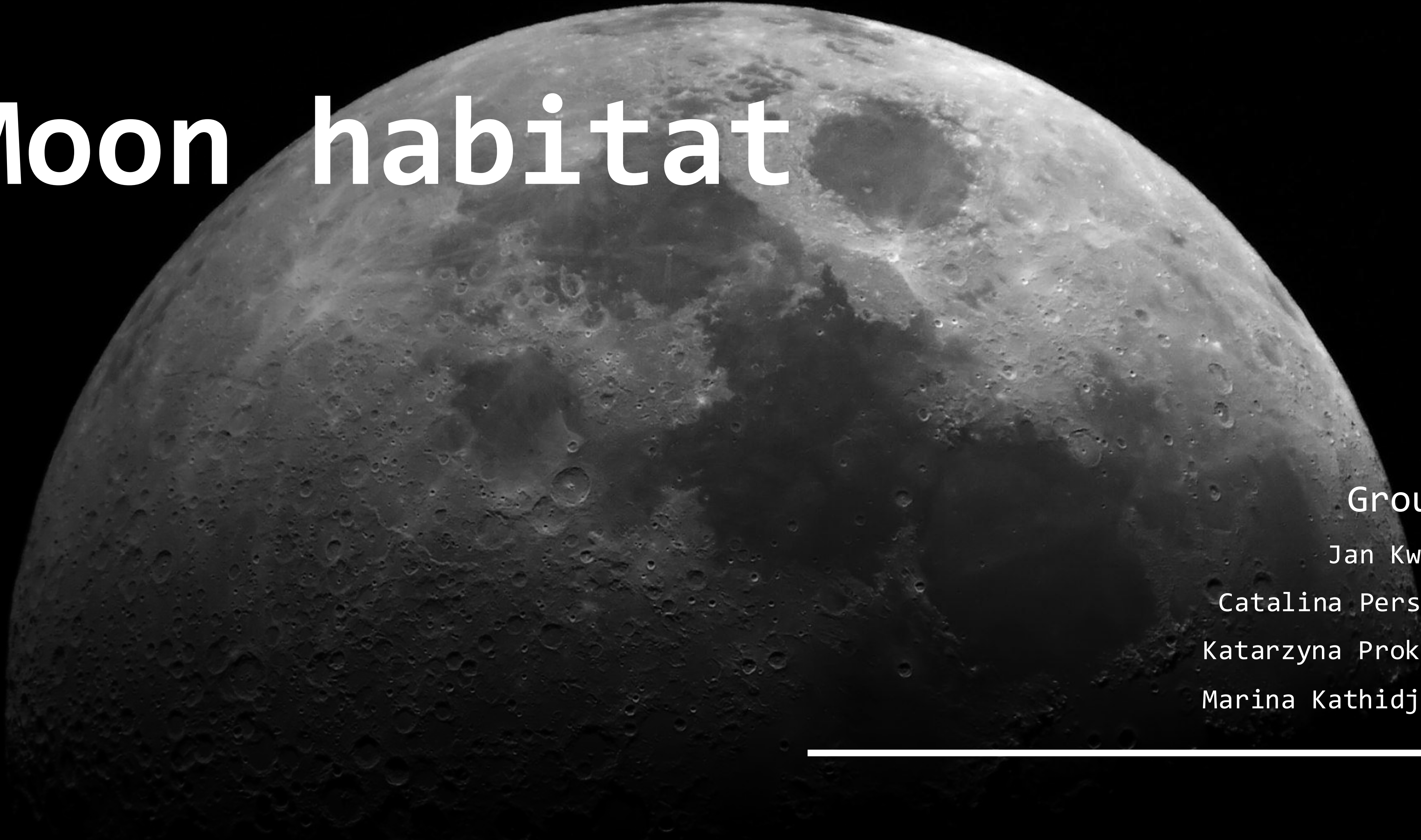
Moon habitat



Group 2

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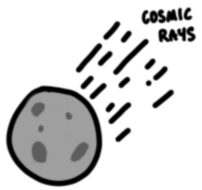
Context

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

Moon's surface gravity is **1.62 m/s**, 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**;

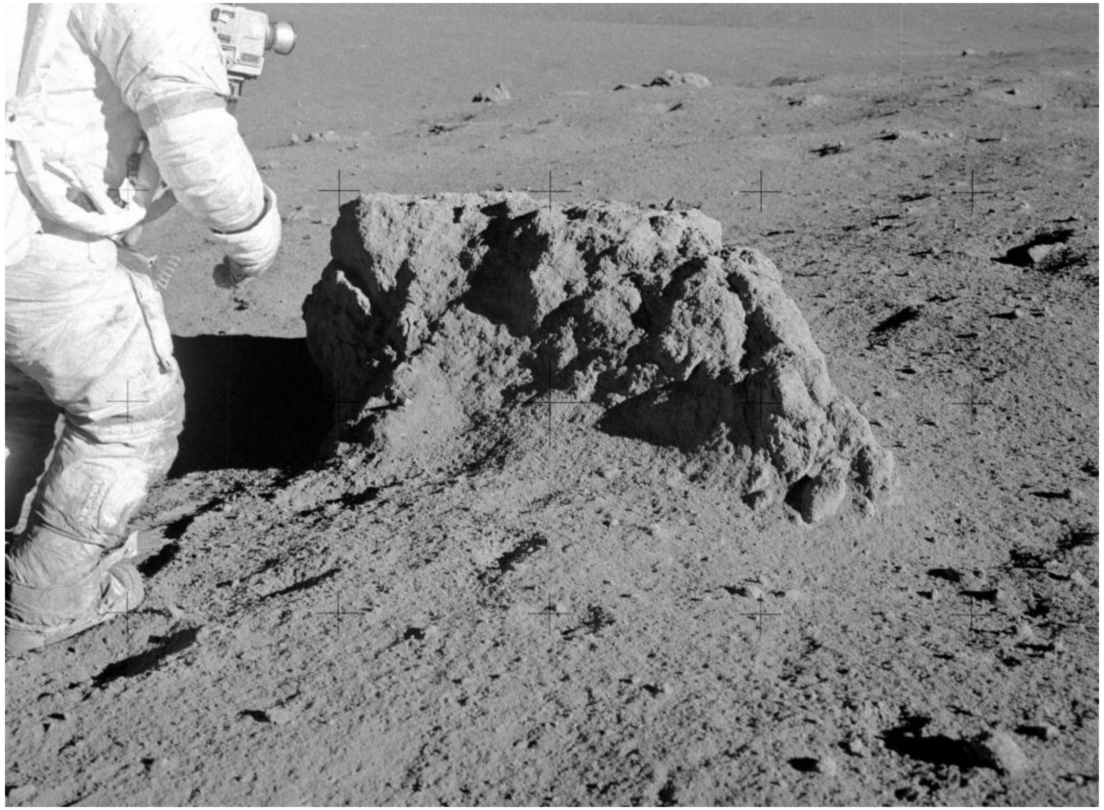


Ionizing radiation from cosmic rays is **200 times more** than on Earth's surface;

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.

