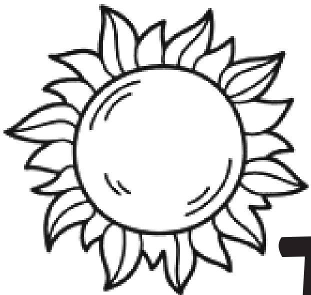
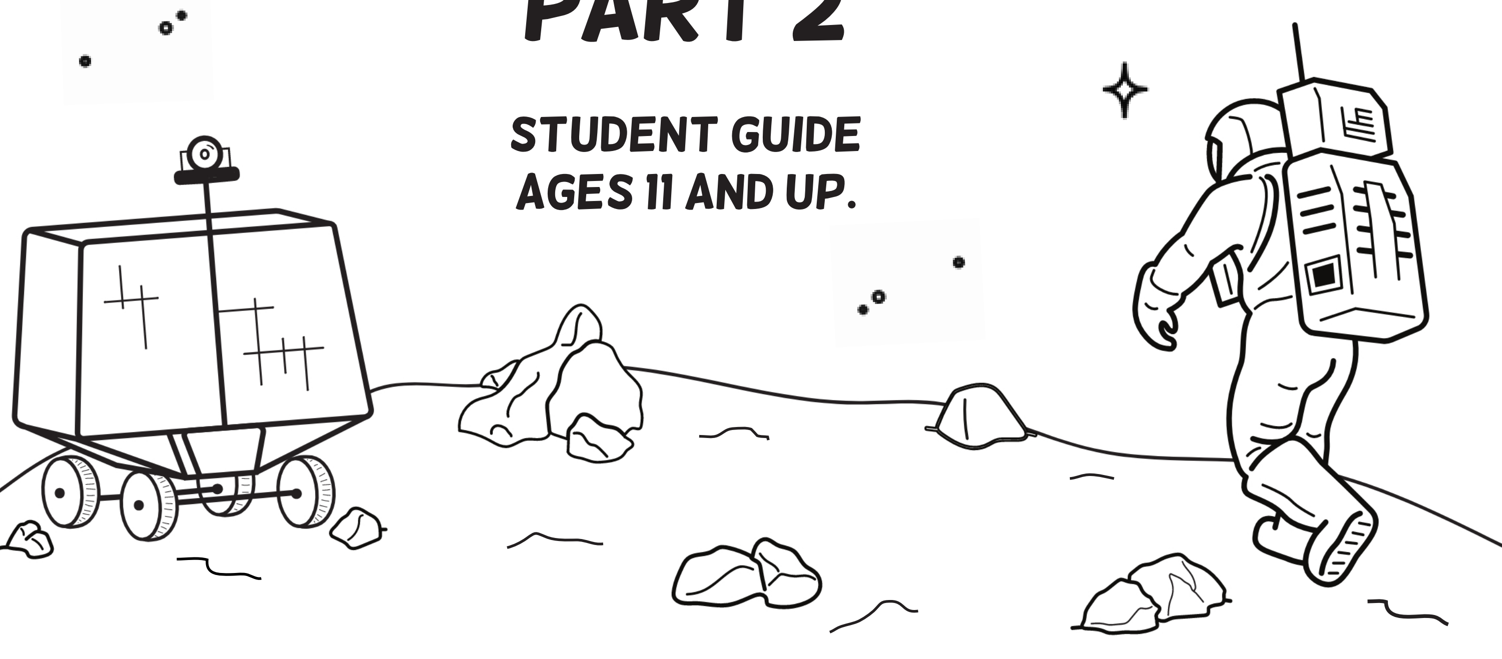


THE MYSTERY OF LUNAR WATER

HELP SCIENTISTS UNCOVER WATER ICE ON THE MOON

PART 2

STUDENT GUIDE
AGES 11 AND UP.



STUDENT GUIDE

INTRODUCTION

Identifying locations with water ice on the surface is only part of the puzzle scientists and engineers are trying to solve. The harsh environments that host water ice are not very safe for human exploration. Robots and humans have to find a way to survive where there is no sunlight, extremely cold temperatures, and hazardous travel kilometers deep in a crater. A safe and successful mission would have conditions such as plenty of sunlight for power, relatively flat surfaces (<15 degrees slope), and be able to see and communicate with Earth (good line-of-sight communication).

