

The Science Behind *The Moon and Beyond*

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Space
Biosciences
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What do humans need to survive?

- Water

Challenge 3

- Oxygen

Challenge 4

- Power

Challenge 5



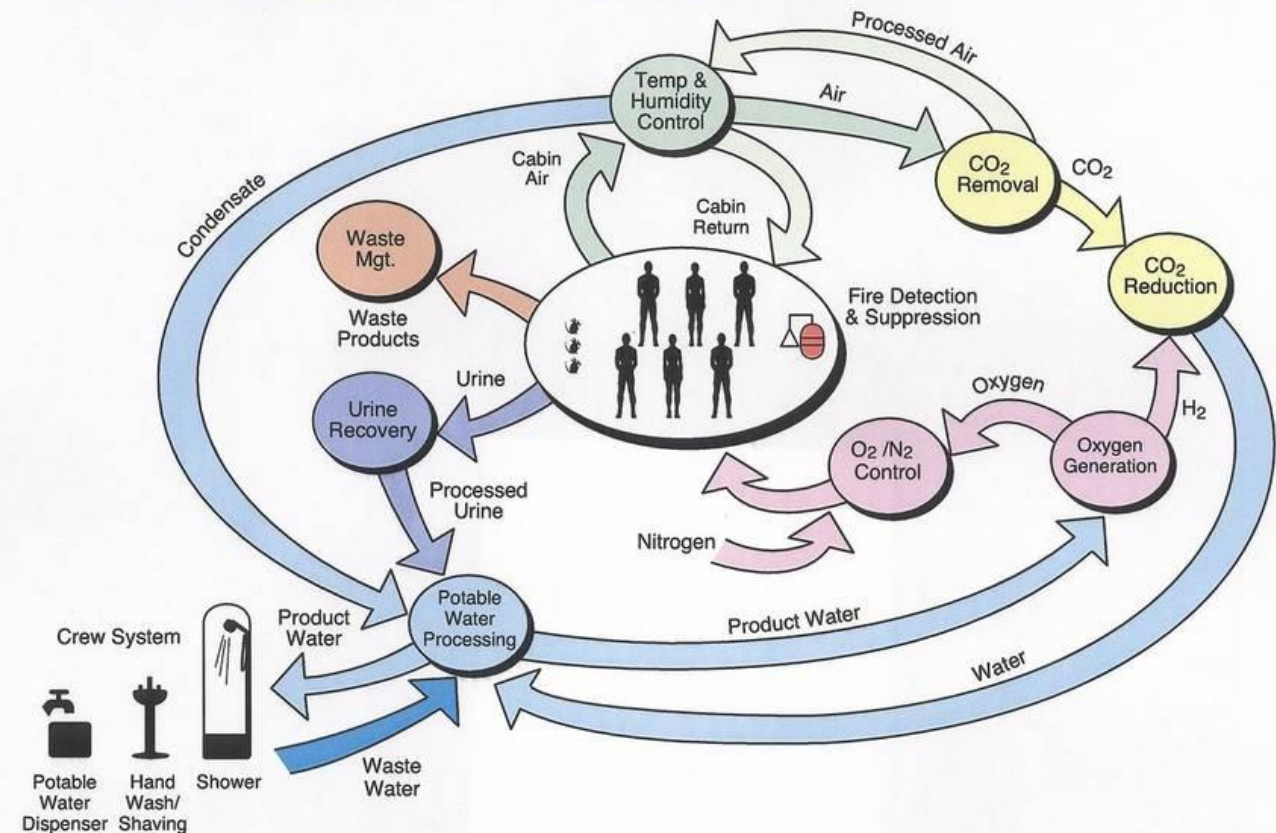
Water

Challenge 3

Water is vital for the survivability of life in space:

- Resource Utilization
- Closed Loop System

Space Station Regenerative ECLSS Flow Diagram (Baseline and Scarring)



