NASA MarsXR Challenge

Upgrades proposed for the martian
virtual training environment XOSS

Team: Overheat

Members:
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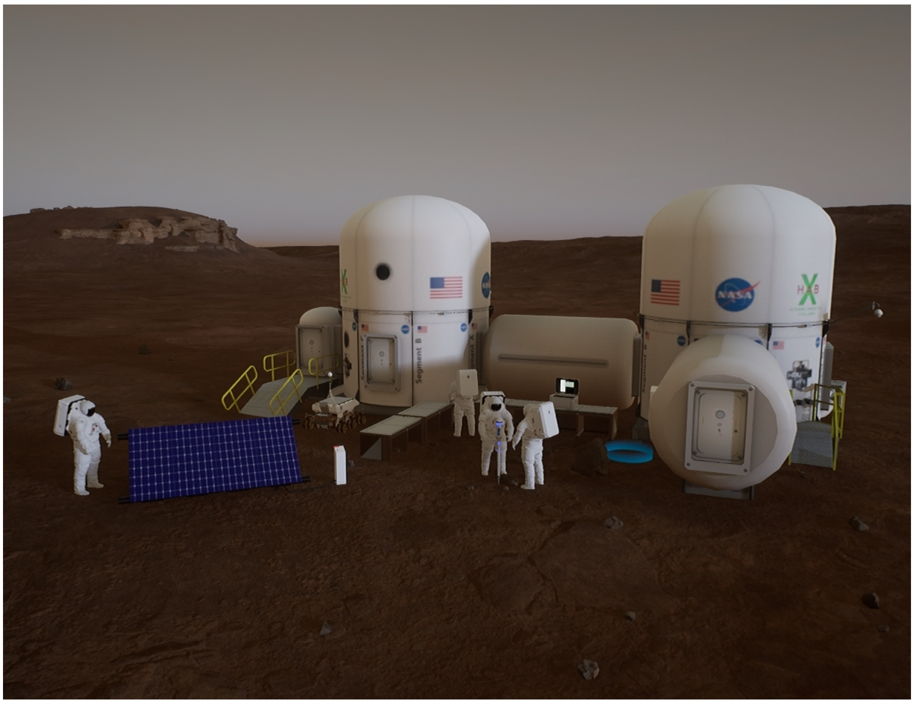

Contents

1 Introducction

Space exploration has been an interest for humanity for a long time. So many missions have been completed, and there are yet many more to come.

For one of these missions, which will take place on the red planet, NASA, Buendea and Epic Games have initiated the second iteration of the NASA MarsXR challenge, and are requesting people to create new scenarios and assets for the new Mars XR Operations Support System (XOSS) environment, using Epic Games' Unreal Engine 5.

For the first part of the challenge, competitors are asked to design scenarios as storyboards. In our case, we have decided to also add this LaTeX documentation, to add some explanations to our ideas. The storyboards could be followed without having to read the full document, but it will give more detailed explanations about the idea of the storyboards and the different assets that are presented. It also has the reference to the information that we have used to justify our ideas.

Figure 1: Overheat's team logo

1.1 Assumptions

For our storyboards, we are assuming that there are some facilities already built and working (except if specified otherwise in a specific scenario):

- **Habitat:** A place with the necessary facilities where the astronauts will live.
- **Energy production system:** A system to produce electricity. We are assuming that there are at least solar panels. There might also be other sources of power.
- **Greenhouse:** A place for the astronauts to plant different crops.
- **CENTAUR rover:** A rover that can be used to transport materials and tools, or mount certain tools.
- **Drone:** A remote controlled drone with a camera and other systems.

2 Storyboard: Greenhouse

This storyboard is focused on building and preparing the greenhouse for future use. The idea is that astronauts will need to learn to grow crops on Mars and study them, but this will be done in person, not in EVA missions. Therefore, for the purpose of the XOSS simulation, this scenario focuses on building the greenhouse, make it a habitable area, and gather resources for use inside.

There are 4 types of resources that will be needed:

- **Water:** One of the basic elements for plant growth is water. The mission assumes that there are ice blocks under the surface[8], so the astronauts need to go to the cave to mine some of the ice pieces, and then melt them and filter them, to use them to grow the plants. In case it's not a viable option, the mission part could be change to obtain water from other sources, like atmospheric condensation.
- **Soil:** Another element that the plants need is soil. The idea is that the astronauts will collect martian soil, so they can test how crops grow using it.
- **Nutrients:** With just the Martian desertic ground, crops will not grow. They need nutrients that will need to be brought from Earth. In the mission, astronauts will have to move them from the storage to the greenhouse.
- **Seeds:** The last element that they will bring to the greenhouse are the seeds. They will also be brought from Earth, so astronauts will have to move them from the storage to the greenhouse too.

During the mission, there could be some events that break the flow of the storyboard, and that the astronaut will need to deal with before completing the mission. Also, we have designed some metrics to assess in the correct execution of the scenario. Both things are explained in the following sections.

