NASA MarsXR Challenge

Upgrades proposed for the martian
virtual training environment XOSS

Team: Overheat

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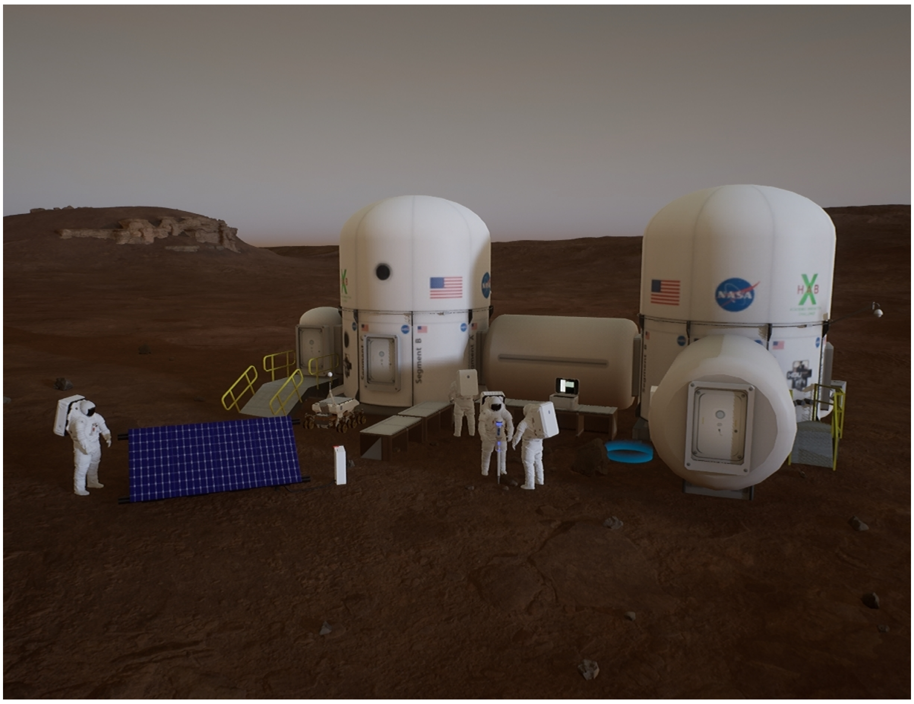


Contents

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: Holographic map

This storyboard is focused on getting a 3D representation of the Martian terrain. Even though there are already scans of the martian soil, it can be useful for the astronauts to get a more detailed scan of the zone where they will live. This scan can be done with the drone, for better accuracy.

For this mission, the astronauts will need to build a structure to display the 3D hologram map that they will scan. To scan it, they will do it with the drone, flying at a certain altitude and taking some scans using the LIDAR system (or other techniques).

This will then give a set of points scanned, that will need to be transferred to the map structure. There, a Digital Elevation Model (DEM) of the terrain will be created and displayed as an AR hologram.

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.
- **Area scanned:** A metric that could be tracked is how much area has been scanned using the drone. [1]
- **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. (NOTE: if the structure is placed close enough, extensors might not be needed.)
- **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.
- **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:

[1] Assuming that the drone uses a LIDAR and creates a squared result, and that the square scans are done at certain intervals or when the astronaut decides to do them, computing the total area takes $O(n^2)$ time, where n is the number of scans done, using a trivial algorithm.