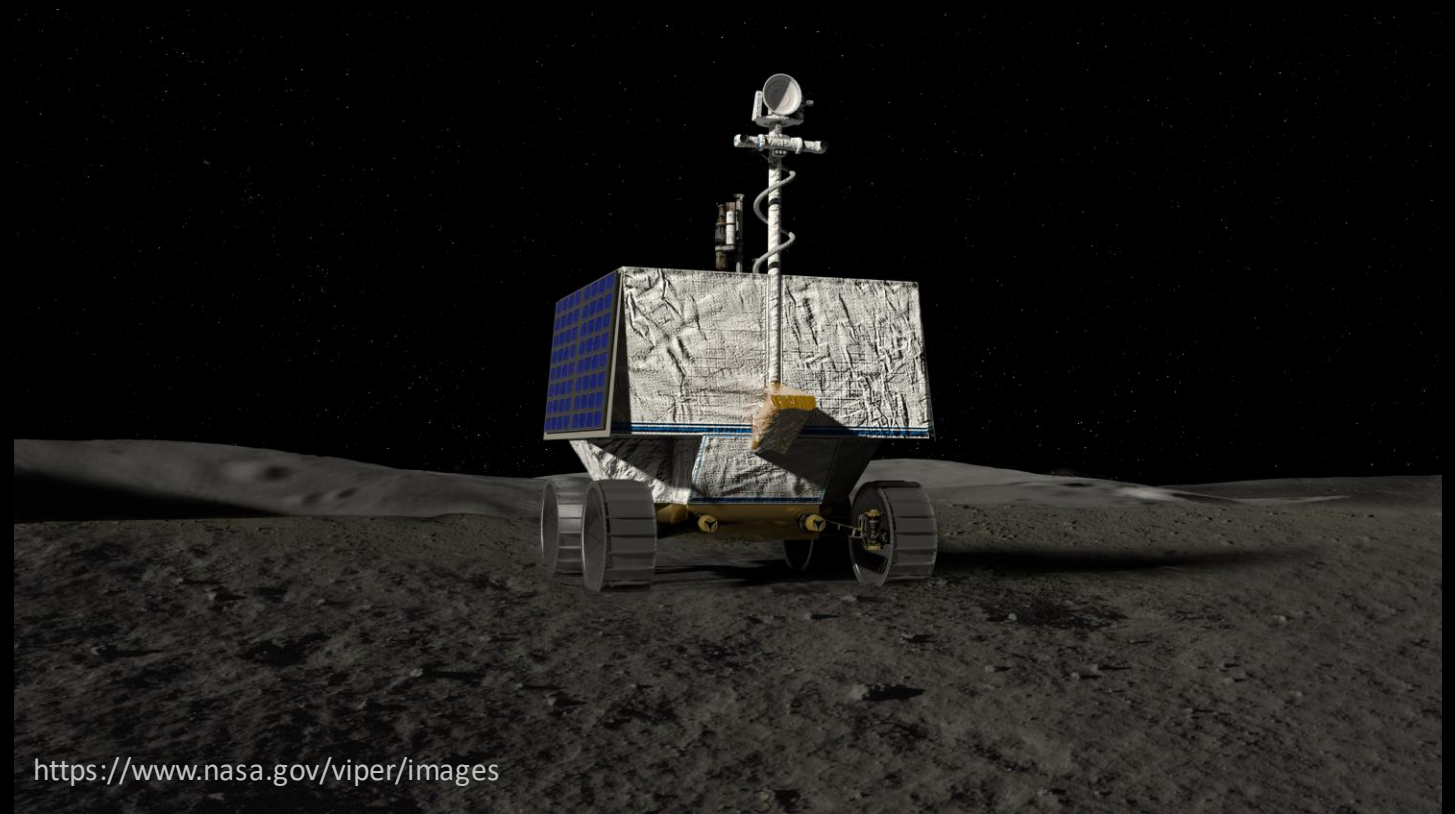
MSFC/5-23920

Water

Challenge 3

NASA VIPER Mission

- Volatiles Investigating Polar Exploration Rover
- VIPER will go to the moon's South Pole to get a close-up view of the water imbedded in the soil.
- The water could eventually be harvested to sustain human exploration on the Moon, or to Mars and beyond.



