Fitness & Fun in a Microgravity Environment

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Introduction

Astronauts spend a long time in space, living and working in small spaces with no gravity. This can affect their physical and mental health. Without gravity, astronauts lose muscle and bone strength. If they don't stay active, they can suffer from **muscle atrophy**, which means their muscles weaken and shrink. Astronauts can also feel lonely or bored, which can make it hard to stay focused and positive.

Our challenge is to create a game environment that helps astronauts stay fit, happy, and connected as a team, using the fun aspects of living in a weightless environment.

1. Problem Overview

Astronauts living on space stations face two big challenges:

- **Physical Health**: Without gravity, astronauts lose muscle and bone mass. If they don't stay active, they can suffer from **muscle atrophy**, which makes it harder for them to move and stay healthy. While they do regular exercise, it can become boring over time.
- **Mental Health**: Spending long periods in space, far from family and Earth, can make astronauts feel bored, homesick, stressed, or lonely. This can hurt their mental health and make teamwork harder.

2. Why This Problem Matters

2.1 Preventing Muscle Atrophy

In space, astronauts need to stay active to avoid **muscle atrophy**, which happens when muscles weaken from lack of use. Within just two weeks, astronauts experience a loss of up to **20% muscle** mass which compromises strength and performance.

The major muscles that will suffer from muscle atrophy are: Core, Back, Hip Flexors, Quadriceps, Calf, and Hamstrings, so a physical exercise is a must to keep their bodies strong. We think a game that encourages movement can make this more fun and help astronauts stay motivated to exercise.

2.2 Keeping Their Minds Sharp

Space missions are really **expensive** and crucial; the success rate must always be **100%** so, without fun or stimulating activities, astronauts can feel mentally tired. A game can give them a break from their work, help them relax, keep them connected with their families & friends, and keep their minds sharp, reducing stress and boosting their happiness.

2.3 Building Team Spirit

Astronauts depend on each other to complete their mission. A game that promotes teamwork can strengthen their bonds, making it easier for them to work together and stay positive during difficult times.

3. Why Solving This Problem Is Important

3.1 Protecting Astronauts' Health

If astronauts don't stay active, they risk muscle atrophy, which could make it harder for them to perform their tasks. A game that combines physical activity with fun will help prevent this and keep them in better shape for their mission.

Also having many astronauts having muscle atrophy might discourage other young people to apply to become new astronauts.

3.2 Ensuring Successful Space Missions

Astronauts need to be physically strong and mentally focused to succeed. By keeping them active and engaged, games can help them perform better, even in tough situations. This will increase the chance of mission success.

3.3 Preparing for Longer Space Journeys

As we plan for longer space missions, like trips to Mars, keeping astronauts fit and mentally healthy becomes even more important. Games and activities that keep them moving and thinking will help for the success of these long journeys.

4. Proposed solution

Our idea combines software and hardware into a system that gives astronauts a really interactive experience. It simulates energy exertion and muscle use, while creating Earth-like environments to help them feel more comfortable and at ease. This approach takes care of both the mental and physical health of astronauts, which is super important for long space missions.

The proposed system is a smart fitness machine that uses motorized resistance instead of traditional weights, making it perfect for **microgravity**. It has a camera linked to computer vision to track the astronaut's movements, count repetitions, and show all the data in a mobile app through an API. To make the workouts seem more realistic and fun, astronauts can wear a VR headset to play games and mimic earth environments. Below is a detailed explanation of the system components:

- Gym Cable Machine

The gym cable machine will serve as the central piece of equipment for all physical exercises, making it the core of our workout setup. It will be the only actual gym tool used in the system. Other components, such as VR and the health monitoring application, are tailored around it to expand its functionality and offer a wide range of exercises

DESCRIPTION AND MECHANISM

The device might look like a regular gym cable machine, but it's packed with some high-tech upgrades! Instead of traditional weights, it uses motors to create resistance that feels just like lifting real weights even in microgravity.

With two powerful motors, one on each side, and adjustable cables, astronauts can customize the setup for different exercises, targeting arms, legs, biceps, triceps, and more. This versatility makes it the perfect all-in-one gym tool for space workouts, allowing for a variety of exercises without taking up much space. Easy to use and adaptable, it's like having a complete gym packed into a single machine.

BENEFITS

We picked this machine because it's space-saving. It can be folded and doesn't take up much room, which is important in space. It's also easy to use. The adjustable height and motor resistance make it simple for astronauts to switch between exercises. And it's affordable, by using motors instead of heavy weight keeps the cost low, which makes it a good choice for space missions.

PRICES AND CHOSEN MODEL

The current used exercise equipment used in the International Space Station (ISS) called the Advanced Resistive Exercise Device (ARED), costs approximately $250,000 to build and deploy.