- **Calibration error:** One thing that could randomly happen is that the drone is not well calibrated. If this event happens, then the controls won't do as expected (for example, the go strait action will make the drone rotate). The astronaut will then have to follow some sequence of recalibration to make it work.
- **Malfunctioning part:** It might be possible that a part of the drone is malfunctioning, so the astronaut will need to replace it for a new one.
- **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.
- **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, Holographic Map

Storyboard Title, Sequence, & Description

1

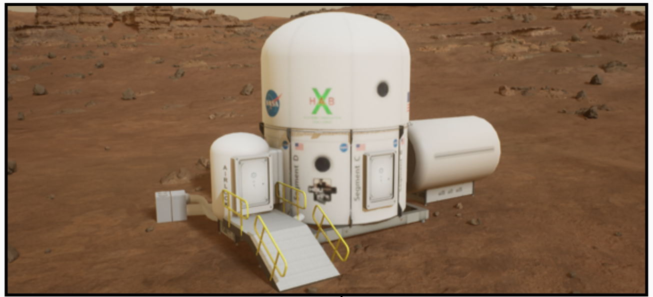
Prepare the resources

First, the astronauts need the materials to mount the holographic map structure. For that, they need to go to the resources location with the CENTAUR Rover and pickup the material boxes.

Assets Available in this Storyboard

- CENTAUR Rover
- CENTAUR Remote Controller
- Boxes

5



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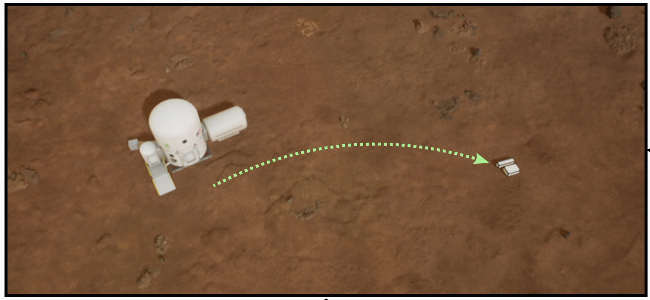

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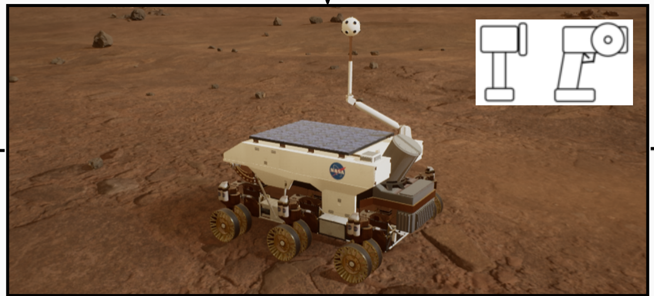

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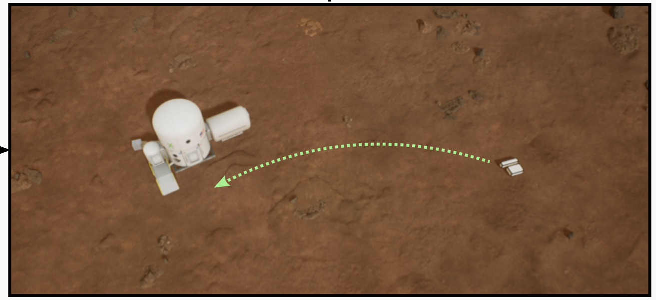

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Actions Executable in this Storyboard

1. Get the CENTAUR remote controller
2. Turn ON CENTAUR
3. Go to Resources location
4. Carry the resouces on the CENTAUR
5. Come back to the base
6. Unload the material boxes
7. Park the CENTAUR
8. Turn OFF CENTAUR
9. Store the CENTAUR remote controller

Frame Descriptions

1 CENTAUR Rover + Remote Controller

2 Return to Base Route

3 Go to resources Route

4 Boxes

5 Start Mission Location - Main Base

Overheat, Holographic Map

2

Storyboard Title, Sequence, & Description

Prepare the Map Module

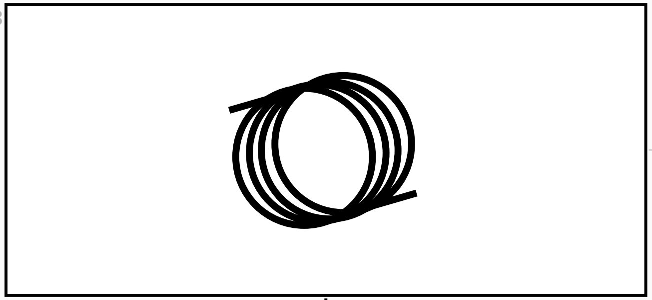
Before start using the map, the astronauts had to prepare the needed structure to visualize the holographic map. Using the appropriate screws, the astronauts can mount the map and connect it to the electric system.

