SUBMARTIAN

(new vernacular on mars)

ANALYSIS

Cooperation

Innovation

Economy

Science

Future

JPL-Caltech/NASA

Harsh Environment

extreme temperatures (-143°C to 20°C), high radiation exposure, thin atmosphere, and frequent dust storms

landscape with canyons, volcanoes, and craters

Resources & Energy

metal richness, water ice reserves

solar and wind energy

Psychological & Health Considerations

low gravity (38% of Earth's), day-night cycle

isolation

ESA/DLR/FU Berlin; JPL-Caltech/University of Arizona/NASA

What?

a mix of fine dust and coarser particles with a deposits of iron oxide (red), silicates, sulfates, mg carbonate, and perchlorate

Why?

using in-situ resource to reduce the transporttion process from Earth

compatible with 3D printing process (made by robots)

How?

created from processes like wind erosion and volcanic activity

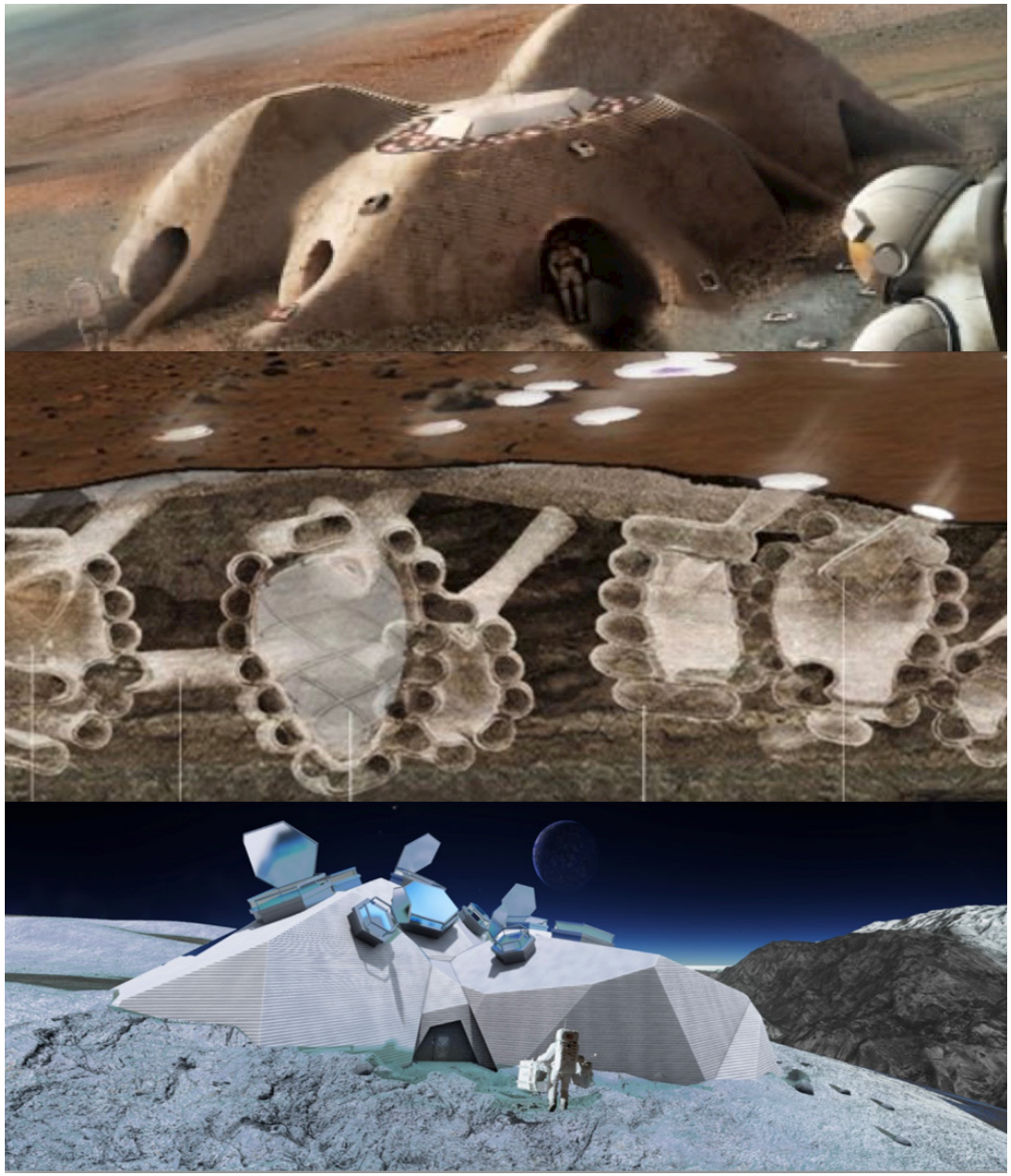
NASA/JPL-Caltech/MSSS

Mars Habitat, Moonzome, Rhizone 1.0

Sustainability (energy and resource sources)

Volume (circulation and connections)

Methods (construction, implantation)



fosterandpartners.com- Mars Habitat; moonshotplus.tudelft.nl - Rhizome 1.0, MOONZOME

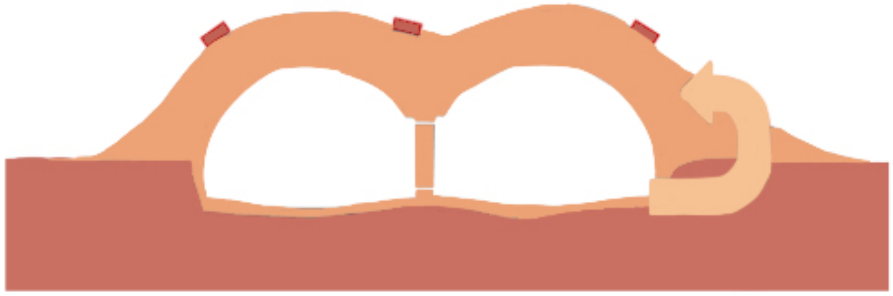
Mars Habitat (Foster + Partners)

Volume

Site

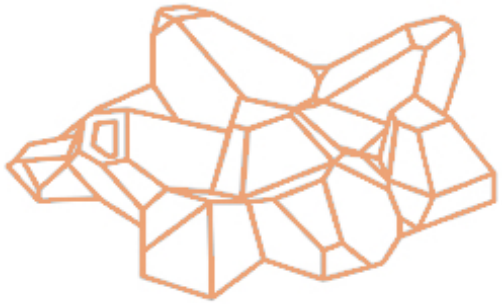
Function & Route

Material, Structure & Sustainability



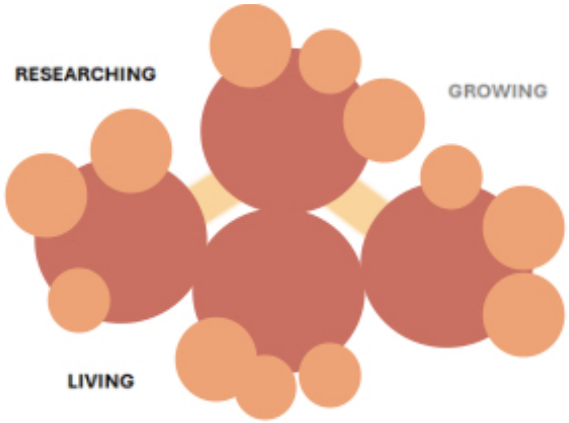
Moonzome

Volume

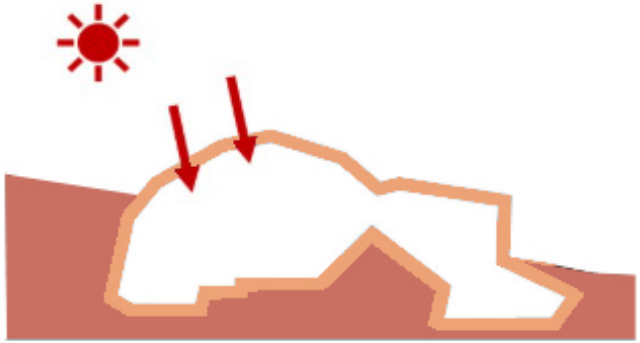


Site

Function & Route

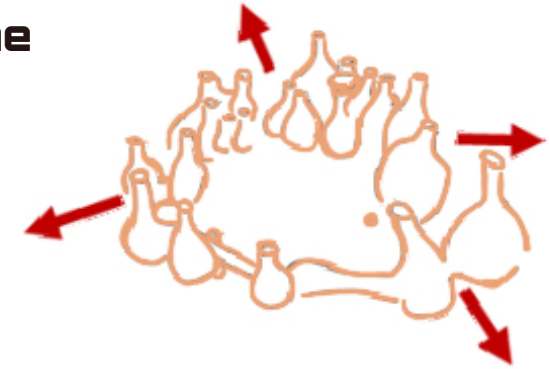


Material, Structure & Sustainability

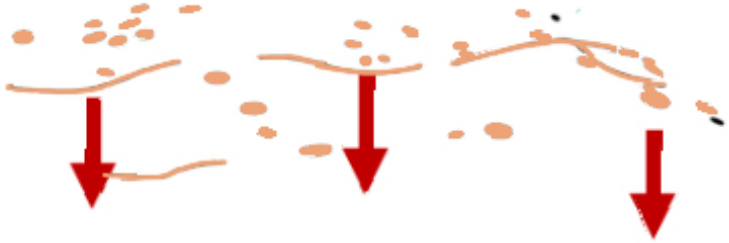


Rhizone 1.0

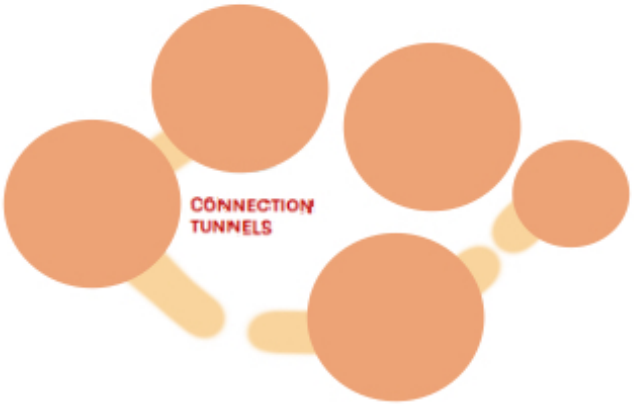
Volume



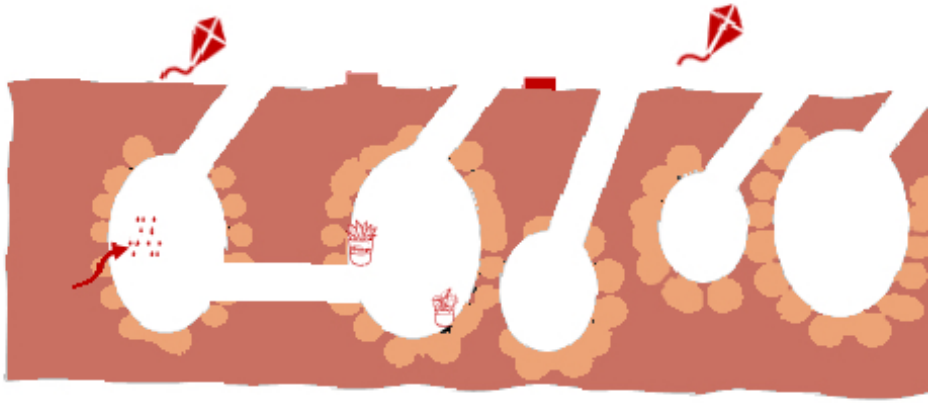
Site



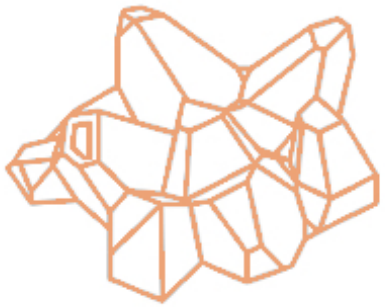
Function & Route



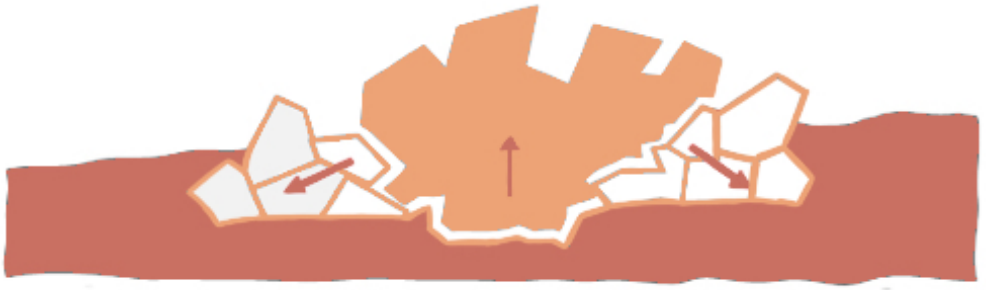
Material, Structure & Sustainability



Volume

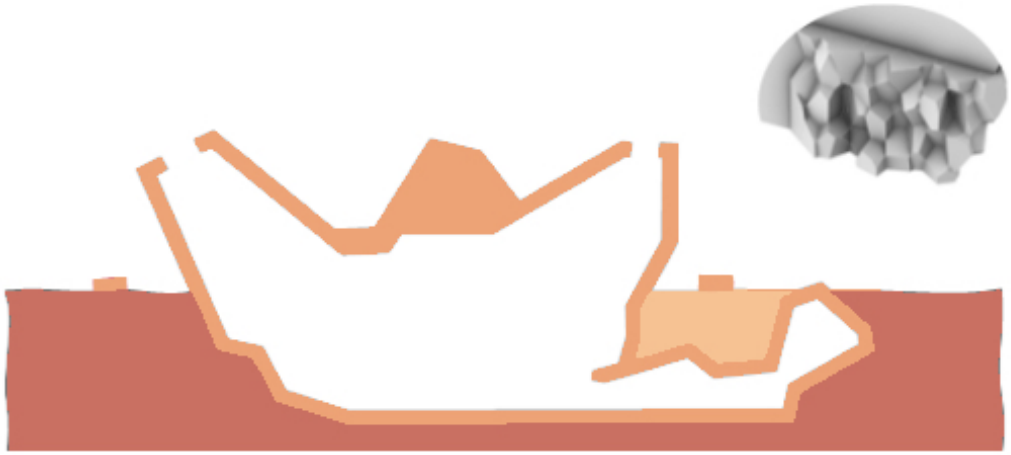


Site



Function & Route

Material, Structure & Sustainability



Rhizome 1.0

Excavated and surface structures

3D printing

Modular

Moonzome

Domed surface structures

3D printing

Modular

Communal Housing Typology on Mars

Excavated and surface structures

3D printing

Bio inspired approach

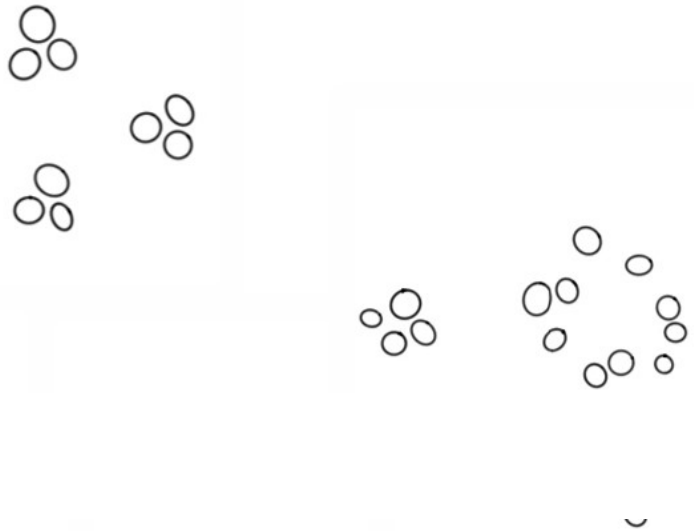
Internal coating

Communal Housing Typology on Mars

Interconnected modular units.

Common spaces to promote communal living.

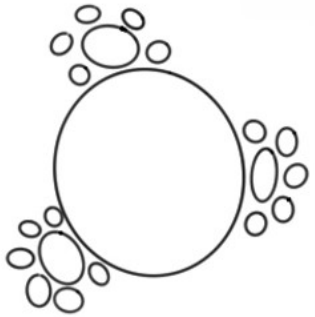
Optimized circulation between modules, with transition zones to minimize heat loss.