On the other hand, our machine aims for space efficiency, ease of use, and a much lower cost.

By using motorized resistance instead of the normal weight, our device can deliver similar resistance while significantly reducing the size and the complexity.

In our research we looked for decent motors and we found 3 different choices:

Motor Type	Brand	Torque	Price	Description
High-end Stepper Motor	Applied Motion Products HT23-601	425 oz-in (3.0 Nm)	$200 - $250	Designed for high precision and industrial applications, offering strong torque and durability.
Mid-range stepper motor	NEMA 23 Stepper Motor by StepperOnline	270 oz-in (1.9 Nm)	$80 - $120	Provides a balance between performance and price, suitable for exercise resistance in zero gravity.
Cost-efficient Stepper Motor	Usongshine NEMA 17 Stepper Motor	84 oz-in (0.6 Nm)	$30 - $50	Affordable but lower torque; suitable for light-duty applications.

- VR Headset

Since using just one exercise machine can get repetitive and boring for the astronaut, we decided to integrate VR technology with the physical equipment to make workouts more engaging and less monotonous. A similar approach is already being used on the International Space Station (ISS), where astronauts use VR headsets paired with an exercise bike to simulate cycling on Earth. However, this setup is quite basic and focuses primarily on recreating familiar scenery. We propose enhancing it with a variety of immersive environments and more challenging activities that target different muscle groups while extending it to spacecrafts too for long missions.

BENEFITS

We identified several key benefits that this technology would bring:

1) Minimal Equipment: VR systems require only headsets and light resistance tools, significantly reducing the logistical challenges of transporting and maintaining fitness equipment in space.

2) Space-Saving: The use of virtual environments eliminates the need for more bulky gym equipment to entertain the astronaut, making it ideal for confined spaces like spacecraft.

3) Minimal Effort: The intuitive nature of VR interfaces allows for easy navigation and use, making workouts accessible even for those with limited experience in exercise.

4) Adding fun to a microgravity environment: Astronauts could experience a simulated "fresh air" environment while exercising in space, making workouts more engaging and less monotonous with repetition especially for long missions.

PRICES AND CHOSEN MODEL

VR headset prices vary widely based on brand, model, and features, starting from around $15 for entry-level models to over $1,000 for high-end devices. In space, the main headsets used are the HTC VIVE Focus 3 and the Oculus Rift. The VIVE Focus 3 is specially designed for microgravity conditions on the ISS, while the Oculus Rift was previously used for neuroscience experiments on the station.

Since astronauts will mostly remain stationary and the VR's purpose is to simulate a static environment rather than complex moving games, there's no need for advanced or high-cost VR systems. A simpler option would suffice. Following that we decided to go with Mid-Range VR Headsets. These VR headsets offer very good quality displays, advanced tracking technology, and a range of features such as hand controllers and higher refresh rates which is perfectly suitable with what we want. After thorough research we decided to use the Oculus Quest 3, highlighting the key reasons why we chose this model:

Name	Type	Advantages	Disadvantages	Prices
HTC VIVE Focus 3	High-End VR headset	- specially adapted for microgravity to prevent motion sickness using a custom tracker.	- slightly heavier than other models. - Complex use. - Costy.	$1,300
Oculus Rift S	Mid-Range VR Headsets	- Ease of use - Better tracking precision for room-scale - Lighter design compared to the Quest and VIVE.	- Requires a powerful PC to run. - Lower resolution display. - Wired, limiting mobility and freedom of movement.	$400-$500

Oculus Quest 3	Mid-Range VR Headsets	- wireless and portable. - Large content library available for both standalone and PC VR.	- Slightly heavier than the Rift S. - Needs Facebook login to use. - Battery life is limited to 2-3 hours without being connected to a PC.	$399 for the 128GB model and $499 for the 256GB model.

ENVIRONMENTS

The VR system offers two immersive modes tailored for both mental and physical health:

1. Gaming Mode:

Designed to engage astronauts in fun activities that prioritize mental well-being while incorporating elements of physical training. It includes:

- Single-Player Mode: Perfect for solo engagement, helping astronauts manage stress and keep mentally sharp through interactive adventures like a Star Wars campaign.

- Multiplayer Mode: Encourages camaraderie and healthy competition with games like virtual baseball or tennis. This mode nurtures a sense of teamwork, boosting morale and creating social connections crucial for long-duration missions.

