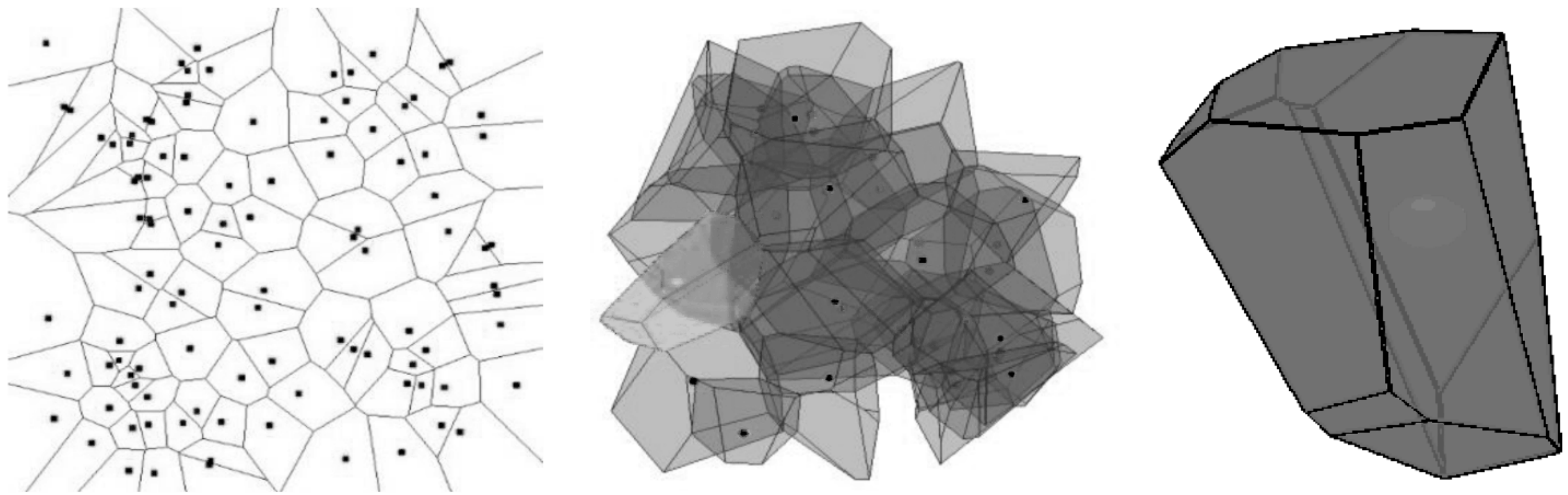
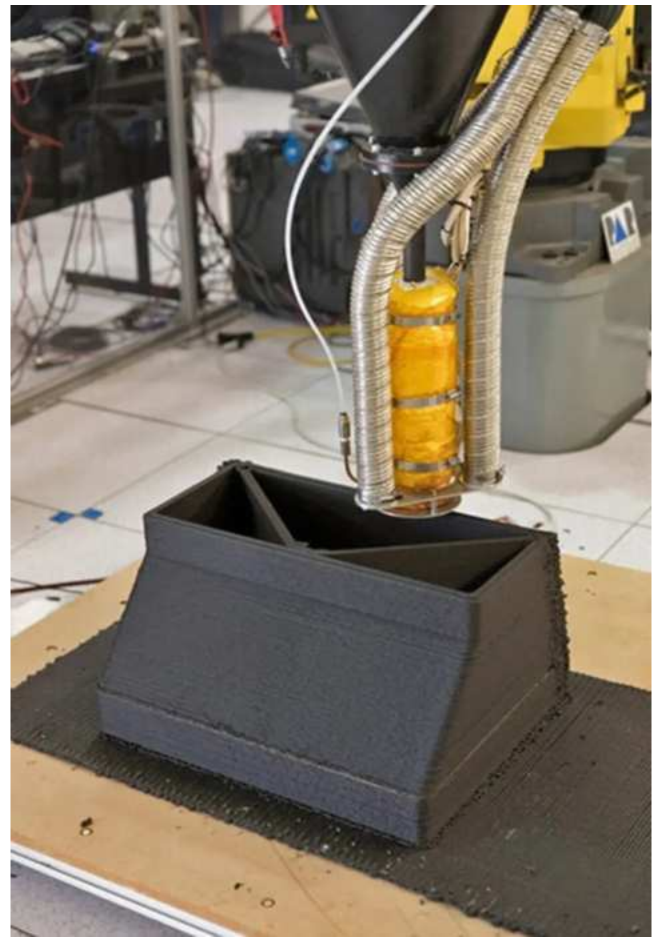
MOON HABITAT

Catalina Persunaru
Jan Kwasnik
Katarzyna Prokopiuk
Marina Kathidjiotis

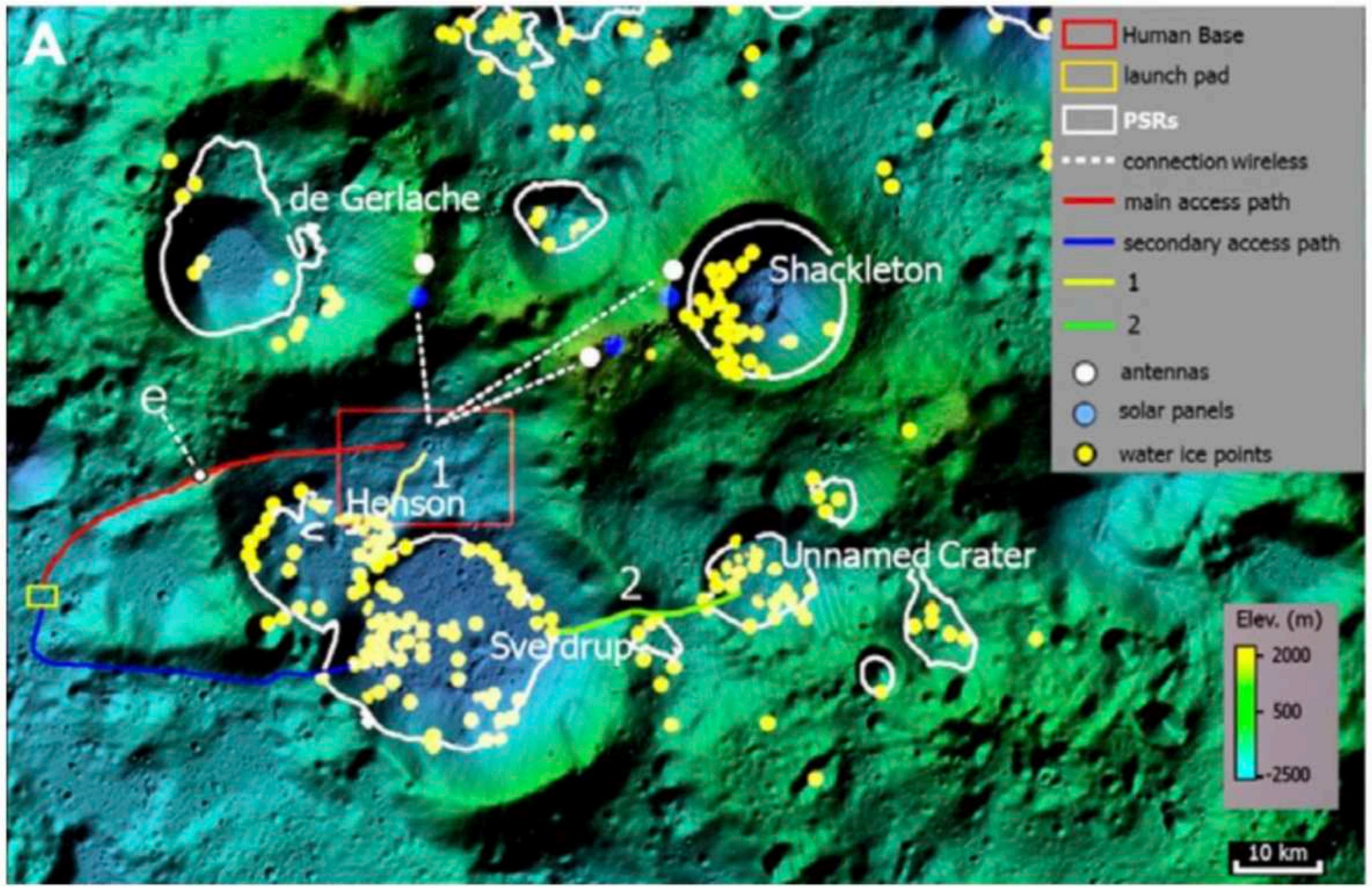
SCHEME



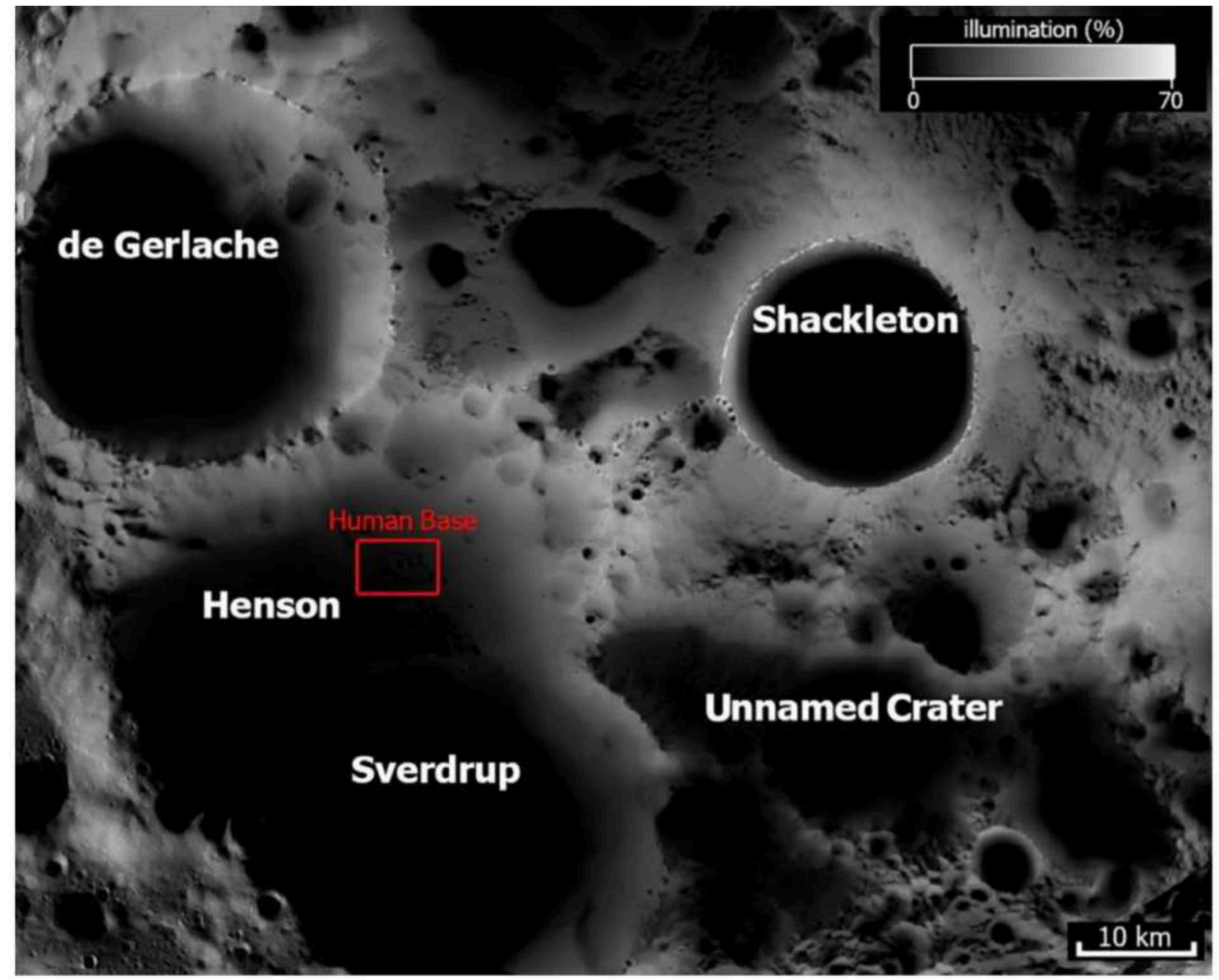
VORONOI PRINCIPLES



IN SITU MANUFACTURING

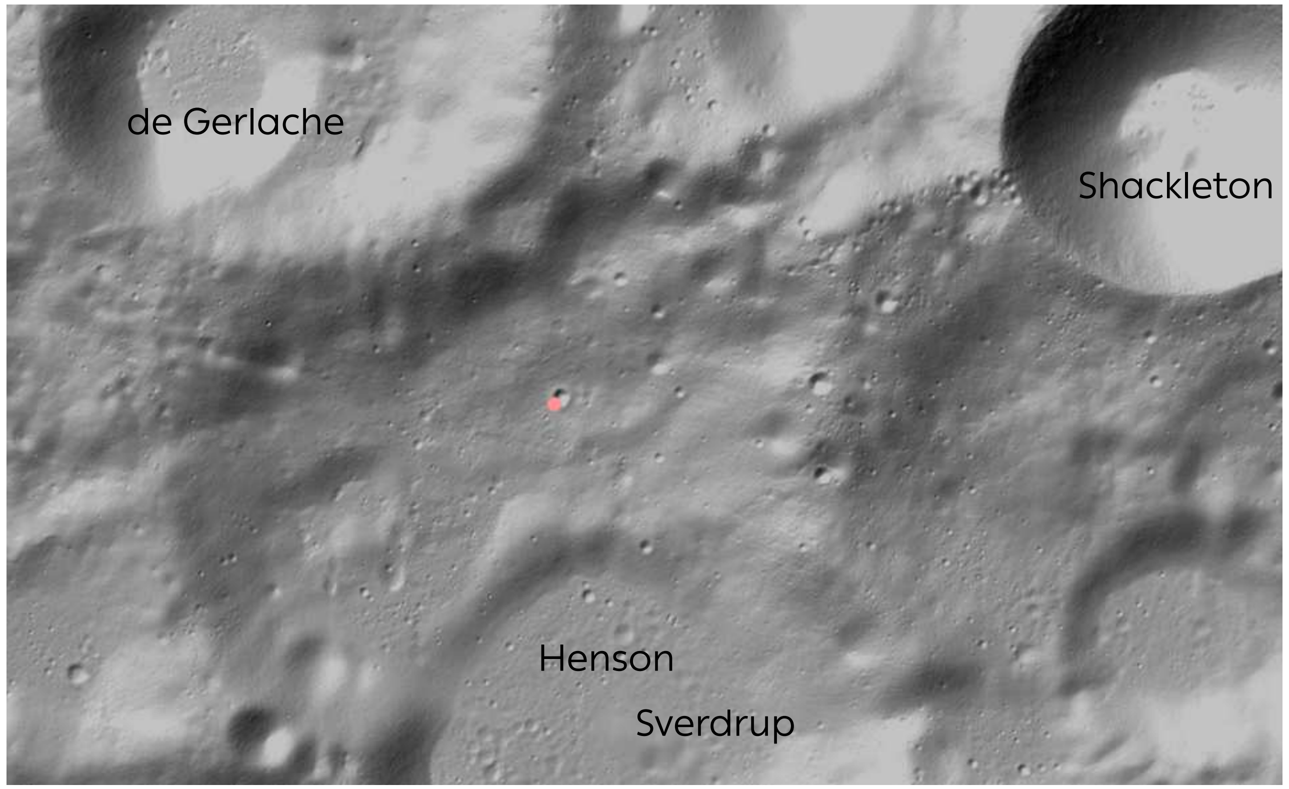


The chosen location on the lunar South Pole: multiple water ice points, variable resources, (semi) continuous visibility of Earth, constant daylight

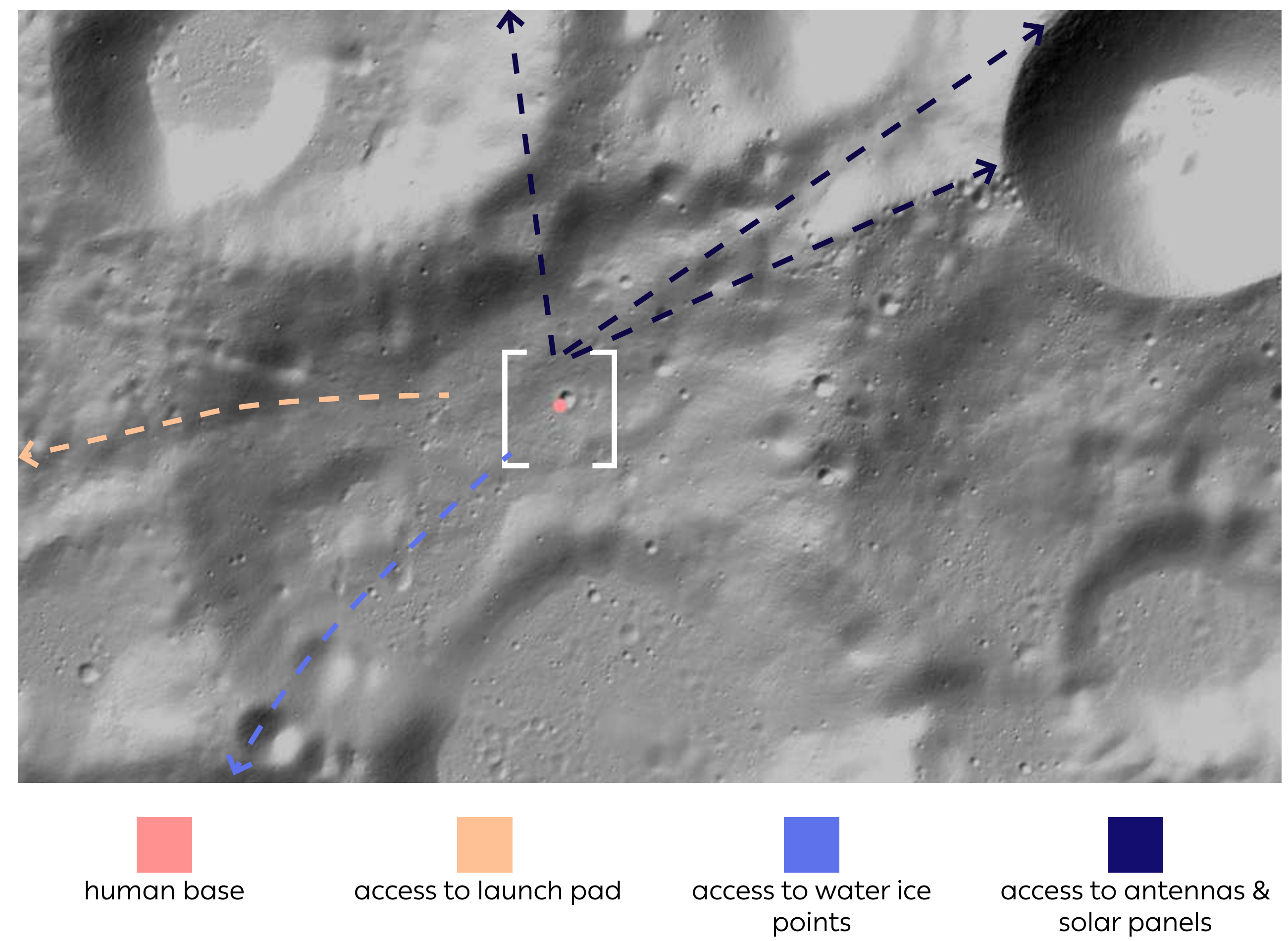


Optimal sunlight exposure – possibility of power generation without excessive radiation

SITE SELECTION



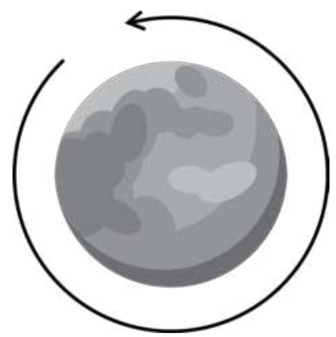
The chosen location on the lunar South Pole: multiple water ice points, variable resources, (semi) continuous visibility of Earth, constant daylight



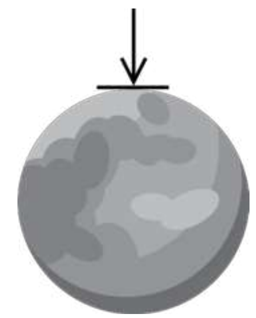
Optimal sunlight exposure – possibility of power generation without excessive radiation

SITE SELECTION

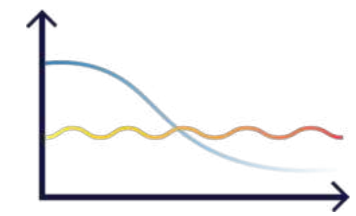
MACRO



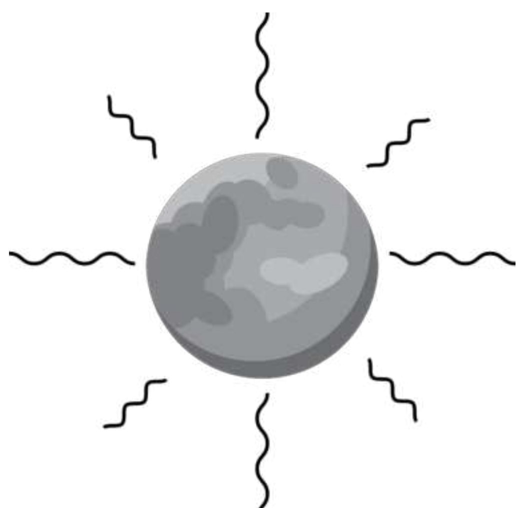
One lunar day is equivalent to
29.53 Earth days



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

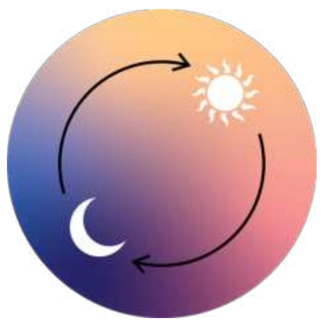


Ionizing radiation from cosmic rays is
200 times more than on Earth’s surface

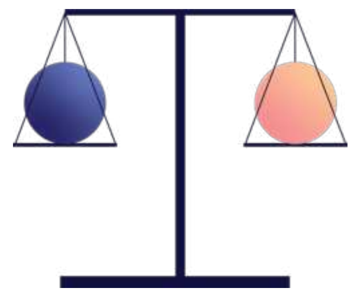
A permanent dust cloud exists around
the Moon that sticks to the suits of the
astronauts. If carried in their quarters
while it can cause health issues

The Moon’s atmosphere is nearly

CONTEXT ANALYSIS

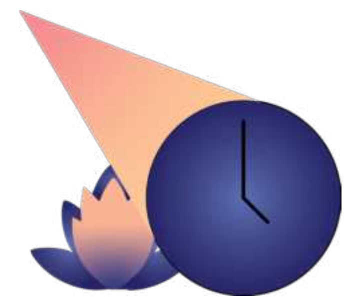


They prepare our bodies for expected changes in the environment.