2.1 Metrics

For this mission, the metrics that we propose are the following ones:

- **Time:** The most basic metric that could be implemented is tracking the time that the astronauts take to complete the mission. It could be tracked in both ways: as a global time, and an individual time for each step. This way, scientists can measure which tasks are more complicated.
- **Percentage of screws screwed:** Another metric that could be useful is how tight are the screws (globally). Every screw can have a percentage of how screwed it is (0% being completely outside, 100% being completely inside and tightly fixed). The astronauts can decide when to stop screwing, but if the screws are not well fixed, it could have some bad repercussions during the mission. The metric would be then the average of percentage of every screw.
- **Number of extensors placed:** Another metric could be how many electric externsor sockets have been placed. It is important to minimize the material that is sued, so a large number might indicate an inefficient placement.
- **Meters of wire used:** Related to the metric above, this will track the total length of cable used. As before, the more cable is used, the worse it will be.
- **Resources gathered:** The idea is to provide the greenhouse wit supplies, so the more resources that are gathered, the better. (This includes the ice, soil bags, water bottles, nutrients and seeds).
- **Tool's battery usage:** For the electrical tools that are used, if they are used with batteries, checking the amount of battery that has been used will help the astronauts make a better use of them.
- **Overheat:** This metric counts the time that a tool has been working without stopping. The idea is to track if the astronaut reaches a high level of overheat, which could damage the tool or the products that is being worked with.

2.2 Events

For this mission, the events that we have designed that break the flow of the storyboard are the following ones:

- **Malfunctioning tool:** The tool might stop working for different reasons, like having a broken part. The astronaut needs then to go back to the base and get a new one.
- **Obstructed filtering machine:** The water filtering machine gets obstructed due to having too much dirt in the filters. The astronaut should then replace the filters and continue with the water production.
- **Tool's battery drained:** The battery of the tool has been completely drained. The astronauts need to grab a new battery and replace it before continuing with the task.
- **Tool overheat:** The tool has been used for too long without a pause, and it has stopped working. The astronaut needs to wait for the tool to cool down. (The event will be triggered when the overheat metric reaches the maximum).

2.3 Storyboard

Overheat, Greenhouse

1

Storyboard Title, Sequence, & Description

Tool gathering

This scenario is focused on preparing the greenhouse. The missions are focused on building the structure and preparing it for its later use (ouside the simulation, as it's not an EVA activity).
For that purpose, the astronauts need first to get the material and go the location where the greenhouse will be built.

Assets Available in this Storyboard

- CENTAUR Rover
- CENTAUR Remote Controller
- Toolbox
- Boxes

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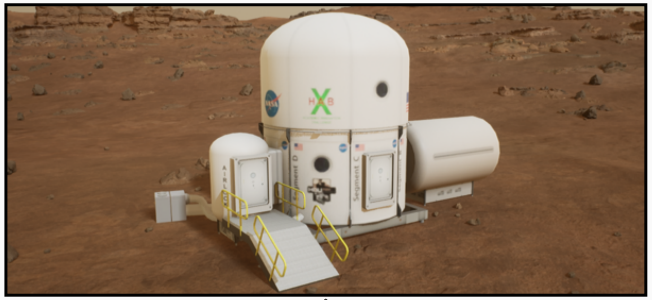

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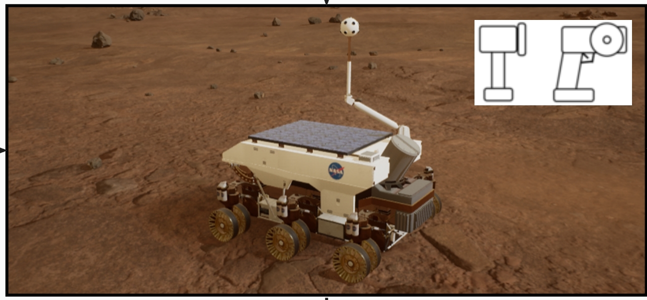

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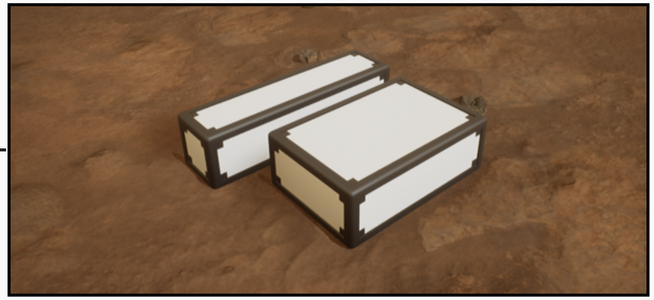

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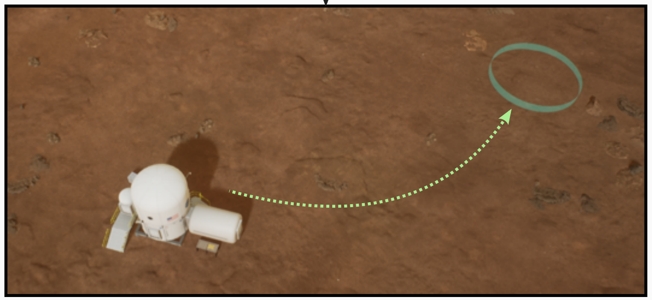