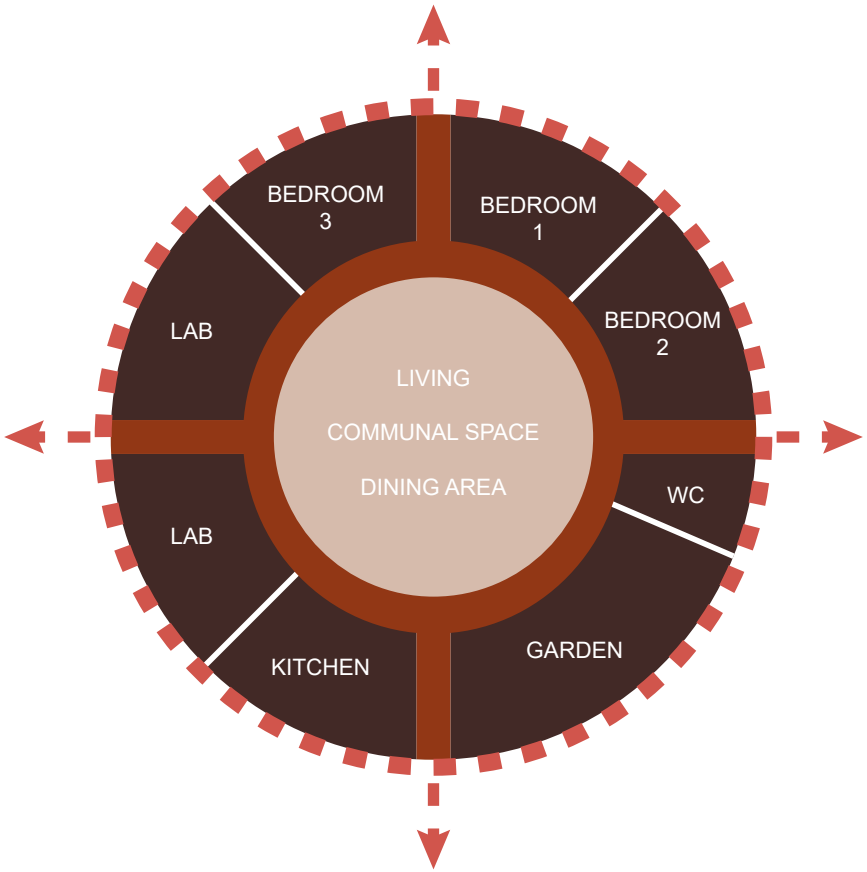


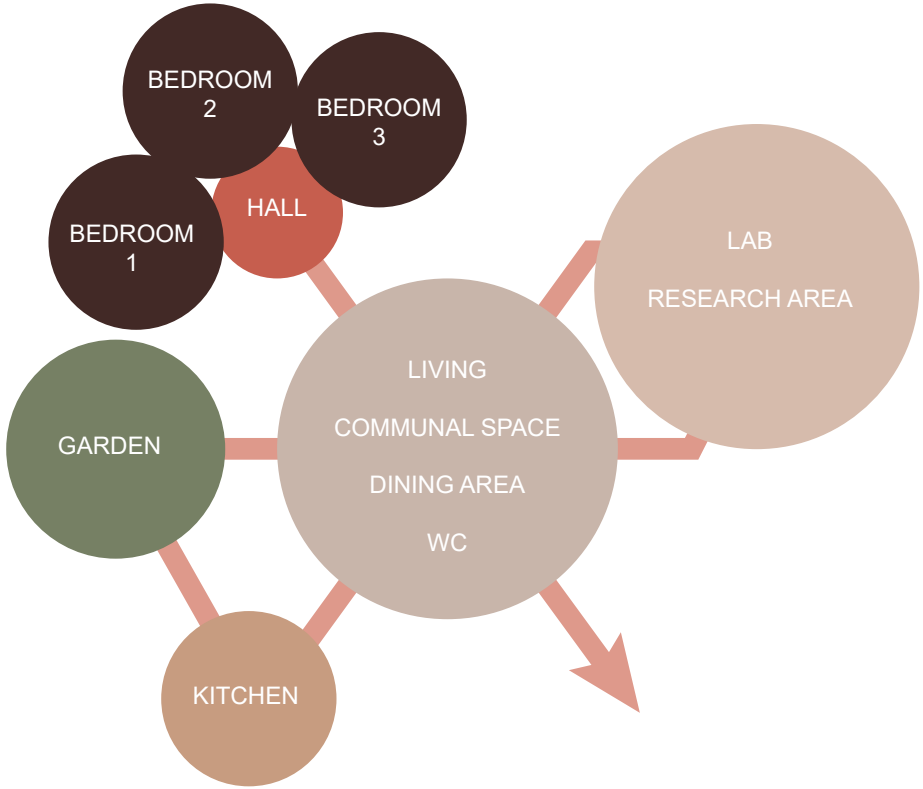
Moonzome

Integration of internal circulation pathways to limit exposure to extreme conditions.

Hierarchical spatial organization, separating living, working, and recreational areas.




BEDROOM 3
BEDROOM 1
LAB
BEDROOM 2
LIVING
COMMUNAL SPACE
DINING AREA
WC
LAB
KITCHEN
GARDEN


BEDROOM 2
BEDROOM 3
BEDROOM 1
HALL
LAB
RESEARCH AREA
GARDEN
LIVING
COMMUNAL SPACE
DINING AREA
WC
KITCHEN

Environmental analysis

Implementation and construction strategies

The Martian environment, marked by extreme conditions – intense radiation, sudden thermal variations, low atmospheric pressure and dust storms – requires a rigorous approach in the choice of implantation sites and construction techniques. In this context, the exploitation of in situ resources appears as an essential strategy to guarantee the autonomy of habitats and minimize dependence on materials imported from Earth.

The objective of this study is to define implantation principles adapted to the Martian environment by relying on experiments and simulations to assess their relevance.

Physical and climatic environment

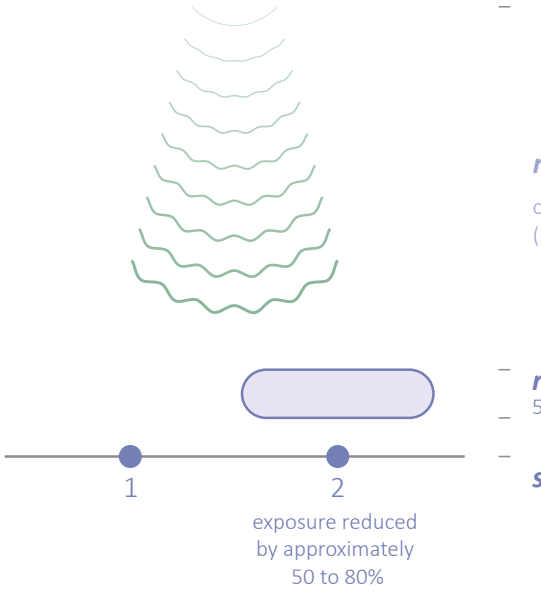
Extreme temperatures (-125°C to +20°C)

Very low atmospheric pressure (~0.6% of Earth's)

Atmosphere composed mainly of CO_2 (≈95%)

Global dust storms and cosmic/intense radiation

Radiation protection



radiation source

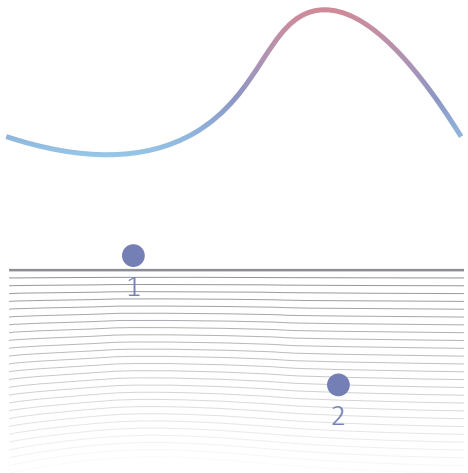
cosmic radiation and solar UV
(up to 250 mSv/year compared to 2.4 mSv/year on Earth)

regolith layer
50 cm to 1 m thick

sensors

Partial burial or regolith cover

Since the Martian atmosphere is very thin, cosmic radiation and solar UV are extremely intense (up to 250 mSv/year compared to 2.4 mSv/year on Earth). A habitat must be protected by a layer of regolith or be semi-buried to reduce exposure.



Adaptation to extreme thermal conditions

temperature differences

from-125°C to +20°C

exposed habitat

strong temperature fluctuations ~120°C difference

buried habitat

more stable temperature; variation limited to ~30°C

Partially buried or thermally insulated structures

Temperature differences vary from-125°C to +20°C, causing thermal expansions that weaken structures. An underground installation or the use of materials with high thermal inertia (compacted regolith, ice, sulphur concrete) would help to mitigate these variations.

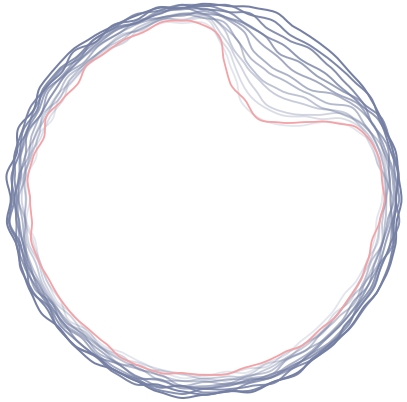
Aerodynamic shapes and inlet filtration

Les tempêtes de poussière martiennes peuvent durer plusieurs semaines et enrober la planète, réduisant la production énergétique et obstruant les systèmes. Des formes arrondies ou semi-enterrées réduiraient l'accumulation de poussière et la résistance au vent.

Towards Ethical Settlement:

Preserving Mars by Minimizing Our Footprint

The establishment of habitats on Mars raises fundamental questions about our relationship with extraterrestrial environments. While the strategies developed so far address the physical and technical constraints of the Martian environment, they fail to consider a crucial issue: preserving Mars as a natural and scientific heritage.



Mars: A Heritage to Protect?
Like the rest of space, Mars is a territory untouched by human influence, an unaltered archive of the history of the solar system. Its soil, atmosphere, and geological formations are invaluable records, particularly for research on past habitability and the potential existence of microbial life. Any human settlement risks irreversibly altering this evidence, raising the question of our responsibility toward this unique environment.

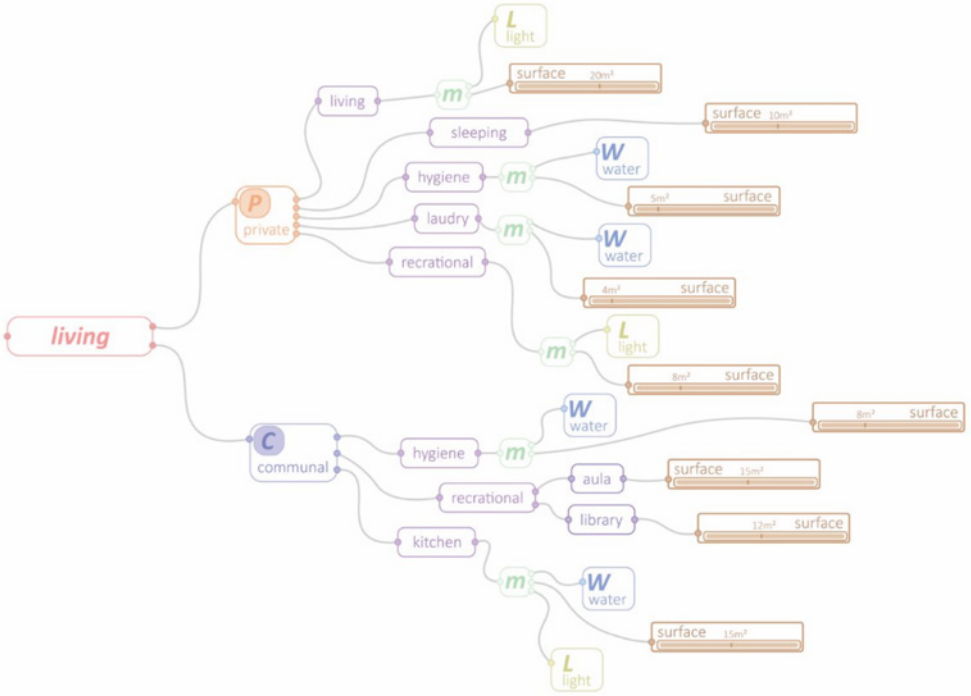
Are Our Strategies Too Invasive?
Traditional settlement approaches heavily rely on the in-situ use of Martian resources (regolith, water ice, etc.) and terrain modification to ensure structural stability and protection. While these methods are technically effective, they may have significant ecological and scientific consequences:

The Risks of Human Intervention

Biological contamination:
The unintentional introduction of terrestrial microbes could contaminate potential native life and compromise future astrobiological research.

Alteration of the Martian landscape:
Excavation, large-scale regolith extraction, and visible infrastructure could permanently change the planet's appearance.

Irreversible resource exploitation:
The extraction of Martian water ice and minerals raises concerns similar to those of terrestrial mining: how far should we go without disrupting a fragile equilibrium?


living
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sleeping
hygiene
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recrational
C
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hygiene
recrational
kitchen
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library
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water
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surface 10m²
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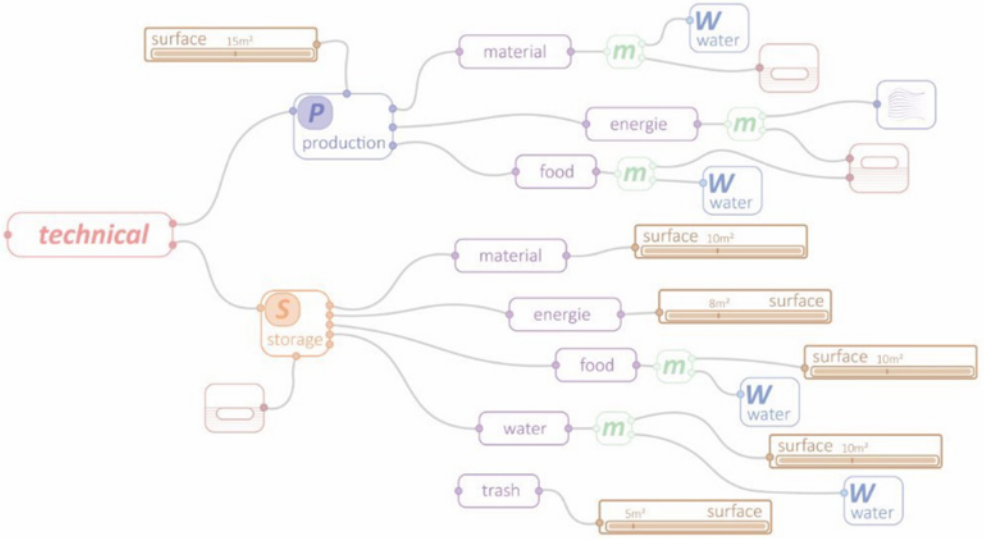
8m² surface
8m² surface
surface 15m²
12m² surface
surface 15m²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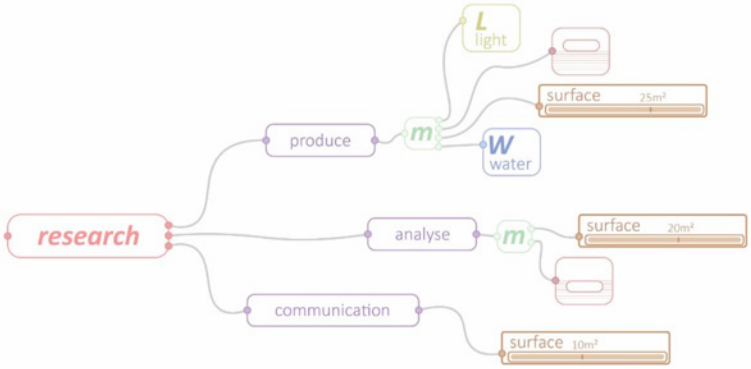
surface 10m²
5m² surface


research
produce
analyse
communication
m
L
light
W
water
surface
surface 25m²
surface 20m²
surface 10m²

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CONCEPT

Related to the Context

Traditional Building Methods

Local Recources

Influenced by Cultural Aspects

Based on Local Needs

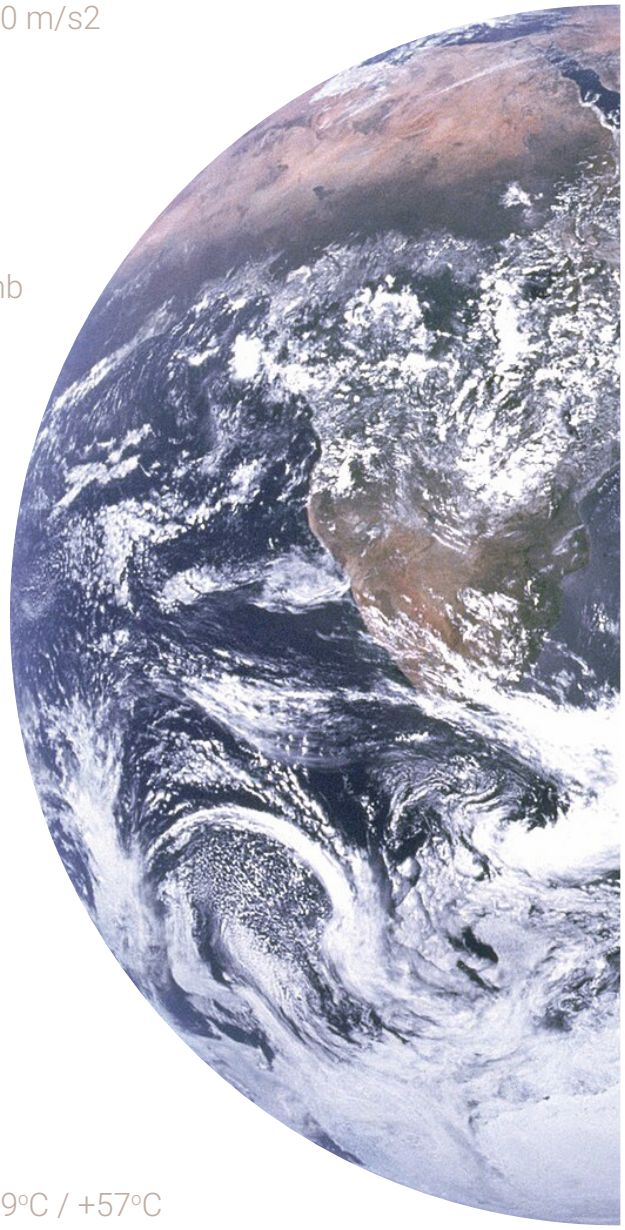
mean surface gravity: 9.80 m/s2

surface pressure: 1014 mb

lenght of day: 24 hours

lenght of year: 365 days

temperature extremes: -89°C / +57°C



Related to the Context

In-Situ Resource Utilization

Influenced by Human Factors

Based on Environmental Adaptation

mean surface gravity: 3.71 m/s2

surface pressure: 6.36 mb

lenght of day: 24.6 hours

lenght of year: 687 days

temperature extremes: -143°C / +20°C

Environmental Adaptation

habitats on Mars may need to be built underground or shielded with local materials to protect inhabitants from radiation