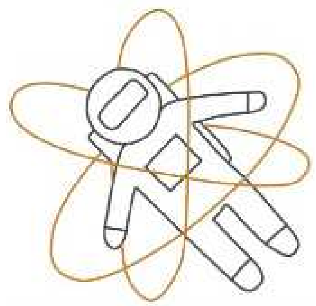
Darkness at night is as important as brightness during the day.

It is important to have a variety of stimuli

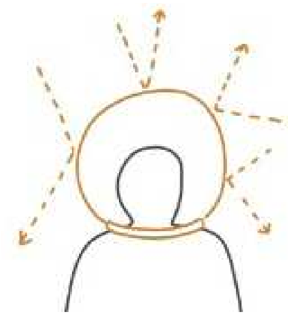


Bright light regulates hormones production and sleep-wake cycles.

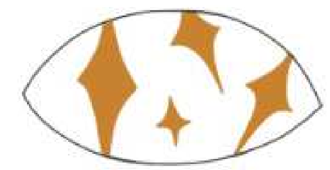
CIRCADIAN RYTHMS



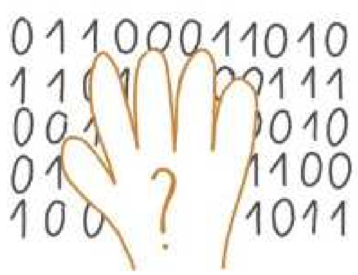
Multiple aspects that cause changes in circadian rhythms.



Senses become numb because of monotonous stimuli.

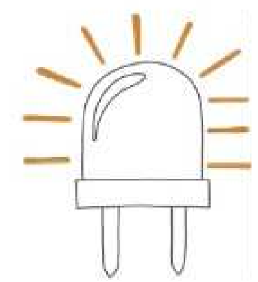


Ionizing radiation can cause visible flashes of light.



Human factor is the biggest unknown in space.

Astronauts need to get enough sleep.



Space infrastructures mostly use artificial LED lights.

PSYCHOLOGICAL EFFECTS OF SPENDING TIME IN SPACE

- 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.

MAINTAINING CIRCADIAN RHYTHMS FOR MENTAL WELLBEING

Current Uses of AR/VR in Space:

- Robot Operation: Utilizing AR/VR for remote robot operation in space missions.
- Exercise (Cycling): Incorporating VR cycling for astronaut exercise routines.
- Maintenance Assistance: AR/VR aiding astronauts in space station maintenance tasks.
- Observing Perception of Time and Space: Studying crew members' perception of time and space using AR/VR.
- Documenting Life in Space: Capturing and sharing life in space experiences with AR/VR for Earth audiences.
- Research on Movement in Microgravity: Studying movement dynamics in microgravity environments through AR/VR simulations.

Therapeutic Effects of VR:

- Contact with nature simulations through VR has demonstrated significantly higher therapeutic effects compared to 2D HD TV screens (Yeo et al., 2020).

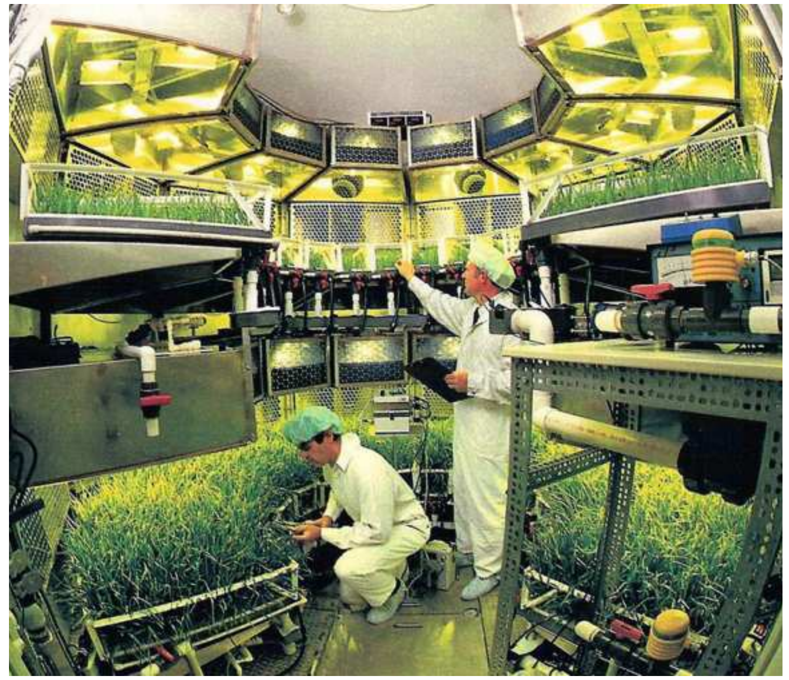
CAVE VR for Group Immersion:

- CAVE VR technology enables multiple users to experience immersive environments simultaneously.
- User's head and hands movements are tracked to synchronize with 3D immersive images projected in the CAVE space.
- As users move within the CAVE, the 3D images update, providing a dynamic and interactive virtual world experience.

VR TECHNOLOGIES

- 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).

Credit: NASA



Credit: Green Sense Farms Holding Inc.

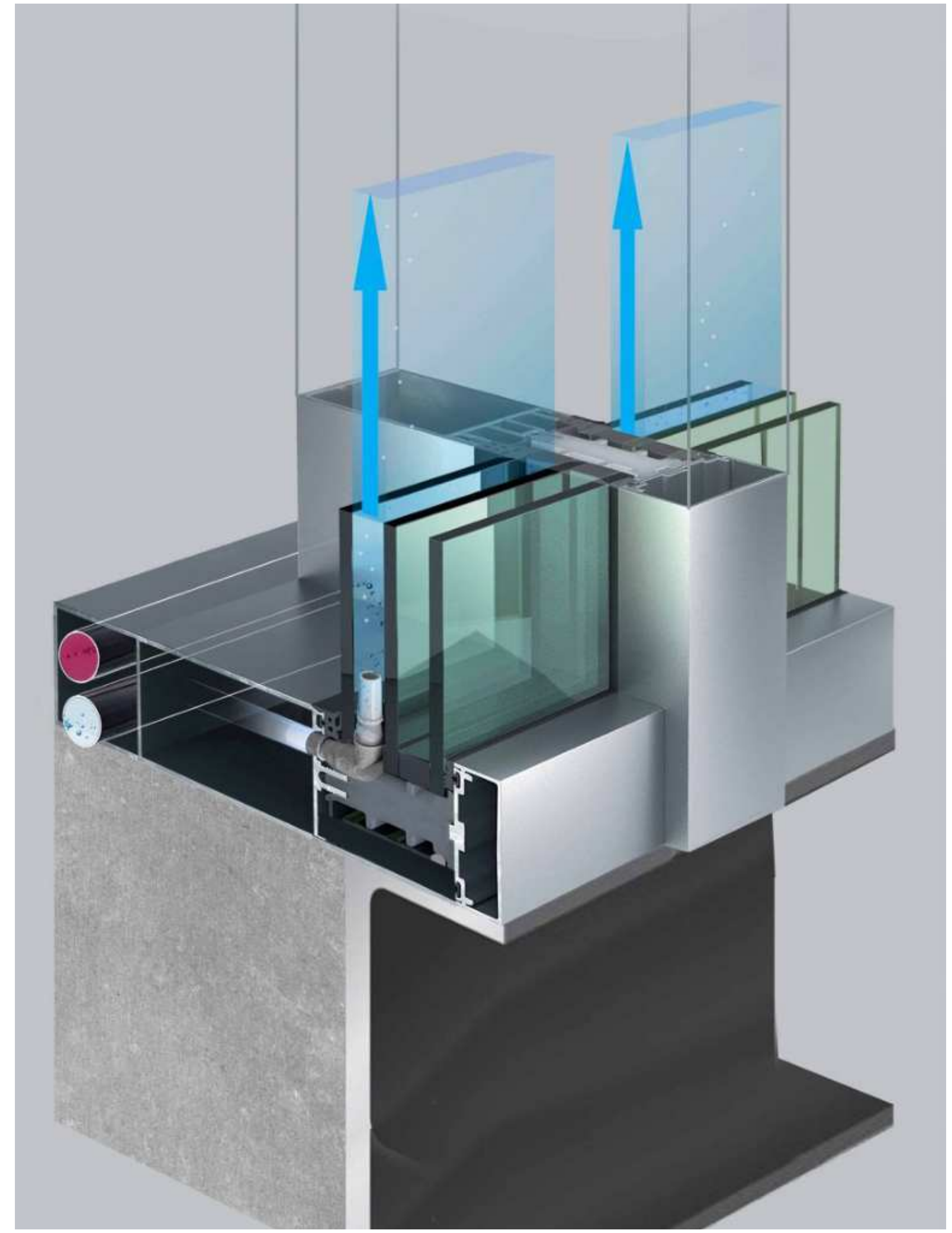
Credit: Plenty Unlimited Inc.

SELF-SUFFICIENCY ON THE MOON

- 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.

Credit: VoxelMatters



Credit: https://www.waterfilledglass.com/

MAIN CHALLENGE - RADIATION

-Entrance space

-Emergency exits

-Sleeping rooms(6 x 10m2)
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.

-Common Room (58m2)
Multifunctional space for food preparation and consumption + a hub for social interaction

-Food production (50m2)

-Control Room (Environmental Control and Life Support System) (46m2)
Space to host complex control equipment for maintaining the internal environment of the Habitat.

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

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

-Observatory (50m2)

-Rover Hub (40m2)
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

-3D printing room (30m2)
should be accessed from both inside and outside

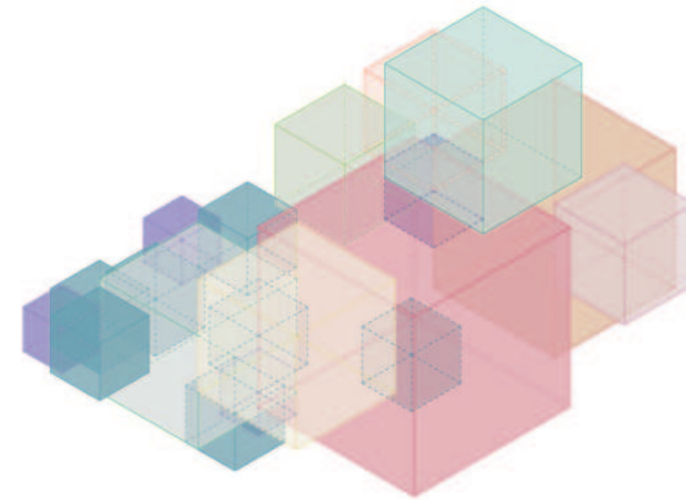
-Meditation room with VR+AR (20m2)
should be accessed from both inside and outside

-Unisex toilets + bathrooms + medical care (38m2)
Combined units

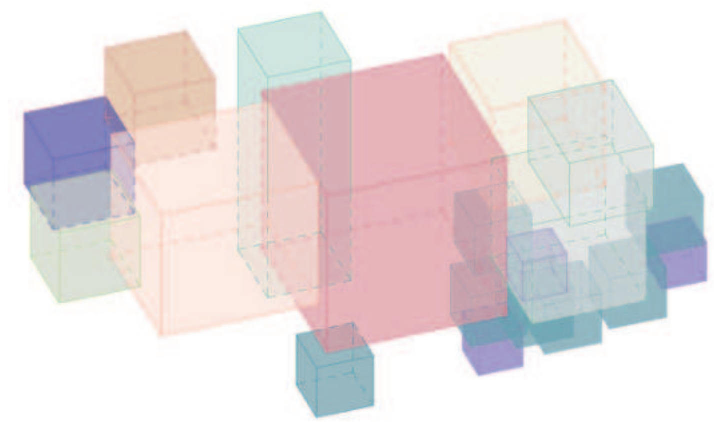
-Lounge (40m2)

-Computer room (25m2)
A place filled with computers which store the information gatehered there and help you communicate with the people on Earth

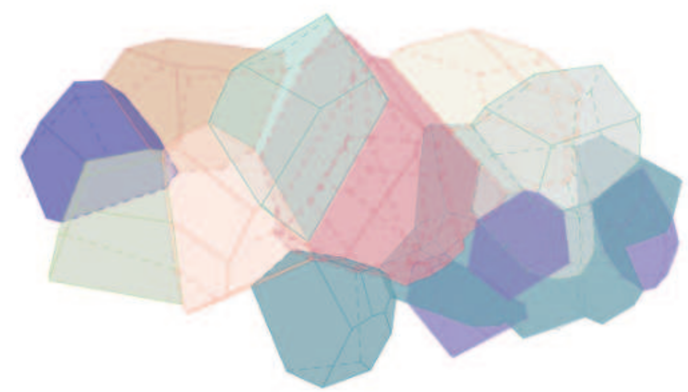
note*: the program in bold was added in the next iteration



1. The program of the building and its correspondent area are arranged

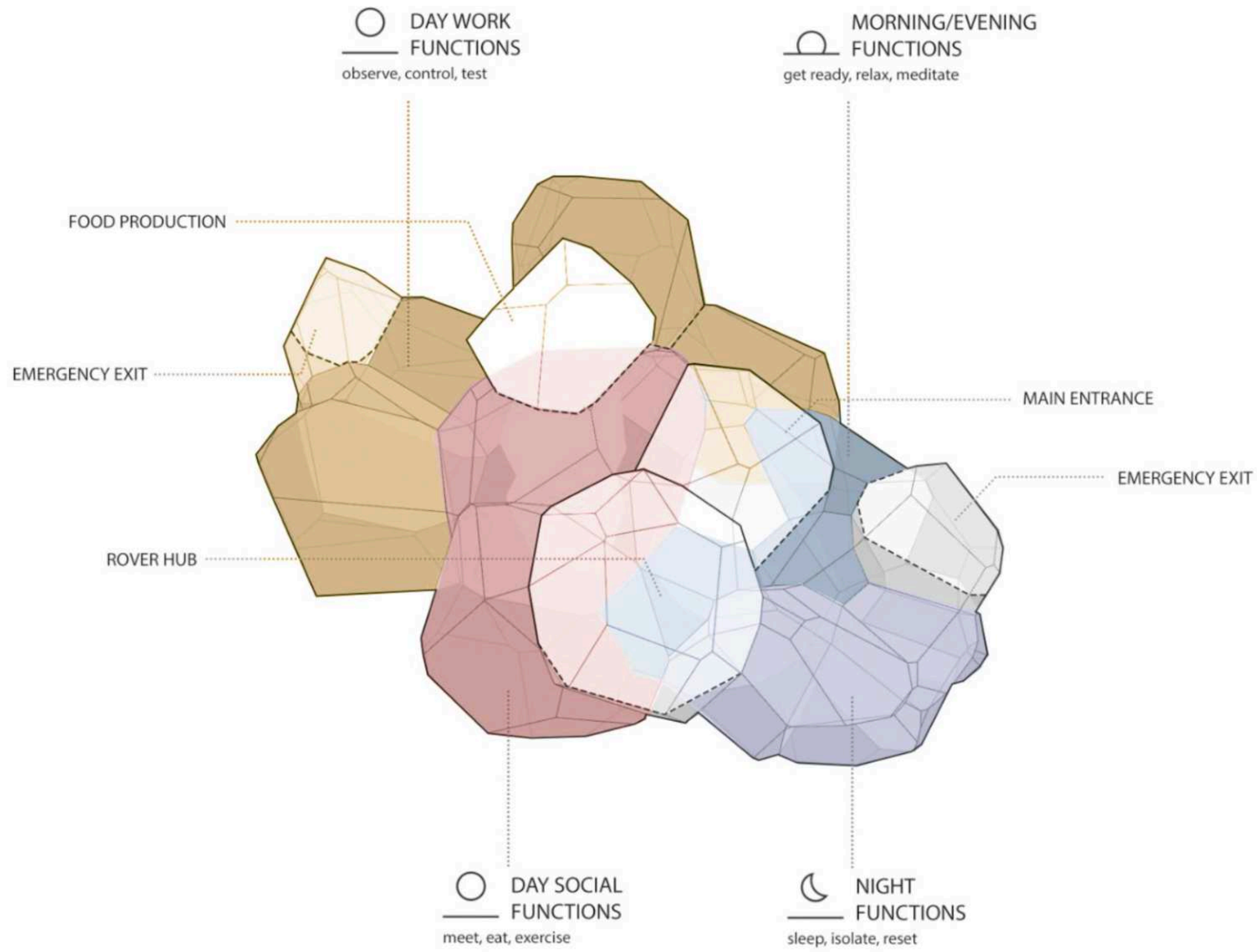


2. The volumes' position in plan and section is rearranged according to the site.



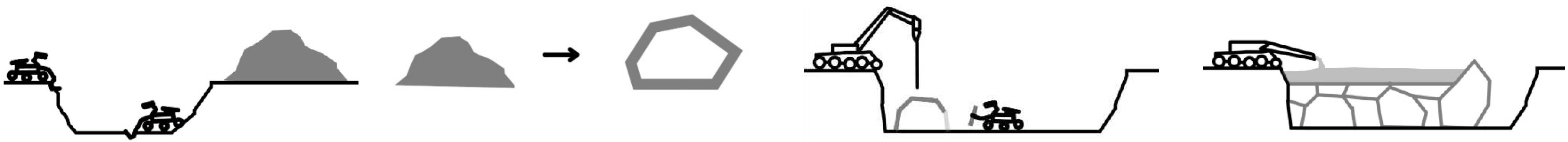
3. The reference cubes are transformed into voronoi volumes.

PROGRAM



Our project explores the idea of circadian rhythms in relation to spending time in space. The design follows the idea of creating spaces in the building which help to maintain a healthy internal clock. This effect is achieved through zoning the station into parts dedicated to activities usually associated with specific parts of the day.