Actions Executable in this Storyboard

1. Load the toolbox on the rover
2. Get CENTAUR's remote controller
3. Start CENTAUR and check that it boots correctly
4. Load the boxed Greenhouse parts on the rover
5. Go to the building site

Frame Descriptions

1 CENTAUR Rover + Remote Controller

2 Boxed Greenhouse Parts

3 Toolbox

4 CENTAUR Route to Building Site

5 Mission Start Location - Main Base

2

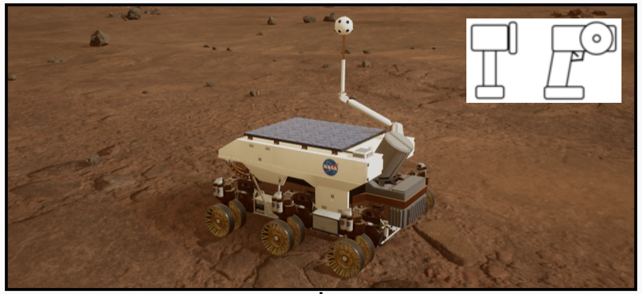
Storyboard Title, Sequence, & Description

Greenhouse structure

Once the location is reached, the astronauts wil need to mount the greenhouse by parts. First it will be the floor, then the frame, and then the plastic cover/dome.
Once it's all mounted, the building will need to get presurized and filled with the right gases.

Overheat, Greenhouse

5

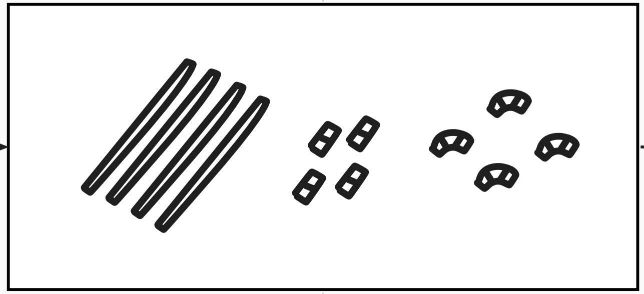


Assets Available in this Storyboard

- CENTAUR Rover
- Boxes
- Greenhouse Frame Parts
- Greenhouse Cover
- Greenhouse Status Console
- Cable extensor set (cable + sockets)
- O2 Pipes

3

1



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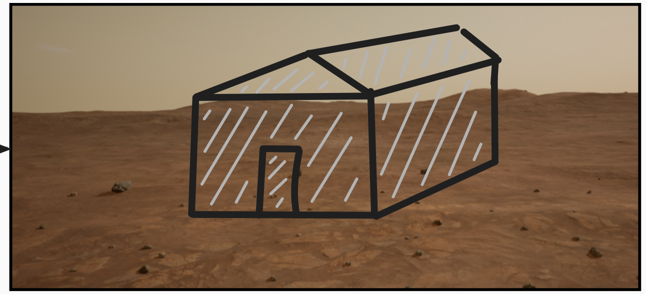
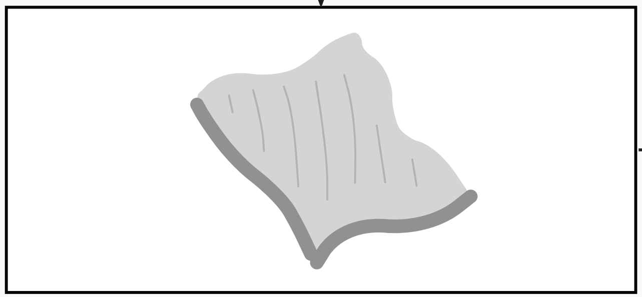


Actions Executable in this Storyboard

1. Unload the material from the CENTAUR
2. Extend the floor sheet in the corresponding place
3. Mount the building frame on top of the floor sheet
4. Put the cover dome material on top of the frame, and tight it securely with the floor, to avoid any leaks
5. Connect the greenhouse to the main habitat (air and pressure suply)
6. Check that the greenhouse is at the right pressure

4



Frame Descriptions

1 Greenhouse Frame Parts

2 Mounted Greenhouse

3 Boxes

4 Greenhouse Cover

5 CENTAUR Rover + Remote Controller

Overheat, Greenhouse

3

Storyboard Title, Sequence, & Description

Tools gathering for ice mining

The astronauts need a specific toolset for gathering ice. The ice is located in cold areas such as caves forming big ice rocks.

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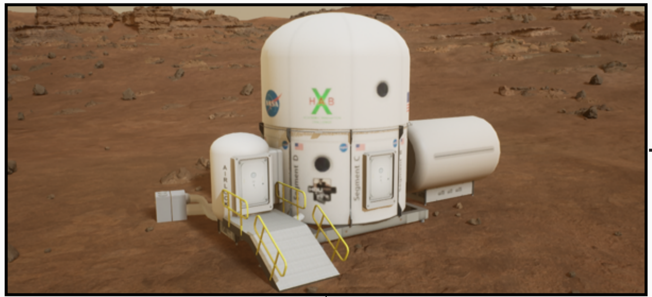
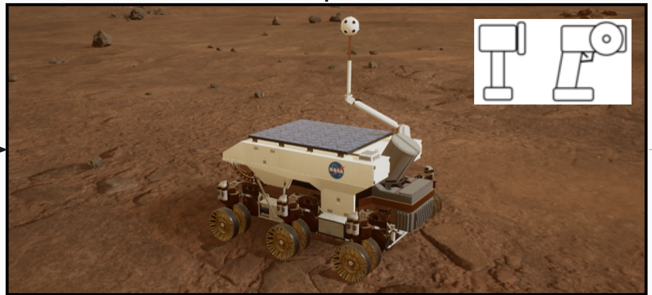