Assets Available in this Storyboard

- Toolbox
- Screwdriver
- Screwdriver bits box
- Boxes
- Map Structure
- Cables

5

3



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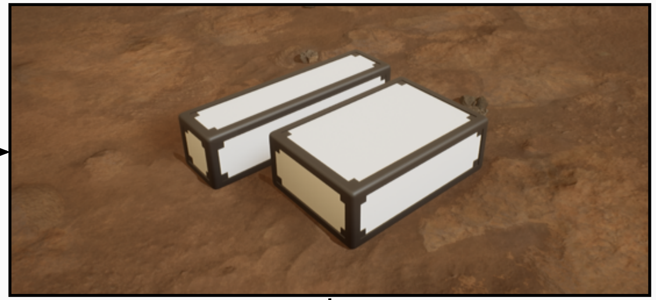

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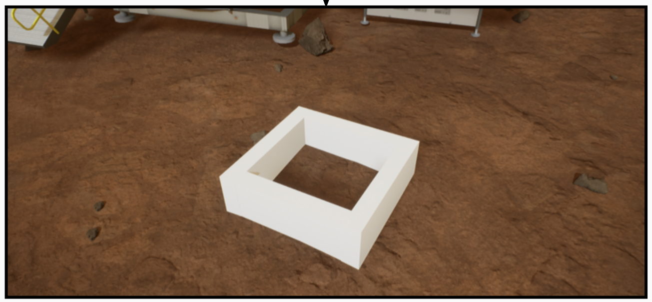


Actions Executable in this Storyboard

1. Open the toolbox
2. Get the Screwdriver and the bits box
3. Open the boxes
4. Mount the map structure
5. Get the cables
6. Connect the map to electrical suply
7. Store the tools

Frame Descriptions

1 Screwdriver + Bits Box

2 Boxes

3 Cables

4 Map Structure

5 Toolbox

Overheat, Holographic Map

Storyboard Title, Sequence, & Description

3

Cleanup

Once the map structure is ready is time to tidy the base, save the tools in their toolboxes and store the empty boxes.

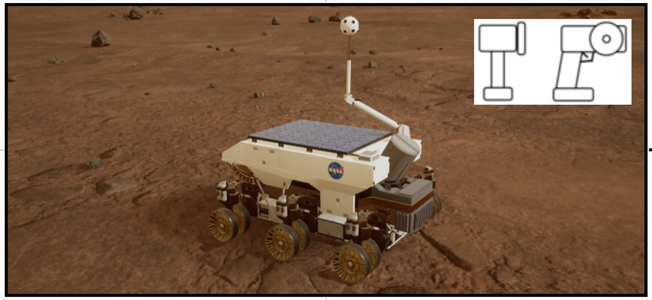
Assets Available in this Storyboard

- Toolbox
- Screwdriver
- Screwdriver bits box
- Boxes
- CENTAUR Rover
- CENTAUR Remote Controller

5

3

1



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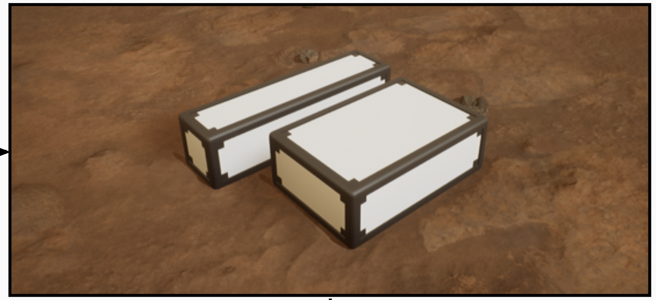