SIMULATING THE EARTH DAY CYCLE



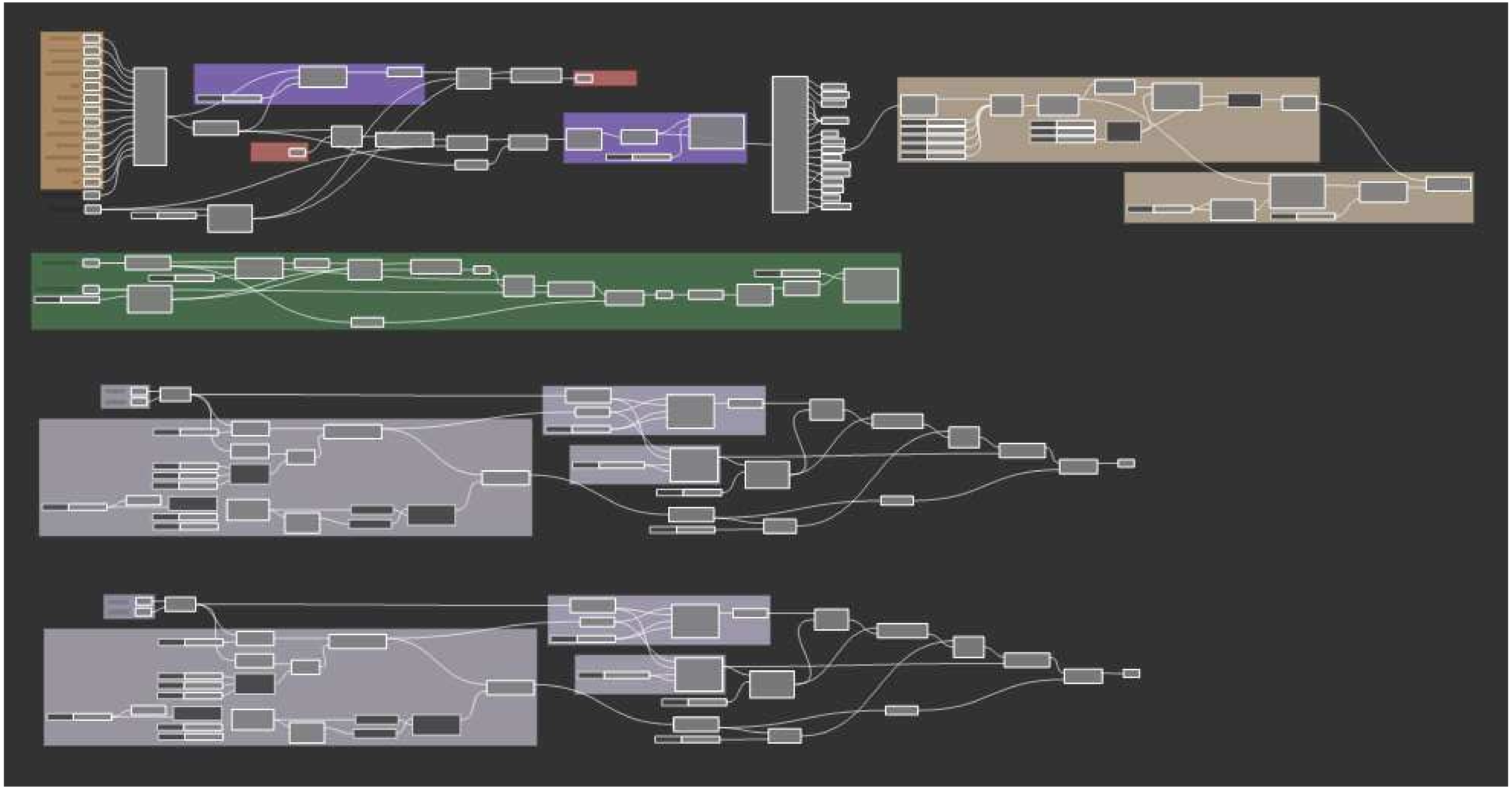
1. Excavation of the site

2. using the excavated soil for additive manufacturing

3. in-situ assembly

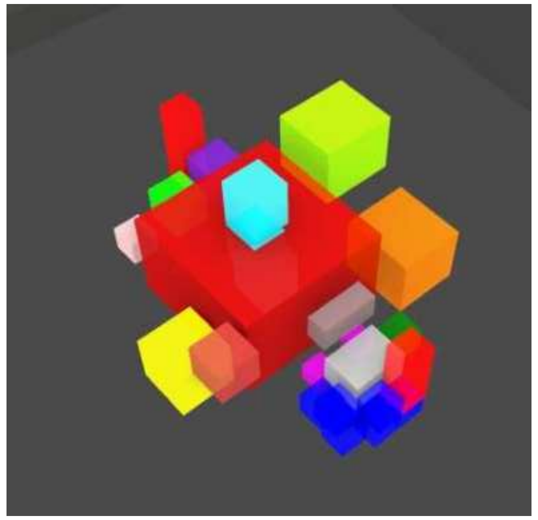
4. remaining soil as protective layer on top of living spaces

ASSEMBLY CONCEPT



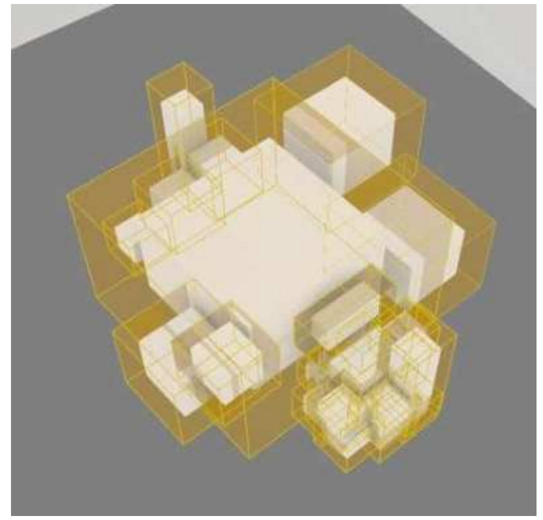
THE ALGORITHM

1



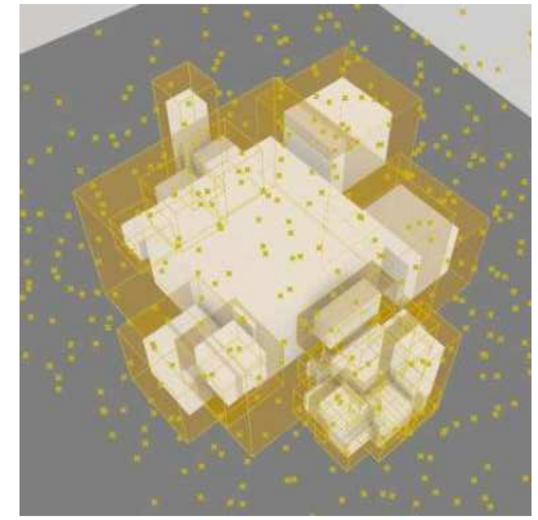
Input: boxes representing each function

2



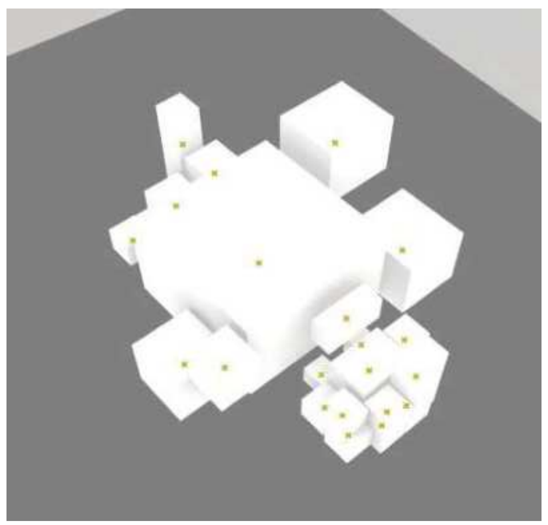
Offset the volumes to restrict possible points

3



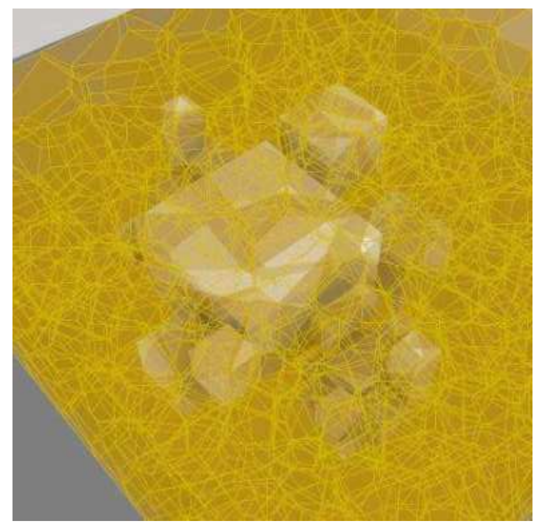
Populate box with points outside offset volumes

4



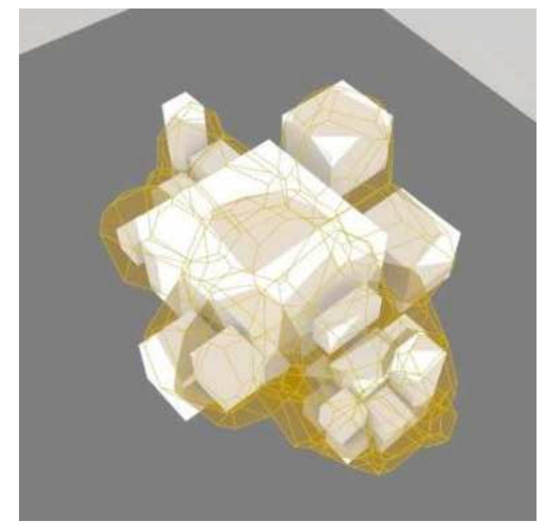
Find centers of each box and merge with other points

5



Voronoi 3d

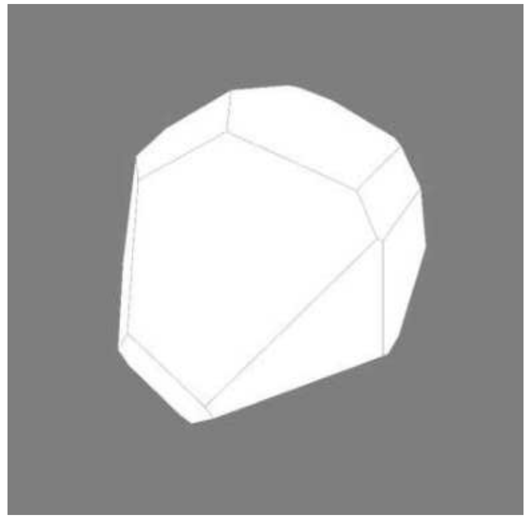
6



Select the cells with the same centers as the boxes

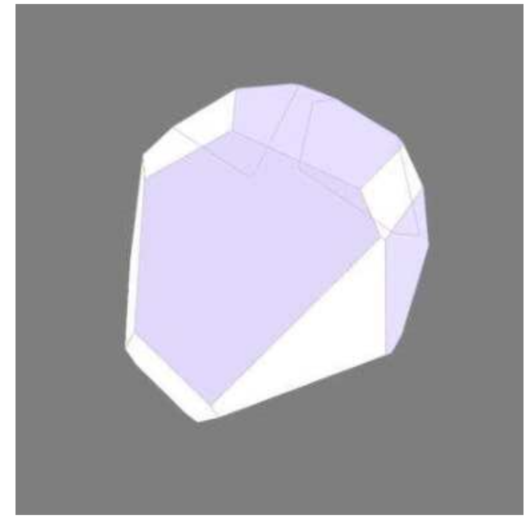
ALGORITHM - BUILDING

1



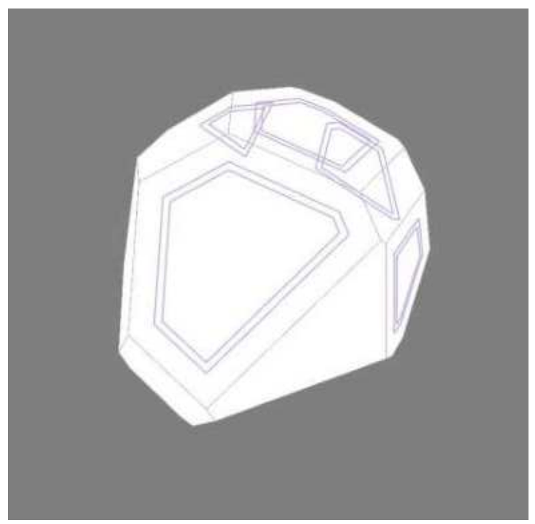
Input: selected cell representing the observatory

2



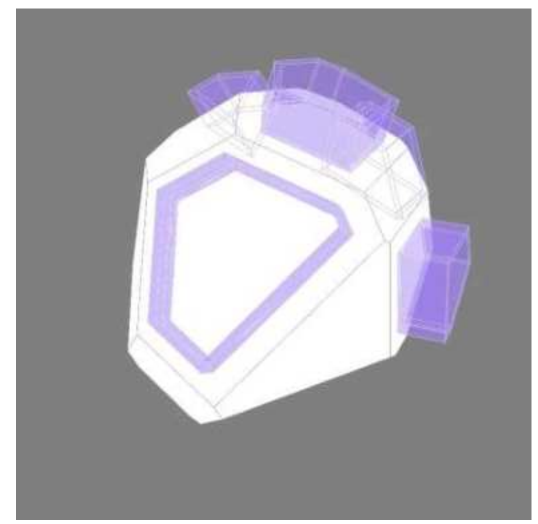
Select the faces that will have windows on them

3



Offset the edge curve of the surface twice to create thickness

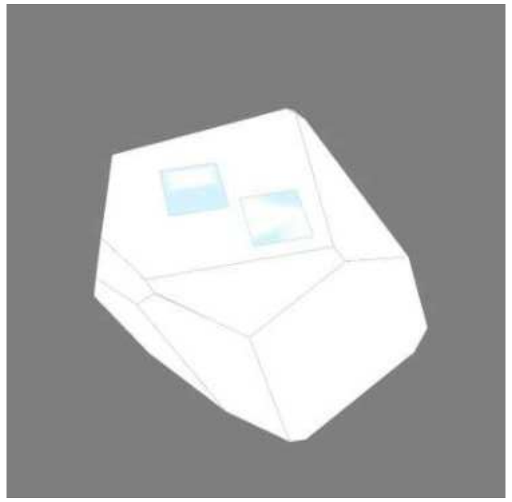
4



Loft the curves and extrude the surfaces to make window frames

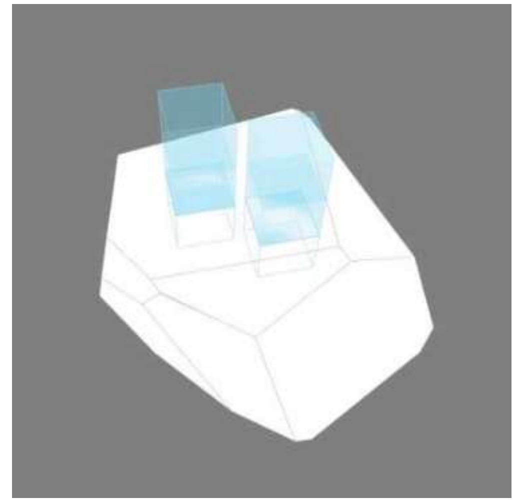
ALGORITHM - OBSERVATORY

1



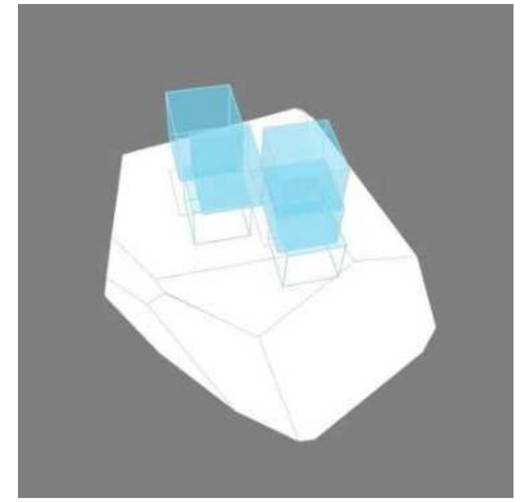
Input: rectangles drawn as the base of the skylight

2



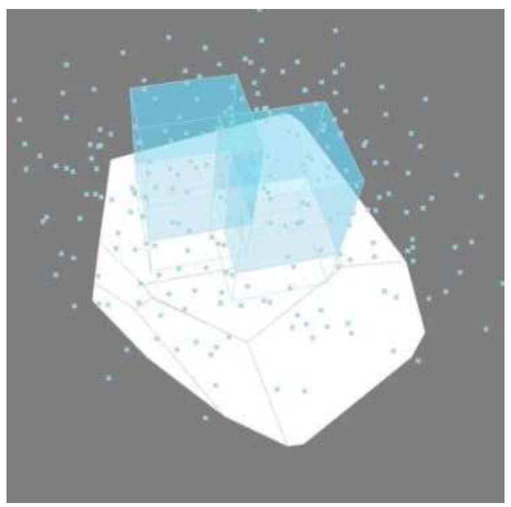
Three boxes on top of each other, one inside the cell

3



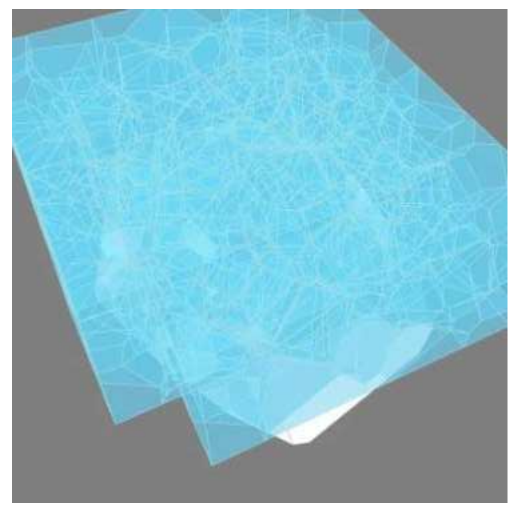
Slightly move the boxes by a random vector for irregularity

4



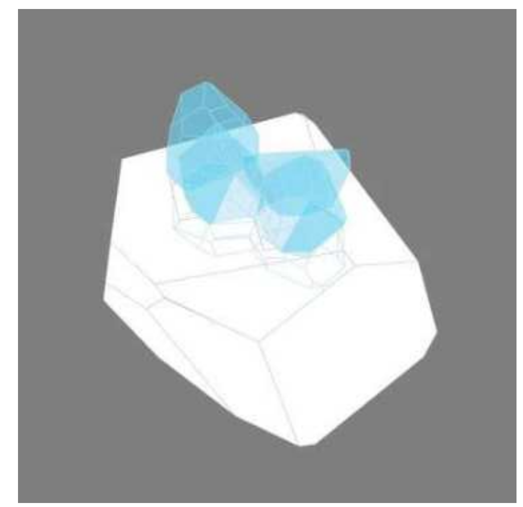
Offset the boxes and populate the volume outside of them

