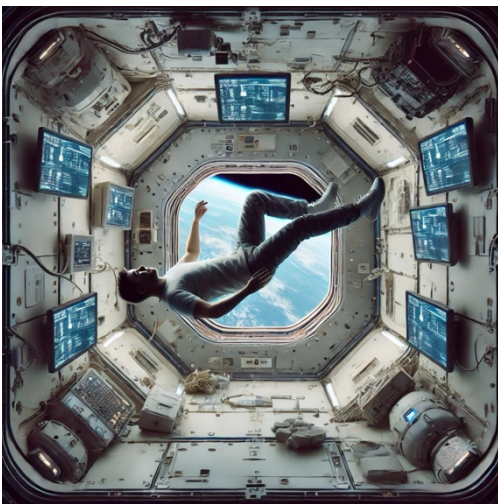
Detailed Project Description

- What exactly does it do?

Our game is an interactive LED-based game specifically tailored for astronauts in a microgravity environment. The game utilizes a combination of LED lights, haptic feedback, and resistance mechanics to create a stimulating experience.

- How does it work?

There are two main game modes: **Free** and **Stationary**. The free mode focuses on memory tasks, a race, and an All In One option, which can be played solo or with others. The screens can be set up in one location or spread out, allowing for flexible and dynamic gameplay. In Stationary mode, the LEDs are fixed in designated positions. It includes sub-modes such as memory, learning, and musical challenges, combining physical strength (enhanced by the vest) and reflexes.



Memory Mode:

In this mode, the cognitive training devices light up in a specific sequence, and the user must press the devices in the correct order.

Learning Mode:

On the tablet used to configure the game modes, a question with multiple-choice answers appears. Each

device corresponds to one of the options, and the player must press the device with the correct answer.

Musical Mode:

The tablet will display a song, and the player must press the device at the correct moments to keep the song playing accurately. Failing to do so will either mute or distort the chord.

Race Mode:

This mode can be played competitively or individually. In solo play, the player must press the devices as quickly as possible as they light up. In competitive mode, astronauts race to see who can press them first.

Force and Reflex Mode:

This mode utilizes the specially designed harness, applying force to the muscles when the arms are stretched. The goal is to press the devices as quickly as possible.

All in One Mode:

You are in an ISS module, in a space with five sensors randomly distributed around you.

Step 1: One of the sensors will light up in green. You must approach and touch it to activate the sequence of instructions. At that moment, a 3-minute countdown will begin.

Step 2: When you touch the green sensor, two other sensors will light up in blue. Your goal is to touch them simultaneously, skillfully moving through the space. If necessary, you can grab one of the sensors and bring it closer to the other. If you succeed, both sensors will turn white, and you will hear a confirmation sound.

Step 3: After the confirmation of the second instruction, three sensors will light up in different colors. A voice will tell you about the order in which to touch them, but only once. These sensors will start to vibrate, complicating direct contact. You will need to adjust your posture and speed to counteract this feature. If you touch the sensors in the correct order, they will all turn white, followed by a confirmation command. If you make a mistake, you will need to repeat the sequence.

Step 4: Once the previous instruction is completed, two orange sensors will light up. You must bring them together and fit them while they vibrate. If done correctly, they will turn white, and you will hear a confirmation signal.

Final Step: All the sensors will activate in different colors, with two pairs of sensors of the same color. A voice will give you a single instruction with a color pattern, for example: "GREEN, PURPLE, JOIN BLUES, YELLOW, JOIN REDS." You must complete this sequence in the exact order. If you successfully complete the final instruction, all the sensors will flash three times in white, and you will receive a voice command announcing your victory and your stats. The astronauts will be able to compete against each other or themselves to improve their times.

- What benefits does it have?

Our game offers a great opportunity to enhance the physical and physiological well-being of astronauts. Astronauts in space experience a unique environment characterized by microgravity, which significantly affects their bodies in various ways. The lack of gravitational force leads to physiological changes, including muscle atrophy, bone density loss, and alterations in fluid distribution, which affect how the brain processes spatial information.

In the stationary mode, the game allows players to exercise their reflexes and offers an opportunity to track their reactions and view their progress during their tenure in space. Evaluating neurological function can reveal how an astronaut's central nervous system is responding to microgravity conditions. Microgravity can affect astronauts' coordination and balance, measuring their reflexes helps evaluate how they are adapting to the conditions of space and whether they need additional training to maintain their physical ability.

In Free mode, the game leverages the unique characteristics of microgravity, providing newcomers an opportunity to acclimate to their new environment. This mode not only assists in

overcoming potential disorientation but also enhances cognitive functions as players engage in various tasks necessary for completing a successful round.

