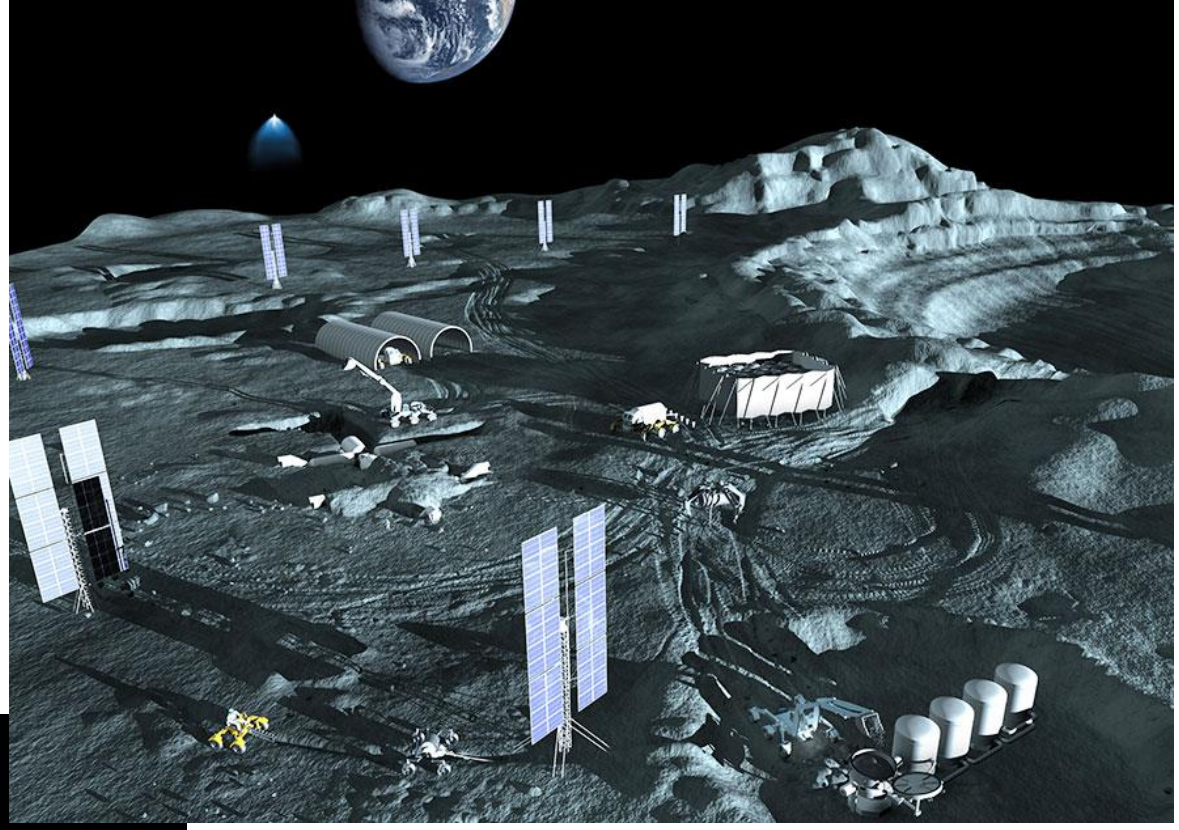
VR Lunar City Planning

Help NASA plan where to build their base of operations for pulling ice from craters and having a permanent location for humans to live and work on the moon.



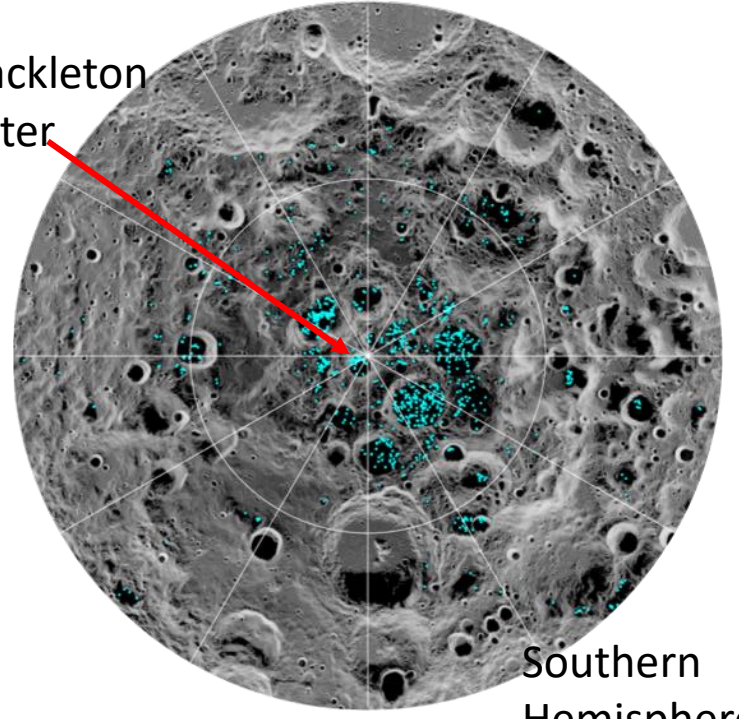
Early Lunar base with solar panels, oxygen tanks, robotic rovers, work areas and long shadows from the sun when on the South Pole.