Assets Available in this Storyboard

- CENTAUR Rover
- CENTAUR Remote Controller
- Toolbox
- Samples Box

3

1



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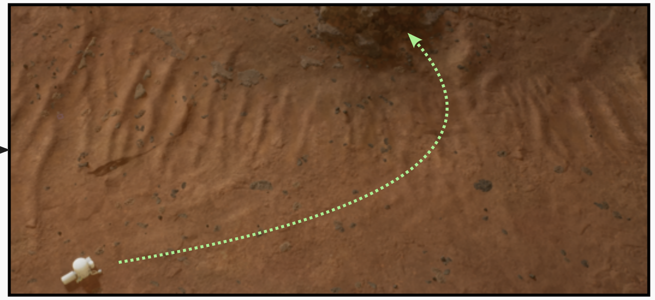

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Actions Executable in this Storyboard

1. Return to the base
2. Unload all the extra materials and tools
3. Load the ice gathering toolbox on the CENTAUR
4. Load the empty box for ice pieces on the CENTAUR
5. Go to the ice mining site

Frame Descriptions

1 CENTAUR Rover + Remote Controller

2 Route to Mining Site

3 Toolbox

4 Samples Box

5 Location - Main Base

Overheat, Greenhouse

Storyboard Title, Sequence, & Description

4

Ice mining

To obtain ice, the astronauts must break the ice rocks into small ice rocks.

Assets Available in this Storyboard

- Toolbox
- Pickaxe
- Samples Box
- Ice Rock
- Ice Sample..

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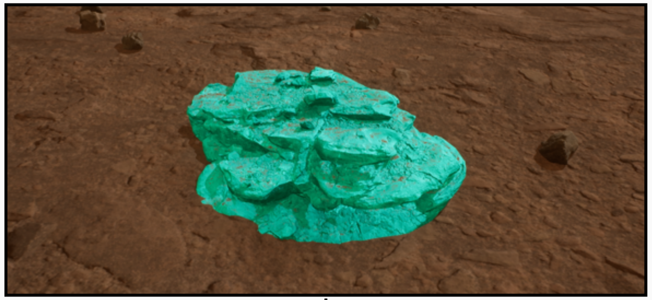

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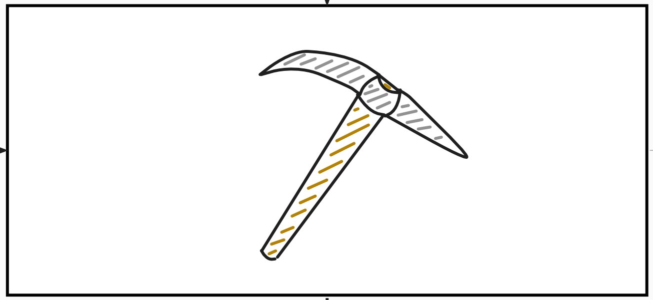

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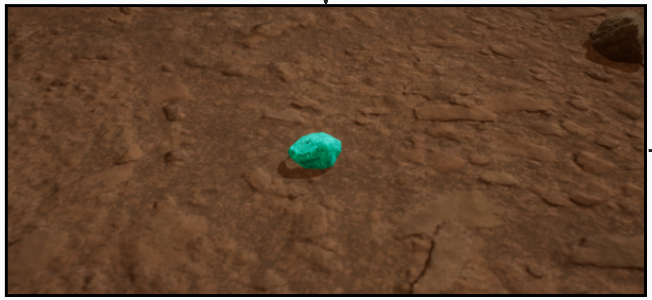


Actions Executable in this Storyboard

1. Open the toolbox
2. For each ice sample:
    a. Mine the ice untill it breaks
    b. Store the ice pieces in the samples box
3. Store the tools

Frame Descriptions

1 Pickaxe

2 Samples Box

3 Toolbox

4 Ice Sample

5 Ice Rock

Overheat, Greenhouse

Storyboard Title, Sequence, & Description

5

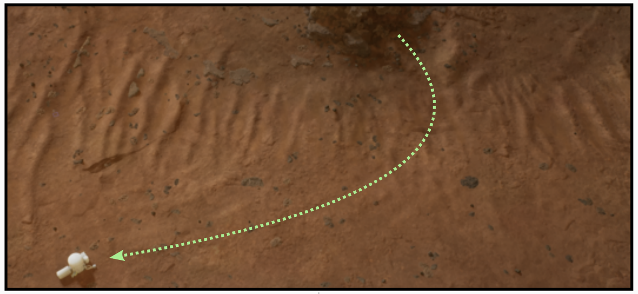
Process Ice Samples

Astronauts must process the ice stone before using the water to make it apt for consumption, for that they are gonna use the melting machine to turn ice into water and the filtering machine to filter the liquid.

