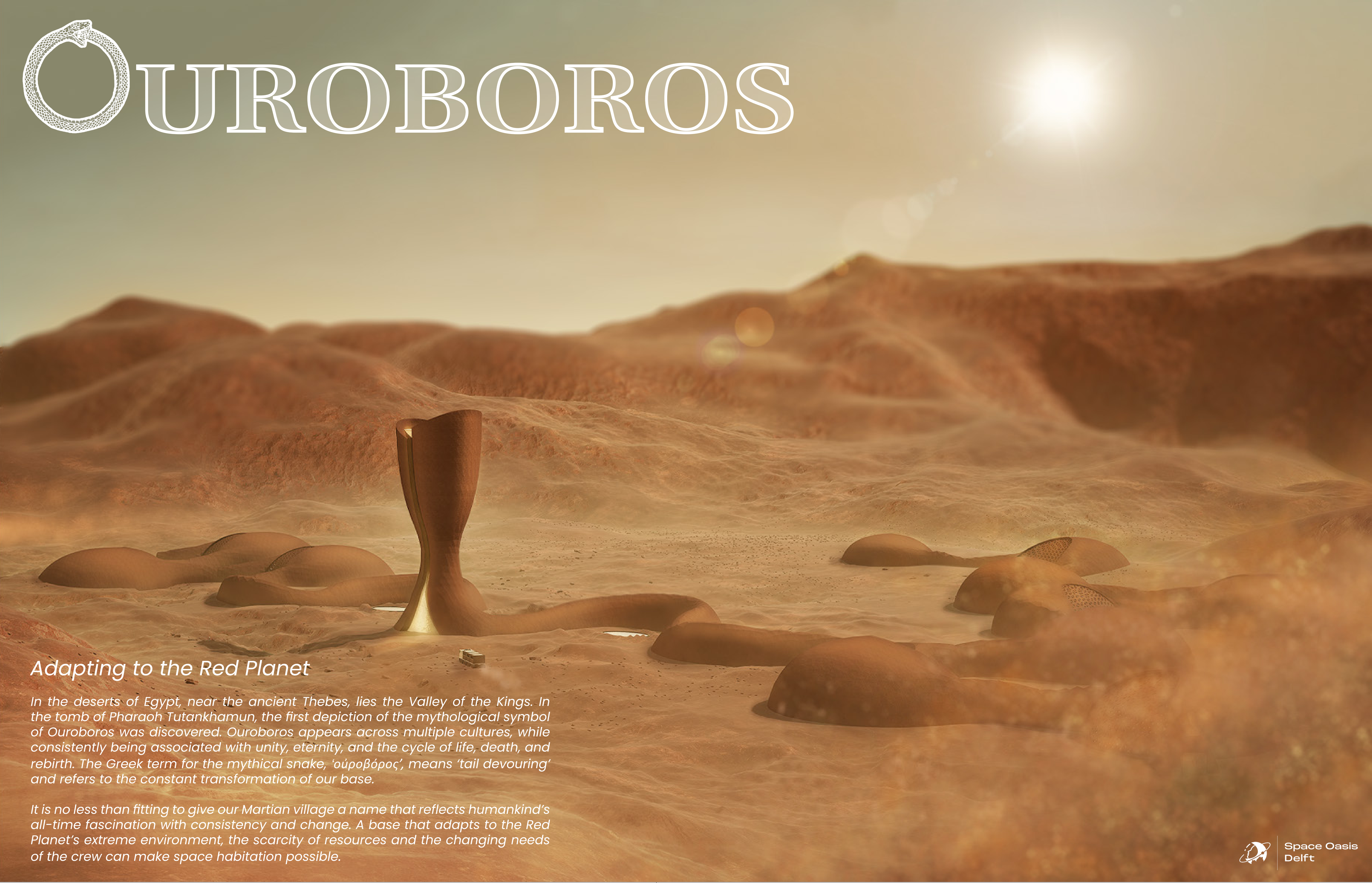

OUROBOROS

Adapting to the Red Planet

In the deserts of Egypt, near the ancient Thebes, lies the Valley of the Kings. In the tomb of Pharaoh Tutankhamun, the first depiction of the mythological symbol of Ouroboros was discovered. Ouroboros appears across multiple cultures, while consistently being associated with unity, eternity, and the cycle of life, death, and rebirth. The Greek term for the mythical snake, 'οὐροβόρος', means 'tail devouring' and refers to the constant transformation of our base.

It is no less than fitting to give our Martian village a name that reflects humankind's all-time fascination with consistency and change. A base that adapts to the Red Planet's extreme environment, the scarcity of resources and the changing needs of the crew can make space habitation possible.

Space Oasis Delft

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GÉNÉRATION ESPACE MER
ACADÉMIE DES BEAUX-ARTS

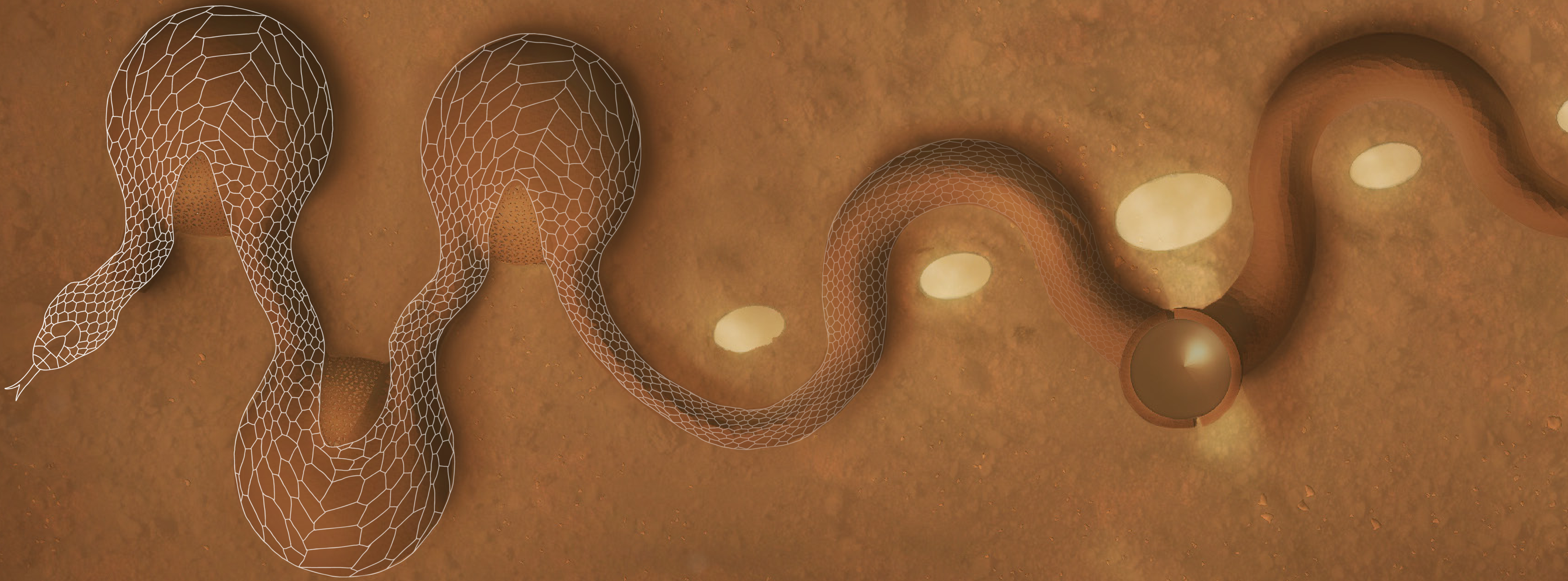
BIOMIMICRY

The adaptability of the snake

The mythological symbol of Ouroboros is shaped by a creature that is recognised as a snake. Snakes are highly adaptable creatures, slithering through challenging terrains and shedding their skin in order to adjust to their own needs. By mimicing these strengths, the base transforms the Red Planet from an inhabitable environment into a place where the crew can thrive.

