



MoonSane

Designing Lunar Habitats for
Improving Mental Wellness

Approaching Lunar Architecture

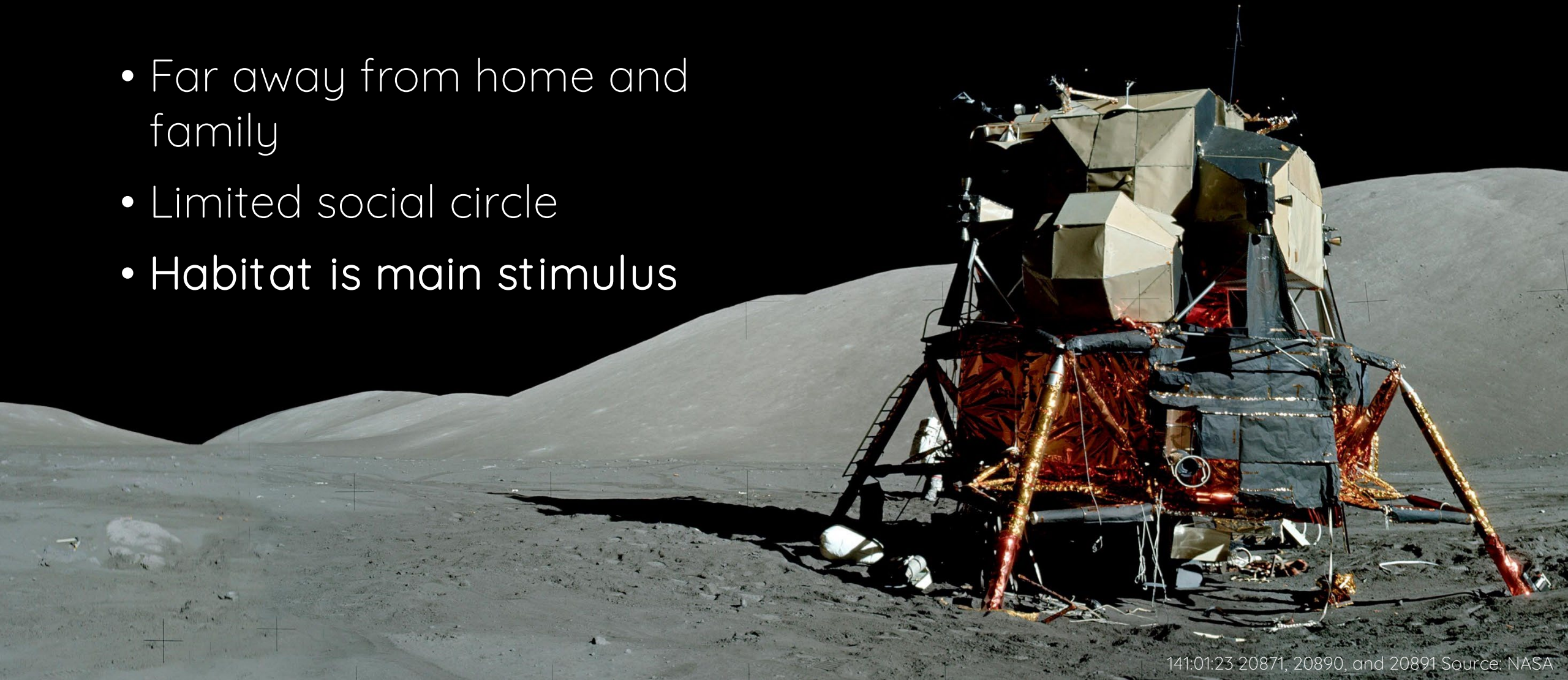
Blank
Canvas



Extreme
Environment

Habitat conditions

- Far away from home and family
- Limited social circle
- Habitat is main stimulus





ISS



Views





Research question

How can human spatial perception be used in the design of Lunar habitats, to mitigate the negative mental health effects of living long-term on the moon?