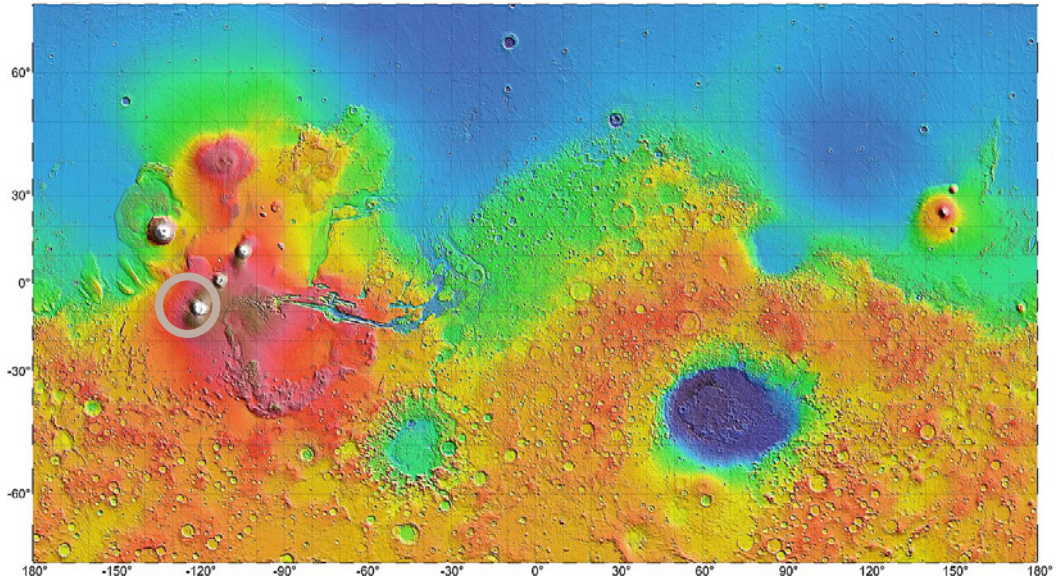
Lava Tubes = Protection

against radiation, micrometeorite impacts, and extreme temperature variations

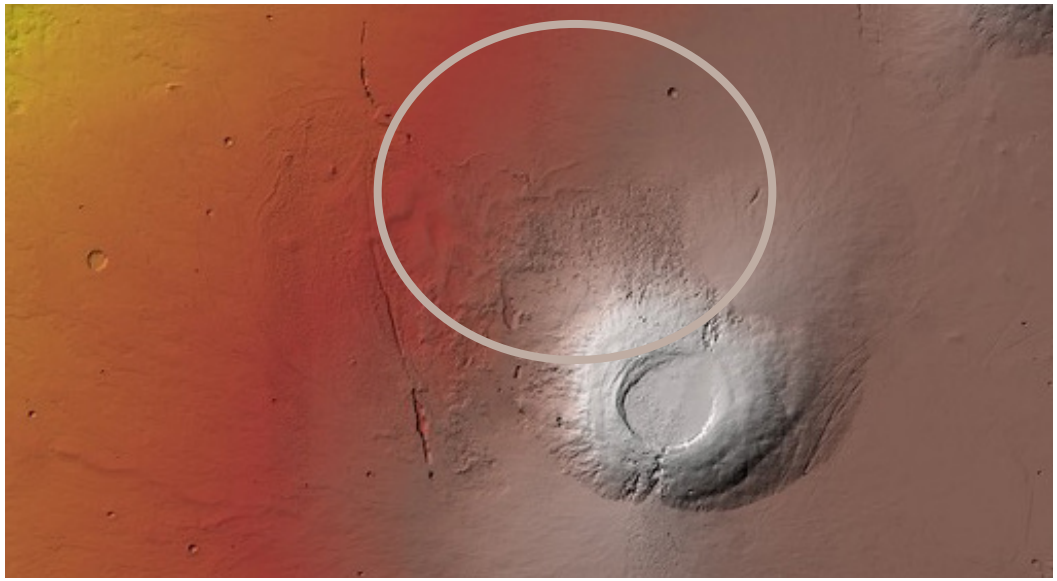
insulating properties eliminate the need for additional radiation shielding, making them more economical for human habitation (Tettamanti, C., 2019)

Lava Tubes Presence

several entrances have been discovered near the Arsia Mons



NASA / JPL / USGS - Topography of Mars by MOLA

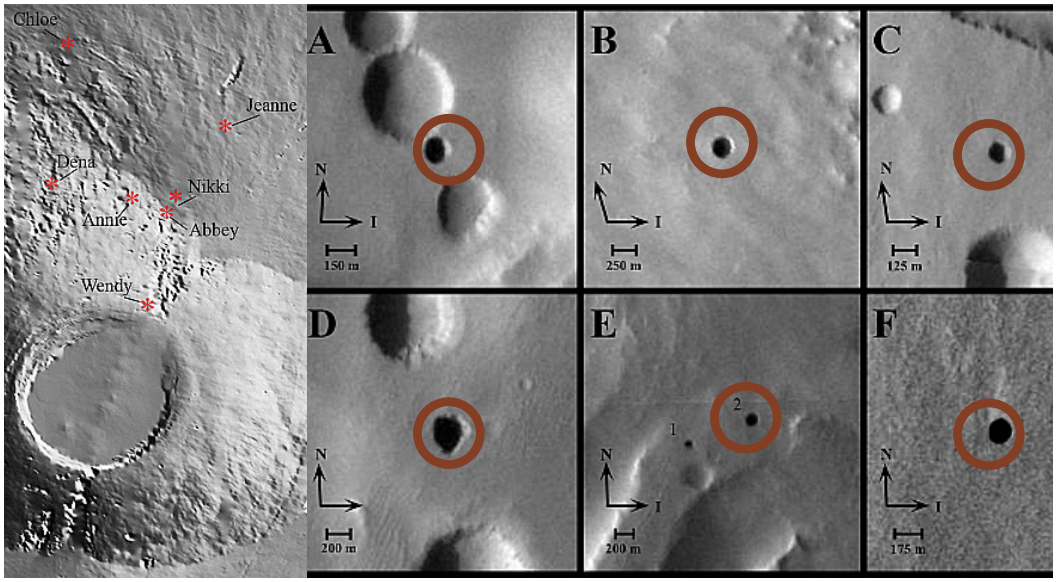


MGS MOLA and Mars Express HRSC

Structural Integrity

structural composition need to be studied further to determine which tubes are the safest

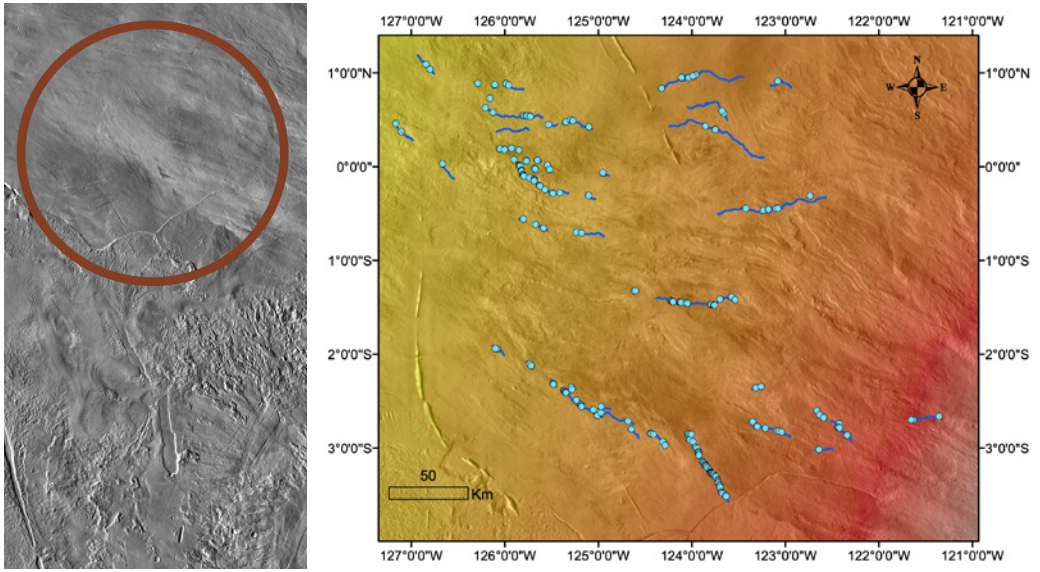
Martian lava tubes are expected to be more stable than their Earth counterparts due to lower gravity (Tettamanti, C., 2019)



Cushing et al. (2007)

Potential Water Ice Presence

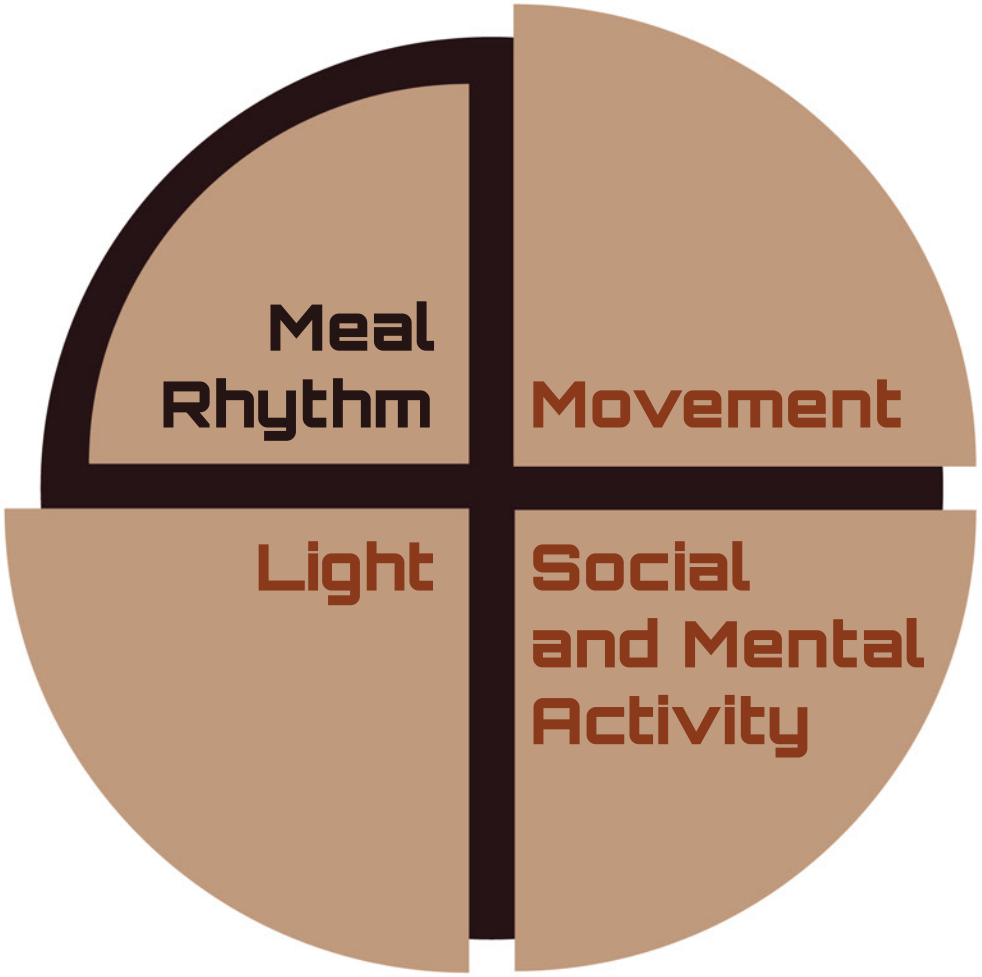
Arsia Mons exhibits repeated cloud formations, which some studies suggest could be water vapor, potentially indicating the presence of water ice in the region (JPL; Burnham, 2018; USRA, 2012; Kolb, 2007)



MO THEMIS-IR Day; Tettamanti, C. (2019)

Potential of Wind Energy

reasonably high wind speeds (Schmehl et al., 2022)

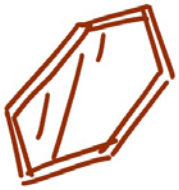


VERTICAL FORM

vertical habitats enhance circulation by naturally integrating staircases and atriums

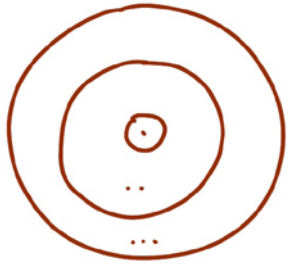
LIGHTING

regulation of circadian rhythms



WINDOWS

design countermeasures for physical and emotional stressors, isolation and confinement



ZONING

space distribution considering habitability aspects and crew dynamics

Growing plants

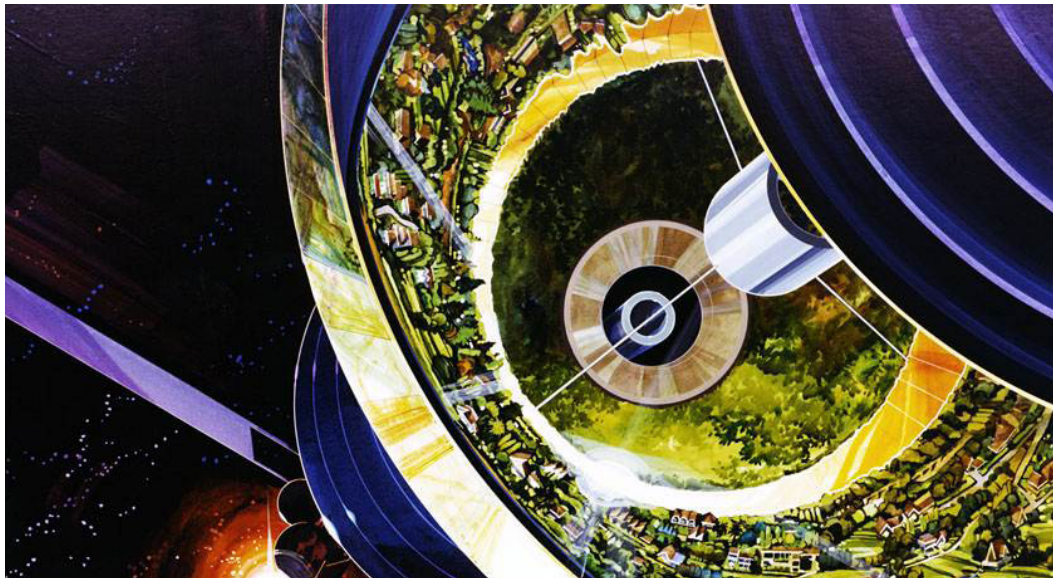
for food necessary

DLR / NASA / Bunchek - EDEN-ISS

ESA

Plats support well-being

Silent Running (1972)



NASA/Painting by Rick Guidice - Bernal Sphere

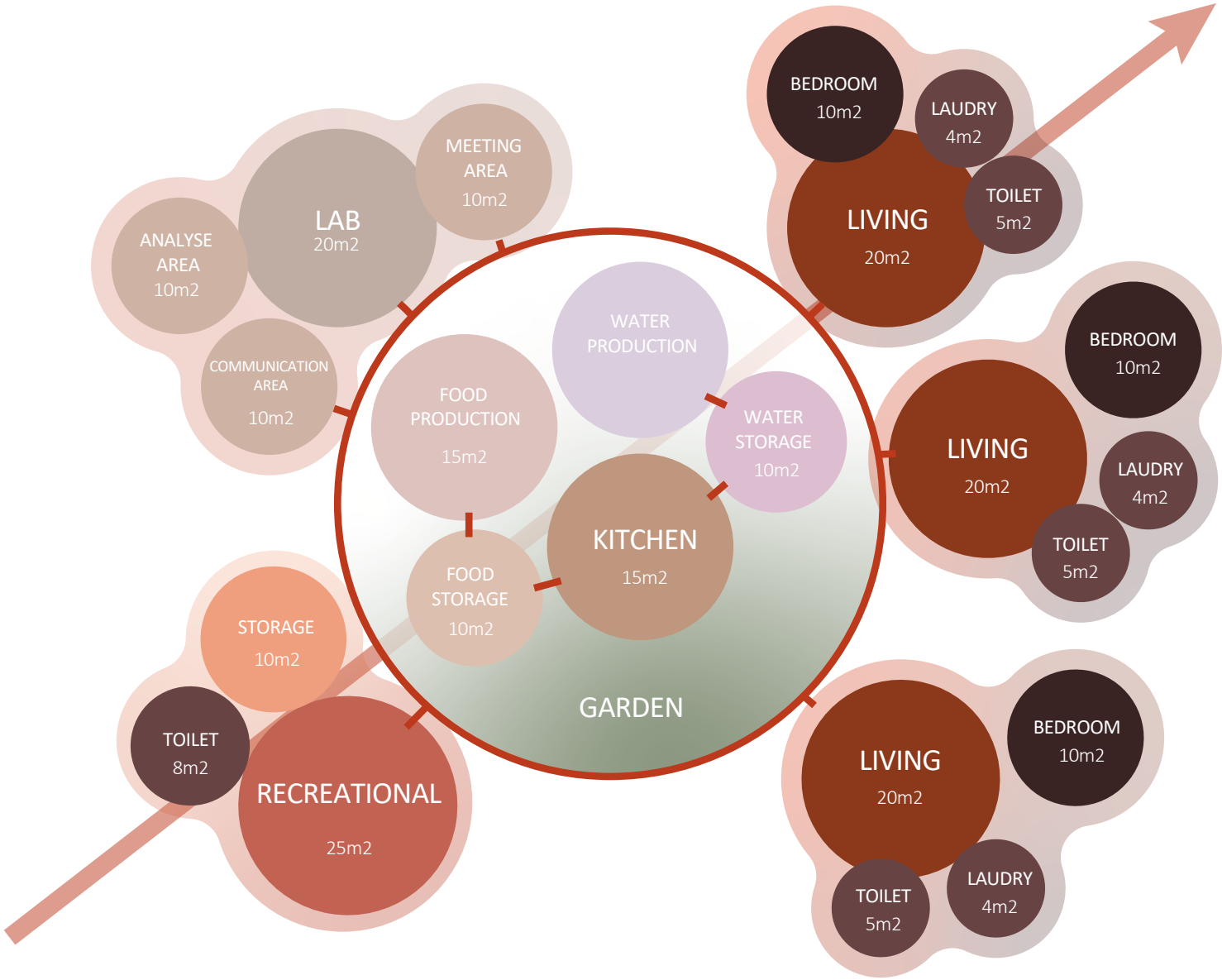
Part of Our Tradition

Around the Globe

Riad, Morocco; Tsuboniwa, Japan; Atrium, Ancient Rome; Malay Stilt House ; Balinese Houses; Sheyuan, China

SUBMARTIAN

an underground habitat system on Mars where architecture and nature work together to create a self-sustaining environment.


