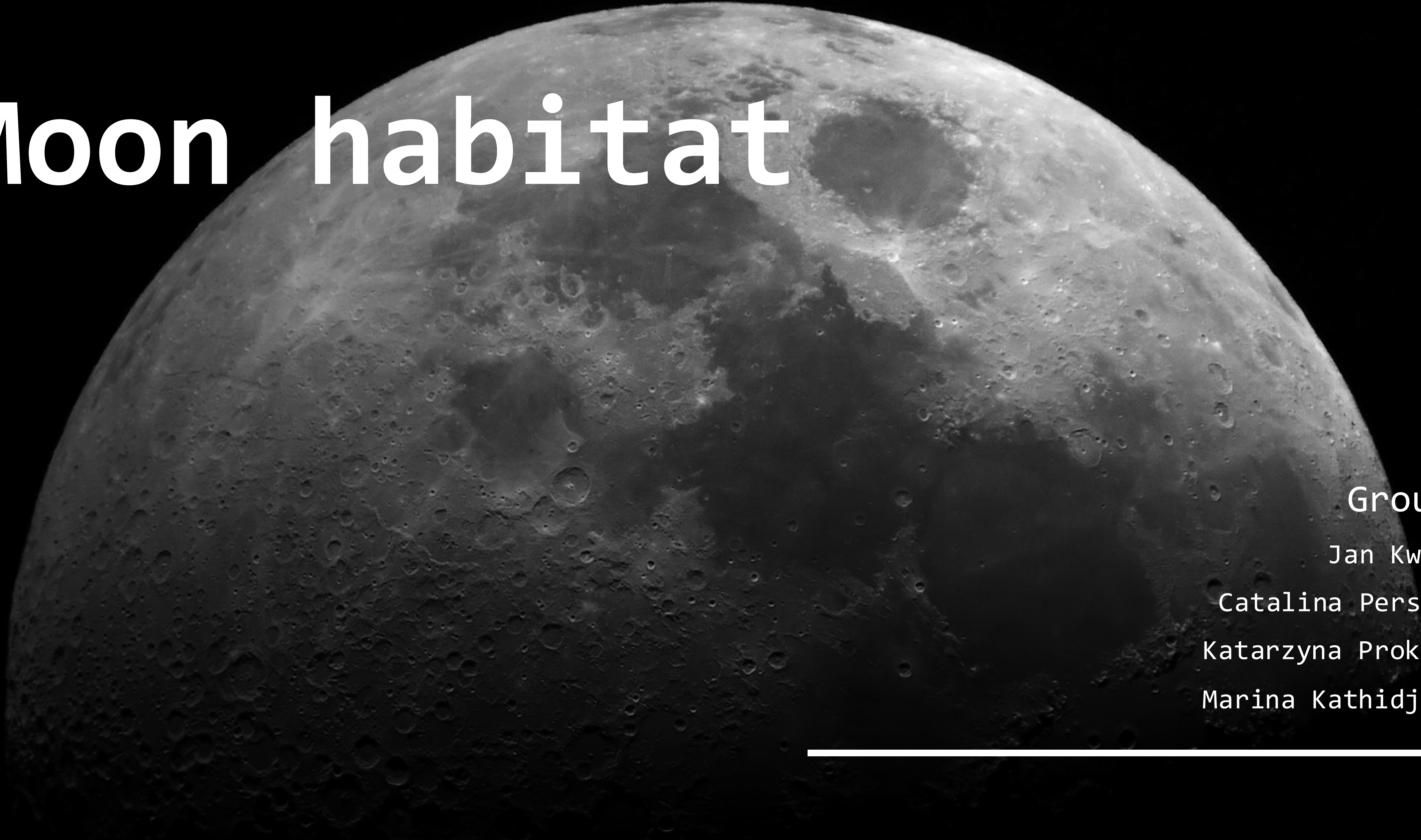
Moon habitat



Group 2

Jan Kwasnik

Catalina Persunaru

Katarzyna Prokopiuk

Marina Kathidjiotis

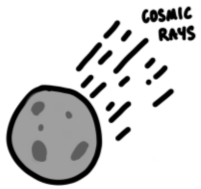
Context

One lunar day is equivalent to **29.53 Earth days**;

Moon's surface gravity is **1.62 m/s²**, 1/6 of the Earth's one;

Drastic temperature differences from day to night. The temperature of a surface also varies when in sunlight or shadow;

The Moon's atmosphere is nearly **vacuum**;



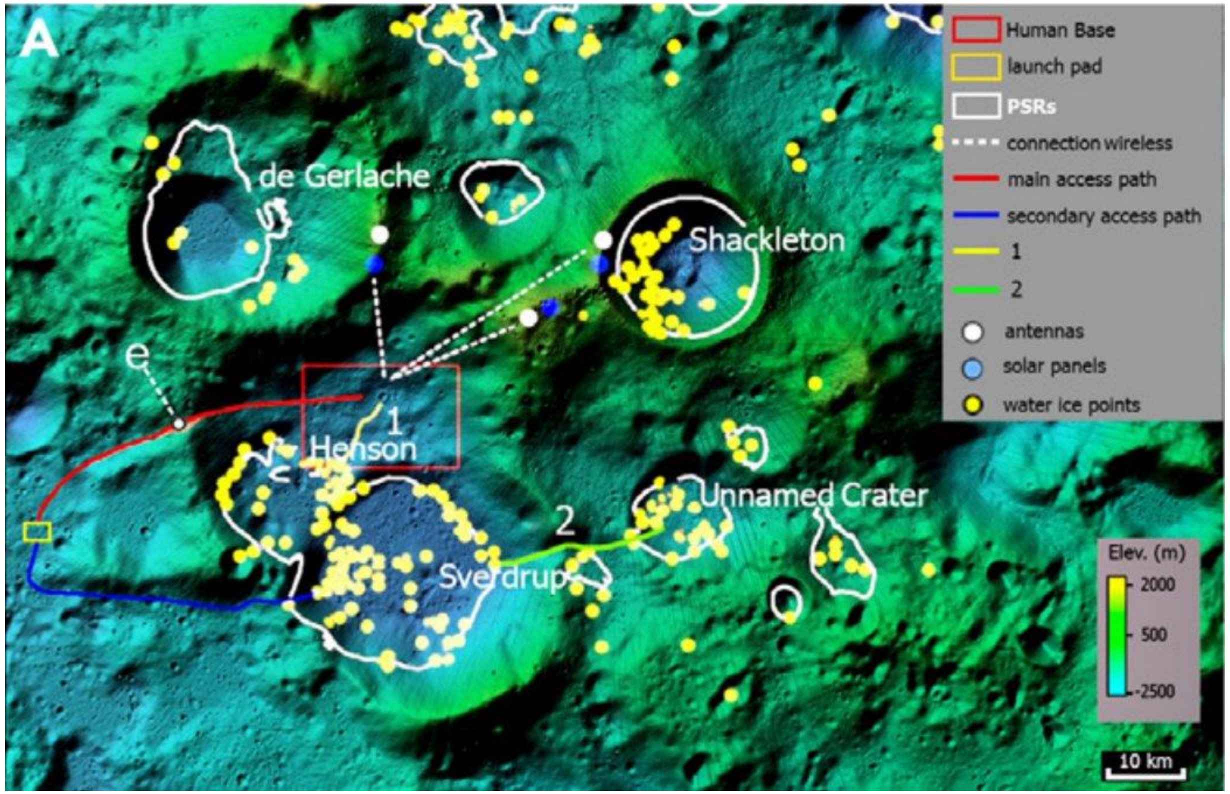
Ionizing radiation from cosmic rays is **200 times more** than on Earth's surface;

A permanent **dust cloud** exists around the Moon that sticks to the suits of the astronauts. If carried in their quarters while it can cause health issues.