Adaptability to environment

Just as snakes can slither through difficult terrains, gliding over uneven rocks and through narrow crevices, this Martian base makes use of adaptable solutions. For the crew to thrive and survive, the design of the base needs to respond to the hostile and unpredictable conditions.



Adaptability to human needs

Just as a snake needs to shed its skin to allow it to grow, our design adapts to the growing needs of the crew. The base adheres to the necessity of expanding the base and facilitates personalisation of the individual's surroundings to counter the alienation from Earth.

Adaptability to limitations

A snake can eat its shedded skin to counter unnecessary loss of nutrients. A base on Mars, being an average of 225 million km away from Earth, also requires that strategy of efficiency. To reach this, the base uses in situ resources in a closed-loop system.

MISSION

Research missions on a five year cycle

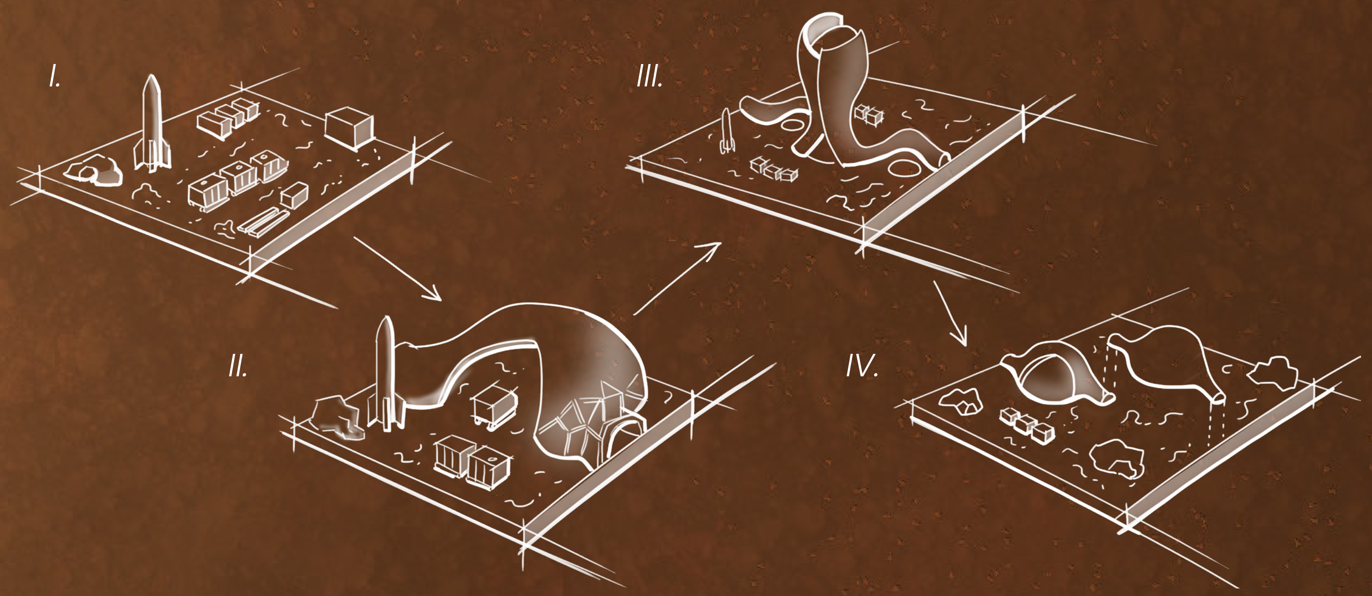
Mars is a topic of fascination for all. For decades, scientists have been interested in the possibilities of past, present and future life on Mars. Robots are researching soil, satellites are scanning for water and soon, we need human researchers to continue the investigation.

The journey from Earth to Mars takes six to nine months, with a minimum of two years before the return can commence. To create a continuous cycle of research and knowledge transfer, the crew would perform their research in durations of twenty-six months. However, the base facilitating this mission requires more than protection from radiation and dust storms. Humans can not only survive, humans need to be able to live.

Ouroboros is located in the larged valley of Mars: 'Valles Marineris'. The location contains more water-equivalent hydrogen, minimal temperature fluctuation and less dust storms than other locations on Mars.

Building phases

With the site for Ouroboros chosen, the construction of the Martian base unfolds in carefully planned phases. First, rockets and autonomous robots arrive to gather resources and prepare the site (phase *I*). In phase *II*, robots construct the habitat's frame and coat it with a protective pykrete layer. To make the habitat livable, phase *III* develops the centre with essential systems like life support and airlocks. With the centre ready, the first crew arrives and production scales up, allowing the Ouroboros base to expand with new habitats (phase *IV*).



Requirements - per day for 150 people

	Capacity	Food	Air	Water	Waste	Power	Structure	Transport	Medical health
Human Needs	Total Crew: 150 - Scientists - Technical crew - Social/Medical 23x 97x 30x	Required Food: - 375000 kcal (2500 kcal per person) 375000 kcal 150x	Air Composition: CO_2 H_2O O_2 N_2 O_2: ~ 153 kg CO_2: ~ 150 kg 150x	Required Water: 500 L Drinking 20600 L Non-drinking 45487 L Farming	Human waste: 217,5 kg Inedible plant waste: 2132 L Water: 322 L Air-quality 20600 L Non-drinking 43533 L Human liquid	Required power: - Food production: 60 MW - Transport: 2858 kW - Pressurizing: 280 kW - Air-quality: 23,9 kW - Water: 3,7 kW Total of: 65 MW	Inside pressure: - 0.57 bar Shielding: Max experience of 200 mSv during the whole mission	Required transport: for research for resources	Required medical care and health: for mental health for physical health
The Design	Total Habitats: 12 - Habitat H120-15 - Habitat H60-15 - Habitat H120-10 Total Houses: 30 Total Bedrooms: 150 4x 4x 4x	Hydroponics Farm: 19549 m^2 2560 m^3 60 MW	Algea-biorector: 80 m^3 216 kg CO_2 168 kg O_2 CO_2 and Humidity Capture System: 48 m^3 250 kg CO_2 600 L H_2O CO_2 Treatment System: 15 m^3 O_2 Capture system: 18 m^3 624 kg O_2	Circular water system: - FIltering machines - AnMBR bioreactors - CNT filtering 66587 L 66587 L If needed: extacting	Human waste: Composting Water treatment Recycling Incinerator Inedible plant waste and water: back in circular water system	Power: 105 MW 1x Solar Power Tower 2x Nuclear reactor (210 MW)	Pressure: - Dome structure - Conrolled by airlock system / metal shell Shielding: - Pykrete	Electric driving vehicles: - Vehicle medium duty: 7 - Vehicle heavy duty: 3 Transport trailers: - Research cart: 2 - Storage cart: 6 - Water-rich soil cart: 6 - Fuel & LOX tank cart: 6 10x Vehicles 20x Trailers	Medical area: 360 m^2 Lab area: 75 m^2 ~ 6 beds Medical area consists of: patient rooms, diagnostic and treatment areas, waiting areas, staff facilities, support spaces and hallways

THE URBAN DESIGN

Adaptability to environment & human needs

The unknown Martian environment leaves no room for error. This calls for an adaptable urban design that is prepared for uncertainties, rather than solving unforseen circumstances. We prepare to be flexible in case of physical obstacles that may be in our way when building, but also to take the eventual growth of the settlement into account.