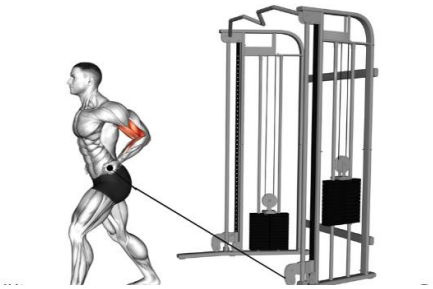
2. Sports Mode:

Aimed at maintaining and improving physical health, Sports Mode features three dynamic environments, each focusing on different muscle groups and fitness goals:

- Cardio Zone: Engage in simulated running or cycling sessions set in Earth-like terrains, with customizable sceneries to match individual preferences.

- Virtual Gym: A digital gym stocked with a range of strength training exercises, tailored around our gym cable machine. Perfect for astronauts to maintain muscle mass and strength, even in microgravity. The game will simulate some gym exercises in a way to keep the astronaut active and in good mental health. Some of the gym exercise that the astronaut will be able to do:

1. Bayesian Curl, this exercise targets the Biceps muscle



2. Cable Triceps Pushdown, this exercise for Triceps muscle

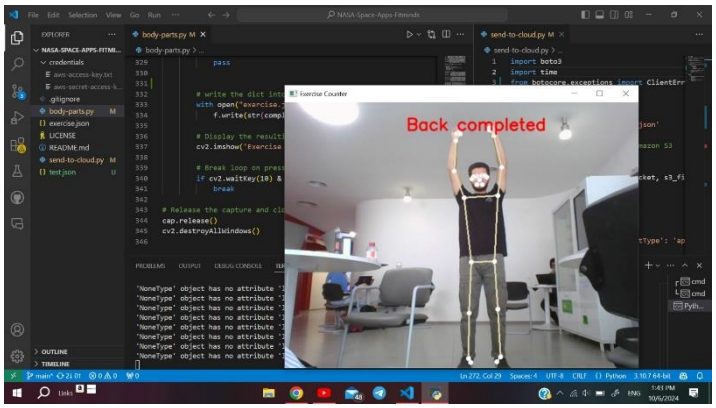
3. Squat, this exercise focuses on quadriceps, hamstrings, and glutes but also engages your core and upper body.

4. Pull up, this exercise targets many muscle groups in your upper body including the latissimus dorsi, rhomboids, brachialis, biceps, and even the rectus abdominis.

The VR system transforms exercise and recreation into engaging experiences, keeping astronauts fit, focused, and connected.

- Computer Vision Camera

During exercises, a camera is positioned in front of the astronaut and connected to a computer to monitor their movements. The system tracks which muscles are being engaged and counts the number of repetitions for each muscle group. The main focus is on training the back and legs, along with the triceps and biceps. This setup ensures that astronauts maintain proper form and stay on track with their fitness goals.



The data collected by the CV camera is transferred using APIs to a health tracking app on the astronaut's smartphone. This allows the astronaut to easily review which muscle groups were targeted and see an exact count of the reps completed during each workout session.

- ## Body Composition Scanning Watch

A great addition to our system is a body composition scanning watch—a lightweight device worn by the astronauts daily. It routinely monitors their physical health and sends notifications about muscle mass and fat mass to the health tracking app on the astronaut's smartphone, helping them keep track of their fitness status effortlessly.

Our main focus for the astronaut's physical health is preserving muscle mass, so we spent a lot of time researching watches that can measure it accurately and are also suitable for use in microgravity. Right now, there aren't many smartwatches that can reliably track muscle mass, especially in space conditions. However, there are a few promising models that can measure body fat and overall composition, which could still be useful for monitoring health during long missions. The models are displayed below in a table:

Model Name	Description	Price
Samsung Galaxy Watch 4	Measures body fat and composition using bioelectrical impedance analysis (BIA), Accuracy is comparable to the (DXA) scan	Approximately $399.99
Amazon Halo Band	Estimates body fat by taking photos to create a 3D image for analysis.	$99.99

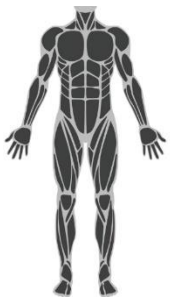
While the Amazon Halo Band is more affordable than the Samsung Galaxy Watch 4, research indicates that the Galaxy Watch offers greater convenience and effectiveness for use in space. It has been found to provide higher accuracy rates in measuring body composition compared to the Halo Band. Therefore, the increased cost of the Galaxy Watch 4 is justified, and it has been decided to choose this model for your needs.