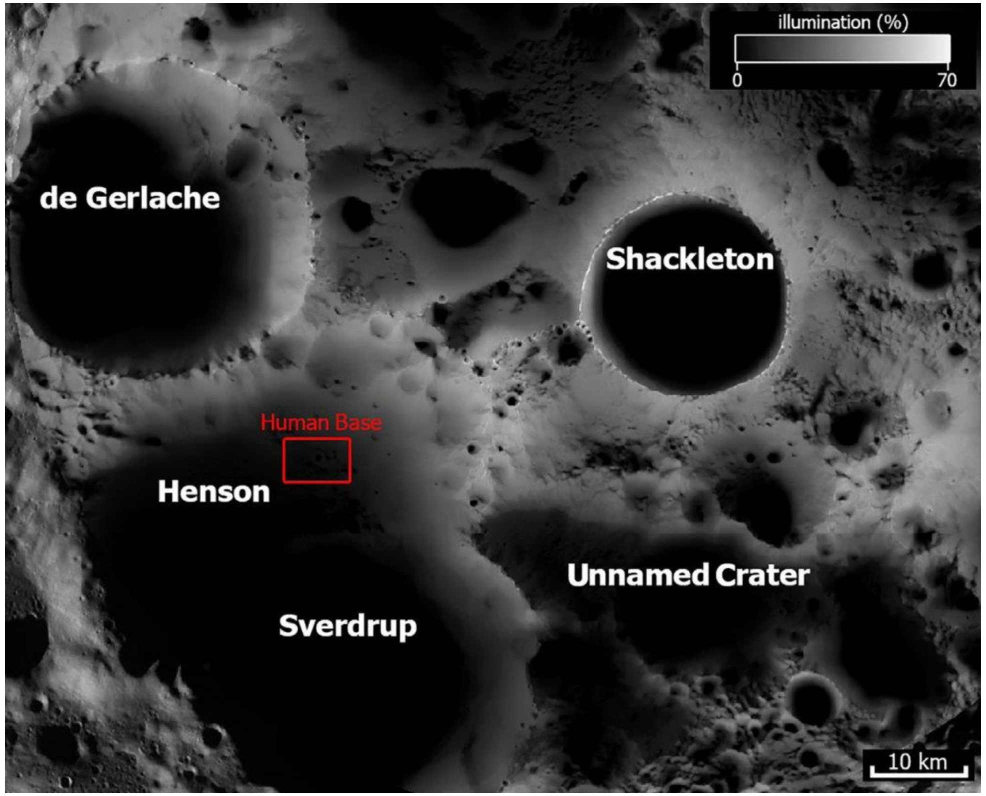
Guidelines based on Moonstation2050 competition:

- **Radiation Shielding and Isolation:** Prioritize the proper isolation of the habitat from the surrounding void and implement efficient countermeasures against various types of radiation to ensure the safety and well-being of inhabitants.
- **Airlock Access:** Provide access points to the outside environment through pressurization/depressurization filter areas known as "Airlocks" to maintain the internal pressure and environmental conditions of the habitat.
- **Glazed Surfaces with External Shading:** While glazed surfaces may be incorporated, ensure they are equipped with external shading systems to mitigate extreme temperature fluctuations, radiation exposure, and potential impacts from micrometeorites.
- **Modular Design with Watertight Closing Systems:** Design each space as an independent module, enabling separability through specific watertight closing systems. This allows for maintenance, repair, or replacement without compromising the functionality of the entire habitat.
- **Redundancy:** Incorporate redundancy into the layout of main infrastructures to mitigate the consequences of system malfunctions or damages. For example, ensure critical components or systems have backups or duplicates to maintain functionality in case of failure.
- **Pollution Treatment:** Implement safe and reliable methods for treating pollution within the habitat, considering the sustainability and health of inhabitants and the surrounding environment.

Site Selection



The chosen **location on the lunar South Pole**: multiple water ice points, variable resources, (semi) continuous visibility of Earth, constant daylight



Optimal **sunlight exposure** – possibility of power generation without excessive radiation

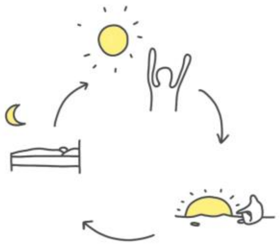
(Leone et al., 2023)

Program

- **Bedrooms (6 x 10m2) - sleep**
  Plain yet comfortable bedrooms. Since the day cycles on moon do not follow the day cycles of earth there is possibly no need for windows in the living quarters.
- **Unisex toilets + bathrooms (3 x 6m2)**
  Combined units
- **Common Hall (75m2) - food preparation**
  Multifunctional space for food preparation and consumption + a hub for social interaction
- **Food production (50m2) - greenhouse**
- **Transition spaces (X x5m2)**
  Since the dust cloud in Moon's atmosphere is toxic, there will be spaces in between the airlocks and internal spaces in which the costumes covered in dust can be taken off
- **Control Room (Environmental Control and Life Support System)(20m2)**
  Space to host complex control equipment for maintaining the internal environment of the Habitat.
- **Computer room (20m2)**
  A place filled with computers which store the information gatehered there and help you communicate with the people on Earth
- **Gym (30m2) - keeping in shape**
  Space to accommodate gym equipment for daily exercise
- **Medical Care (20m2)**
  area dedicated to medical care, easily accessible in case of an emergency
- **Laboratories (60m2) - a space for experiments**
  The research areas should be close to the entrance and exit areas to facilitate the transport of samples into the station
- **Rover Hub (20m2)**
  The connection hub between the station and rovers for mobility. In this space one can enter in rovers safely and find all the necessary elements for the rovers' maintenance
- **Airlocks (X x5m2)**
  Filter areas which enable the passage from pressurized (Habitat) to non-pressurized environment (Moon) in total safety without catastrophic pressure losses
- **3D printing room (10m2)**
  should be accessed from both inside and outside
- **Meditation room with VR+AR (10m2)**
  should be accessed from both inside and outside

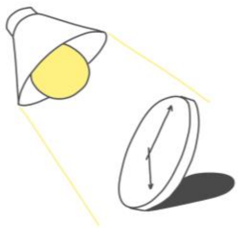
Circadian rhythms

Circadian rhythms are 24-hour cycles that are part of the body's internal clock, running in the background to carry out essential functions and processes. One of the most important and well-known circadian rhythms is the sleep-wake cycle.