Assets Available in this Storyboard

- Samples Box
- Ice Sample
- Melting Machine
- Filtering Machine
- Bottles

5



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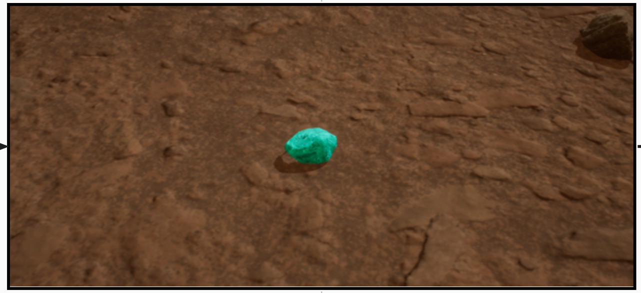

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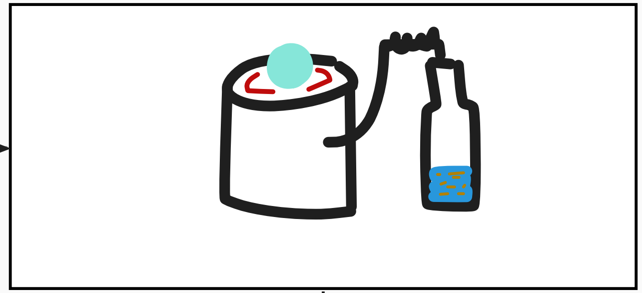

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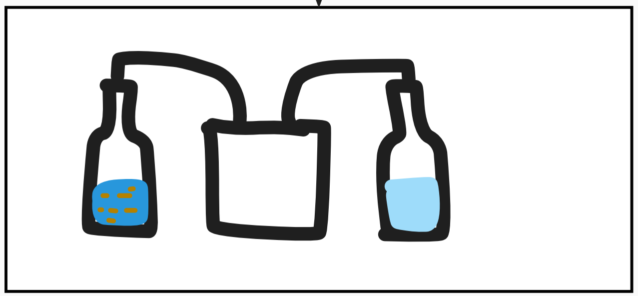


Actions Executable in this Storyboard

1. Return to the main base
2. Put the ice samples from the box into the melting and filtering machines
3. Store the filtered water in the greenhouse

Frame Descriptions

1 Ice Sample

2 Melting machine in action

3 Samples Box

4 Filtering machine in action

5 Return to base Route

Overheat, Greenhouse

6

Storyboard Title, Sequence, & Description

Farm soil gathering

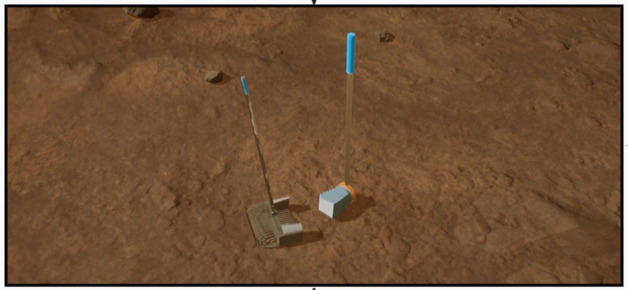
The next step is to obtain soil for the garden. The astronauts will walk out of the base and collect a large amount of soil in order to have somewhere they can plant crops.

Assets Available in this Storyboard

- Toolbox
- Soil Gathering Tool
- CENTAUR Rover
- CENTAUR Remote Controller
- Bag(x3)

5

3



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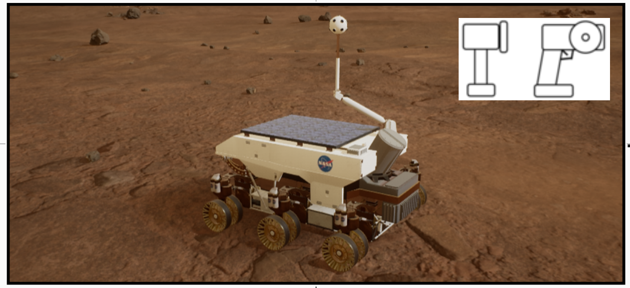

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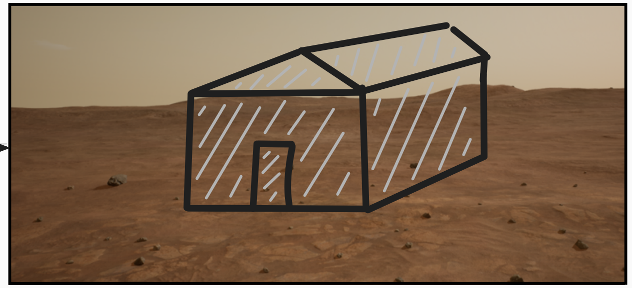