To safely find and use any water ice resources on the Moon, we need to plan a mission that first lands somewhere much safer and sets up a lunar outpost, then travels with a rover to the water ice. Scientists and engineers at NASA as well as other commercial spaceflight organizations are currently using datasets like these to plan future missions to the lunar south pole! Help them to plan a mission by choosing a safe landing site, then planning a traverse that takes them to a surface water frost location identified in Part 1 of this activity.

INSTRUCTIONS

Now that you have found at least one location where you think astronauts should go to find water ice, help scientists plan a mission to send a manned rover to confirm the findings! Where will the rover land? Where will it go? What PSRs will it study? Using the three provided maps (WAC Polar illumination, LOLA slope, and LOLA earth visibility), identify the safest landing site and traverse path for the rover to travel to find water ice. Use the LOLA DTM hillshade map to plan your mission!

To choose a safe landing site and plan a traverse path for your rover, the following engineering hazards must be considered:

Rover Design:

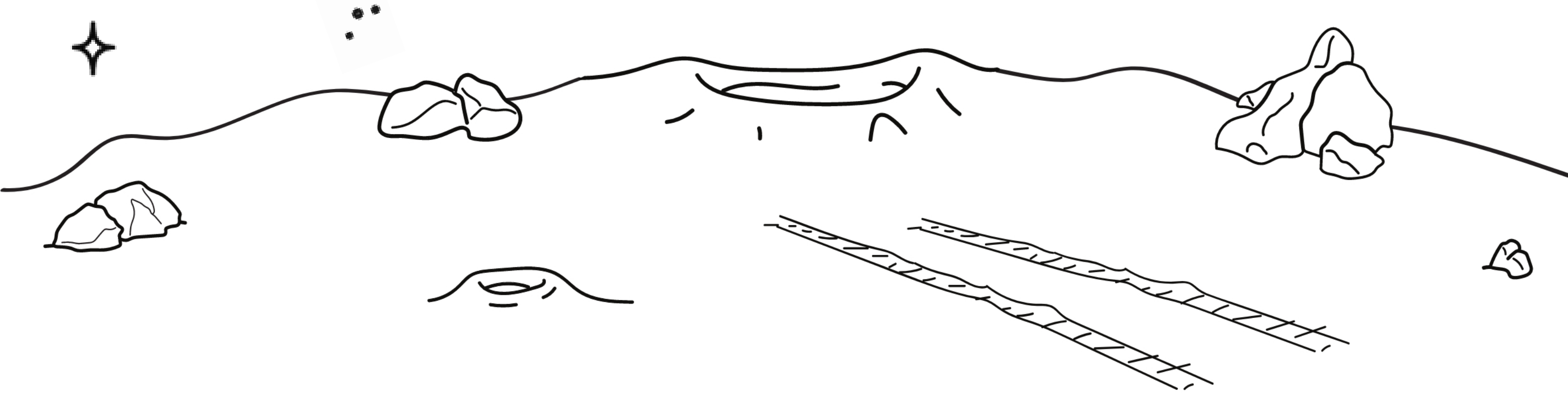
- ***The rover can travel 60 km on a full battery charge.***
- ***The rover travels at up to 15 km/h***
- ***The rover can operate for 78 hours before needing to recharge.***
- ***The rover may survive longer and have extended missions, but has been designed to operate for a minimum of 1 lunar cycle (27.5 earth days).***

Landing site constraints:

- ***The landing area must have a slope <5°***
- ***The landing area must have a view of the Earth for communication during the landing sequence.***
- ***The landing area must have exposure to the Sun to maintain power during initial rover checks.***

Traverse constraints:

- ***The rover must have a view of the Earth to return data.***
- ***The rover must be in sunlight to transmit high-speed science data.***
- ***The rover can climb slopes up to 15°.***



- Use the table below to help you design a safe and successful mission to search for water ice and other resources:

Landing site constraints	Traverse constraints	Associated LRO maps
The site must have exposure to Sun to maintain power during initial rover checks	Rover must be in sunlight to transmit high-speed science data and to receive battery recharge	LROC WAC Polar Illumination Map
Slope <5°; flat terrain is best	Rover can climb slopes up to 15°	LOLA Slope Map
Means of communicating with Earth	Rover must have a view of Earth to return data	LOLA Earth Visibility Map

Table 1. Engineering constraints for a safe landing site and successful rover traverses.