BEDROOM
10m2
LAUNDRY
4m2
TOILET
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LIVING
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MEETING
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LAB
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ANALYSE
AREA
10m2
COMMUNICATION
AREA
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WATER
PRODUCTION
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8m2
RECREATIONAL
25m2
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BEDROOM
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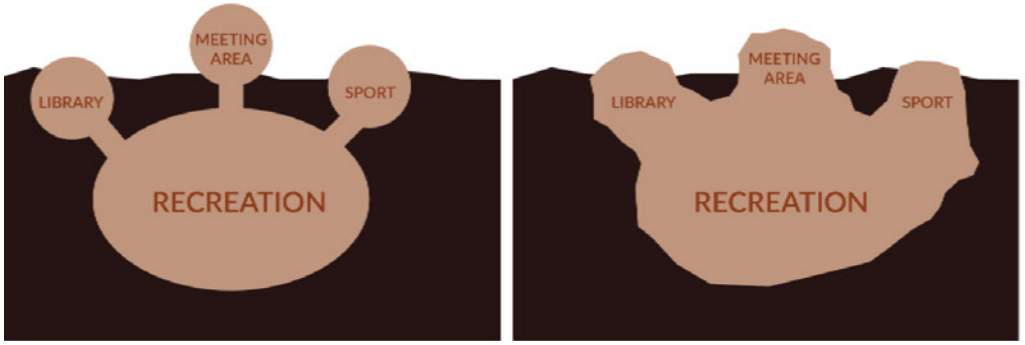
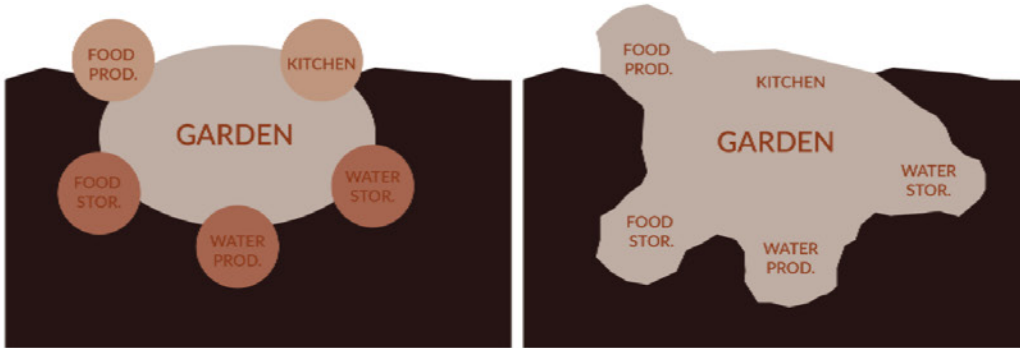
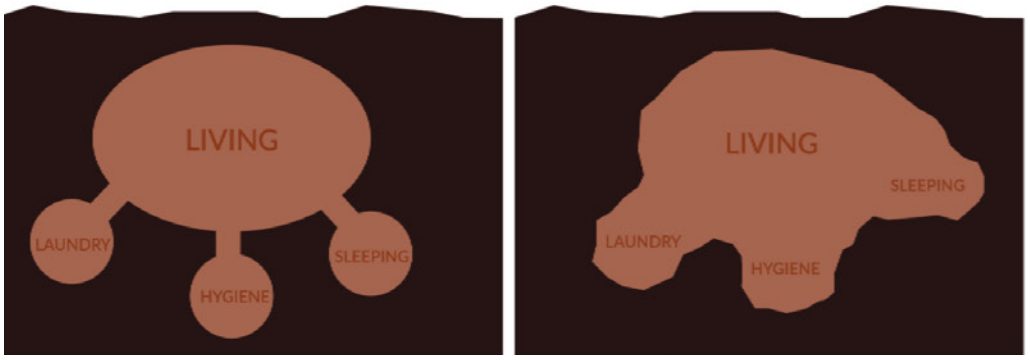
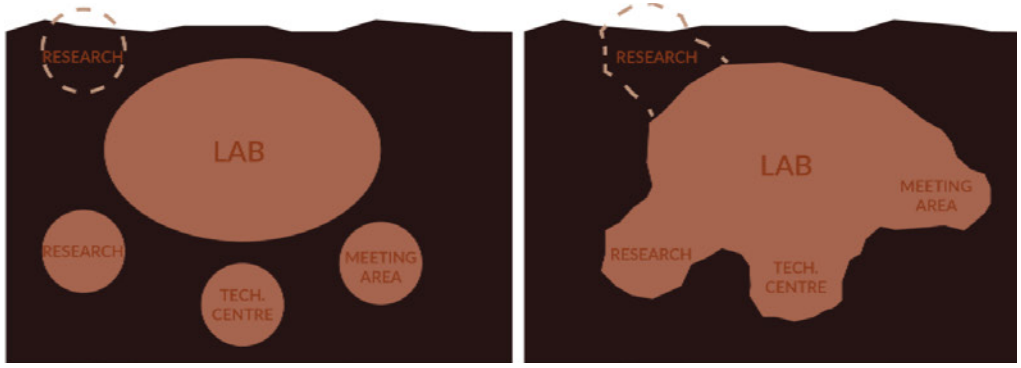
TOILET
5m2
LAUNDRY
4m2

FUNCTIONS: POSITION RELATIVE TO THE TERRAIN



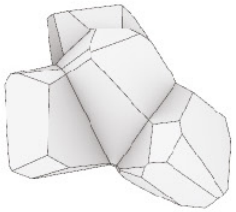




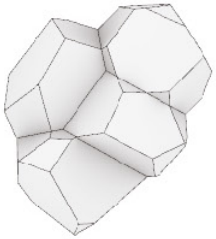


VORONOI STUDY: 3D VIEW

OPTION 1



OPTION 2



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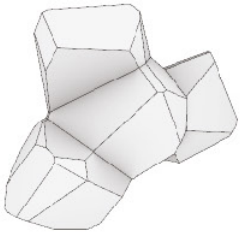

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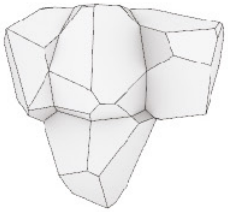

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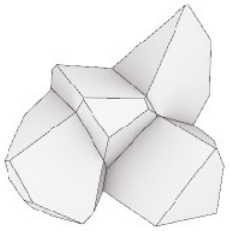

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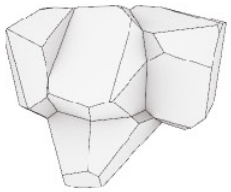

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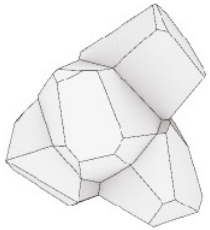

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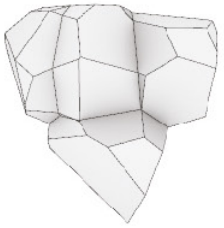

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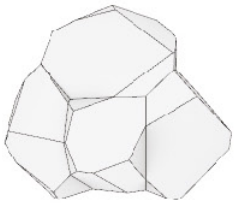

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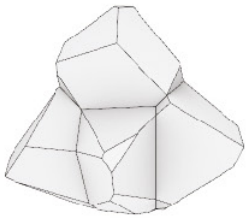

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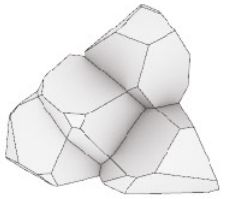

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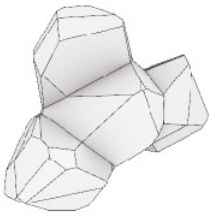
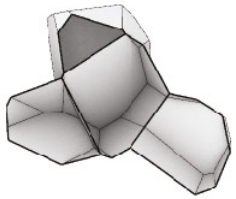


VORONOI STUDY: HORIZONTAL SECTION

OPTION 1



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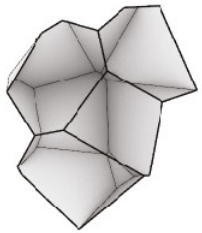

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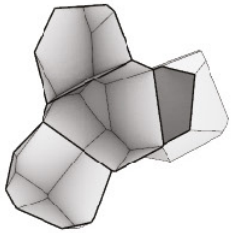

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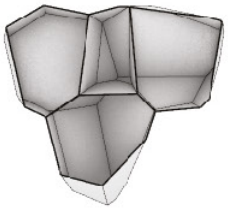

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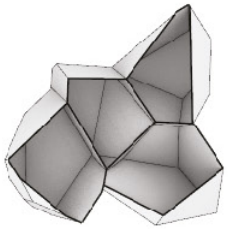

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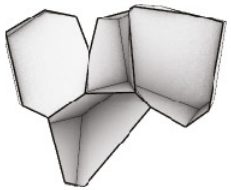

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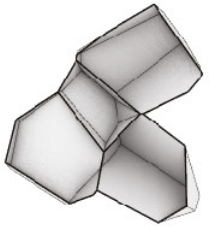

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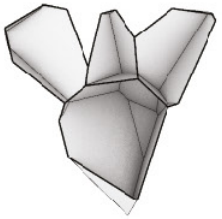

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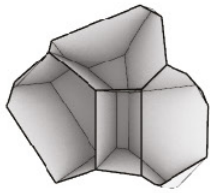

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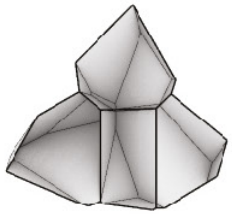

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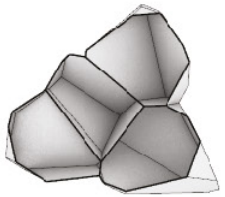

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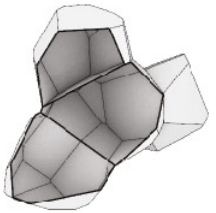
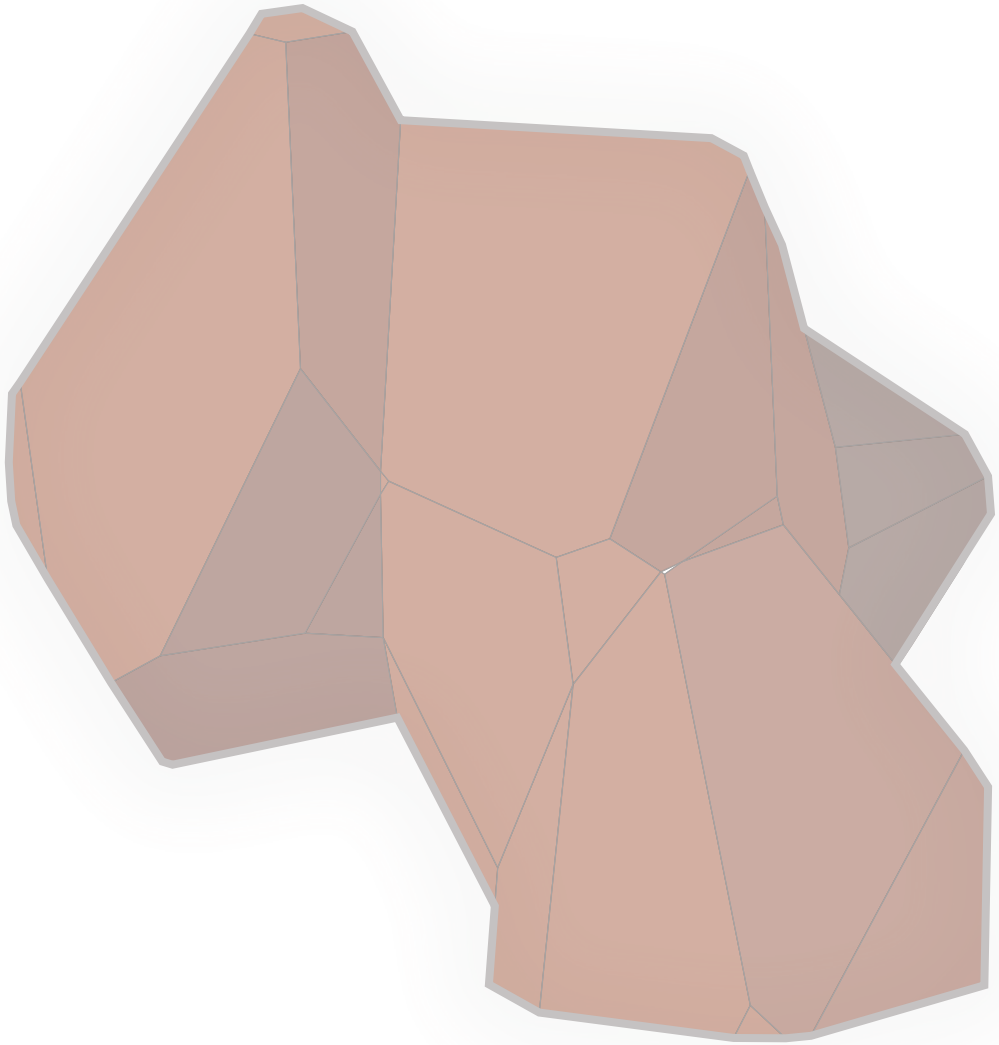




Central Common Space & Rest Area

– Shared area for relaxation and social interaction.

Technical & Food Production Module

– Essential systems and food cultivation.

Research Module

– Dedicated to scientific experiments and studies.

Private & Sleeping Module

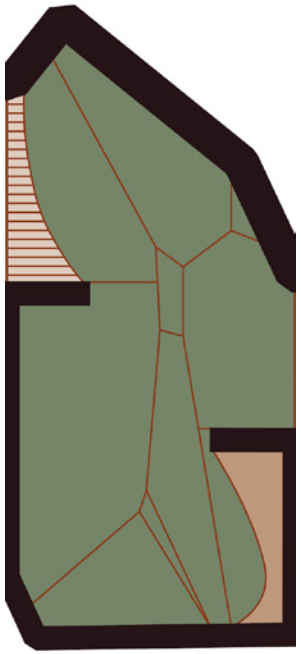
– Personal living quarters and rest areas.