Lunar Soil

- Lunar soil called **regolith** results from continuous meteoroid impacts and bombardment by charged particles from the sun and stars.
- It is approximately 4-5 meters thick in mare regions and 10-15 meters thick in highland areas, containing a range of materials from large boulders to sub-micron dust particles.
- Lunar soil grains tend to have sharp edges and fresh fractured surfaces, as they are not worn down by wind and water.
- Components of lunar regolith include rock chips, mineral fragments, impact and volcanic glasses, and a unique component called "agglutinates," with their ratios varying across different lunar soils;
- **It is possible to carry out interventions both on the surface and in the underground space of the Moon with no specific restrictions.**



Programme suggestions based on the context analysis

Assumption: **No stairs** are needed to get from one level to the other because of the low surface gravity

The proposal must be **completely sealed** due to the lack of atmosphere

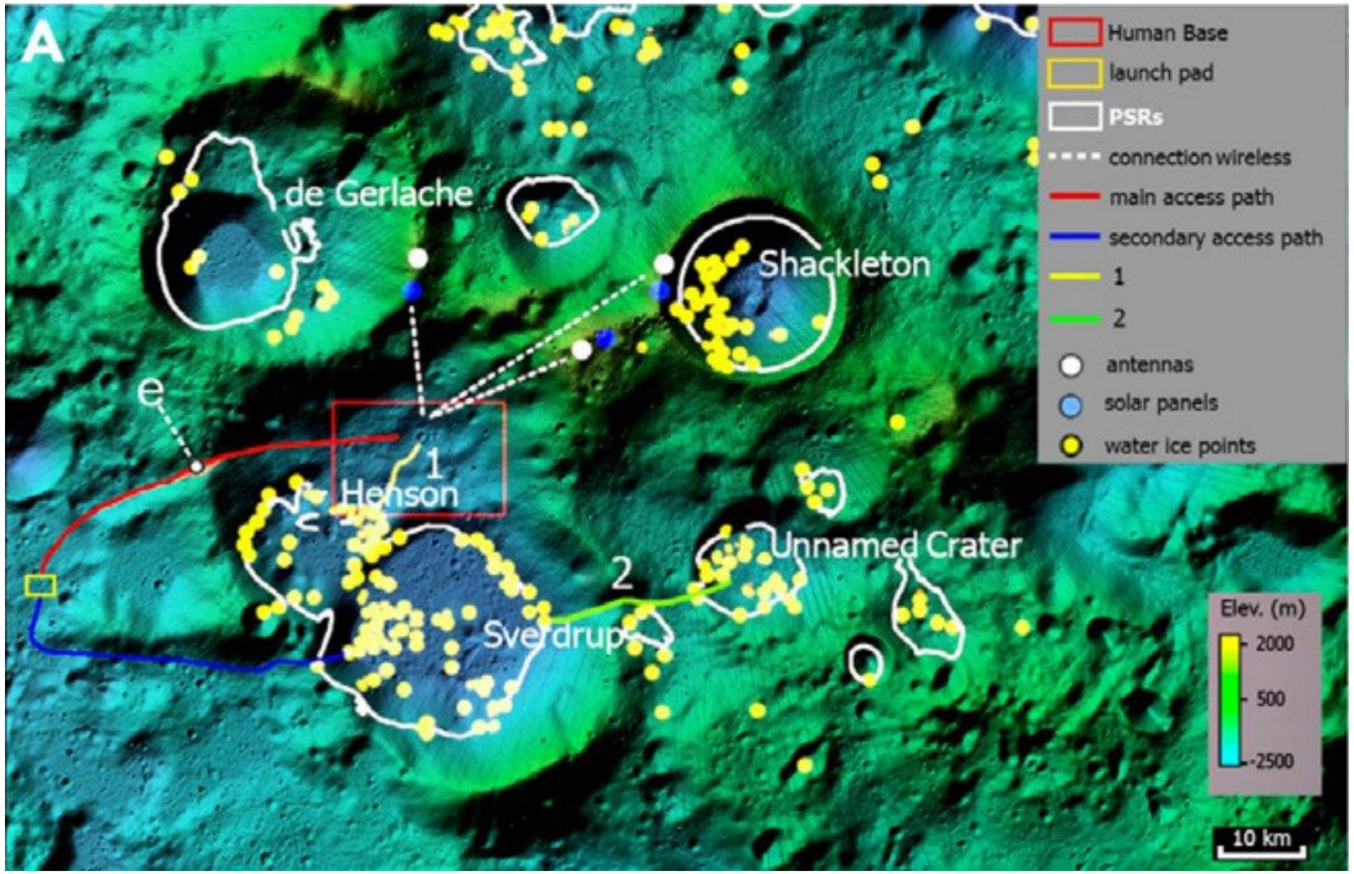
A **transition room** will be needed from outside to inside in which the costumes covered in dust can be taken off

Programme 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.