If you would like more of a challenge, consider the following questions using table 1 and 2:

- ***Using the rover's capabilities, how many water ice deposits can be visited by the rover during its limited time?***
- ***If the rover were on an extended mission, could it explore the most interesting areas, and be in a good position to continue exploring other targets if it survives longer than planned?***

Power constraints, assuming that on the Moon the rover weighs 116 kg:

- ***The battery capacity of the rover is 8700 watt hours.***
- ***A 1300 W load would last about 6 hours.***
- ***Half the speed would use half the power.***
- ***Given a solar panel that could output 300 W, the rover could recharge 300 W of battery per hour assuming full illumination.***
- ***It would take the rover approximately 29 hours (or a little over one day) to fully recharge.***

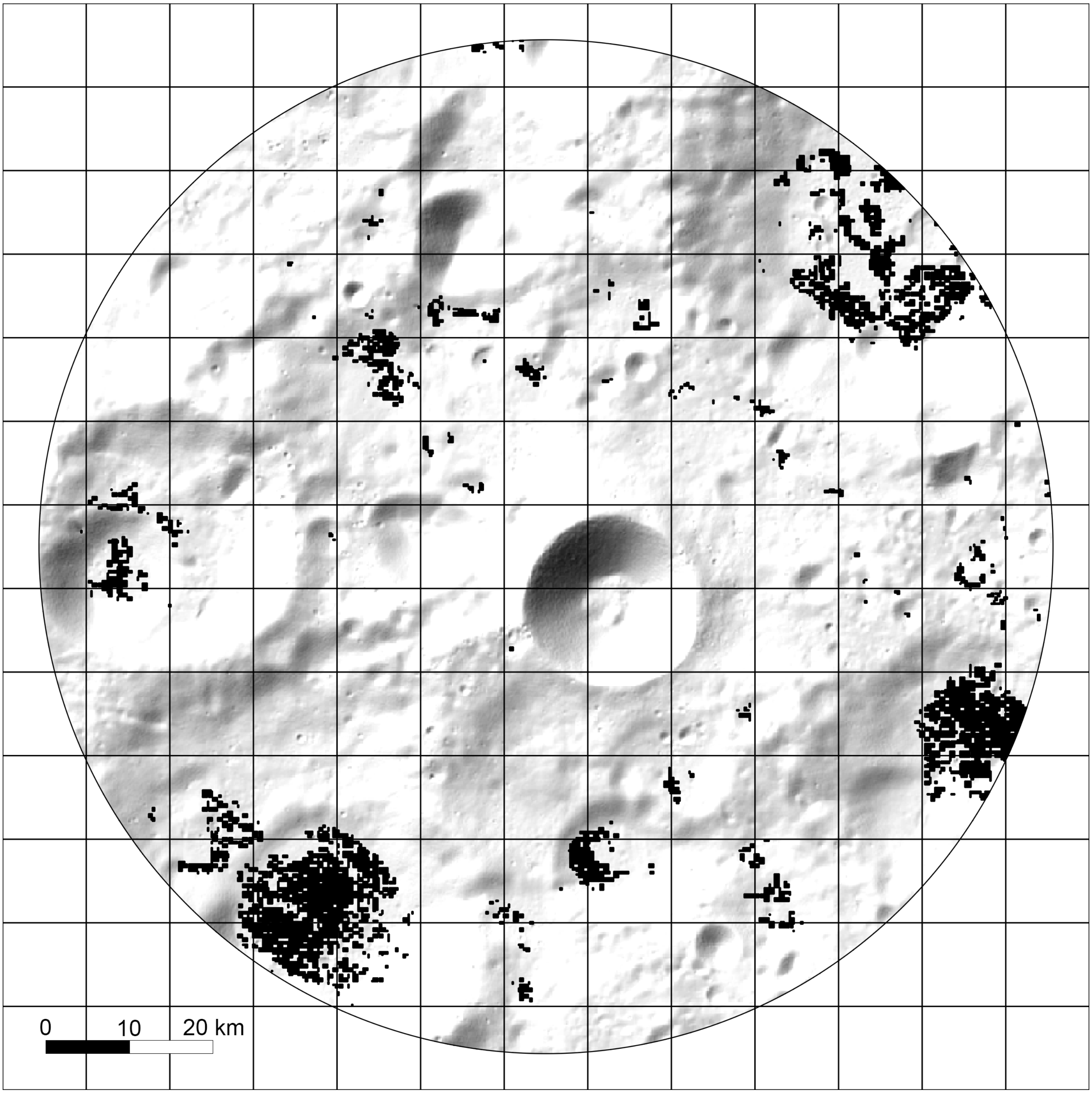
Slope (°)	Speed	Power Requirements (Watts)
Relatively flat (+/- 2°)	15 km/hr	646 W
5°	15 km/hr	893 W
10°	15 km/hr	1303 W
15°	15 km/hr	1693 W

