AR0122/ 1:1 INTERACTIVE ARCHITECTURE PROTOTYPES

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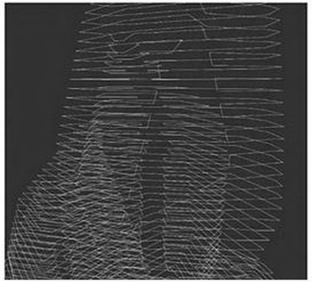
Moon station 2050

Team: Emilee Chen, Sodaba Khalili, Tzu-Shou Huang, Ziyue Yu



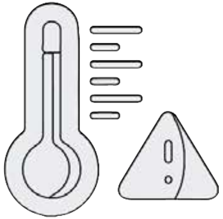
MOONZOME

Moon station 2050

Team: Emilee Chen, Sodaba Khalili, Tzu-Shou Huang, Ziyue Yu

Lunar Architecture_Considerations

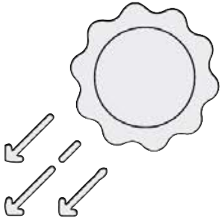
Low gravity ($1.6 m/s^2$)



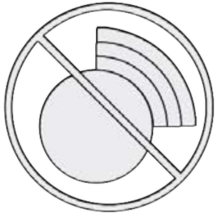
Extreme thermal cycle
(-173°C to +117°C)

29.53 earth days
for one lunar day

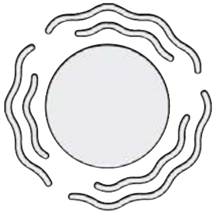
Limitated access
to liquid water



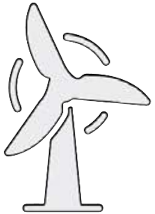
High level of radiation and
solar particle events



Lack of atmosphere

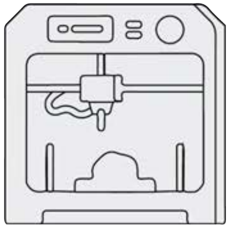


Higher seismic activity
than for Earth

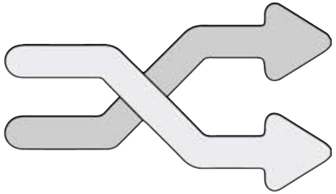


No weather: no wind:
no wind turbines

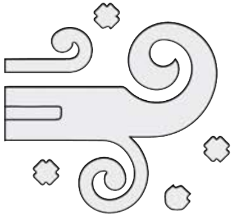
Lunar Architecture_Materials



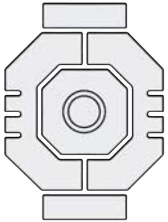
Lunar soil for 3D-printing



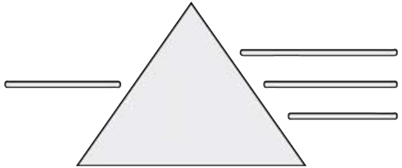
Interlocking parts
for 3D-print (flexibility)



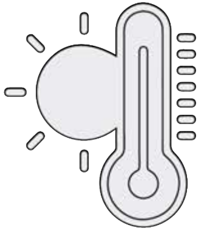
Airtight at all times



Airlocks as openings

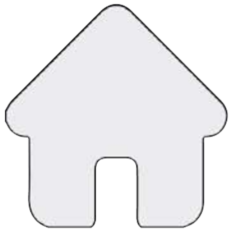


Smaller/lighter materials

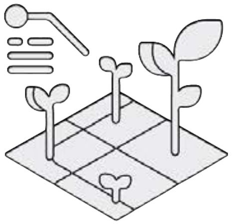


Protection from the radiation
and meteoroids

Lunar Architecture_Program Requirements

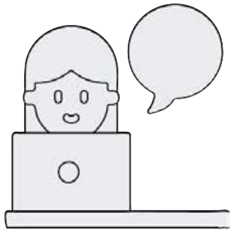


Eating/sleeping areas for 3-6 people



Grow food

Research and experiments



Communication with earth

Site Analysis

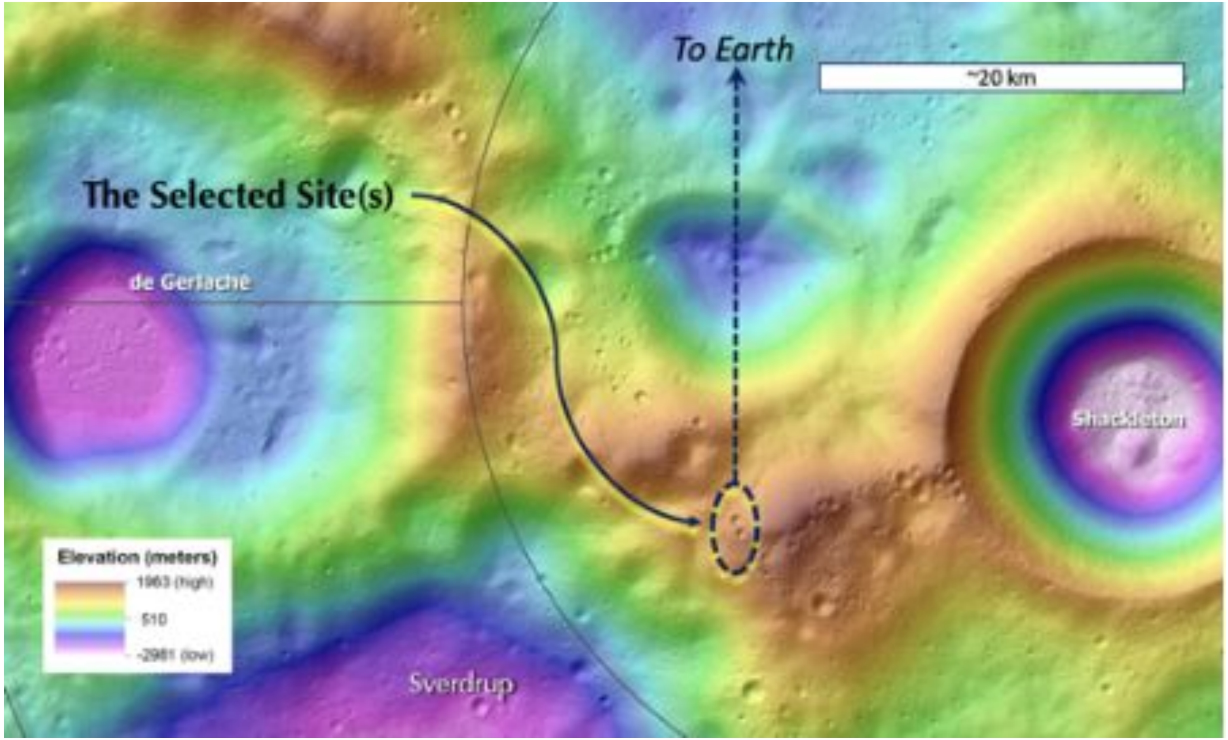
Site Selection

Site 2:

The Lunar south polar ridge on the left of Shackleton Crater

Station Site:

Along the Earth-facing slope of the Lunar south polar ridge, along the upper edge of an approximately 800m diameter crater there, facing downslope and toward Earth (which should be occasionally low on the south polar horizon).

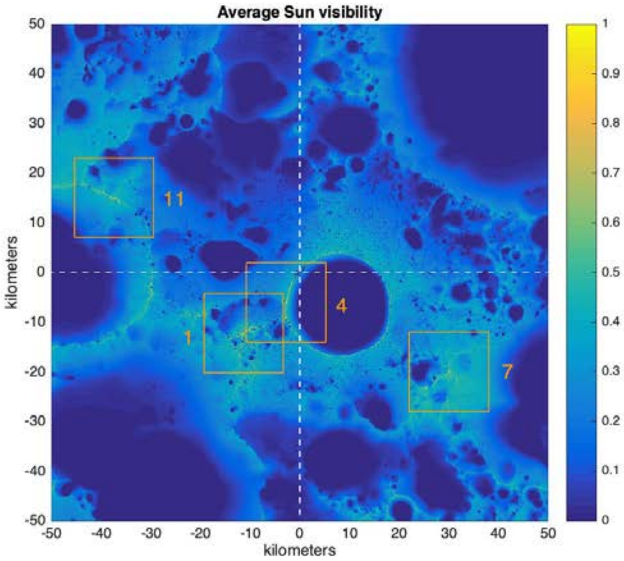


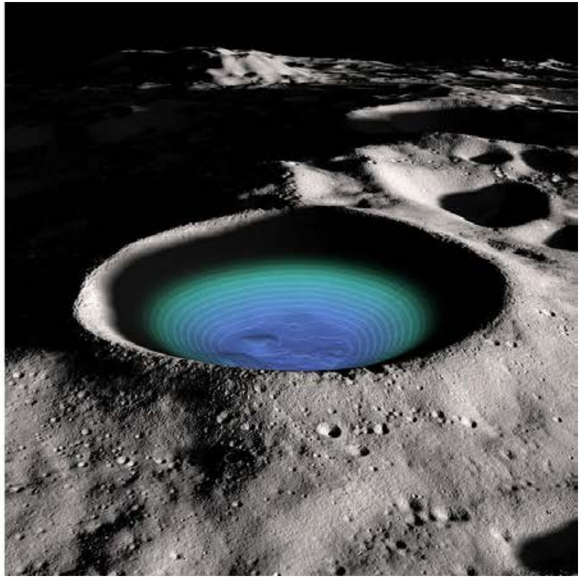
Site Selection_Considerations + Opportunities

+ The ridge along the crater's rim is exposed to almost **constant sunlight**

+ The interior of the crater is perpetually in shadow that may indicate the **presence of water ice**

+ The variance in sunlight and resource quality allows for spaces of different functions



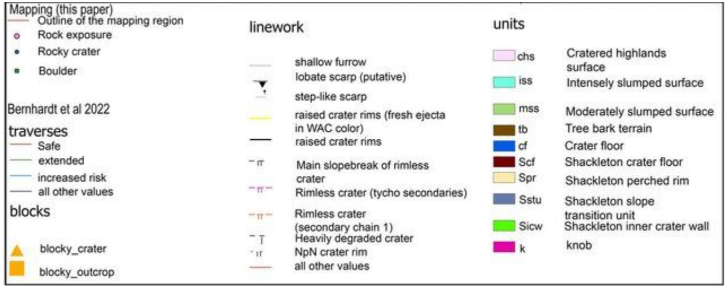


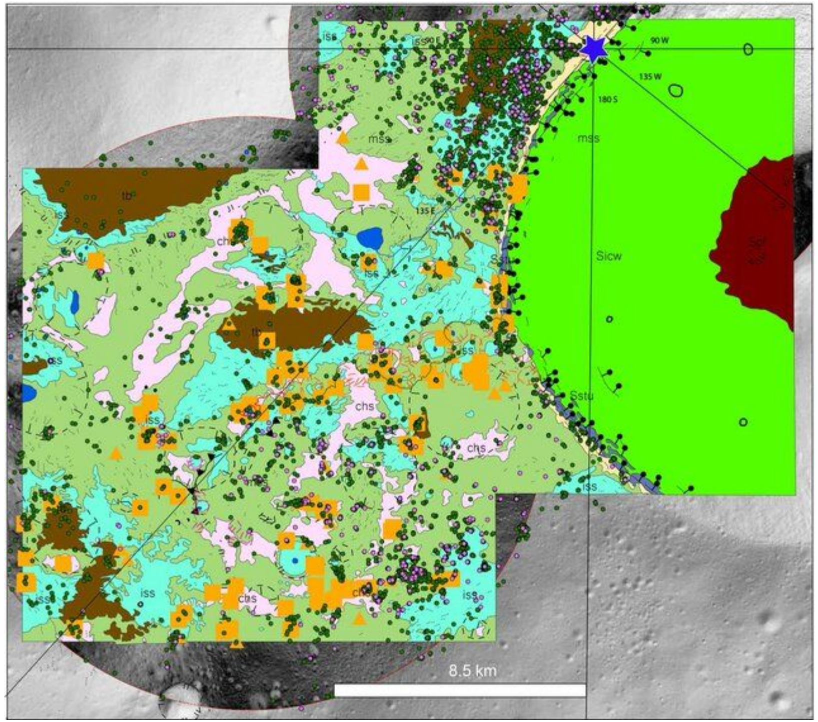
Barker, M.K., E. Mazarico, G.A. Neumann, D.E. Smith, M.T. Zuber, and J.W. Head, 2021: Improved LOLA Elevation Maps for South Pole Landing Sites: Error Estimates and Their Impact on Illumination Conditions. Planetary and Space Science, 203, 105119, doi:10.1016/j.pss.2020.105119.

Site Selection_Features

+ Features mapped (isolated boulders, rock exposures, rocky craters) overlaid on geomorphological map.

+ Distribution of features in relation to the geomorphic units can be seen, including around the "Connecting Ridge" the moderately slumped unit aligns with the mapped features.

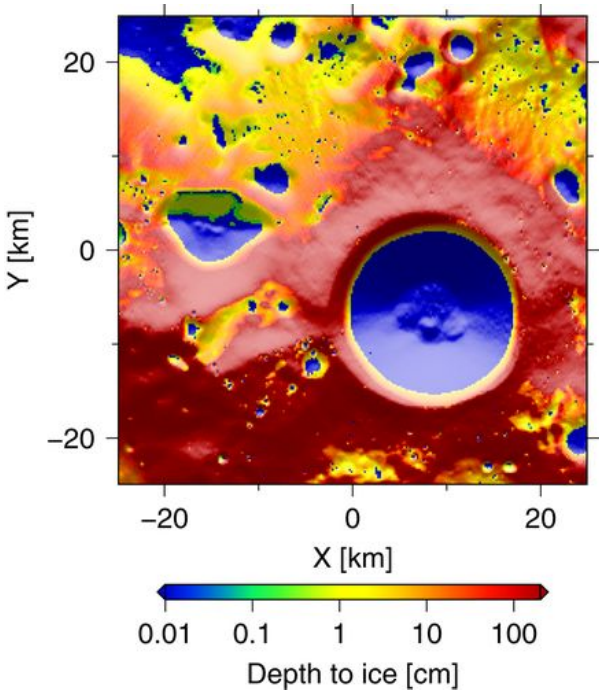




Sarah. J. Boazman et al., "The Distribution and Accessibility of Geologic Targets near the Lunar South Pole and Candidate Artemis Landing Sites," The Planetary Science Journal 3, no. 12 (December 1, 2022): 275, https://doi.org/10.3847/PSJ/aca590.

Site Selection_Features

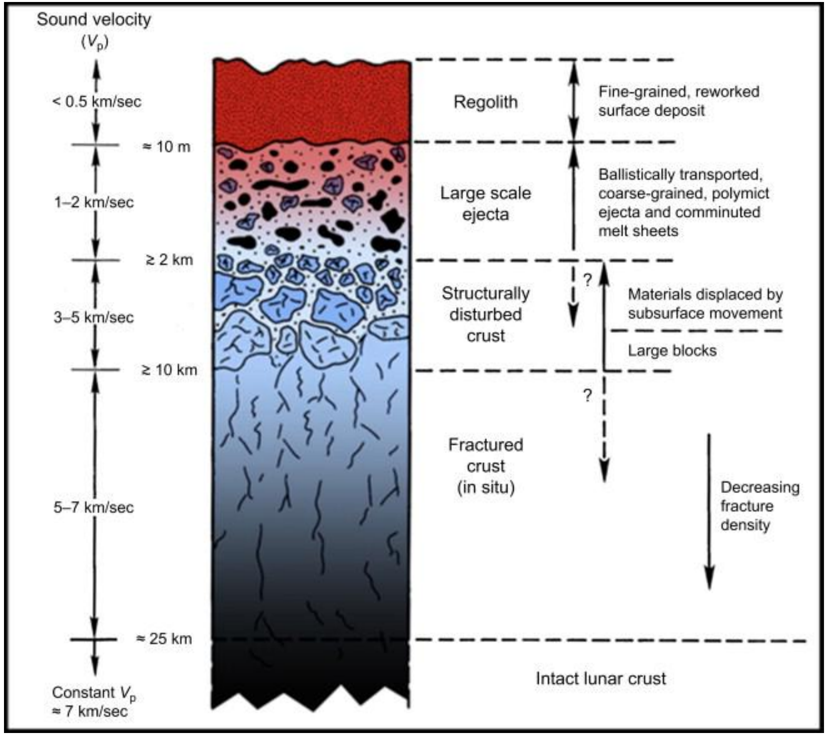
- Depth of ice in the area mapped
- Provides insight into possible water collection and system to be implemented, as well as water that can be used for in-situ material use
- Insight on ground composition for **foundations and excavation**



Sarah. J. Boazman et al., "The Distribution and Accessibility of Geologic Targets near the Lunar South Pole and Candidate Artemis Landing Sites," The Planetary Science Journal 3, no. 12 (December 1, 2022): 275, https://doi.org/10.3847/PSJ/aca590.

Site Selection_Features

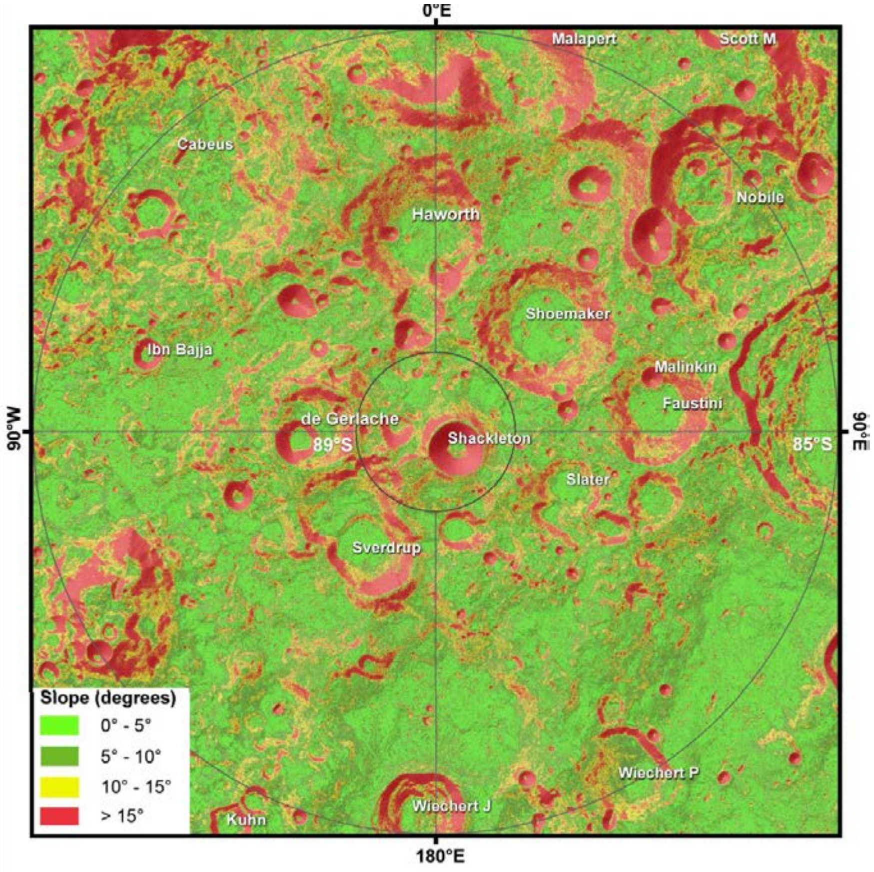
+ Assumed ground composition of the site area.
+ Shows depth of excavation possible, and potential material collection for in situ construction
+ Loose regolith can be collected to use for 3D print construction material: **cementless concrete or geopolymers**



Sarah. J. Boazman et al., “The Distribution and Accessibility of Geologic Targets near the Lunar South Pole and Candidate Artemis Landing Sites,” The Planetary Science Journal 3, no. 12 (December 1, 2022): 275, https://doi.org/10.3847/PSJ/aca590.