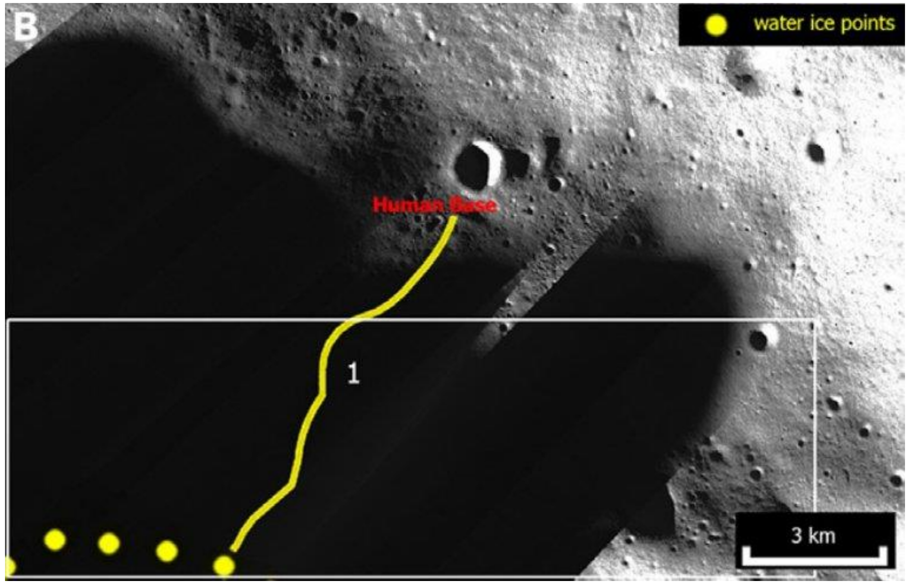
Site Selection

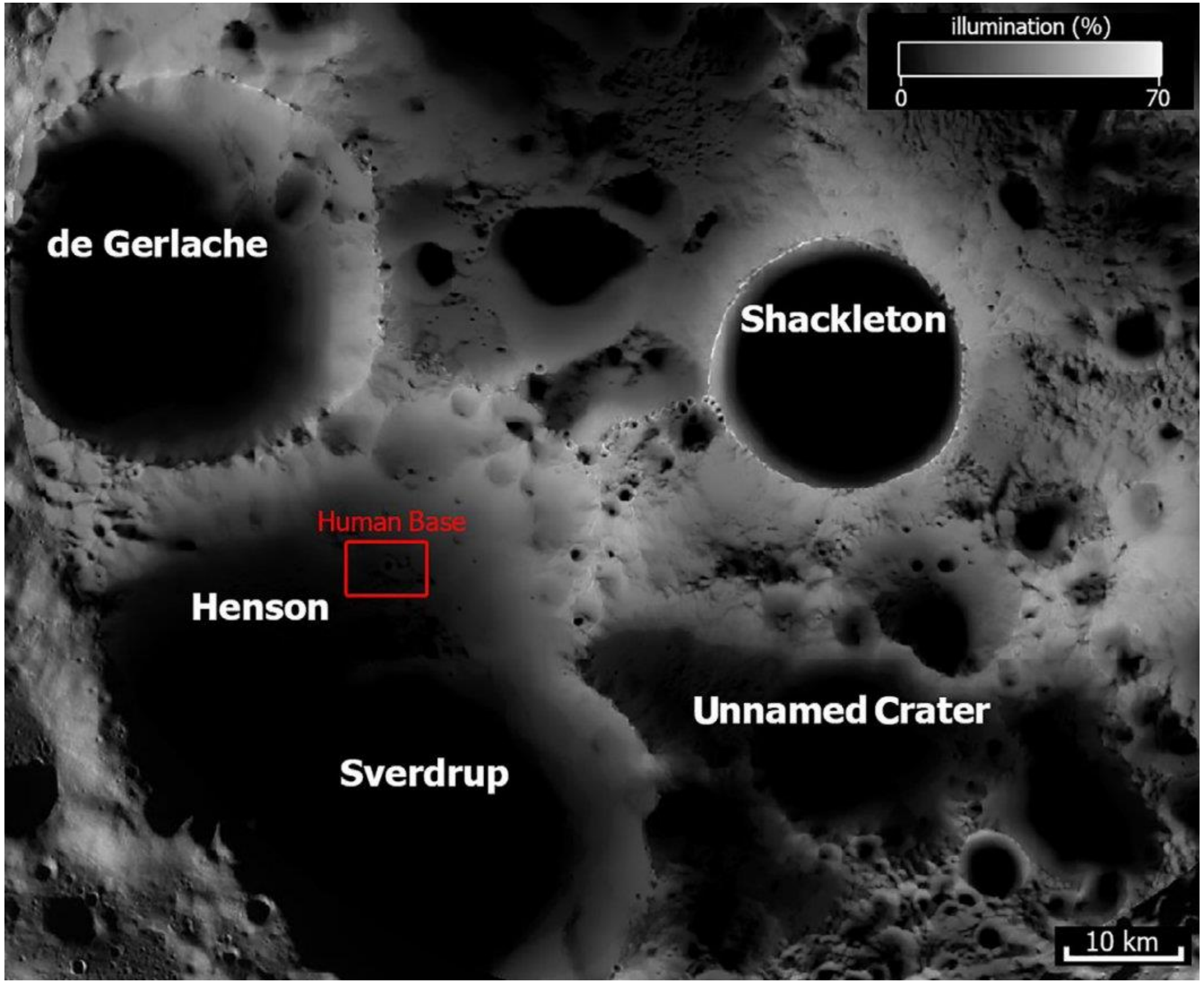
- The lunar South Pole is currently considered one of the most intriguing study regions for a first lunar base
- Multiple water ice points are located near the site
- The presence of variable resources within the regolith would be useful for ISRU activities
- (Semi-)continuous visibility of Earth for communication, remote control of robotic operations, and crew safety and morale.



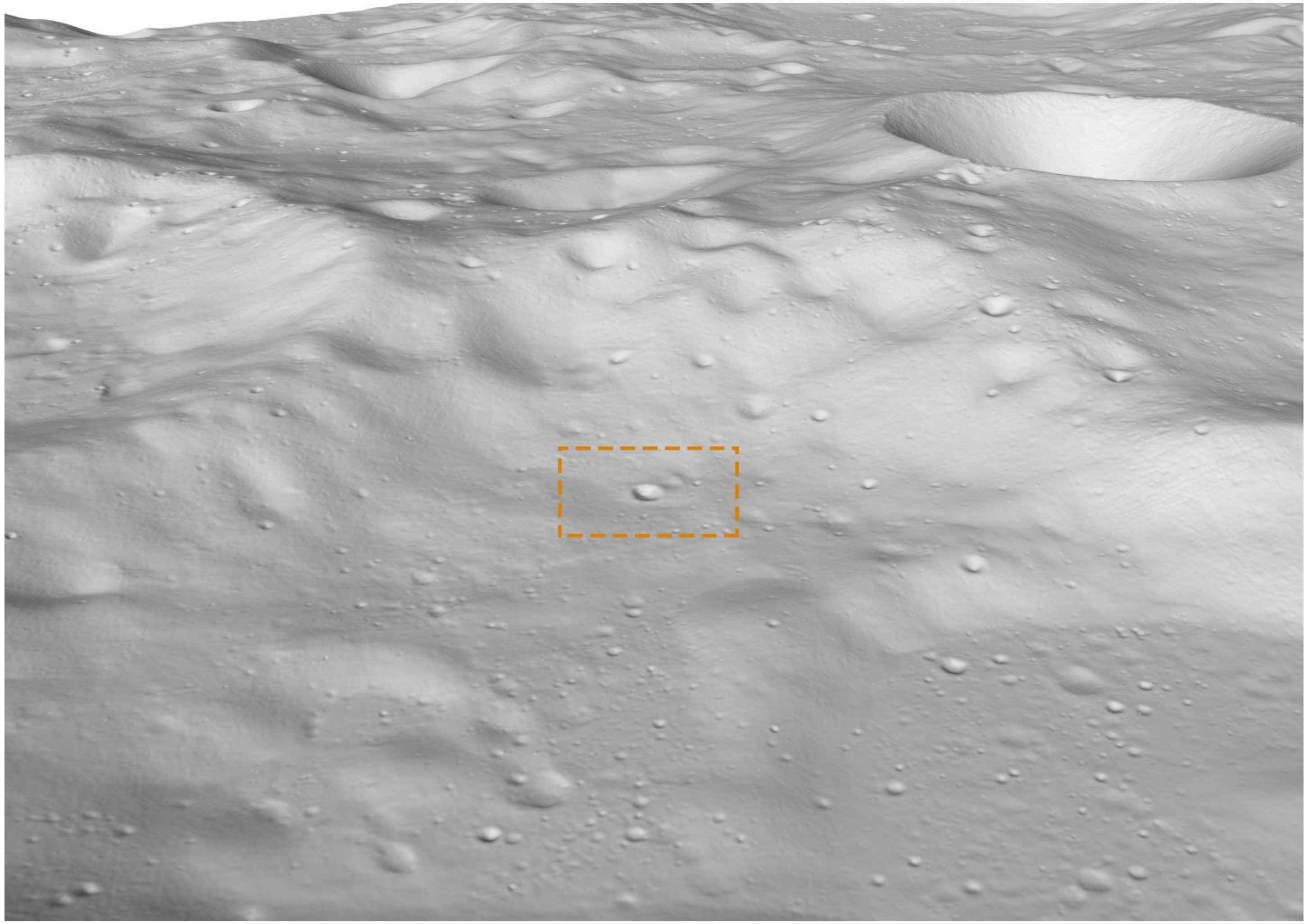
Sun exposure

- Selected site has >50% of the lunar day exposed to sunlight for power generation through solar panels