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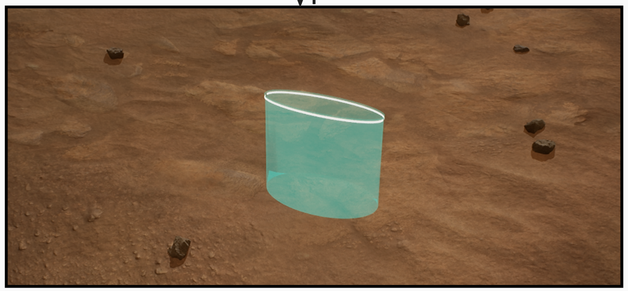

Actions Executable in this Storyboard

1. Load the soil gathering toolbox on the CENTAUR
2. Get the CENTAUR remote controller
3. Get out of the base
4. Open the toolbox
5. Pickup the soil gathering tool
6. Fill at least 3 bags of soil:
   a. Plug a bag inthe tool
   b. Operate the tool until the bag gets full
   c. Unplug the bag and close it
   d. Store the bag in the CENTAUR
7. Return to the base
8. Store the bagged soil in the greenhouse

Frame Descriptions

1 CENTAUR Rover + Remote Controller

2 Current Mission Step Location - Main Base

3 Soil Gathering Tool

4 Bag

5 Toolbox

7

Storyboard Title, Sequence, & Description

Nutrients and Seeds

Martian soil is not fertile, to use it for crops, the astronauts had to add nutrients and make it fertile.

Overheat, Greenhouse

Assets Available in this Storyboard

- Seeds Box
- Nutrients Bag
- Seeds Bag
- Greenhouse

5

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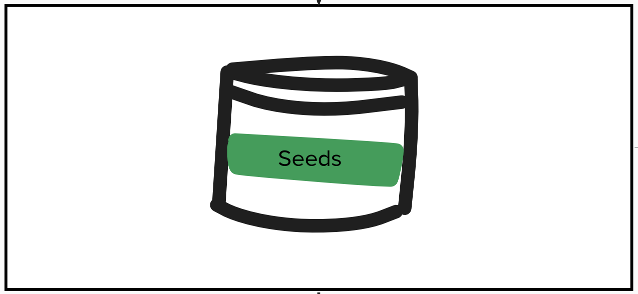

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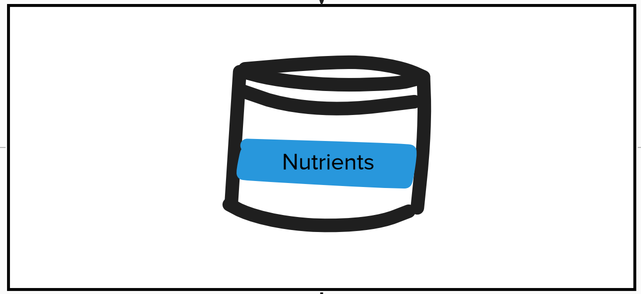

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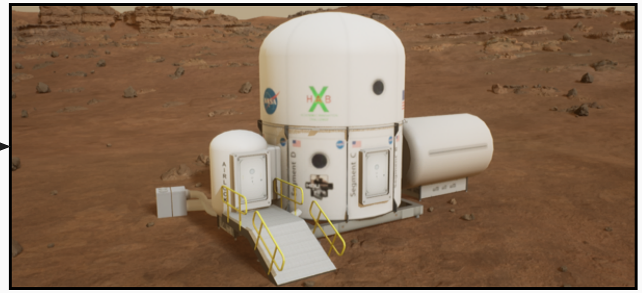

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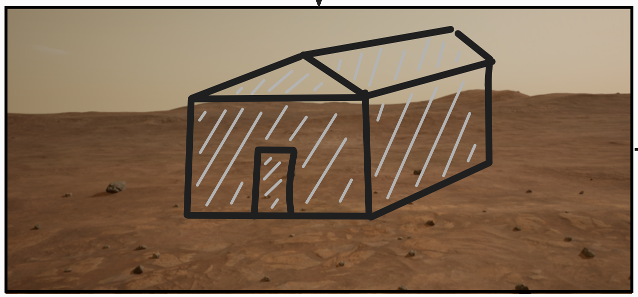

Actions Executable in this Storyboard

1. Open the seeds box
2. Get 1 nutrients bag
3. Get 1 seeeds bag
4. Close the seeds box
5. Let the bags in the greenhouse
6. Go back to the base

Frame Descriptions

1 Nutrients Bag

2 End Location - Main Base

3 Seeds Box

4 Greenhouse

5 Seeds Box

3 Props

In this section we describe a little further all the props that have been mentioned in the storyboards. Our goal is to include a little description of the prop that we have in mind, to make it more clear for the people who wants to develop our scenarios.

We also want to add some reasoning on why the asset would be useful, and what makes us think that it's possible to create it, so people can get a better understanding of the prop and their role in the different scenarios.

3.1 Toolbox

To maintain order during the mission, and avoid losing the tools, it will be necessary to have a toolbox. It might be needed different instances of this prop with different sizes, as not every tool might perfectly fit in a generic toolbox.

Figure 2: A model of a toolbox from the XOSS editor.

3.2 Screwdriver

A useful tool that might be needed in Mars is an electric screwdriver. The screwdriver should be able to perform the following operations:

- Screw
- Unscrew
- Change power applied
- Change the bit

The different bits that can be applied to the screwdriver are related with the screws that are used, and they are both described in section 3.3.