Scope of habitat solutions

Lighting:

- Allowing the passage of sunlight*
- Habitat day/night cycles
- Improved environmental lighting

Stimulating senses:

- **Improved colours** of environment
- Reduced noise levels
- **Variations** in habitat environmental factors
- Comfortable air temp/ humidity
- Nature/plants included on station

Crew interaction:

- Private quarters

Views:

- Views of the habitat from the windows
- **More observation windows**
- **Direct views of earth**

Additionally:

Spatial geometry

Screens simulating windows

Logan M. Smith, "The psychology and mental health of the spaceflight environment: A scoping review." *Acta Astronautica* 201, 2022, 496-512, ISSN 0094-5765, <https://doi.org/10.1016/j.actaastro.2022.09.054>.

Light

- Experiment: circadian rhythm lamps in the LUNARK module
 - “Waking up to a sunrise inside our sleeping pods was an incredible natural feeling ”
 - Stationary

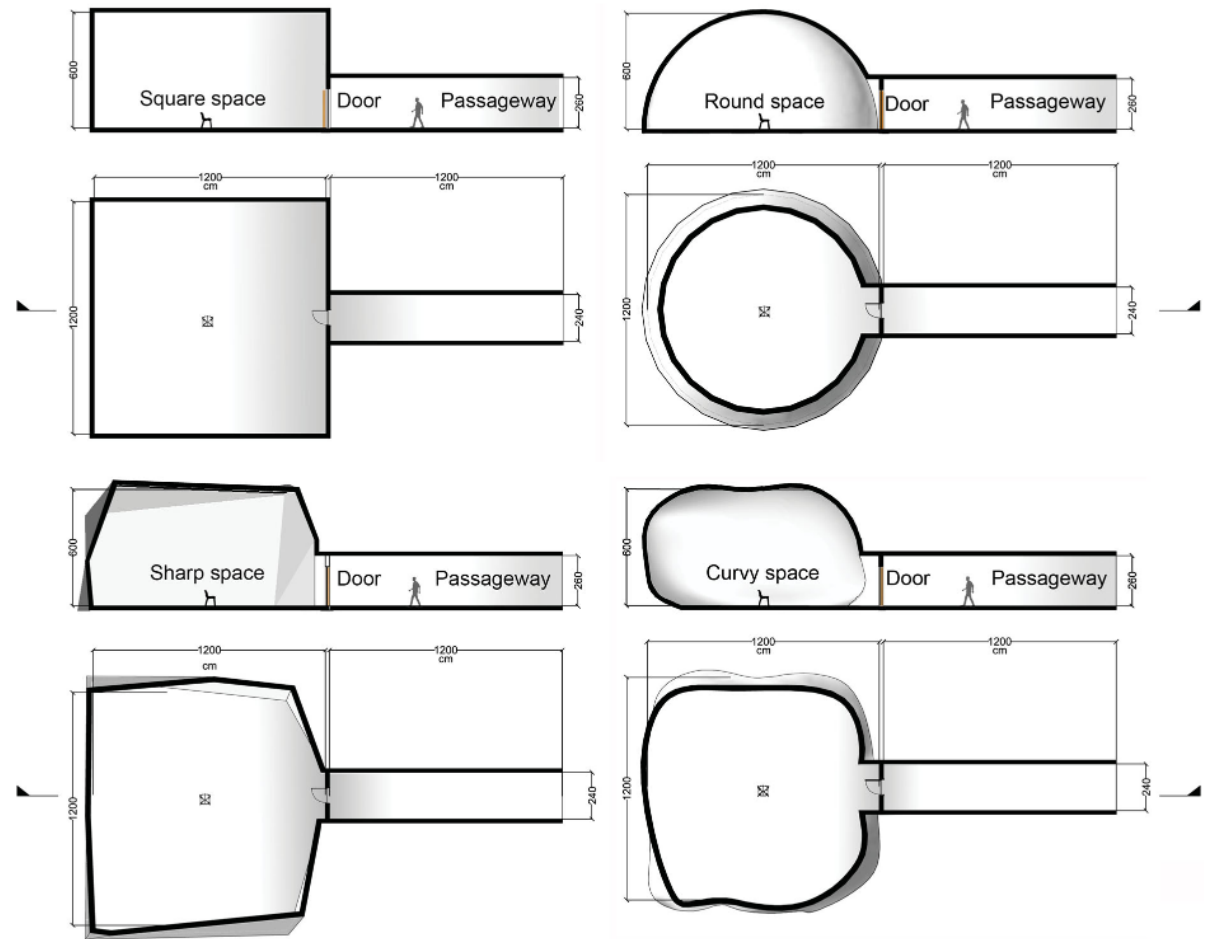


Spatial geometry

Study using VR

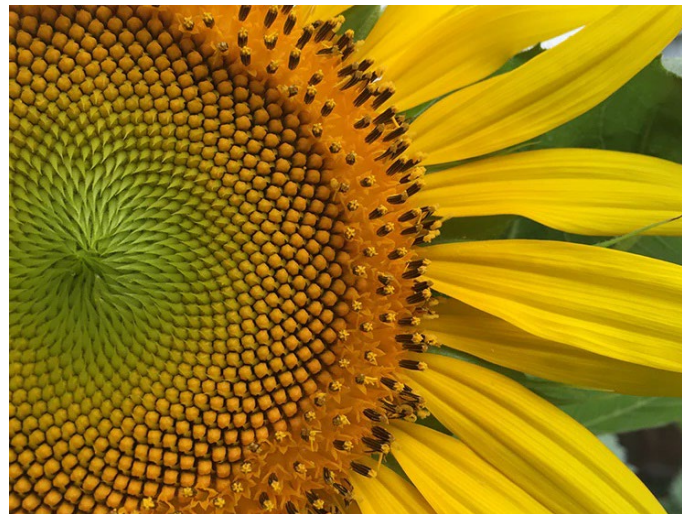
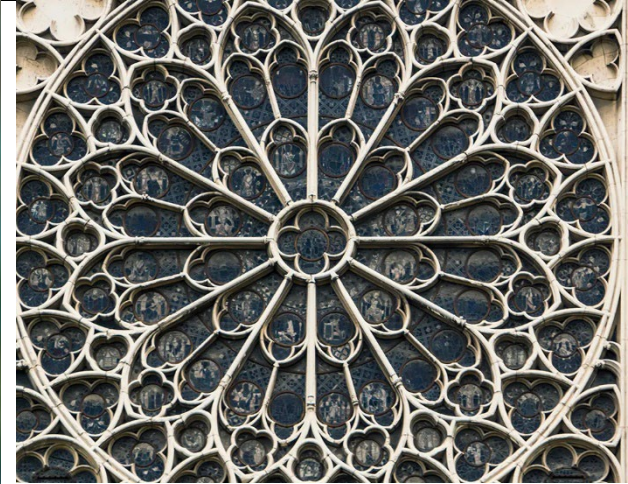
- Asymmetric spaces general preference
- Curved: leisure activities
- Angular: studying/working

Shemesh, A., Talmon, R., Karp, O., Amir, I., Bar, M., & Grobman, Y. J. (2016). Affective response to architecture – investigating human reaction to spaces with different geometry. *Architectural Science Review*, 60(2), 116–125.



Geometry: fractal patterns

- Repeating shapes
 - Calming effect
 - Hidden in nature: biophilia
- Dynamic fractal patterns
 - Light through foliage
 - Light reflection on water



Earth gazing

- Phenomenon of astronauts who view Earth from space
- Awe-inducing
 - Increased empathy and sense of purpose
 - Decrease in stress hormones



Earth gazing & “Skyspace”



