# **Project Title: International Space Station Classroom Model**

# **Introduction**

The purpose of this document is to explain the needs of our client and how we plan to address them. As software development is an iterative process, it is expected that the actual product will evolve during development. What is proposed here should be treated as an initial standard rather than a rigid description of the final prototype.

Key definitions:

* **International Space Station (ISS)** - The largest modular space station in low Earth orbit that acts as a research laboratory for experiments that require an environment in microgravity. It is utilized by five space agencies: United States’ NASA, Canada's CSA, Europe’s ESA, Japan’s JAXA, and Russia’s Roscosmos.
* **International Space Station National Laboratory** - The ISS National Lab is a low Earth orbit laboratory that serves as a platform for research, development, and education that is uniquely suited for the study of how the conditions of space affect the organisms and systems we are familiar with on Earth.
* **Vegetable Production System (aka Veggie)** - is a space garden residing on the space station. Veggie’s purpose is to help NASA study plant growth in microgravity.
* **Astronaut Propulsion Unit (APU) -** is a back mounted device used to move an astronaut relative to the station during aspacewalk.

This document first reviews the needs of our client, the various constraints imposed by these needs, and details the potential risks that may be faced during development. It then goes into more detail about the specific functionality of the planned prototype and provides two operational scenarios describing the experience of two hypothetical users.

# **General Overview and Design Guidelines**

## **Client Needs**

Our client is a science/history teacher for high-school age children and wants to give students hands-on experience with the history of the International Space Station and its ongoing scientific impact. Specifically, she wants students to be able to reenact an important scientific experiment in order to understand its significance and how the ISS was essential in making the experiment possible. Specific requirements include: 1) simulation of zero gravity, 2) educational information on experiments performed on the ISS, and 3) an interactable experiment that utilizes zero gravity.

## **Design Constraints**

### *Hardware Constraints*

The ISS's pressurized module, where most experiments have been conducted, is 67 meters (218 feet) in length, and the inside is very cramped with all The equipment that is required by the crew and various experiments. Based on these facts the hardware should be able to support a trackable space at least 12' in length while the width could be 6' at a minimum. The hardware used must be able to support a tracked space of this size. Either a wired or wireless HMD can be utilized based upon availability or preference. However, a cable management system is recommended if a wired HMD is used.

External tracking systems are recommended if available for their addition to the overall accuracy as the utilized space should remain static and will not be moved often, if at all.

Based on the above constraints the user can use most commercially available HMD's on the market today with specific choices being determined by preference. For a more enhanced graphical experience and more accurate tracking systems, the Valve Index is recommended. For a more budget friendly option, the Quest series of HMD are acceptable and will not impact the overall performance of the final product.

### *Software Constraints*

This application will simulate a zero gravity environment and growing plants in microgravity. Due to the slow rate of growth that plants undergo in real life, if any growth stages are implemented, they will occur on an accelerated timeline in order to provide a more convenient educational experience.

Newton’s third law of motion states that “for every action there is an equal and opposite reaction” and because of zero gravity environments, real astronauts must take into account acceleration from grabbing and releasing objects. For the sake of giving users more control over their motion, we will not be accounting for Newton’s third law in interactions between objects and the user.

### *User Constraints*

Users must conform to typical requirements for HMDs (e.g. cannot have epilepsy, must not be extremely susceptible to motion sickness), with an added emphasis on not being extremely susceptible to motion sickness as there is likely to be some form of zero gravity movement which could negatively impact users.

### *Physical Constraints*

This application needs to be deployed in a minimum of a 12’x6’ space with a level floor. Users must be completely unobstructed within this space.

## **Risks**

The primary risk associated with this project is danger of VR sickness. Since a zero gravity environment can already be disorienting/sickening on its own, putting someone in VR where they don’t have physical cues or certain simulated senses, could cause increased chances of VR sickness. We plan to mitigate VR sickness by fading to black when teleporting, possibly limiting which axis of rotation the player has control over inside the station, and taking inspiration of mitigation techniques from other zero gravity VR experiences. Should it be determined that creating a non-disorienting zero gravity experience is infeasible, the user will only be allowed to maneuver as if they were in normal gravity with zero gravity effects being represented by other objects.