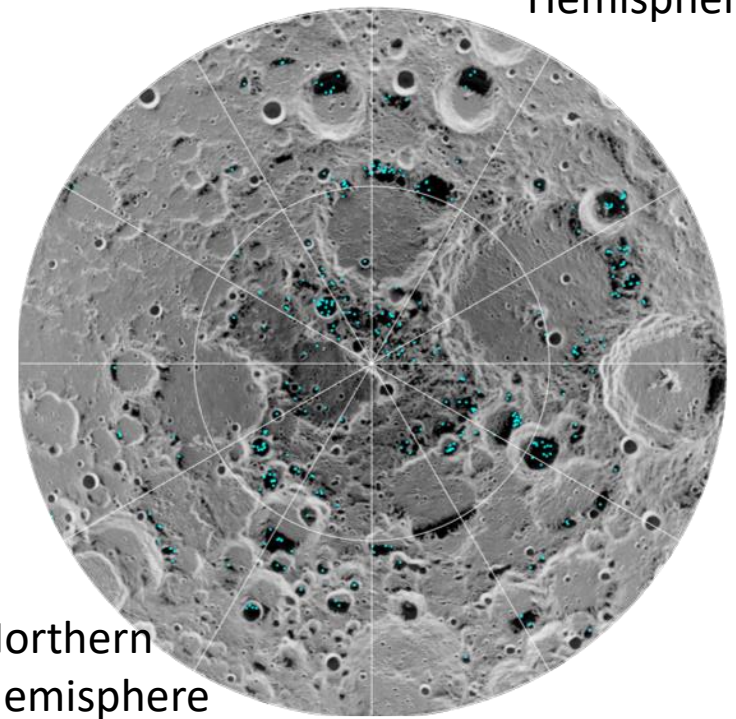
Lunar landing pads.

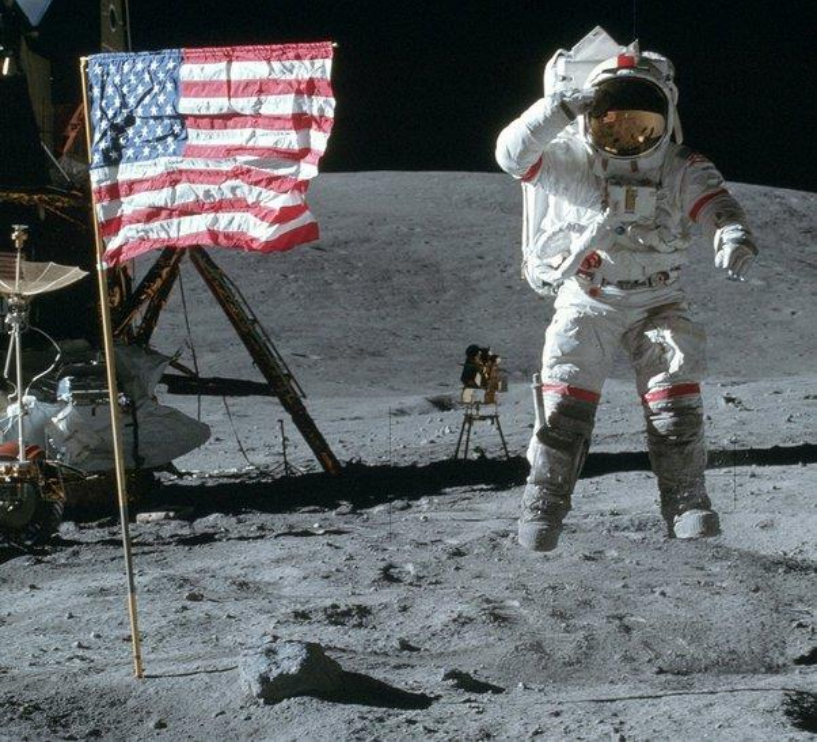
Lunar City Planning

Background information

- Orbiting Lunar satellites show there is water ice in the craters around the North and South Poles of the moon where the sun is never able to shine into the bottom of the craters and they remain eternally cold. Scientists are not sure how the ice is distributed—could be little flakes and crystals, could be ice cubes or a very thin sheet under some dirt. NASA's current plan is to land people near the South Pole of the Moon to travel into a crater expected to have lots of ice in it and see how it might be extracted and then use the water to make rocket fuel and oxygen to support the lunar base and help fuel missions from the moon to go further into space.
- Setting up a base of locations to work from and explore from is something that is done by oil and mining companies as they explore a site for extracting the materials and minerals they are interested in on a regular basis. This is also something the military does when preparing for a mission. NASA is now in a similar position of needing to plan out a work site in a very difficult location that doesn't include roads or communications or even trees for shade.
- NASA has already determined they are interested in studying Shackleton Crater whose rim is very close to the South Pole. Before setting foot on the location, it would be good to have a plan for how they should lay out equipment so they are not driving over power cables and damaging them, planning how to set up solar panels so they are not being dusted every time a rocket lands or a rover drives by. It would also be good if the solar panels were not in the shadows of each other so they could produce more power. There will be many decisions that need to be decided to make the base more functional and more safe for both the people and the equipment being used.
- Some of the planning will depend on the topography (lay of the land)—hills, cliffs and rocks to avoid.
    - Is there a flat spot for the habitat?
    - Are there hills and rocks or other structures that can protect the people or equipment from radiation?
    - Where is the location inside the crater with the most ice—is there a reason we need to be closer or further away from it?
- Some will depend on the needs of the equipment—
    - Where do solar panels get the most light?
    - How far should the landing pads be from the habitat? From the fuel production plant?
    - How close should the landfill for the trash be to the habitat? What about the bone yard?
- These kind of decisions are made on all big projects that include a piece of property—like when developing the first launch sites at Kennedy Space Center, a training facility at Johnson Space Center, a testing center at Langley and Marshall Space Centers, even high schools and universities. Big facilities need planning so the infrastructure of roads, power, lighting, communications, … support the job and the people that are getting things done. There might also be some decisions that can only be made once people are there. It may also be important to leave room for things we don't know about in the future.