5



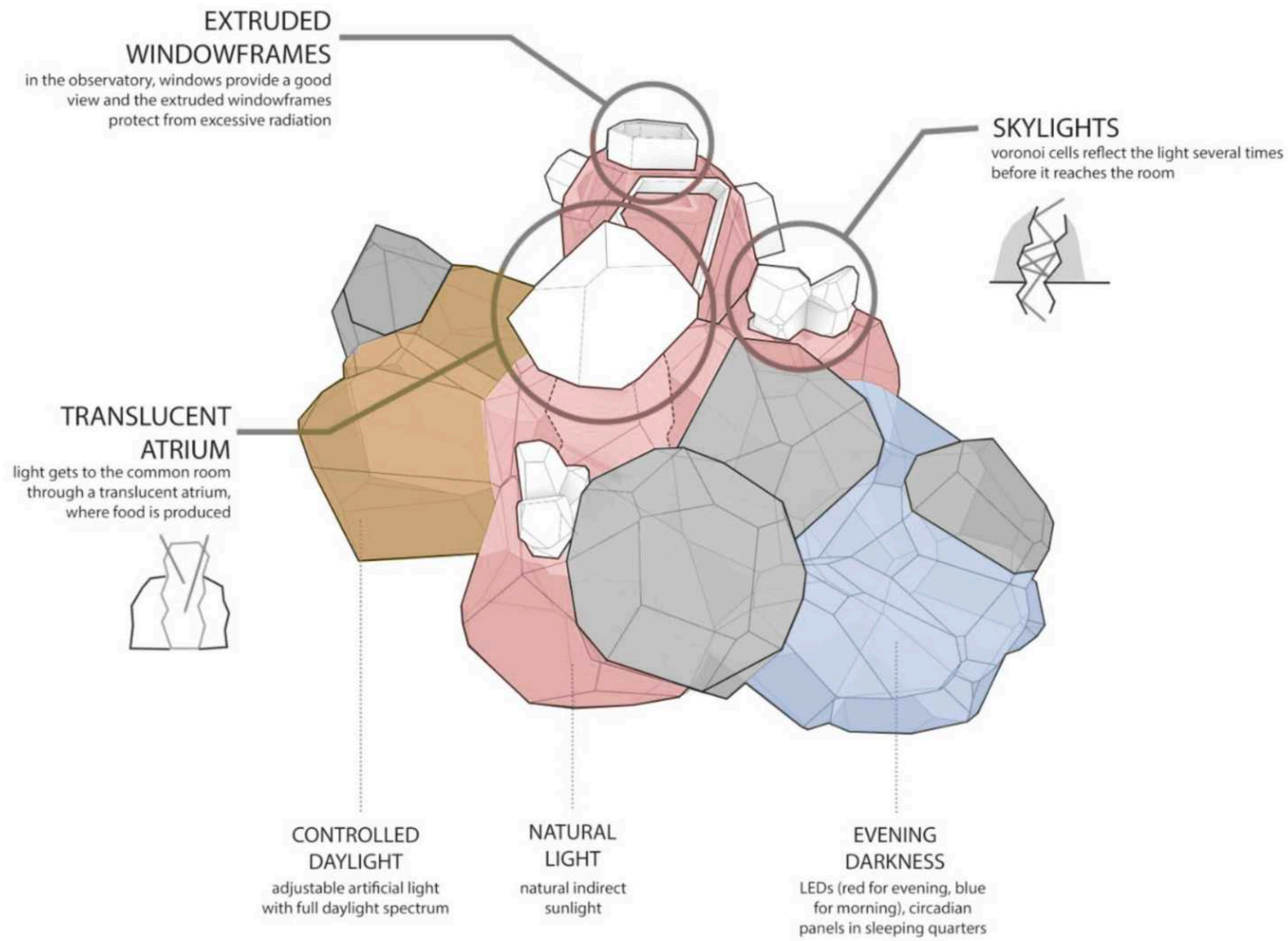
Voronoi 3d

6



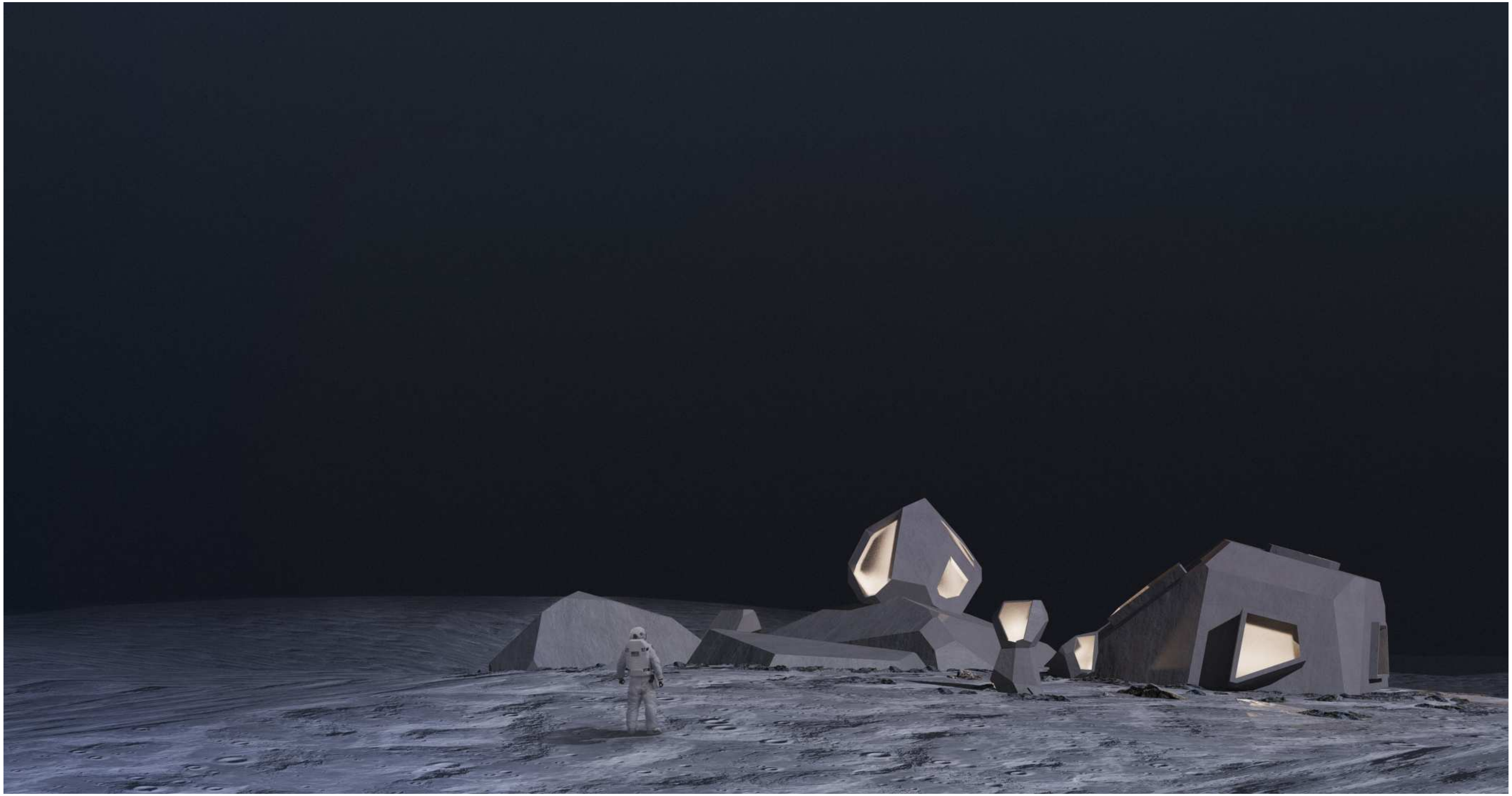
Select cells with the same centers as the initial boxes

ALGORITHM - SKYLIGHT

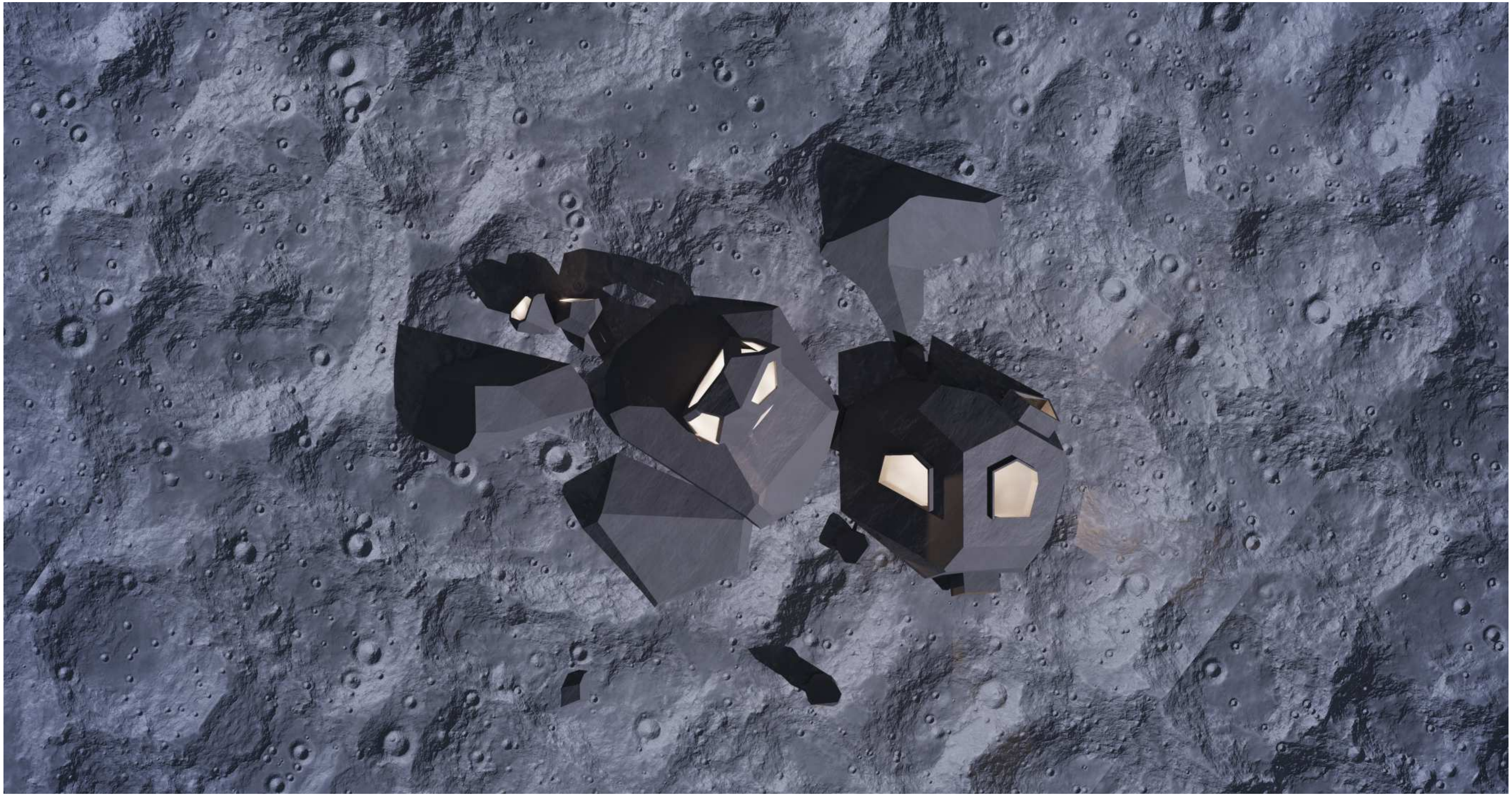


A factor that is crucial for maintaining the circadian rhythms is light. In the design, we implement various lighting strategies that simulate different times of the day. By combining guiding natural light with architectural elements and smart artificial lighting, the design breaks the monotony of outer space and helps the astronauts to stay healthy and rested.