Careful consideration must also be given to the difficulty of the tasks, as this is meant to be an educational experience and not a game or challenge. We will mitigate this risk by limiting the number of ways in which the player could perform an action incorrectly and give them detailed instructions via popup textboxes. Since this is an educational experience, we must also ensure that the information we provide is accurate. This will be ensured by thoroughly researching and using information from reputable sources.

# **System Design**

Upon entering the virtual reality space, the user will be able to see a fictionalized version of the International Space Station National Laboratory. This environment will include both an active lab section, where an experiment about farming in microgravity will be conducted, and a “hall of fame” featuring objects and images representing several experiments that have been conducted on the ISS. Beyond the laboratory and the hall of fame, the user will be able to navigate to an airlock scene and experience a space walk outside of the laboratory.

# **Supported Tasks**

# *Interactive experiment*

As the user approaches the agricultural experiment in progress, proximity-based text instructions will appear identifying the tasks at hand, as well as the current hypothesis on how microgravity is affecting the plants’ growth. The tasks will include:

1. Taking a length measurement of one of the plants’ leaves
2. Planting a new seed in a plant “pillow”
3. Water a plant
4. Turning on an LED light to stimulate plant growth
5. Taking a pH sample of the soil
6. Taking a soil saturation measurement of the soil

Each task will be triggered by user selection of a related object (e.g. pH strip, thermometer, ruler, etc.). At the beginning of the task, a floating text bubble will appear in the user’s field of vision explaining what movement they must make to collect the measurement or otherwise complete the task. For example, if the task is to take a length measurement of the plant’s leaves, the user will see a text bubble after selecting the ruler that will instruct them to manipulate the ruler in a way that allows them to accurately measure the length of the leaf. Once the object associated with a task has either been placed in the correct location (e.g. when the ruler is placed within close proximity to a leaf and is lined up correctly), the measurement will be automatically completed and the “data” will be recorded. The users will be able to view the data recorded by opening and interacting with a notebook on the lab bench, which will display all data that has been collected up until that point and will be populated automatically (the user need not enter actual measurements). The user will generally be unable to move onward with the experiment until they have correctly completed the task associated with the object they are holding.

Once all tasks in the experiment have been completed, a text bubble will appear in the user’s field of vision showing the results of some of NASA’s real-life experiments on farming in microgravity. This will include images of the real ISS National Laboratory, as well as an explanation of the importance and relevance of their findings.

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# *Explore hall of fame*

If the user chooses to move away from the active lab portion of the environment (e.g. by turning/ratcheting to see the rest of the laboratory), they will encounter several objects throughout the environment representing various experiments performed on the ISS. The highlighted experiments will include:

1. The discovery of the 5th state of matter, the Bose-Einstein Condensate
2. The discovery of steadily burning cool flames
3. Research on pulsars and black holes
4. NASA’s wearable robot suit

Various objects and images will be used to represent these experiments, including things like miniaturized versions of the hallmark piece of each experiment. When the user interacts with, say, a sprite representing a cool flame, an informational text bubble will appear giving a summary of the experiment, its importance, and its relevance to the scientific community. Users will be able to move freely throughout this section and can interact with the objects/text as often or as little as they like.

# *Space walk*

Upon turning away from the laboratory and hall of fame, users will see the option to teleport to the airlock to begin a spacewalk experience. This will be indicated by text associated with the transport location. Once in the airlock, the user will equip an APU, which will change the appearance of the room to be slightly tinted. The user will be directed to open the airlock by a green light and a sign above the associated lever. After the user interacts with the lever, opening the airlock, they may exit to observe the exterior of the station and the sights of the final frontier. While outside the station the user will be able to move in all directions utilizing an APU, up to a certain speed, and will be able to move around the entirety of the station itself.