Site Approach

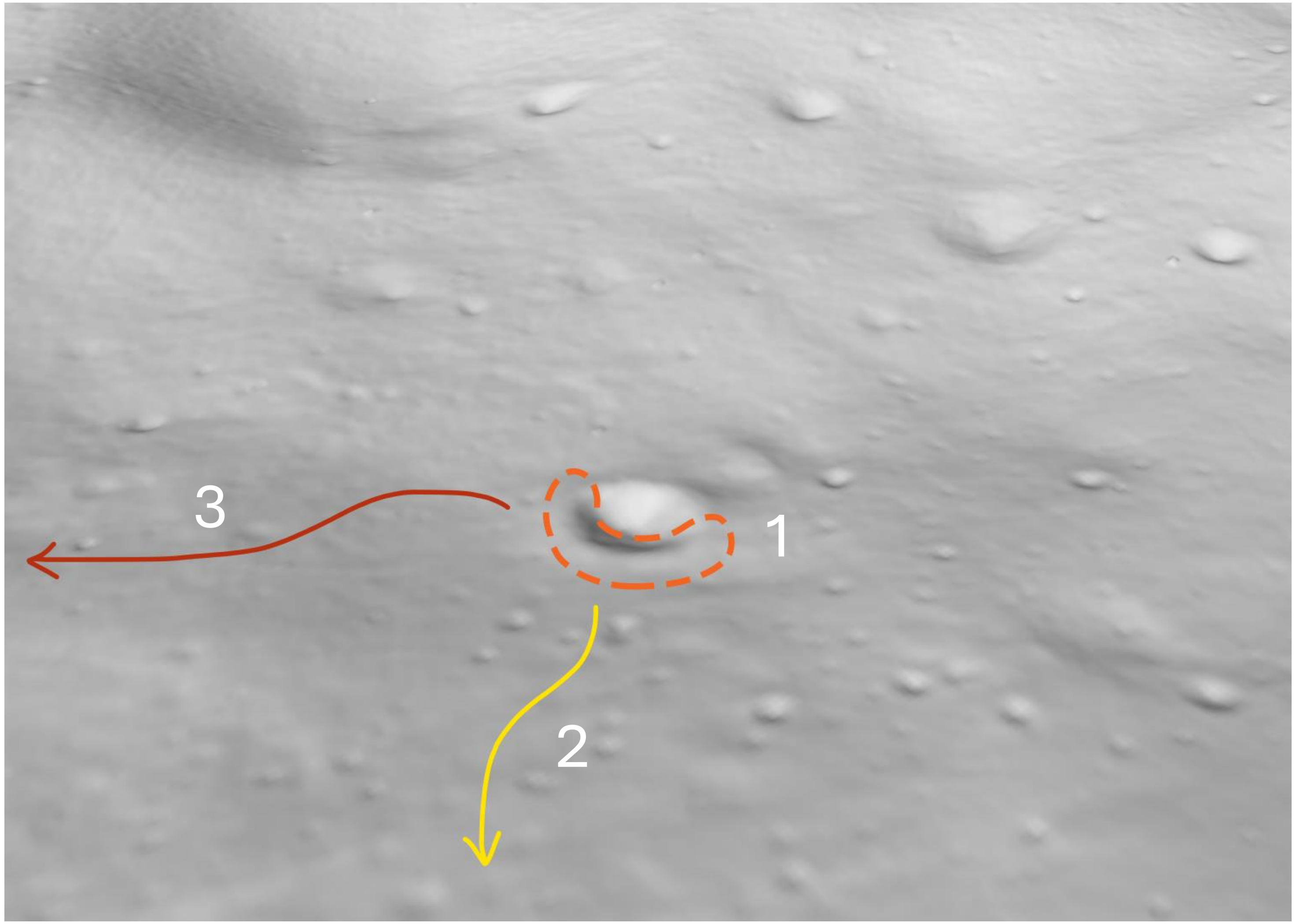


Site Approach

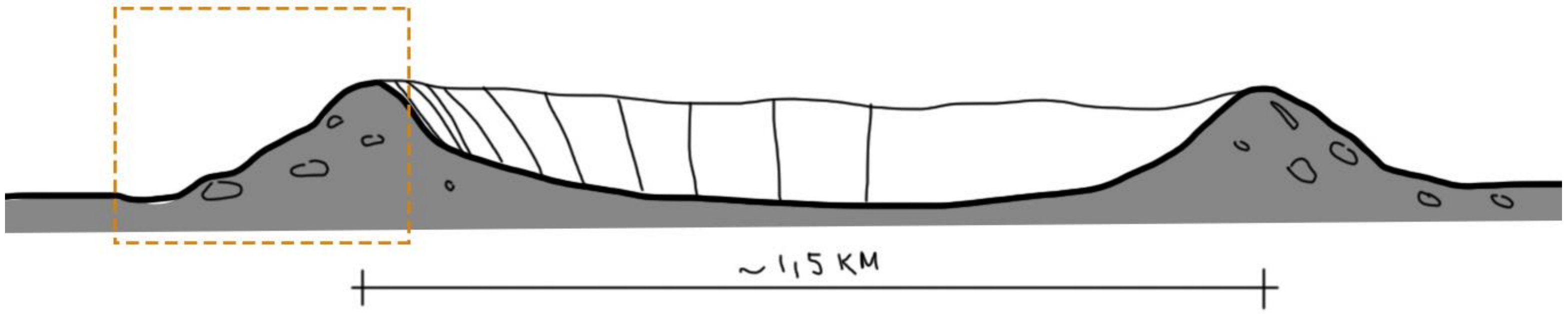
1 – proposed site for the Moon station on the slope of a smaller crater

2 – route towards the closest water/ice source

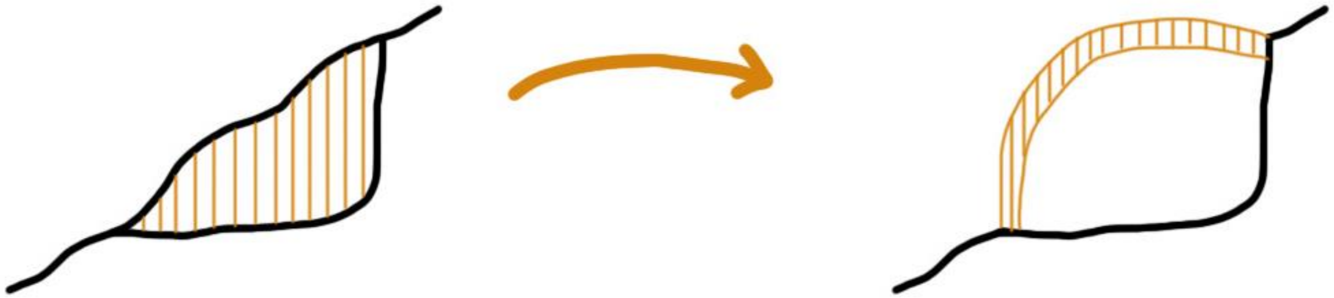
3 – route towards the launch pad



Site Approach



The slope of the crater offers a good **connection with the exterior**



The excavated material can be used to construct the modules

Program

- **Sleeping quarters (6 x 10m2)**
  Plain yet comfortable spaces (n. 6 beds) with n.3 toilet. 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.