Site Selection_Slope

- By looking at mapping of the slopes around the lunar south pole and the selected site, the topography can be leveraged in the design.
- Selected site area has topography between **15° - 20°**



Sarah. J. Boazman et al., "The Distribution and Accessibility of Geologic Targets near the Lunar South Pole and Candidate Artemis Landing Sites," The Planetary Science Journal 3, no. 12 (December 1, 2022): 275, https://doi.org/10.3847/PSJ/aca590.

Site selection

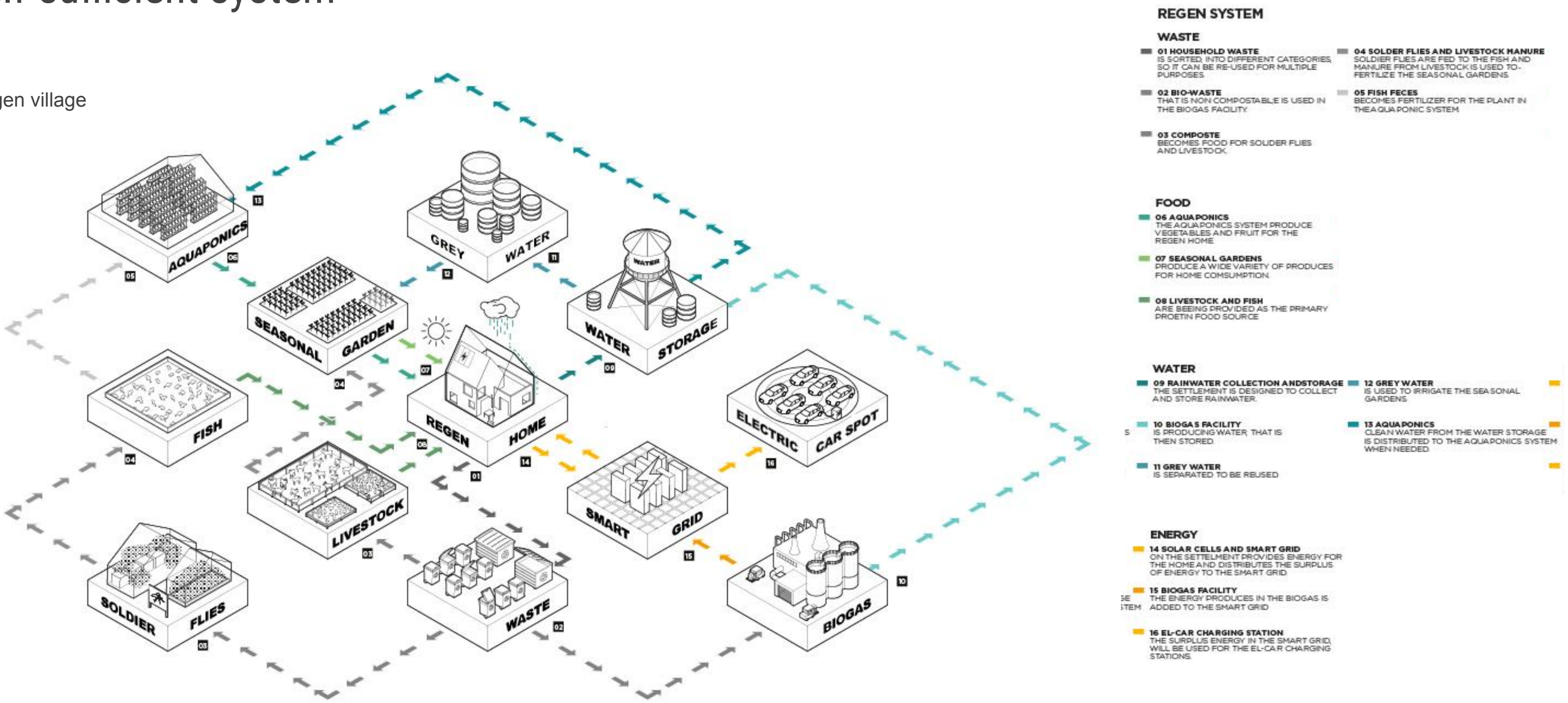
Site Chosen: Area 2:The lunar south polar ridge on the left of Shackleton Crater Station
Center Coordinates: 89.45°, 222.69°E

Conceptual Design

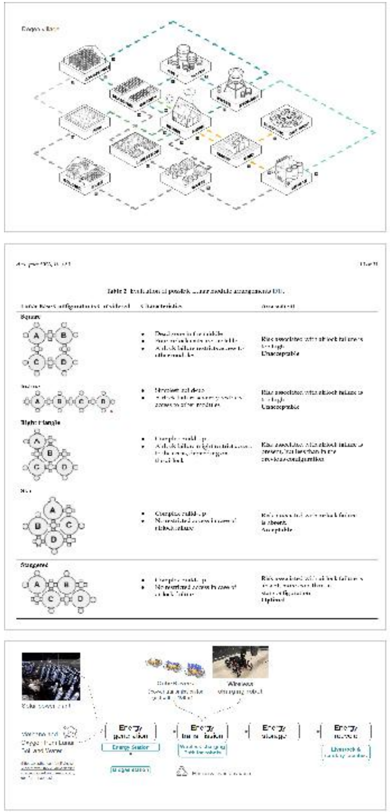
Layout following Lunar Energy & Health and Life support

Self-sufficient system

Regen village



Concept Design_Spatial Layout



Reference
Designing following function

Food
Aquaponics
Produce Vegetables and Fruit for the Living Modules

Algae
.Purifies water and become eatable nutrients

Living Quarters
Circulation
Kitchen
utilises food from the Green-house and the purified water

Energy
Solar Cells and Smart Grid
provides energy for the homes and distribute the surplus of energy to the smart grid

Biogas Facility
Energy produce in the biogas is added in the smart grid

Charging Station
Smart grid, will be used for the robots charging station

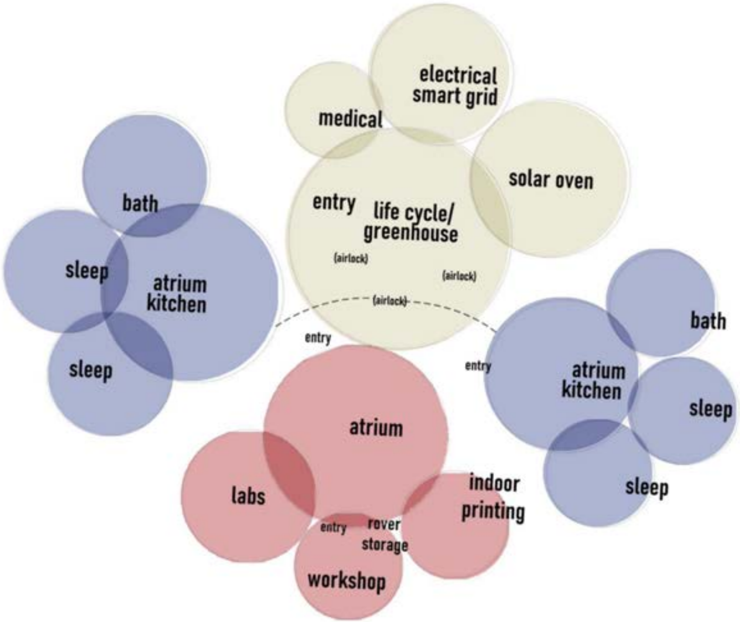
Laser Power Beaming for Lunar Polar Exploration
Base station on the, beaming power to multiple rovers exploring the permanently shadowed craters of the moon

Construction Process
Inflatable Membrane
Deployment of airlock module. After the inflation is completed

Regolith Foundatioin
Multiple printers follow the circumference of the building, depositing raw regolith and binding it layer by layer

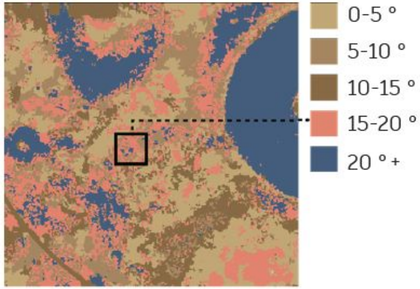
Regolith Foundatioin
The robots will cover the whole membrane with regolith in voronoi form.

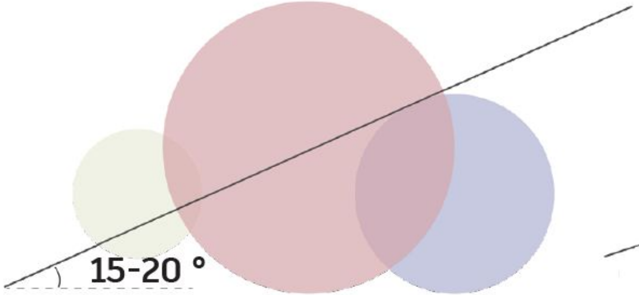
Lunar Base Configuration
Star
Fire and Airlock Failure
Complex build up
No restricted access in case of airlock failure
Low risk associated with airlock failure is absent

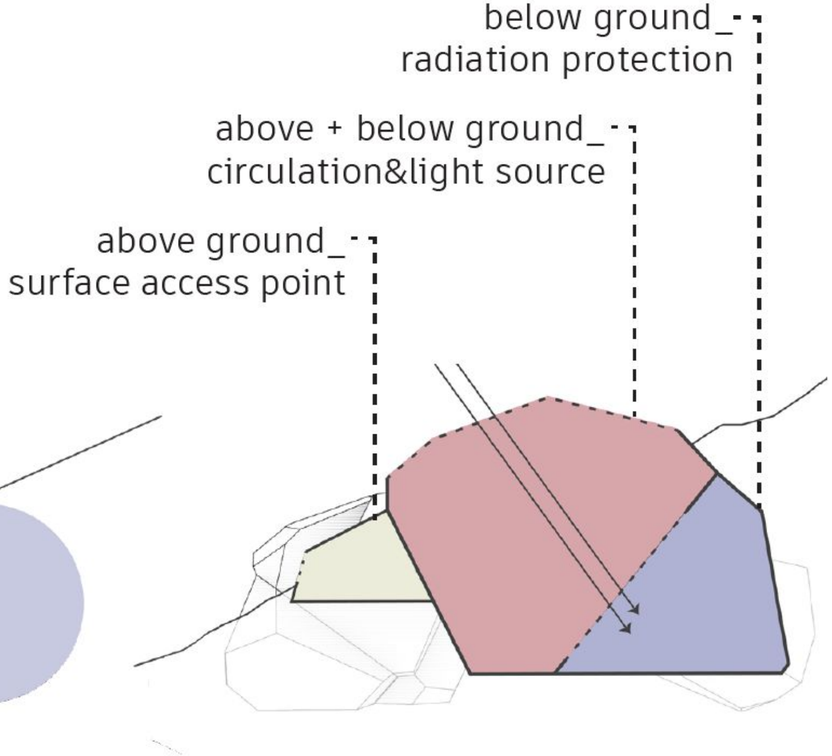


Floorplan
Modulated System Membrane

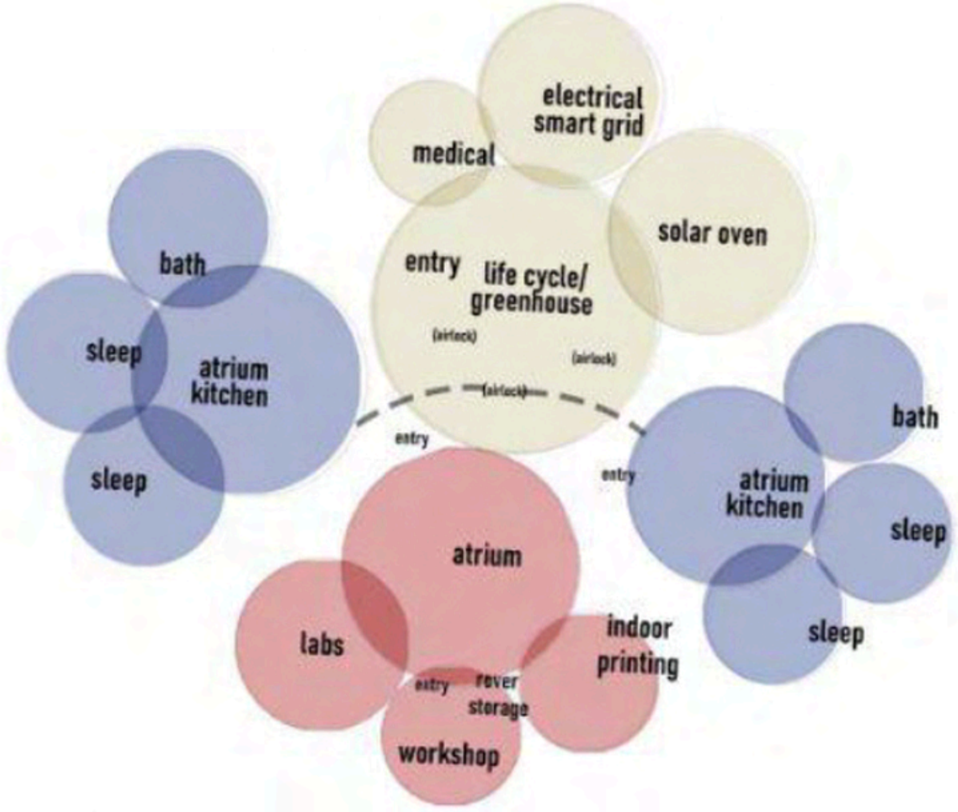
Concept Design_Use of Topography



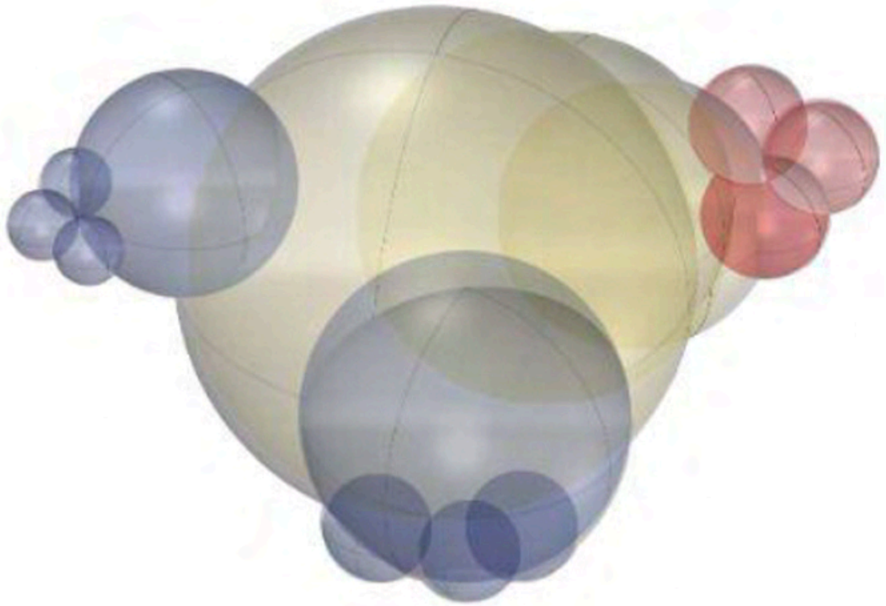




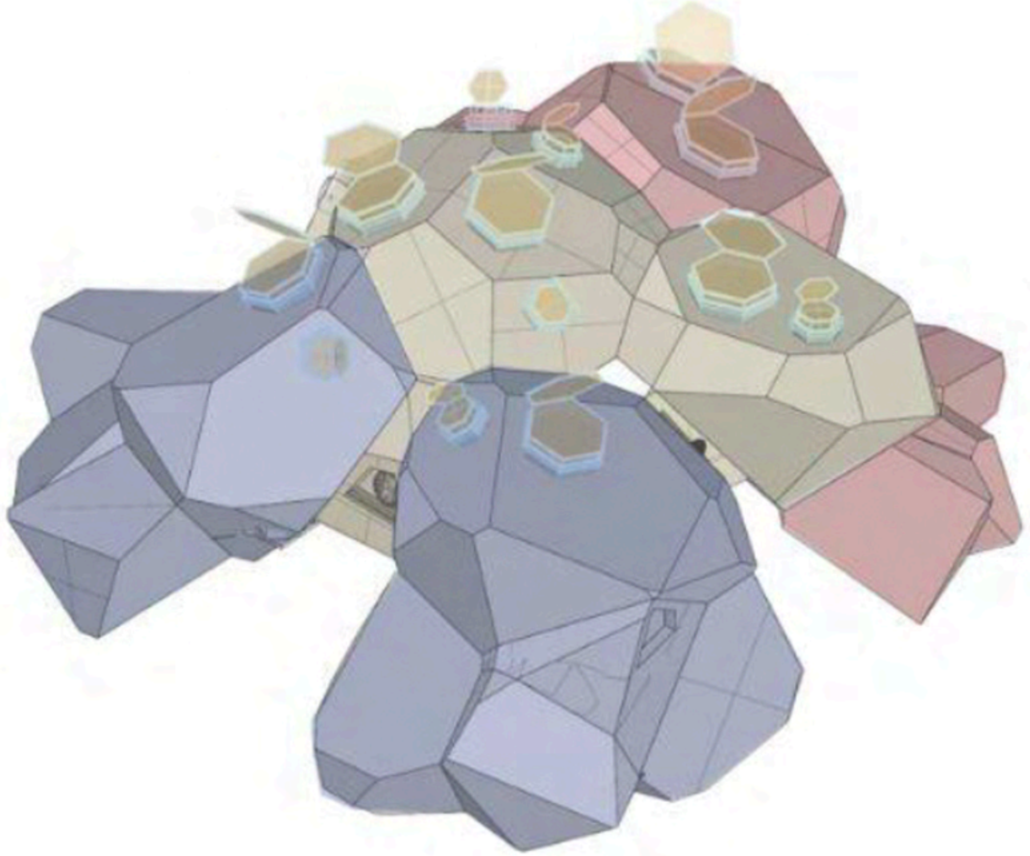
Concept Design_Form Finding



Floorplan



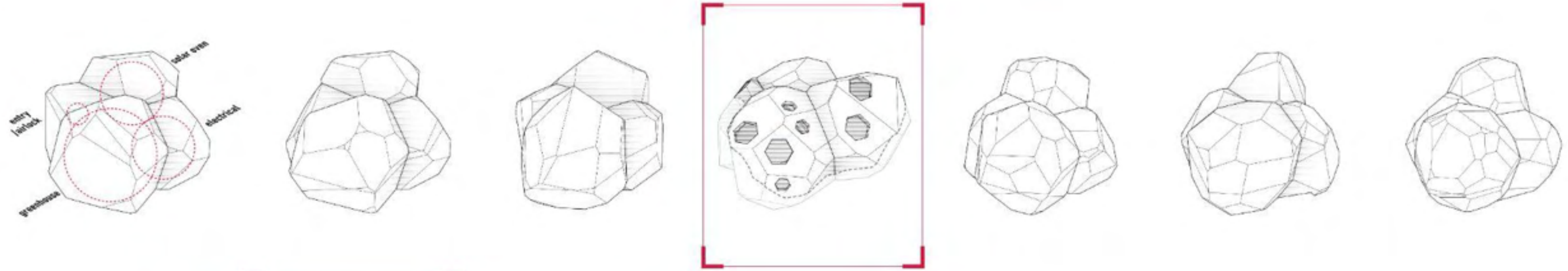
Zoning of space



Voronoi generation

life support cluster_
large voronoi volumes
many openings

considerations:
number of faces
intersecting faces for passage
faces for sunlight
voronoi size deviation