Apollo 16 John Young jumping on the moon in a suit that weighs 180 lbs on Earth.

The intention of the VR Lunar Habitat and the VR Lunar City is to help NASA plan out locations and hardware that have never been built and never been seen by human eyes before. Obviously its not easy to be the first. The other possibility is that your ideas will help develop video games about the moon that will be more realistic because of your innovations.

One of the things I'm hoping students will help out with is teasing out how to use the 1/6th gravity of the moon to our advantage. For example, the International Space Station was built with micro-gravity in mind—the floors and ceiling are used for stowage and experiments the same as the walls. Some of the stowage racks are just made of cloth but the stowed items just float around inside and don't need lots of support. This would not be possible on Earth. The space suits today were optimized for working in microgravity and would be difficult to use on the moon. So….

- If I can jump 18" here on Earth, how high can I jump on the moon?
- If I jump 18" high and land a few inches to the left or right on Earth, how far off to the side will I be when jumping on the moon?
- The 'super strength' of being on the moon will make the astronauts clumsy until they get use to the gravity difference. This will happen for every team that arrives. Your design needs to allow for this adaptation time and also once they are adapted.
- It typically takes around two weeks for people to get their "space legs" when they get to the ISS. Will it be the same on the moon?
- What could be done on the moon with 1/6th gravity that can't be done on Earth?
- What kind of stowage is possible there but not here?
- Do they need the same number of rungs of a ladder or steps on the stairs as we do on Earth?
- How will people transfer supplies from the landers to the rovers and into the habitat?
- All of this will be done in big bulky space suits. All of the supplies will have to fit through the hatches.
- Is there a way that the moon's mini-g could make the transfer easier or safer?

Difficulties with less gravity

VR Lunar City Planning Project

Mike Bennett, Glenn Johnson

Requirements:
Choose a location at the South Pole of the moon close to the Shackleton Crater with easy access for entering the crater for exploring and removing ice from the bottom of the craters– be ready to explain your choice.

Your 4 min. or less video should show:

- Surrounding terrain
- Multi-national flag on pole
- 3 different landing sites—spaced out to avoid dusting the habitat, solar farm, and other landing pads
- Power—
  - Solar Farm
    - Spacing for solar panels to keep shadows off each other.
  - Mini nuclear reactor--SMR
  - Power cables to habitat and other equipment
- Processing plant for removing ice from regolith and separating O_2 and H_2 from the water.
- Trash location
- Boneyard for broken tools/vehicles/robots but still have good parts—organized
- Excavation location for lunar extrusion of soil brick--
- Transportation corridors that avoid dusting solar panels and running over cables
- Lighting for nighttime
- Should show the accurate location for the sun when near the south pole—shadows will be long.

This project can be developed using any type of software that will allow the user to record a video of the user leaving the front hatch of the habitat, going around the rover and taking a tour of the work site that includes the different power facilities, the processing plant, the trash and bone yards, the landing pads and all the hardware listed below. For example, this could be done on **Autodesk Inventor using the steering wheel**. Other CAD software should also have some options for looking around inside and around a part or assembly. Initially, the development of the environment is more important than using a headset and goggles.
https://www.youtube.com/watch?v=gUCM56x8TL0

- Communications tower
- Lunar electric Scooter—bigger wheels needed for undulating, sandy landscape.
- Sample/Tool wagon—hand pull/push
- Astronaut driven Rover
- Lunar Supply Pod Trailor
- Warning Signs
- Garage for working on vehicle
- Power Cables
- Cameras for monitoring moon walks and construction