The Urban Grid

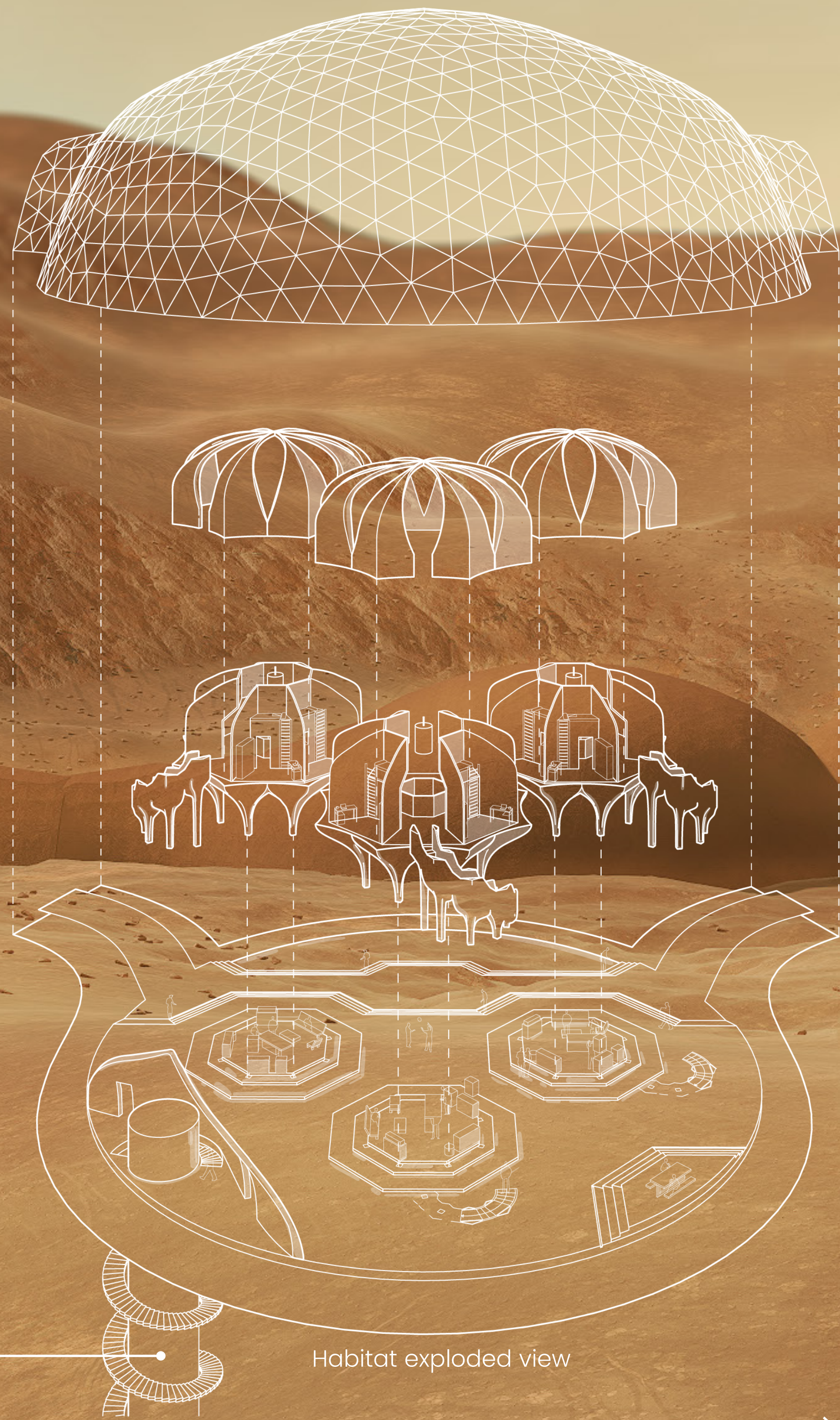
To attain a high level of flexibility, a hexagonal grid and a fixed series of habitats are utilised. The three types of modules and one type of intersection provide the crew with endless options to configure the base once the terrain is analysed thoroughly.

The Habitats

To ensure variability within the base, the modules differentiate in housing capacity. The modules differentiate in housing ten and fifteen crew members, living in homes for five individuals. In our human-centred design, the crew members live as a close family caring for one another.

Emergency Safety Route

When an emergency arises, the crew will be able to safely escape through the exit stairs connecting to all other habitats and the centre, forming a ladder grid.



Habitat exploded view

Emergency safety route to the city centre

THE CITY CENTRE

Producing, Working and Recreating

Our main goal of researching the past, present and future life on Mars, is achieved in the heart of the base: the city centre. This is the core of the base, a strong foundation for the rest of the base to shift and grow around. Here, the research facilities and human survival support systems are found.