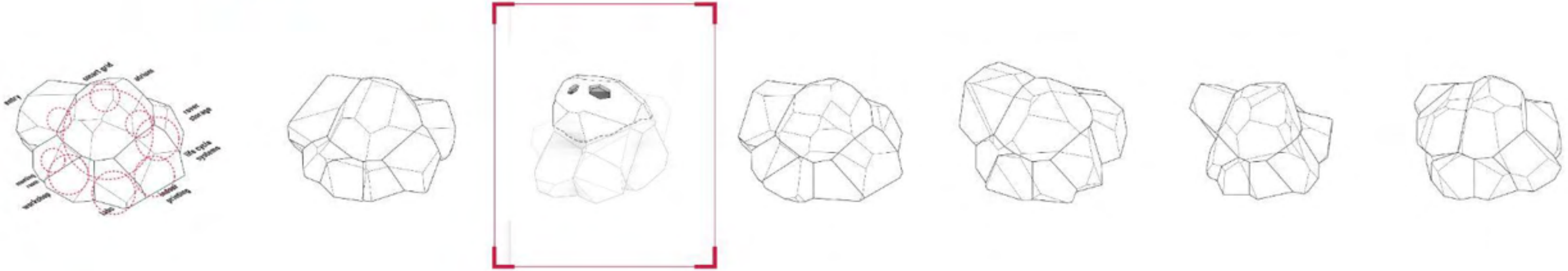


living cluster_
small atrium voronoi volume
many small pod voronoi volumes

considerations:
number of faces
intersecting faces for passage
atrium voronoi size
sleeping pod stacking
voronois below ground

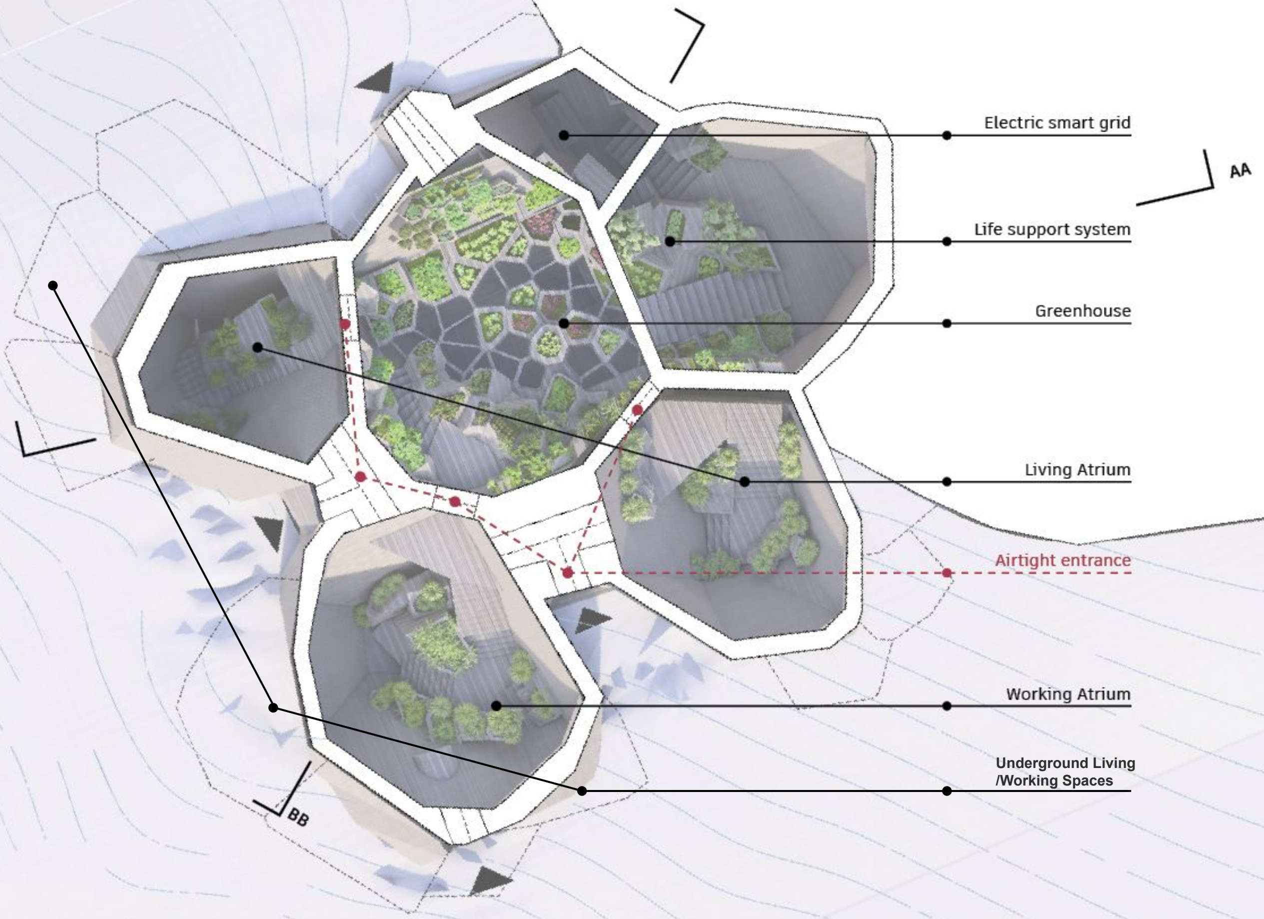
working/lab cluster_
large atrium voronoi volume
many medium voronoi volumes

considerations:
number of faces
intersecting faces for passage
atrium voronoi size
entry voronoi size
volumes stacking for circulation



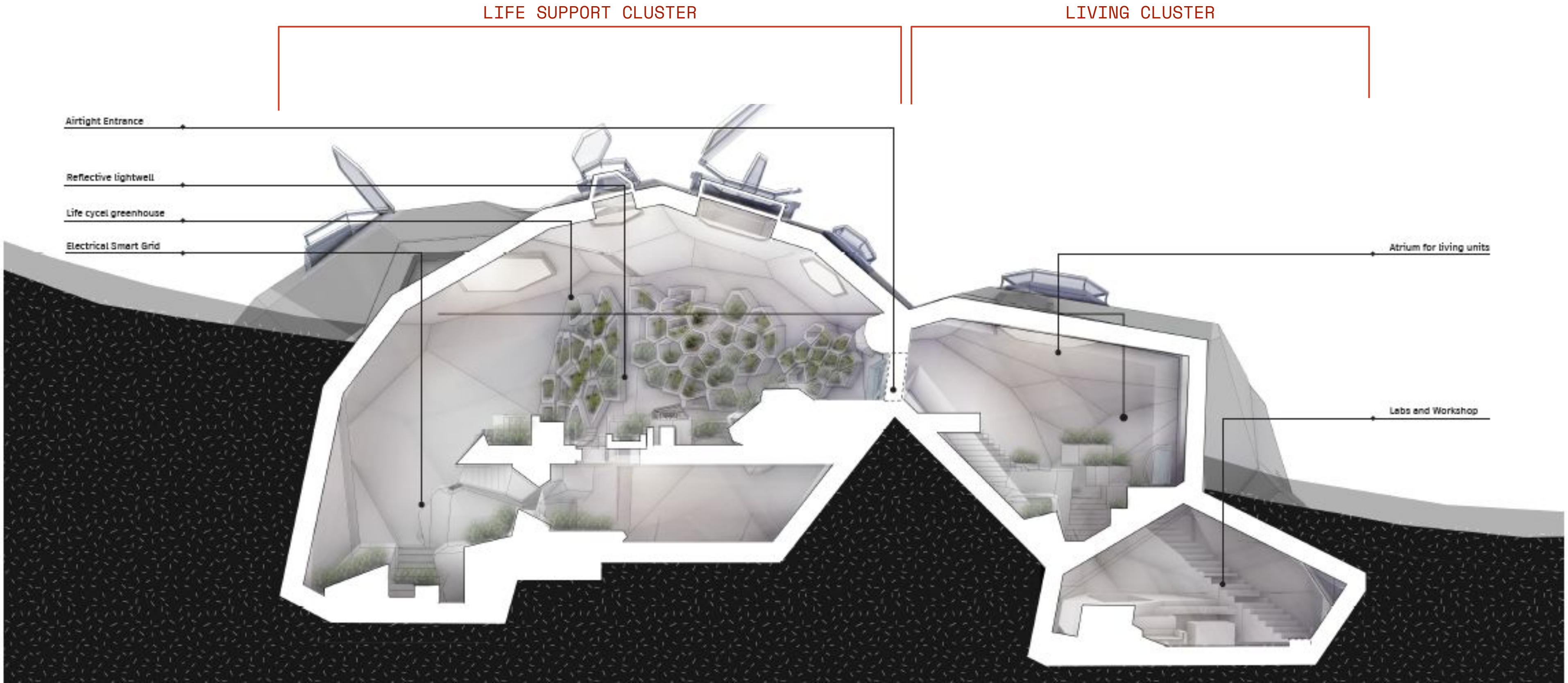
voronoi complexity

Floorplan



Electric smart grid
AA
Life support system
Greenhouse
Living Atrium
Airtight entrance
Working Atrium
Underground Living
/Working Spaces
BB

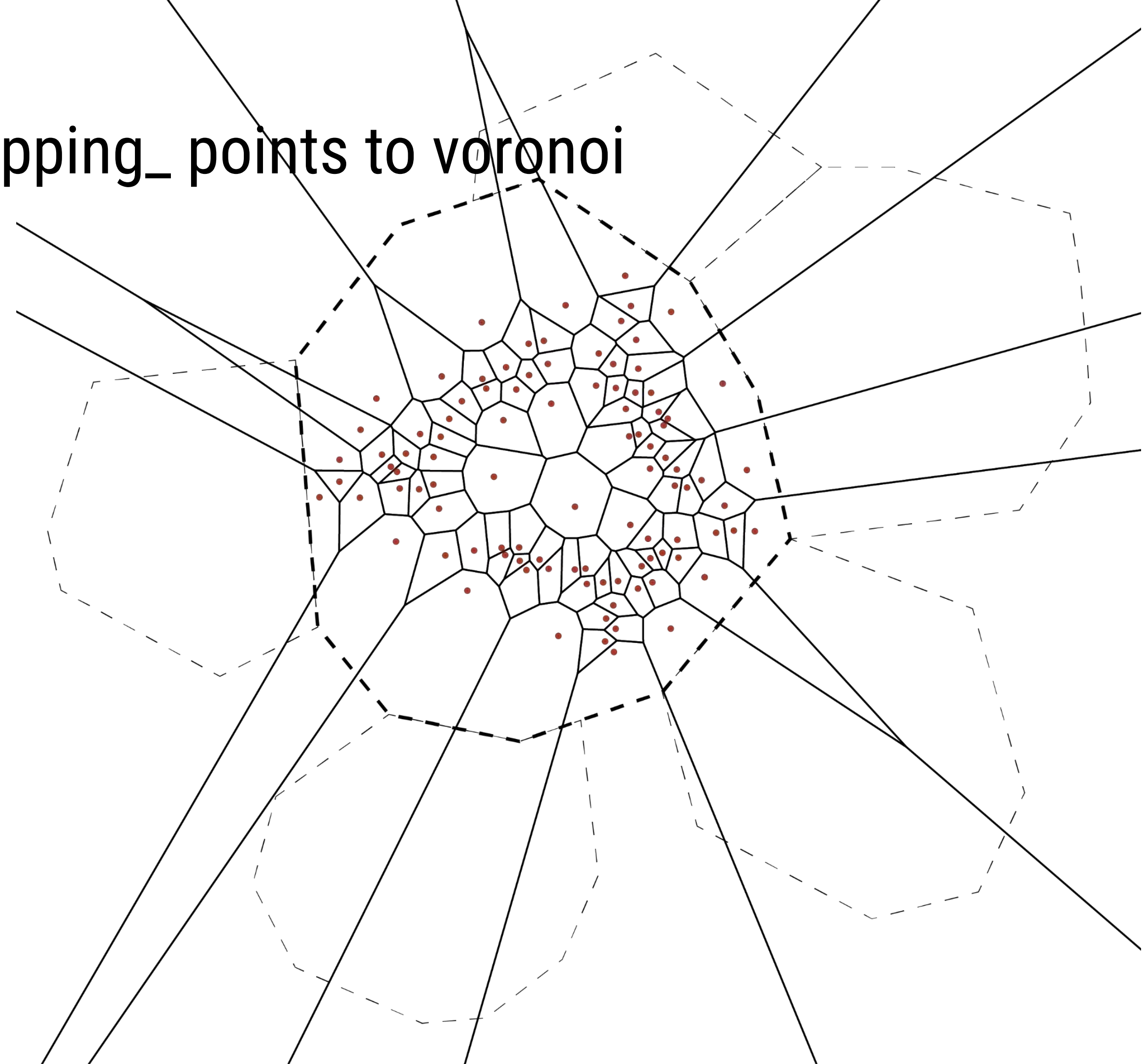
Section



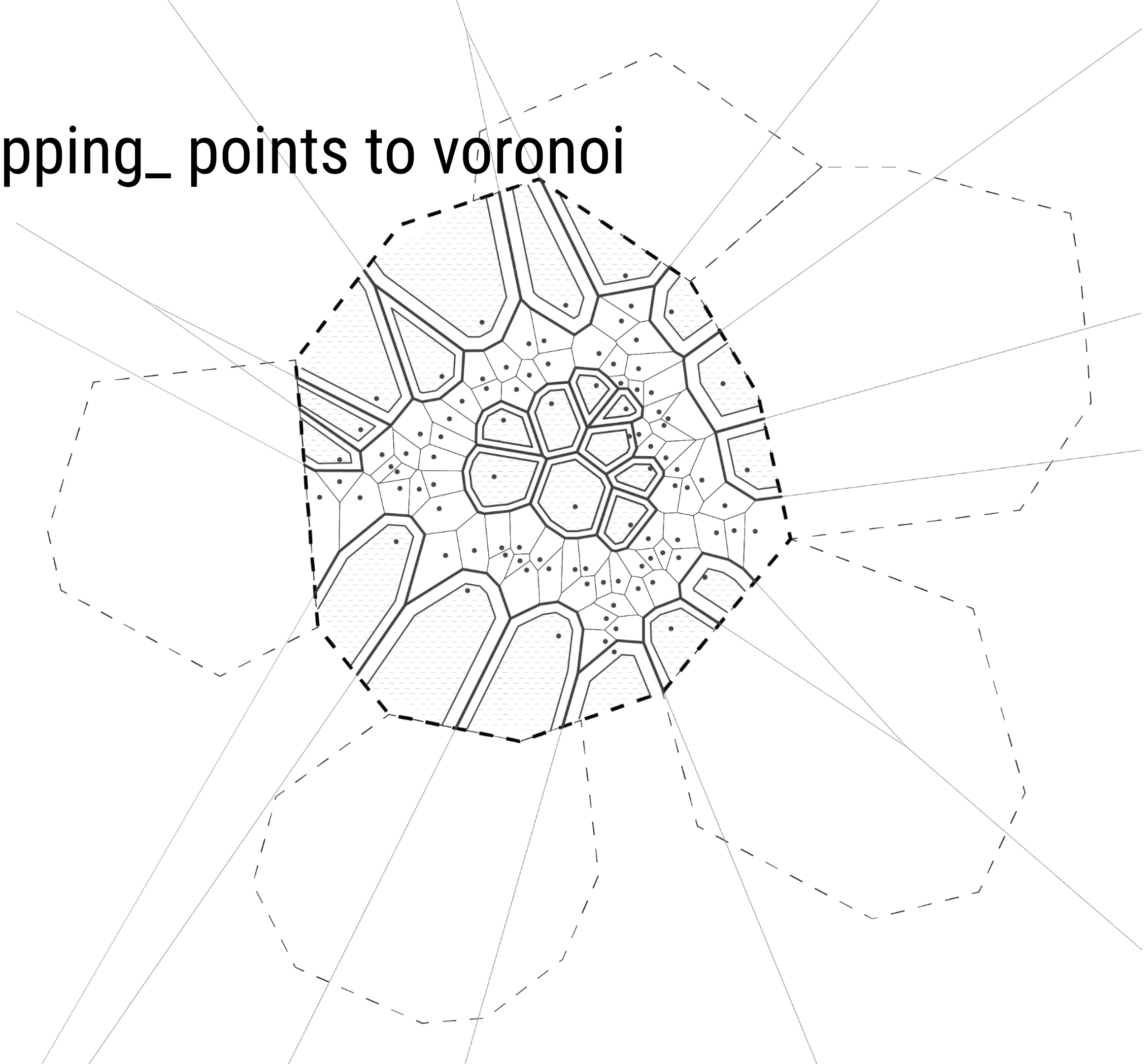
LIFE SUPPORT CLUSTER
LIVING CLUSTER
Airtight Entrance
Reflective lightwell
Life cycel greenhouse
Electrical Smart Grid
Atrium for living units
Labs and Workshop