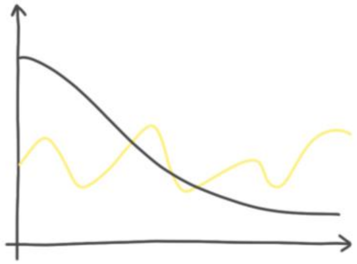
They prepare our bodies for **expected changes in the environment**.

Darkness at night is as important as brightness during the day.



Bright light regulates **hormones production** and **sleep-wake cycles.**

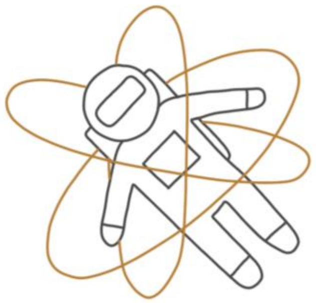
It is important to have a **variety of stimuli**.



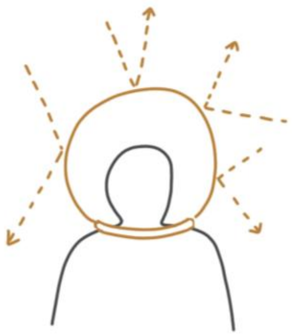
Disruptions affect psychiatric health, metabolism, and possibly the immune system.

(van den Wymelenberg, 2014; *Module 2. Circadian Rhythms Have an Important Purpose* | *NIOSH* | *CDC*, n.d.-b; Suni & Singh, 2023b)

Psychological effects of spending time in space



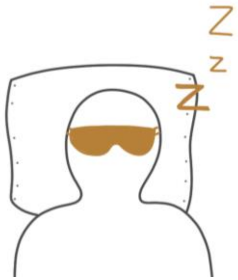
Multiple aspects that cause **changes in circadian rhythms**.



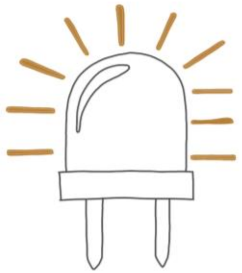
Senses become numb because of monotonous stimuli.

Ionizing radiation can cause visible **flashes of light**.

Human factor is the biggest unknown in space.



Astronauts need to get **enough sleep**.



Space infrastructures mostly use **artificial LED lights**.

(Turner, 2019; Arone et al., 2021b; Guo et al., 2014)

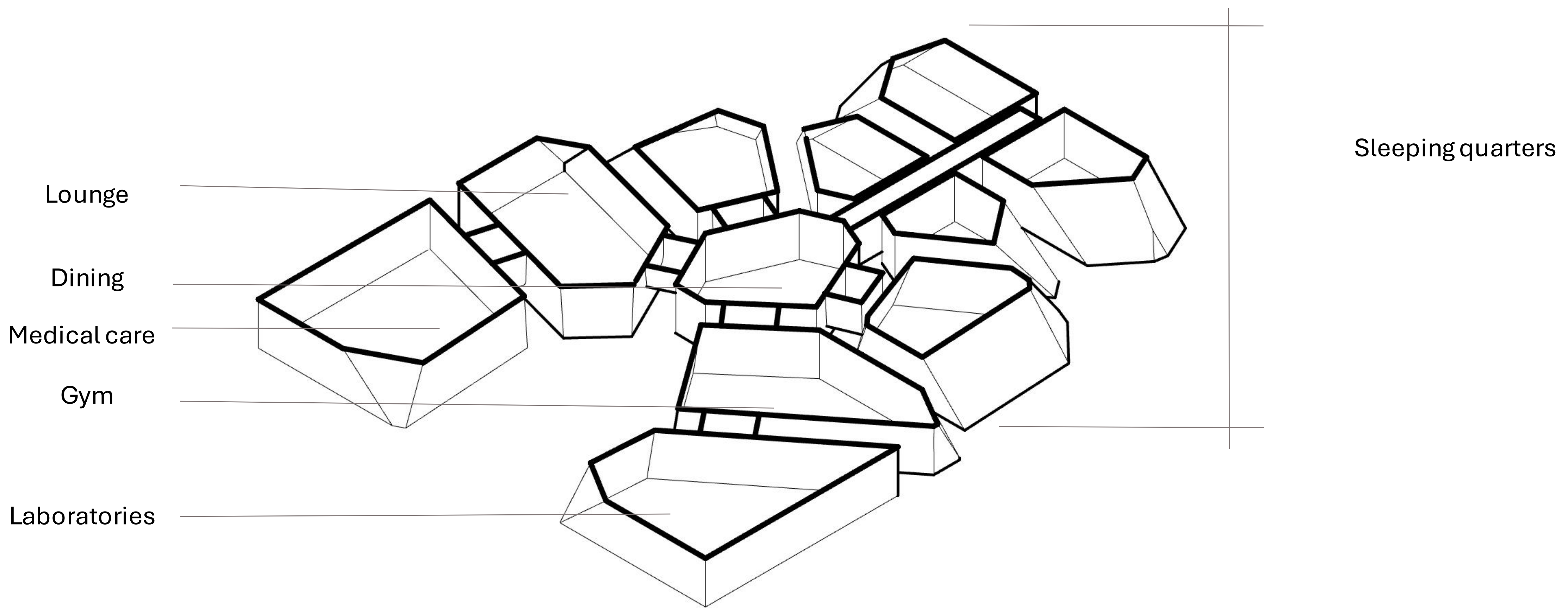
Maintaining circadian rhythms for mental wellbeing

- On the ISS (International Space Station) a **24-hour day** is simulated using Universal Coordinated Time.
- There are **LED systems that help to maintain the circadian rhythms**. They use stronger blue light in the morning, and more red light before sleep.
- It is beneficial to **simulate the changing sky throughout 24 hours**: dawn, sunrise, daylight, sunset, dusk.
- **Variation from day-to-day** to better mimic the variable nature of natural lighting found on Earth.
- Astronauts need **private sleeping quarters** to limit disturbances.