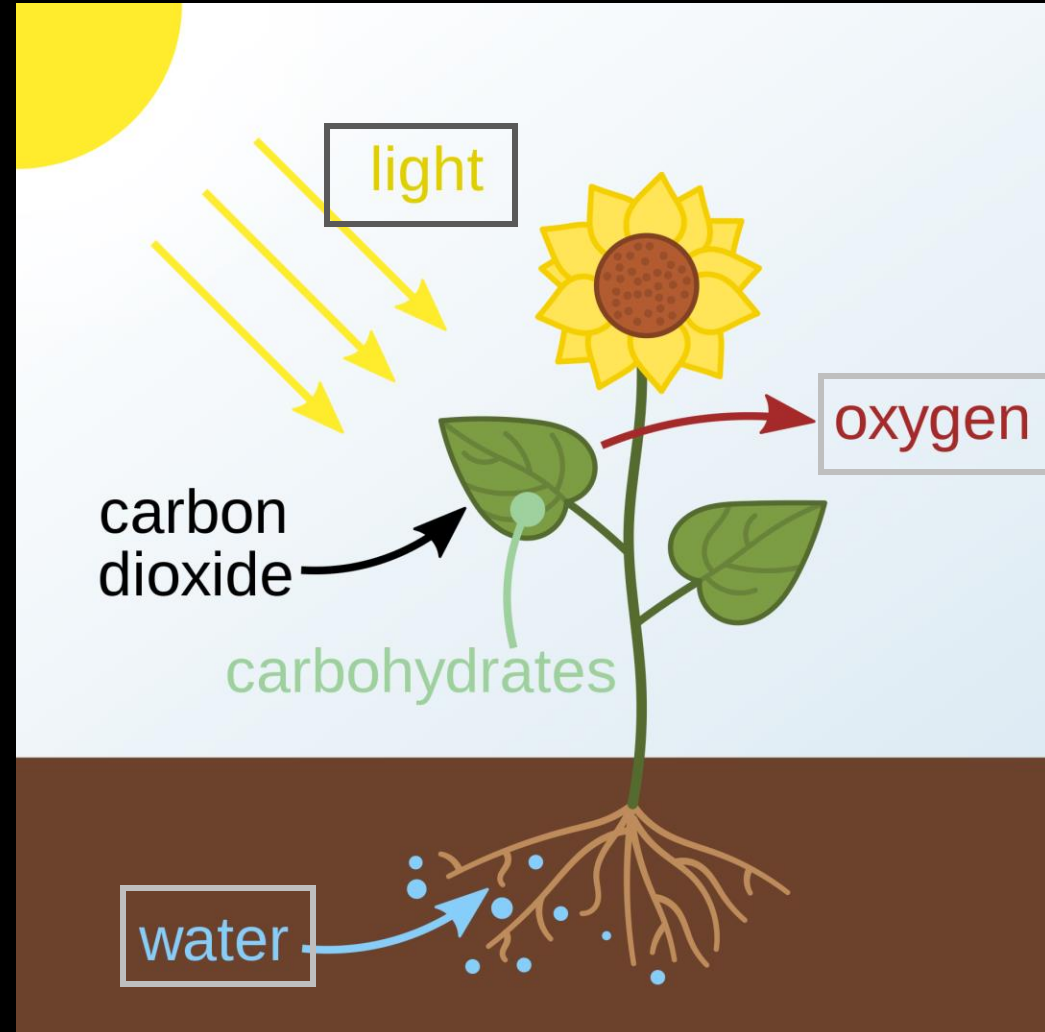
<https://www.nasa.gov/viper/images>

Oxygen

Challenge 4

Almost all O₂ on Earth is produced by organisms through oxygenic photosynthesis

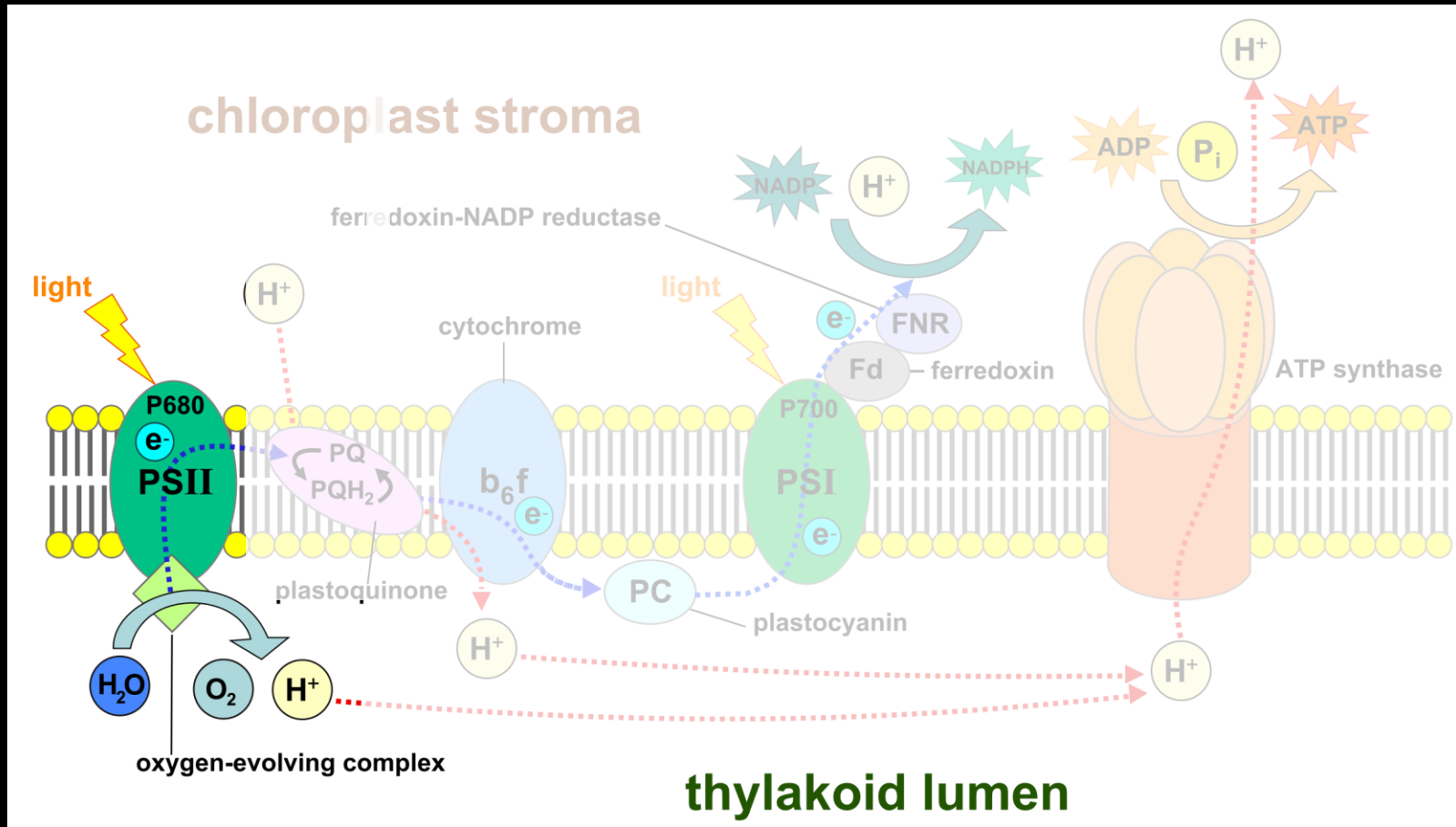
How we do it on Earth



https://en.wikipedia.org/wiki/Photosynthesis#/media/File:Photosynthesis_en.svg
CC BY-SA 4.0

Oxygen

Challenge 4



The Light Reaction uses solar energy to split H_2O into O_2 and H^+ , removing an electron

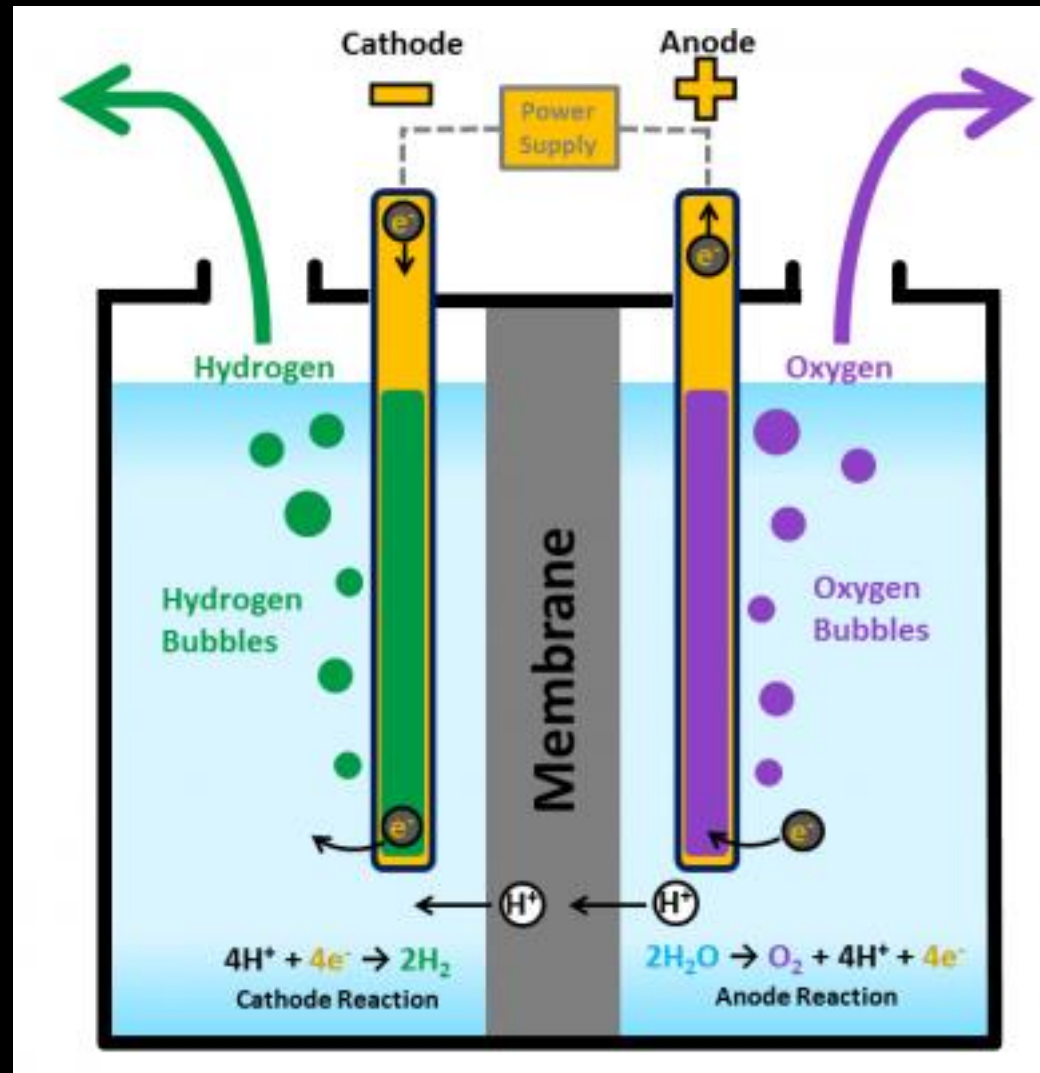
Oxygen

Challenge 4

The ISS needs 2.52 kg of O_2 per day. Much of that is from **electrolysis**!