Central

Circulation

Volume

SPORT
GARDENING

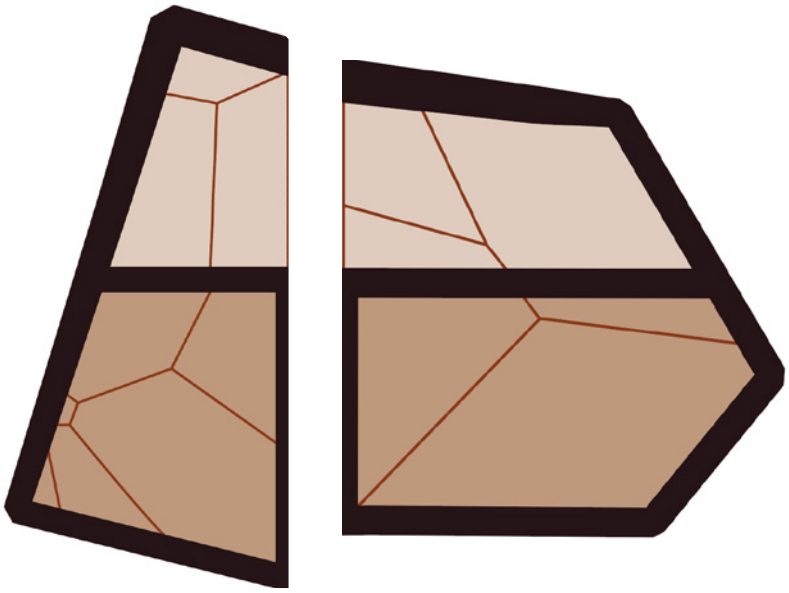


REST AREA

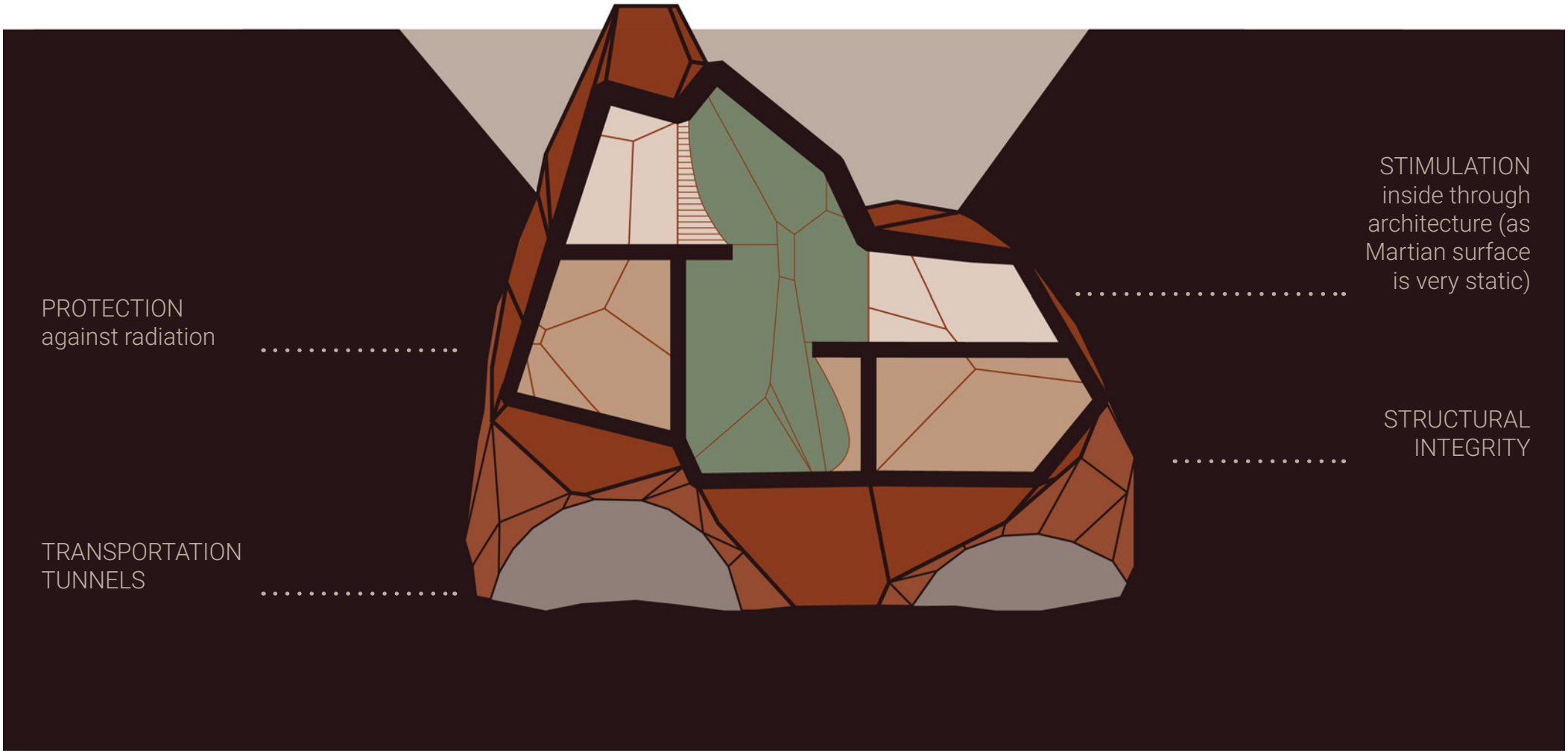
RESEARCH
FOOD PRODUCTION
HYGIENE

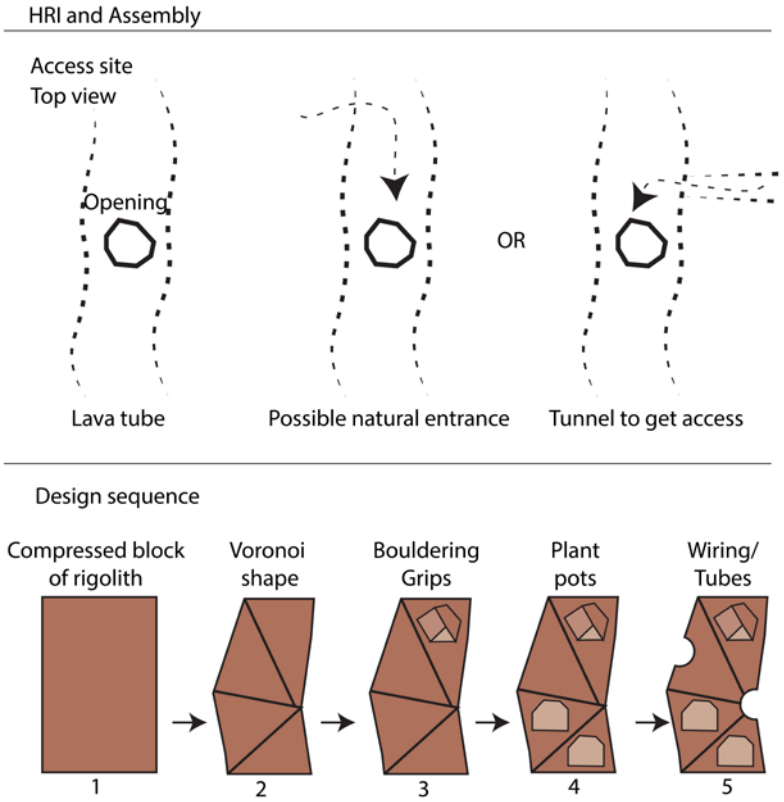
Loud - Light

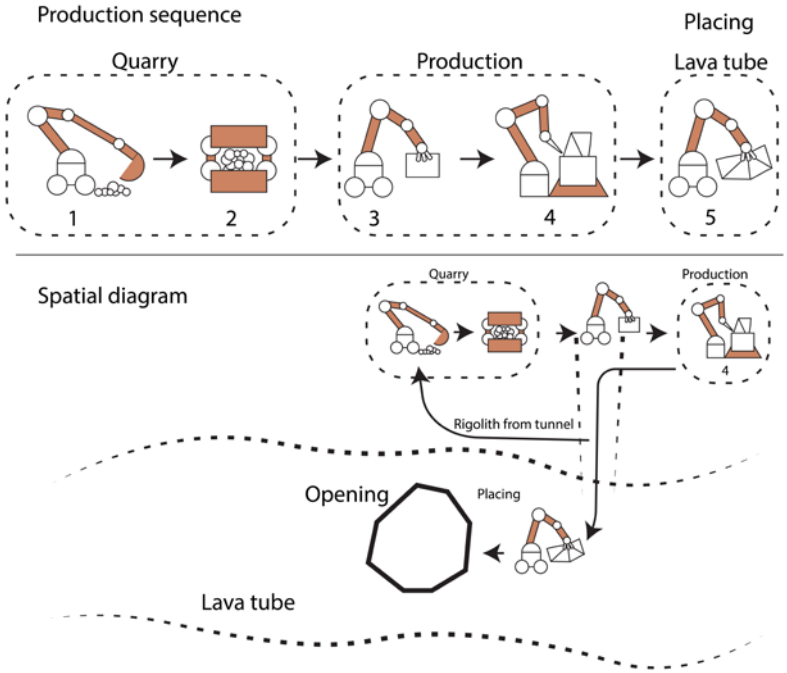
Quiet - Dark



STORAGE
TECHNICAL
SLEEPING


PROTECTION
against radiation
TRANSPORTATION
TUNNELS
STIMULATION
inside through
architecture (as
Martian surface
is very static)
STRUCTURAL
INTEGRITY

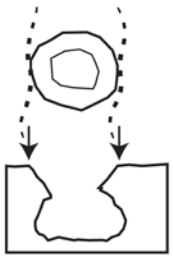

HRI and Assembly
Access site
Top view
Opening
OR
Lava tube
Possible natural entrance
Tunnel to get access
Design sequence
Compressed block of rigolith
Voronoi shape
Bouldering Grips
Plant pots
Wiring/ Tubes
1
2
3
4
5


Production sequence
Placing
Quarry
Production
Lava tube
1
2
3
4
5
Spatial diagram
Quarry
Production
4
Rigolith from tunnel
Opening
Placing
Lava tube

CONSTRUCTION PROCESS

Construction sequence

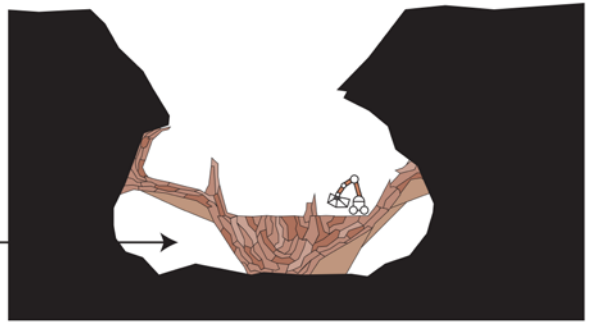
Section lava tube



1

2

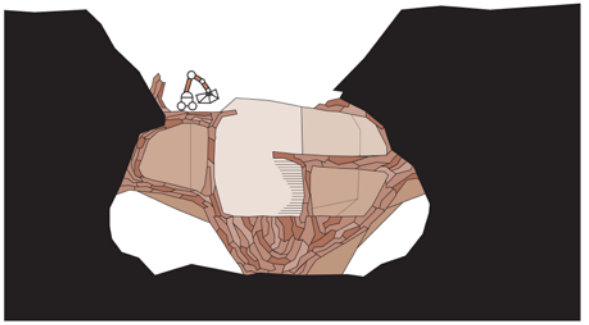
Constructing from ground up



Access route, future expansion

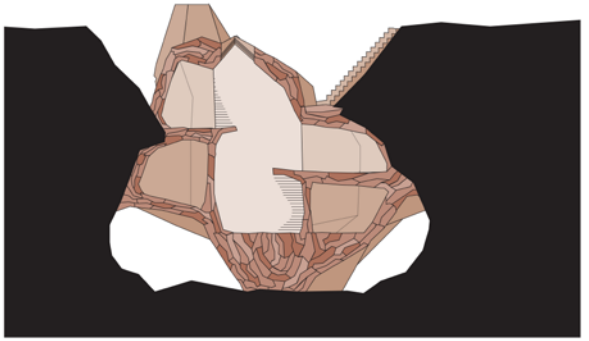
3

Structure strengthens
lave tube formation



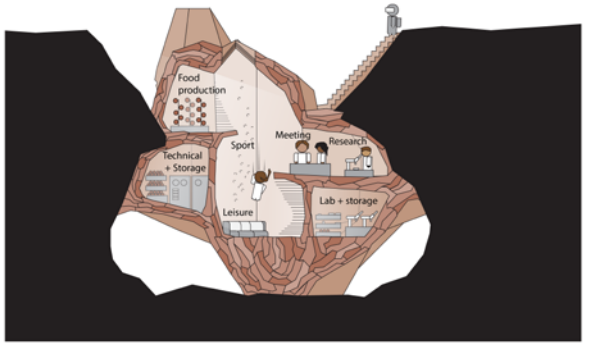
4

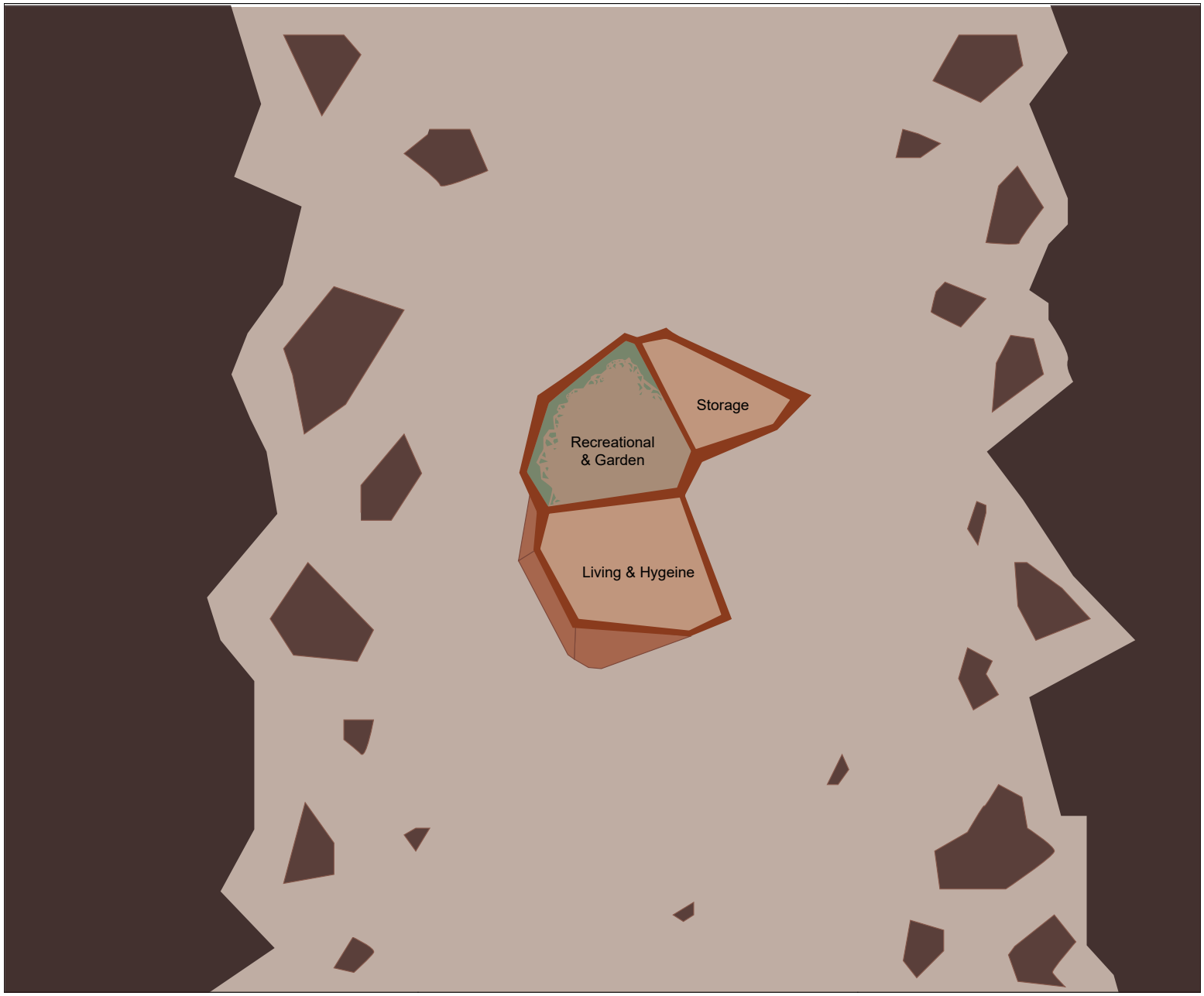
Structure shows a
minimal exterior footprint