Table 2. Engineering constraints for how much power a rover has during its traverse based on slope of surface and speed travelled.

Supplies:

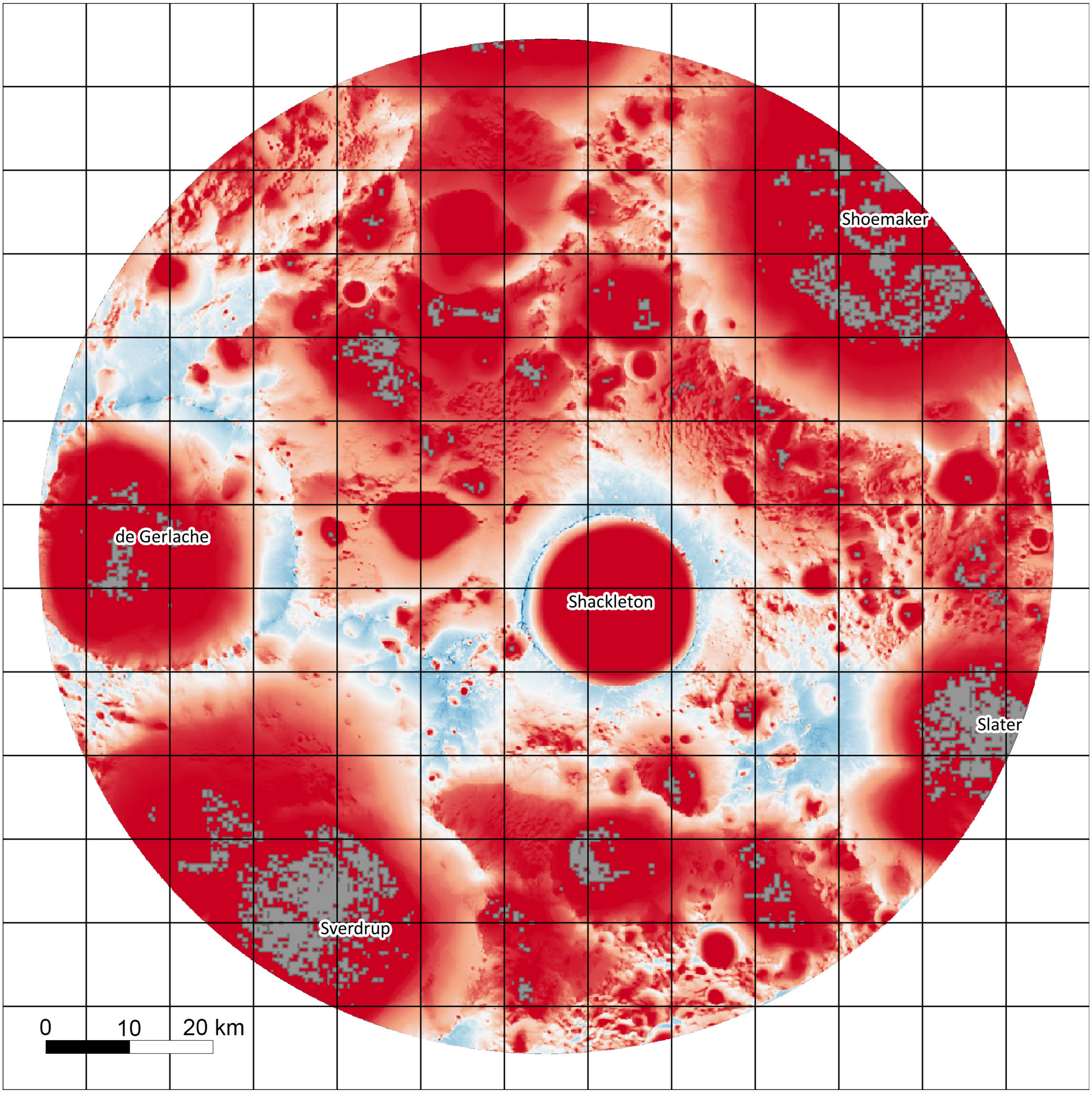
- ***Something to write with: pencil, pen, markers, colored pencils, etc.***
- ***Printouts of the Planning Sheet (Hillshade) to write on for each student.***
- ***Digital or Printouts of the maps.***
- ***(Optional) Ruler to help more accurately measure distances. There are many free, printable rulers online and they are available in most graphics programs.***