Electrolysis of water works like photosynthesis: forcing a current of electrons from the anode to the cathode sucks electrons away from water, splitting it into O_2 and H^+ at the anode end

How we do it in space



Where does the water on ISS come from?

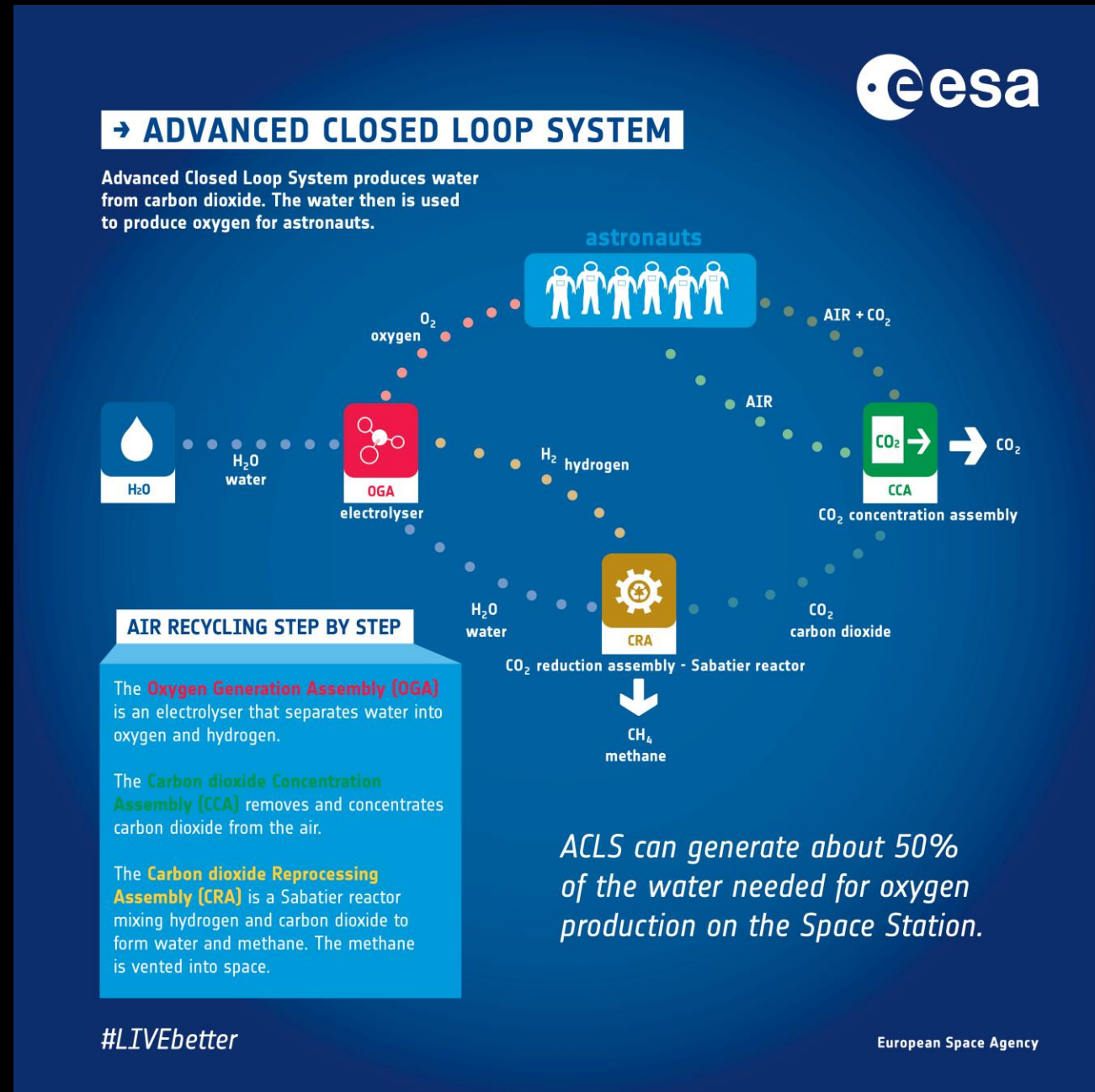
- imported from Earth
- recycled from wastewater
- generated from waste CO_2 (**Advanced Closed Loop System**)

Oxygen

Challenge 4

ACLS uses H_2 left over from electrolysis to reduce CO_2 , producing H_2O and methane

Methane is vented to space



Oxygen

Challenge 4

Electrolysis isn't the only way!



Vika fire on Mir, 1997

<https://appel.nasa.gov/2011/11/02/international-life-support/>

The ISS also...

- gets compressed O_2 from Earth in canisters, imported on cargo trips
- has a backup generator: the **Vika Solid-Fuel Oxygen Generator** uses lithium perchlorate that burns at $\sim 500^\circ\text{C}$.
1 "candle" burns 5-20 minutes, making O_2 for 1 crewmember for 1 day.
The same system that airplanes use for emergency O_2