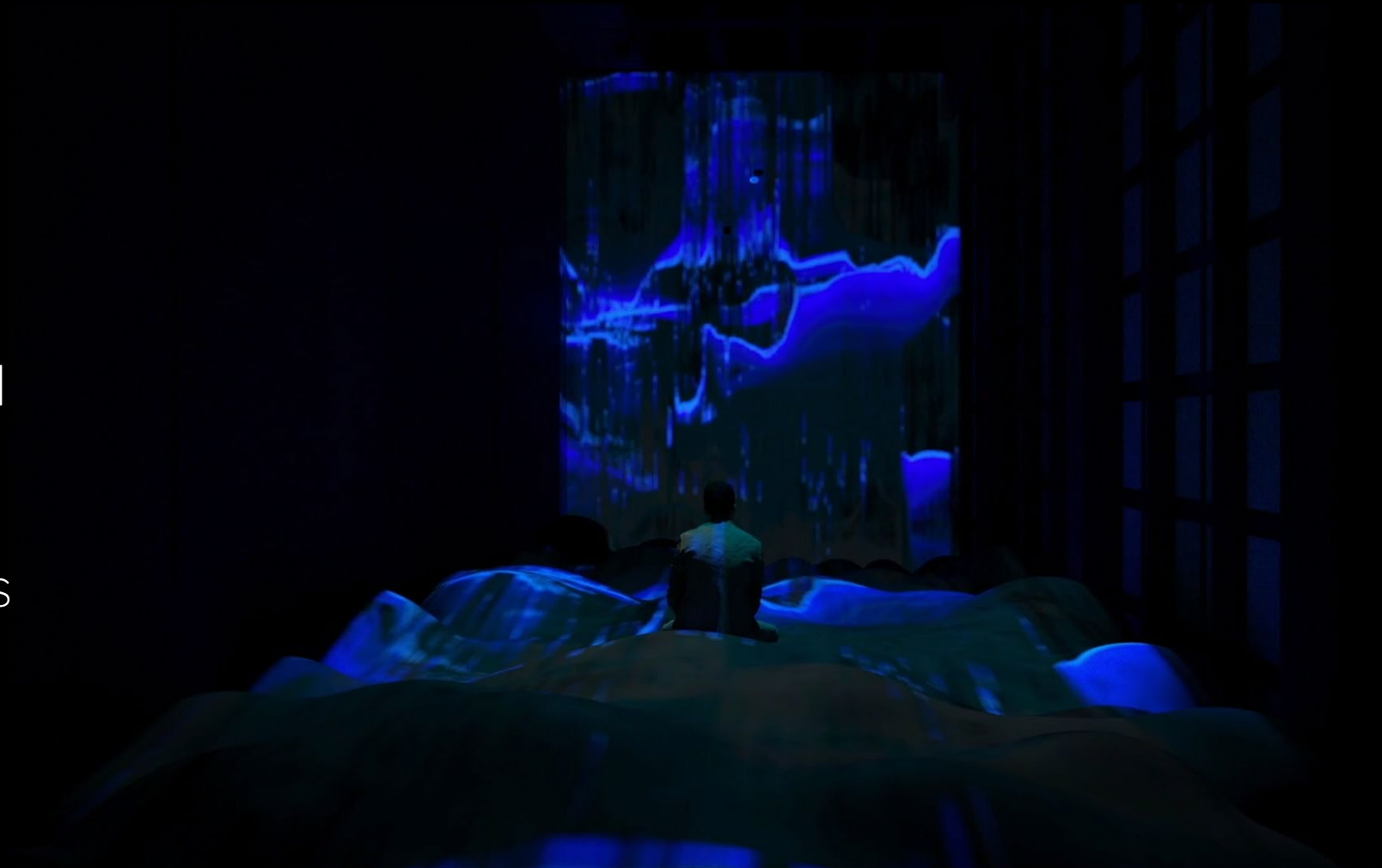
James Turrell – “Skyspace”

- looking upwards – positive effect
- Earth view incorporated?
- Mood lighting added to increase experience (based on mood of astronaut?)

Colour projection

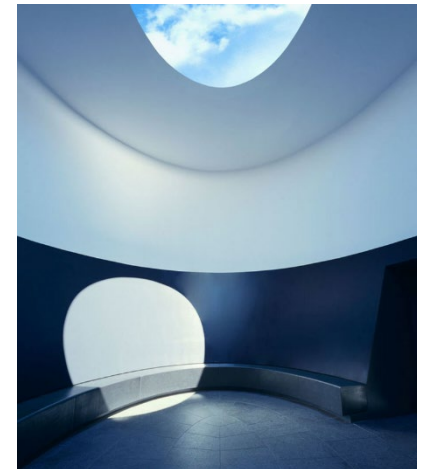
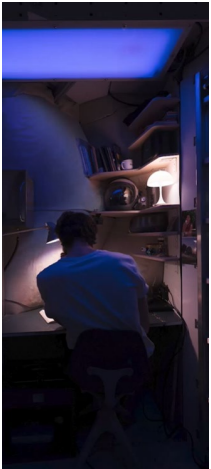
“EMO” – Xiying Bao

- AI technology: facial recognition
- Changes colours and shapes based on perceived emotion
- Adaptive system monitors wellbeing of crew members
 - influence/transform emotions as well?