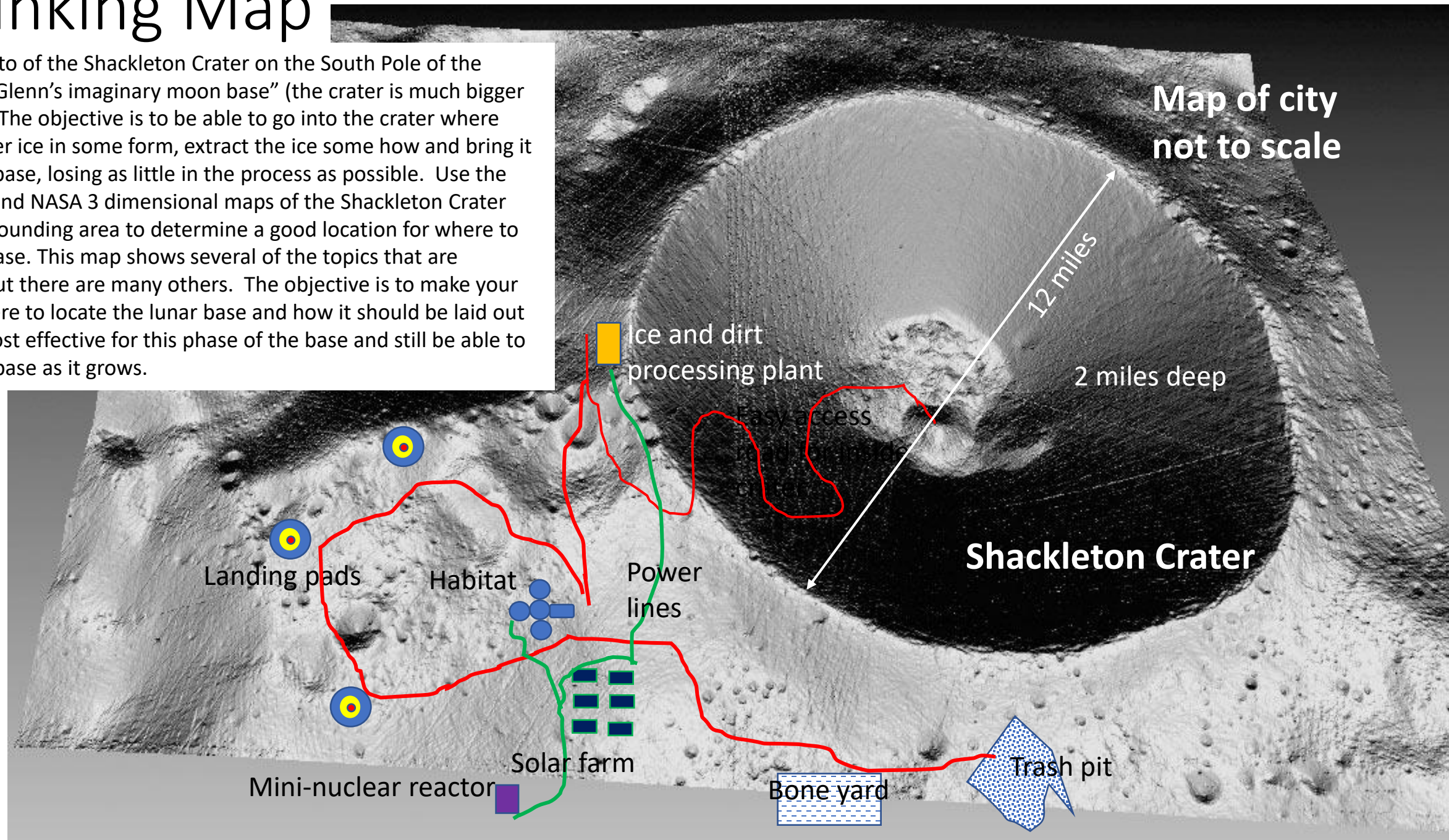
Models you can download

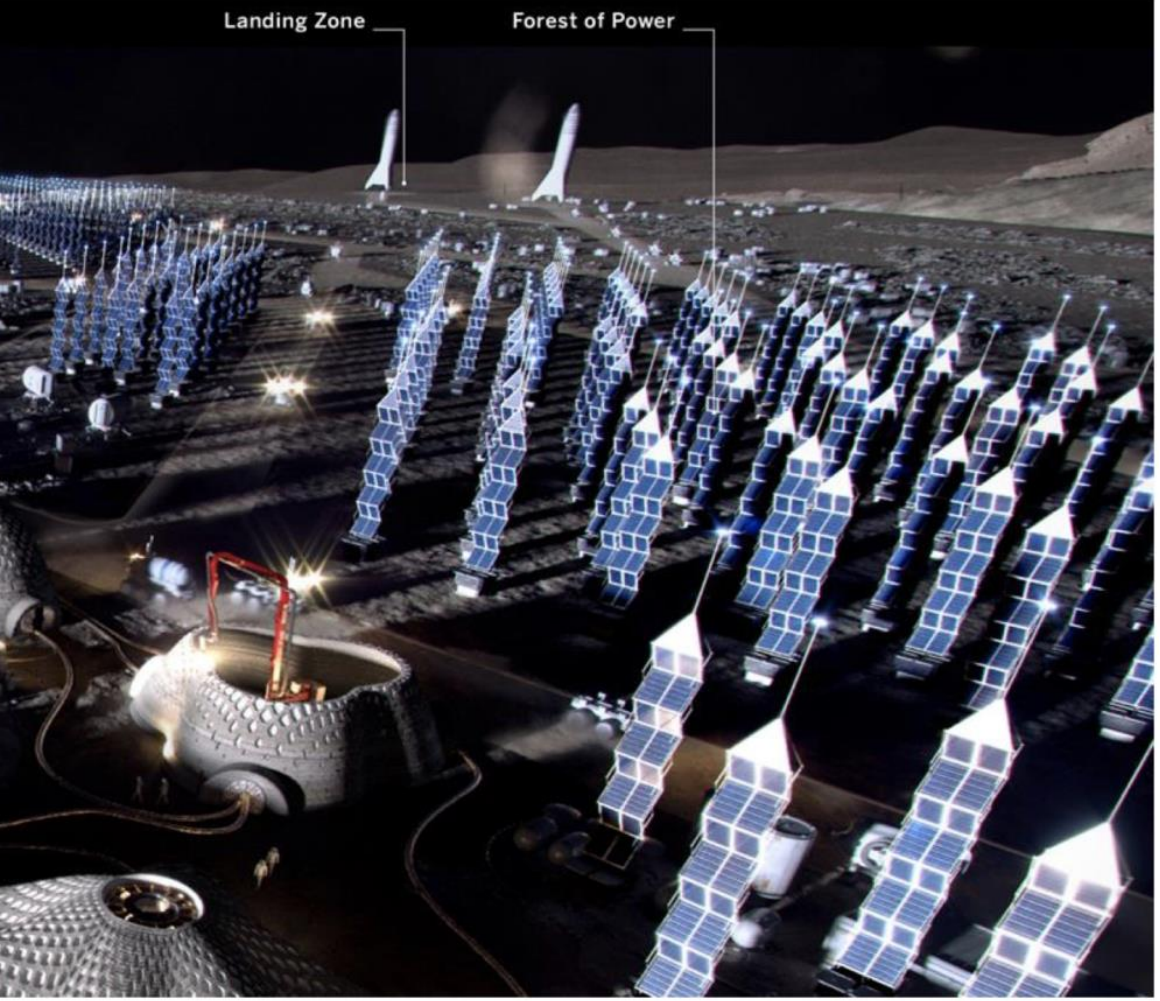
- https://www.cgtrader.com/3d-models?keywords=lunar+south+pole
- http://lroc.sese.asu.edu/archive/downloads