LIGHTING STRATEGIES



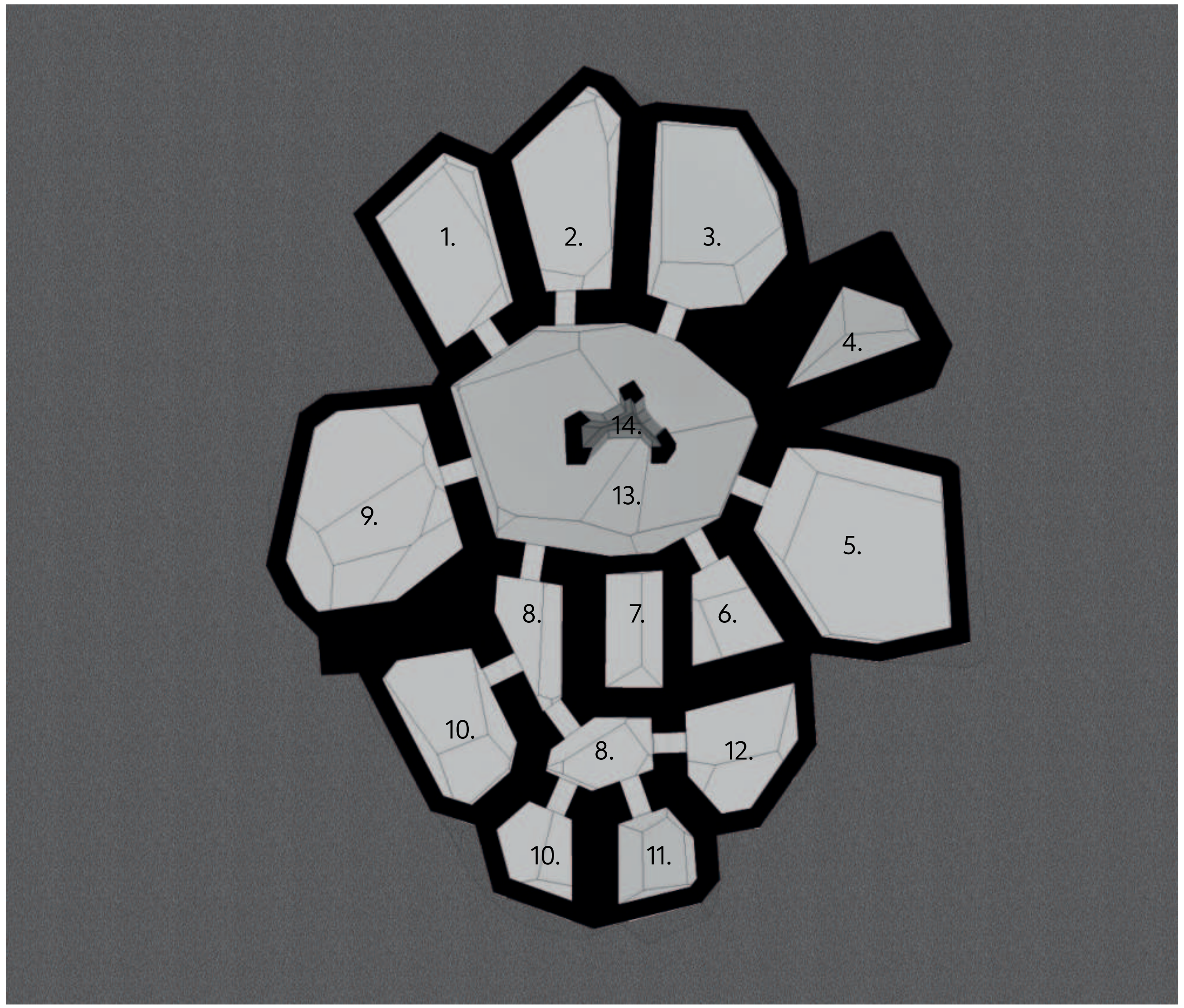
EXTERIOR VIEWS



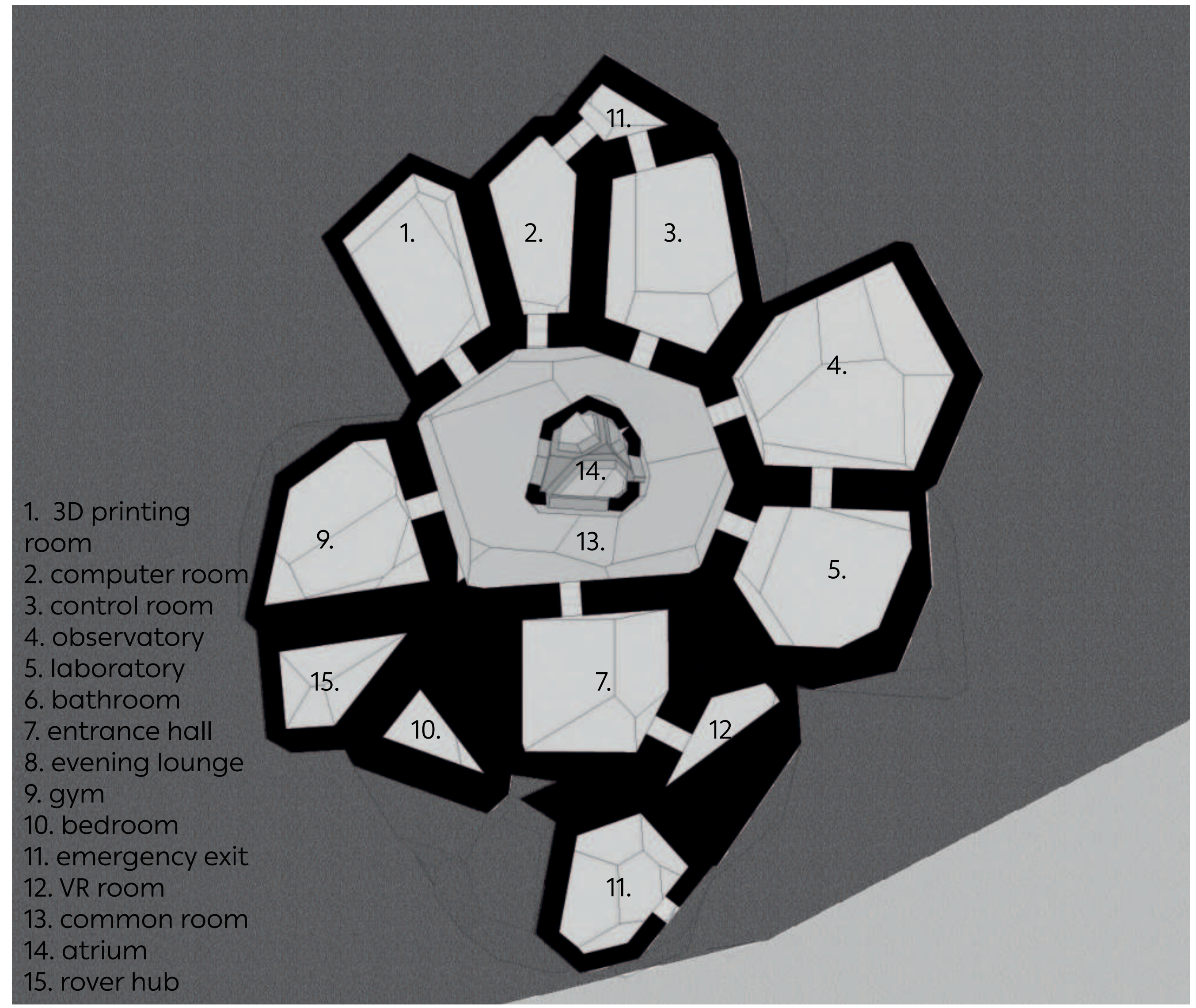
MASTERPLAN

HUMAN HABITAT IN RELATION TO THE CRATER

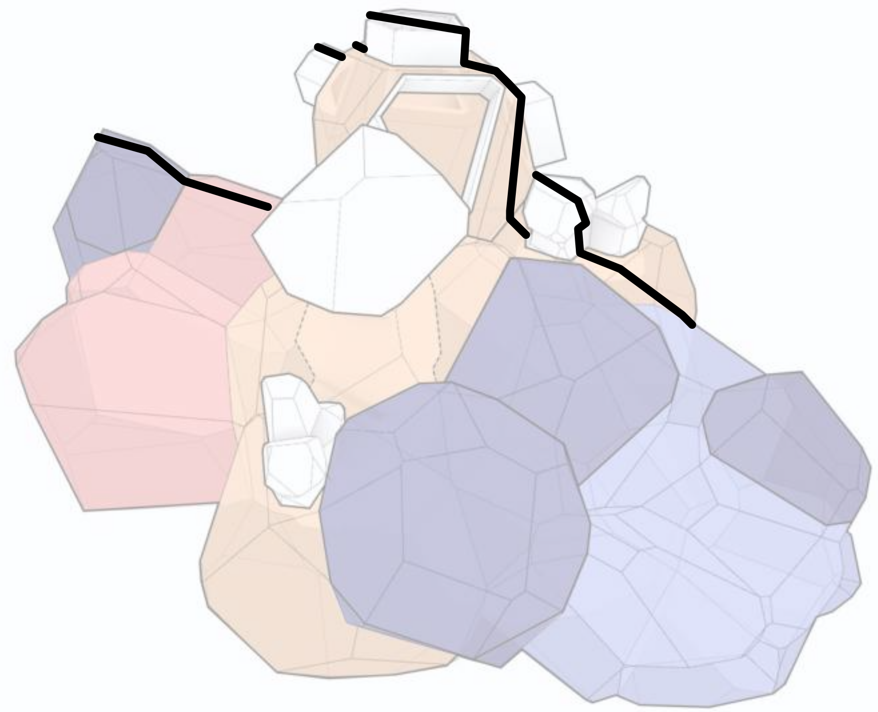
LEVEL -1



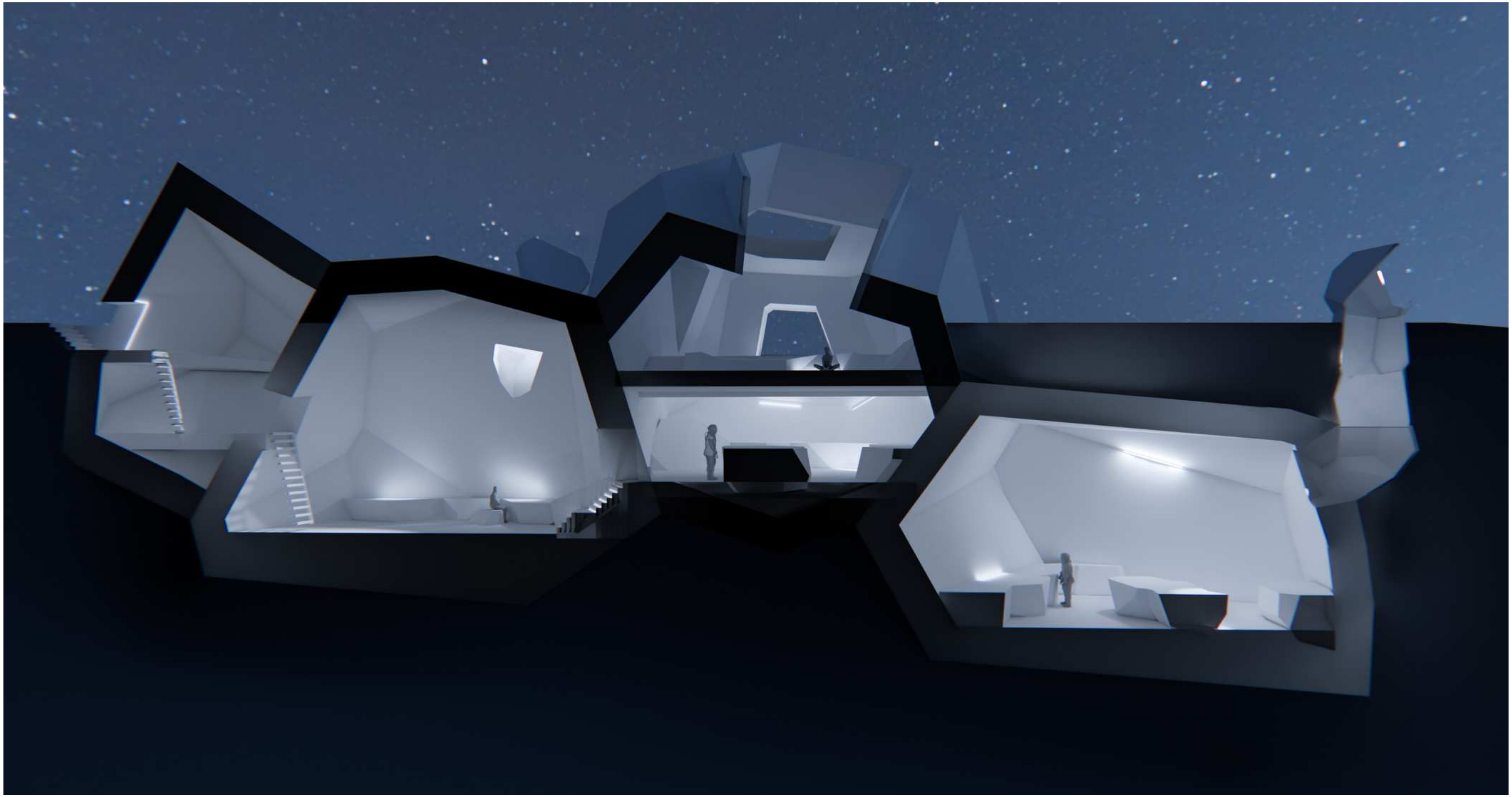
LEVEL 0

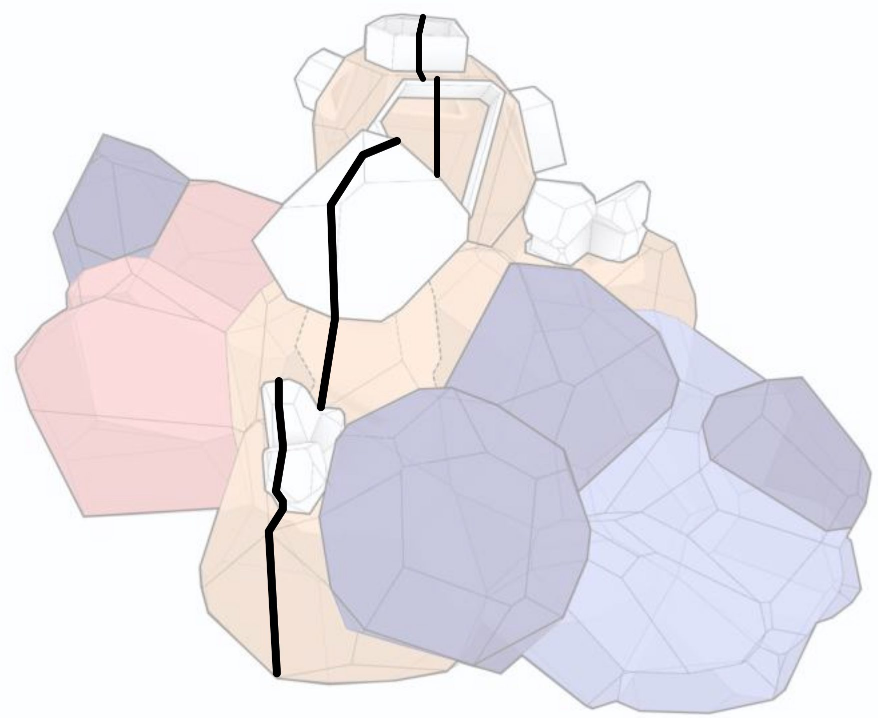


PLANS

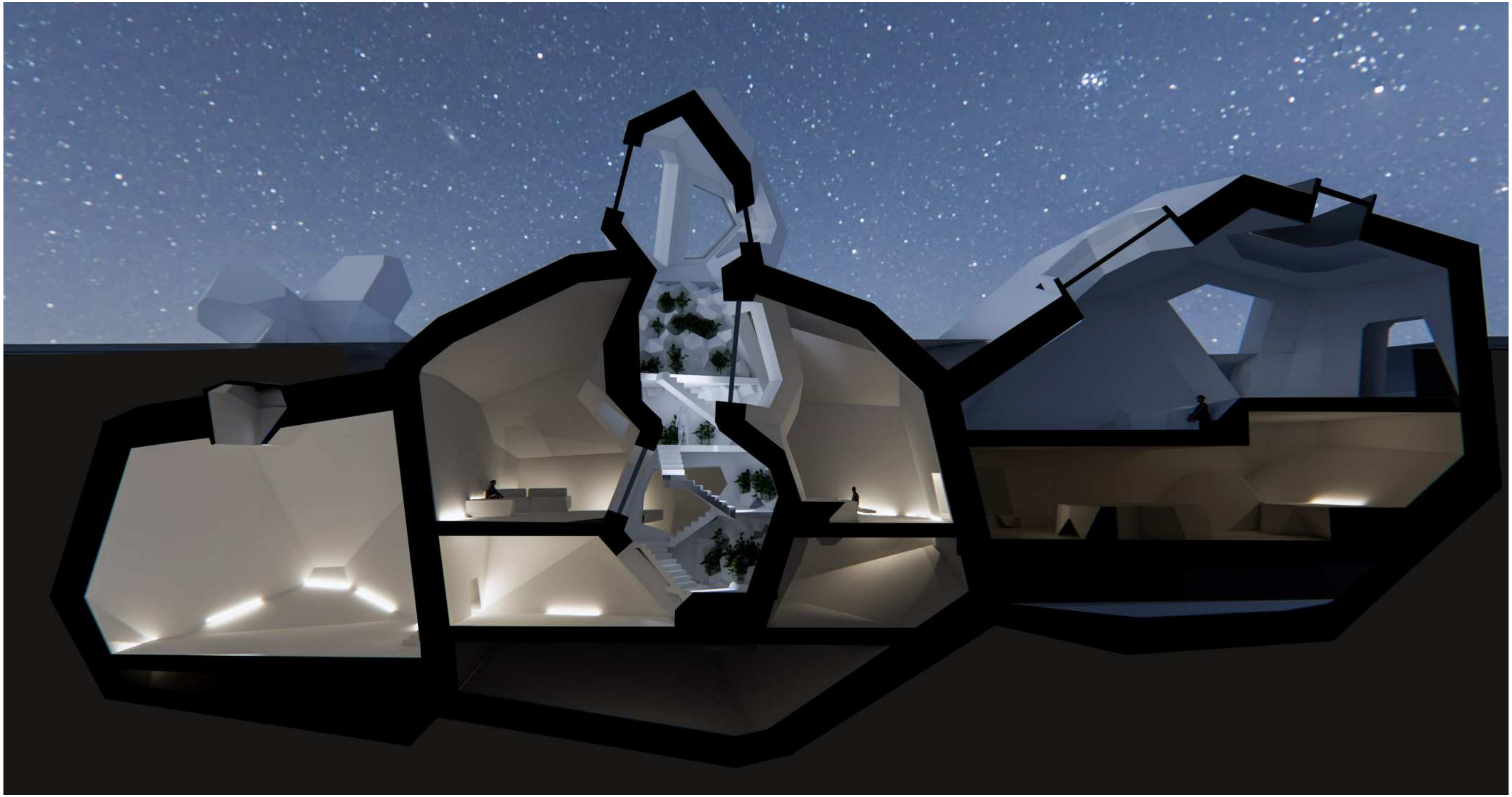


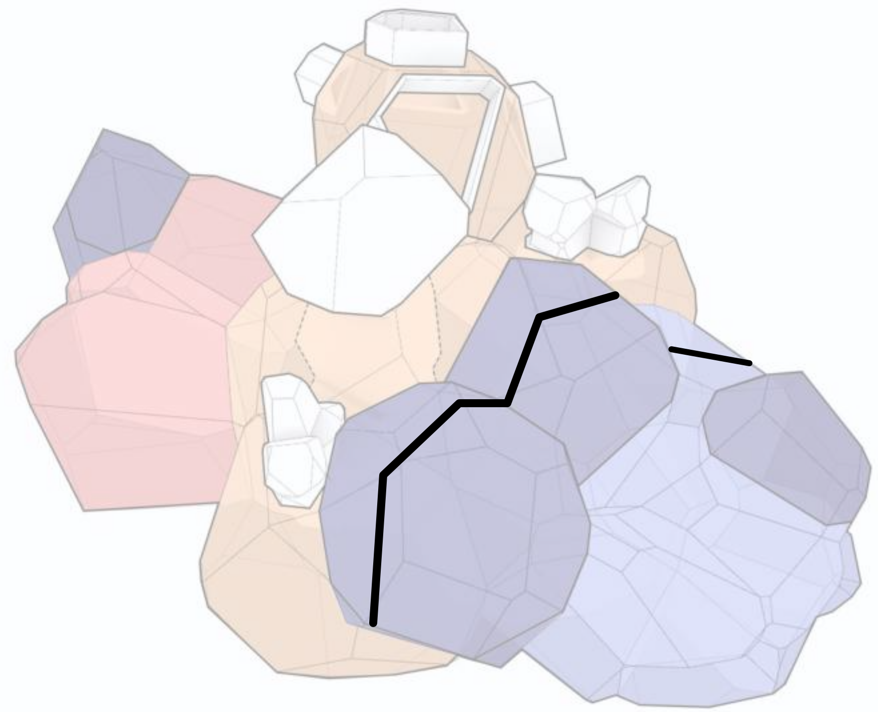
DAY
WORK SPACES





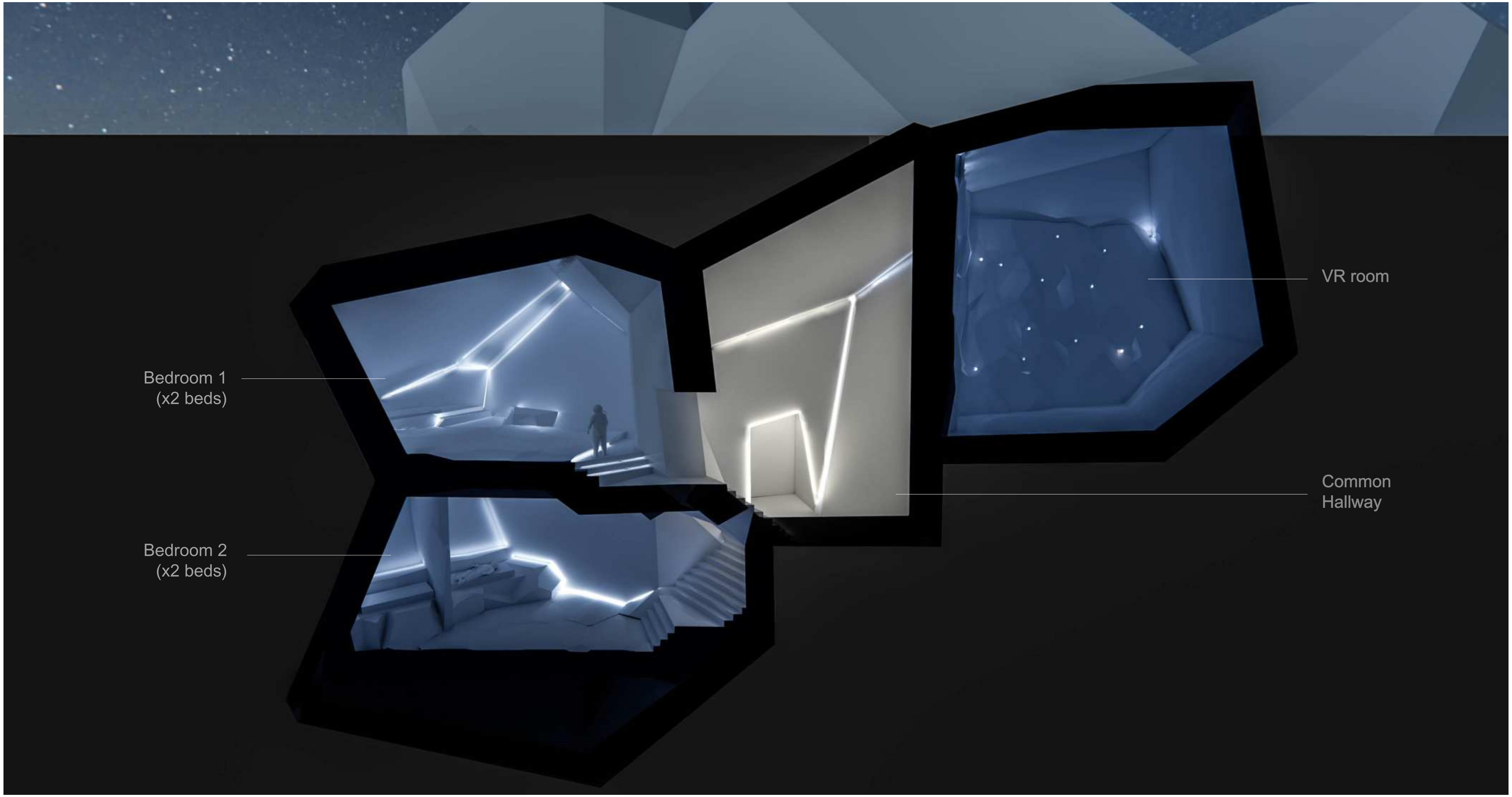
EVENING
SOCIAL SPACES





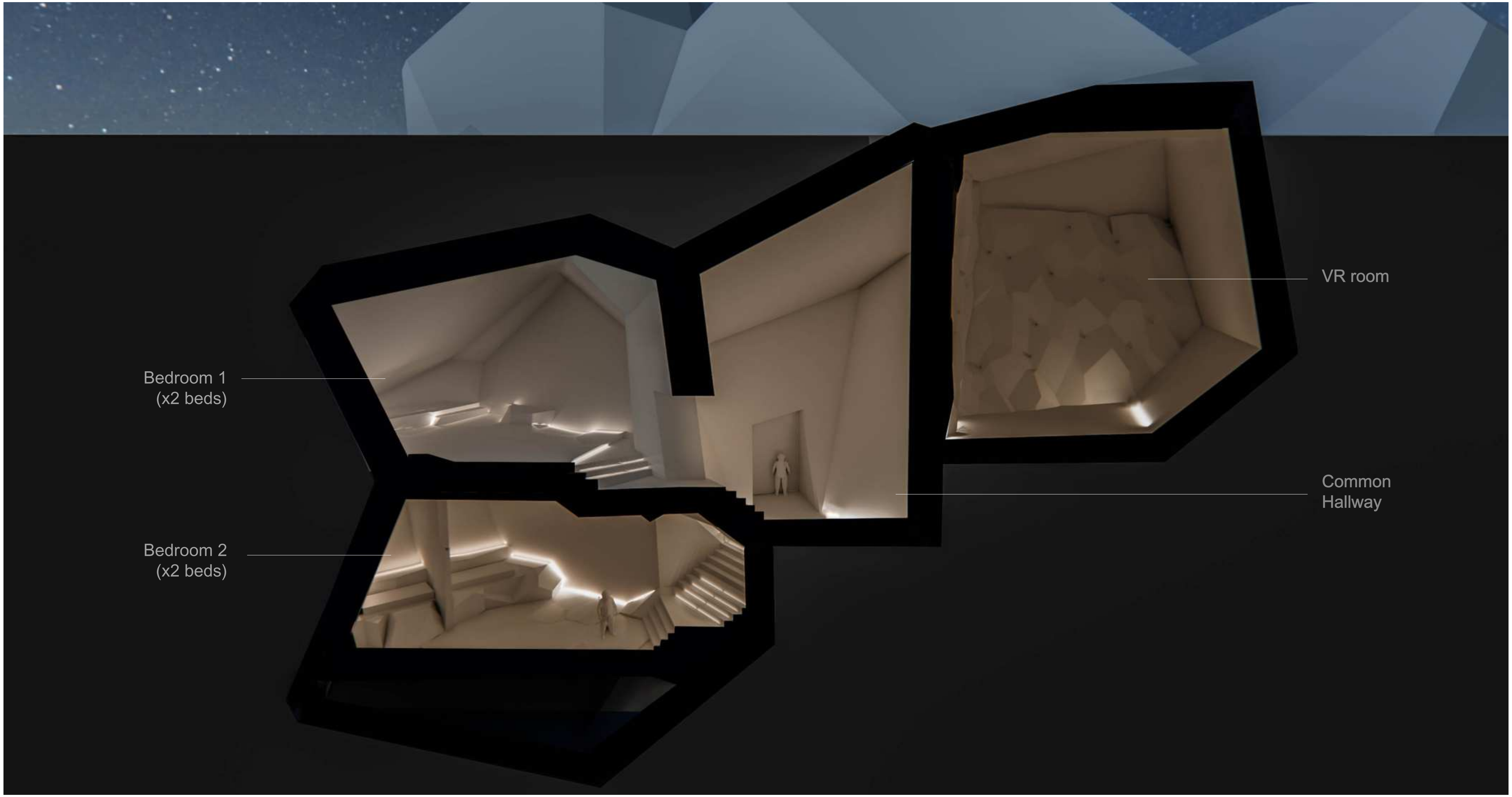
NIGHT
RELAX SPACES

NIGHT



REST AREAS

EVENING

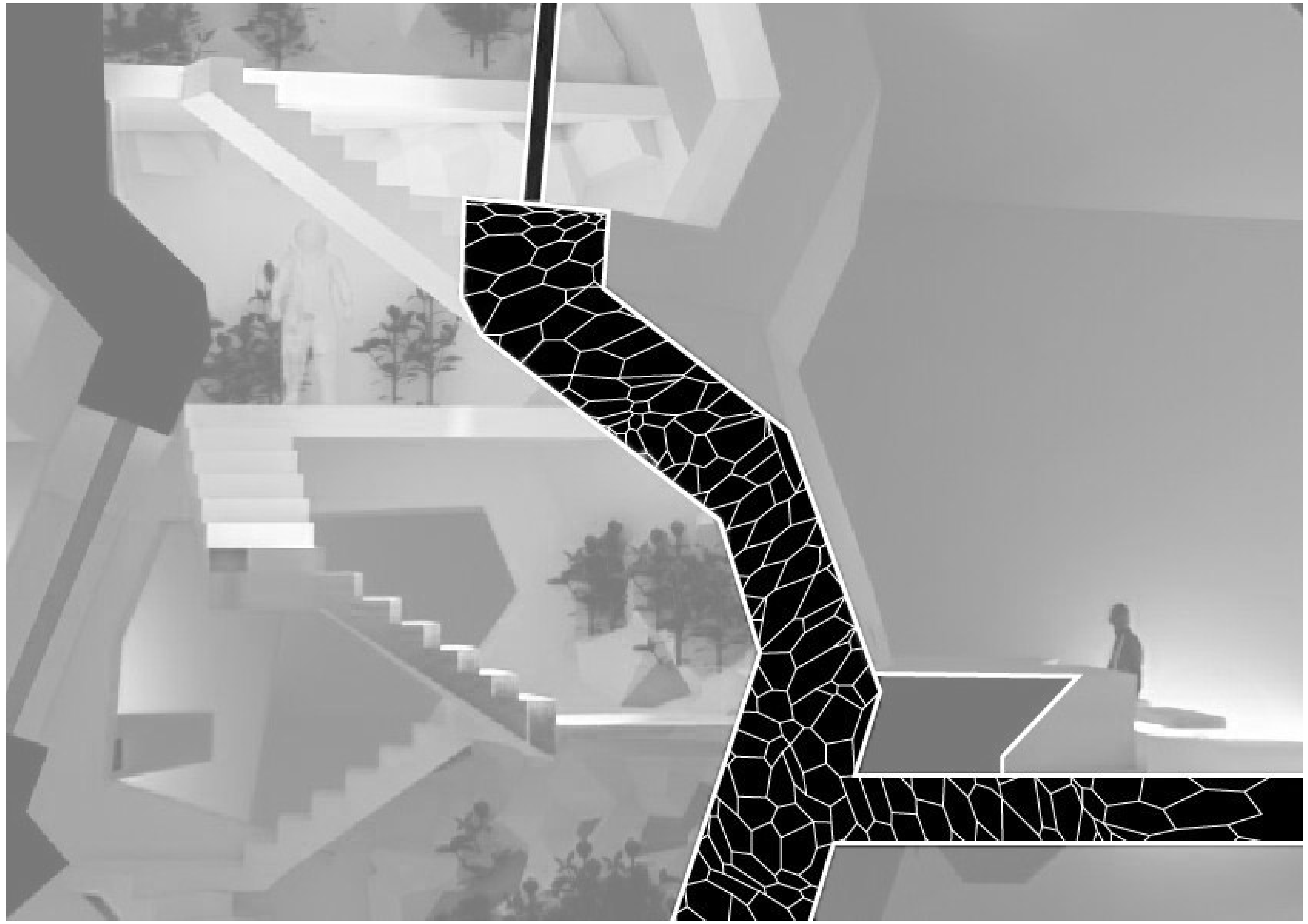