Human Survival

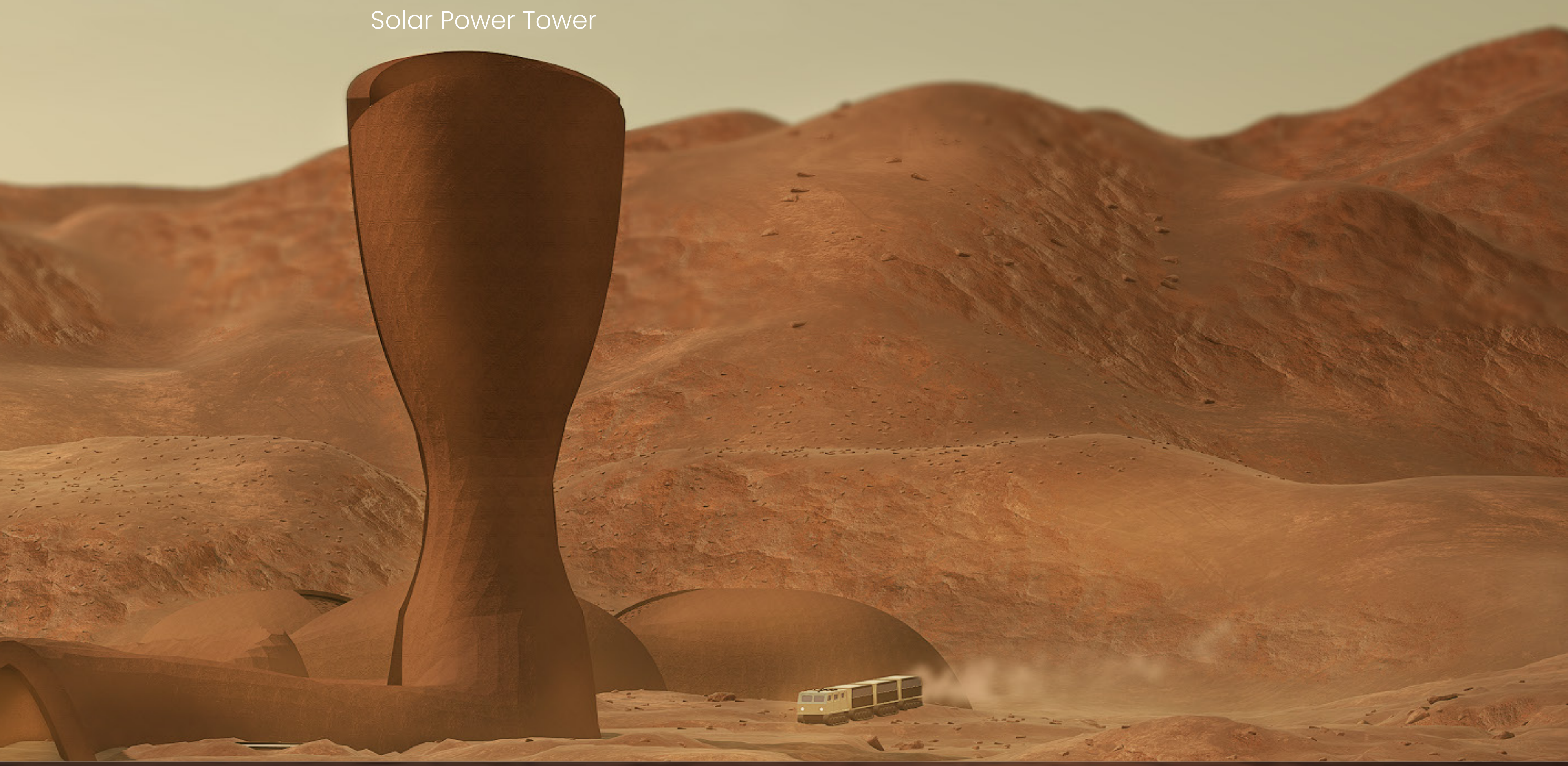
The city centre includes the basic needs, such as nutrition through hydroponic farming and systems that clean and filter the air and water.

Physical and Mental Health

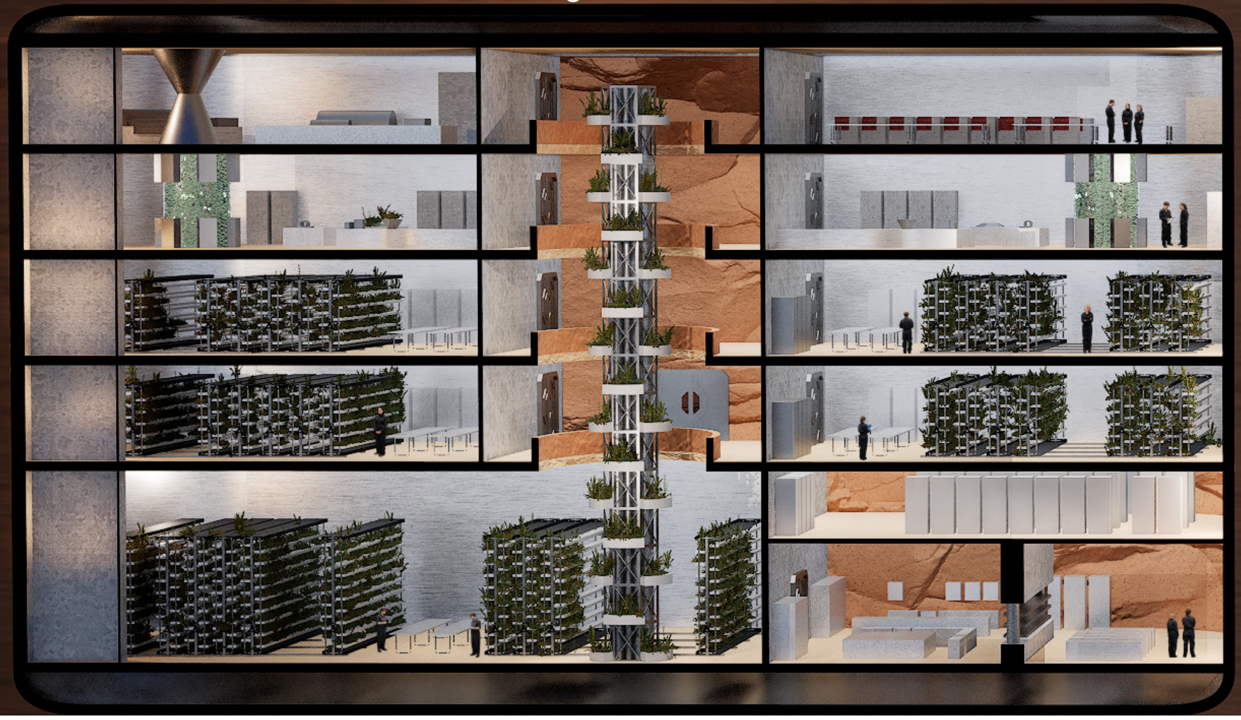
Additionally, the centre is designed to benefit both the physical health and mental health, through the presence of a medical bay, psychiatric office and the mandatory gym.

Production

The production of all structures and materials is also focussed in the centre. The Solar Power Tower is used to bundle the light energy and reach high levels of temperature to melt down metals for production.