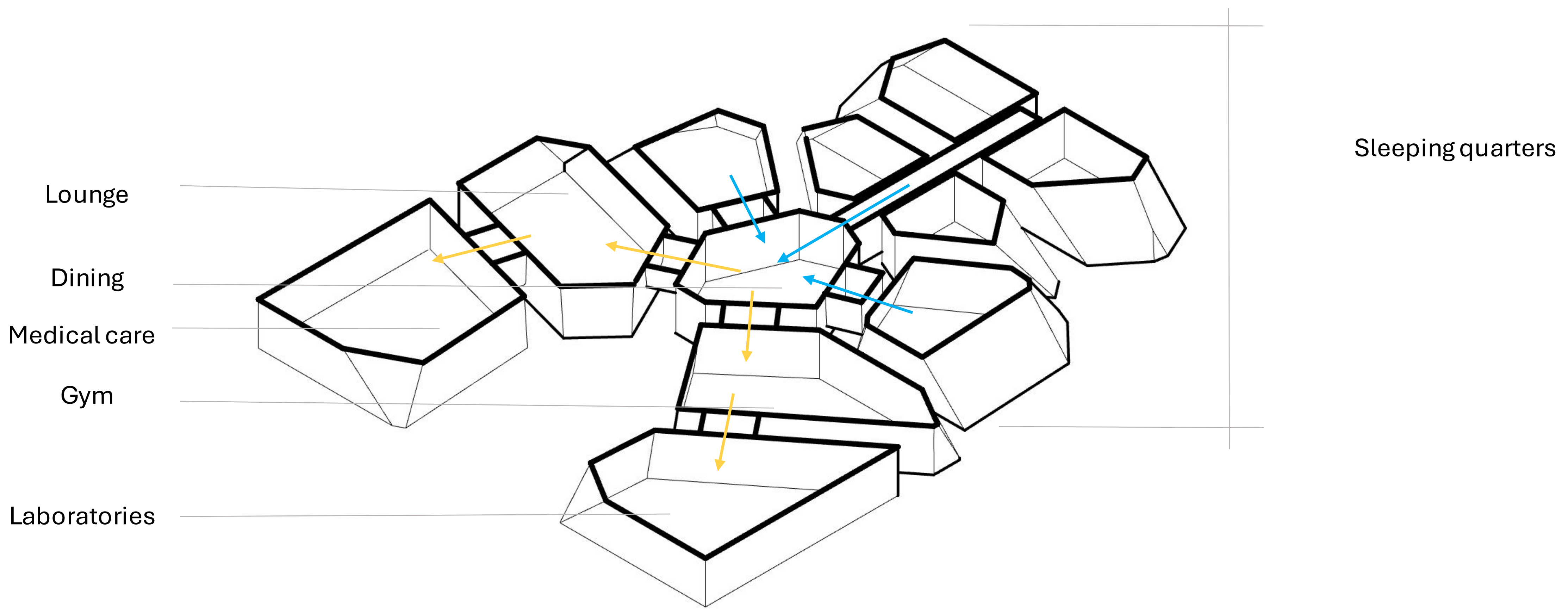
The Circadian Lights – a project by SAGA Architects

(*What Life on the International Space Station Can Tell Us About the Circadian Clock.*, n.d.; Designboom, 2023)

Creating spaces that help the circadian rhythm



Circulation flow throughout the day

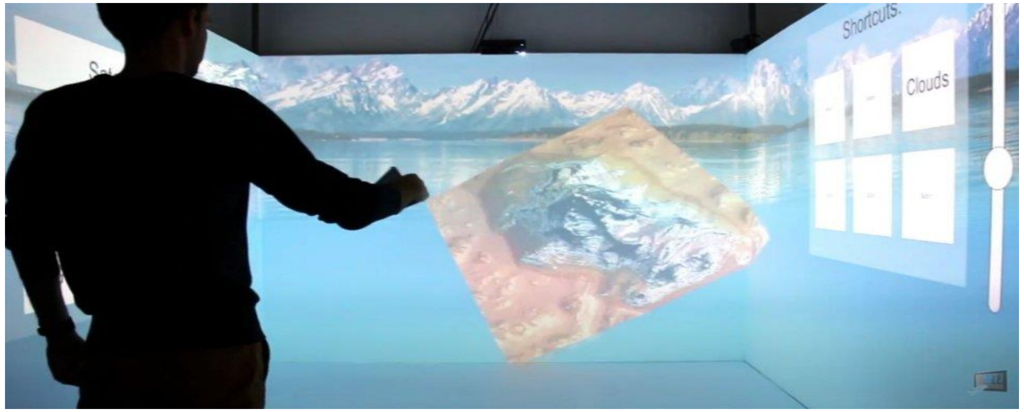


The possibilities of using XR

XR set as a possibility for enhanced training.

VR Cave gives full immersion for its users.

XR solution as support for mental health.

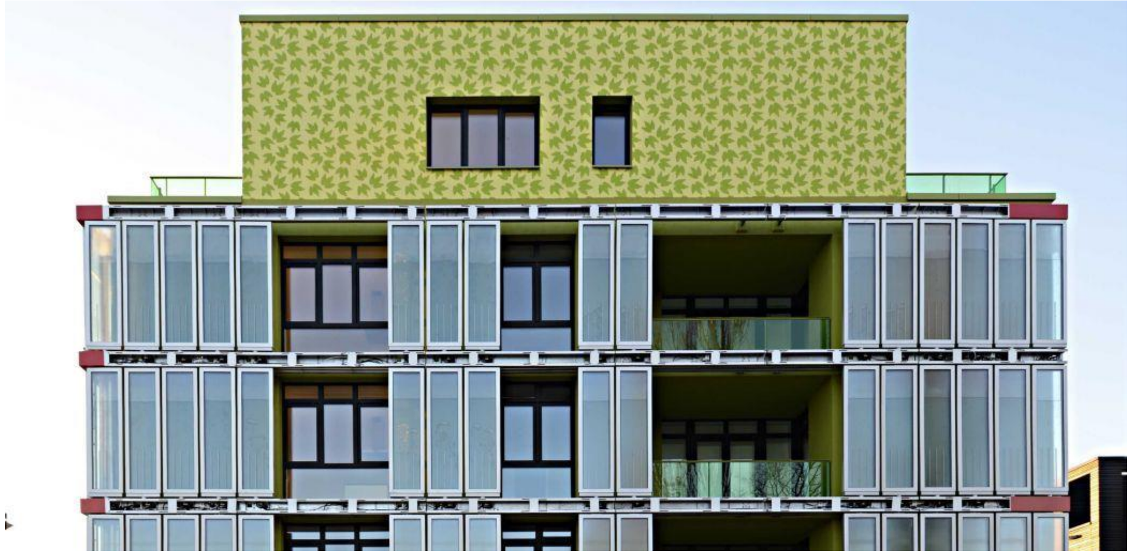


VR set recently launched to the space

VIVE

Self-sufficiency on the Moon

- There are plants growing on the ISS in a system called "Veggie" - using special **pillows to prevent the effects of microgravity**
- **Challenges of space/Moon agriculture**: very high radiation, absence of or reduced gravity, need for fertilizers
- **Lunar regolith** can be used as a growing medium, however crops aren't as good as they were in control samples
- **Hydroponics** seems to be a good solution for vegetables production on the Moon
- The challenges do not apply to the **cultivation of algae** in autonomous bioreactors, because their organization is simpler, the development cycles are shorter, and the biomass is larger.
- Microalgae can become one of the **main sources of food** on the Moon (at least at the beginning).