- **Common Hall (75m2)**
  Multifunctional space for food preparation and consumption, and a hub for social interaction

- **Transition spaces (5m2)**
  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 (20m2)**
  Space to host complex control equipment for maintaining the controlled internal environment of the Habitat.

- **Gym (30m2)**
  Space to accommodate qym equipment for daily exercise

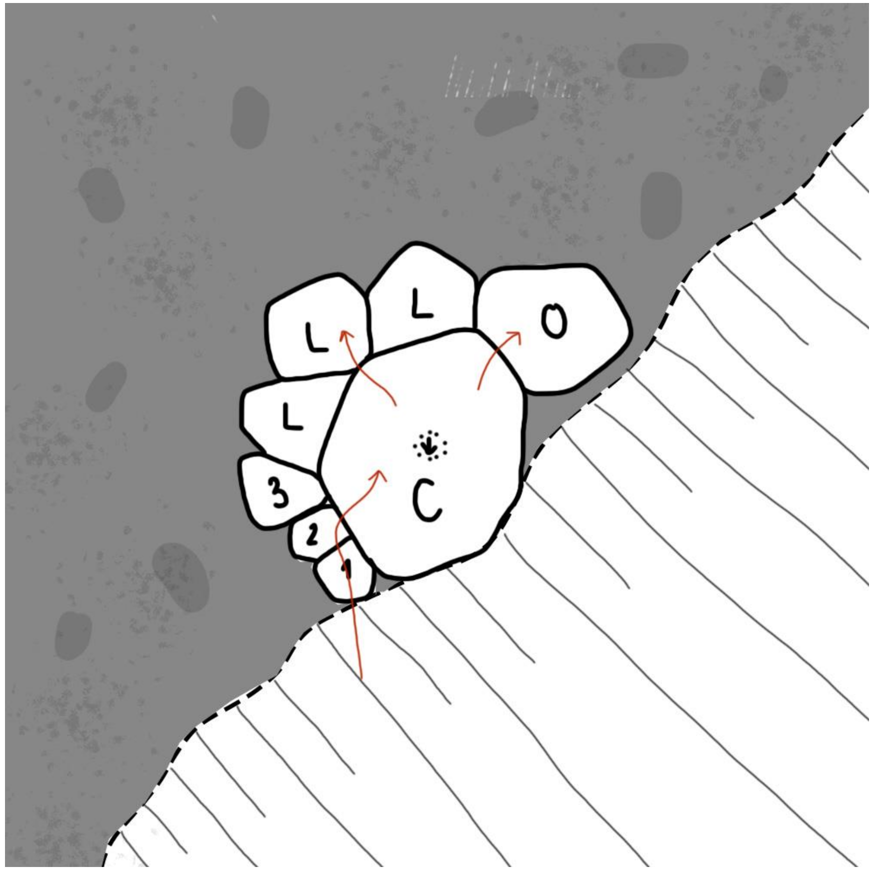
- **Medical Care (20m2)**
  area dedicated to medical care, easily accessible in case of an emergency

- **Laboratories (60m2)**
  The research areas should be close to the entrance and exit areas to facilitate the transport of samples into the station

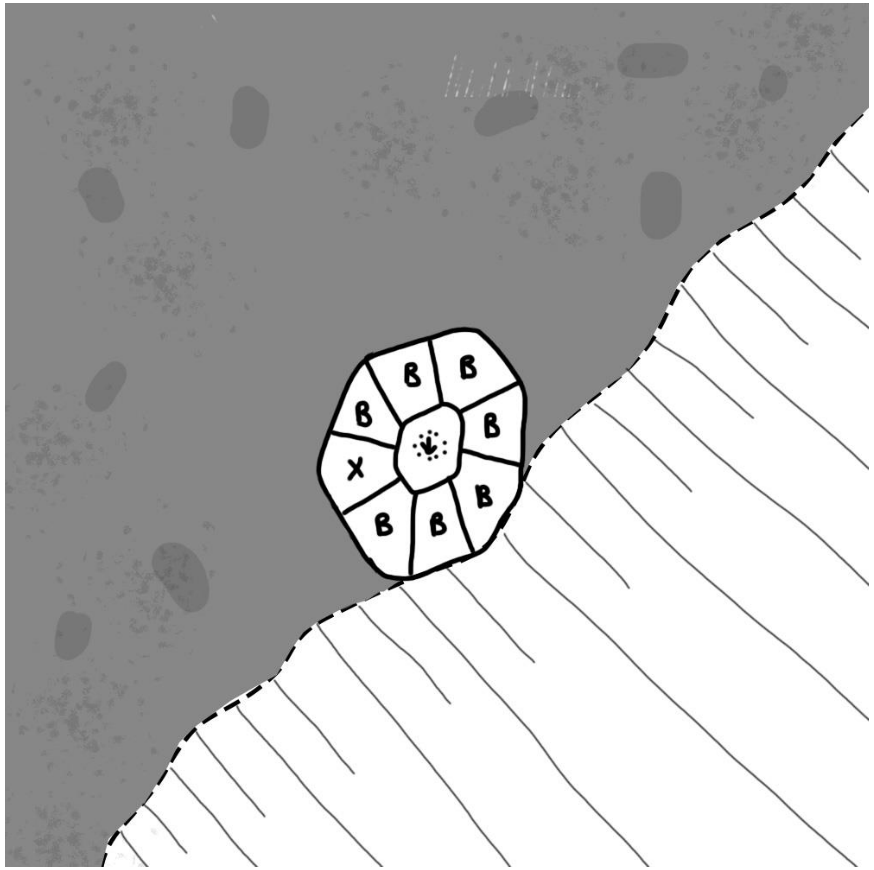
- **Rover Hub (20m2)**
  The connection hub between the station and rovers for mobility. In this space one can enter in rovers safely and find all the necessary elements for the rovers' maintenance

- **Airlocks (5m2)**
  Filter areas which enable the passage from pressurised(Habitat) to non pressurised environment (Moon) in total safety without catastrophic pressure losses