Concept

Designing a Lunar habitat that promotes mental wellness of the crew



Societal relevance

Pandemic:

- Confinement caused mental distress
- Prevention by spatial design

Medical facilities:

- Hospital, dentist etc.
- Decreasing stress by spatial design

Designing Lunar Architecture



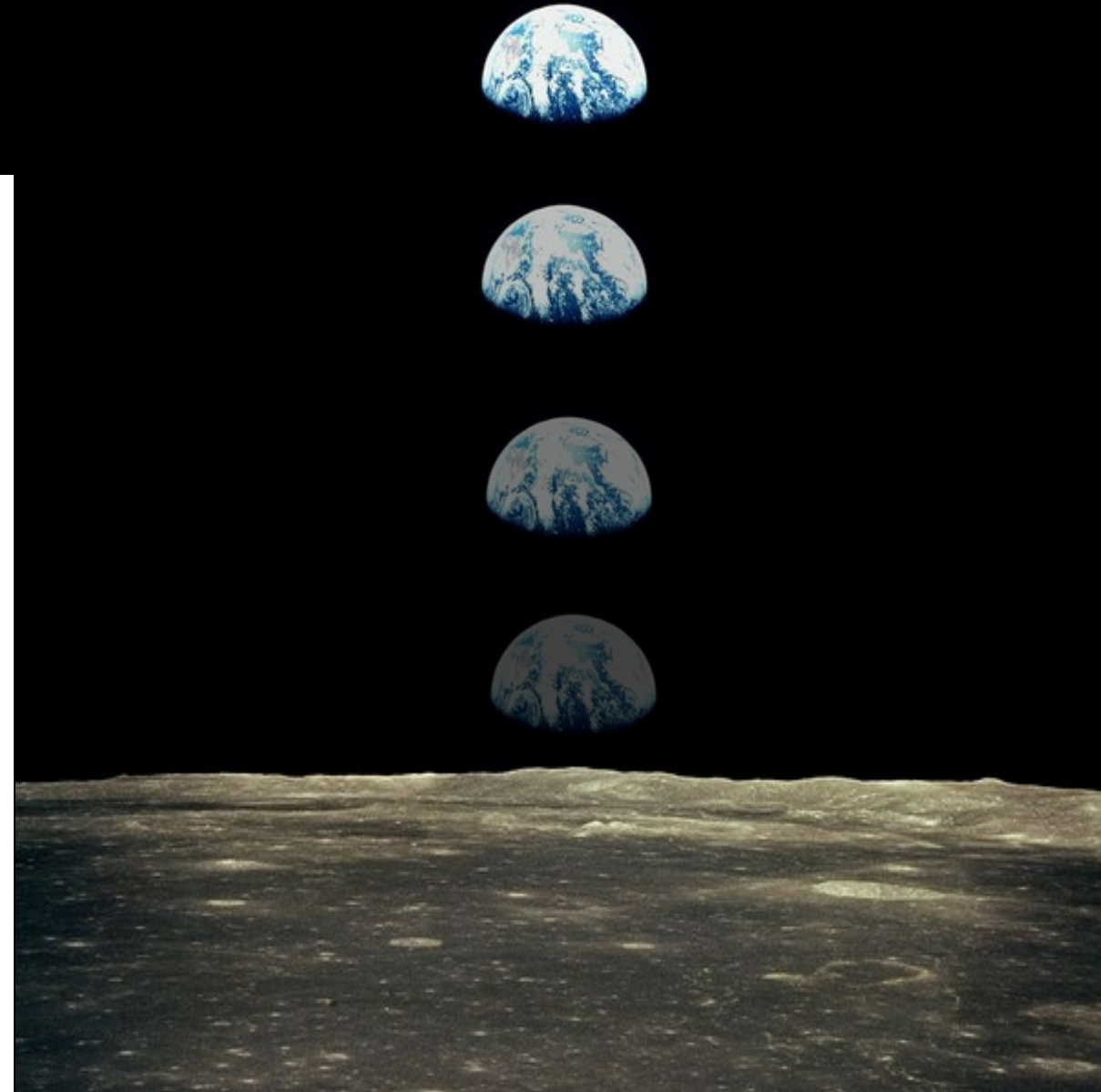
Location: Earth view

Lunar Equator

- Earth directly overhead
- Desirable for earth view from above

Lunar Poles

- Earth visible at the horizon
- Sometimes drops below horizon – not visible



Program: main rooms

Main rooms

- Private quarters
 - Sleeping area
- Living quarters
 - Social area, eating area, kitchen
- Research facility
 - Command and control
 - Workspace
- Gym
- Bathroom (&toilet)
- Medical facility