The screwdriver should also be stored together with the bits and screws in a toolbox like the one in section 3.1.

Figure 3: Early version of the screwdriver model.

NOTE: when in the storyboards we talk about the action of "screwing", we actually mean the whole process of choosing the right bit, get the correct screw, place it in the whole, choose the correct power and mode for the screwdriver, and screw the screw in place. The "unscrewing" action is analogous, but removing the screw and storing it.

3.3 Screws and screwdriver bits

For the screwdriver described in section 3.2 to work, it's needed to have some bits and some screws. To make it more realistic, there should exist different types of screws and their corresponding bits.

Also, for this iteration of the contest, it could be more engaging if the screws are not automatically set in place or they despawn after the use, but rather that the astronaut needs to manually put it in place or remove it and store it in the box.

Both the bits and the screws could be stored in the same toolbox as the screwdriver, to have an easy access to the entire tool set.

3.4 Sample zip bag

During the martian missions, samples will be gathered, (from rocks to regolith or soil). Maybe not only samples, but also bigger quantities of soil. To store them and avoid them getting contaminated by things that were brought from Earth, we have designed this prop: a zip bag.

It should be able to be opened and closed by the astronaut, and different things should fit inside. There could be multiple instances of the prop with different sizes, if you are planning to store very different objects inside.

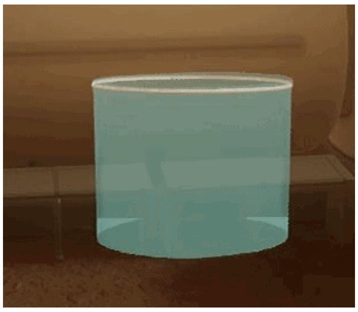

Figure 4: A model of the opened zip bag in the XOSS editor.

3.5 Regolith/soil collector

This tool is used to collect regolith from the martian surface. For the storyboard, we have represented it using two of the assets in the XOSS editor, but it could also be a new asset that (for example) absorbs the regolith.

3.6 CENTAUR rover

For martian missions it will be very helpful to have a rover accompanying the astronauts during the missions. It would also be very useful if the rover could carry some items around, because some material might be heavy or uncomfortable to carry. For that reason, we have designed a prop that it's a remote-controlled rover with some extra capabilities:

- **Carrying objects:** One of the main reasons for the use of the rover is to carry objects of big dimensions or to carry items for long walking distances.
- **Tool mounting points:** Another advantage of having a rover helping in the missions is that it can transport large tools and use them remotely using the controller. For that, the rover should have some places where the astronauts can attach specific tools that require some space to be operated. For example, if the astronauts are going to use a drill of great dimensions, instead of mounting it on every place, they could mount it on the rover, and move the rover from one place to another, which would save them time and energy.

The rover should also be divided in sections that can be disassembled, to be able to do some reparations in case they are needed. And also some interaction interface should be added to it, like a power button, a display or a connector socket (to connect it to other devices).

For this prop, we plan to use the CENTAUR rover that already exists in the XOSS editor, and modify it a bit to meet our ideas. For this reason, we have decided to keep it with the same name.

In figure 5 you can see a version of the actual model from the XOSS editor divided by pieces and fully mounted.

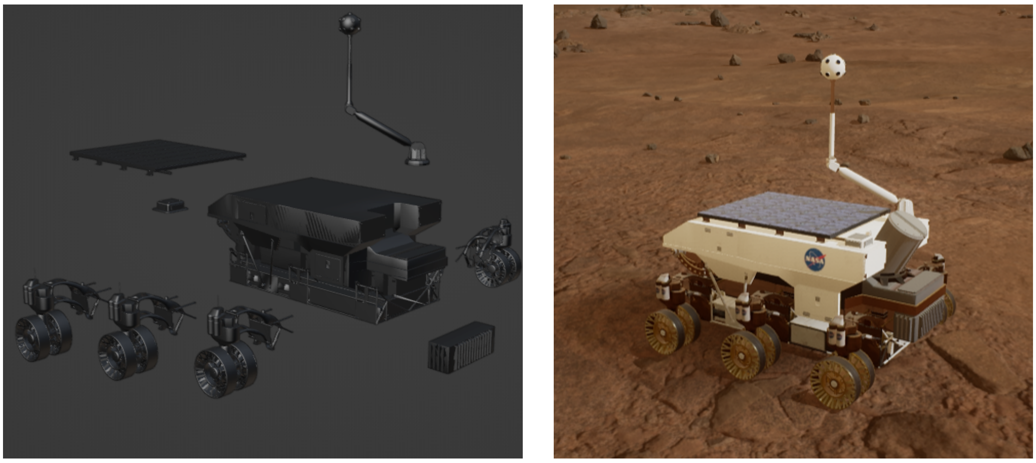

Figure 5: CENTAUR models. From left to right they are the model divided by parts and the model fully mounted and texturized in the XOSS editor.

The remote controller that will be used to move the CENTAUR rover is described in section 3.7.