Life Support + Agriculture

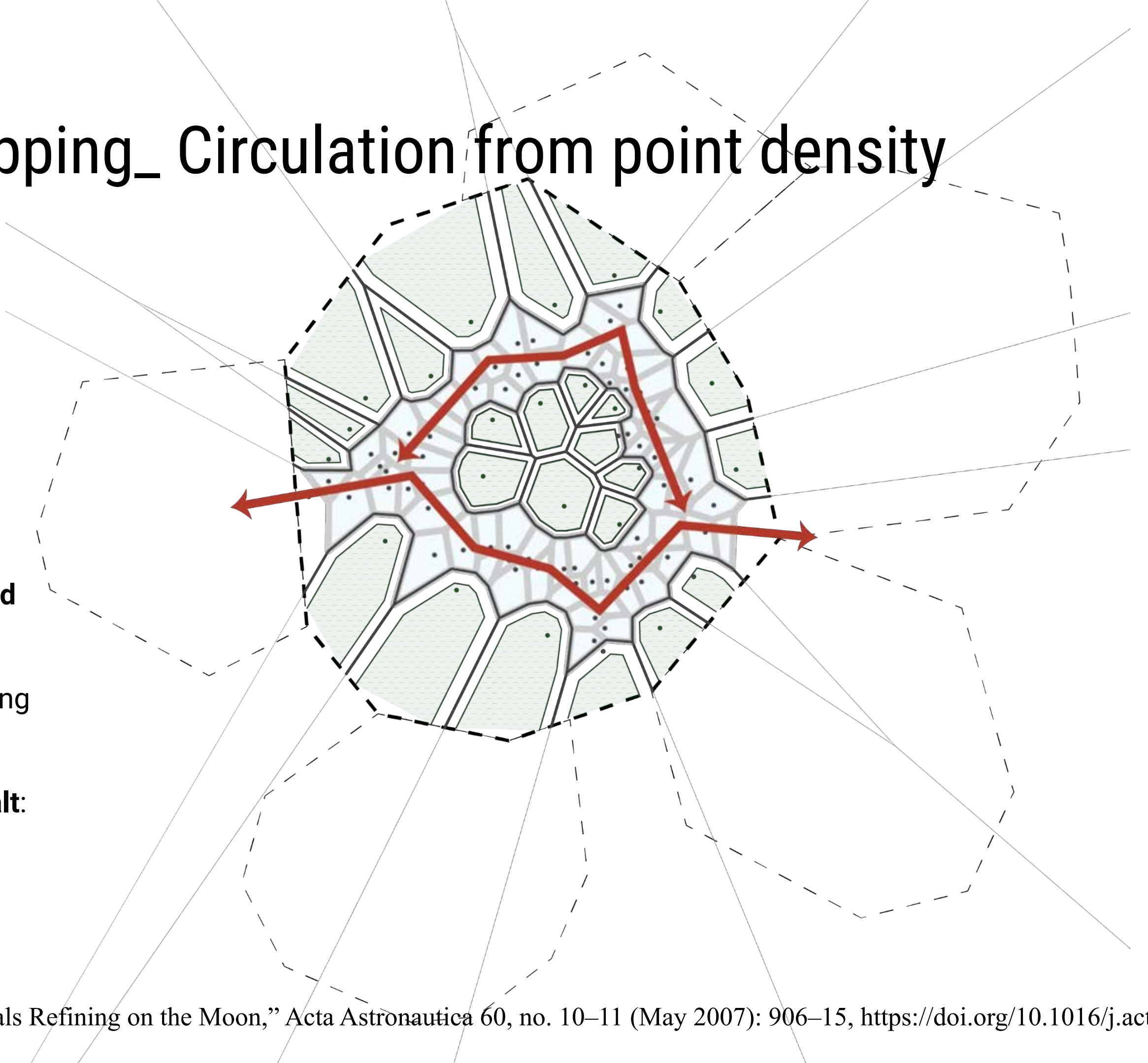
Interior Mapping_ points to voronoi



Interior Mapping_ points to voronoi



Interior Mapping_ Circulation from point density



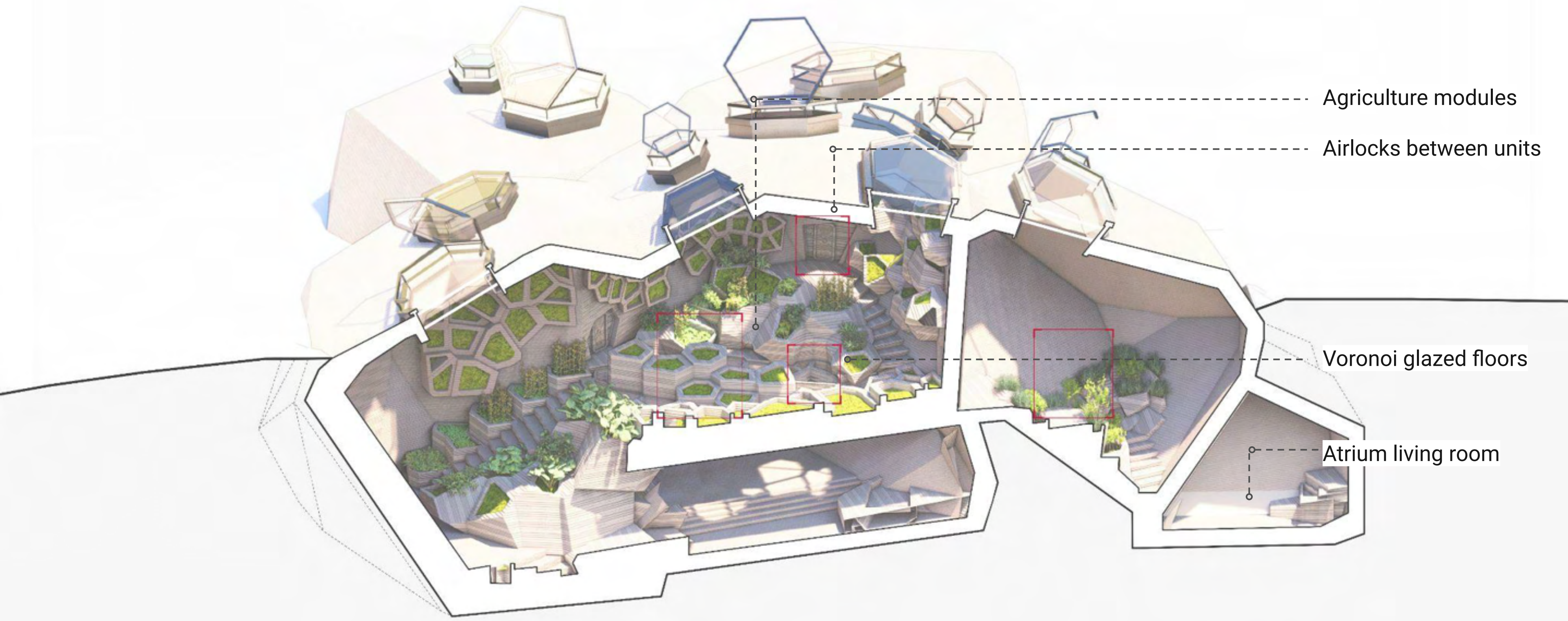
Potential Transparent Materials Manufactured in situ:

Sintered regolith: heating and pressing lunar soil

Quenched molten basalt: rapidly cooling molten basalts.

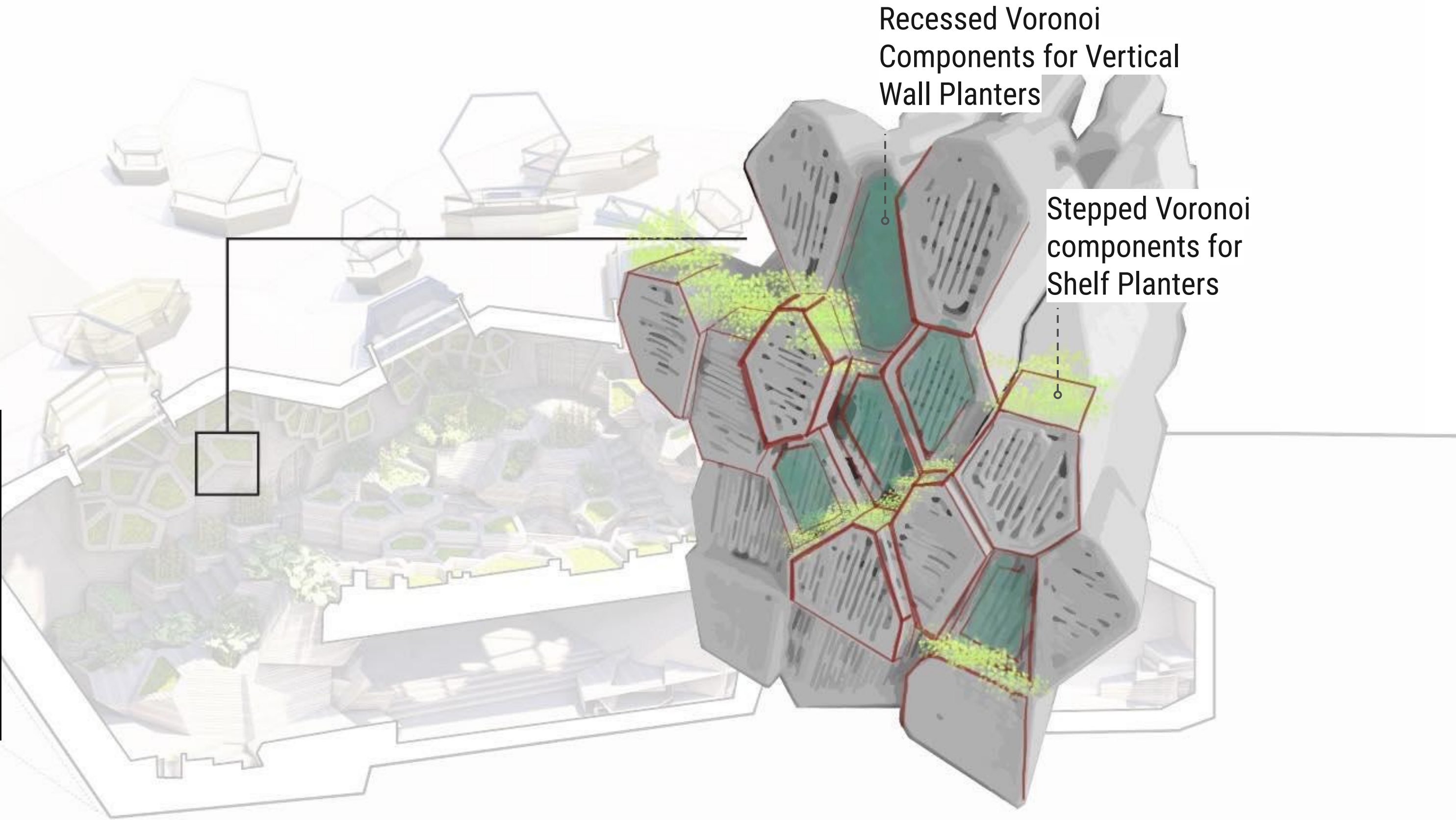
Geoffrey A. Landis, “Materials Refining on the Moon,” Acta Astronautica 60, no. 10–11 (May 2007): 906–15, https://doi.org/10.1016/j.actaastro.2006.11.004.

Axonometric Section



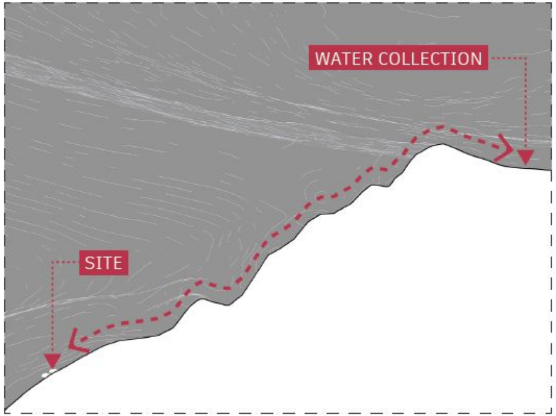
Wall Planters

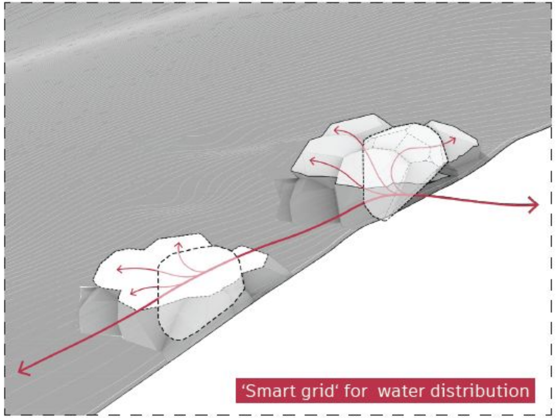
Interior walls can follow voronoi building block logic at a larger scale, creating a not smooth, but textured wall. Depth difference between voronoi components at this scale can be used for furniture and planters.