- Part of this project is for you to find resources. If you can find models of the newest space suits or rovers, use them. You don’t have to generate all of the NASA equipment.

Thinking Map

This is a photo of the Shackleton Crater on the South Pole of the Moon and "Glenn's imaginary moon base" (the crater is much bigger in real life). The objective is to be able to go into the crater where there is water ice in some form, extract the ice some how and bring it back to the base, losing as little in the process as possible. Use the internet to find NASA 3 dimensional maps of the Shackleton Crater and the surrounding area to determine a good location for where to set up the base. This map shows several of the topics that are important but there are many others. The objective is to make your case for where to locate the lunar base and how it should be laid out to be the most effective for this phase of the base and still be able to expand the base as it grows.





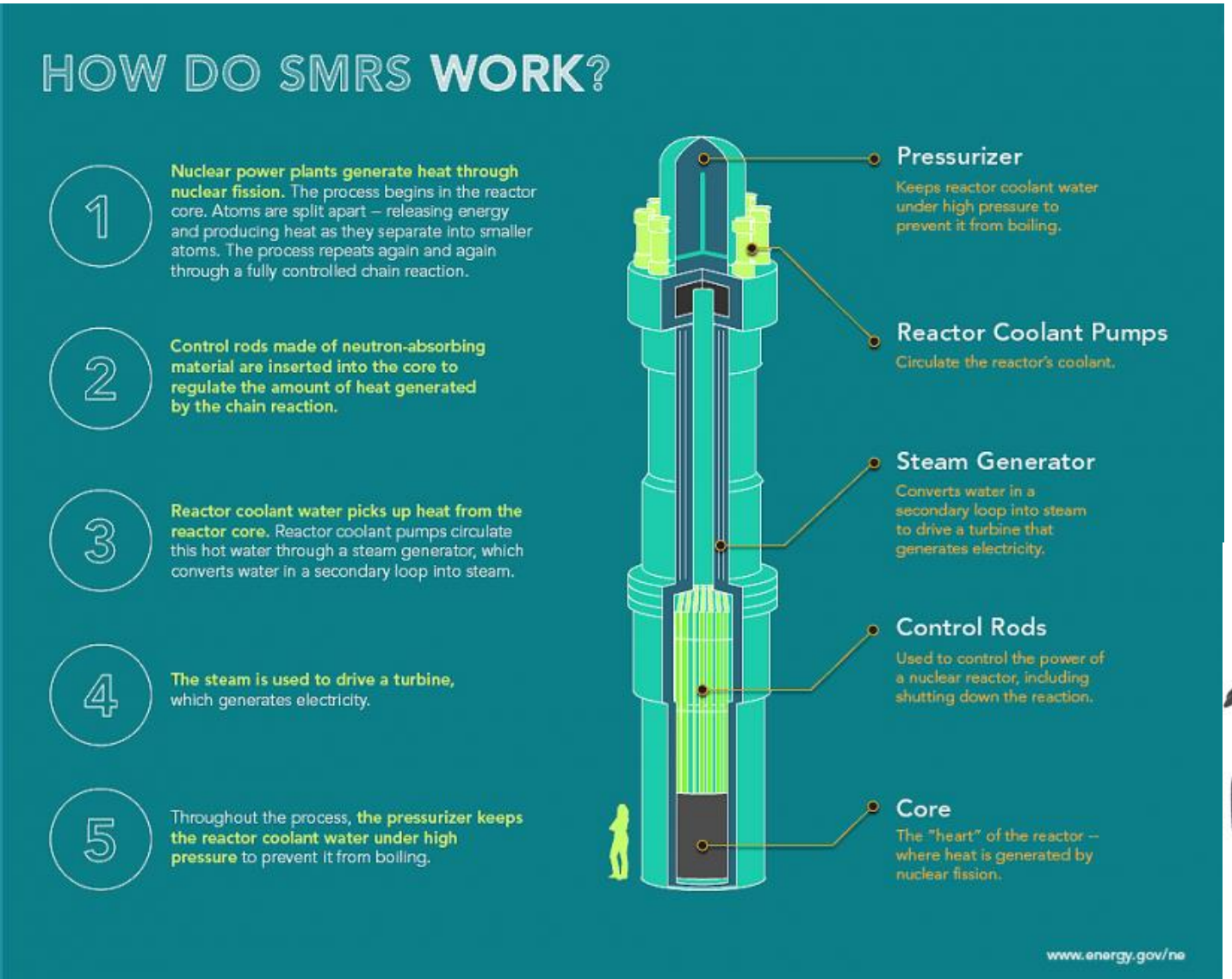
Being close to the south pole means that the solar panels will be sticking up at almost 90 degrees and casting long shadows behind them. Look at your spacing. Try to minimize your cable lengths but be far enough away that dust from work and construction are not getting on the panels.
https://www.nasa.gov/feature/goddard/2021/nasa-s-artemis-base-camp-on-the-moon-will-need-light-water-elevation
NASA is working on a VR tour. You can be a part of that development with your ideas and spin.