PLANNING SHEET - HILLSHADE



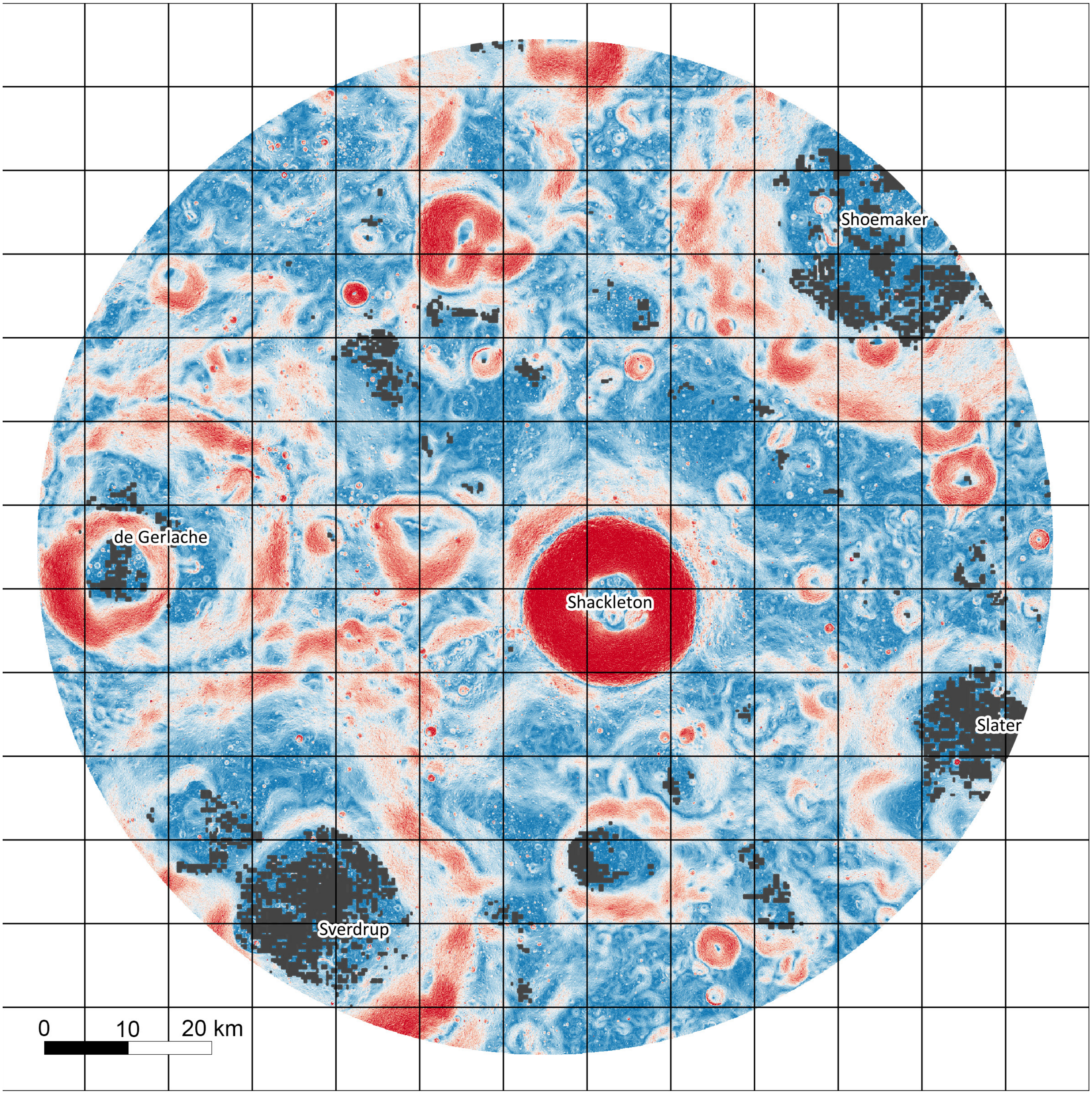
This is the map to print for planning the manned rover mission. It is a hillshade created from a 150 m pixel scale Lunar Orbiter Laser Altimeter (LOLA) digital terrain model (DTM) with the results from the surface-frost analysis overlaid in black.