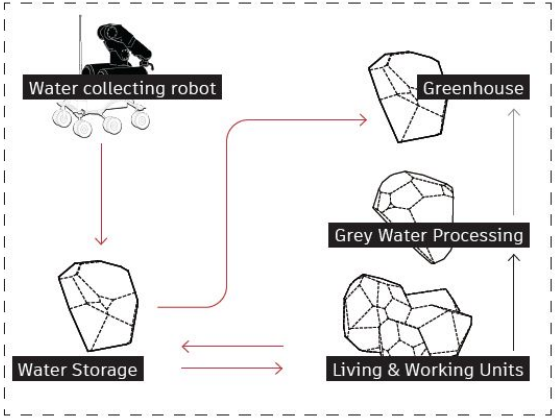


Interior: Greenhouse

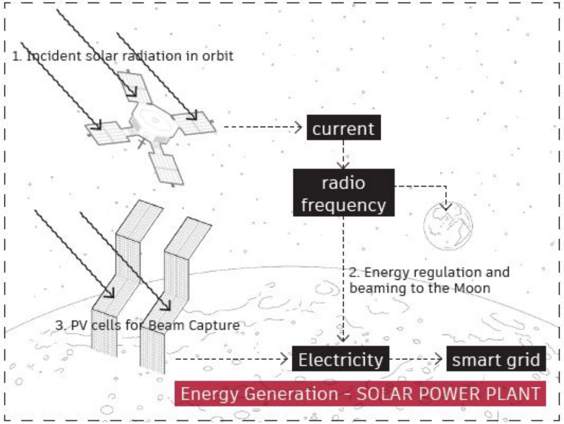
Life Support_Water

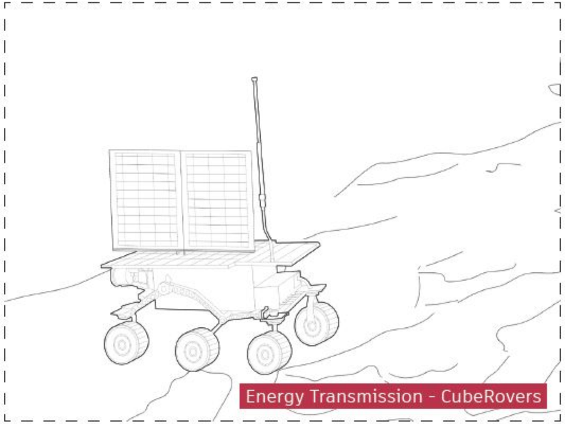


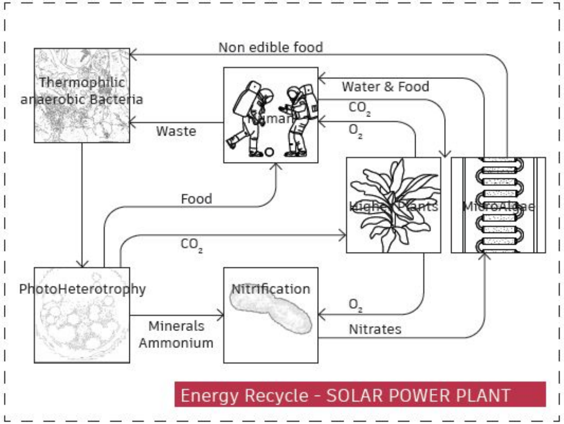




Life Support_Energy

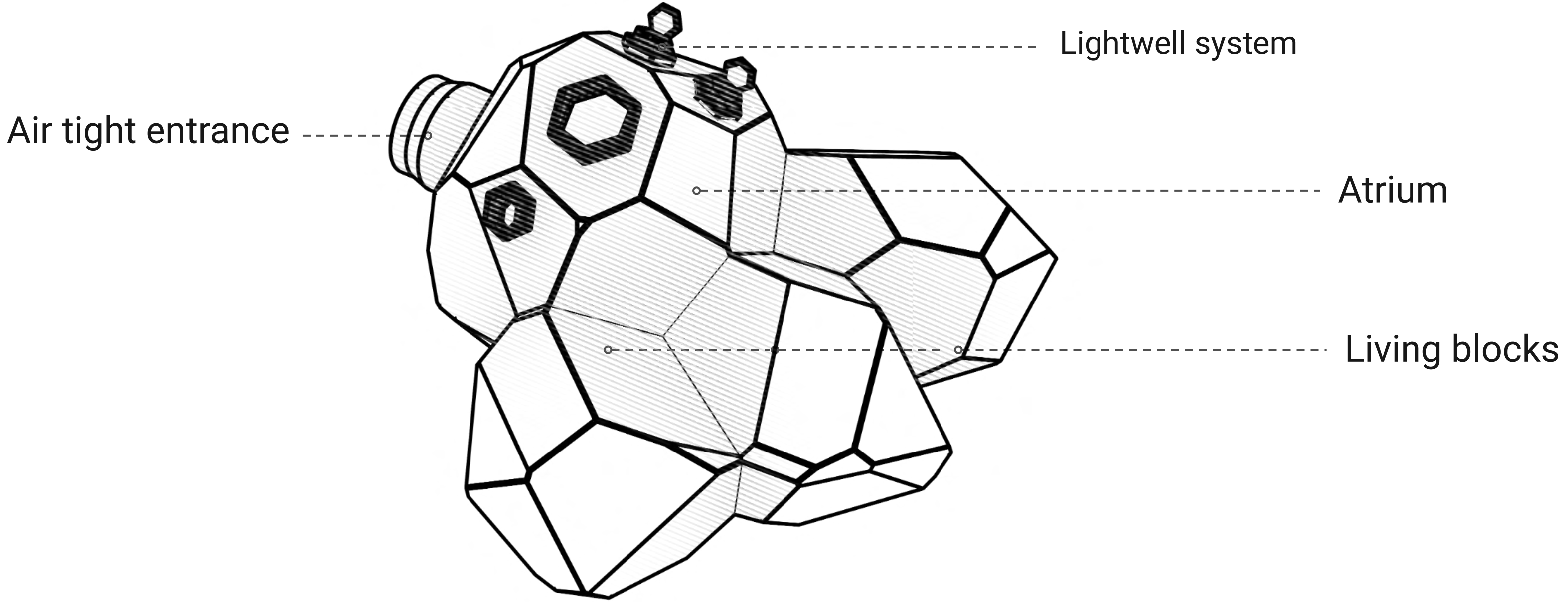




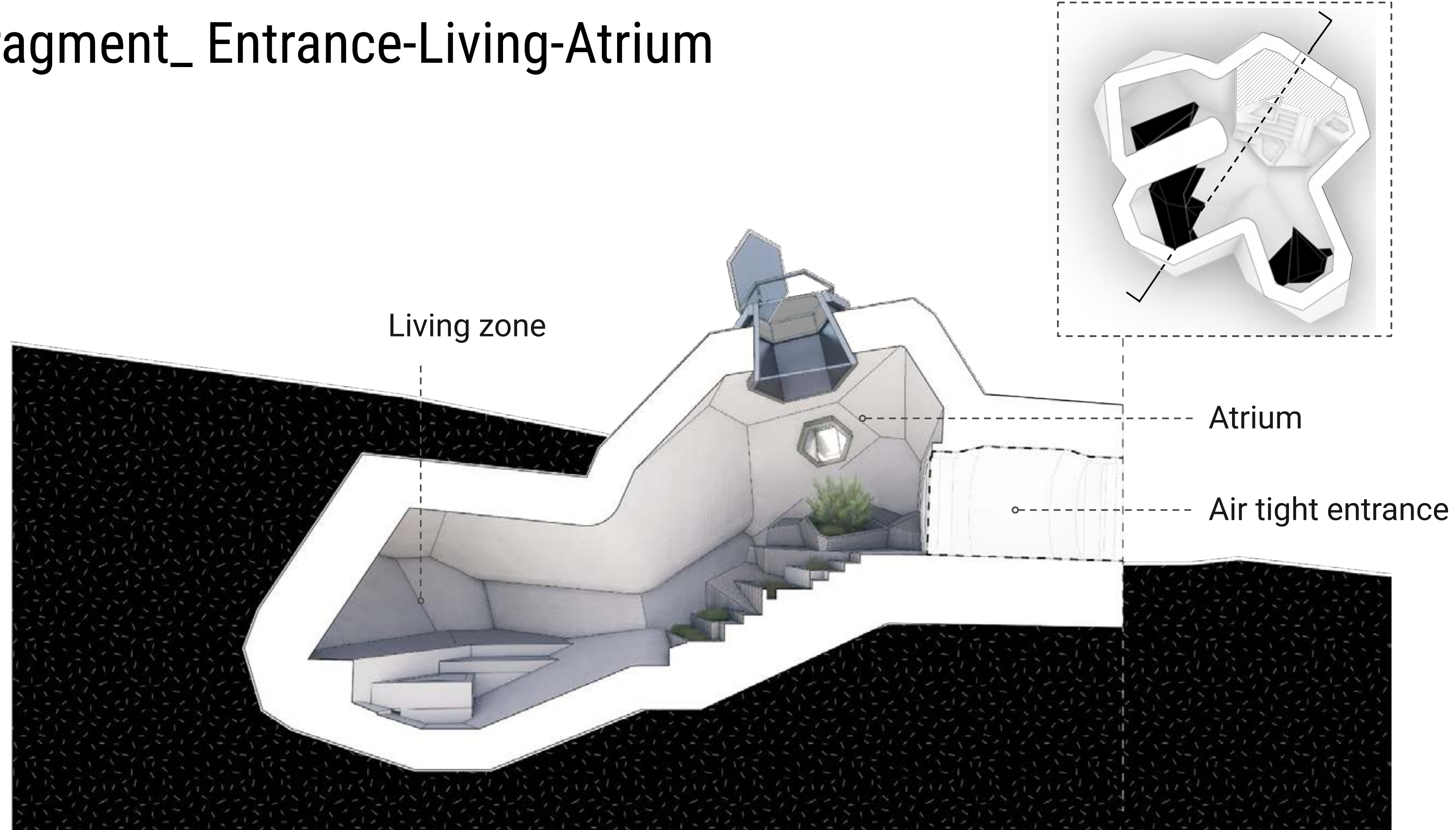


Living Fragment

Fragment_ Entrance-Living-Atrium



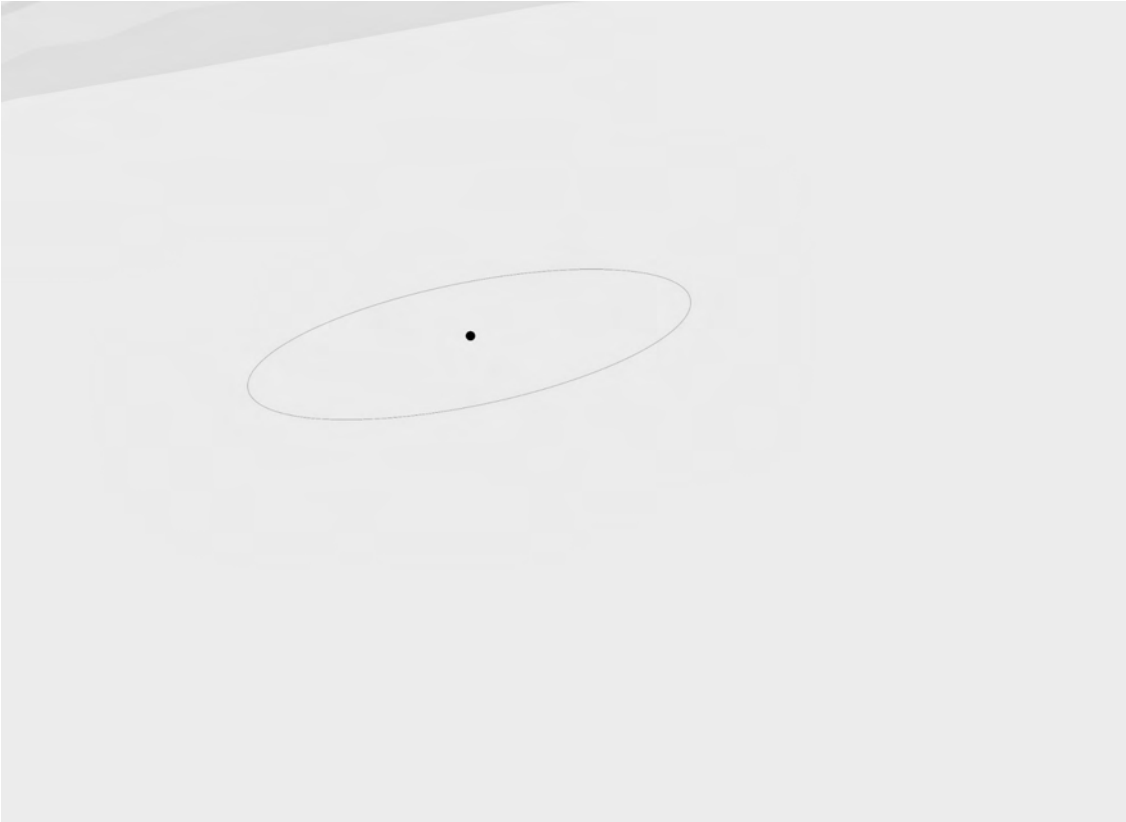
Fragment_ Entrance-Living-Atrium



Fragment_ Form Finding

Central point selection
for atrium

Fragment_ Form Finding

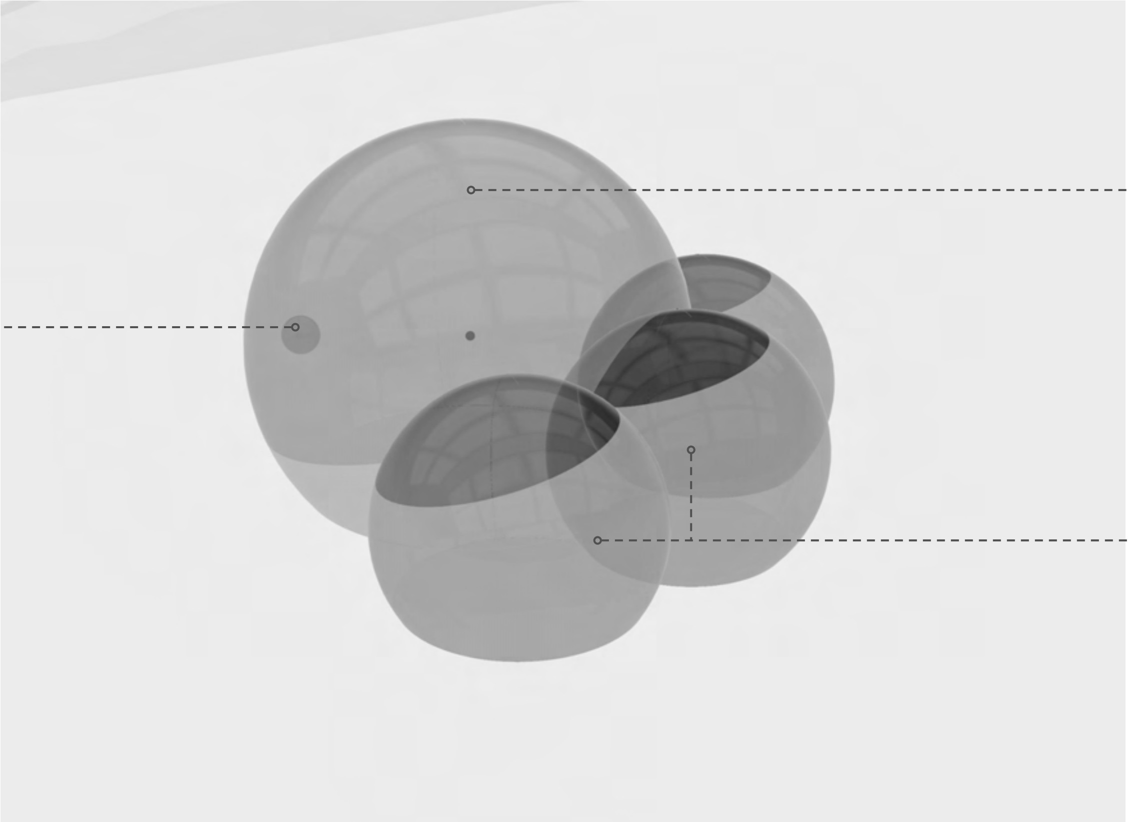


Circle generated from
the atrium central point

Fragment_ Form Finding

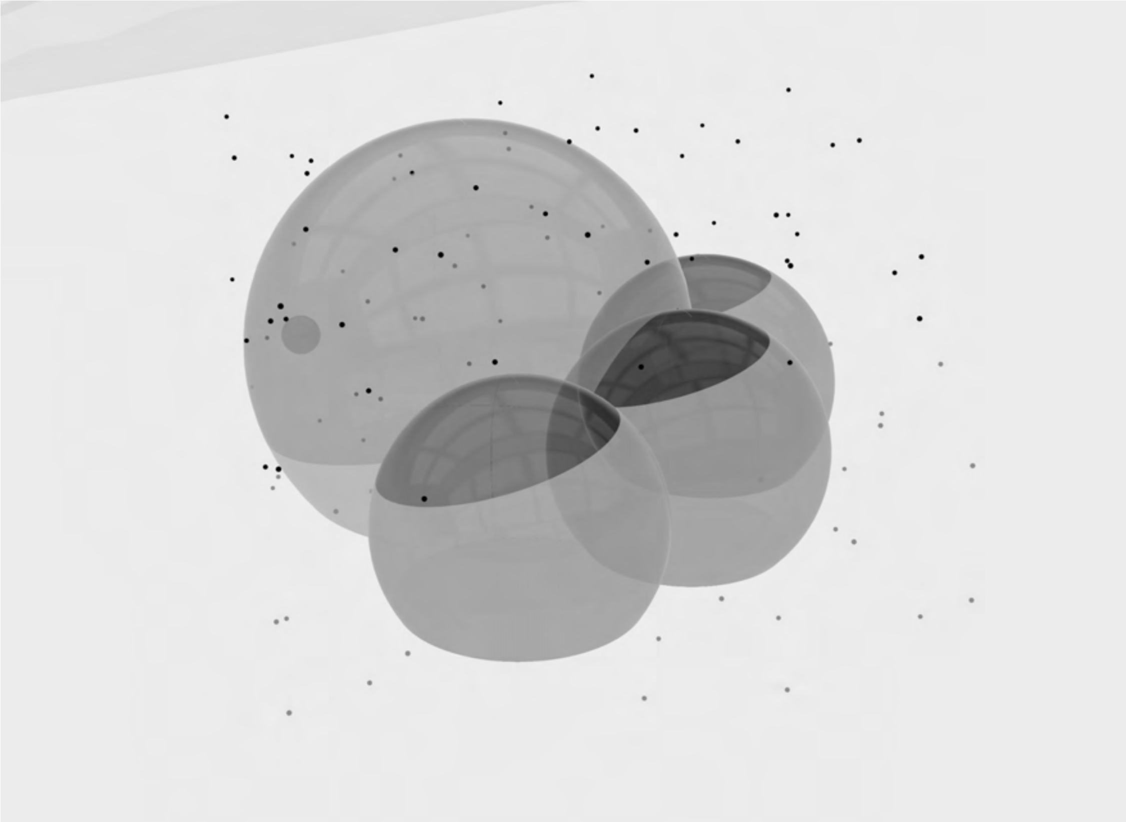
Circle points selection for entrance and living units

Fragment_ Form Finding



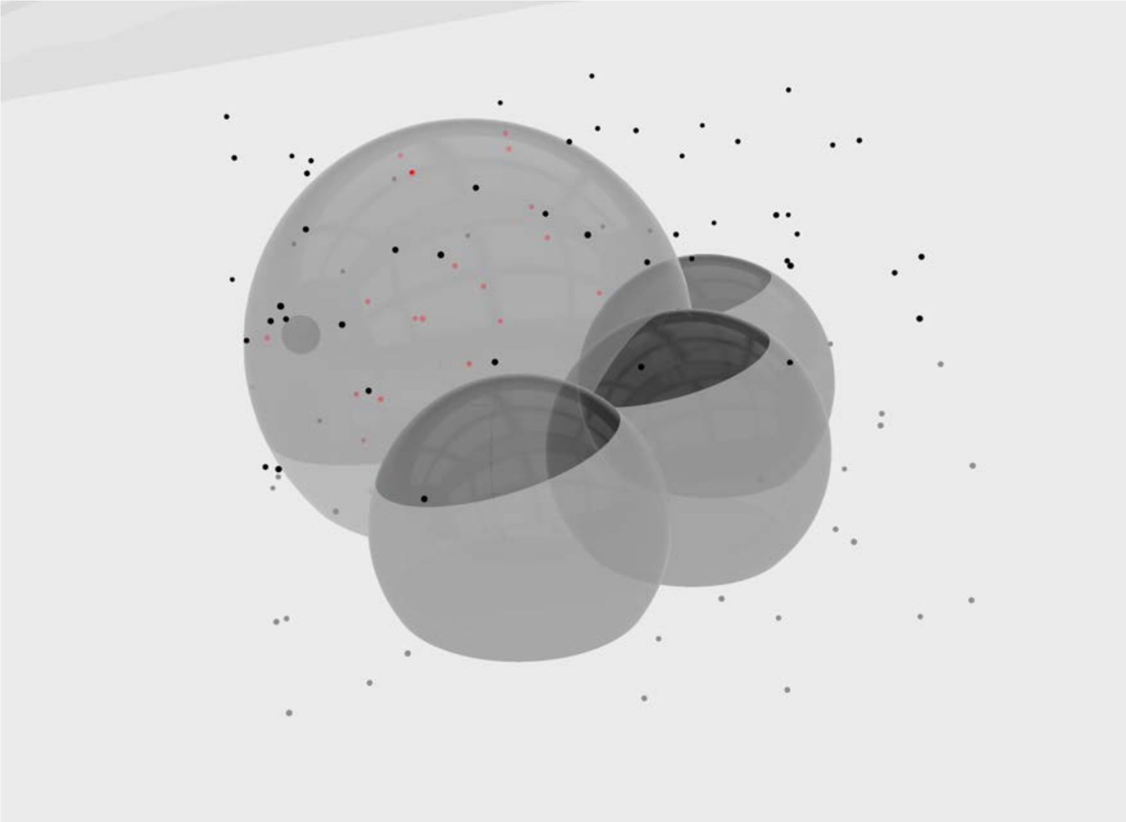
Bubble generation based on area needed for each function