5

Completed habitat
Further development:
Furniture integrated in design

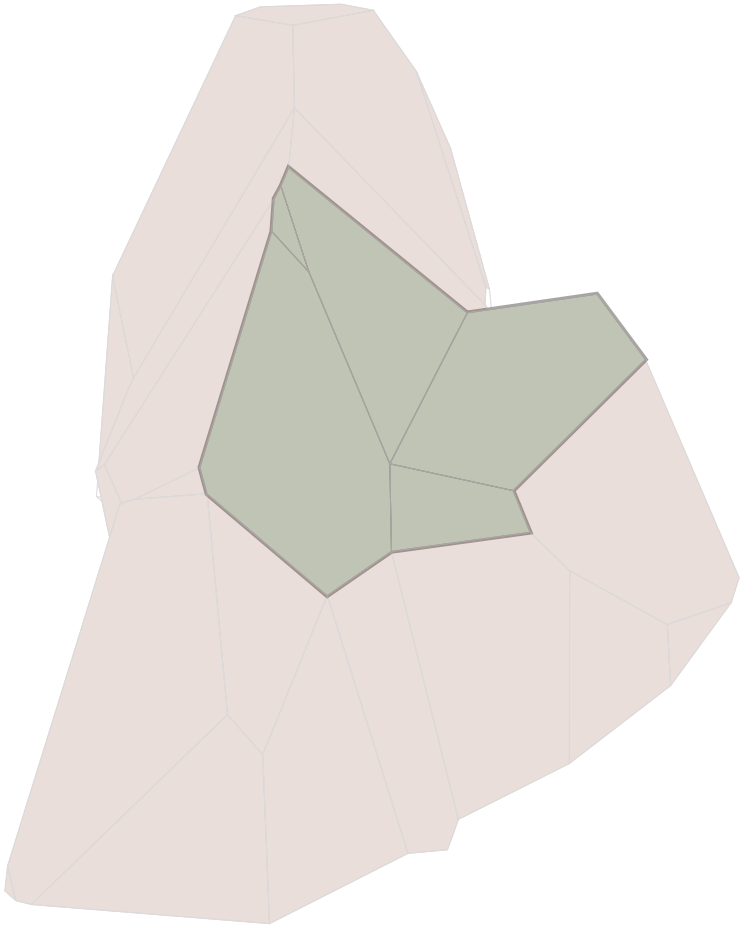


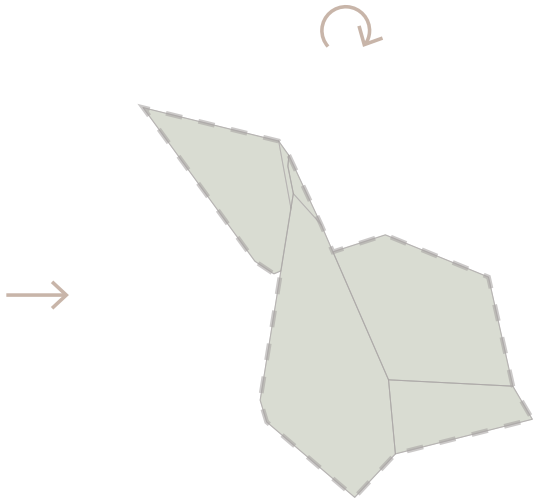

Storage
Recreational
& Garden
Living & Hygeine

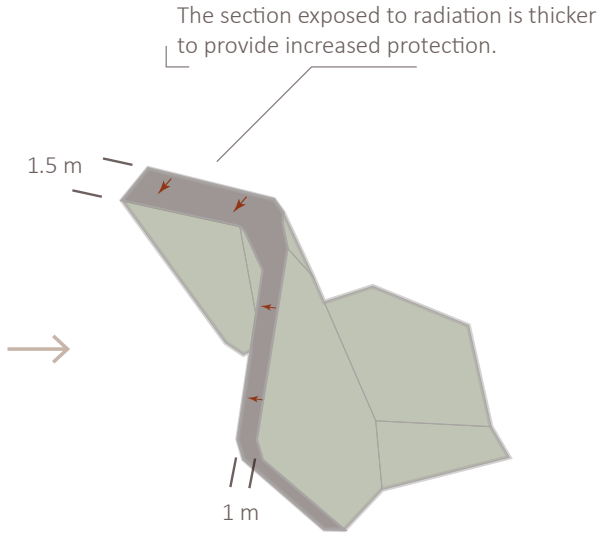

Technical space
Research
Recreational
& Garden


Food production
Research
Recreational
& Garden

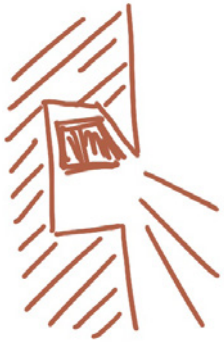
CHOSEN FRAGMENT








Movement
Light
Social
and Mental
Activity



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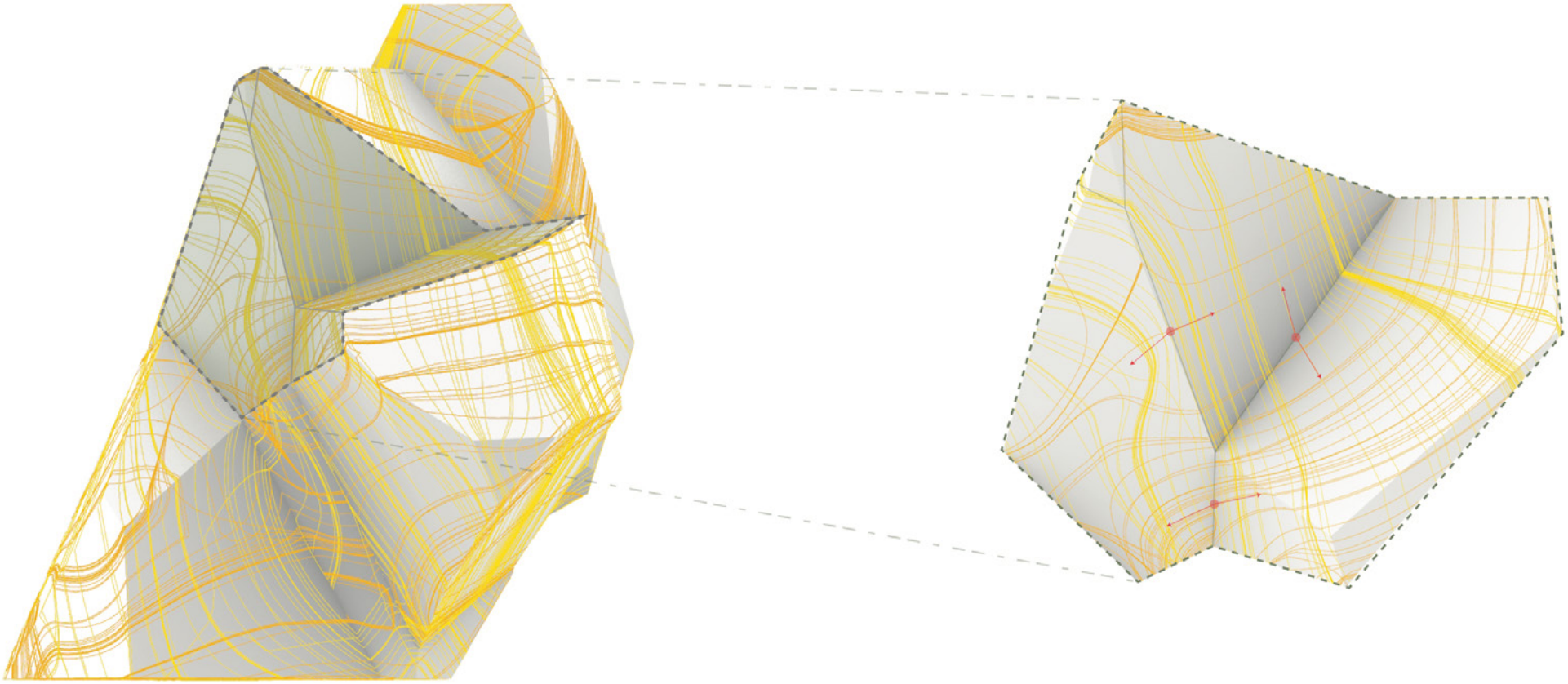
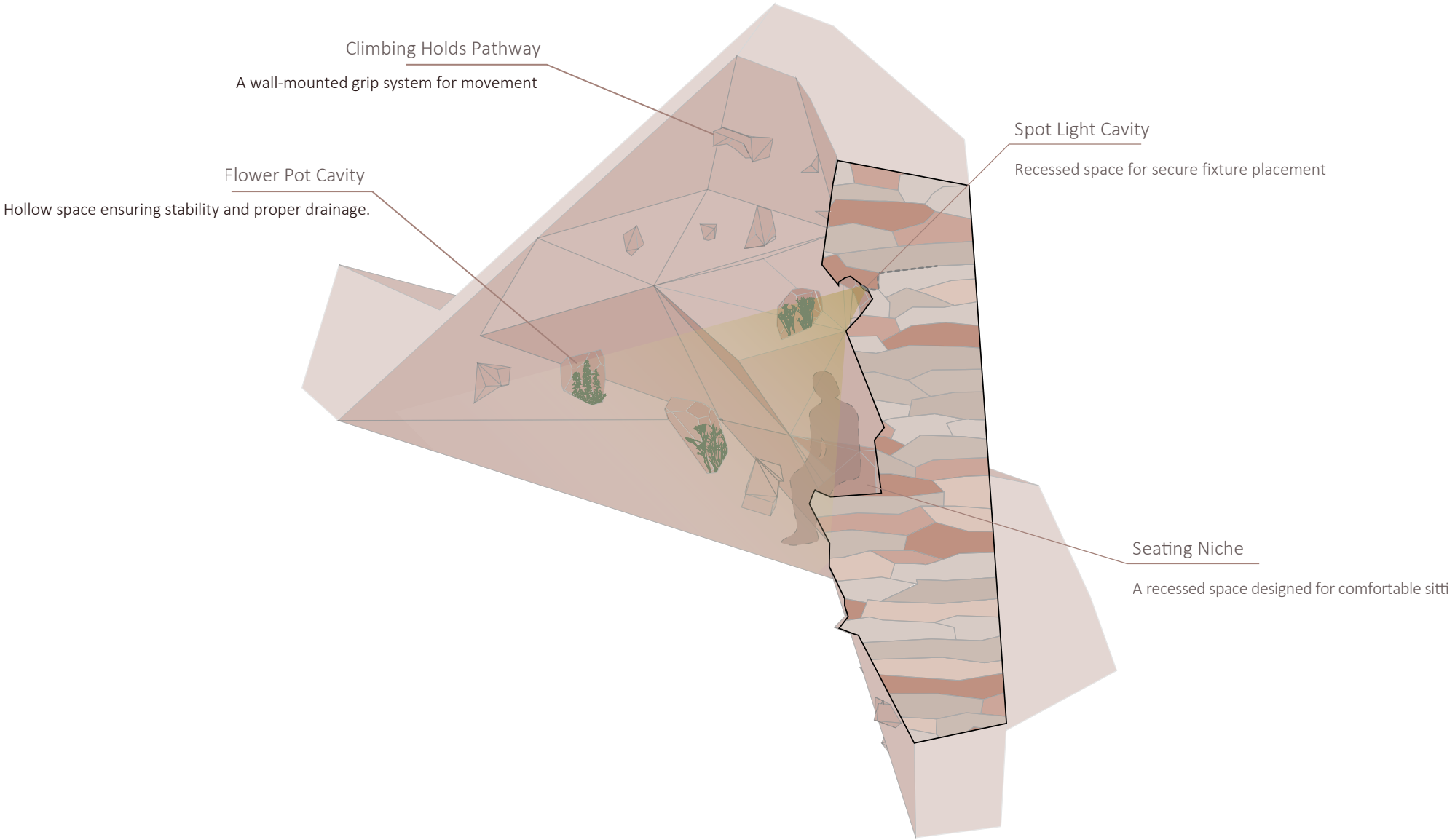
DESIGN

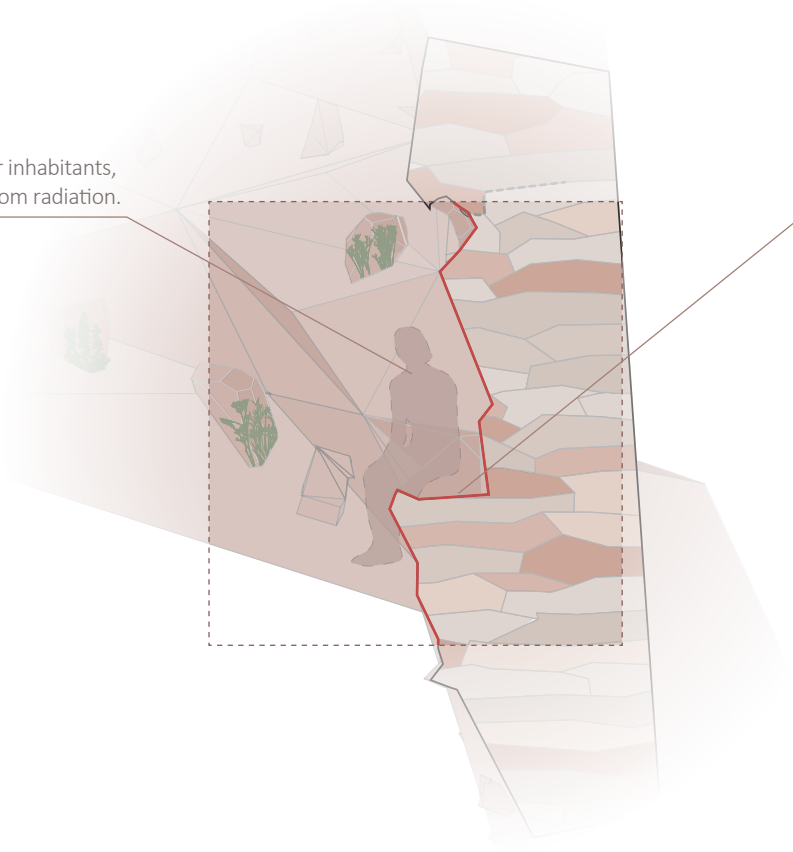


KEY IDEA: BOULDERING, SEATS, LIGHT AND PLANTS



KEY IDEA: SEATING NICHE

A resting or observation point for inhabitants,
protected from radiation.



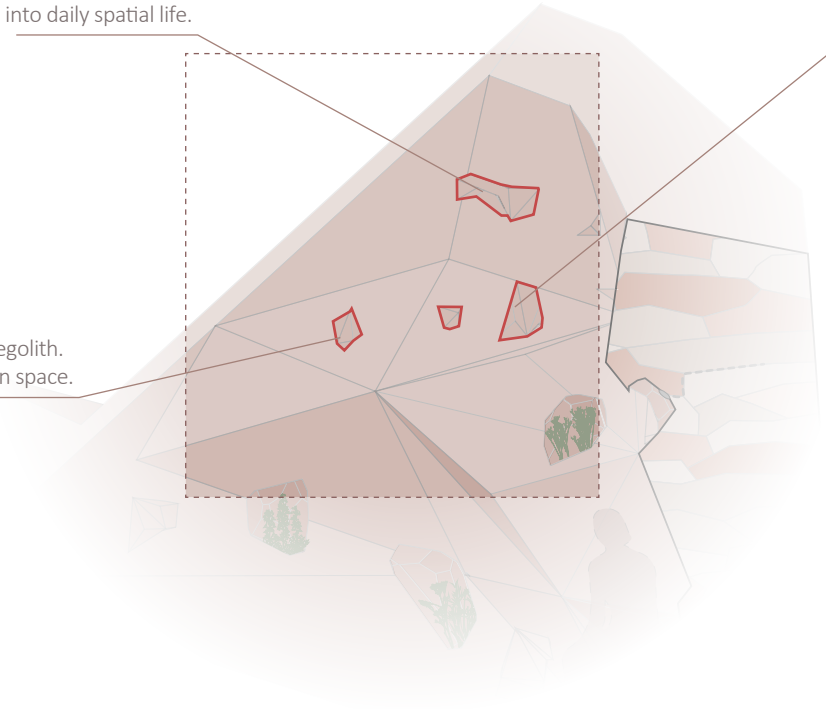
Seating Niche

Carved into a Voronoi block, the niche follows
the natural curvature of the cell, creating a cocoon-like recess.

KEY IDEA: BOULDERING NICHE

Encourages physical activity in low gravity, integrating movement into daily spatial life.

3D-printed holds using polymers or reinforced regolith.
Climbing Martian walls as a way to reconnect with one's body in space.



Climbing Holds Pathway

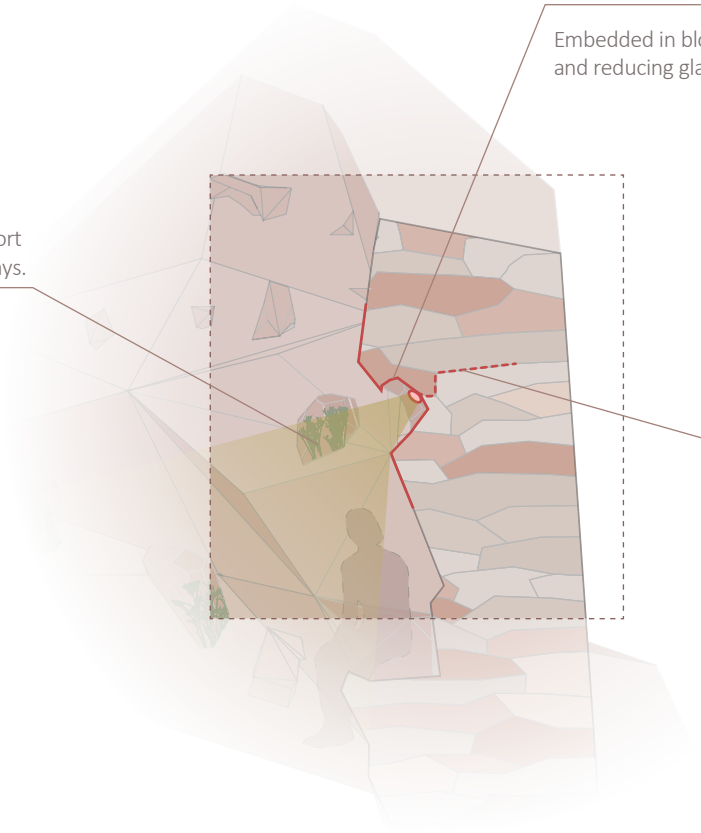
Holds are aligned along the internal edges of Voronoi cells, using their organic geometry to create a flowing path.

KEY IDEA: LIGHT NICHE

Spot Light Cavity

Embedded in block surfaces, allowing indirect lighting and reducing glare in enclosed spaces.

Carefully calibrated lighting sequences support the inhabitants' biological clocks during long-term stays.



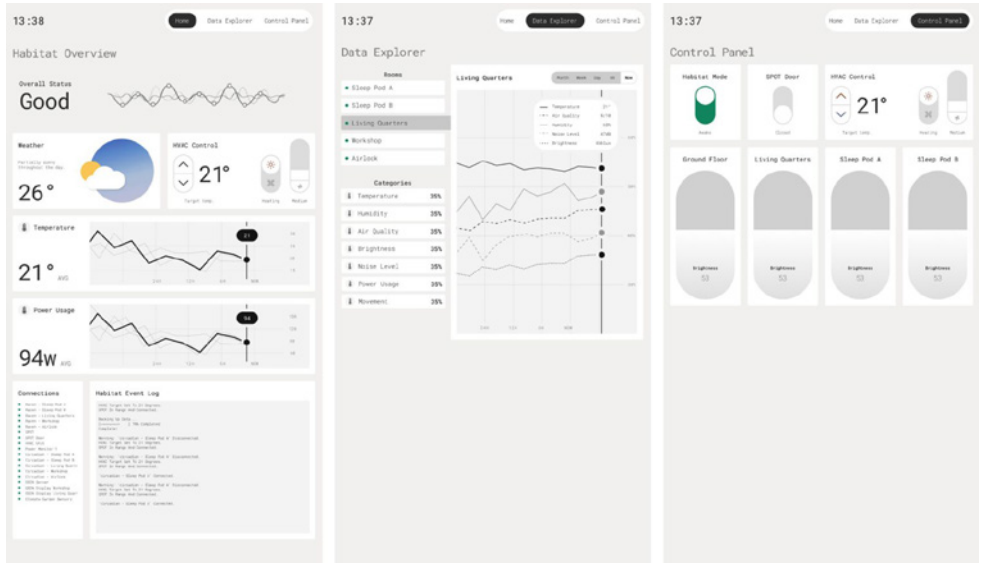
The electrical cable is fully integrated into the Voronoi logic it follows the edges and intersection lines between the cells, becoming part of the structural and spatial system.