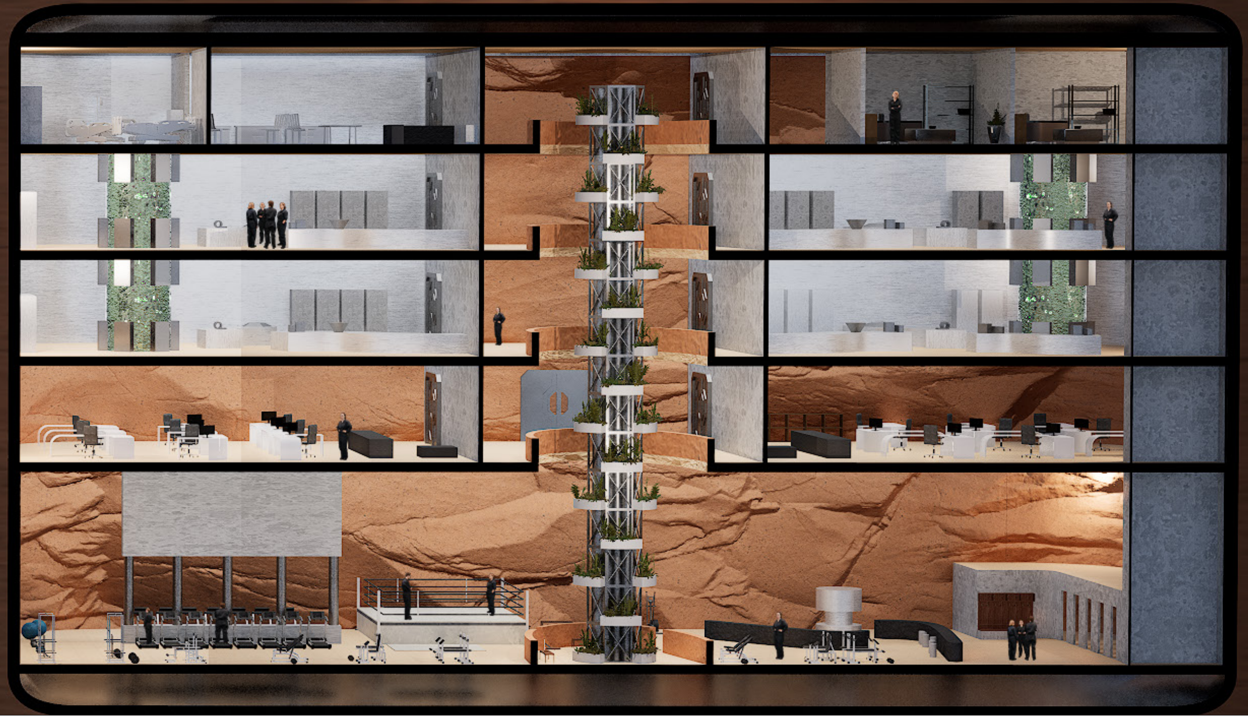


Farming and Research



Grand Hall

Exercise and Research



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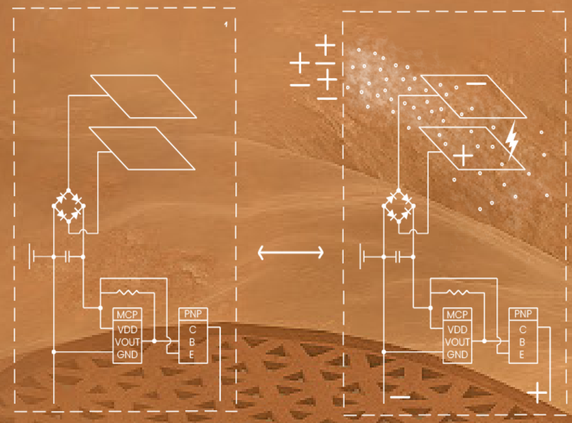
PANELS

Adaptability to environment

The Martian environment is dynamic, with frequent dust storms that blanket the landscape. The fine, sharp, and electrically charged particles can damage structures and cling to surfaces. This renders visibility through (ice) windows nearly absent. Inspired by the adaptive mechanisms observed in snakes, the outside structure is designed to dynamically respond to and endure these environmental challenges by biomimetically taking inspiration from Petunia flowers and plant cell osmosis.

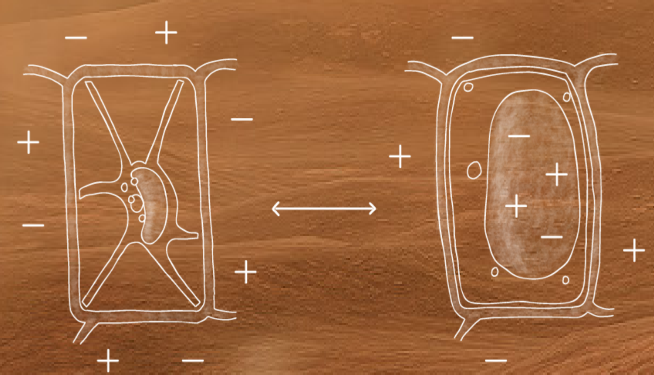
The design mimics biological principles from Petunia flowers, which sense the electrostatic charge of pollinators to trigger pollen release. Similarly, electrostatically charged Martian dust activates the biomimetic window-covering panels.

Activates - Pollen release

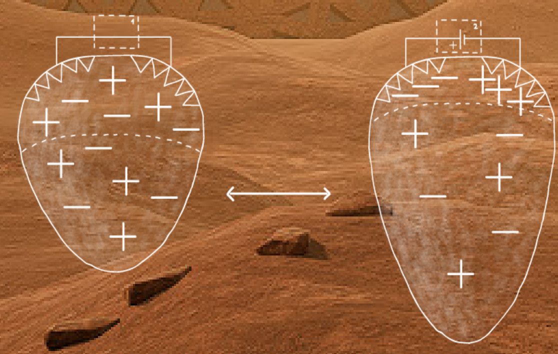


Activates - Mechanism

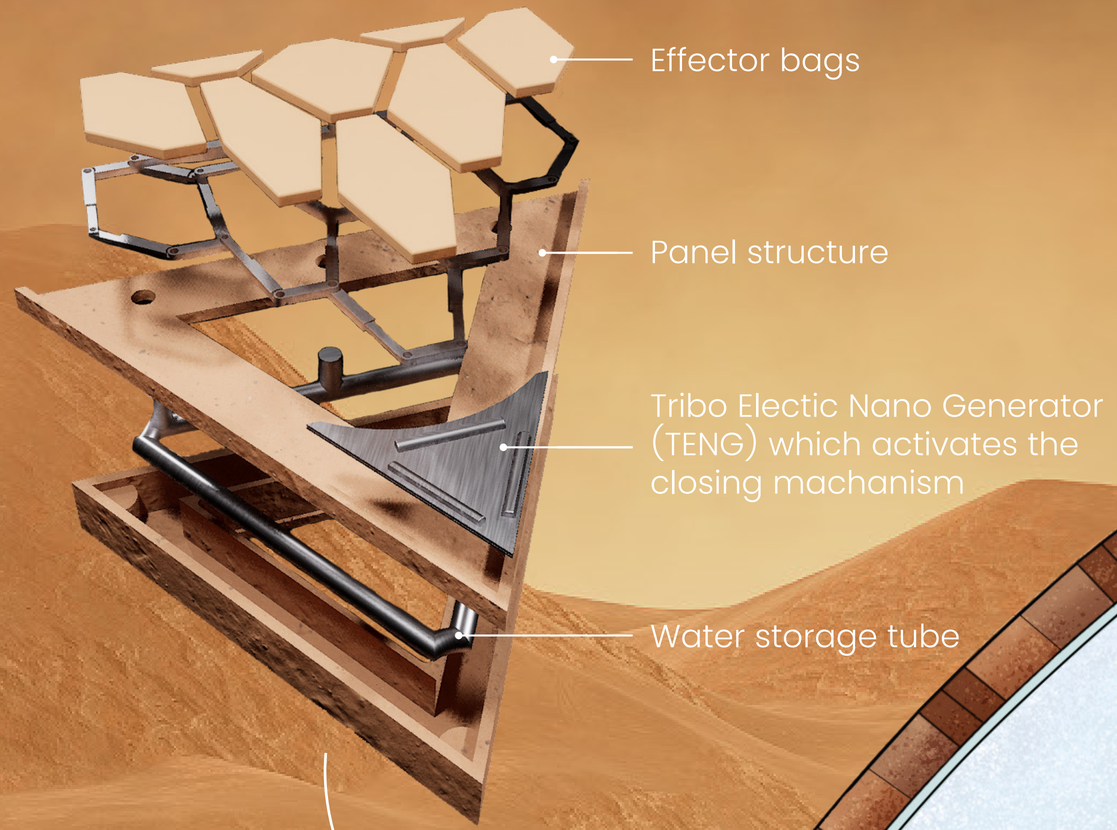
This activation initiates a closing mechanism modeled on plant cell osmosis: in plants, differential osmotic pressure induces water flow between cells, enabling movement. In the design, dissolved ions in the electroactive control unit (ECU) are immobilized by electrodes, causing water to flow across a semipermeable membrane into effector bags. These bags, reinforced by a honeycomb-structured skeleton, swell in a controlled manner to cover and