# **Environment Description**

# *Lab/Hall of Fame (ISS National Laboratory)*

The environment will be a version of the ISS with fictional components added for educational purposes. In the US module of the ISS(a long rectangular shaped room with ports on either end) will be the Veggie box with a pop-up indicating that this is where the user starts the experiment. On the wall near the box will be multiple different items to be used in the experiment, such as a ruler, vials, syringe, and a notebook, attached via tethers and velcro.

To the left, right, and on the wall opposite the Veggie Box will be various items from notable experiments including, but not limited to, NASA’s space robot and a burning heptane drop. Each artifact will have proximity based pop-ups that give educational information on the experiment and discovery associated with the item.

Through one of the ports to another module will be an observation window in which the user will be able to look outside of the ISS and view Earth.

# *Airlock/Space Walk*

Through the other port on the US module will be an airlock and Astronaut Propulsion Unit(APU). By equipping the space suit and pressing a button to seal and depressurize the airlock, the user will be able to exit the ISS and experience floating in space. Visible will be the ISS exterior, stars, Moon, Earth, and Sun.

# **Locomotion and Interaction**

# *Maneuvering Inside the ISS*

Users should be able to maneuver through the space by physically walking. The user should also have the option to teleport to explore the other parts of the ISS. Vision should fade to black in the scenario that the user attempts to put their head through any structural components of the ISS(walls, ceiling, etc.). Physical turning of one's body should be the main mode of rotation but in the case the player needs to rotate in the environment, ratcheting will be enabled.   
Users should be able to manipulate objects by placing their controllers against or inside of the target object and pressing and holding the grip button. The objects should be released when the grip button is disengaged. In the scenario of UI or buttons, the user will use a ray to manipulate and interact with it. Objects with velcro will snap to parts of structural components indicated by another piece of velcro. Objects with tethers will freely float in range of the tether.

# *Maneuvering Outside the ISS*

The user will equip an APU to maneuver outside the ISS. Locomotion will be controlled with the thumbsticks. The thumbstick on the left controller will control movement along two translation axes, directly allowing the user to move forward, backward, left, and right. The thumbstick on the right controller will allow movement on the rotational axes, allowing the user to rotate clockwise, counterclockwise, forward, and backward. All motion outside of the ISS will be continuous.

# **Operational Scenarios**

# **First Scenario**

Alex is a high school student in Tanya Raymond’s class with an interest in science and technology. He is excited to learn about how experiments are conducted on the ISS. He loads up the application, puts on the HMD, and immediately sees that he’s in a laboratory. When looks straight forward, he sees a pop-up label saying “Active Experiment.” He walks immediately toward the active lab section where he can see a box filled with a leafy variety of plants. To the right of the box, he sees an experiment kit attached to a small lab bench. As he approaches, a text bubble appears explaining that the experiment in front of him is about growing plants in microgravity. It also explains that the box he sees is called a Veggie box, and is used to grow plants in space.

After closing the text bubble, Alex sees a ruler in the lab kit, which is labeled with a short-lived pop-up text, and is highlighted with yellow. He grabs the ruler, prompting another text explaining that he should carry the ruler over to the box of plants and hold it against one of the leaves of the plant. He accidentally lets go of the trigger that allows him to grip the ruler, and he finds that it floats slightly away in the direction that his hand was moving. He reaches out for it and grabs it again. He looks back toward the instruction pop-up, which is still visible. He follows the instructions, and upon placing the ruler next to a nearby leaf, making sure that the initial mark of the ruler is approximately near the tip of the leaf. He hears a short “ding” sound indicating that he has done the motion correctly. He then sees a flashing indicator to his right, indicating that he should shift his attention back to the experiment kit. He is prompted to place the thermometer back by a highlighted space in the kit where the thermometer used to sit. Once the thermometer is put away, he sees that a lab notebook in the experiment kit has been highlighted next. He selects the notebook, which opens to reveal that the length of the leaf is 16 cm long.