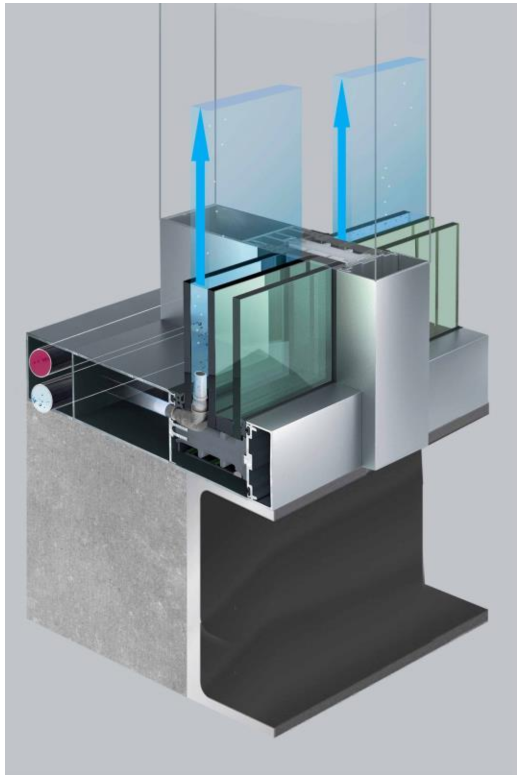


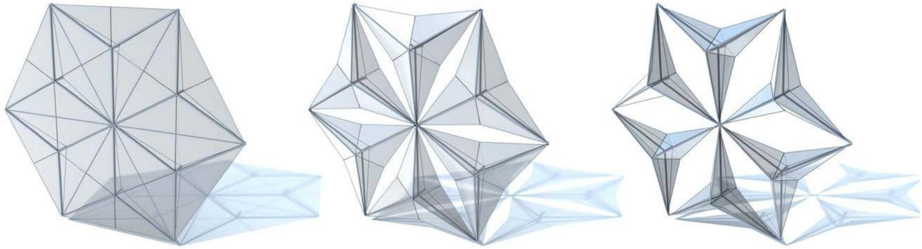
SolarLeaf – a façade design by Arup. It incorporates panels with algae growing inside them. They grow in cycles and are harvested after a few days or weeks to produce energy, food, or cosmetics. A little amount of algae is left in the cell to start a new cycle of growth. The building is claimed to be fully powered by the algae filled walls, they also contribute to oxygen production.

https://dodosustainabilityjournal.wordpress.com/2016/03/19/algae-filled-walls-green-wall-powering-a-green-building/

(ABIBOO, 2022; *Growing Plants in Space - NASA*, n.d.; Ward, 2023)

Main challenge - radiation



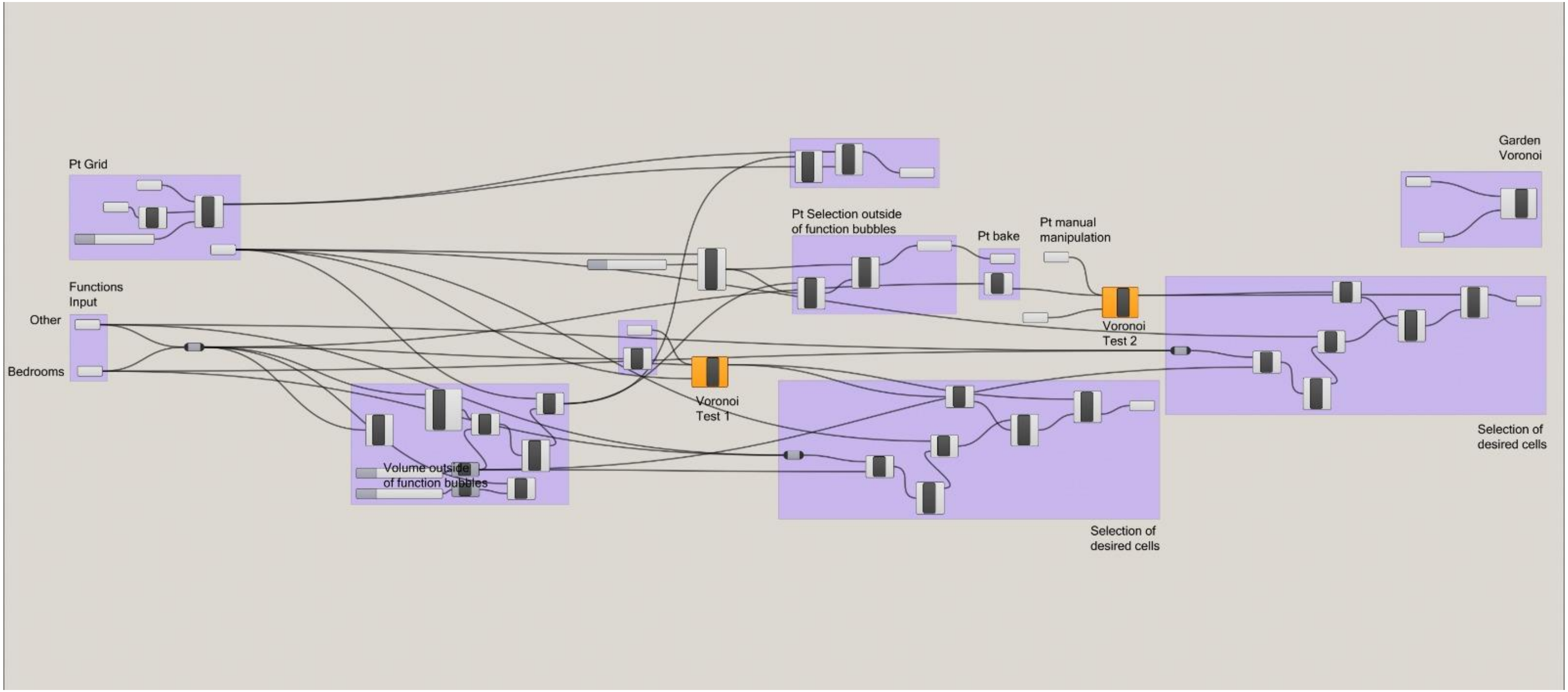


Hydrogen-rich shielding reduces the crew's exposure to space radiation.
The **lunar regolith** can provide substantial protection against radiation.

Water-filled windows can absorb radiation, but they do not completely stop it. They are also an energy-saving cooling system.