Power

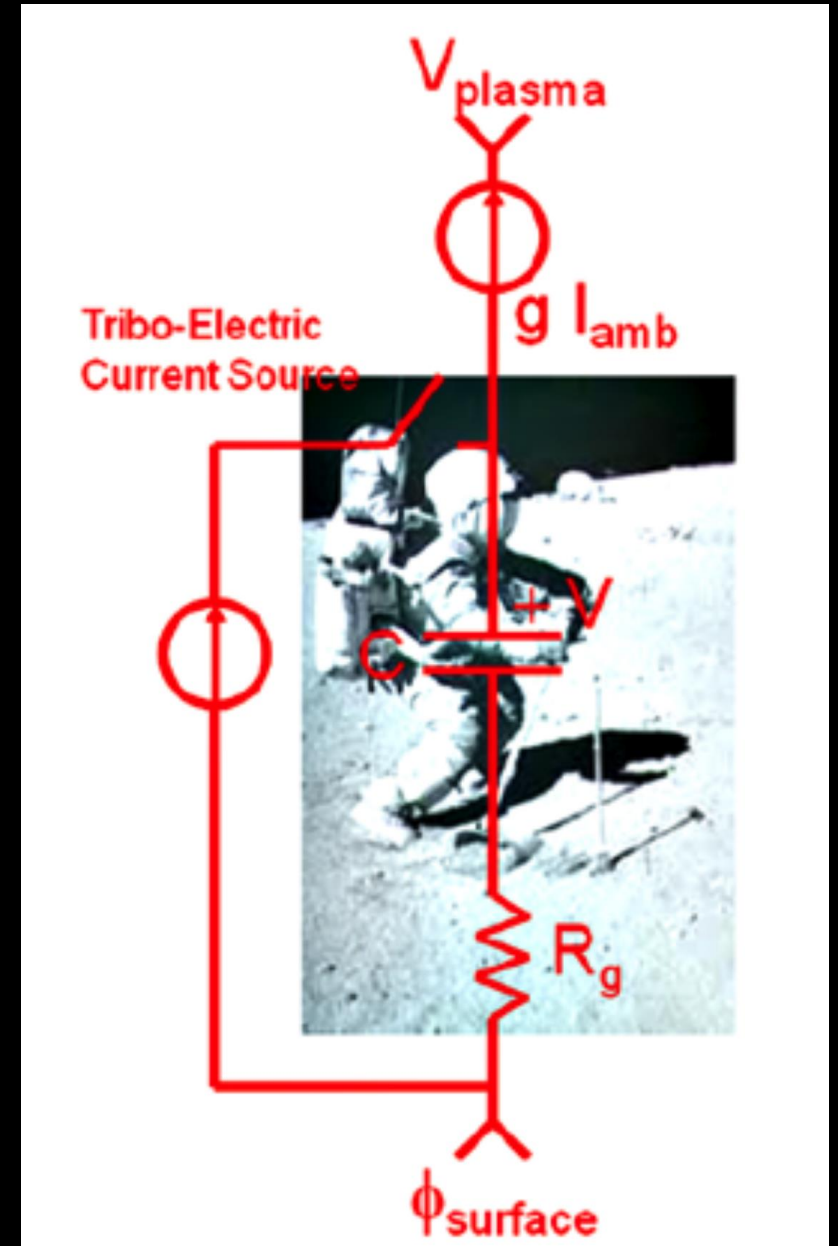
Challenge 5

Challenge 5 is about building a circuit using conductive materials.

The human body is conductive, but what if it's wrapped in a space suit?

Apollo era space suits were insulating – and static charge generation attracted a lot of moon dust!
One NASA group is advocating for giving space suits a conductive skin to provide better grounding

But what **IS** the power source we're connecting to?