Lunar scrap yard

Organized landing locations to minimize work/moving time

When developing a lunar base, there will be a large amount of leftover materials from deliveries to the moon and equipment that gets damaged or worn out over time. All of this collection of slightly used equipment and broken stuff will end up being like a farmers bone yard where materials like scrap pipe or an old tractor might be used for repairing other equipment or the development of new equipment on the fly. A scrapyard for cars is a type of bone yard and there are bone yards for airplanes like in New Mexico so they can get spare parts when they need them. It would be wise to plan for this kind of bone yard from the beginning of the lunar base to avoid having to spend precious astronaut time on moving equipment from place to place. Some landers will be reusable and some may not be. There will be empty supply containers, damaged tools, broken rovers, bent pipes, scrap aluminum panels, … By planning the bone yard at the beginning, we can plan for where single use landers should set down so their engines, tanks and landing legs don't clutter the habitation zone and the payload they are bringing doesn't have to be trucked a long way to where it will be used.

Nuclear power

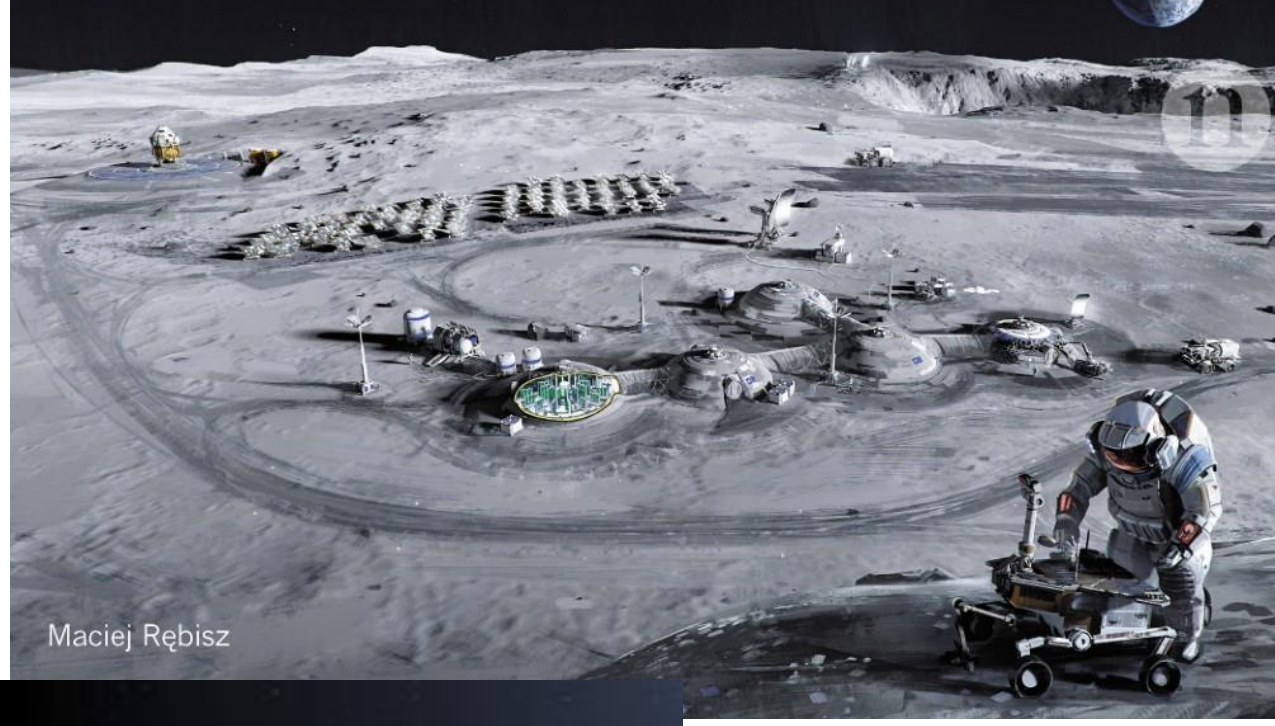


On the moon there will be day light for about 14 days and dark for about 14 days. When the people are initially building the base, they will probably only be there during the day time when there is lots of solar power and stay into the lunar night as long as they have batteries. However, as the activities and diversity of projects increase, they will eventually need more power that is consistent for the long nights.