REST AREAS

O DAY

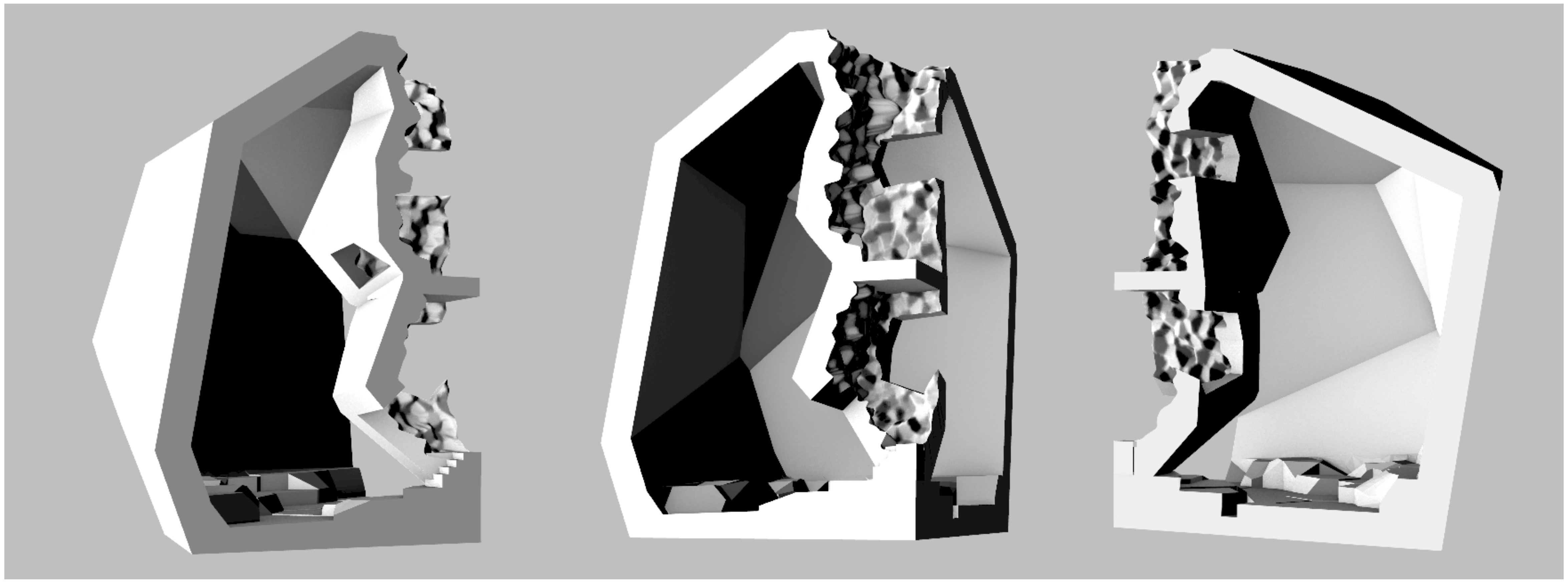
REST AREAS

COMMON HALL AND FOOD PRODUCTION SPACE



DETAIL SECTION – TYPICAL STRUCTURAL STRATEGY

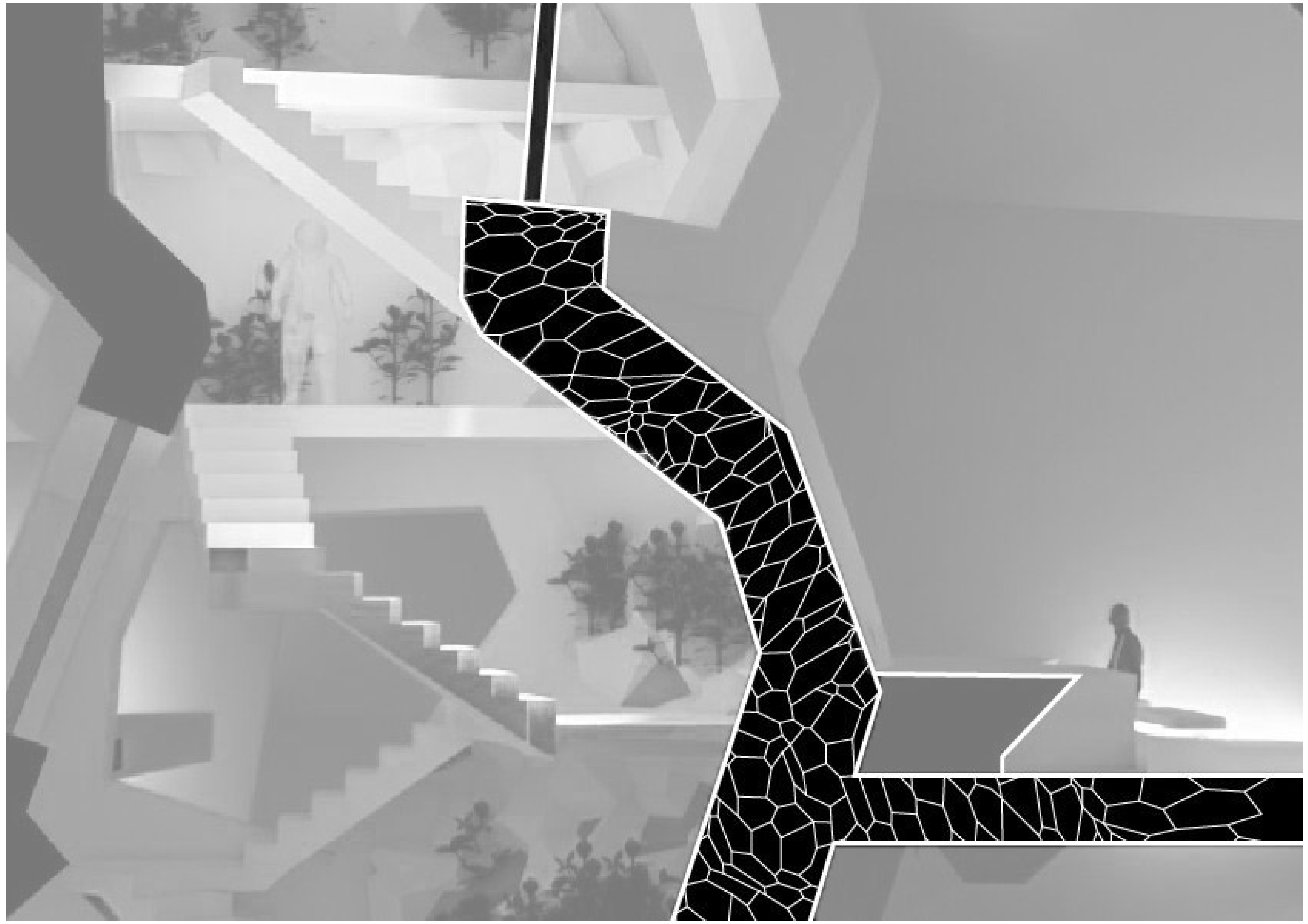
MESO



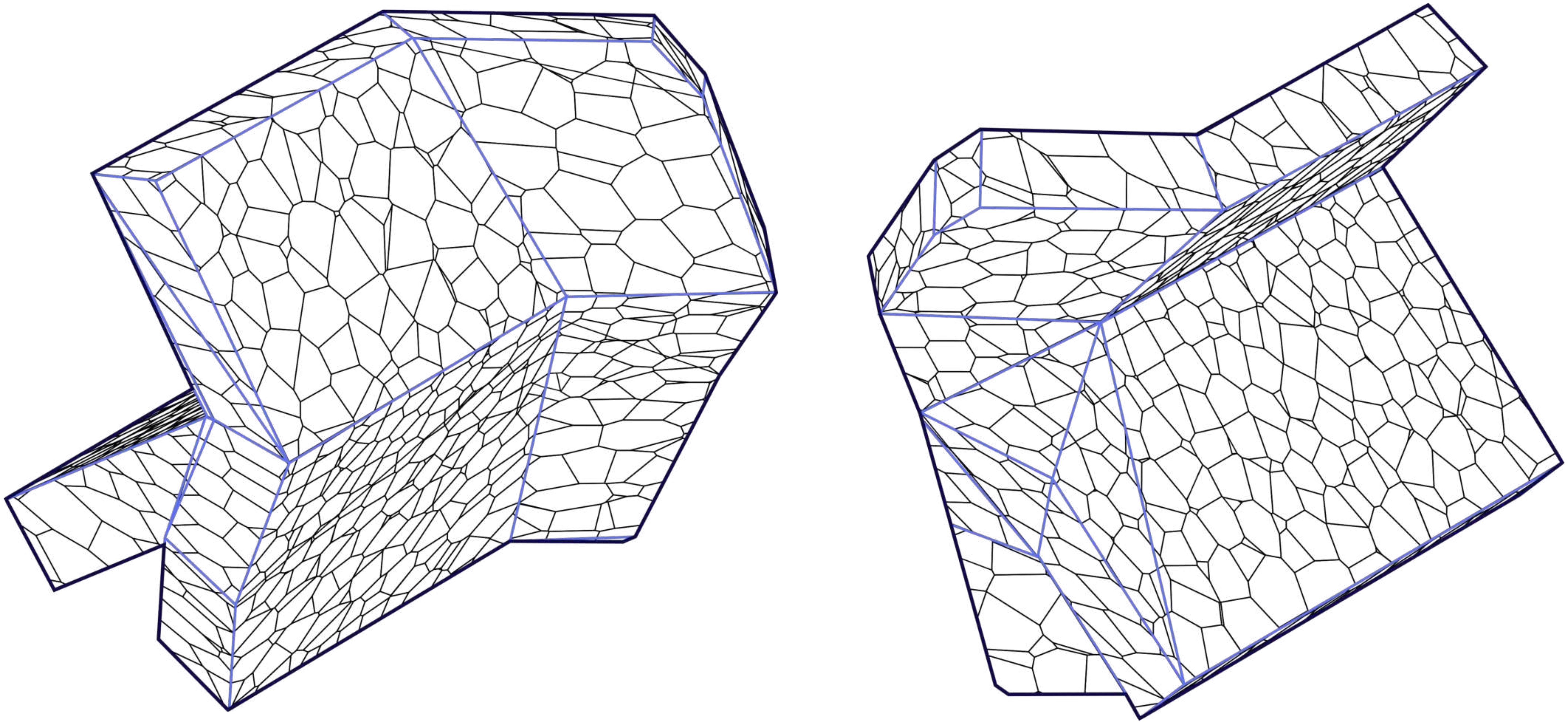
COMMON ROOM AND ATRIUM FRAGMENT

COMMON ROOM AND ATRIUM FRAGMENT - 3D PRINTED MODEL

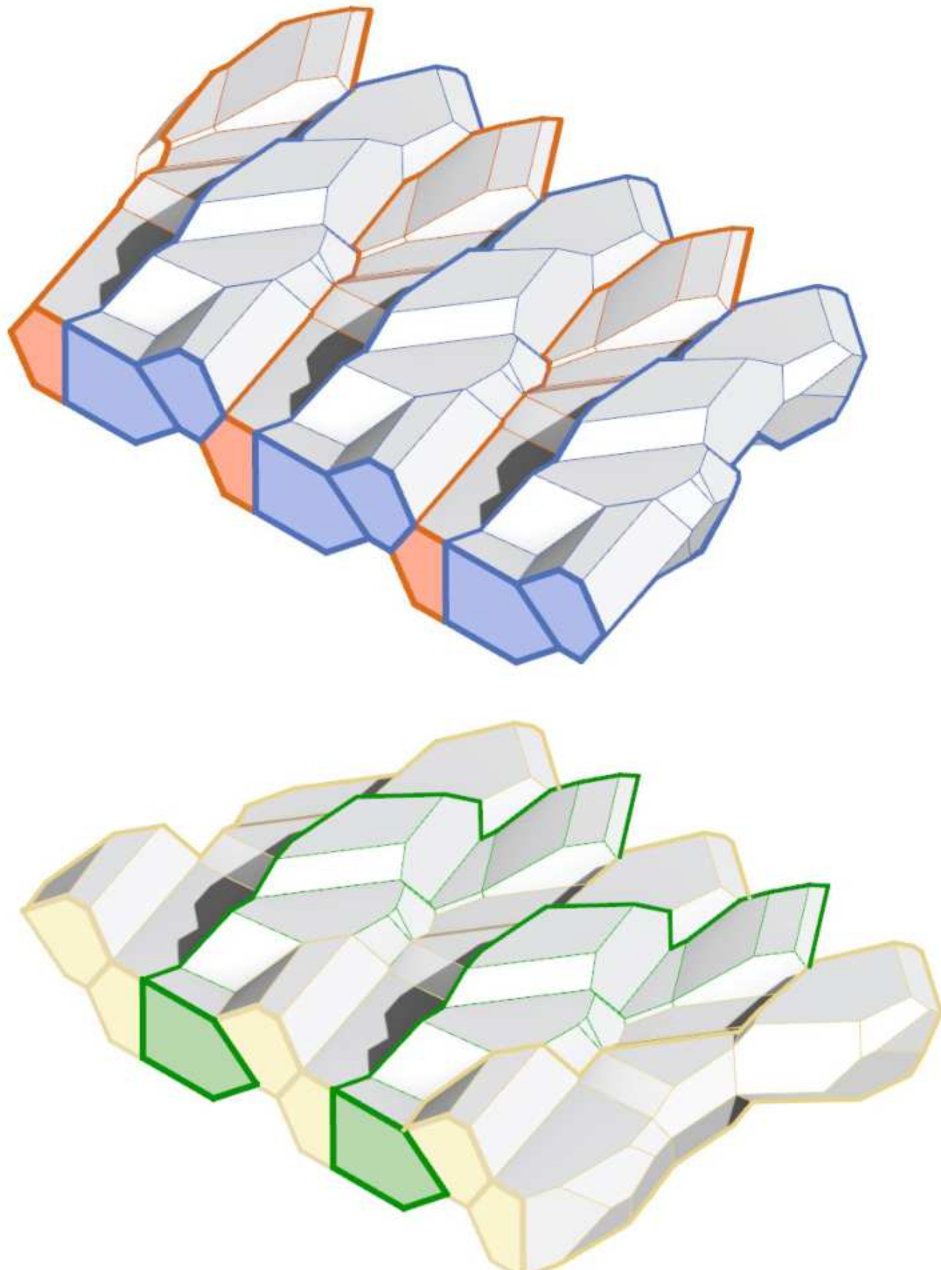
MICRO

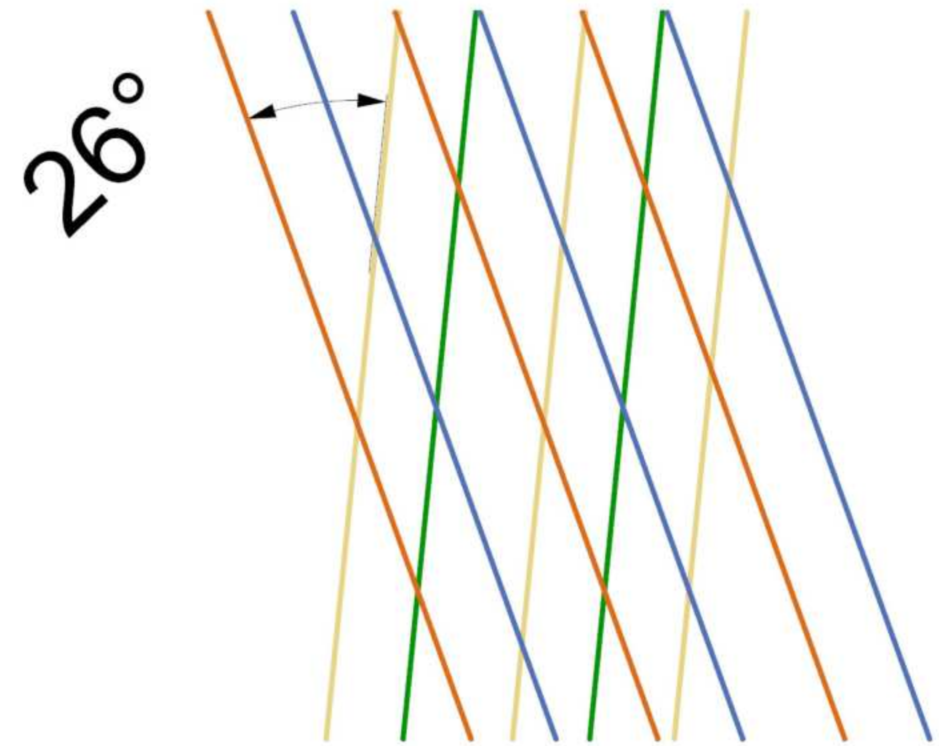


DETAIL SECTION – TYPICAL STRUCTURAL STRATEGY



SELECTED FRAGMENT FOR DETAIL DEVELOPMENT





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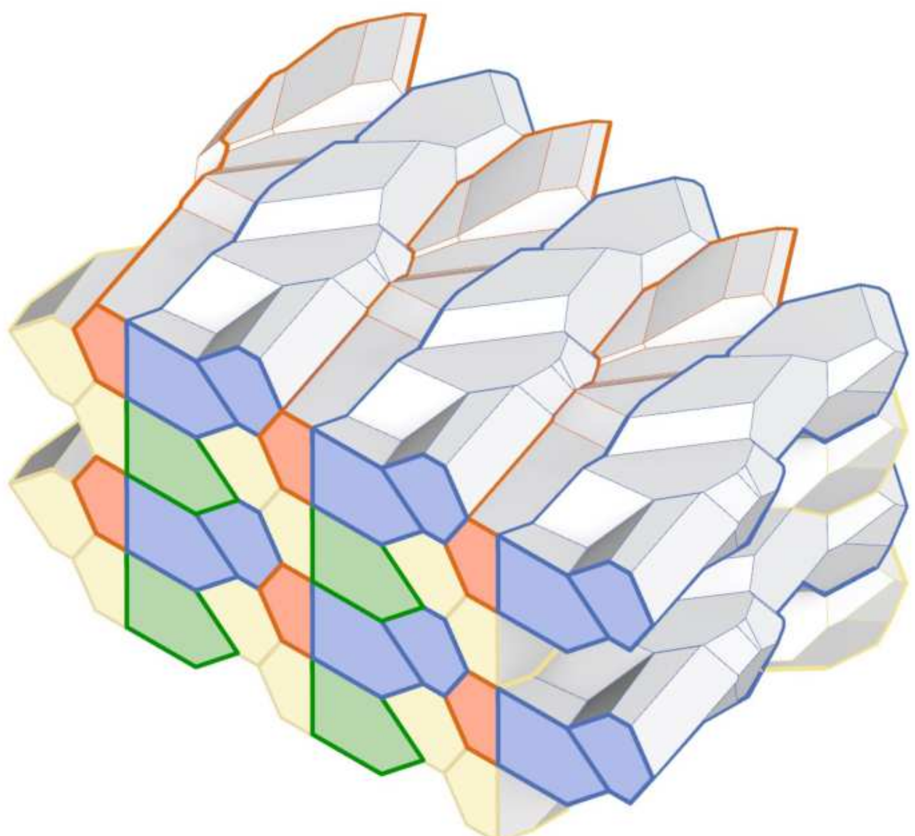