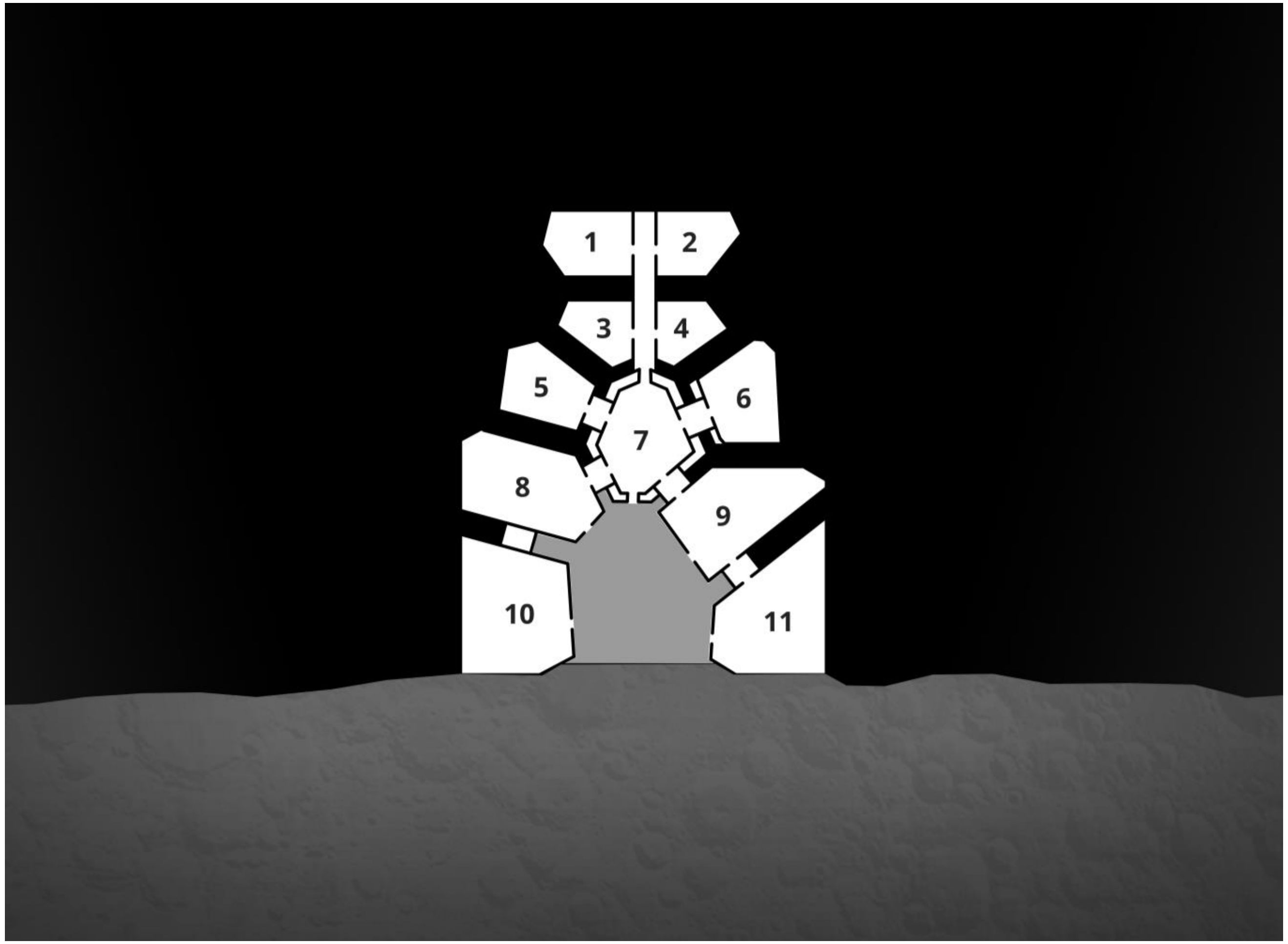
Kinetic, responsive, triangulated **shading system can be coated with** lightweight polyethylene plastic (**RFX1**), a material composed of lightweight carbon and hydrogen atoms