Plan layout

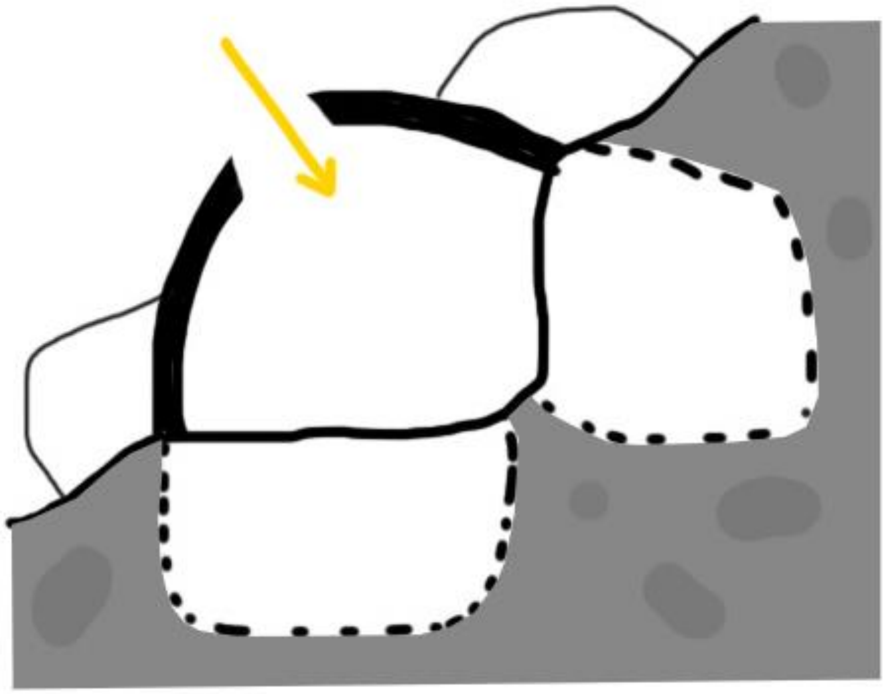


Plan level 0 (C – common room, O – observatory, L – lab, 1 – airlock, 2 – transition space, 3 – control room)

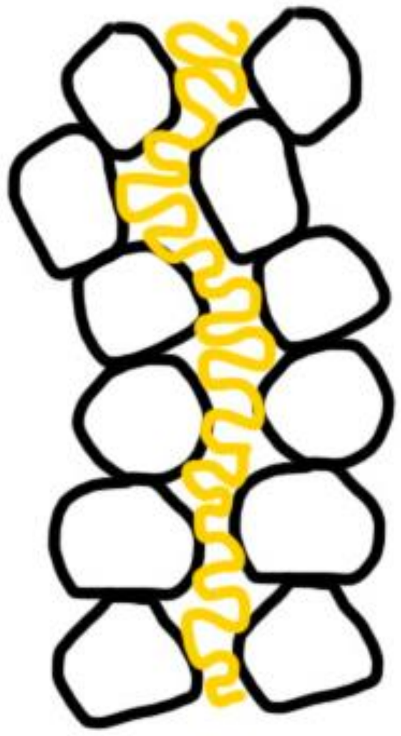


Plan level -1 (B – bedroom, X – toilets/appliances)

Design with climate

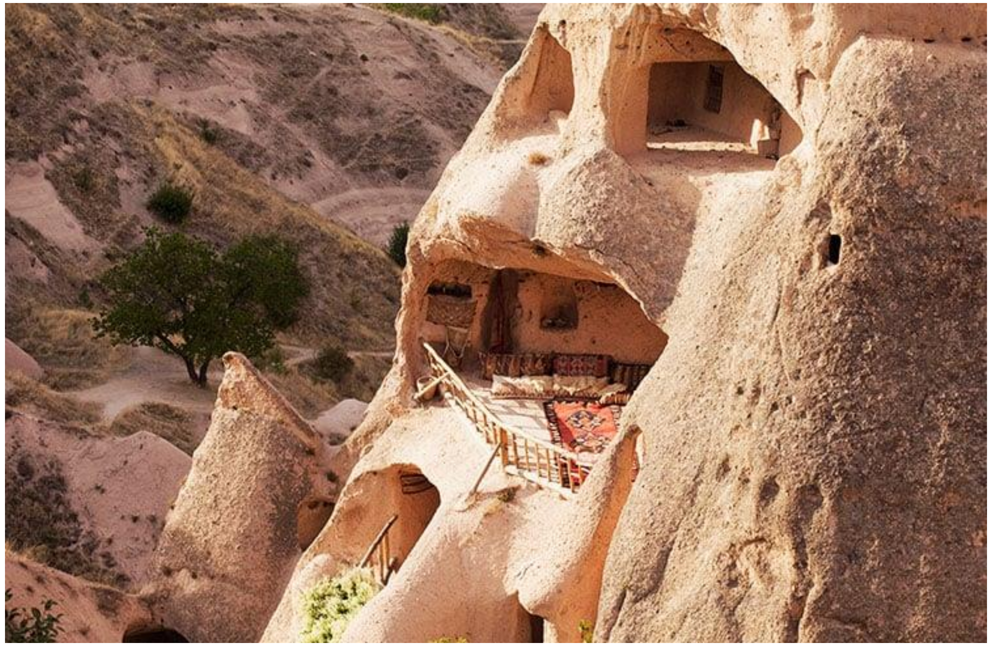


Providing **light** to the common room and moving functions that don't need light **underground**



Double 3d-printed wall with an **insulation layer** in the middle

Inspiration



Cave houses in Capadoccia, Turkey

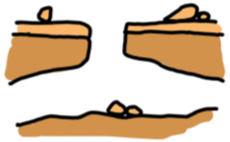
Nüwa City project by ABIBOO Studio

Case study: Rhizome 1

Development of an Autarkic Design-to-Robotic-Production and -Operation System for Building Off-Earth i.e., Mars Habitats

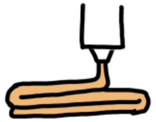
Project Brief

1. **Off-Earth Habitat Construction**: The project focuses on developing methods for constructing habitats on celestial bodies such as Mars using locally available materials, particularly regolith.



2. **Subsurface Living**: Instead of surface structures, the project explores the feasibility and benefits of building habitats underground, specifically in empty lava tubes, to provide natural protection from radiation and stable thermal conditions.

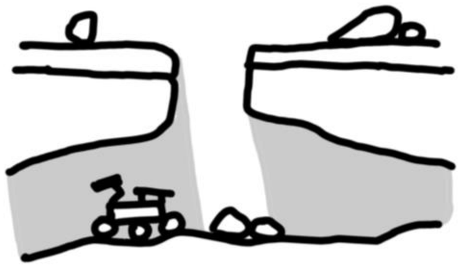
3. **Autonomous Construction**: A key aspect involves the use of autonomous mobile robots for various tasks including scanning, mining resources, and constructing the habitat. This reduces the need for human intervention and facilitates efficient construction.



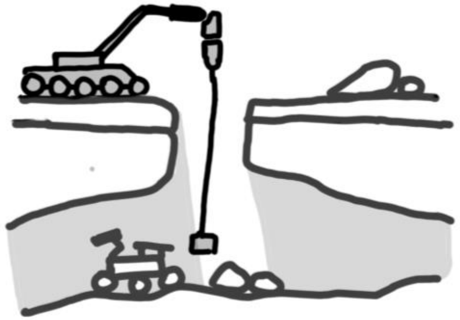
4. **Innovative Construction Techniques**: The project employs advanced techniques such as 3D printing with regolith mixed with cement to create structurally optimized, porous habitats that offer enhanced thermal insulation properties.