3.7 CENTAUR controller

This prop is the remote controller of the CENTAUR rover (described in section 3.6). The idea is that it's able to control the rover's movement and other functionalities that it might have. In figure 6 you can see an sketch of the controller.

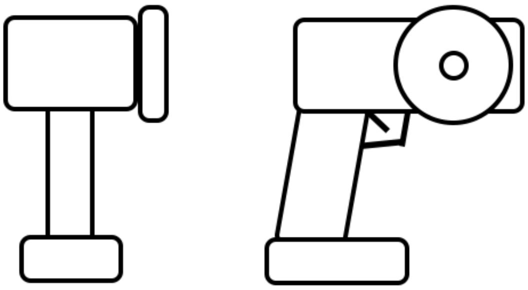

Figure 6: Sketch of the CENTAUR's controller. The image on the left is the rear view and the one on the right is the lateral view.

3.8 O_2 pipes

Pipes that are used to transport oxygen and other gases to make the habitat and the greenhouse breathable.

3.9 Cable

This prop is an electric wire that is mainly used for the solar panels connection, but it can also be used in other electrical systems. It should be attachable to the habitat and the extension sockets (which are explained in section 3.10).

3.10 Extension sockets

To connect the solar panels with the habitat, instead of using 1 long cable, we propose to use some electrical extension sockets. These sockets should be attached to the ground, to avoid having the cables floating away when there is a bit of wind.

This also helps the astronauts in the reparation, as if a cable is damaged, it will be easier to change a small cable rather than a long one.

3.11 Box

This prop is a modular box that contains different materials or samples. The astronauts should be able to disassemble it and take each part individually, so they can recycle the box once the materials are outside of it.

To assemble it or disassemble it, it could be programmed to work with the screws and the screwdriver, so it makes sense that the box can hold sensible materials.

The box should be able to be instantiated in different sizes, as not every object has the same dimensions. In figure 7 you can find some examples of the boxes.

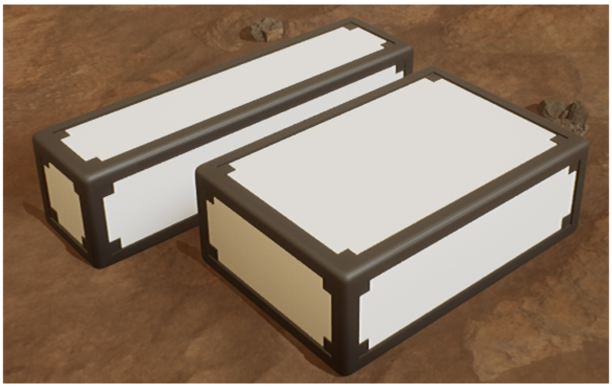

Figure 7: Two boxes of different sizes in the XOSS editor.

3.12 Greenhouse

This prop should be stored by parts, so that the astronauts can easily mount it. It should have a frame, a cover, and a control console, to track the status of the interior of the greenhouse.

Once the building is ready, the astronaut can attach the oxygen pipes and the cables to it, to connect it with the habitat.

The greenhouse should have some storage that is accessible through the inside and the outside, so that astronauts can recharge the supplies using the EVA suit, and they can also use them without having to go outside to get them.

3.13 Ice

This is a resource that can produce water if it's treated with the right tools. It consists of 2 props:

- **Ice rock:** A big rock made out of ice, probably located inside the cave. It can be mined using a pickaxe, to obtain ice samples.
- **Ice sample:** A piece that has fallen from an ice rock. It can be turned into water using the melting machine 3.15 and the filtering machine 3.16.

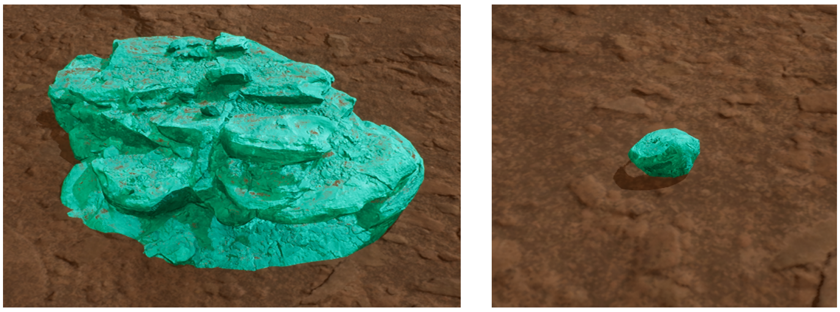

Figure 8: Left image: ice rock. Right image: ice sample. They both are in the XOSS editor.

3.14 Pickaxe

A tool used for breaking the ice rocks explained in section 3.13. It can either be a traditional pickaxe or an electrical version that can be used to break the ice.

3.15 Melting machine

This prop can take an ice sample and melt it, storing the resulting water in some bottles.

3.16 Filtering machine

This machine takes the melted ice from the bottle and filters it from the environmental and dirt particles. The resulting water is stored in another bottle.

The machine should have removable filters, to be able to implement the "*Obstructed filtering machine*" event.

3.17 Bottle

A recipient used to store water. It should be able to hold the colt temperatures for a while, avoiding that the water inside freezes immediately.

4 References

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