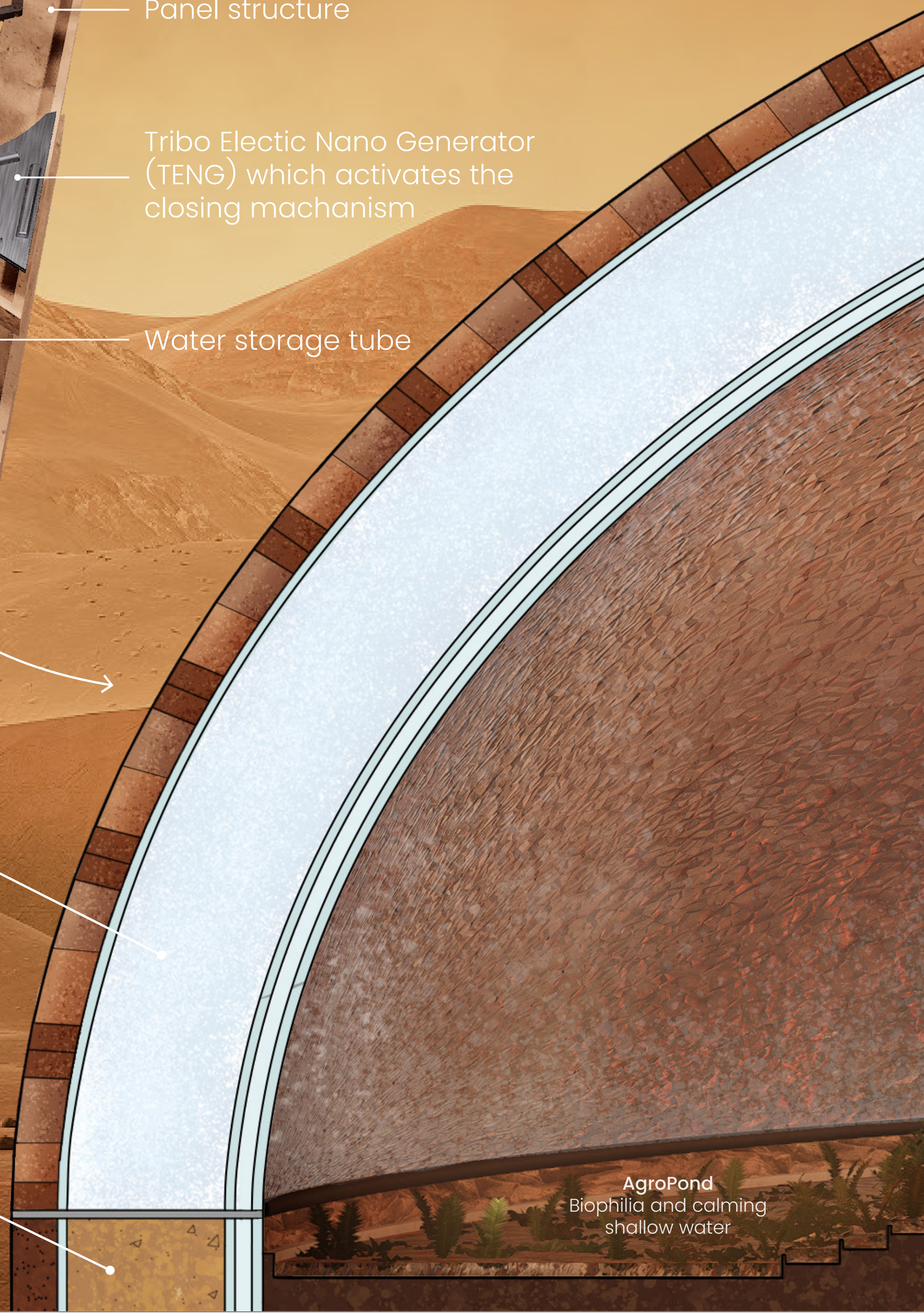


Mechanism - Osmosis



Mechanism - Effector bags

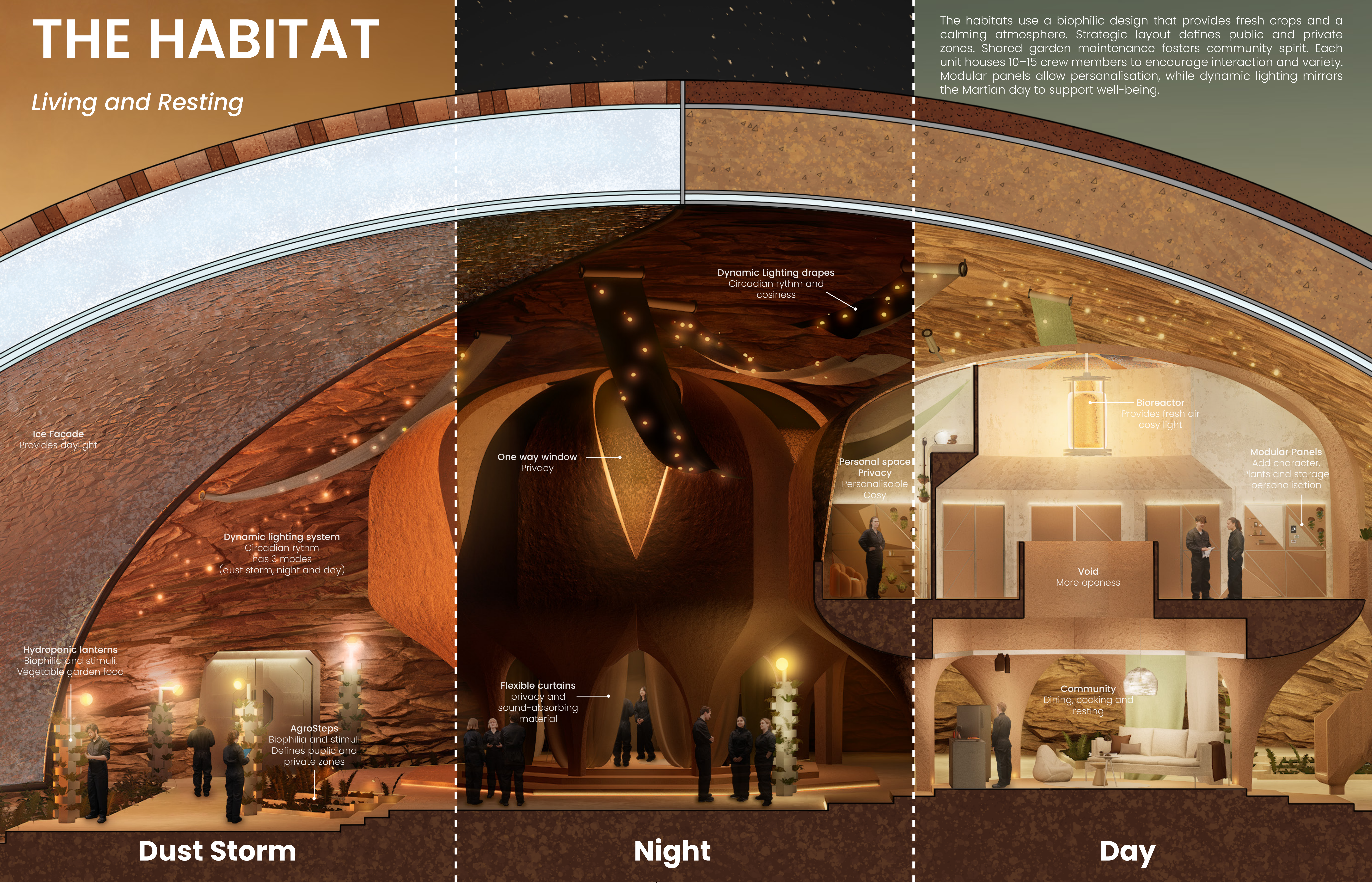




THE HABITAT

Living and Resting

The habitats use a biophilic design that provides fresh crops and a calming atmosphere. Strategic layout defines public and private zones. Shared garden maintenance fosters community spirit. Each unit houses 10–15 crew members to encourage interaction and variety. Modular panels allow personalisation, while dynamic lighting mirrors the Martian day to support well-being.



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THE PROPERTIES OF PYKRETE

Adaptability to limitations

On Mars, resources are limited. Pykrete is well-suited for addressing resource limitations on Mars due to its unique composite properties: a mixture of ice, retrieved from the Martian soil, and cellulose fibers, a waste product from the agricultural systems in the base. This makes for responsible usage of the limited resources.
Additionally, Pykrete offers high radiation shielding, adequate mechanical strength, self-healing capabilities, and a circular, modular lifecycle that allows it to be melted and refrozen to suit expanding needs.

Radiation