LROC WAC POLAR ILLUMINATION MAP



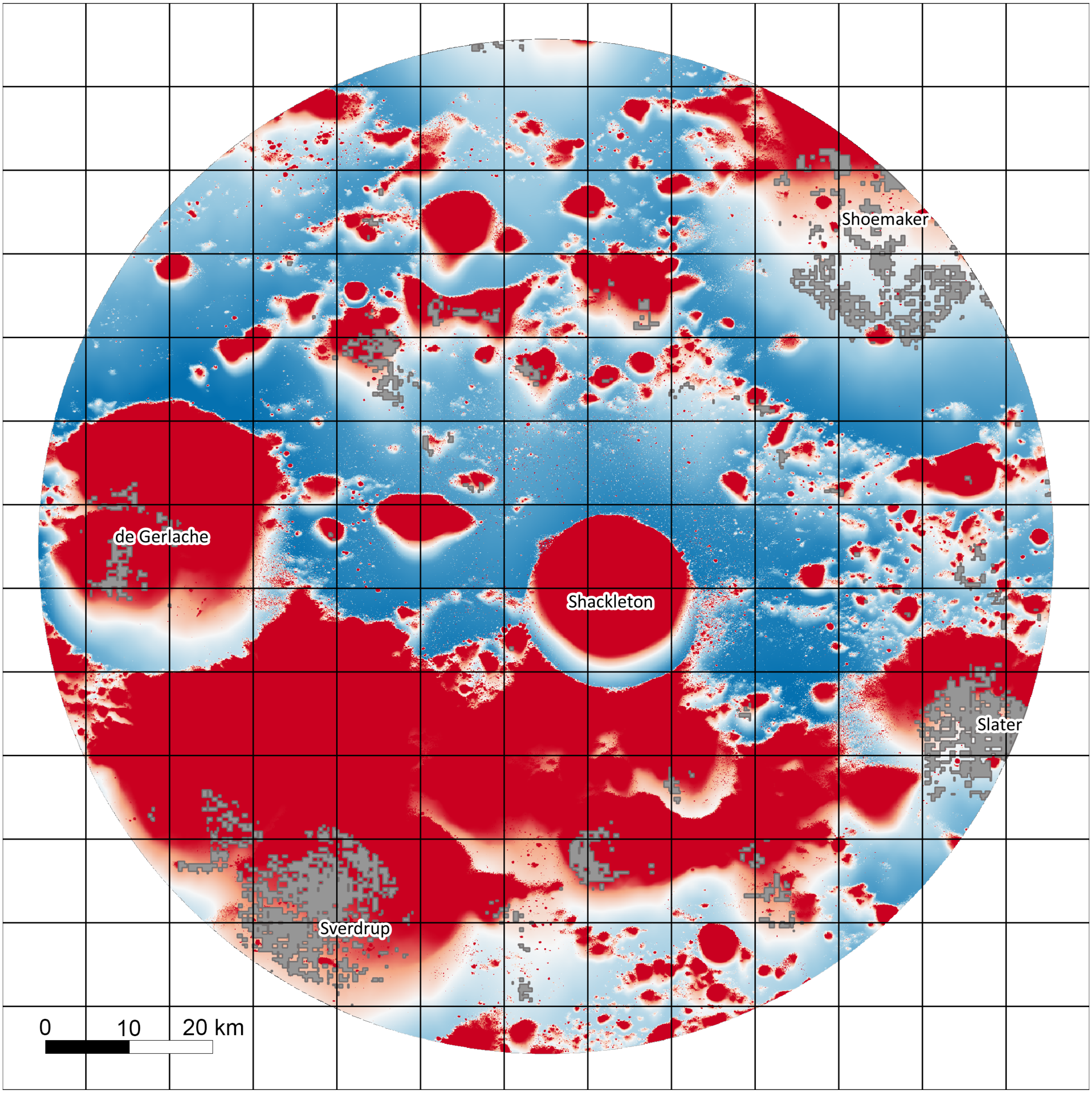
This map is created from the Lunar Reconnaissance Orbiter Camera (LROC) Wide Angle Camera (WAC) taken over an entire year, and the values in it represent the percentage of time that each pixel was illuminated during that year. Areas with surface frost are indicated by gray. Any areas that are blue are illuminated more than 45% of the time, with areas that are dark blue having the most sunlight.