- Antechamber for EVA's
 - (regolith cleaning and suit doffing)
- Stowage

Additional rooms

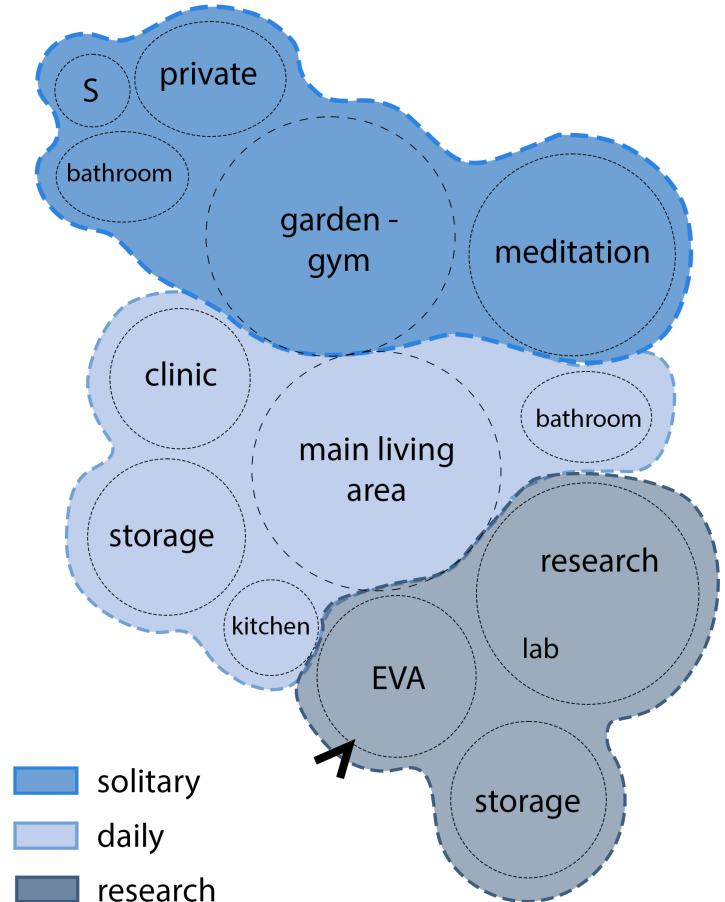
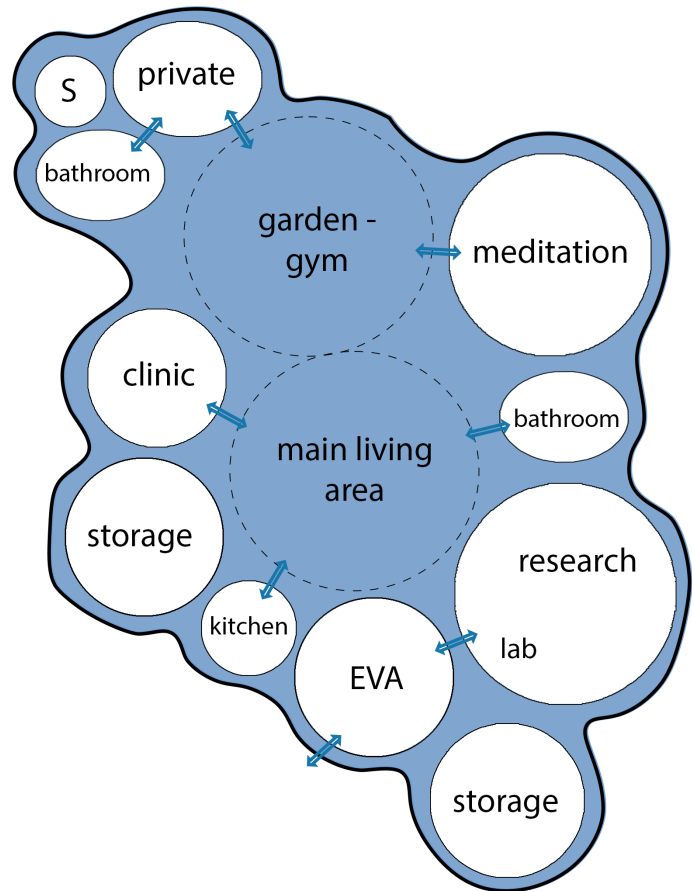
- Garden
- Meditation space
 - earth viewing