Algorithm behind the design

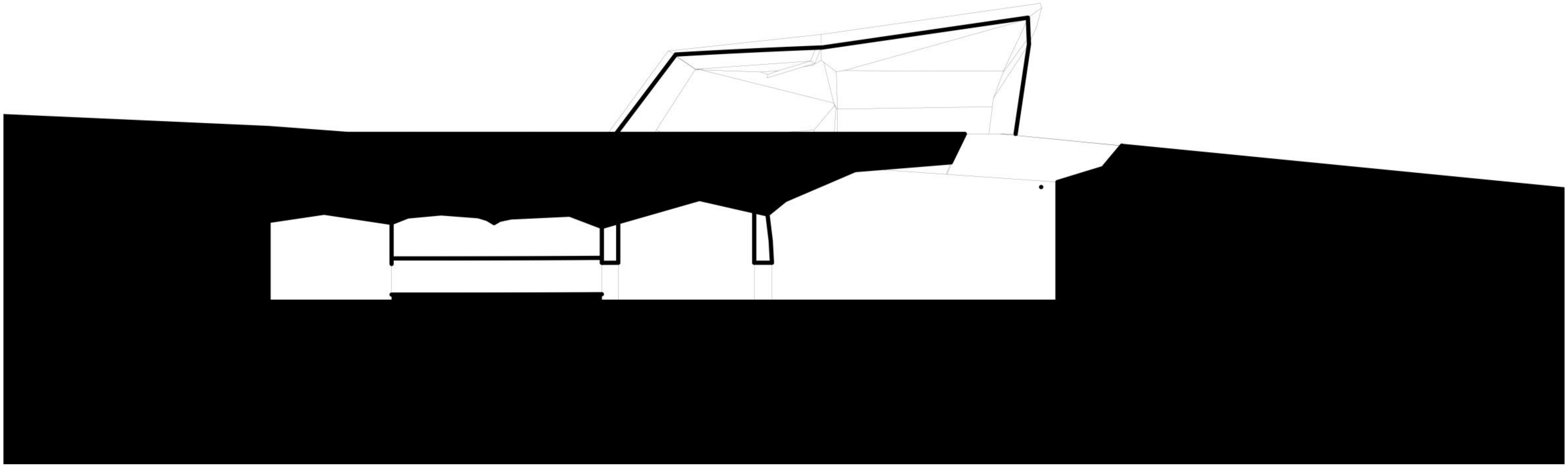


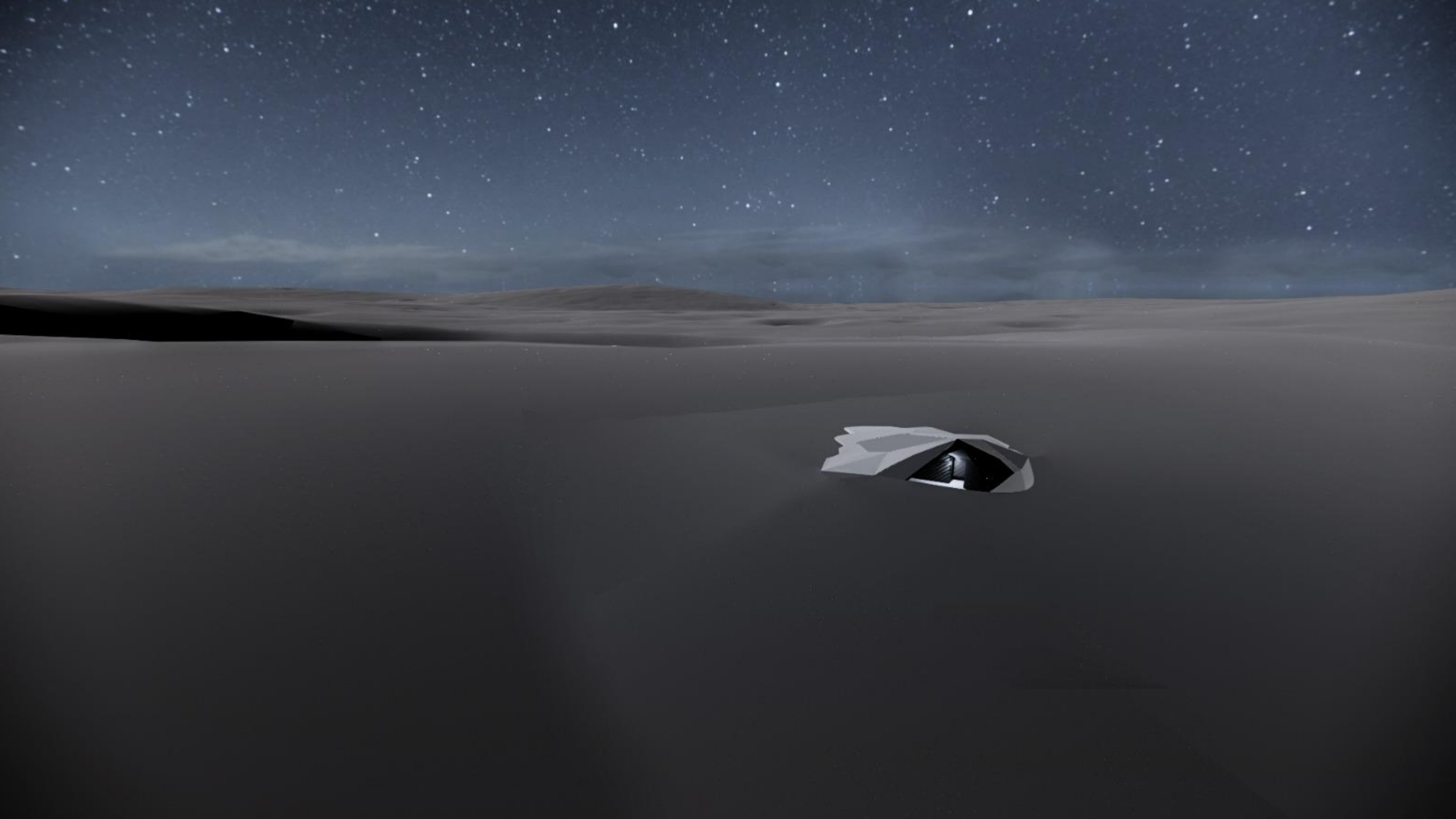
Plan

1-6	sleeping quarters
7	dining
8	lounge
9	gym
10	medical care
11	laboratories

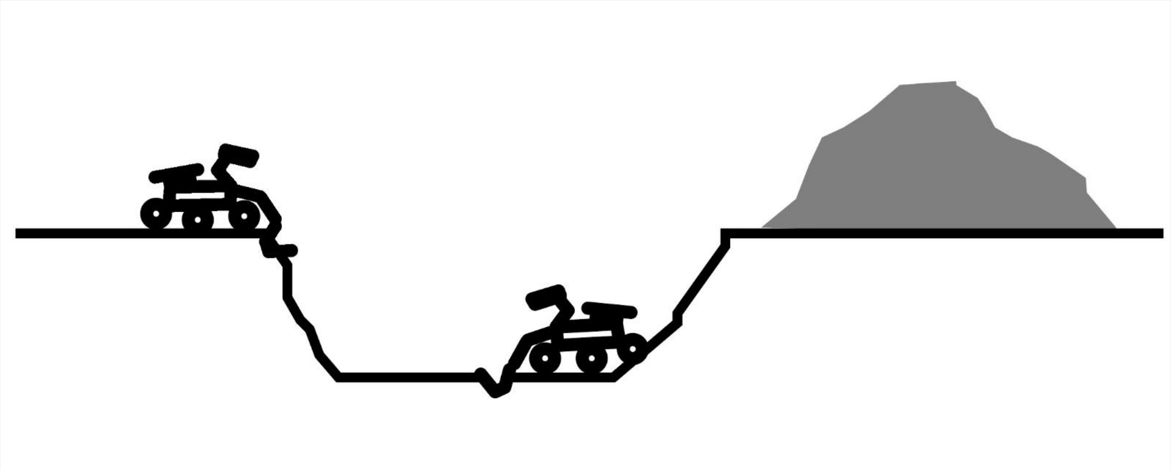


Section

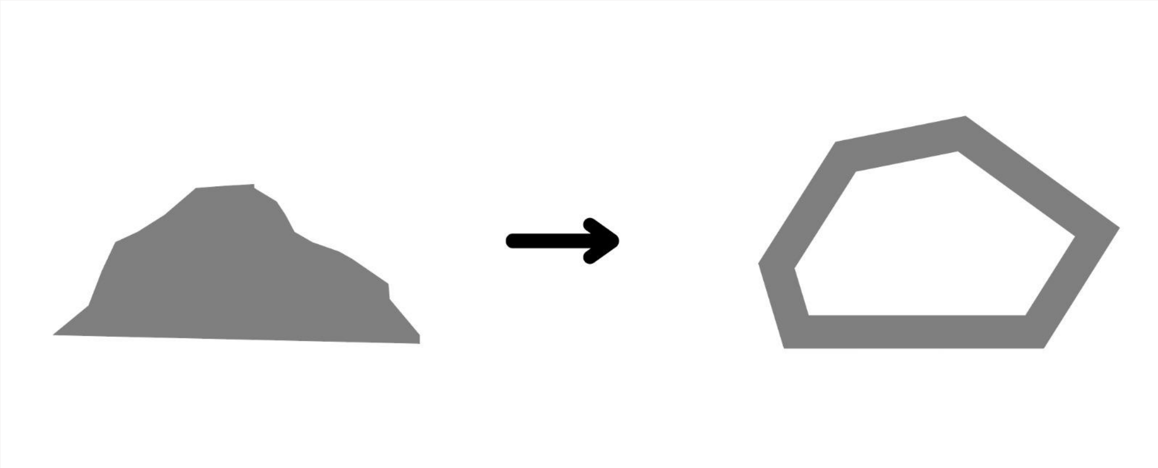




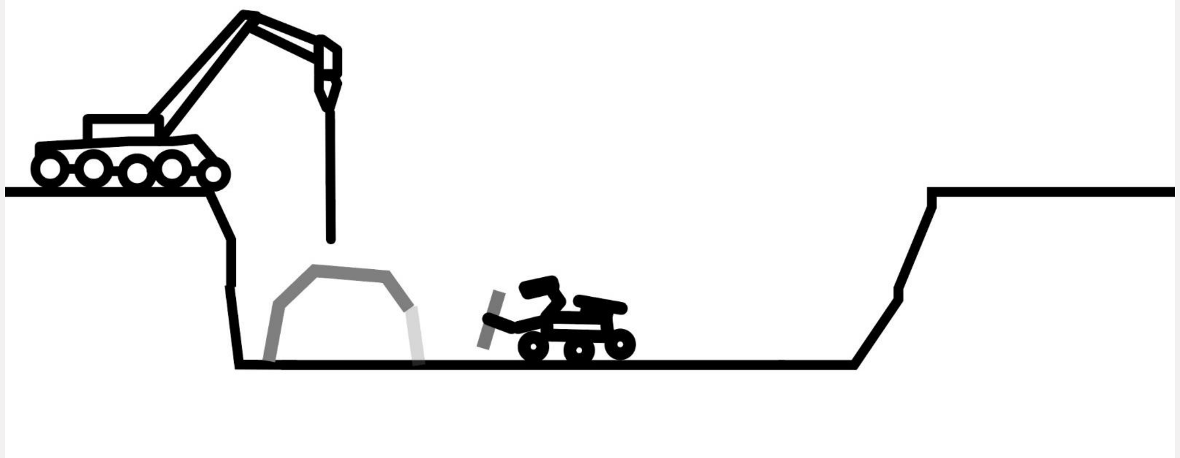
Assembly concept



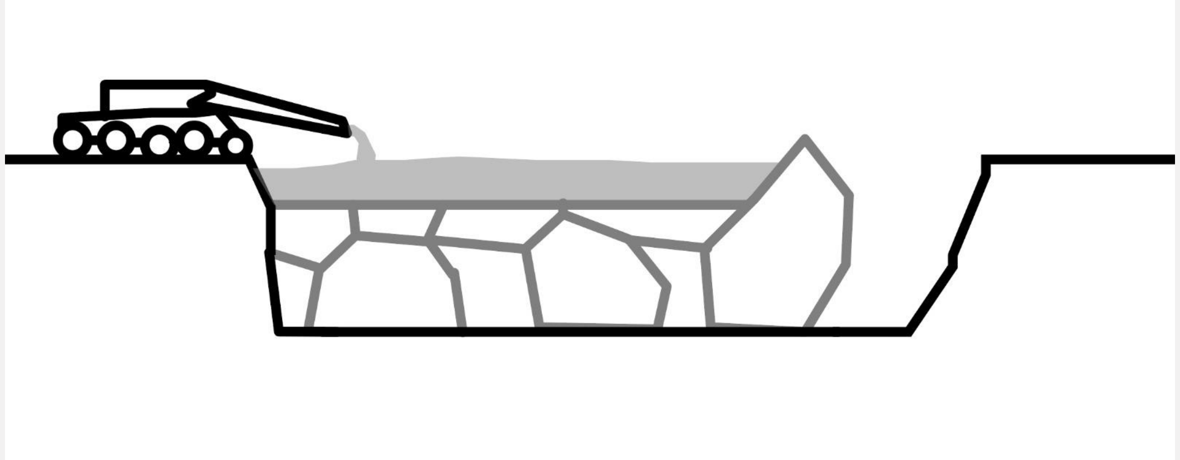
1. Excavation of the site



2. using the excavated soil for additive manufacturing



3. in-situ assembly



4. remaining soil as protective layer on top of living spaces

Sources

ABIBOO. (2022, July 22). **Nüwa, the first sustainable city on Mars** • ABIBOO Studio. ABIBOO Studio. https://abiboo.com/projects/nuwa/

Arone, A., Ivaldi, T., Loganovsky, K., Palermo, S., Parra, E., Flamini, W., & Marazziti, D. (2021b). **The burden of space exploration on the mental health of astronauts: A narrative review.** PubMed, 18(5), 237–246. https://doi.org/10.36131/cnfioritieditore20210502

Designboom. (2023, June 26). **SAGA's multicolored circadian light panel helps astronauts in space beat insomnia.** Designboom | Architecture & Design Magazine. https://www.designboom.com/technology/saga-multicolored-circadian-light-panel-astronauts-insomnia-03-17-2023/

Growing plants in space - NASA. (n.d.). NASA. https://www.nasa.gov/exploration-research-and-technology/growing-plants-in-space/

Guo, J., Qu, W., Chen, S., Chen, X., Lv, K., Huang, Z., & Wu, Y. (2014). **Keeping the right time in space: importance of circadian clock and sleep for physiology and performance of astronauts.** Military Medical Research, 1(1), 23. https://doi.org/10.1186/2054-9369-1-23