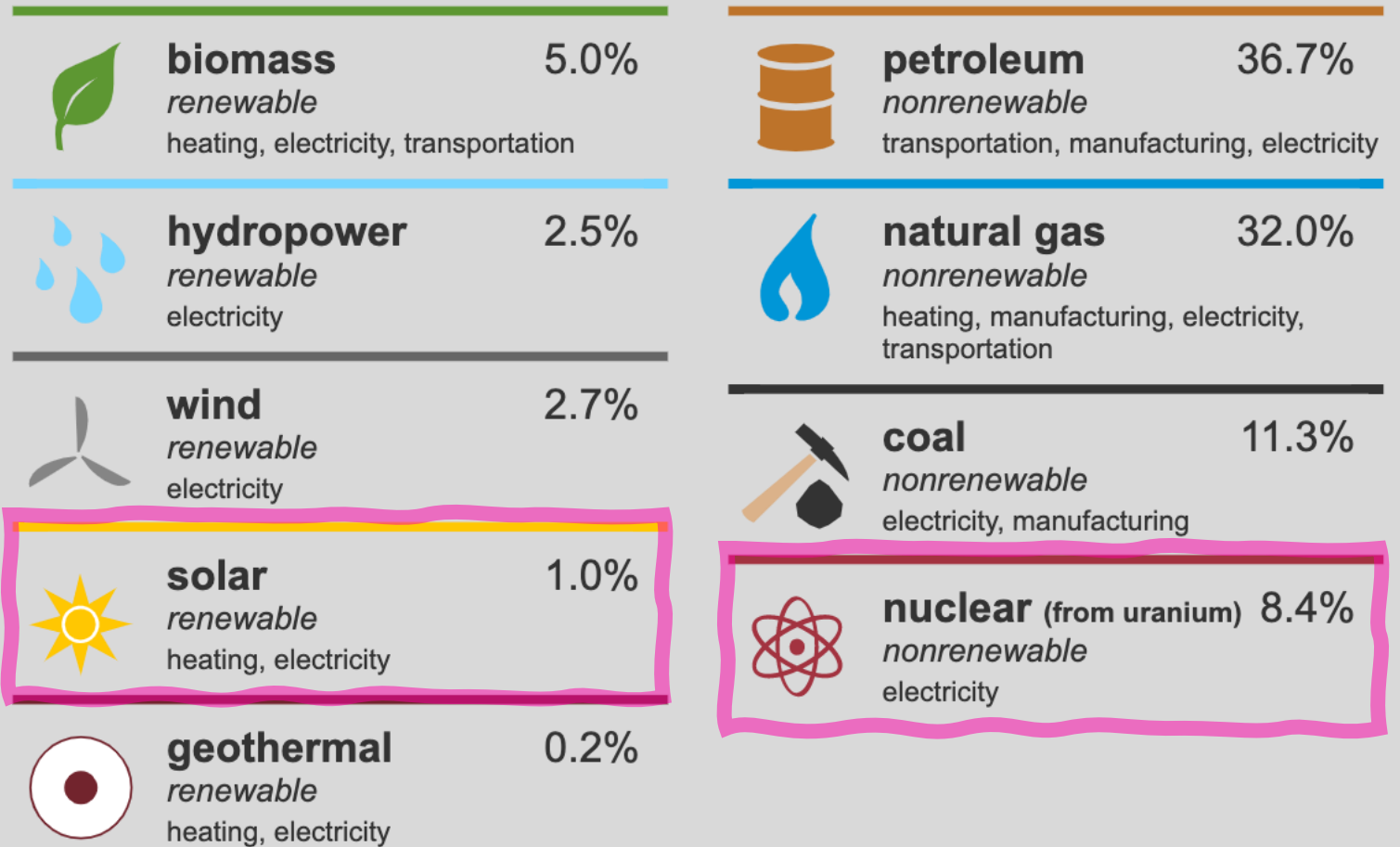
Power

Challenge 5

How we do it on earth

How we do it in space

U.S. energy consumption by source, 2019



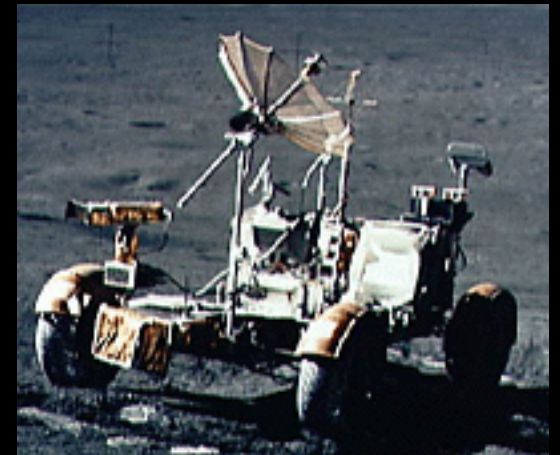
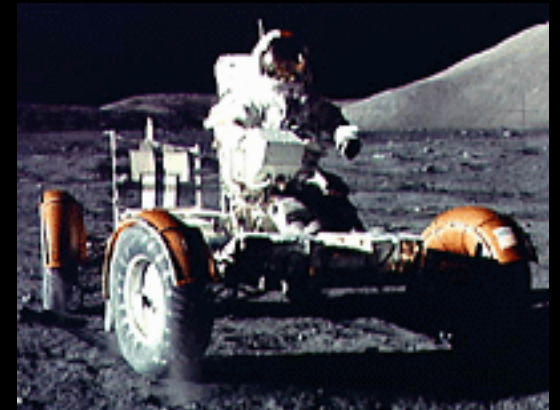
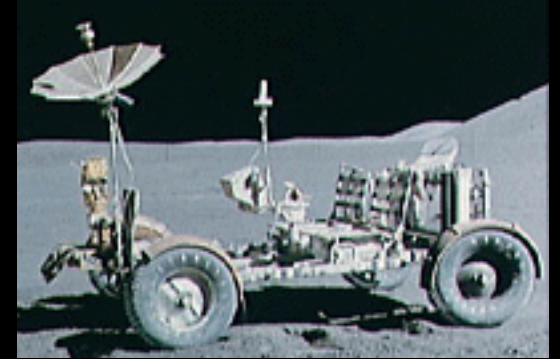
A small amount of sources not included above are net electricity imports and coal coke.
The sum of individual percentages may not equal 100% because of independent rounding.
Source: U.S. Energy Information Administration, *Monthly Energy Review*, Table 1.3, April 2020, preliminary data

Power

Challenge 5

Batteries

- used by Apollo Lunar Roving Vehicles, Apollo missions 15, 16, 17
- each had two 36-volt silver-zinc potassium hydroxide non-rechargeable batteries
- capacity: 121 amp-hr

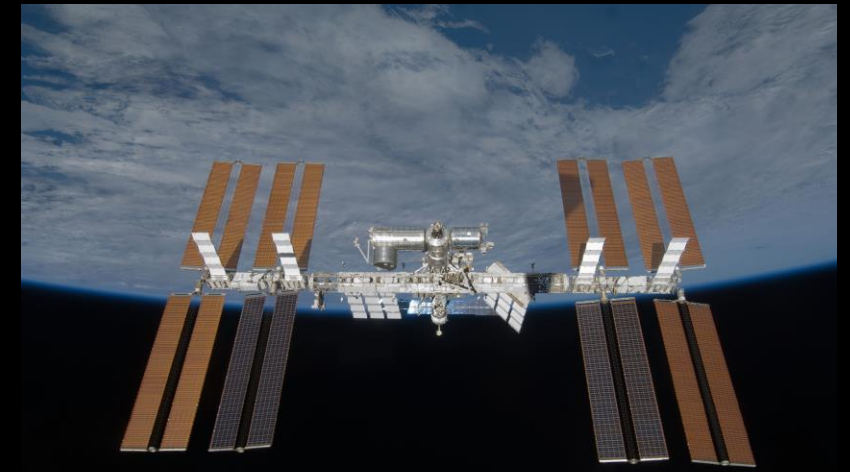


Power

Challenge 5

Solar: ISS

- ISS gets 100% of its power from 8 solar arrays: 262,400 solar cells
- Arrays cover 27,000 square feet: more than half the area of a football field
- connected by eight miles of wire
- generates 84 to 120 kilowatts of electricity -- enough to power more than 40 homes
- 60% of energy in sunny times goes into charging battery for shady times