LOLA SLOPE MAP



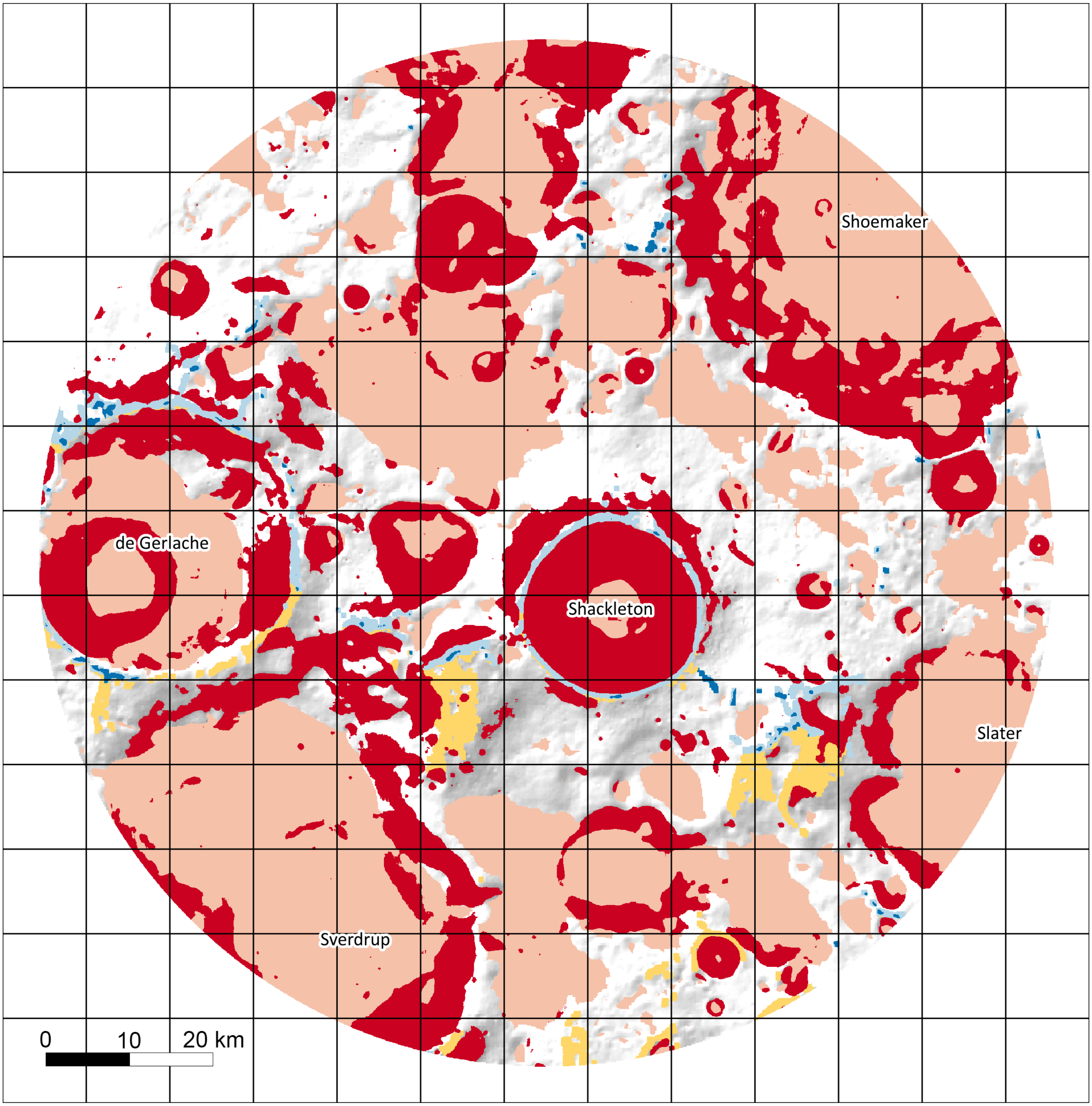
This map shows the angle of the surface, or slope, for the lunar surface. If slopes are 15 degrees or larger the rover cannot traverse them. These are indicated by shades of blue. Landing sites must be even flatter, with slopes <5 degrees (indicated by dark dlue). Areas with surface frost are indicated by dark gray.