J. Miller, L. Taylor, C. Zeitlin, L. Heilbronn, S. Guetersloh, M. DiGiuseppe, Y. Iwata, T. Murakami (2009). **Lunar soil as shielding against space radiation.** Radiation Measurements, 44(2), 163-167. https://doi.org/10.1016/j.radmeas.2009.01.010

Leone, G., Ahrens, C., Korteniemi, J., Gasparri, D., Keresztúri, A., Martynov, A., Schmidt, G. W., Calabrese, G., & Joutsenvaara, J. (2023). **Sverdrup-Henson crater: A candidate location for the first lunar South Pole settlement.** iScience, 26(10), 107853. https://doi.org/10.1016/j.isci.2023.107853

Module 2. **Circadian rhythms have an important purpose** | NIOSH | CDC. (n.d.-b). https://www.cdc.gov/niosh/work-hour-training-for-nurses/longhours/mod2/18.html#:~:text=Circadian%20rhythms%20have%20an%20important%20purpose%3A%20they%20prepare%20your%20body,light%20also%20influences%20the%20pacemaker.

Rask, J., Vercoutere, W., Krause, A., Navarro, B. (2008). Space Faring. The Radiation challenge. Module 3: Radiation Countermeasures. https://www.nasa.gov/wp-content/uploads/2009/07/284275main_radiation_hs_mod3.pdf

Suni, E., & Singh, A. (2023b, November 16). **Circadian rhythm. Sleep Foundation.** https://www.sleepfoundation.org/circadian-rhythm

Turner, D. (2019) **Headspace: How Space Travel Affects Astronaut Mental Health.** https://cmsw.mit.edu/angles/2019/headspace-how-space-travel-affects-astronaut-mental-health/

Ward, C. (2023, March 3). **New lunar farming technique puts us one step closer to growing food in space**. *SYFY Official Site*. https://www.syfy.com/syfy-wire/new-lunar-farming-technique-could-grow-food-on-the-moon

What life on the International Space Station can tell us about the circadian clock. (n.d.). https://www.bbc.com/storyworks/in-pursuit-of-wellness/a-nasa-astronauts-guide-to-time-shifting-gwi