Power

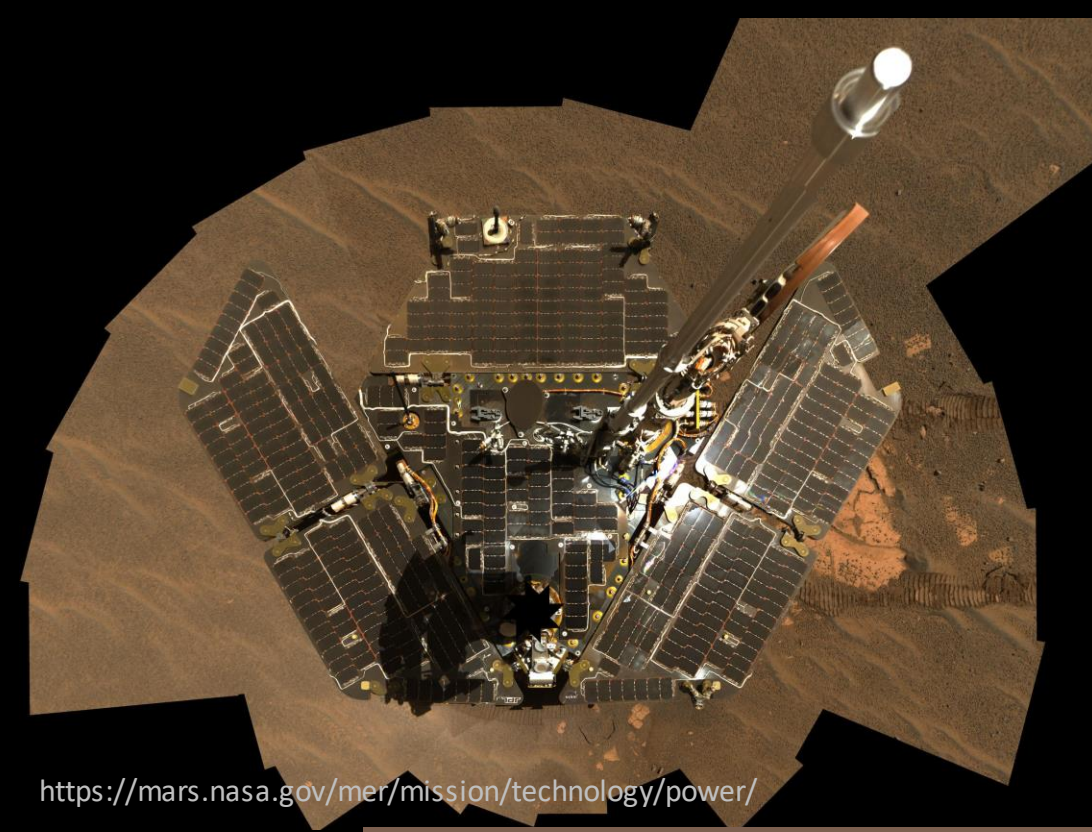
Challenge 5

Solar: rovers

- The Mars rovers Spirit and Opportunity used solar
- ~140 watts, up to four hours per sol
- rovers needed ~100 watts (1 incandescent light bulb's worth) to drive
- 2 rechargeable batteries
- can theoretically last a LONG time (Opportunity worked for 15 Earth years!)

Downsides:

- rovers limited to staying in sunny places
- less power from sun when Mars is further away
- dust impedes charging; Opportunity may have been killed by a dust storm



<https://mars.nasa.gov/mer/mission/technology/power/>



<https://photojournal.jpl.nasa.gov/jpeg/PIA04413.jpg>

Power

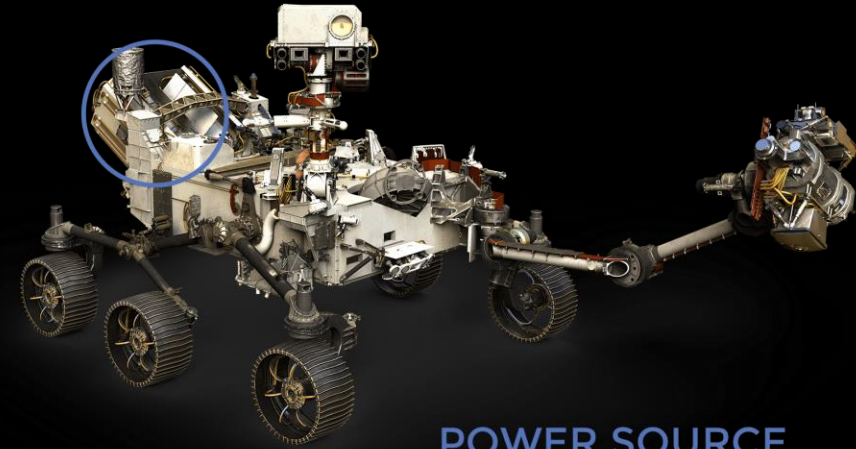
Challenge 5

Nuclear: rovers

- The Mars Curiosity and Perseverance rovers (and many other spacecraft!) use a nuclear power source: the Multi-Mission Radioisotope Thermoelectric Generator (MMRTG)
- plutonium dioxide
- 110 watts
- designed to last 14 years
- no need to stay in sunny areas, no fear of dust storms!

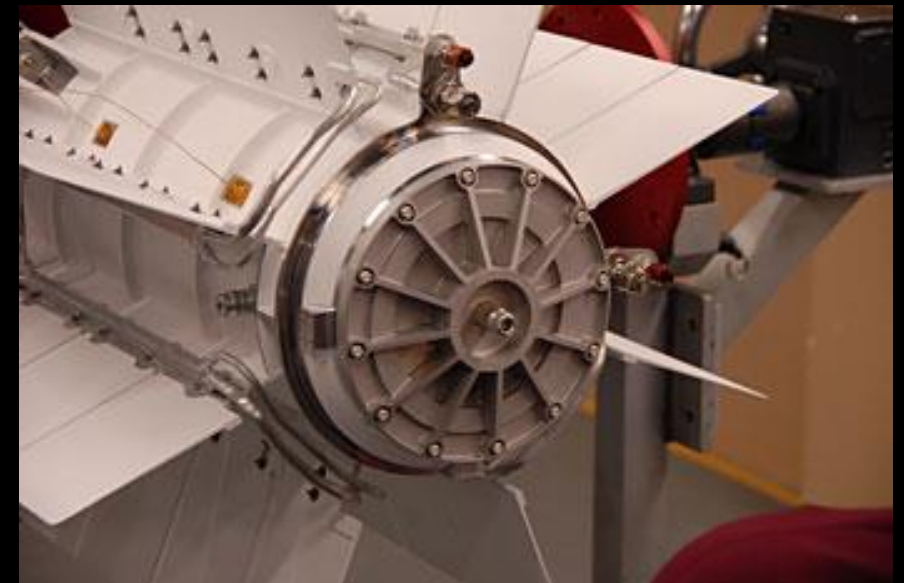
Downsides:

- MMRTG will eventually run out of power!
- safety risks if there are technical problems on Earth. power source has been manufactured in ceramic form and is encased in many layers of protective material to reduce risk



POWER SOURCE

<https://mars.nasa.gov/mars2020/spacecraft/rover/electrical-power/>



<https://www.technologyreview.com/2012/08/07/184595/nuclear-generator-powers-curiosity-mars-mission/>

We don't yet have the answers for how this will work on the Moon!

NASA is aiming to have a sustainable presence on the Moon by 2028.

The Lunar Surface Innovation Consortium is an organization working with NASA and researchers in industry and academia to solve problems like:

- In Situ Resource Utilization
- Surface Power
- Extreme Environments
- Extreme Access
- Excavation and Construction
- Dust Mitigation



Lunar Surface Innovation

C O N S O R T I U M

We need new scientists and engineers to help solve these problems!