Small Modular Reactors are fission nuclear reactors that are small enough to be portable before they are turned on and can serve as a consistent power supply for around 20 years. This is not so different from reactors used in a submarine. Once they are spent, they could be buried and left in place. It would be good for the reactor to be fairly close to the fuel generating equipment and habitat to minimize the need for lots of electrical cables. However, if there is a problem, you don't want it too close to the habitats.

Mini-nuclear power plant

- https://www.youtube.com/watch?v=Od_E2O-YHN8
- https://www.youtube.com/watch?v=uAbjAkXmLXE



Future option?

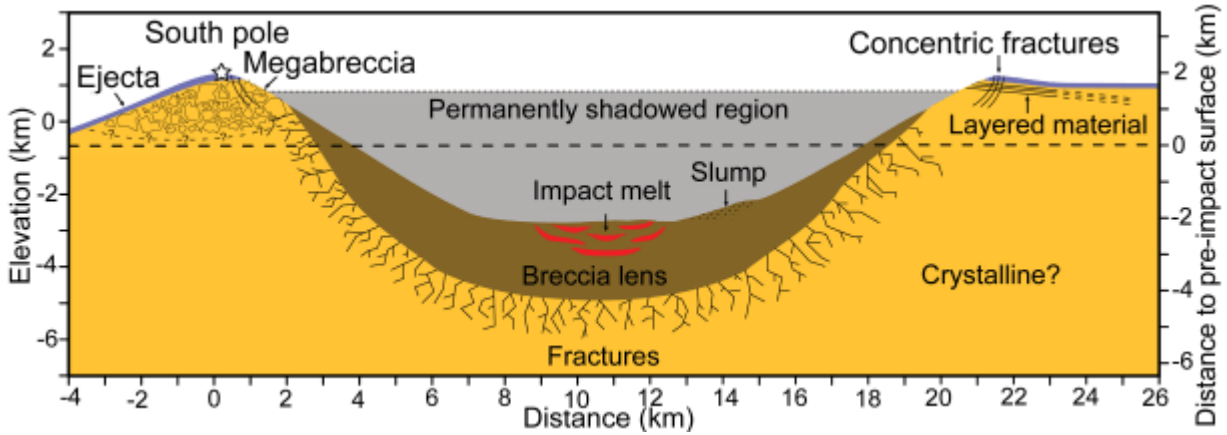
At first everything will start with having to walk and drive when people first work on the moon but it doesn't have to stop there. Here's a funky idea for longer term. Instead of everything being done with roads and driving rovers, what would it be like if there were gondolas for going into a central location in the crater and back?

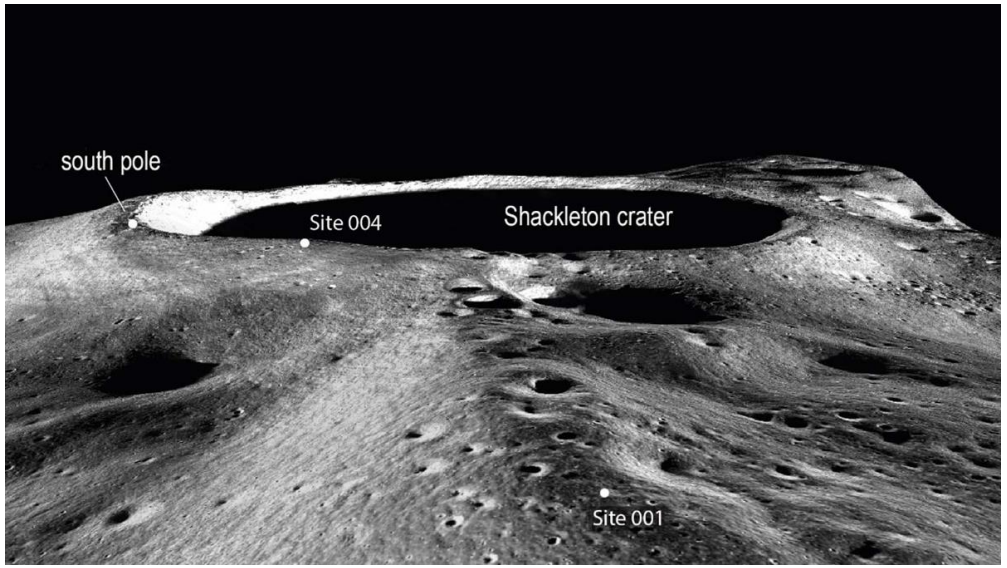
- Less dust from driving.
- Less contact with the regolith containing the ice
- Smoother ride
- More of a continuous feed of material from the crater floor