UNIFIED CONTROL PANEL
to support both human and nature

environmental monitoring

atmospheric regulation

adaptive lighting to support circadian rhythms and plant growth

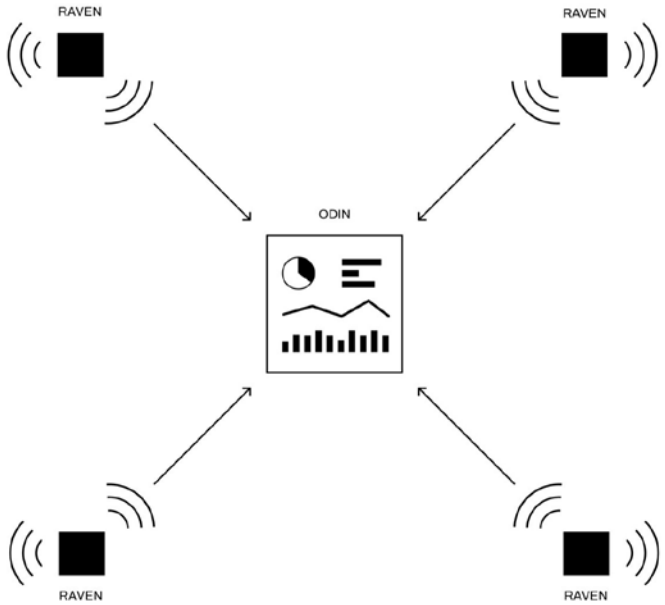


ODYN, RAVEN | SAGA.dk

INTERACTION

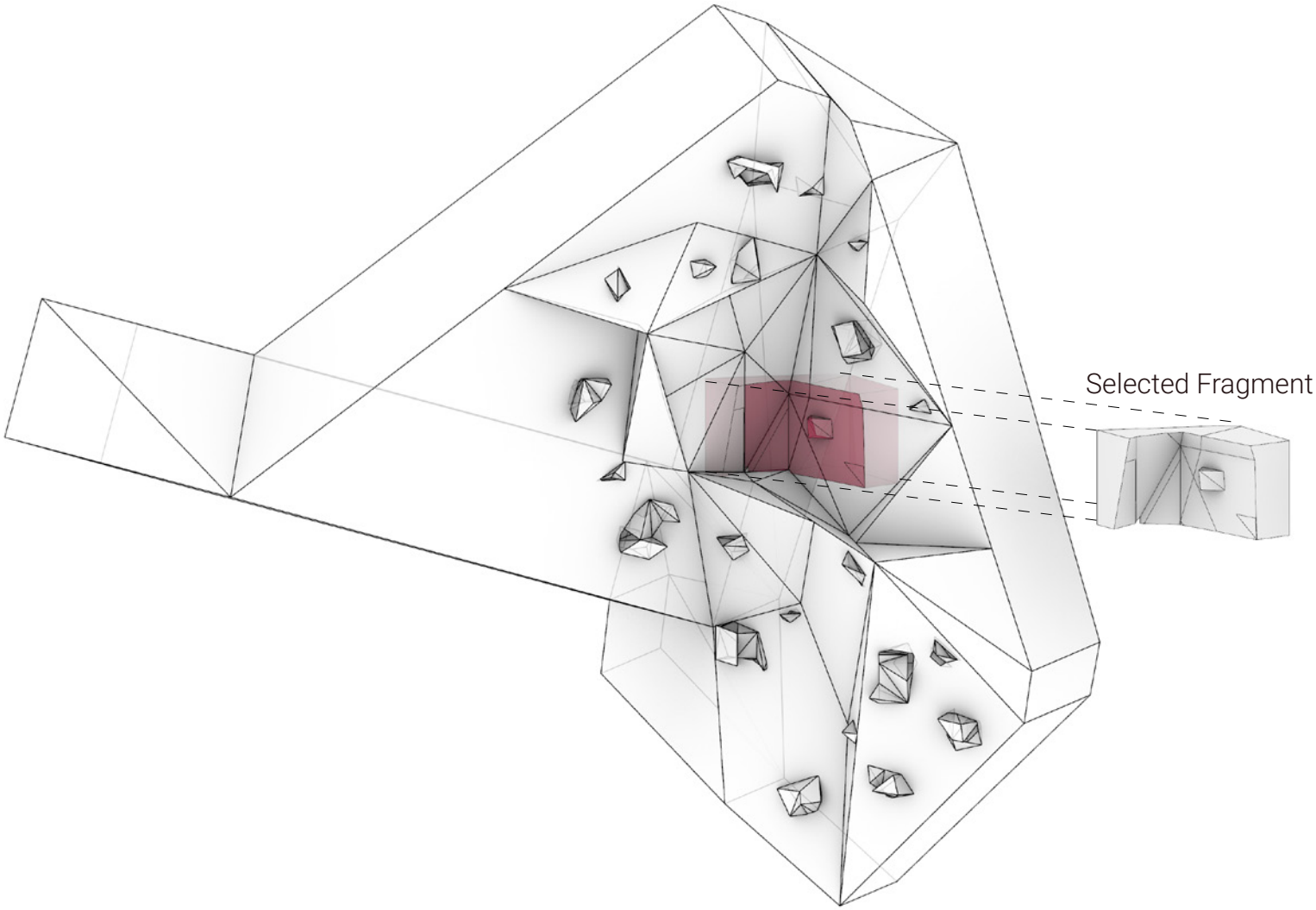
handheld devices

wall-mounted control panels

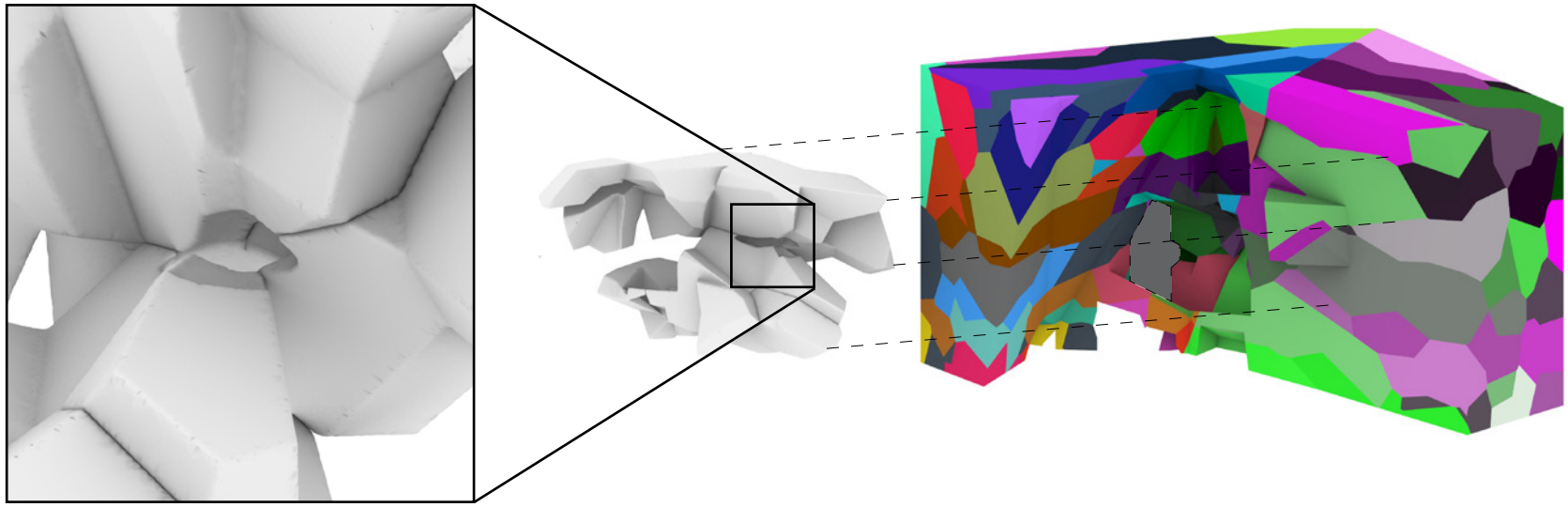


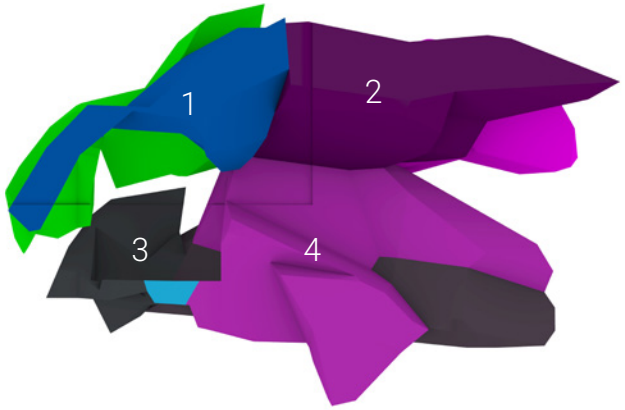
ODYN, RAVEN | SAGA.dk

REAL-TIME MONITORING
REMOTE ADJUSTMENTS
INTELLIGENT AUTOMATION

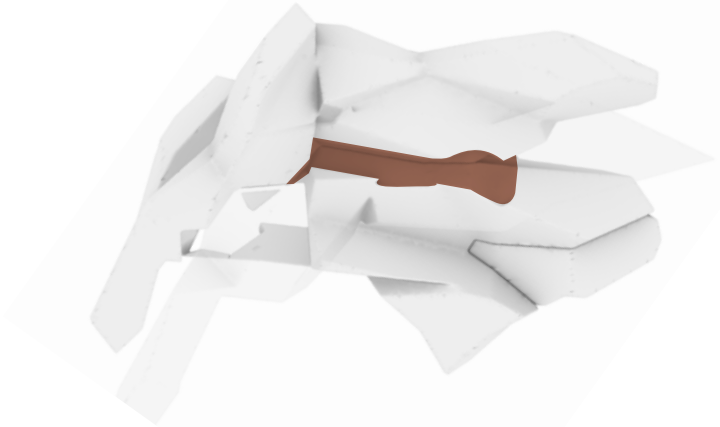

Selected Fragment

Integrated Pipe for Life support system

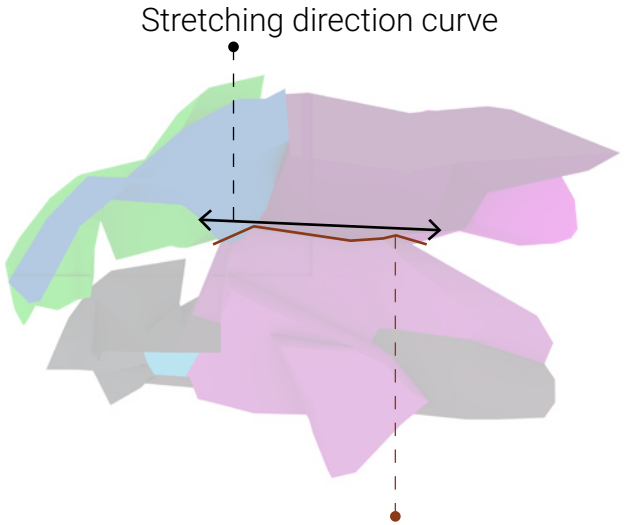




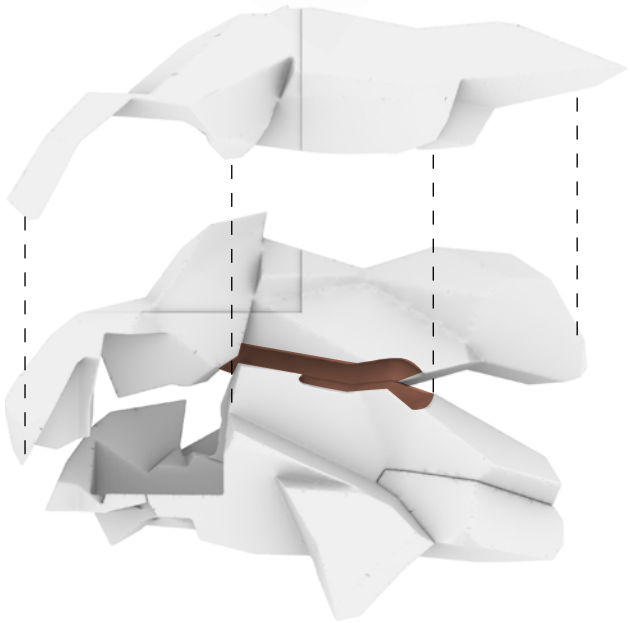
Isometric view : Selected 4 interlocking components