On Mars, radiation from cosmic rays and solar events reaches about 2 sieverts per year, the average dose on Earth is 2.4 mSv in comparison. Materials rich in hydrogen like water are ideal as radiation shielding due to their ability to slow particles and absorb energy, making pykrete, with 90% ice an affective barrier against radiation.

Self-healing

Cellulose fibers in Pykrete stop the propagation of cracks throughout the material. Above -40 °C, surface meltwater seeps into small cracks, refreezes, and strengthens the structure, providing Pykrete with self-healing properties.

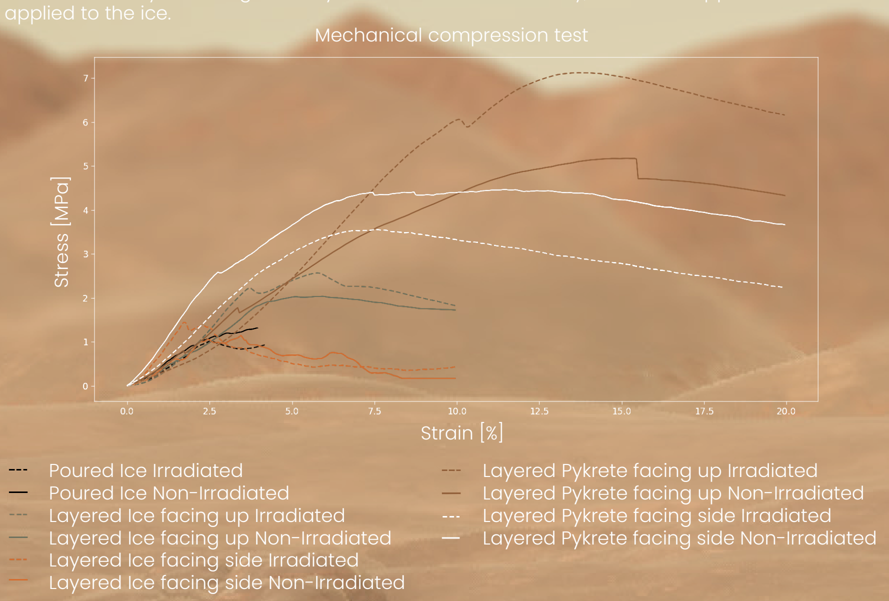
Adaptable and repairable

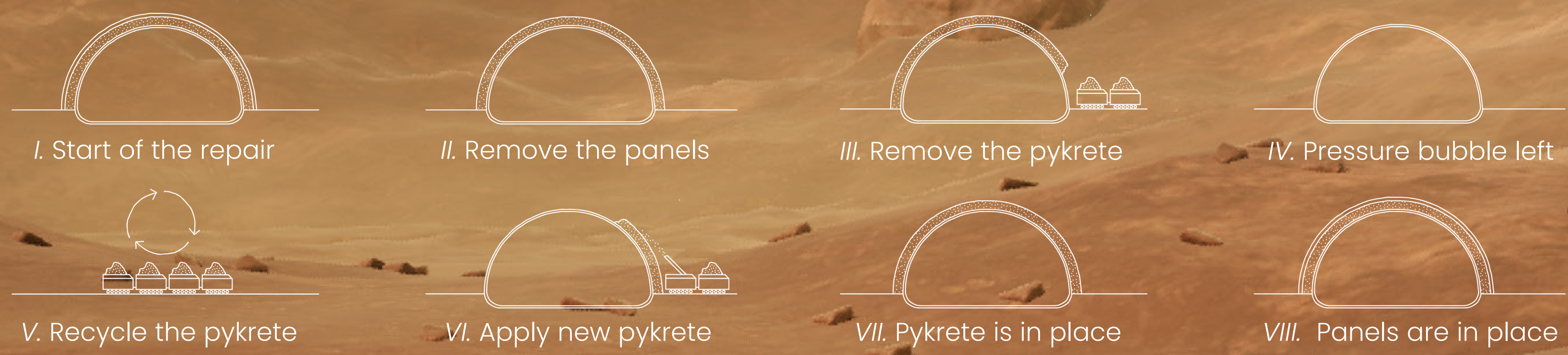
Pykrete's ice-cellulose mix enables in-situ production and easy repair, supporting a circular lifecycle. The material's adaptability allows scalable, resilient construction aligned with closed-loop systems on Mars.

Strength

The hydrogen bonds between water and cellulose fibers in pykrete provide concrete-like strength. Under Earth conditions at -15 °C, the material is strong in compression and weak in tension. Comparing this to ice, the material becomes less stiff, less brittle and is able to withstand a higher ultimate stress. Our research shows that a ten year dose of radiation does not significantly weaken pykrete, which enables long-term use on Mars and gives the crew sufficient time to replace the modular, repairable construction.