- ## Health Tracking Application

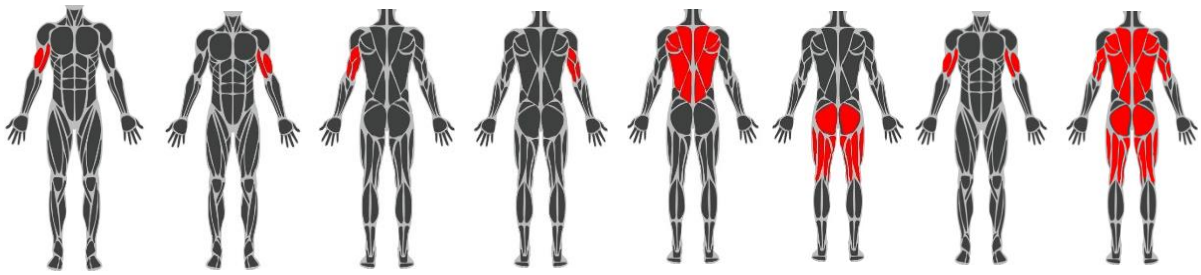
We developed an app that takes readings from the smartwatch and the computer vision system (CV) and displays the data for the astronaut in a user friendly interface.

The smartwatch routinely tracks the muscle mass of the astronaut and sends it to the application. The app compares these readings with previous measurements, and if it detects a drop in body composition percentage, it alerts the astronaut that it's time to exercise. This feature helps ensure that astronauts maintain their physical health during missions.

The application also displays a photo of the astronaut's muscles, highlighting them in dark colors for better visibility, as shown below:



Once the astronaut begins exercising, the CV camera captures all the active muscles and sends the data to the application in real time. The application then highlights the exercised muscles in red and displays the number of repetitions performed. Below are the various combinations of exercised muscles:



The application provides a comprehensive summary for the astronaut, making it easy for them to monitor their health and fitness.

5. Demo

Meet Anakin Skywalker, a 22-year old astronaut who is very eager to dive into space and bring balance to the galaxy, and he has generously volunteered to test our system. Anakin was sent on a mission to Endor that will last approximately six months. During this time, he must prioritize both his physical and mental health, as the long journey demands focus and resilience.

After successfully setting up our health tracking app and installing his gym cable machine on the spacecraft, Anakin set off into space equipped with the **Samsung Galaxy Watch 4**. Just one week into his journey, the application notified him that there was a decrease in his muscle mass and that he needed to begin his training routine to prevent further loss.

Anakin set up his machine, activated the CV system, and put on his VR headset. He then selected a scenery and exercise routine that he liked, creating an engaging and motivating environment for his workout.

During the exercise, the camera tracked Anakin's every movement and sent the data in real time to the application. As he trained, the muscles being engaged turned red in the image displayed by the app, allowing him to see which parts of his body were being worked out. This visual feedback kept Anakin informed and motivated throughout his session, ensuring that he stayed on track with his fitness goals.

This became part of Anakin's daily routine throughout the mission, helping him maintain both his mental and physical health. Compared to other traditional methods for staying fit and entertained in space, this approach showed significant improvements. It was not only more engaging but also simpler and more cost-effective, making it an ideal solution for long-term missions. The combination of VR, real-time monitoring, and feedback kept Anakin motivated and focused, ultimately enhancing his overall well-being.

6. Conclusion

Staying active in space isn't just important, it's necessary. Without exercise, astronauts can suffer from **muscle atrophy**, and their mental health can decline. Our game will use the unique environment of space to keep astronauts healthy, happy, and working well as a team. This will help them succeed on long-term missions and thrive in space.

7. Resources

a. **NASA Living and Working in Space: what it's like for astronauts to live and work in space:** livingandworkinginspace508c.pdf
b. **NASA Experiments to Unlock How Human Bodies React to Long Space Journeys:** Human Bodies in Space
c. **NASA What is Microgravity? – Learn more about microgravity, how it works, and why NASA studies it:** What is Microgravity
d. **NASA The Human Body in Space - NASA – Explore the effects of space travel on the human body:** The human body in space
e. **NASA 7 Sports Astronauts Love Without Gravity:** Sports Astronauts Love Without Gravity
f. https://pimax.com/blogs/blogs/how-much-is-a-vr-headset?srsltid=AfmBOopC4CPPelaOuFzy32sN9hqCwxm8z4Inz-MiT6pBIi3Qnf2Pyi-9
g. https://www.knowyourmobile.com/wearable-technology/smartwatch-wearable-measures-body-fat/
h. **NASA Exercise:** https://www.nasa.gov/missions/station/iss-research/astronaut-exercise/
i. **NASA's Exercise Device for Orion To Pack Powerful Punch:** https://www.nasa.gov/missions/artemis/orion/exercise-device-for-orion-to-pack-powerful-

punch/#:~:text=On%20the%20space%20station%2C%20astronauts,feet%20within%20the%20space%20station.

j. **NASA Fitness Facilities:** https://www.nasa.gov/starport/fitness-facilities/

k. **NASA Space Exercises:** https://nasa.tumblr.com/post/136706596374/exercising-in-space

l.