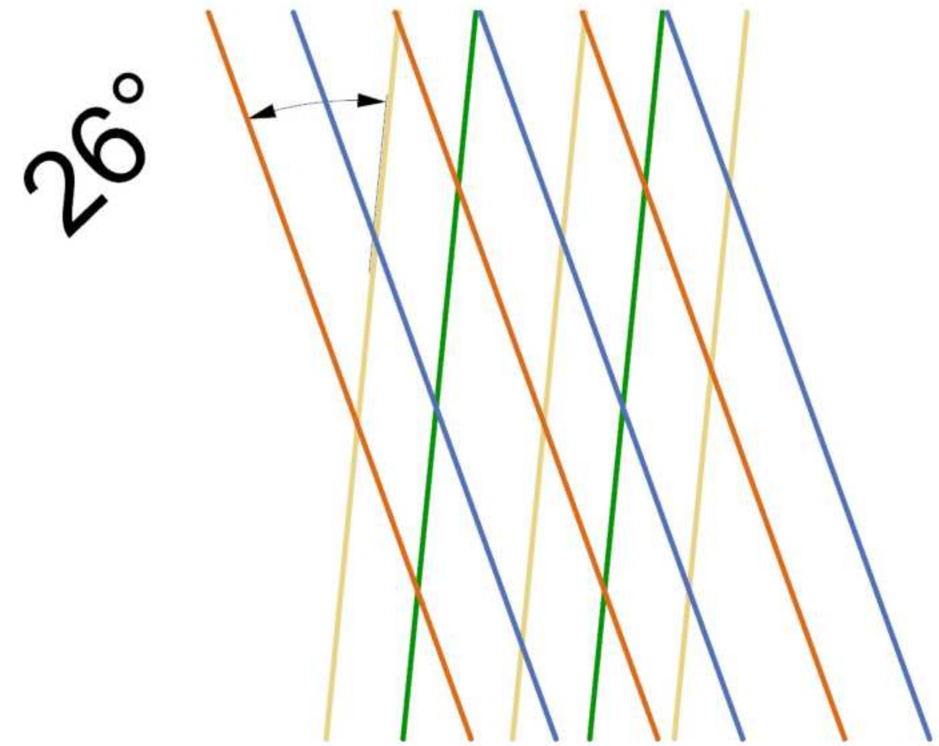

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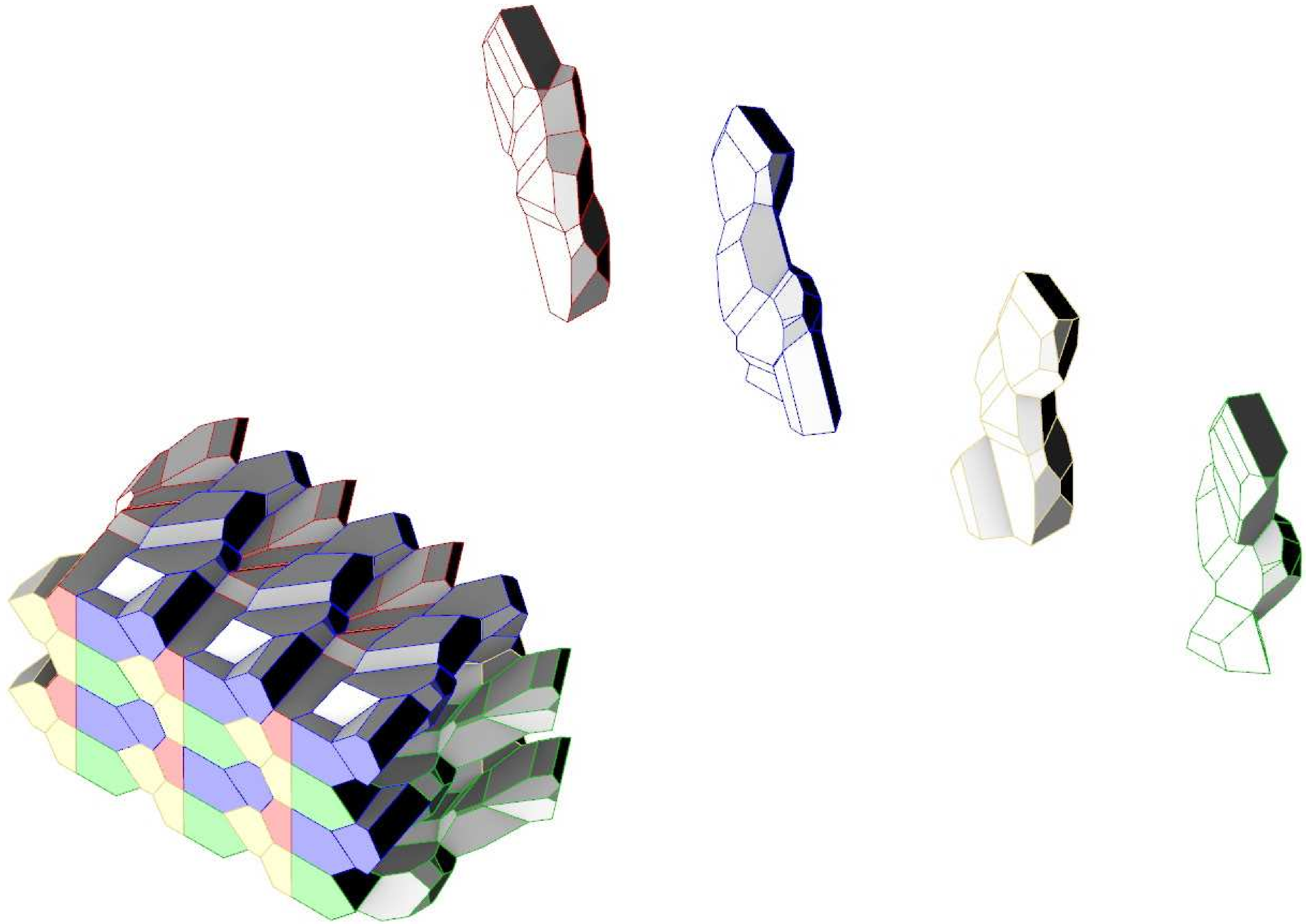
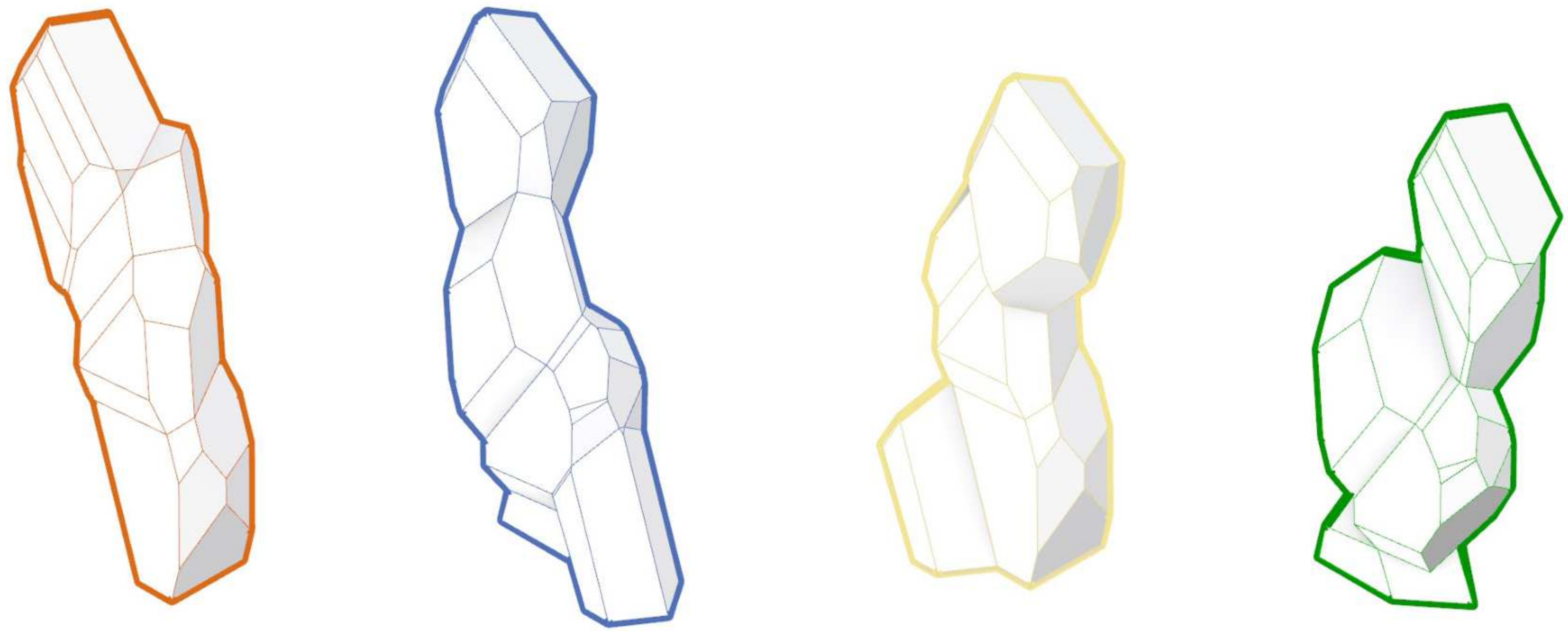


SELECTED VORONOI COMPONENTS



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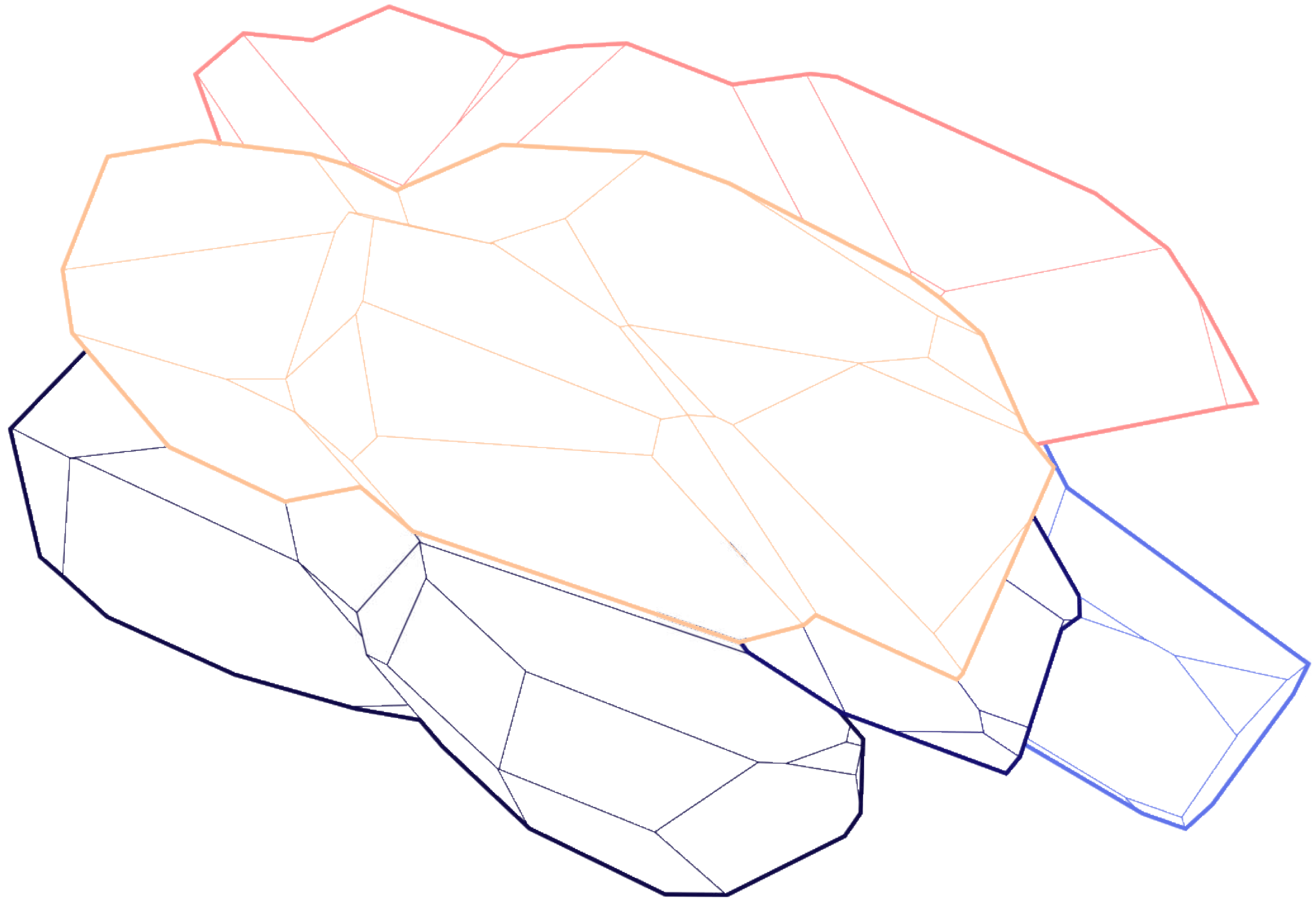
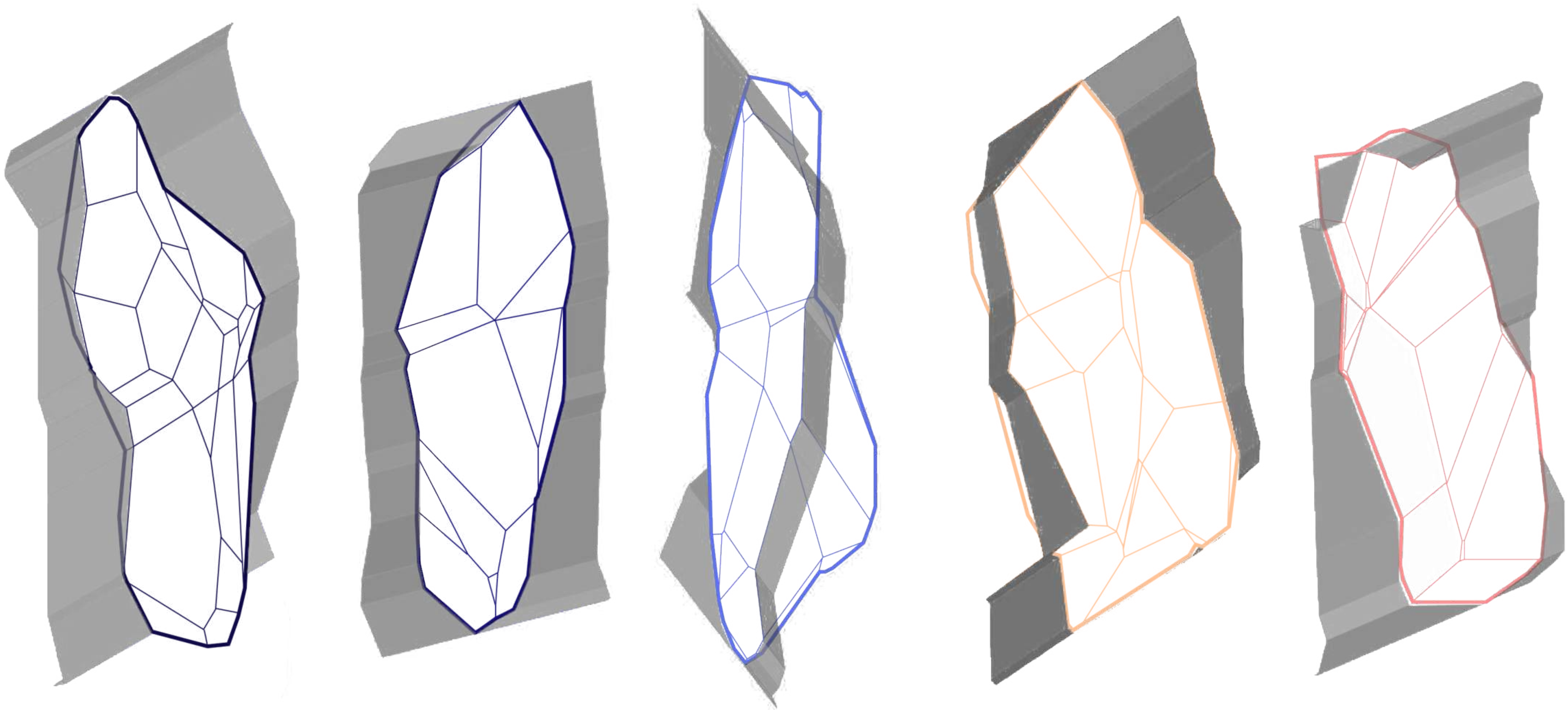
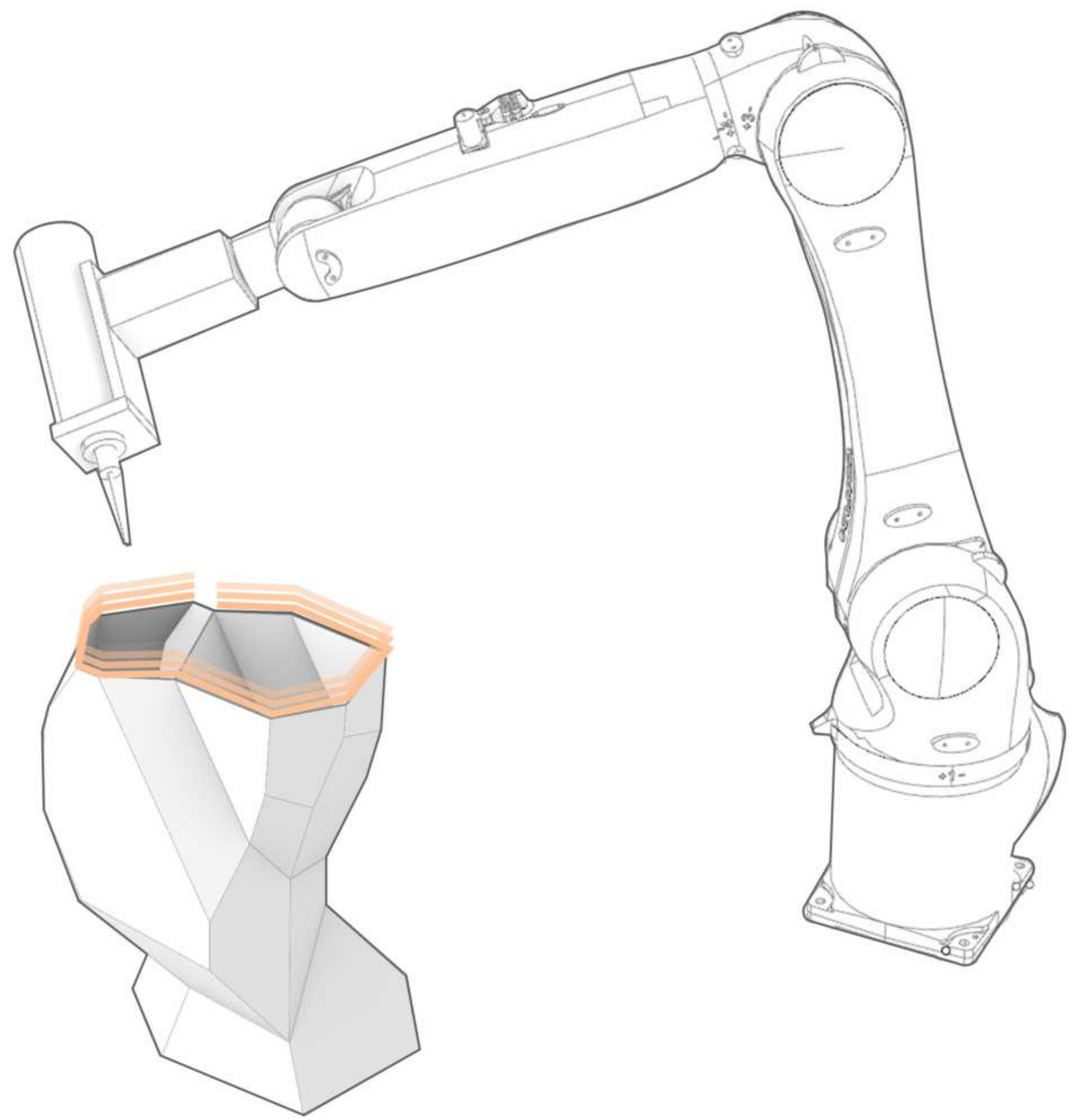