In this research, different methods of constructing ice and pykrete were tested. To prevent the cellulose from the poured pykrete to settle at the bottom, a layered version of pykrete was developed. This layered pykrete was tested in two orientations: with the layers facing upward and with the layers facing sideways. To maintain consistency, the same approach was also applied to the ice.





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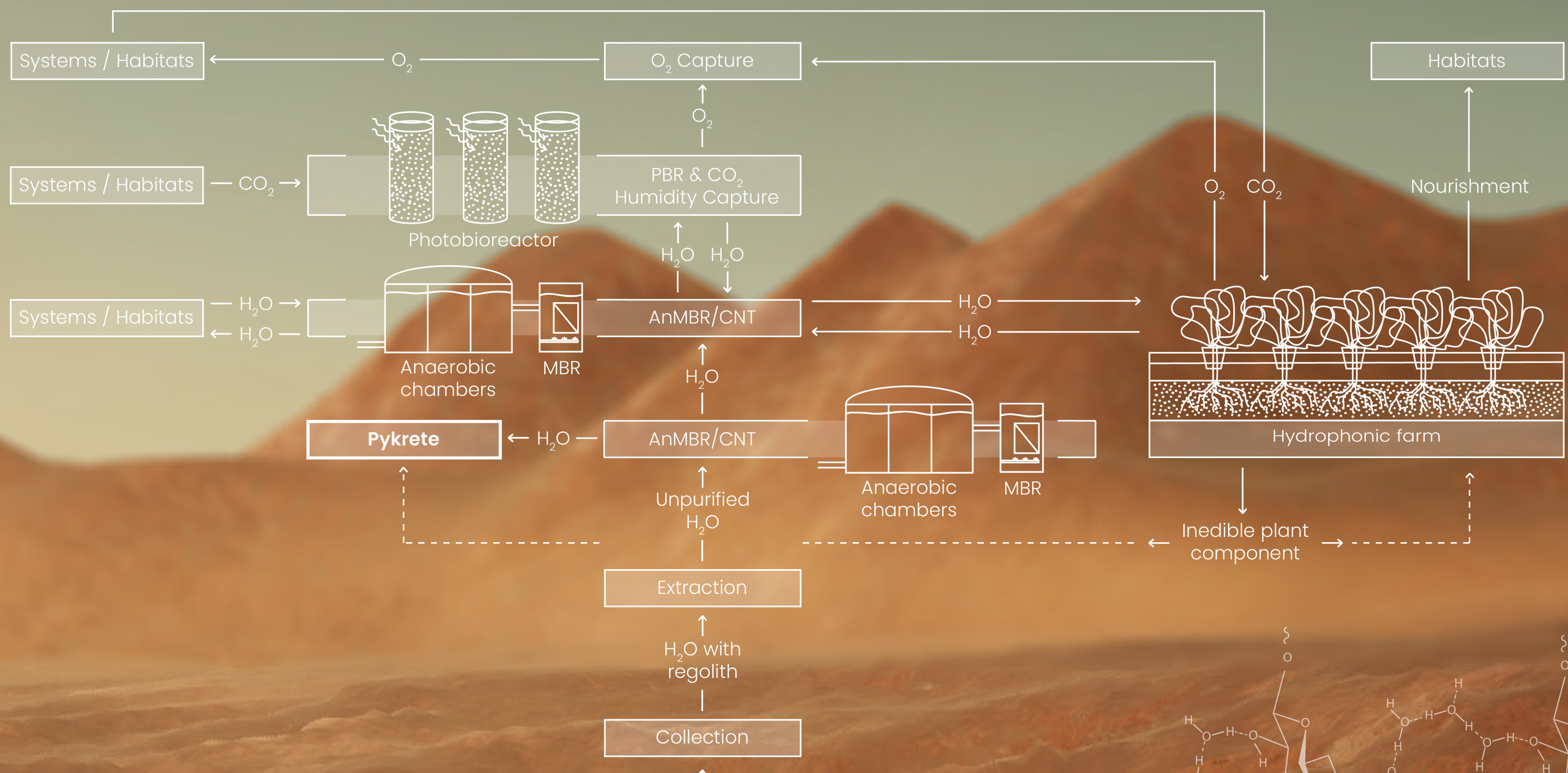
THE MAKING OF PYKRETE

Adaptability to limitations

Pykrete is produced by combining pure water with cellulose-rich waste from the agricultural system, forming a reinforced ice composite. Pykrete embodies the principle of adaptive resource utilisation, while minimizing waste and maximizing efficiency within closed-loop systems.

The water is harvested from Martian regolith, which is collected by robotic vehicles and processed through controlled sublimation. By heating the regolith mixture to the sublimation point of water, ice transitions directly to vapor, leaving behind contaminants such as perchlorates. By heating the regolith mixture to the sublimation point of water, ice transitions directly to vapor, leaving behind contaminants such as toxic perchlorates. This step simultaneously purifies the water and removes unwanted compounds.

In parallel, food production systems generate significant amounts of inedible biomass, such as woody stems. These byproducts, which are rich in cellulose, are not suitable for human consumption but are ideal for reinforcing ice. While part of this plant waste is composted to produce nutrient solutions for crops, a portion is allocated for Pykrete production. Water and shredded cellulose waste are mixed and sprayed layer by layer in the desired structural form. In the cold Martian atmosphere, each layer freezes naturally, forming a durable, radiation-shielding shell. Together, this forms a reinforced ice structure that shields the inhabitants of the base against radiation. According to our research, it is two to three times stronger than ice.



Molecular structure pykrete

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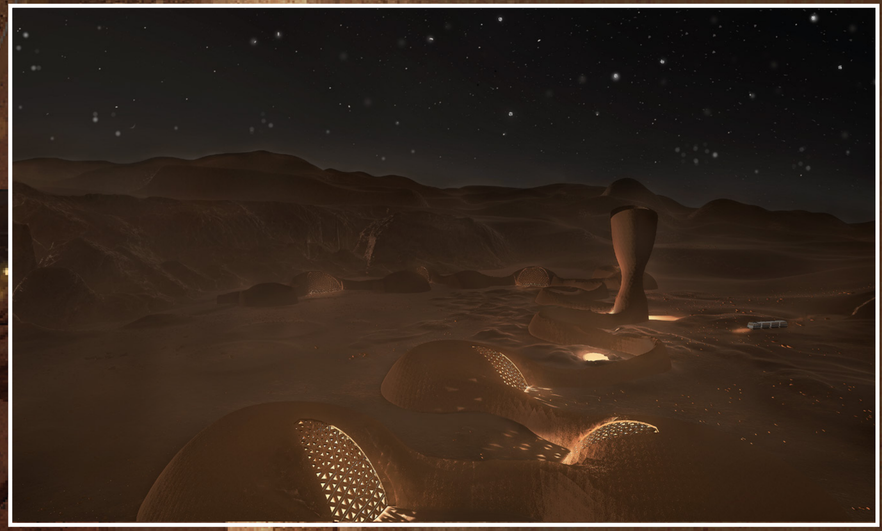
πάντα χωρεῖ καὶ οὐδὲν μένει

‘Everything changes and nothing stands still’
~ Plato, Cratylus, section 402a

The base at night



The hydroponic farms

The private quarters

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The primary source, encompassing all research and testing conducted, is accessible here:

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