Top view : showing integrated pipe location



Isometric view : Set attribute curve for integrated LSS channel

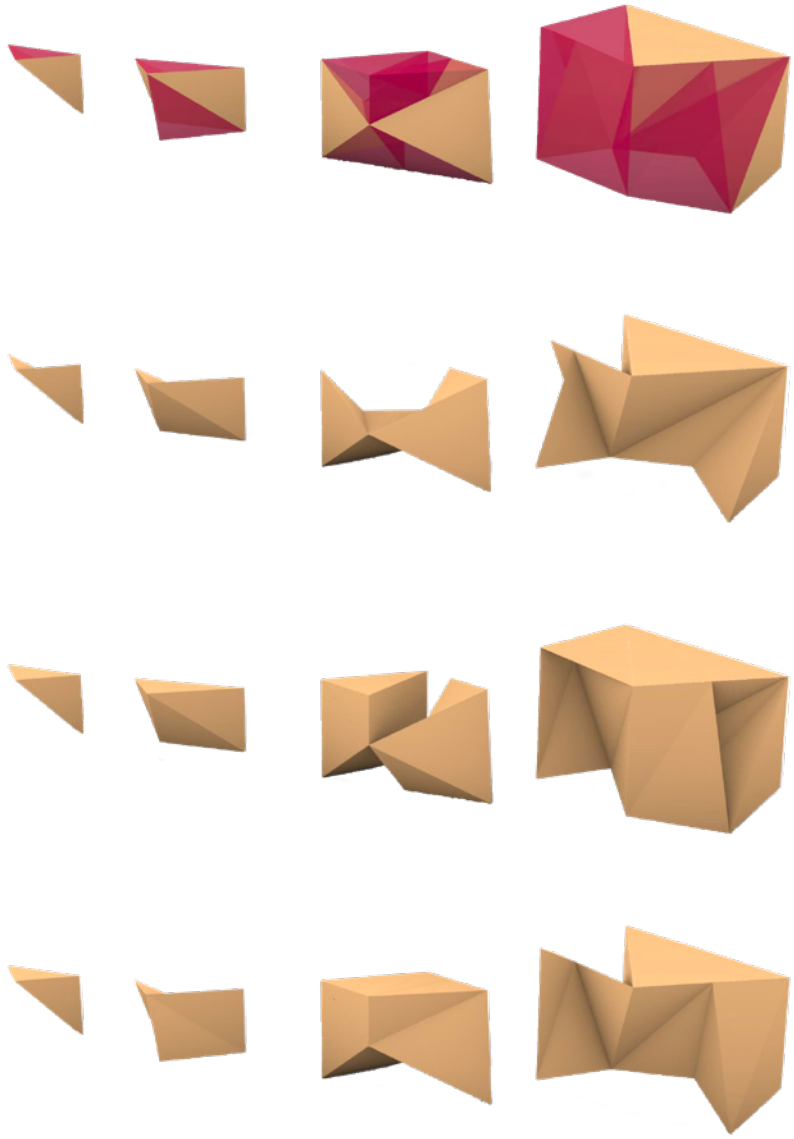


Exploded isometric view : showing integrated pipe location

Additive - Subtractive

Randomized

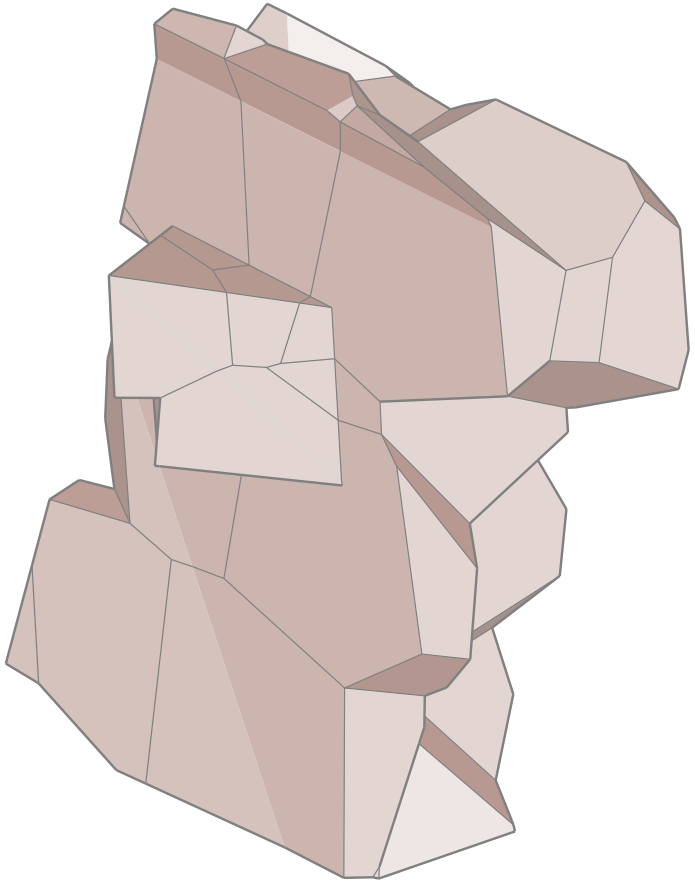
System

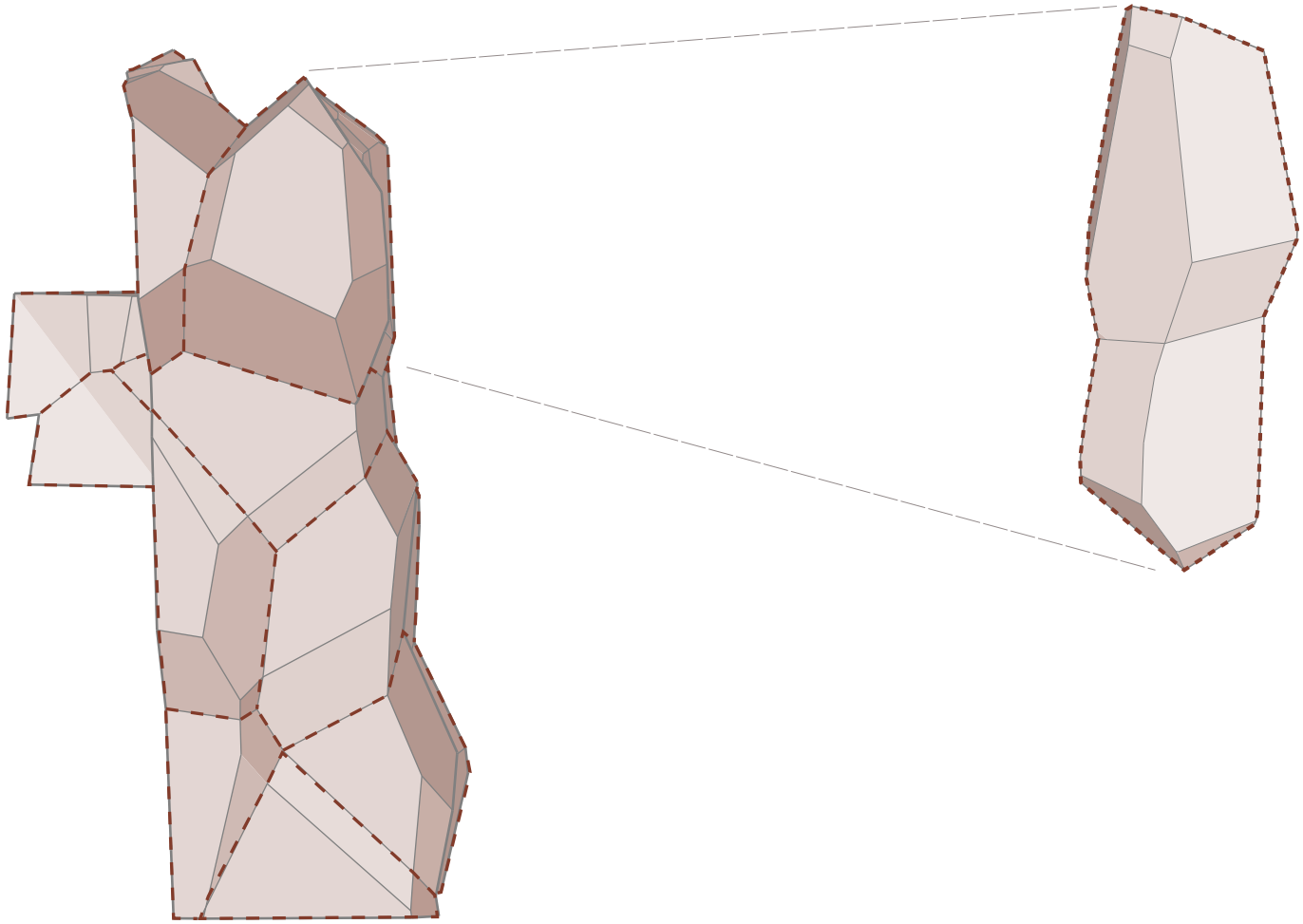


Additive - Subtractive

Randomized

System

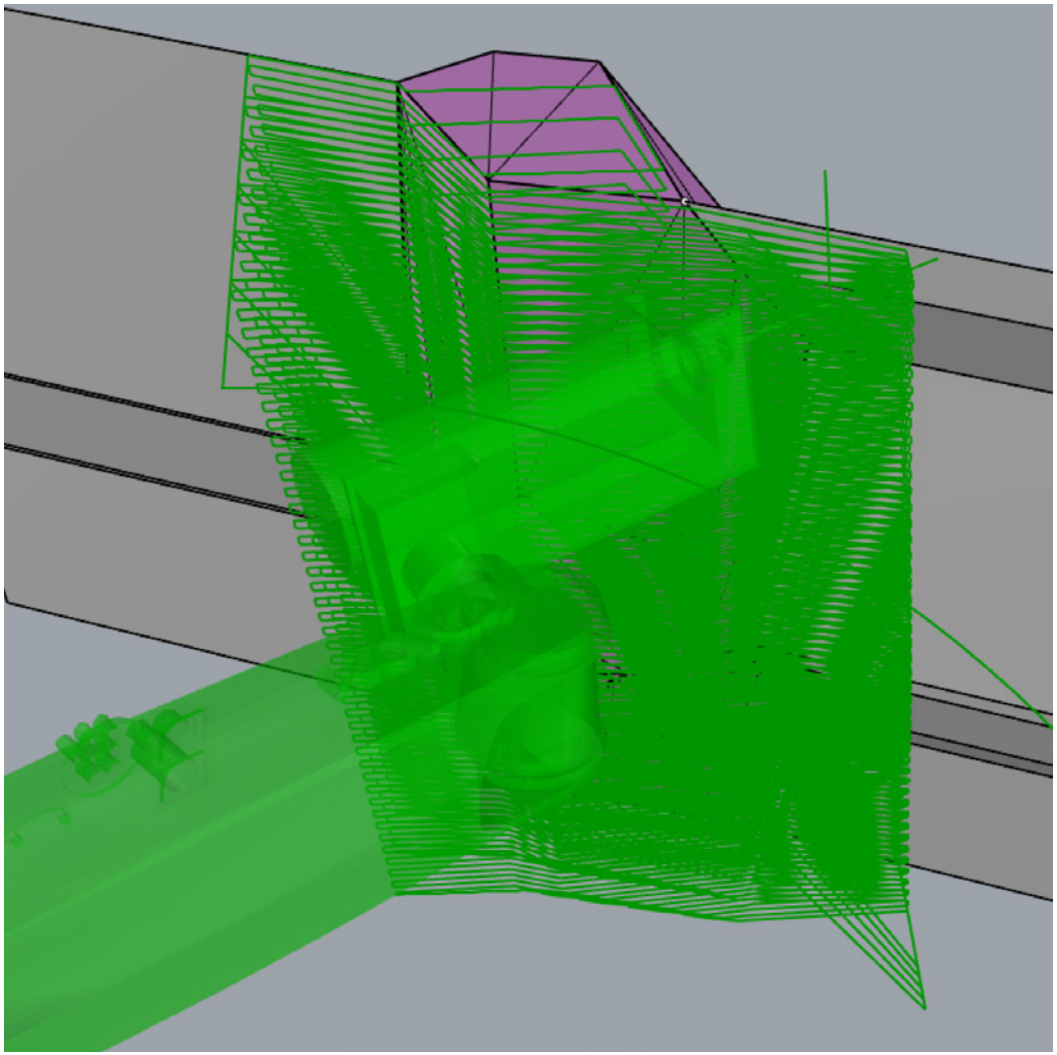




Extracted Structural Element

Ready for excavation and relocation

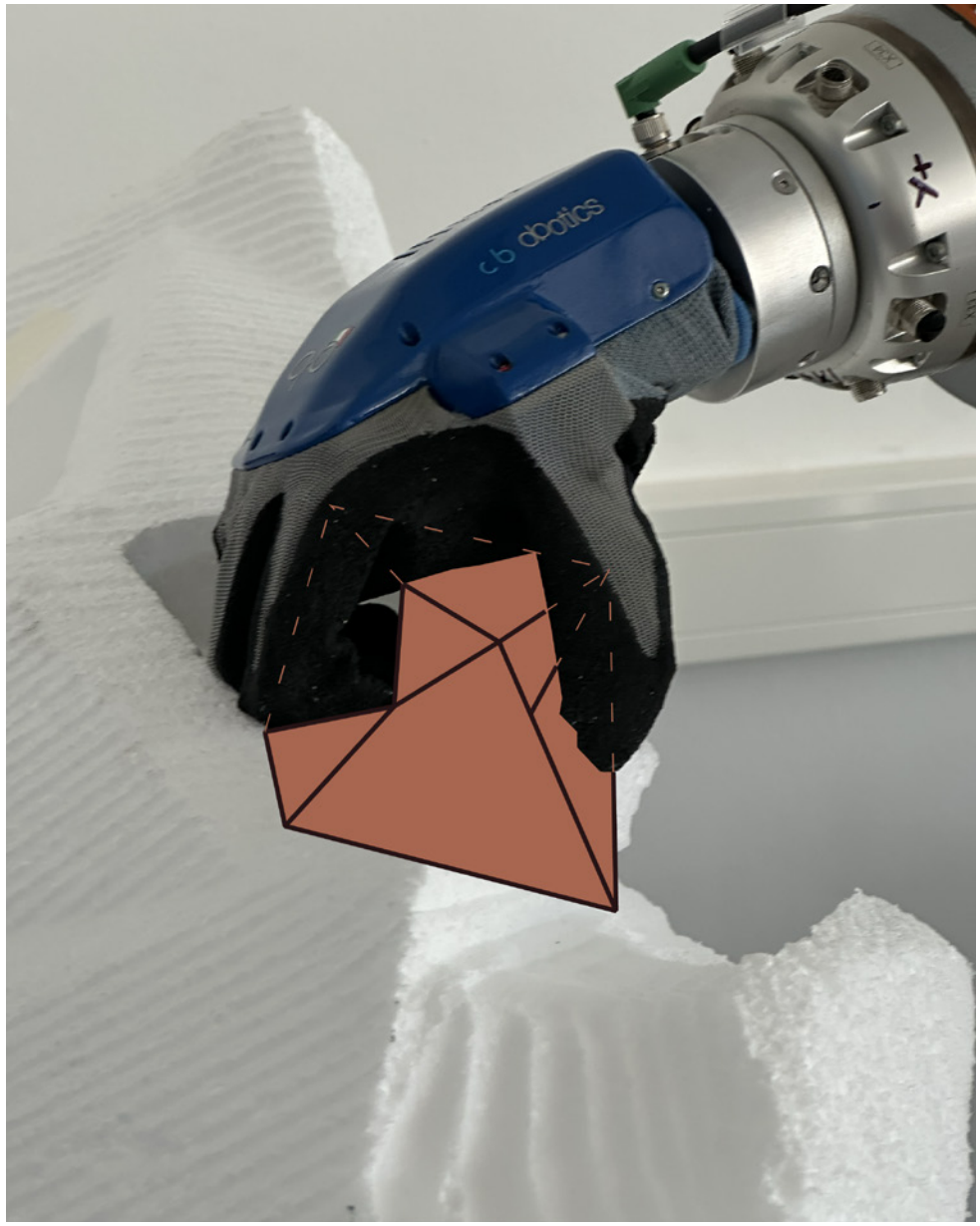
Milling path for prototype

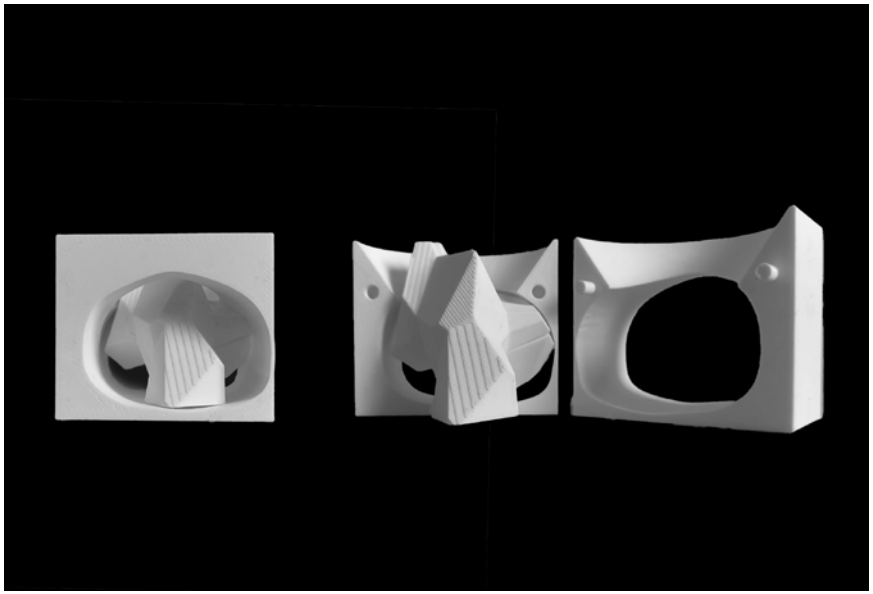


Bouldering Rocks

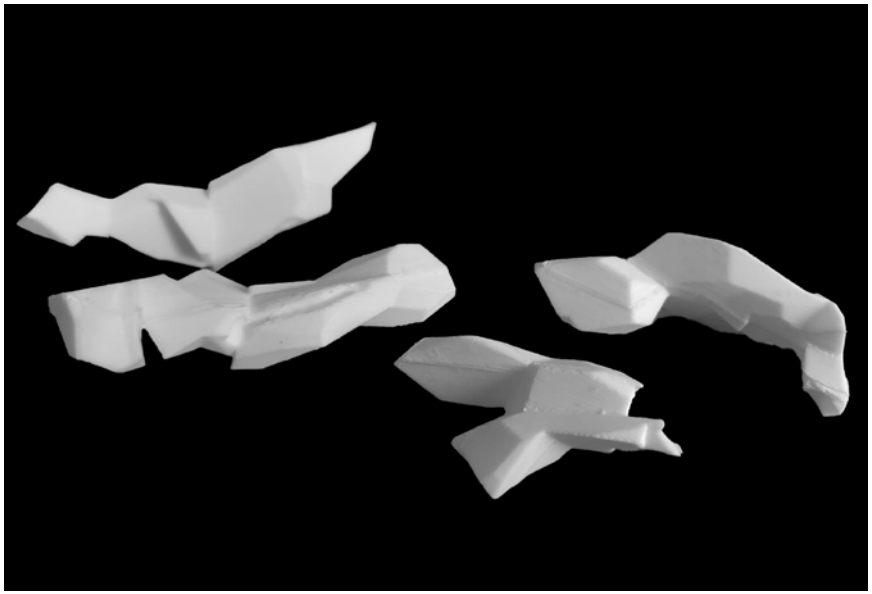
Suitable for Both

Human and Machine

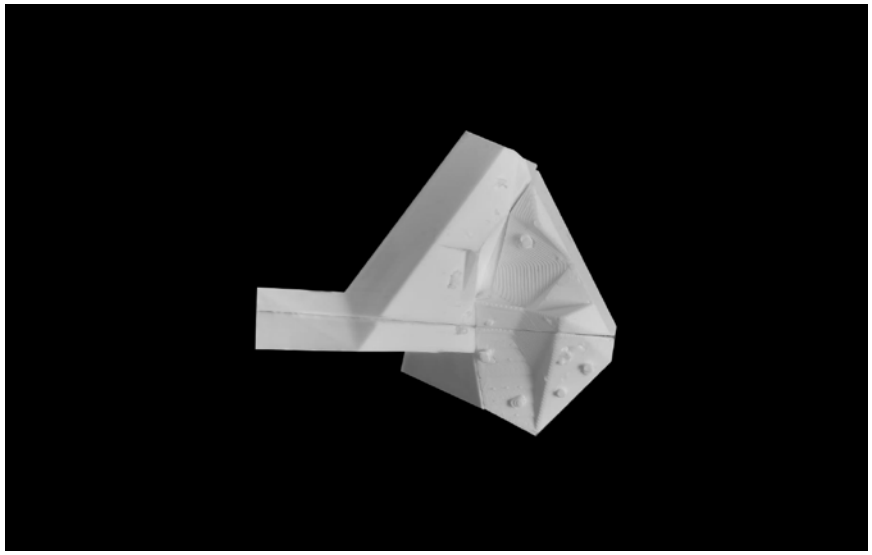




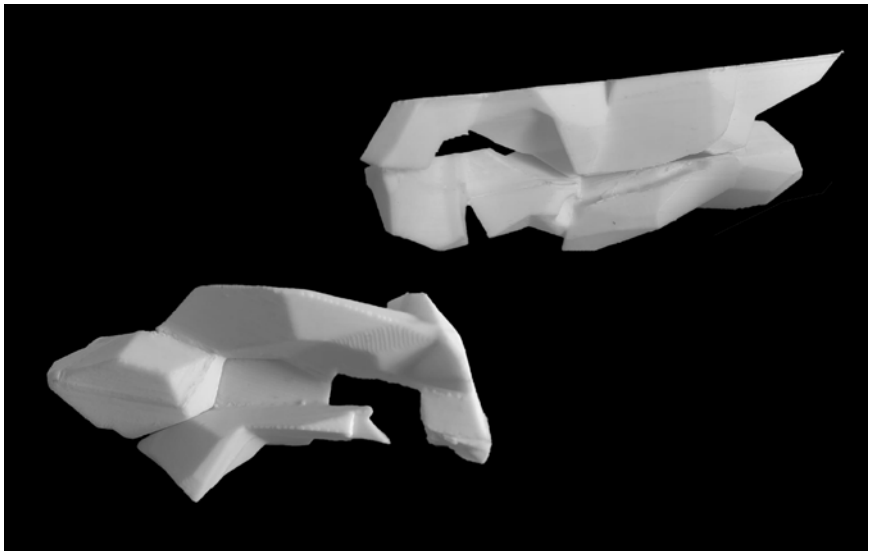
Physical model : Submartian inside of the lava tube



Physical model : 4 interlocking fragments



Physical model : Fragment with seat and bouldering area



Physical model : Fragments with integrated LSS channel

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