He closes the notebook, then sees that a different thing has been highlighted in the experiment kit. He interacts with it and sees a pop-up stating that it is a packet of seeds. A text bubble appears telling him that these are Chinese Cabbage seeds and instructing him to drag them over to the empty plant pillow in the Veggie. He carries the packet over to the Veggie and places the seed packet on top. The packet changes into a small pile of three seeds, which are surrounded by a white substance. He hears the “ding” again and sees an indicator to look back over at the experiment kit. He sees that the notebook is once again highlighted and he opens it to find a short statement about what the plant pillow is made of and how the seeds are attached to the pillow with guar gum (which was the substance he saw).

After closing the notebook, a syringe in the kit is highlighted next. He selects it and a text bubble appears telling him that this syringe will be used to water the plants. He is instructed to stick the syringe into the pillow of the cabbage seeds he just planted. Turning back to the Veggie, he points the syringe at one of the pillows and presses the grip button to release the water into the pillow. He hears another “ding” indicating that he’s done this correctly, so he turns back to the experiment kit and places the syringe back in its place. He selects and opens the notebook again to find a short explanation of why the plants are watered this way.

Now comfortable with the process, he closes the notebook and looks back at the experiment kit. This time he sees a lightbulb in the kit highlighted. He grabs it and a text bubble appears telling him to turn the light dial near the Veggie to magenta. The lightbulb is no longer in his hand, but he follows the instructions and finds a circular dial with several color options. He turns the dial to magenta, hears the “ding” indicating that this was correct, then sees an indicator telling him to look back toward the equipment kit. In the kit, he sees that the notebook is highlighted again. He opens it to find an explanation on why the magenta light helps the plants to grow.

He closes the notebook again and sees two items highlighted in the equipment bag, including something that looks like a thermometer and a vial of what looks to be dirt. He hovers over both objects before interacting with them because he wants to know why there are two items highlighted. He discovers that the first is a soil probe and the second is a vial of soil from the Veggie. The pop-up instructs him to insert the probe into the vial of soil. He follows the instructions and hears the “ding” indicating that this was correct. He places the objects back in their places, then opens the notebook. There he sees a note about soil saturation and how cabbage grows well in soil with a 70% saturation.

He closes the notebook and looks back toward the equipment bag. He finds that a small vial of clear liquid has been highlighted, along with the same vial of soil. The pop-up indicates that the first vial contains vinegar. He is instructed to bring the two items together and to look for a reaction between the two. Using both controllers, he brings the vinegar toward the soil, and a third image is produced of the soil and vinegar together in a combined vial. In the vial, he sees that there are now bubbles in the soil. The “ding” sound appears again, so he places the objects back into the kit and opens the notebook again. There he finds an explanation of how cabbage grows in alkaline soil and that the vinegar fizzing/bubbling in the soil indicates that the soil is of the correct pH balance.

After closing the notebook this time, no tools are highlighted. Instead, a pop-up appears congratulating him for tending to the plants well. There is also an explanation of the implications of the research performed using the Veggie and some images of the real-life version. With the experiment completed, Alex removes the HMD and stops the application.

# **Second Scenario**

Sarah is a student in Tanya Raymond’s class who wants to learn about a lot of different experiments that the ISS National Lab has conducted, but she’s not as interested in completing an experiment. Sarah loads up the application and puts on the HMD. Upon entering the environment she sees that she is in what looks like a laboratory. When she looks ahead, she sees a pop-up labeled “Active Experiment”. She turns her head to the left and right where she sees various objects around the room, some tethered to walls and pipes, others floating around. She starts on the left side of the laboratory, where she sees what appears to be a purple ball floating in the air.

She sees the ball drifting and decides to approach it. She hovers over the item with her controller and a pop-up title appears at the top of the screen telling her that it is a burning heptane droplet. She moves closer to the heptane droplet and a pop-up appears telling her about the discovery of relatively cool flames burning in microgravity. After reading, she walks away and the pop-up closes.

She then turns to the right and sees what she recognizes as a large robot. Again, she hovers the controller over it and learns that it is NASA’s robot suit. She moves closer to it and an information page appears about the use of robot suits to study human motion in microgravity. She also sees an image of the real-life robot suit in the information page.

Sarah feels like she’s seen enough of the objects in the hall of fame, so she removes the HMD and hands off the headset to another student so that they can enter from where she left off.