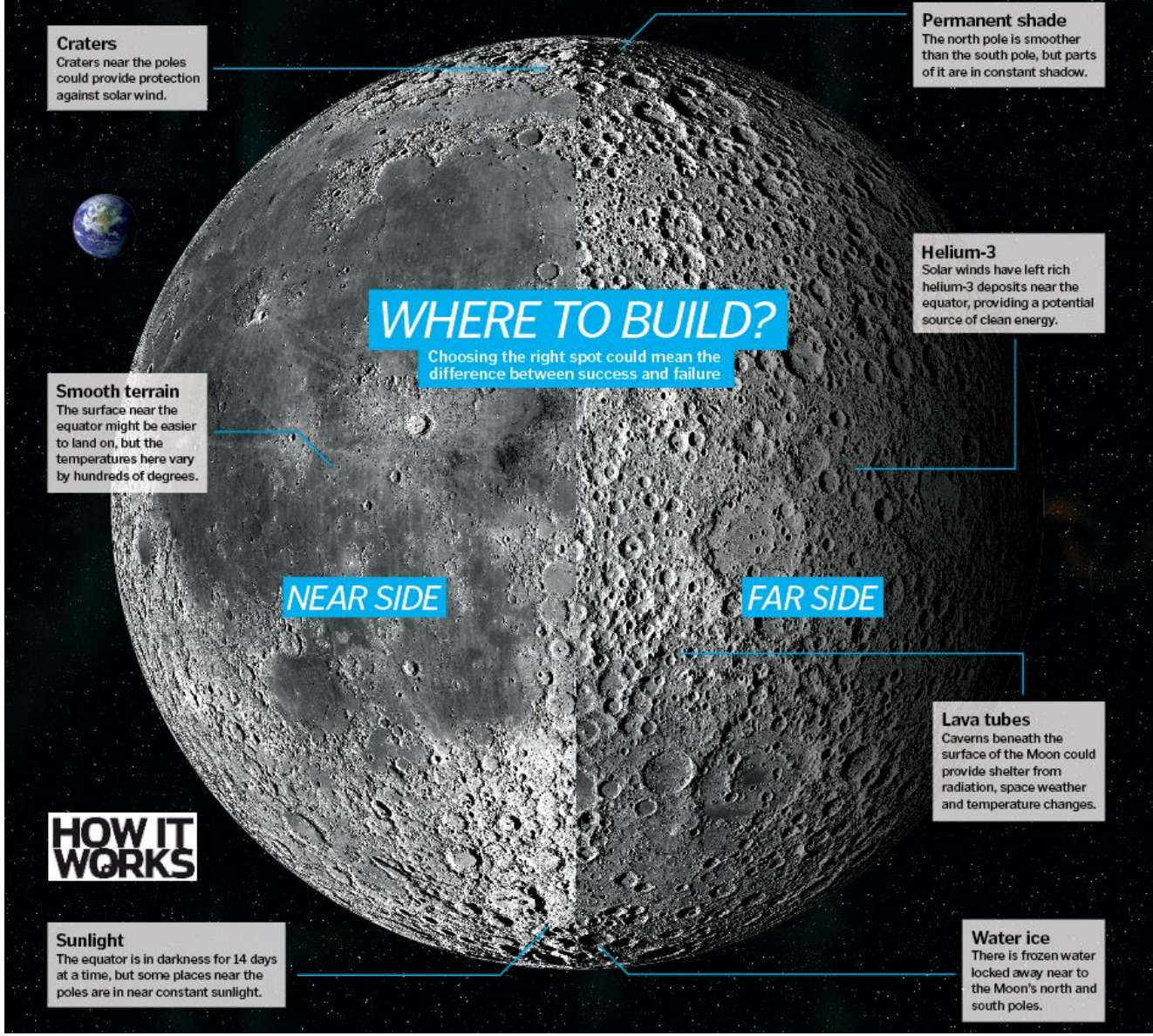
Initially they might start with some kind of a rope tow system that could pull buckets or sleds of regolith and ice up and down the crater until they could get the larger materials to the moon.
How could they use the existing materials for supporting this
How would the lower gravity help this development?

I got this idea when at the US Ski and Snowboard Hall of Fame in Ishpeming in Michigan where they have cool tech related to skiing.

Material Ropeway for carrying limestone in Sweden


South pole
Ejecta
Megabreccia
Concentric fractures
Permanently shadowed region
Layered material
Slump
Impact melt
Breccia lens
Crystalline?
Fractures
Elevation (km)
Distance to pre-impact surface (km)
Distance (km)


south pole
Site 004
Shackleton crater
Site 001


Craters
Craters near the poles could provide protection against solar wind.
Permanent shade
The north pole is smoother than the south pole, but parts of it are in constant shadow.
WHERE TO BUILD?
Choosing the right spot could mean the difference between success and failure
Helium-3
Solar winds have left rich helium-3 deposits near the equator, providing a potential source of clean energy.
Smooth terrain
The surface near the equator might be easier to land on, but the temperatures here vary by hundreds of degrees.
NEAR SIDE
FAR SIDE
Lava tubes
Caverns beneath the surface of the Moon could provide shelter from radiation, space weather and temperature changes.
HOW IT WORKS
Sunlight
The equator is in darkness for 14 days at a time, but some places near the poles are in near constant sunlight.
Water ice
There is frozen water locked away near to the Moon's north and south poles.