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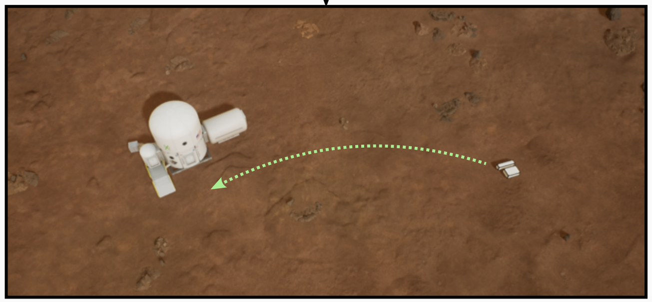


Actions Executable in this Storyboard

1. Store the Screwdriver
2. Store the bits box
3. Close the toolbox
4. Carry the empty boxes on the CENTAUR
5. Go to designated area
6. Store the boxes
7. Return to the base
8. Park the CENTAUR
9. Turn OFF CENTAUR

Frame Descriptions

1 CENTAUR Rover + Remote Controller

2 Boxes

3 Screwdriver + Bits Box

4 CENTAUR Back Route

5 Toolbox

Storyboard Title, Sequence, & Description

4

Get Terrain Data

For the terrain data, the astronauts need to perform terrain recognition, for that, they can use the drone. Flying the drone along the area will make the drone camera get data and store it in a USB memory.

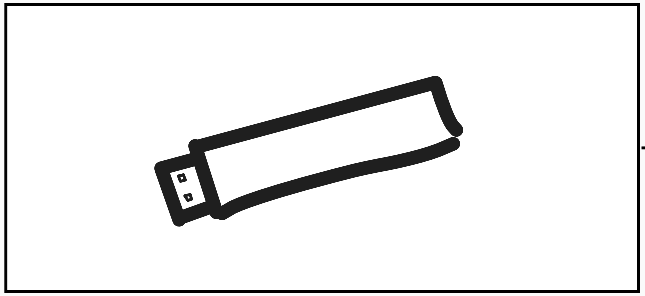
Overheat, Holographic Map

Assets Available in this Storyboard

- Drone Box
- USB
- Drone
- Drone Remote Controller

5

3



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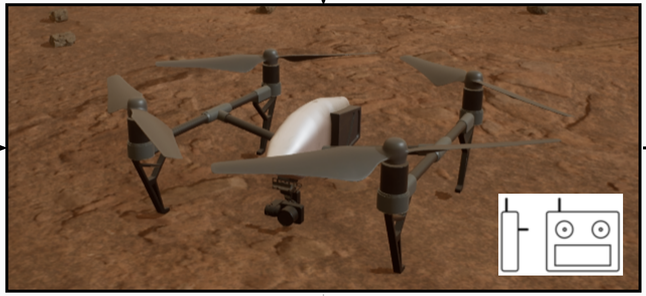

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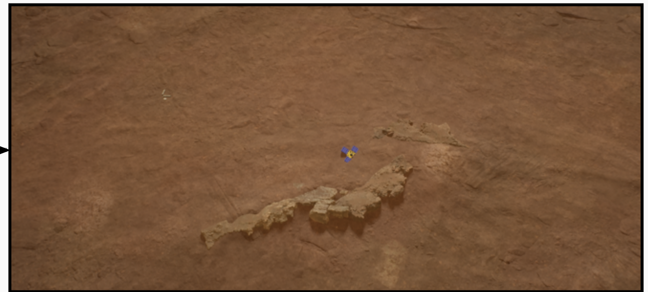