The vest provides elastic resistance, assisting players in effectively exercising their muscles. Research indicates that astronauts aged between 30 and 50 years who spend six months in space can lose nearly half of their muscle strength. While this vest is not intended to replace their exercise routines, it serves as a valuable tool for enhancing their overall health and physical condition.



- What tools, coding languages, hardware, or software did you use to develop your project?

Hardware and Transmission

In space, electronic equipment faces exposure to different types of radiation, including Total Ionizing Dose (TID), Non-Ionizing Dose (TNID), and Single Event Effects (SEE). These forms of radiation can affect the long-term reliability of electrical, electronic, and electromechanical (EEE) parts, often leading to malfunctions or failures in spacecraft systems. To mitigate the risks associated with exposure to radiation in space, Rad Hard sensors and processors are chosen for their enhanced resilience. These components are specifically engineered to withstand the adverse effects of Total Ionizing Dose (TID), Non-Ionizing Dose (TNID), and Single Event Effects (SEE).

FPGA Virtex-5QV

The **Virtex-5QV FPGA** is specifically designed for space applications. It provides robust radiation tolerance, making it ideal for controlling LED screens, managing data transmission, and processing critical information onboard spacecraft.



APDS-9960 Sensor

The APDS-9960 sensor offers multiple functionalities; we employ it as a motion sensor for LED screen systems in our project. Despite its lack of radiation hardening, we have faced challenges in finding a space-grade alternative that suits the specific needs of our LED display system. Consequently, the APDS-9960 was selected as a provisional solution to address our proximity sensing requirements.

Zigbee Module

To communicate the LED screen devices.

Data Transmission

To not interfere with other signals in the station, we decided to implement the Zigbee communication protocol, which offers some key benefits for wireless communication. Firstly, it operates with low power consumption, which is essential for energy efficiency in the station. Secondly, Zigbee's mesh networking capability enhances system reliability by allowing devices to communicate through multiple connection paths. This mesh topology ensures that if one path is obstructed or fails, the data can be dynamically rerouted through alternative routes, minimizing the risk of communication breakdown. This redundancy is crucial in a space

environment, where maintaining consistent and reliable connectivity is vital for operational success.

MQTT

To facilitate effective data storage and transmission, we utilize the MQTT protocol to log sensor data, such as reaction times. Each motion sensor is connected to an MQTT client (Virtex-5 FPGA), which acts as a central hub that collects data from the sensors and publishes it to an MQTT broker, which, in our case, is a tablet application.

The Virtex-5QV FPGA not only sends the sensor data but also includes timestamps to accurately track reaction times. The MQTT broker, functioning on the tablet, manages the distribution of messages to any subscribed clients, ensuring that all relevant data is available for monitoring and analysis.

This system allows for efficient, lightweight communication, making it ideal for environments like the International Space Station (ISS), where bandwidth may be limited. Furthermore, MQTT's publish/subscribe model enhances scalability and flexibility, enabling the integration of additional sensors or devices as needed without significant redesign.

NASA & Space Agency Partner Data

<https://www.youtube.com/watch?v=yqHiShYGkZQ>

The video explores life in microgravity aboard the International Space Station, where astronauts carry out unique experiments leveraging this environment. It gave us a deeper understanding of the theory and reality of microgravity, allowing us to observe phenomena and processes not seen on Earth, benefiting research in areas like physiology and materials science.

<https://nasa.tumblr.com/post/138886145114/7-sports-astronauts-love-without-gravity>

This post led us to consider whether it's possible to engage NASA members in an activity that involves controlled, active rotation. Their ability to handle these challenges recreationally shows they are more than capable of such tasks.

<https://www.nasa.gov/humans-in-space/experiments-to-unlock-how-human-bodies-react-to-long-space-journeys/#:~:text=the%20following%20themes.-,Bone%20and%20Joint%20Health,after%20landing%20back%20on%20Earth>

This resource provides valuable insights into our challenge, detailing physical exercises, medical care, and even the behavior of astronauts' brains, as well as their daily routines.

<https://www.nasa.gov/mission/station/research-explorer/investigation/?#id=122>

The previous link, sourced from NASA's official website, discusses the physiological factors that contribute to changes in functional performance post-flight.

Quoting from the article: "Exposure to space flight causes adaptations in multiple physiological systems, including changes in the sensorimotor, cardiovascular, and sensorimotor systems. These changes may affect a crew member's ability to perform critical mission tasks immediately after landing on a planetary surface."

Our approach is to address this issue by implementing game modalities designed to target both the sensorimotor and cardiovascular systems.

While not exclusively cardiovascular, the strength training provided by the vest can also promote cardiovascular health by increasing muscle mass and improving circulation—critical in microgravity environments, where muscle and bone mass are lost.