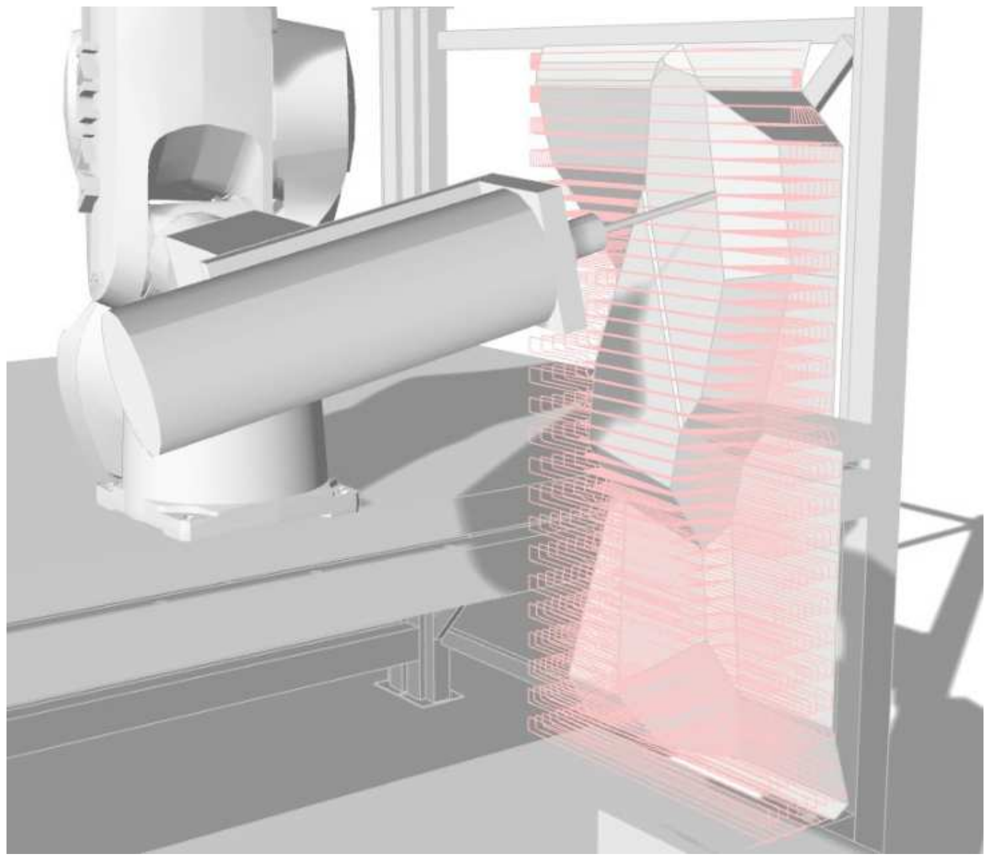
INTERLOCKING VORONOI COMPONENTS



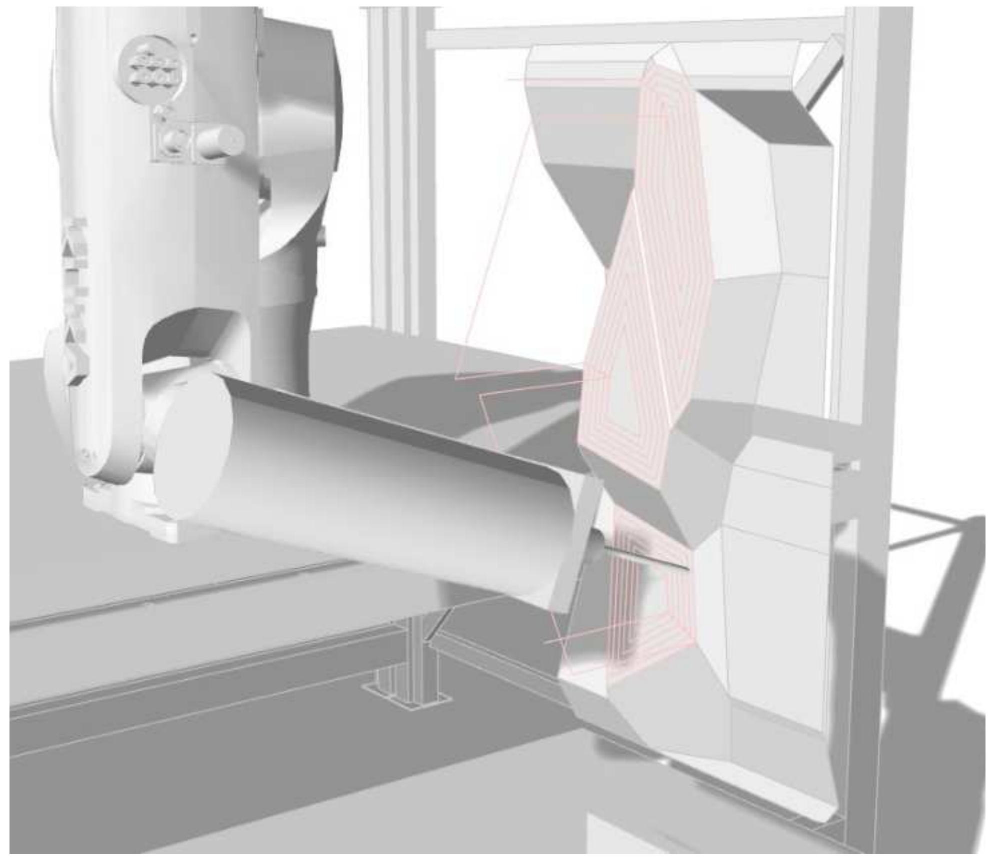
FINAL VORONOI COMPONENTS CHOSEN FOR PRODUCTION
& SURFACE DIVIDING THE MILLING PROCESS IN TWO SIDES



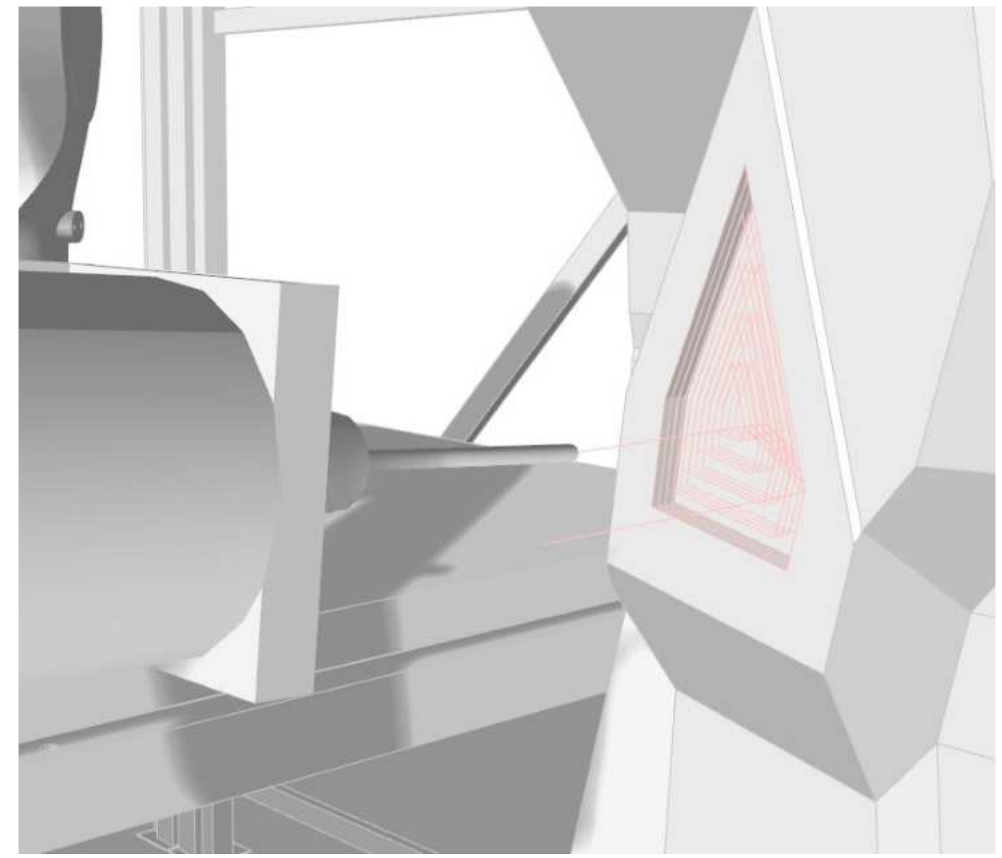
MILLING PRODUCTION



MATERIAL REMOVAL



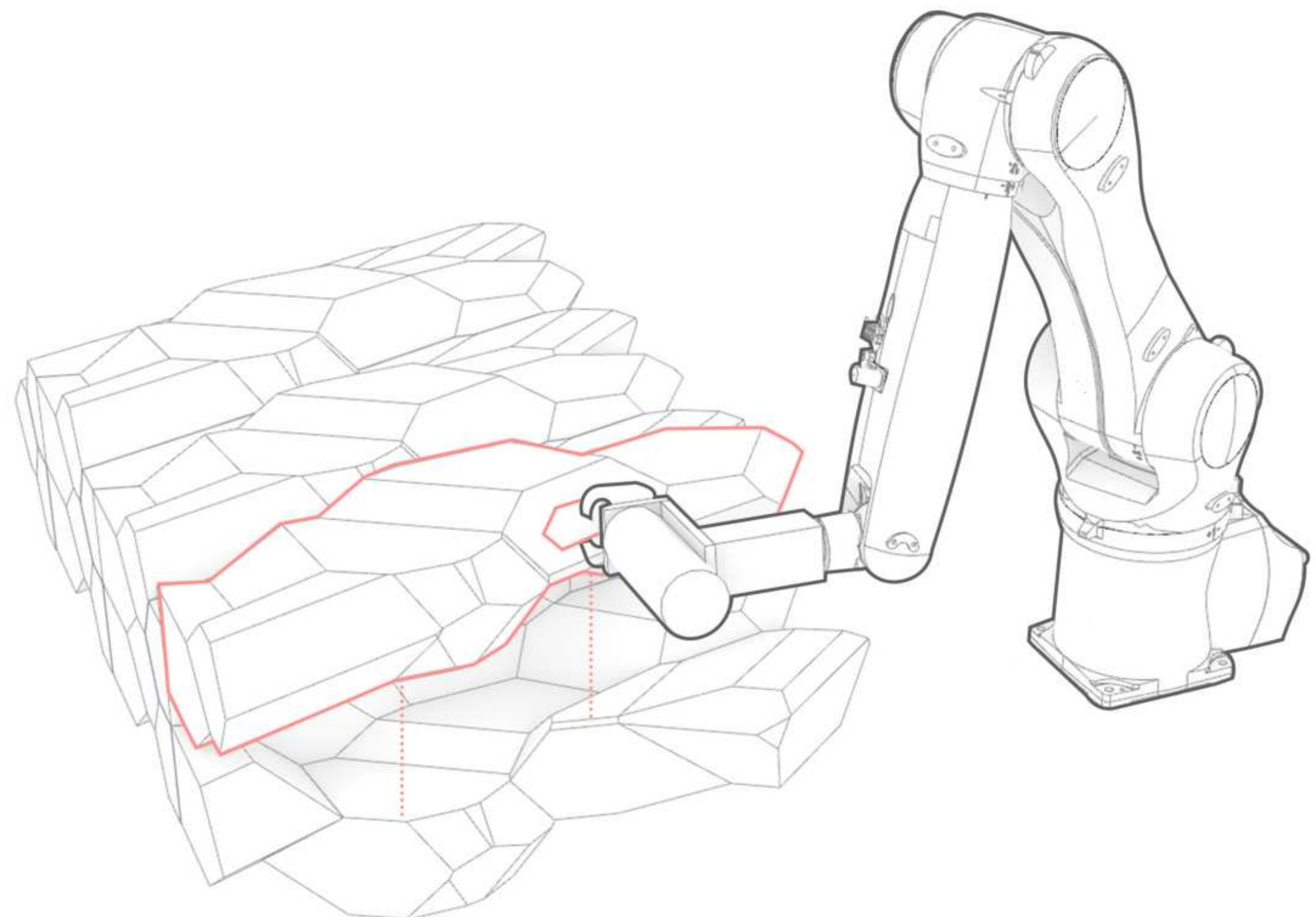
SMOOTHING THE SURFACES



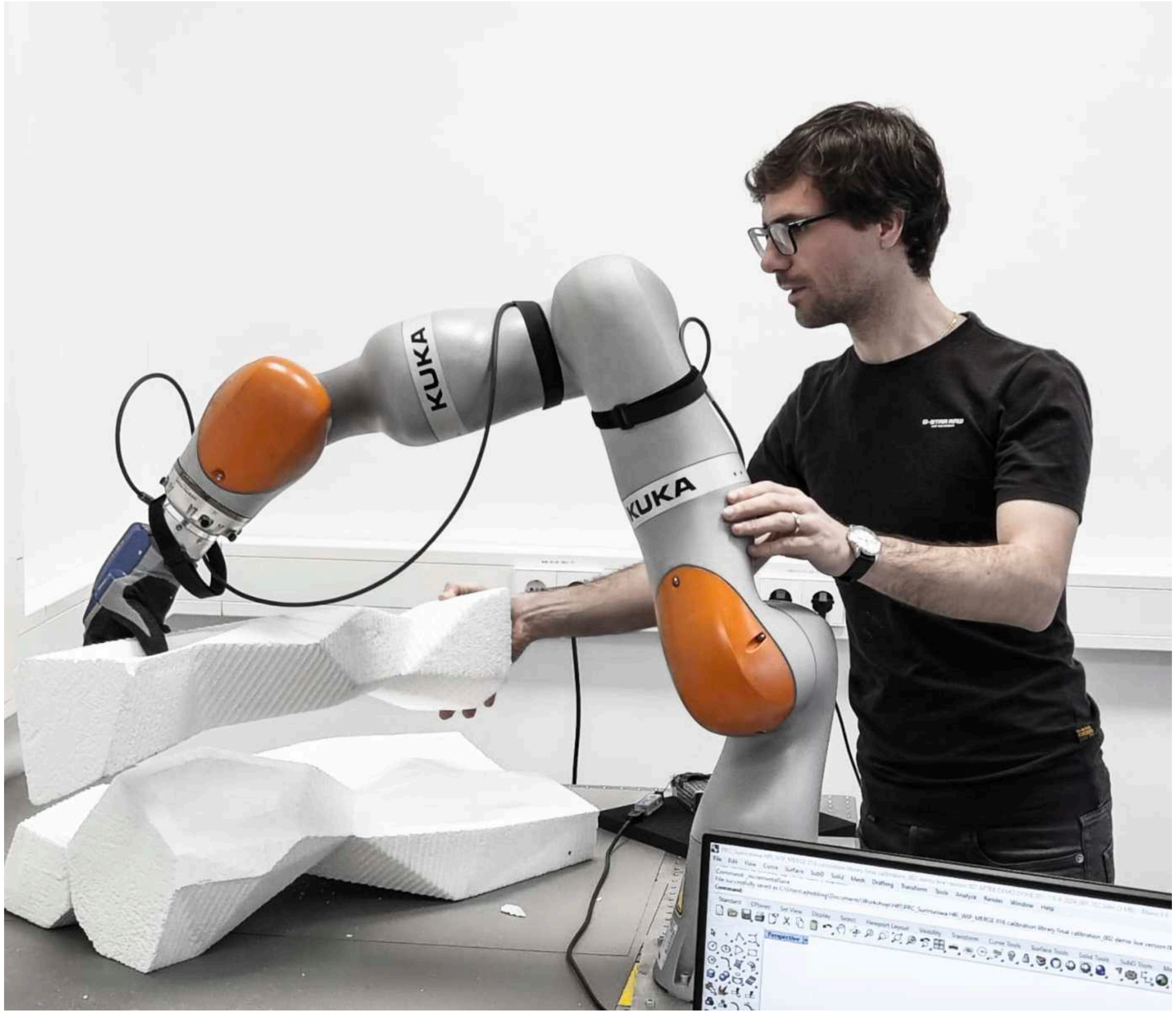
GRABBING HOLE

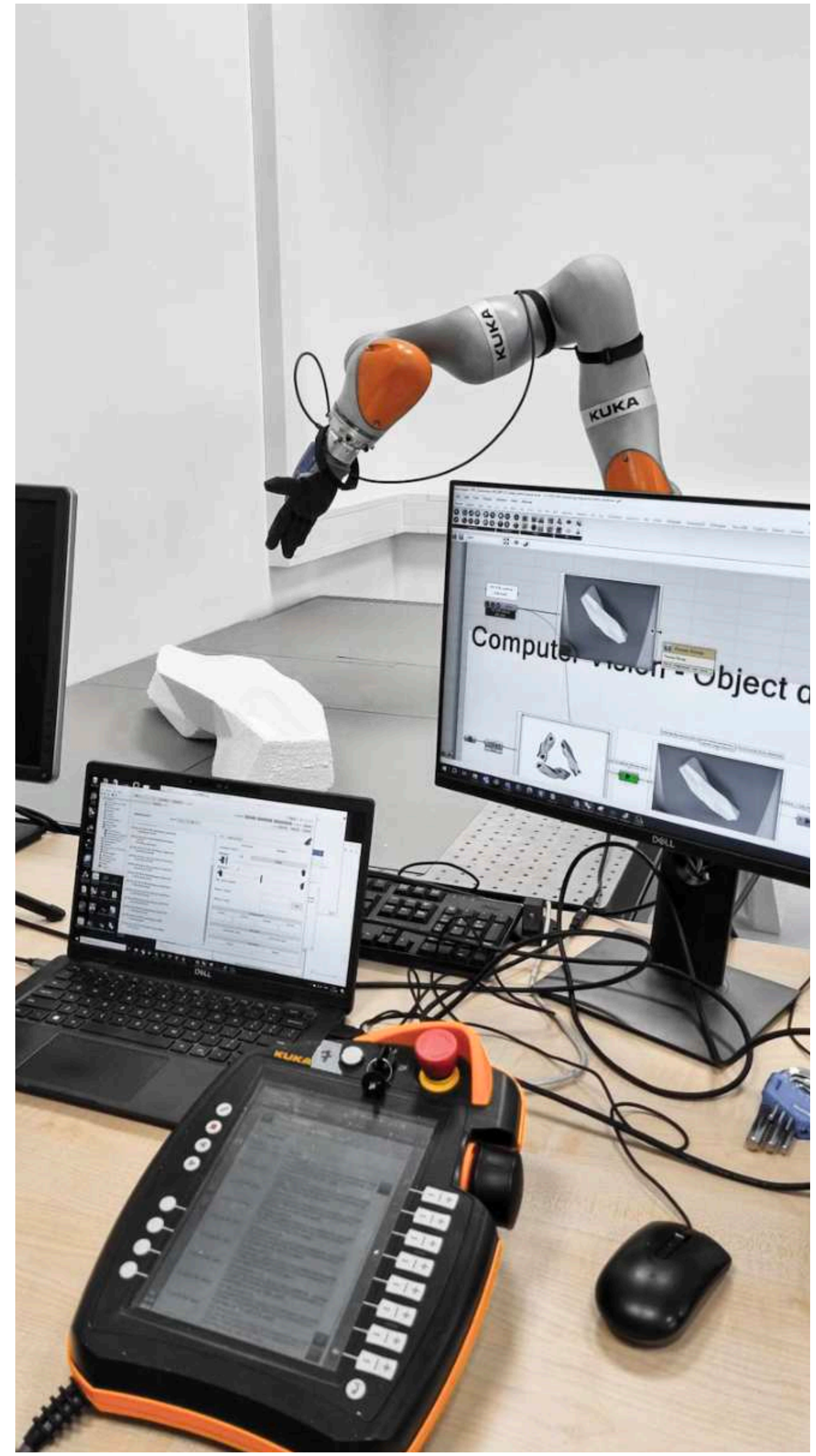
MILLING PRODUCTION

MILLING PROCESS



HRI ASSEMBLY





HRI ASSEMBLY PROCESS