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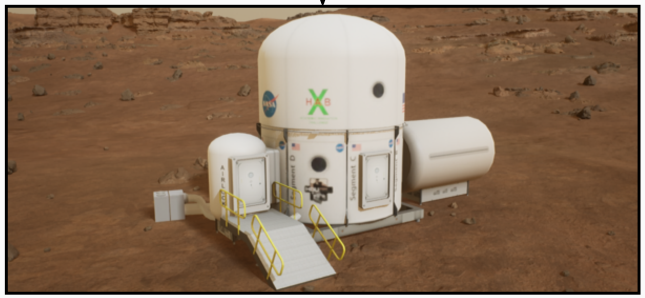


Actions Executable in this Storyboard

1. Open the drone box
2. Get the USB
3. Connect the USB in the drone
4. Get the drone controller
5. Turn ON the drone
6. Perform a flight for the area
7. Take OFF
8. Turn OFF the drone
9. Remove the USB
10. Store the drone and the remote controller

Frame Descriptions

1 Drone + Remote Controller

2 Flying Drone

3 USB

4 End Location - Main Base

5 Drone Box

Overheat, Holographic Map

Storyboard Title, Sequence, & Description

5

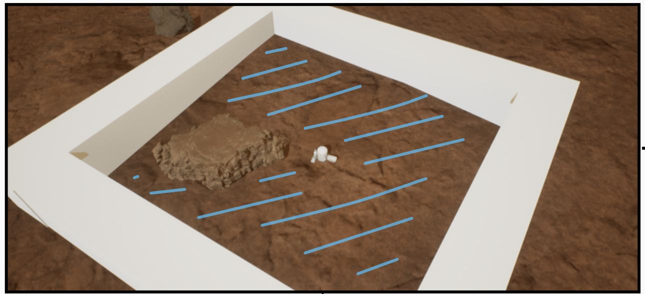
Start Holographic Map

With the data, the only thing left is to connect the USB to the map console and boot it to display the map.

Assets Available in this Storyboard

- USB
- Map Structure

5



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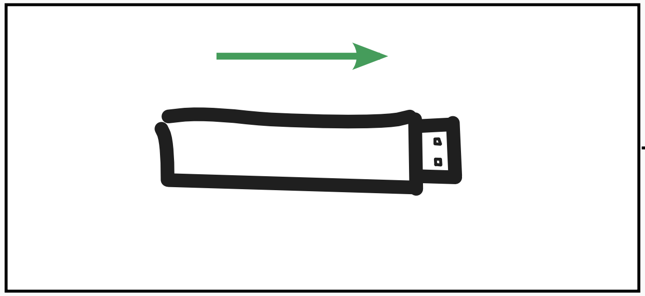

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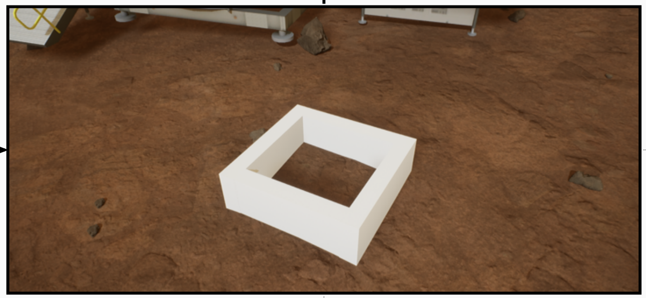

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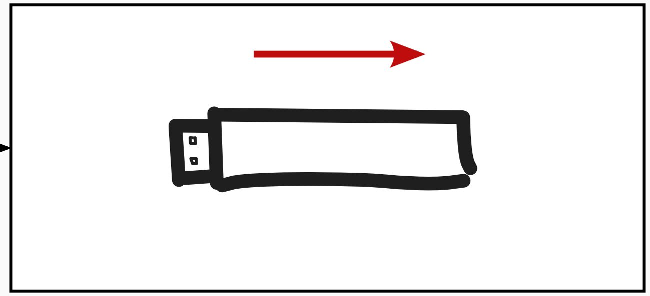