LOLA POLAR EARTH VISIBILITY MAP



This map shows the average visibility of Earth from the lunar south pole. The Moon is tidally locked, so the same side, called the nearside, faces the Earth. To communicate with Earth, rovers need direct line-of-sight communication with Earth. This map shows the average percent of the Earth is visible with direct line-of-sight communication. Areas that are blue have enough visibility to send data back to Earth. Areas with surface frost are indicated by gray.

ANSWER SHEET FOR PART 2



Ideal exploration conditions for sustained surface activities involve relatively flat traverse surfaces (<15°), plenty of sunlight for power (>50%), and good line-of-sight communication with Earth (>50%), all within a reasonable distance from water ice deposits. Impassable terrain (>15° slope) is indicated by red, >45% sunlight is indicated by yellow, ideal landing sites (<5° slope, >50% communication and sunlight) is shown in dark blue, and communication and recharge zones (>45% sunlight and communication) are indicated by light blue. Surface-frost analysis is overlaid in black.

GLOSSARY

Albedo - A measure of how bright or dark materials are.

Commercial spaceflight organizations - Nongovernmental companies that provide space goods, services, or activities. Some American commercial spaceflight organizations that work with NASA include Boeing and SpaceX.

Drive system - A system that controls speed, rotation, and direction of a motor in a machine.

Earth line-of-sight communication - Communications between Earth and rover are made possible because Earth is in constant view. Only the nearside of the Moon is in constant line-of-site.

Electromagnetic spectrum – Made up of waves (wavelengths) that travel through space at the speed of light. Waves differ in frequency (long vs. short waves).

Elements – Chemical elements that are matter in the universe. Elements are atoms with a specific number of protons.

Engineering - Designing and building new products, machines, or systems using chemistry, physics, and math to solve problems. Different kinds of engineering are often used together when designing something. Building a rover for example uses a combination of electrical engineering (designing how the machine is powered), mechanical engineering (the design, construction, and use of the machine), and materials engineering (designing and building new materials).

Farside - The face of the Moon that faces away from Earth. Sometimes inaccurately called the "dark side". During a New Moon on Earth, the Farside is illuminated by the Sun.

Kelvin - K, the abbreviation for Kelvin, is the base unit of temperature in the International System of Units.

Nearside - The face of the Moon that we see from Earth is called the nearside.

Pixel scale - A pixel (short for picture element) is one of many small squares that make up a picture. The number of small squares in a picture is referred to as resolution. In a satellite image, how much ground is covered by one pixel is referred to as the pixel scale.

Power - In physics and science power refers to the rate, or how fast, energy is used. Power comes from work, or heat or energy transferring to an object.

Surface frost - On Earth, frost is a thin layer of ice on a solid surface. Frost forms when water vapor (a gas) comes into contact with a frozen surface, thus changing the water vapor into ice (a solid). On the Moon, surface frost is not only water, other elements such as sulfur and nitrogen are thought to exist as well.

Suspension system - How the wheels are connected to the rover; provides control of how the rover interacts with the terrain.

Tidal Locking - The Moon rotates about its axis in about the same time it takes to orbit the Earth, resulting in the same side of the Moon always facing towards Earth.

Traverse - Planned path that rover will travel during mission duration.

Vacuum - The vacuum of space is empty and cold; the vacuum of space is nothing.

Water ice - Frozen materials such as water can be trapped in the permanently shadowed regions on the Moon because of such cold temperatures. There is no liquid water on the Moon.

Watts - Unit used to measure how fast energy is used. Power is measured in Watts.