Fragment_ Form Finding



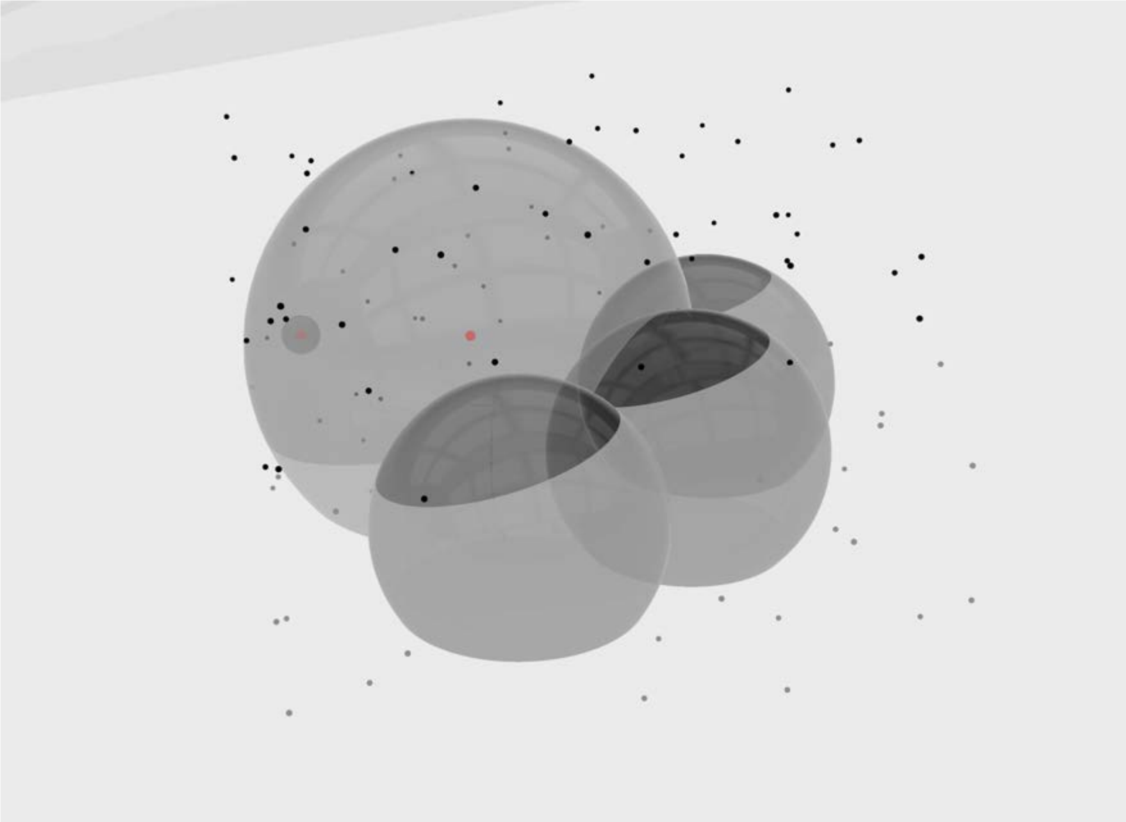
Generation of random point cloud

Fragment_ Form Finding



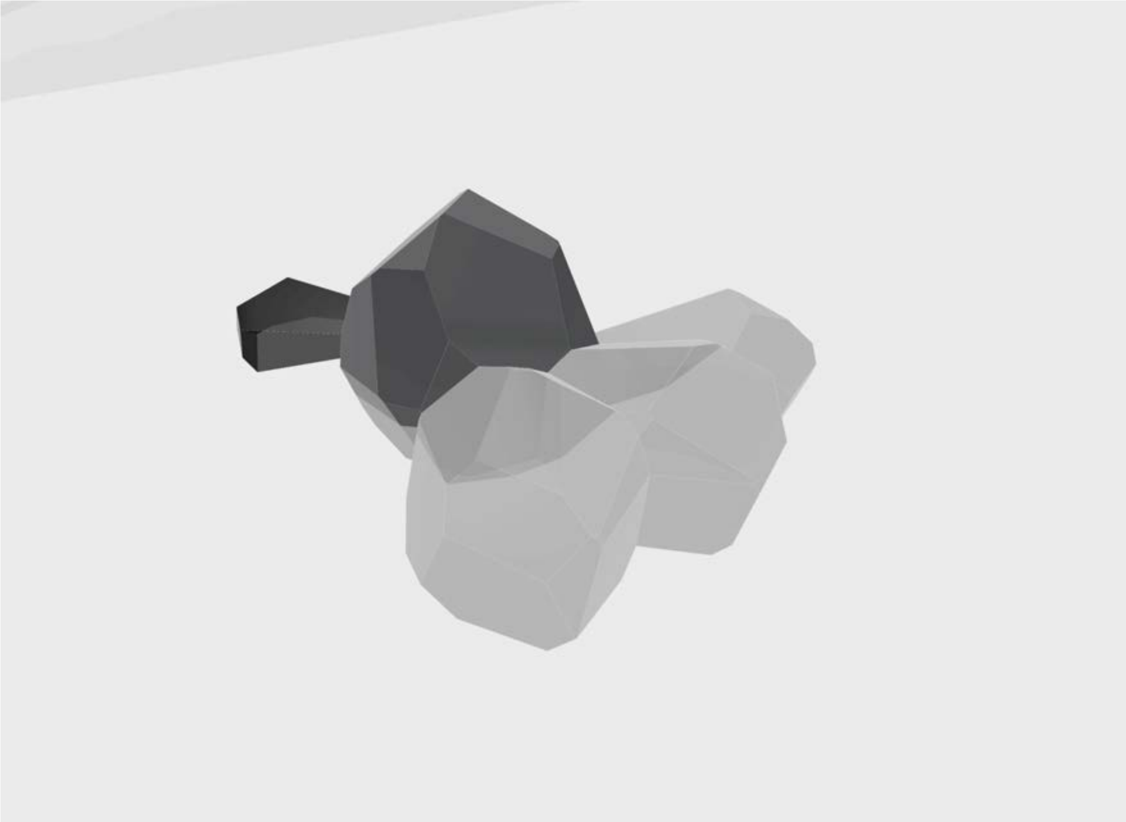
Dispatch of points inside and outside the bubbles

Fragment_ Form Finding



Replacement of points inside the bubbles to central points of the bubbles

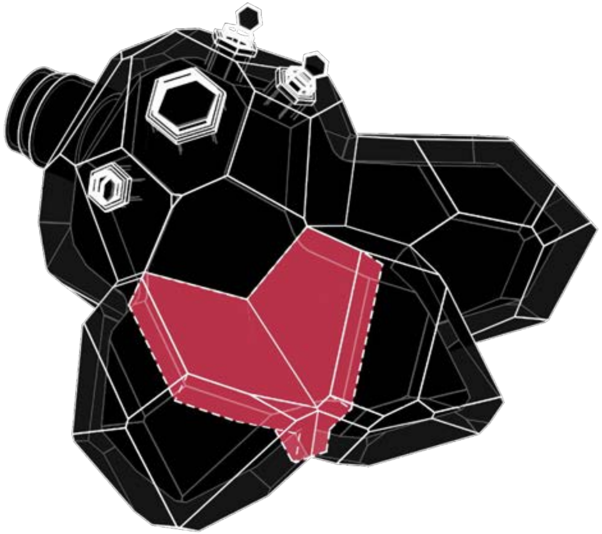
Fragment_ Form Finding



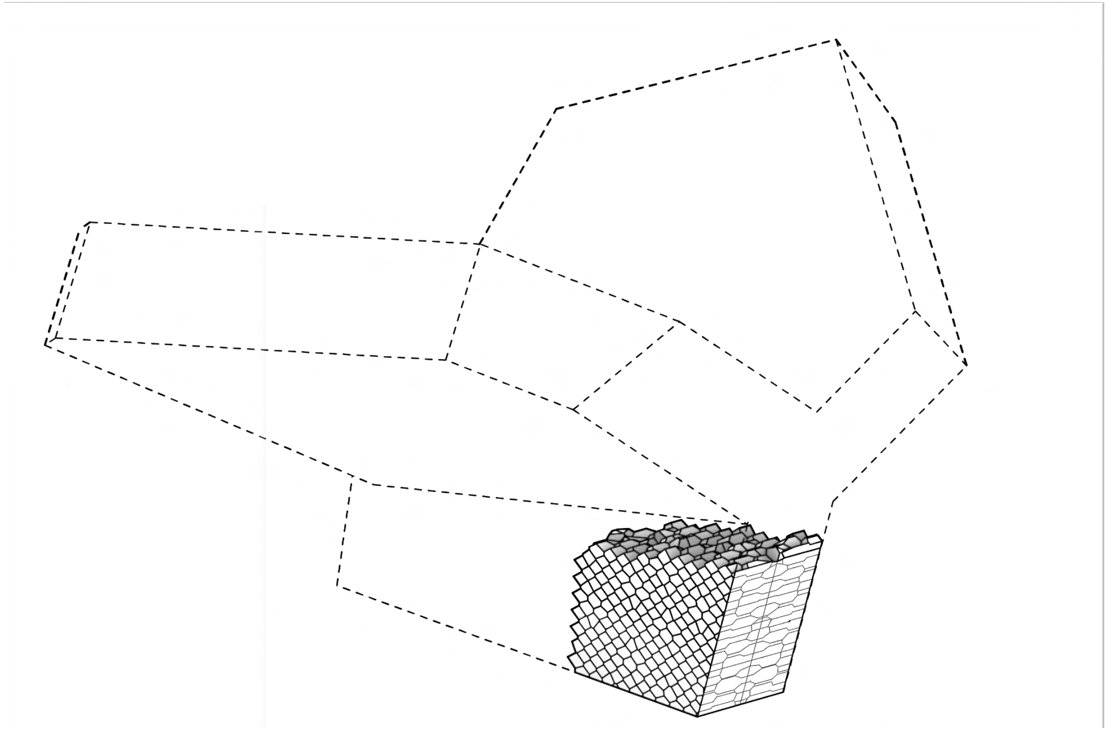
Corresponding voronoi shape of the bubble

Assembly Concept + Interlocking Fragment

Fragment_ Entrance-Living-Atrium



Fragment



Assembly_ Interlocking concept_ Scutoids

Scutoid Brick

The Designing of Epithelial cell inspired-brick in Masonry shell System

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[1,2,3]Cornell University
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This paper focuses on the design of individual bricks in a masonry shell system that are inspired and informed by the reorganization of epithelial cells within tissues. Starting from a newly discovered shape called "Scutoid", we first investigated how epithelial cells within living animals are packed three dimensionally within tissues. We focused on the living mechanisms within these cells that facilitate tissue curvature in the creatures' organs, skin, and blood vessels. By utilizing this generative geometric approach, we created a series of parametric generators and modeling kits to represent this mechanism and process. We then explored the potential for adopting this mechanism into larger-scale settings. Meanwhile, we discovered that the deformation of individual epithelial cells during the bending process generates an intriguing triangular connection along the bending direction. We managed to translate this unique feature to the architectural scale as a joint system for connecting bricks in a masonry shell structure. Based on the above findings, we designed and fabricated a set of models for the masonry shell structure that are generated from scutoid bricks and this unique joint. The geometrical characteristics of scutoid bricks allows the packing of four bricks with just two joints. The work that we have generated thus far contributes to solving issues of shell design and fabrication from the perspective of individual units. The result of the shell structure model demonstrates that applying the epithelial cell inspired-block masonry system is a feasible approach for the construction of shell structures.

Keywords: *Epithelial cell, Scutoid, Bio-inspired Design, Generative Design, Masonry shell*

INTRODUCTION & BACKGROUND

Due to the limitation of imaging technology at the nanoscale, a comprehensive visualized description of epithelial cells' three-dimensional appearance has been missing from the field until recently. Most biological researchers understood the shape to be similar to columnar prisms or a frustum shape. In 2018, through the approach of mathematical modeling, A group of scientists from Universidad de Sevilla (G'omez-G'alvez, Pedro, et al, 2018) unexpectedly

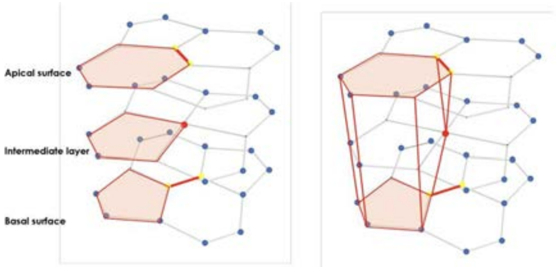
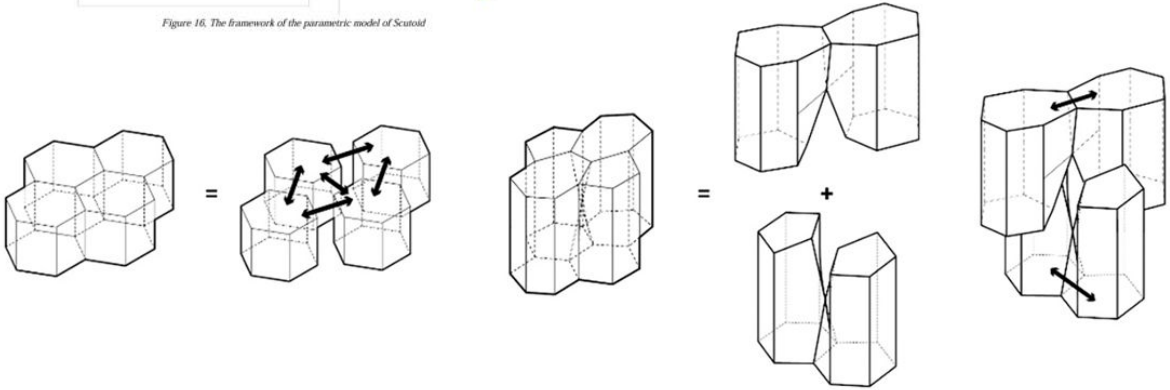
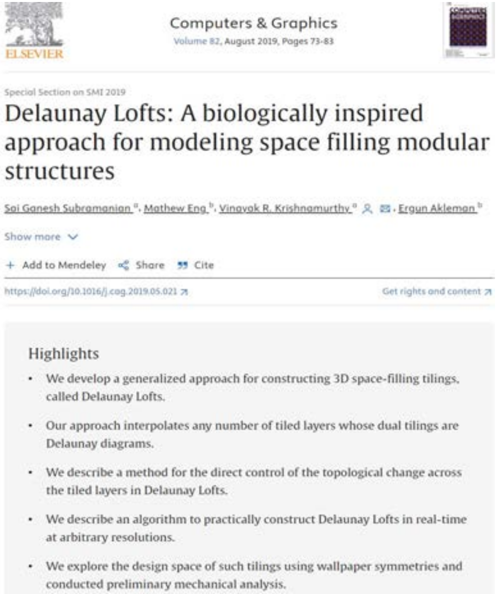


Figure 16. The framework of the parametric model of Scutoid



Assembly_ Interlocking concept_ Scutoids



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Special Section on SMI 2019

Delaunay Lofts: A biologically inspired approach for modeling space filling modular structures

Sai Ganesh Subramanian [a], Mathew Eng [b], Vinayak R. Krishnamurthy [a], Ergun Akleman [b]

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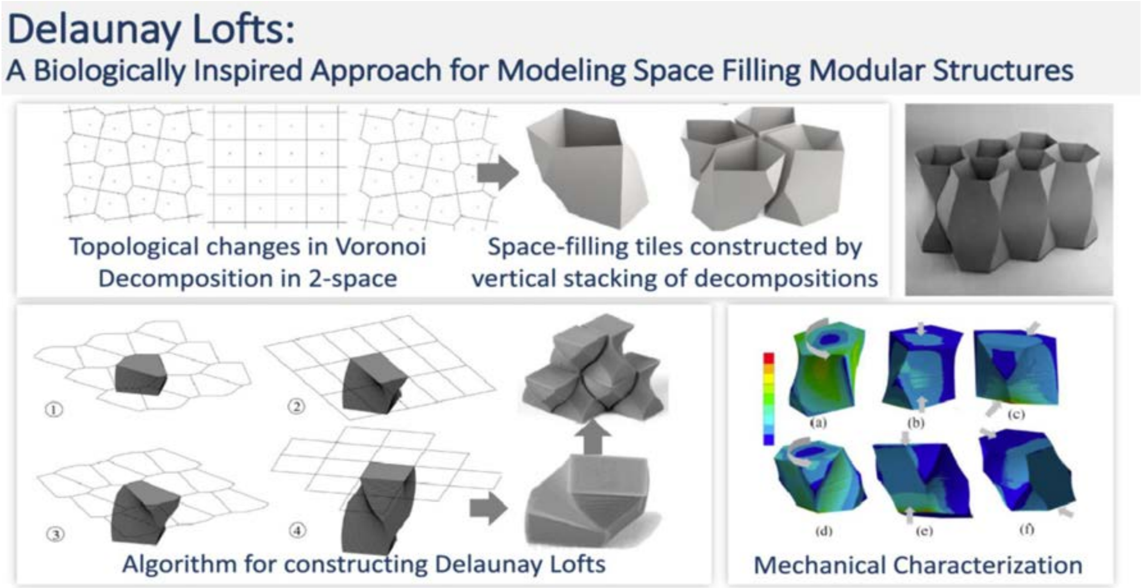
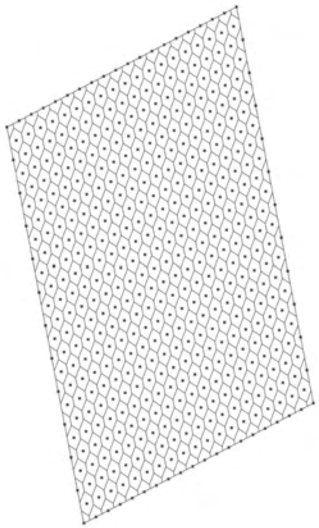
Highlights

- We develop a generalized approach for constructing 3D space-filling tilings, called Delaunay Lofts.
- Our approach interpolates any number of tiled layers whose dual tilings are Delaunay diagrams.
- We describe a method for the direct control of the topological change across the tiled layers in Delaunay Lofts.
- We describe an algorithm to practically construct Delaunay Lofts in real-time at arbitrary resolutions.
- We explore the design space of such tilings using wallpaper symmetries and conducted preliminary mechanical analysis.