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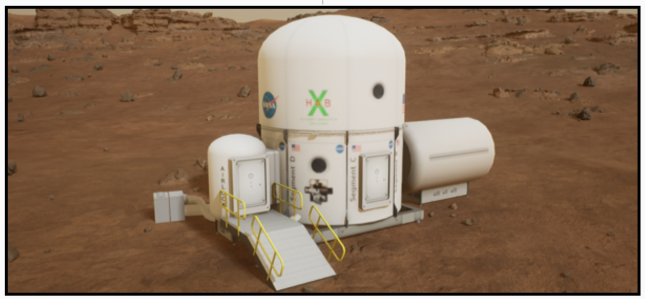

Actions Executable in this Storyboard

1. Connect the USB
2. Boot the Map
3. Remove the USB
4. Store the USB

Frame Descriptions

1 Map Structure

2 USB - Unplug

3 USB - Plug

4 End Location - Main Base

5 Booted HoloMap

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

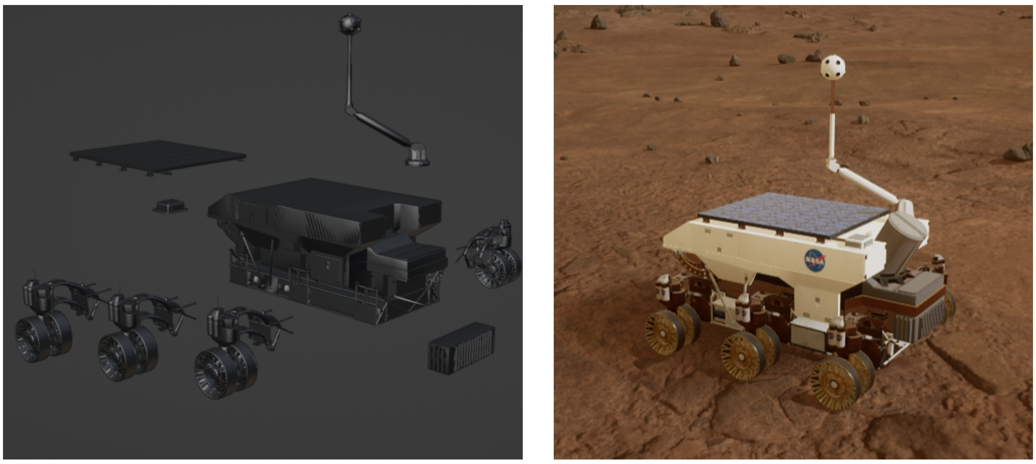

Figure 4: CENTAUR models. From left to right they are the model divided by parts and the model fully mounted and texturized in the XOSS editor.

The remote controller that will be used to move the CENTAUR rover is described in section 3.5.

3.5 CENTAUR controller

This prop is the remote controller of the CENTAUR rover (described in section 3.4). The idea is that it's able to control the rover's movement and other functionalities that it might have. In figure 5 you can see an sketch of the controller.

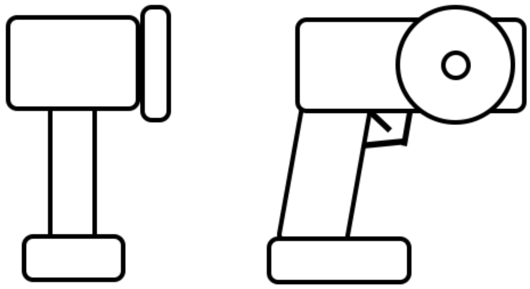

Figure 5: Sketch of the CENTAUR's controller. The image on the left is the rear view and the one on the right is the lateral view.

3.6 Drone

The drone is an asset that is already implemented in the XOSS editor, but it needs some modifications to work with our scenarios.

The drone needs to be remotelly controlled by the astronaut (using a remote controller that is explained in section 3.7). Also, it needs to have a camera to explore the surroundings of Mars and help the astronaut controlling it in farther places.