Site Access

The site of the design is a lava tube which posed challenges in terms of accessibility and energy sources to power the rovers



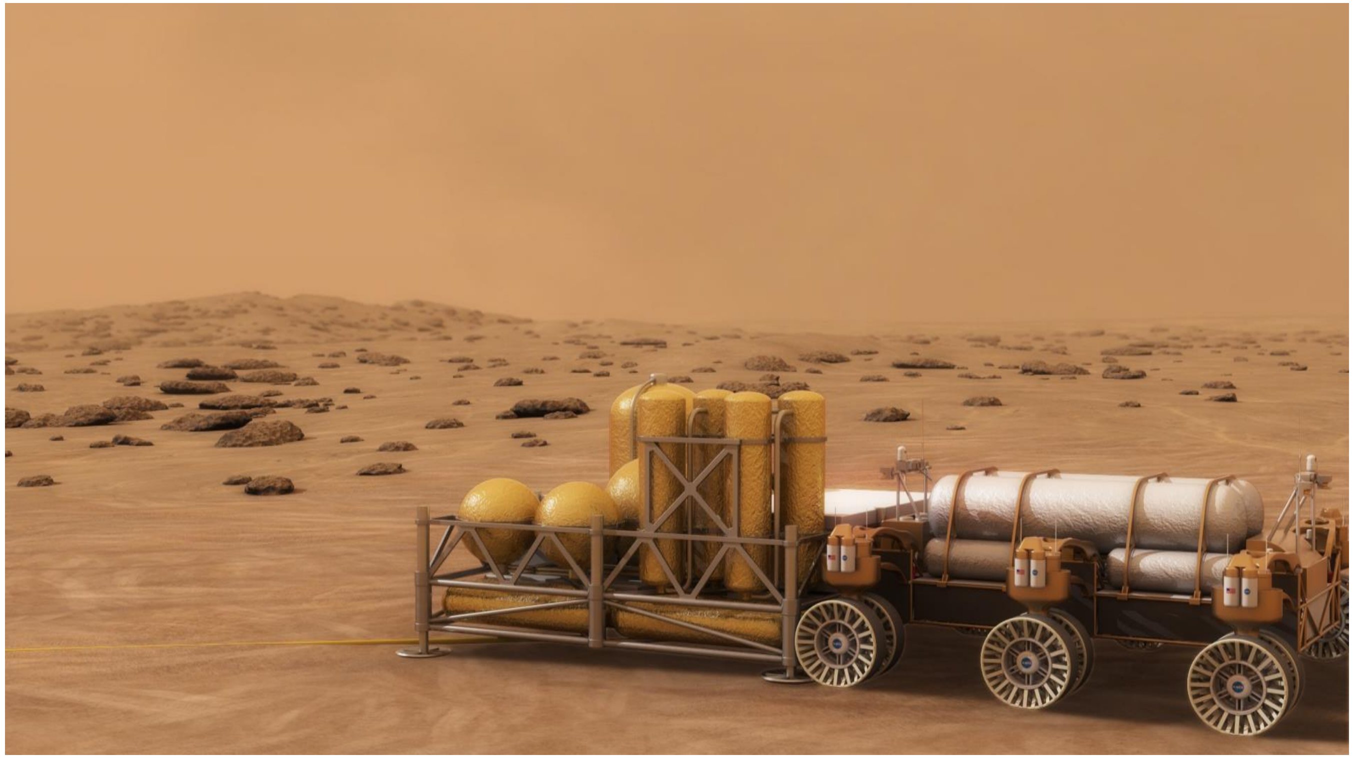
As rovers inside the lava tube would not be exposed to sunlight which would traditionally be used as a power source, an alternative must be utilized



Robotic cranes at the top of the lava tube will be used to both transport materials to the bottom of the lava tube as well as charge the construction rovers

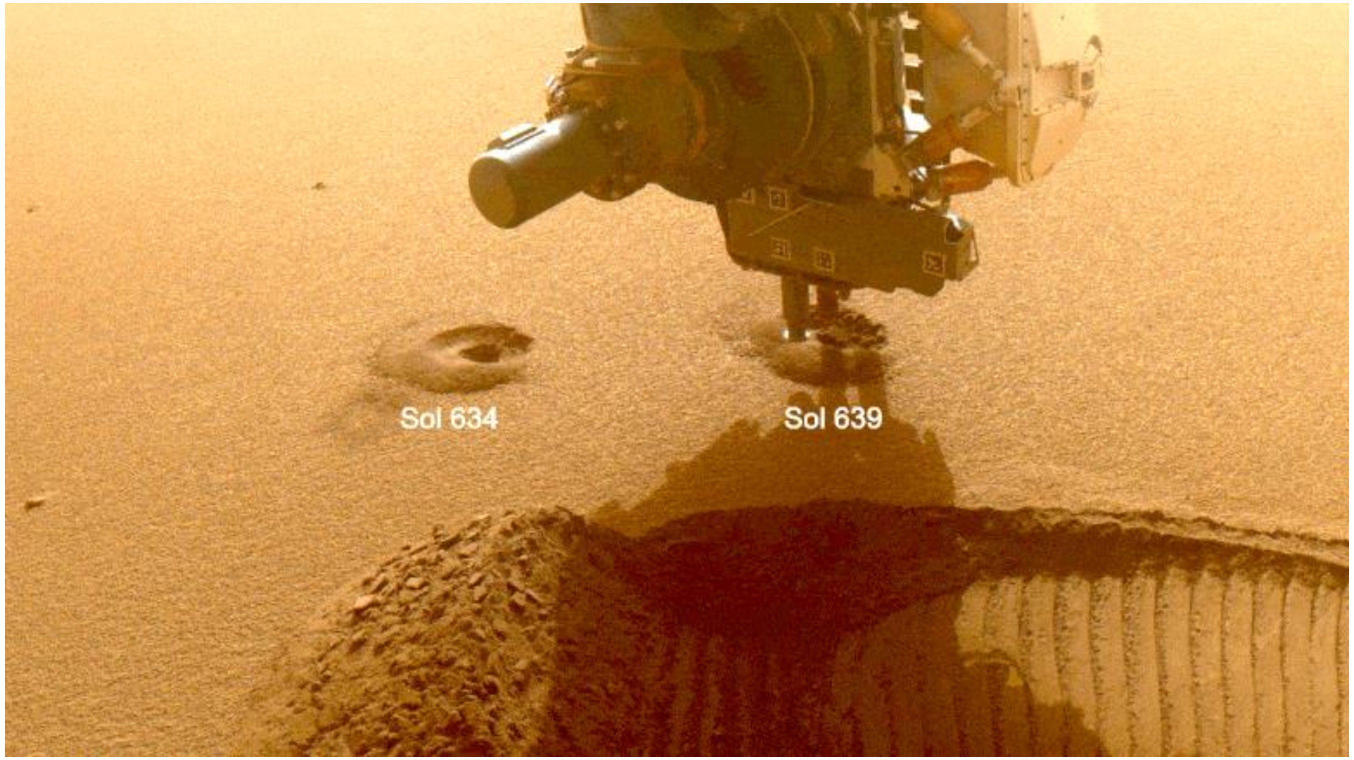
Construction methodology

The design incorporated In-Situ Resource Utilization (ISRU) for its construction, harnessing local natural resources at mission destinations rather than relying on supplies transported from Earth.