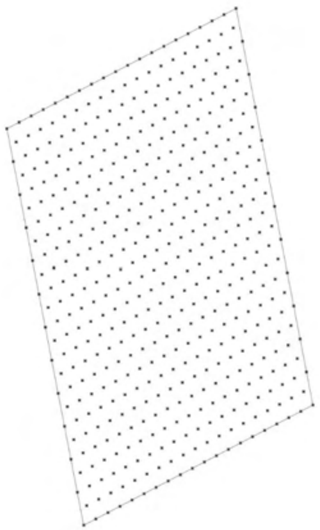


Assembly_ Generating interlocking voronoi



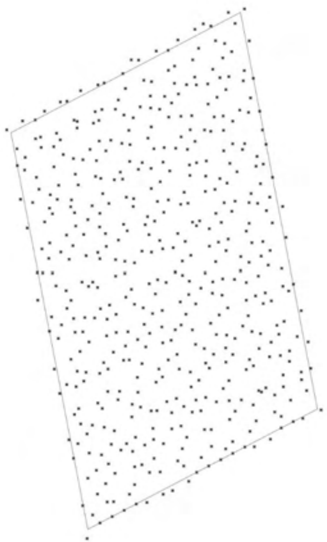
Uniform hexagonal cell generated of the surface

Assembly_ Generating interlocking voronoi



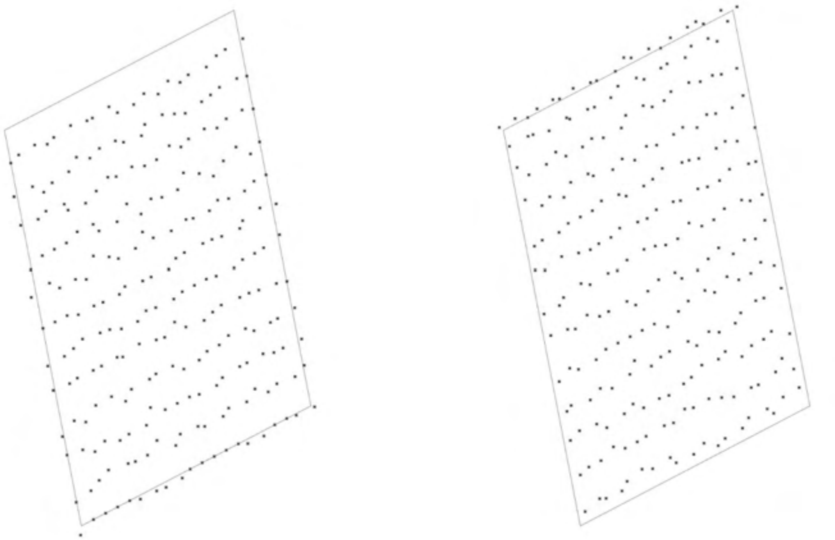
Uniform points grid generated from hexagonal cell

Assembly_ Generating interlocking voronoi



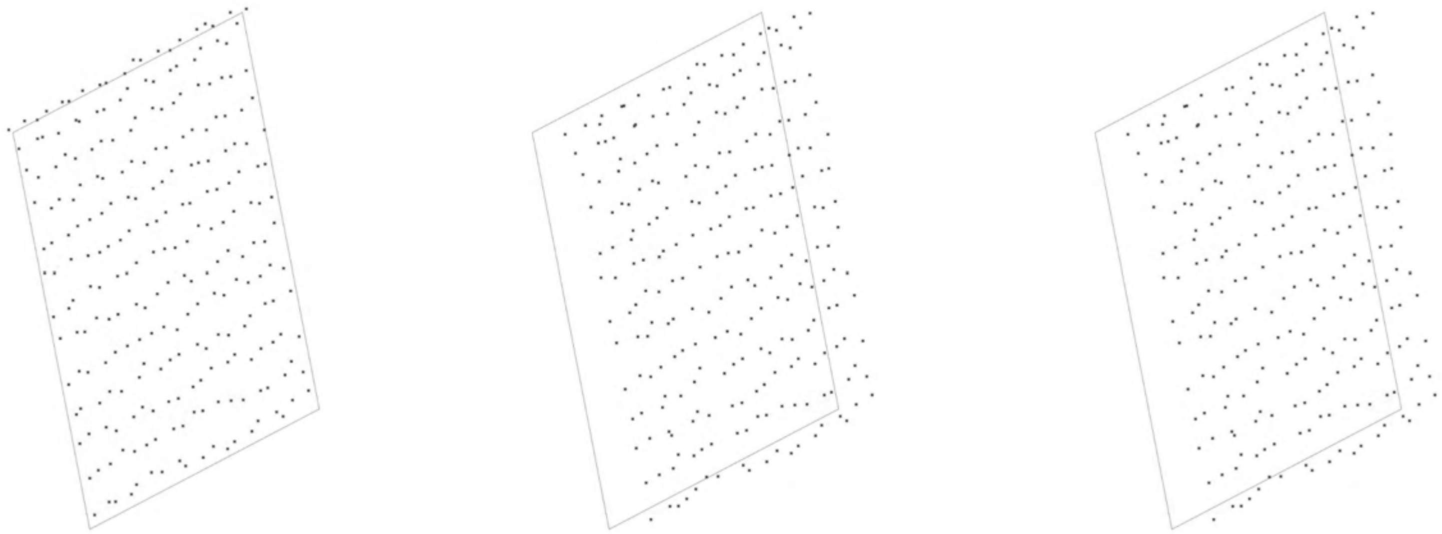
Attractive point to add complexity to the grid
(attractive point might be based on structural optimization
or other factors)

Assembly_ Generating interlocking voronoi



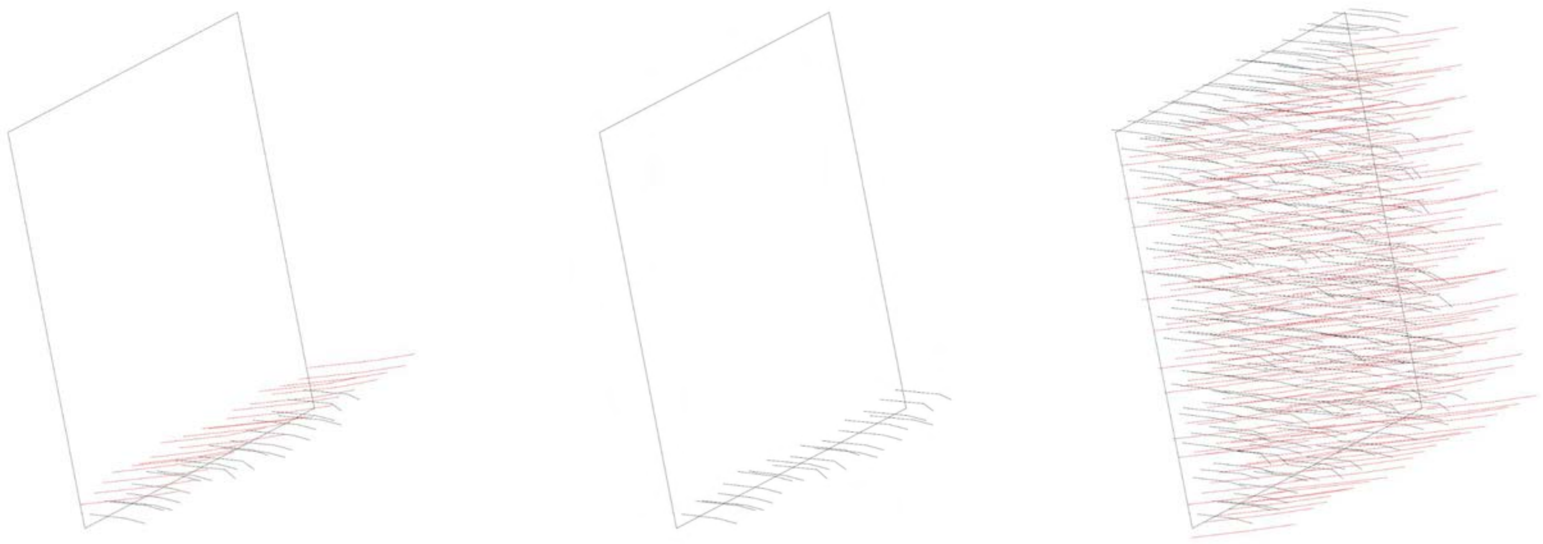
Dispatch the point cloud into 2 clusters

Assembly_ Generating interlocking voronoi



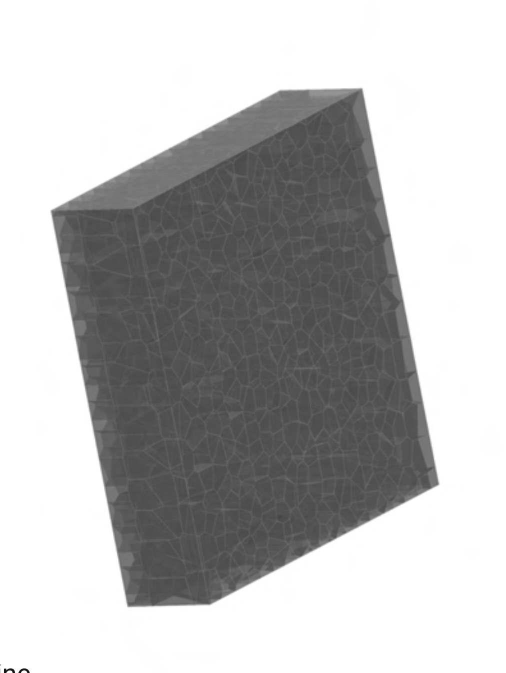
Movement of point in 3 layers

Assembly_ Generating interlocking voronoi



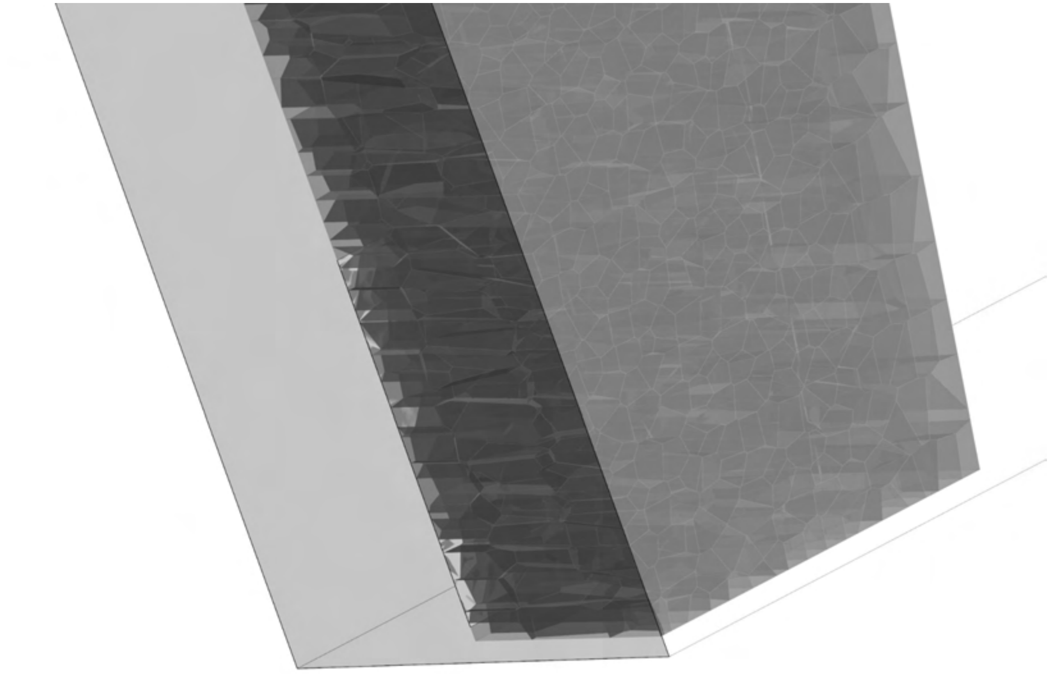
Crossing lines generated as baseline for interlocking voronoi shapes

Assembly_ Generating interlocking voronoi



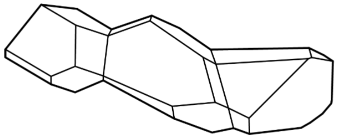
Voronoi shape generated based on points on cross line

Assembly_ Generating interlocking voronoi



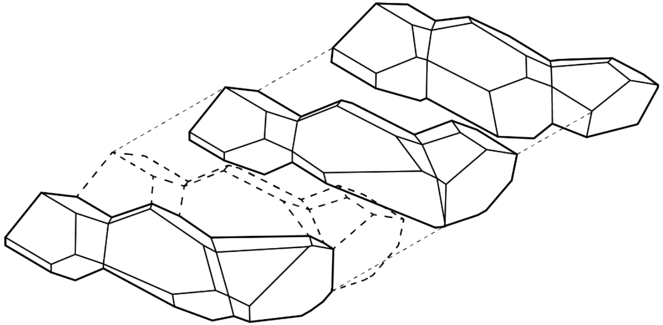
Scaled to the wall thickness

Assembly_ Interlocking component



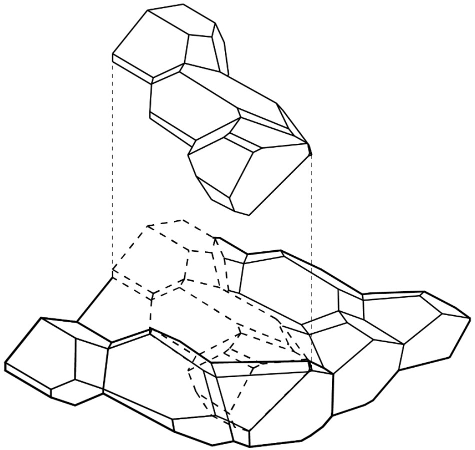
One component generated based on 3 points

Assembly_ Fragment selection



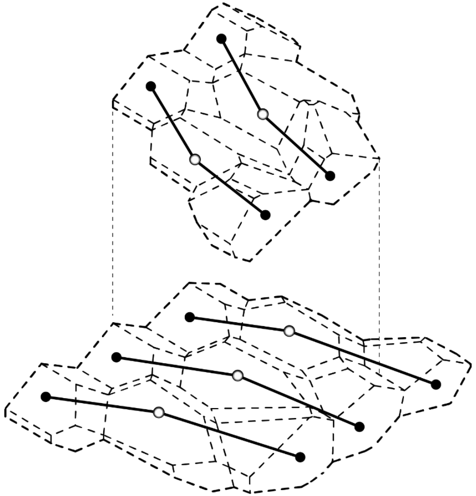
Interlocking horizontally

Assembly_ Fragment selection



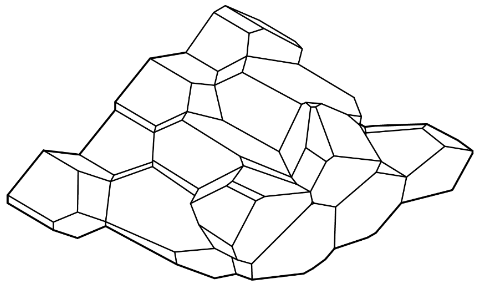
Interlocking vertically

Assembly_ Fragment selection



Interlocking vertically

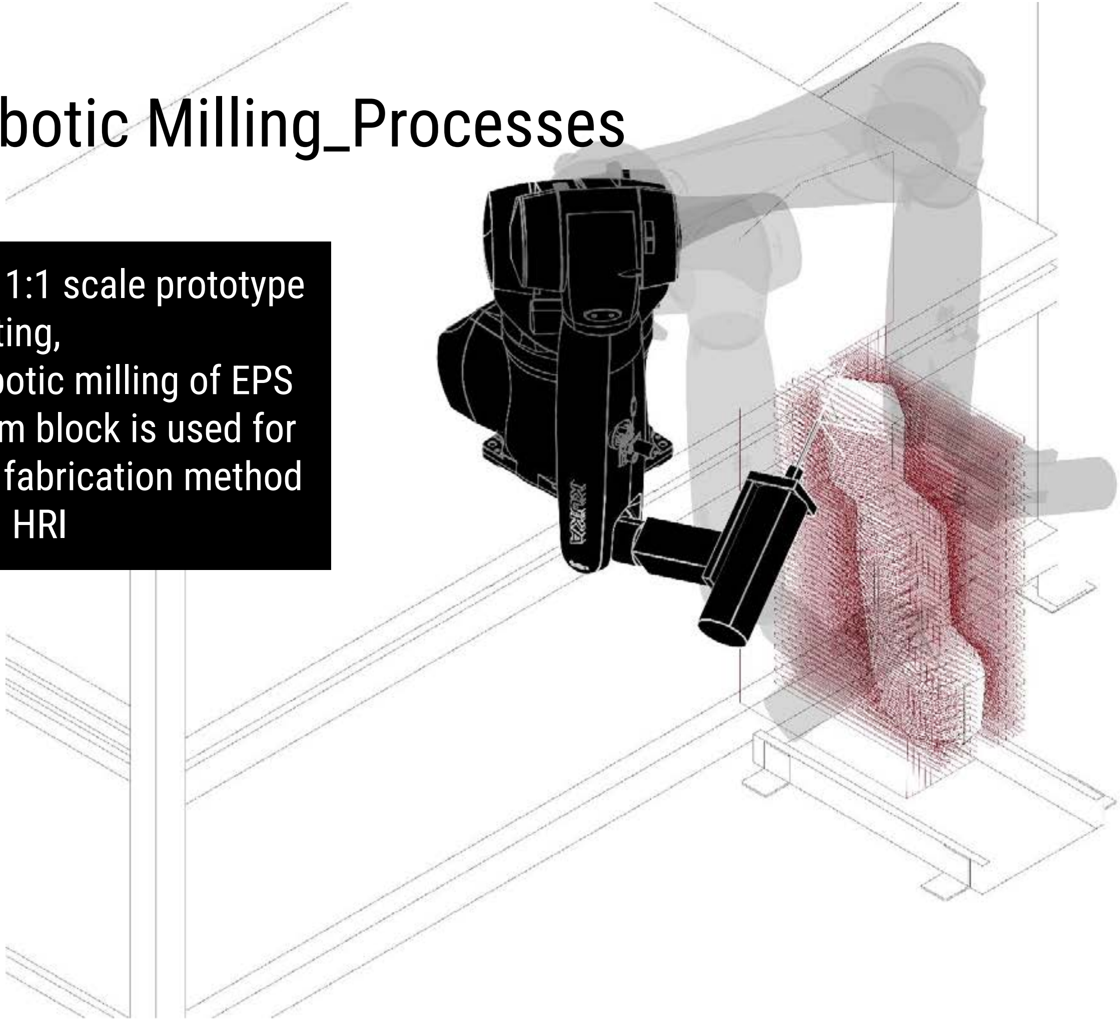
Assembly_ Fragment selection



Prototyping:
Milling Process

Robotic Milling_Processes

For 1:1 scale prototype testing,
Robotic milling of EPS foam block is used for the fabrication method and HRI

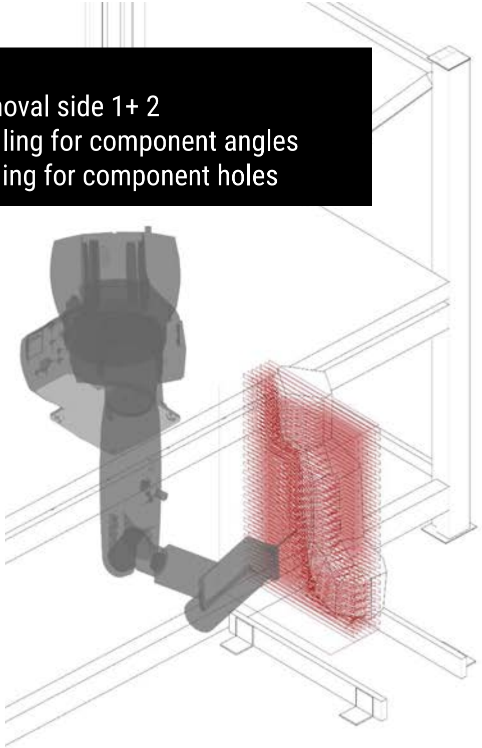


Processes

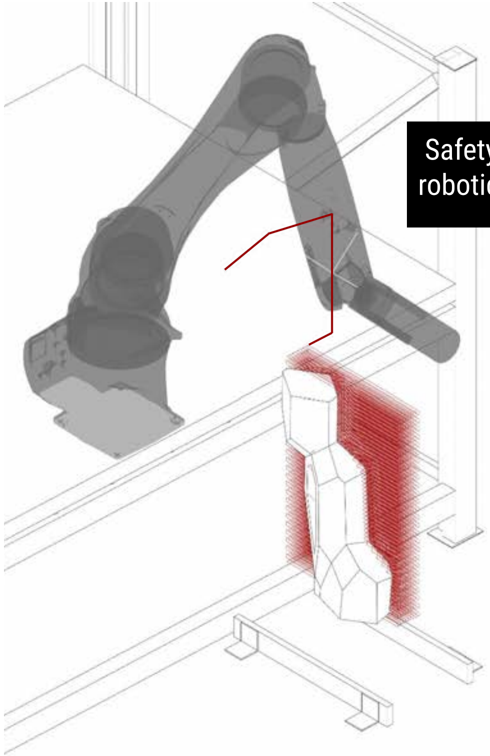
1. Isolate naked faces
1. Create tool paths for the faces
2. Texturized faces and holes