For the purpose of the scenarios, it should also be divided by parts, having the main frame of the drone, the propellers, and the camera as detachable parts. This will allow the astronaut repair it in case of malfunction, or mount it from scratch if it's the first time of use. In figure 6 you can see the drone divided by parts and fully mounted.

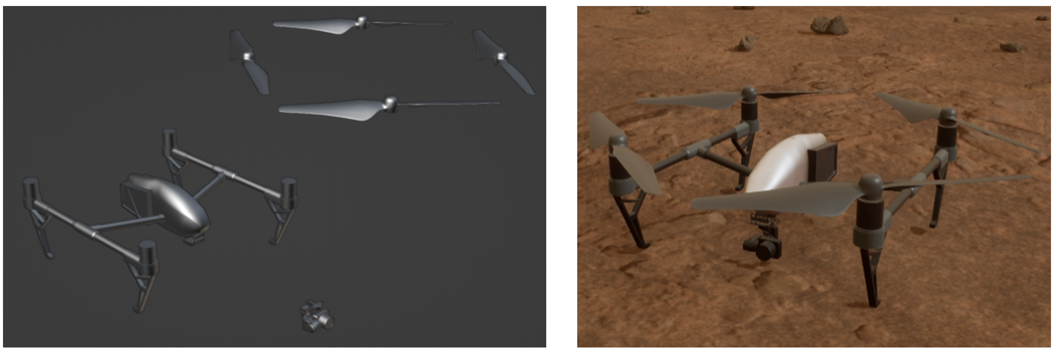

Figure 6: Drone models. From left to right they are the model divided by parts and the model fully mounted and texturized in the XOSS editor.

The drone could also have a LIDAR under it, to be able to scan the terrain more precisely than the scans made using the MRO.

3.7 Drone controller

This prop is the remote controller of the drone (described in section 3.6). The idea is that it's able to control the drone's movement and other functionalities loke the camera or the LIDAR. In figure 7 you can see an sketch of the controller.

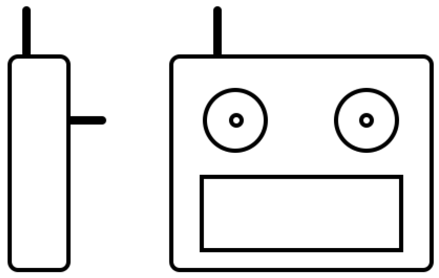

Figure 7: Sketch of the Drone's controller. The image on the left is the lateral view and the one on the right is the front view.

3.8 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 3.9).

3.9 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.

3.10 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 8 you can find some examples of the boxes.

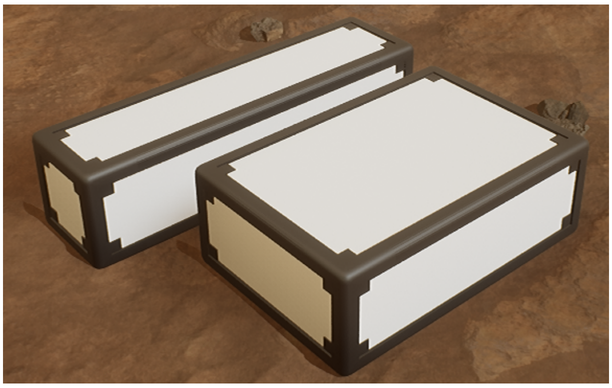

Figure 8: Two boxes of different sizes in the XOSS editor.

3.11 Map structure

This prop is the structure where the holographic 3D map will be displayed.

As the astronauts have access to AR technology in the visor, it will be useful to have a 3D representation of the surrounding terrain, to help them take some decisions. The structure facilitates that process, by making there a common point for the projection of the 3D map.

The structure should be separated by parts, and should be mounted by the astronauts.

Also, it should have some data connector sockets, so the astronauts can load the map using USB drives.

3.12 USB Memory

A USB memory that can be used to transfer data between different devices.

4 References

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