Imagine leading a one-week expedition on the moon and write an essay that tells NASA all about it

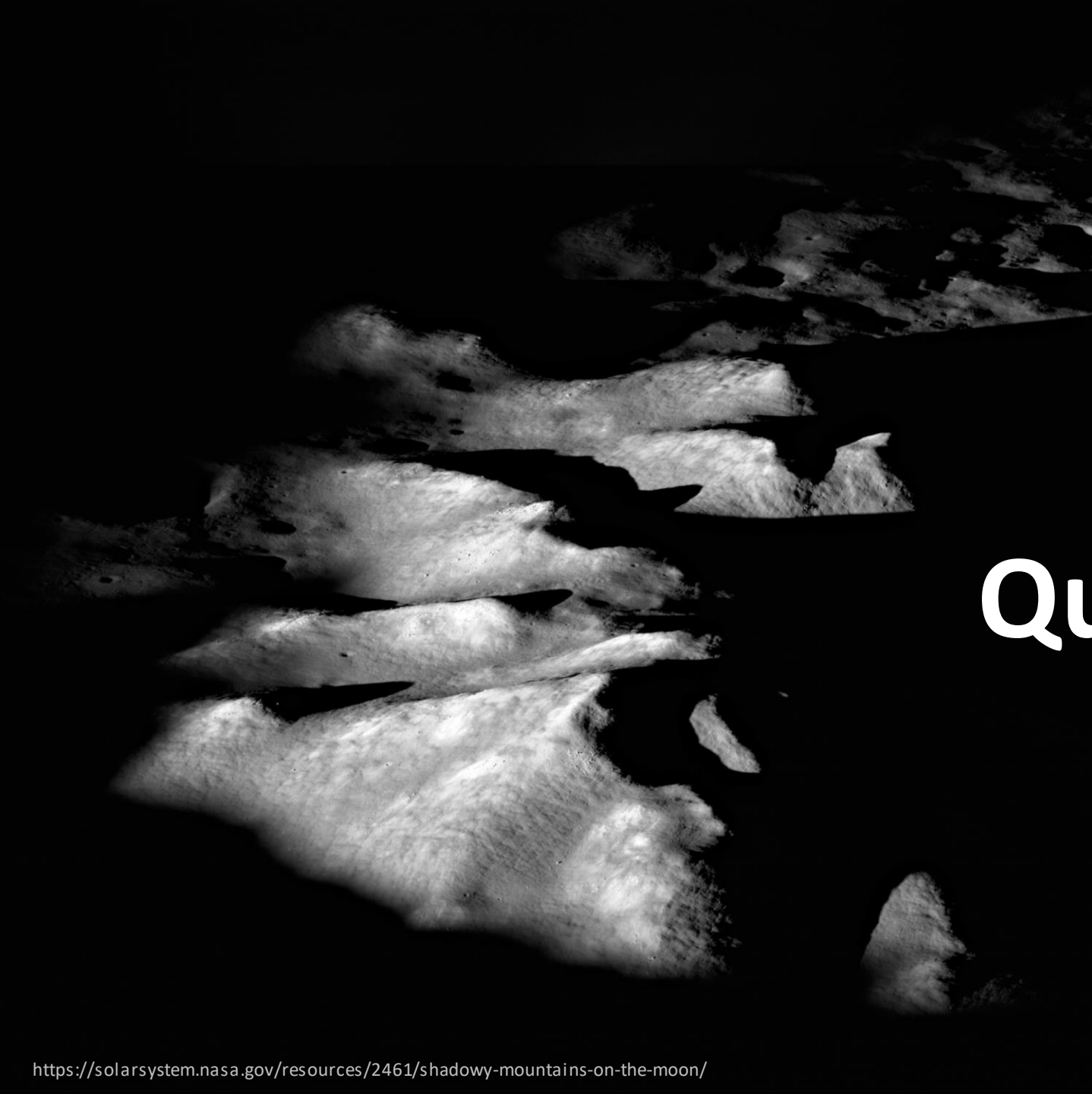
Essay contest open to grades K-12

Deadline December 17, 2020

<https://www.futureengineers.org/artemismoonpodessay>

Your challenge is to imagine leading a one-week expedition at the Moon's South Pole – with the whole world cheering you on. Tell us about the types of skills, attributes, and/or personality traits that you would want your Moon Pod crew to have and why. How many would be in your pod? And of course you'll need high tech gear and gadgets! In your essay, also describe one machine, robot, or technology that you would leave on the lunar surface to help future astronauts explore the Moon.

Selected semifinalists will be invited to represent their state or territory in a series of Artemis Explorer sessions with NASA experts. Nine finalists will travel with a parent to NASA's Johnson Space Center next summer to learn about lunar exploration, and the national winner in each grade division will win a family trip to see the first Artemis test launch to watch the most powerful rocket in the world launch from Kennedy Space Center in Florida.



Questions!

Resources

General

- General Information on the Moon: <https://moon.nasa.gov/>
- Artemis Program: <https://www.nasa.gov/specials/artemis/>
- Space Biosciences Division: <https://www.nasa.gov/ames/research/space-biosciences>

Water on the Moon

- VIPER: <https://www.nasa.gov/viper>
- SOFIA: <https://www.nasa.gov/press-release/nasa-s-sofia-discovers-water-on-sunlit-surface-of-moon/>

Life support systems

- Water in space:
https://www.nasa.gov/mission_pages/station/research/benefits/water_in_space/
- NASA Environmental Control and Life Support System:
<https://www.nasa.gov/centers/marshall/history/ecss.html>
- ESA Advanced Closed Loop System:
https://www.esa.int/Science_Exploration/Human_and_Robotic_Exploration/Research/Advanced_Closed_Loop_System

Power

- conductive space suits: <https://sservi.nasa.gov/articles/the-need-for-conductive-space-suits/>
- ISS solar arrays:
https://www.nasa.gov/mission_pages/station/structure/elements/solar_arrays-about.html
- Mars Spirit & Opportunity solar power:
<https://mars.nasa.gov/mer/mission/technology/power/>
- Mars Perseverance MMRTG (nuclear power):
<https://mars.nasa.gov/mars2020/spacecraft/rover/electrical-power/>
- Apollo 15-16-17 Lunar Roving Vehicle:
https://nssdc.gsfc.nasa.gov/planetary/lunar/apollo_lrv.html