Robotic Milling_Simulation

Steps:
1.Material removal side 1+ 2
2.High Res milling for component angles
3.High res milling for component holes

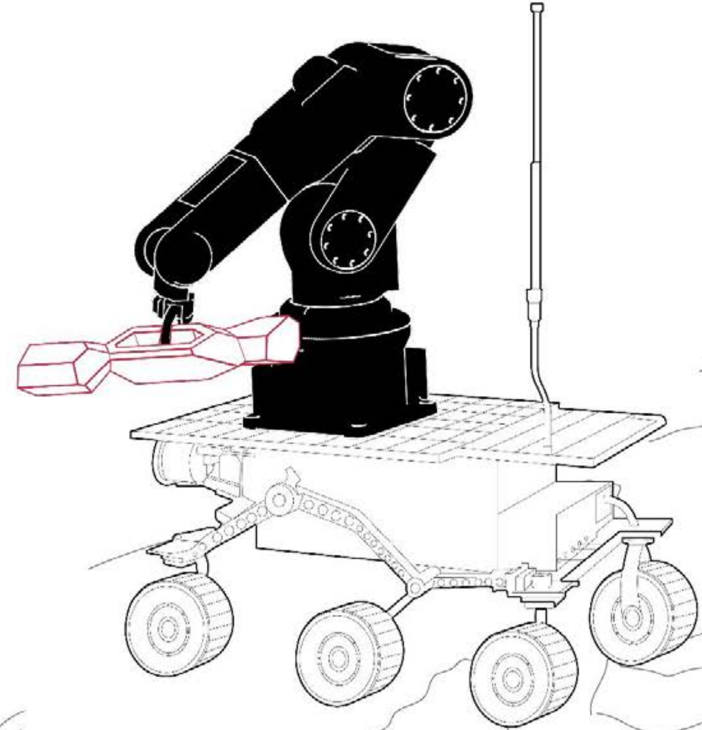


Safety points to guide movement of robotic arm to avoid collisions



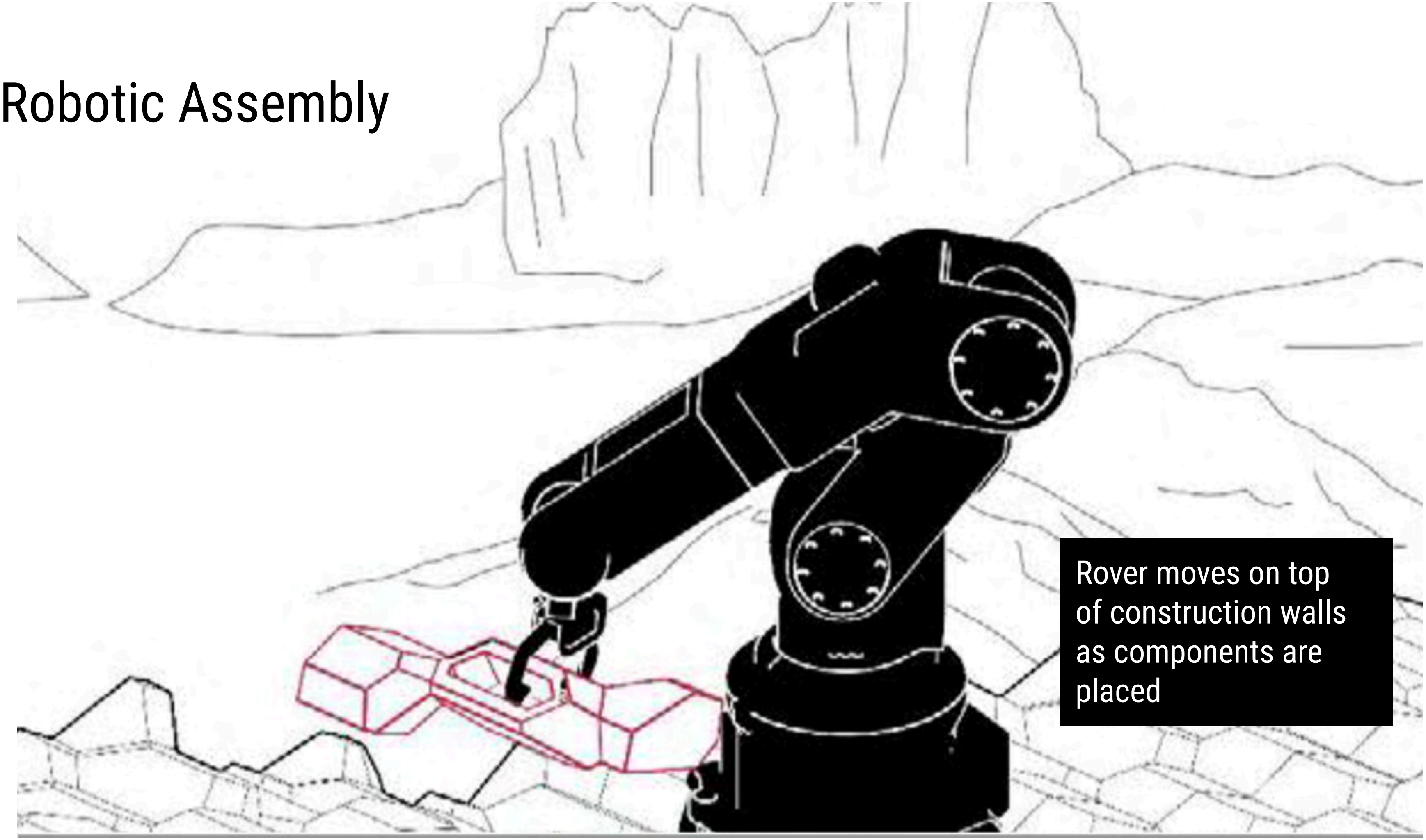
Robotic Milling_Prototype

Construction processes



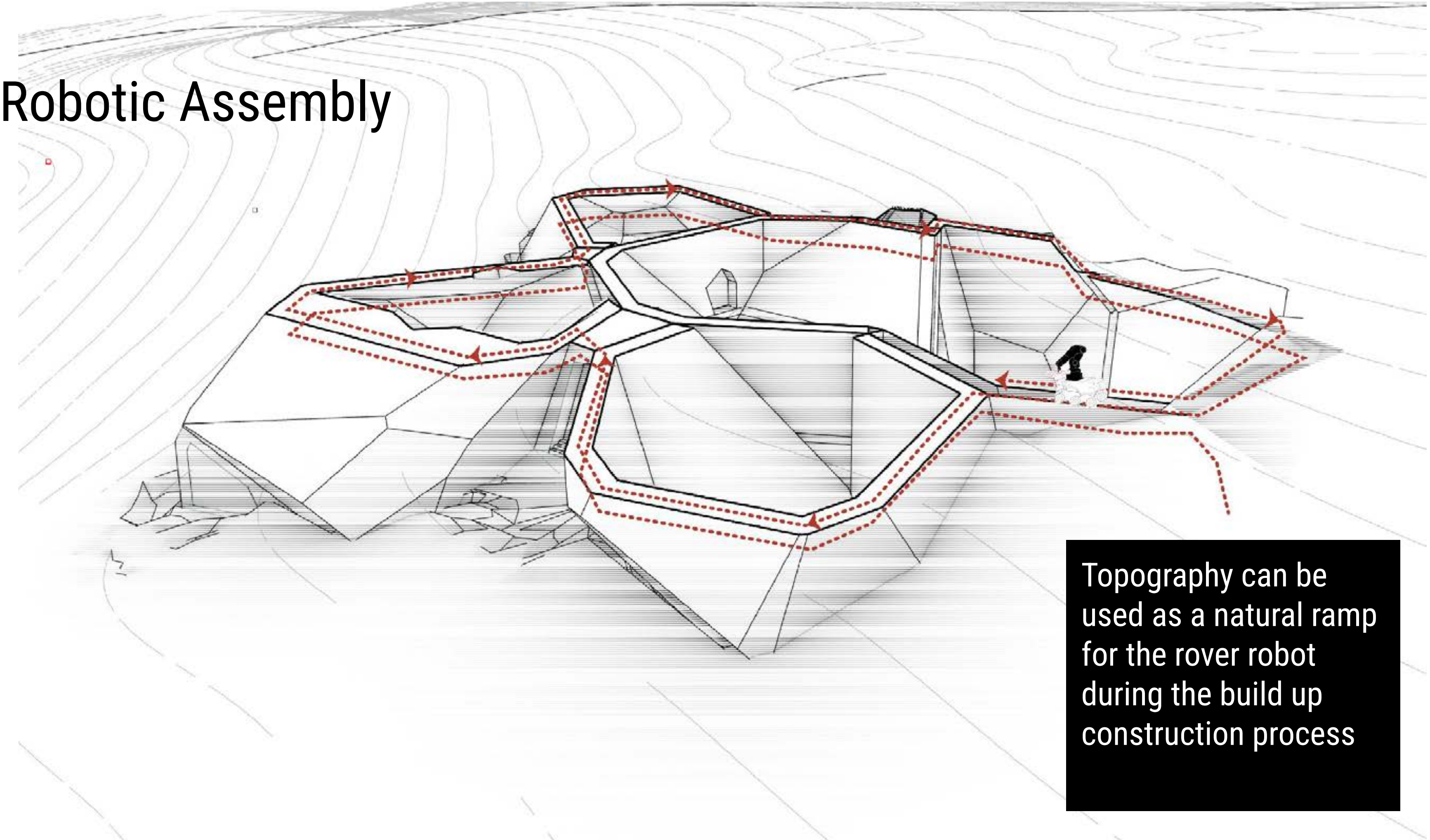
Robotic arm for assembly can be placed on a rover with wheels to move components around construction

Robotic Assembly



Rover moves on top of construction walls as components are placed

Robotic Assembly



Topography can be used as a natural ramp for the rover robot during the build up construction process

Future Expansion

3D printing variations

life support cluster_
large voronoi volumes
many openings

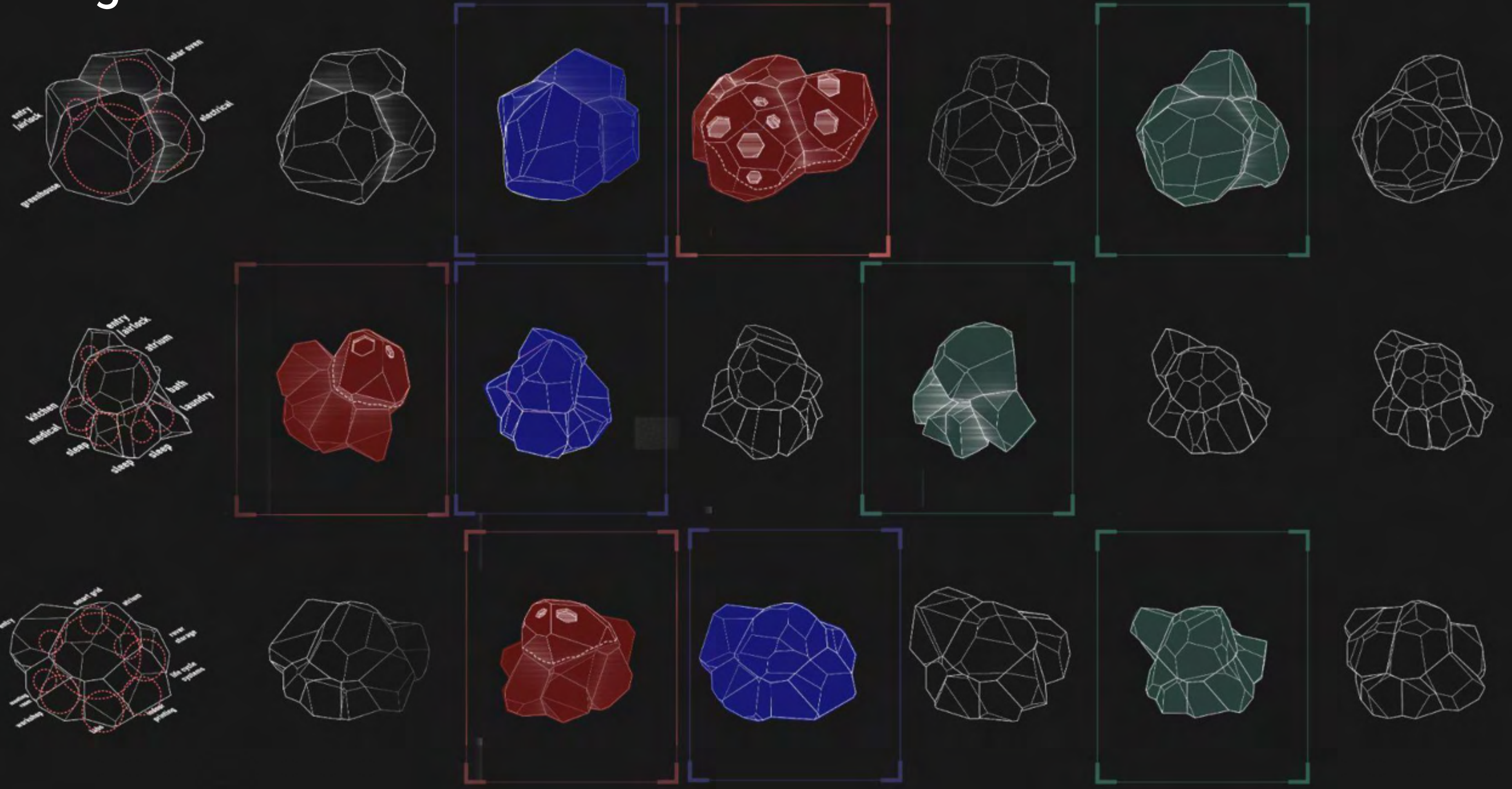
considerations:
number of faces
intersecting faces for passage
faces for sunlight
voronoi size deviation

living cluster_
small atrium voronoi volume
many small pod voronoi volumes

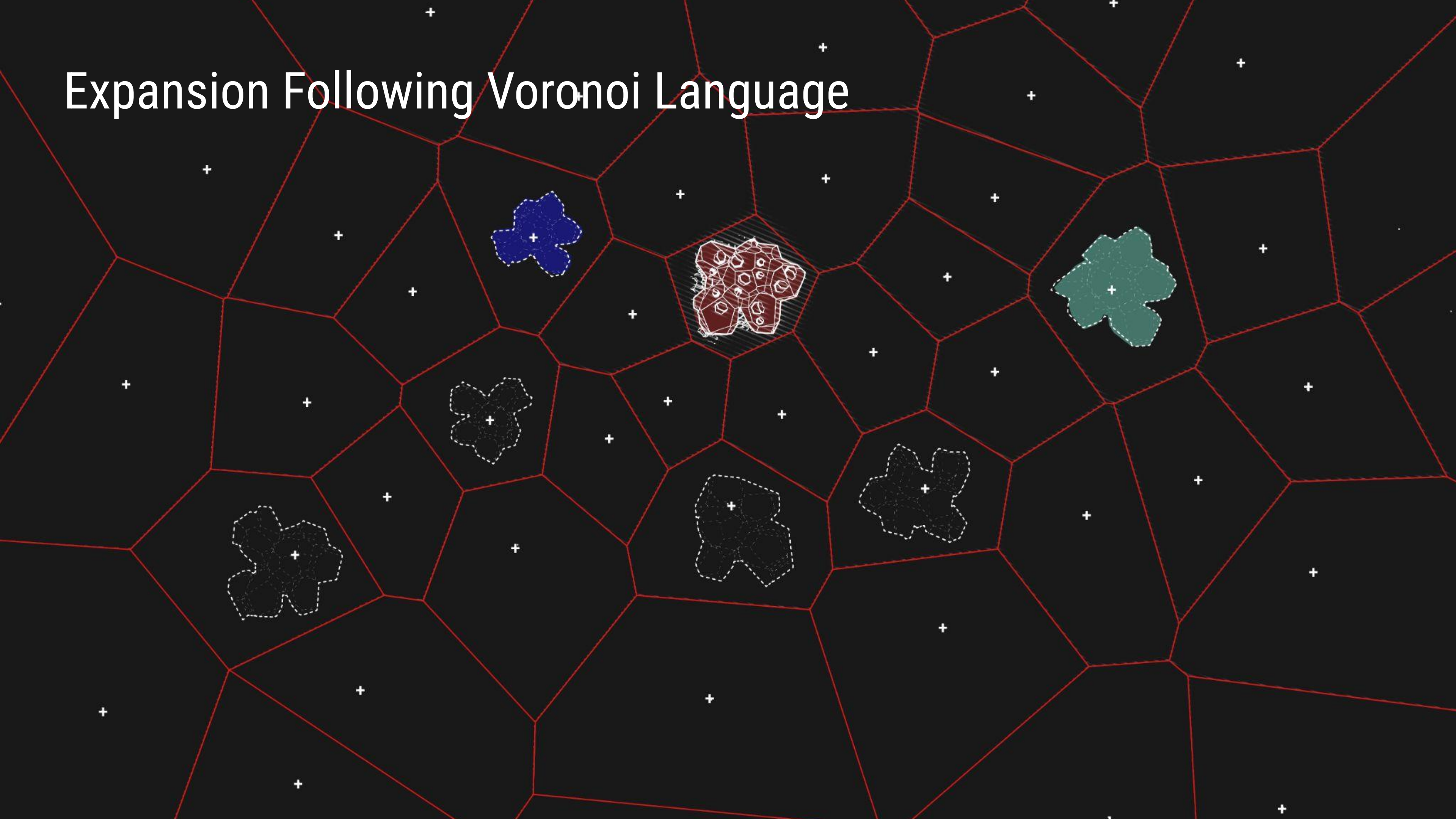
considerations:
number of faces
intersecting faces for passage
atrium voronoi size
sleeping pod stacking
voronois below ground

working/lab cluster_
large atrium voronoi volume
many medium voronoi volumes

considerations:
number of faces
intersecting faces for passage
atrium voronoi size
entry voronoi size
volumes stacking for circulation



Expansion Following Voronoi Language



Animation

http://cpa.roboticbuilding.eu/index.php?title=Shared:WS2024MSc2SAG3Video