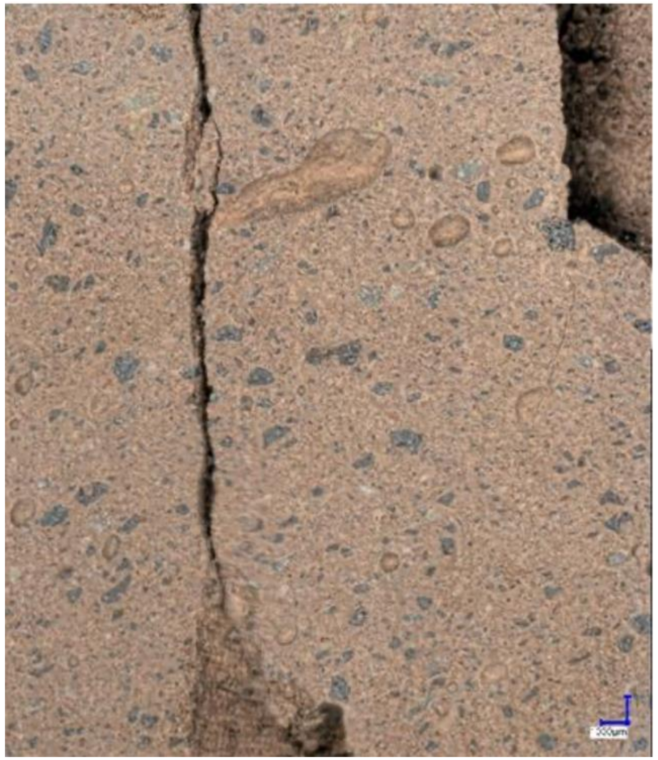
Martian regolith

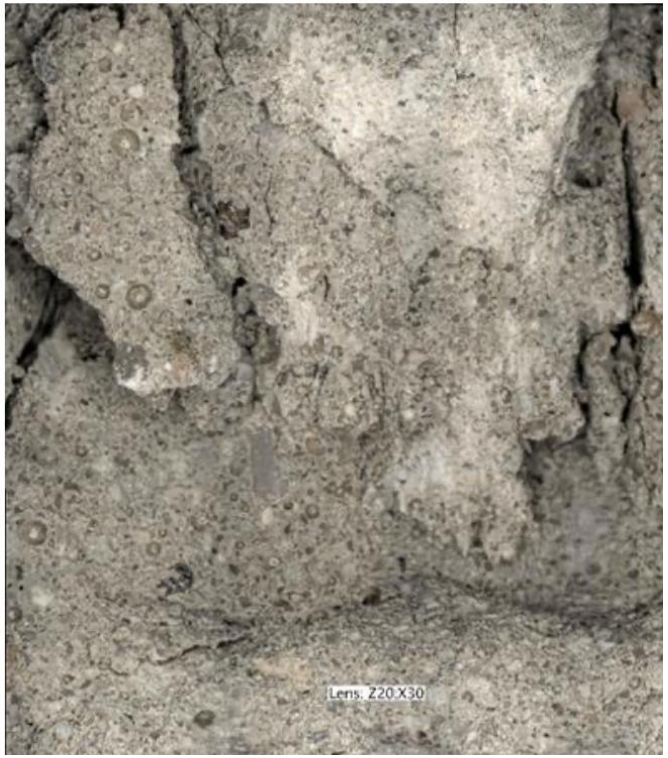
- Martian regolith is a layer of unconsolidated, loose, heterogeneous deposits covering solid rock on the surface of Mars.
- Martian soil is toxic, due to relatively high concentrations of perchlorate compounds containing chlorine.
- Martian soil contains a high concentration of metals and is also characterized by the presence of sulfates and potentially polysulfates



Material testing with regolith-based concrete

- The goal of the testing was to determine the properties of concrete made from artificial Martian regolith.
- The method involved creating cubes with varying proportions of artificial regolith and sand, ranging from 0% to 100% each, and testing them for compression properties.
- Additionally, slices of concrete made entirely from regolith simulant were prepared and tested for their thermal properties.
- The relationship between density/porosity and thermal conductivity for concrete made with 100% regolith simulant was calculated.



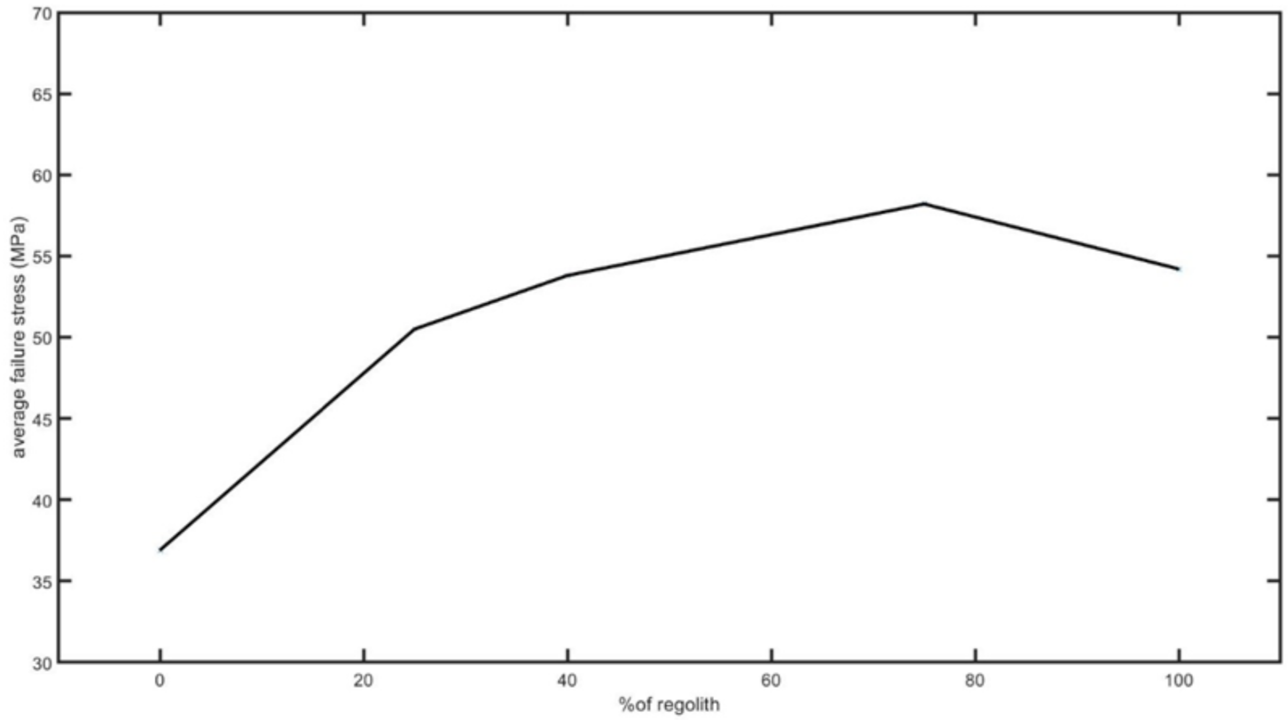


Material testing conclusions

- Specimens with a high concentration of regolith exhibit greater strength and demonstrate less brittle failure compared to those with lower regolith content.

- The strength of these specimens is similar to that of standard terrestrial concrete.

- Thermal properties of regolith-based concrete significantly differ from traditional concrete and offer improved insulation characteristics.



Assembly logic

- The design had to be broken down into modules lightweight enough to be lifted by assembly robots
- The design is using interlocking modules, that all follow a Voronoi-based logic
- Openings in specific faces to enable assembly robots to easily grip and position the modules.