“Minimum volume of **80m³ per person**” (ESA)

Program: size

Room	m3 (1 person)	%	Same time use	Multiply factor	m3 (6 persons)	%
Private crew quarters	2,5	3%	Yes - but separate	x 6	15	3,5%
Living quarters	13,5	15%	Yes	x 6	81	19,5%
Kitchen	2,5	3 %	Not all	x 2	5	1%
Research facility	11	13%	Yes	x 6	66	16%
Garden	13,5	15%	Yes	x 6	81	19,5%
Gym	8	9%	Not all	x 3	24	5,5%
Bathroom	5	6%	Not all	x 2	10	2,5%
Medical facility	8	9%	Not all	x 2	16	4%
EVA antechamber	8	9%	Not all	x 3	24	5,5%
Storage general	8	9%	Yes	x 6	48	11,5%
Subtotal:	80	91%			370	88,5%
Meditation space	8	9%	Yes	x 6	48	11,5%
Total:	88	100%			418	100%

Connecting functions 2D



Connecting 3D: double atrium



	Function
	Living
	Kitchen
	Storage main
	Meditation
	Garden-gym
	Medical
	Private quarters
	Bathroom
	Storage private
	Research
	EVA chamber
	Storage research

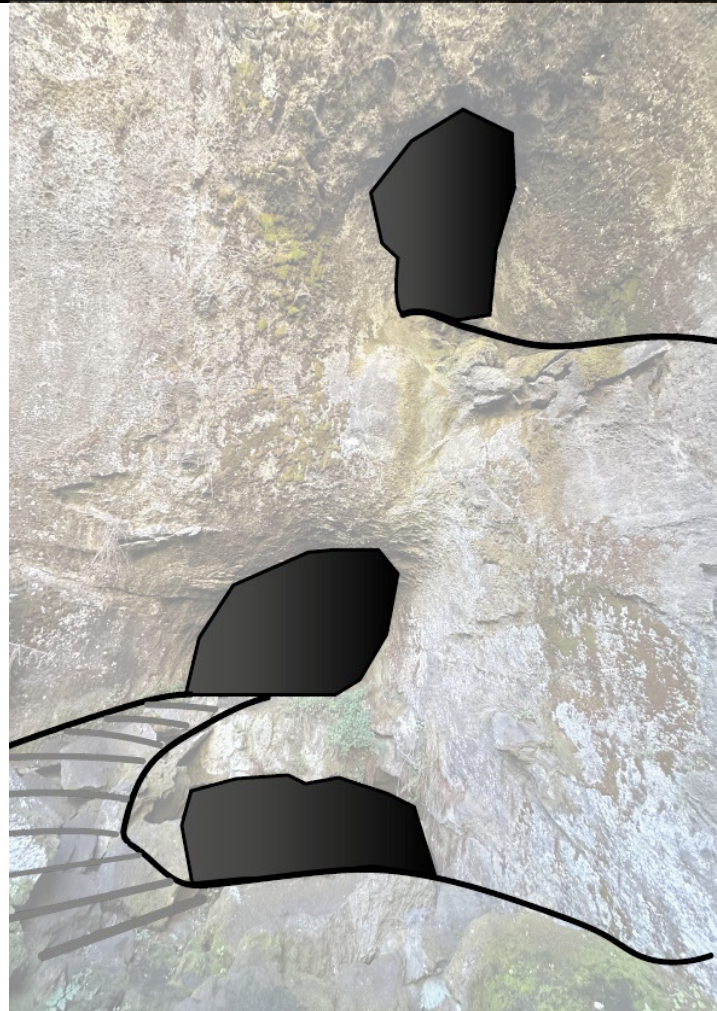
Lava tube mission



- Corridors branching out

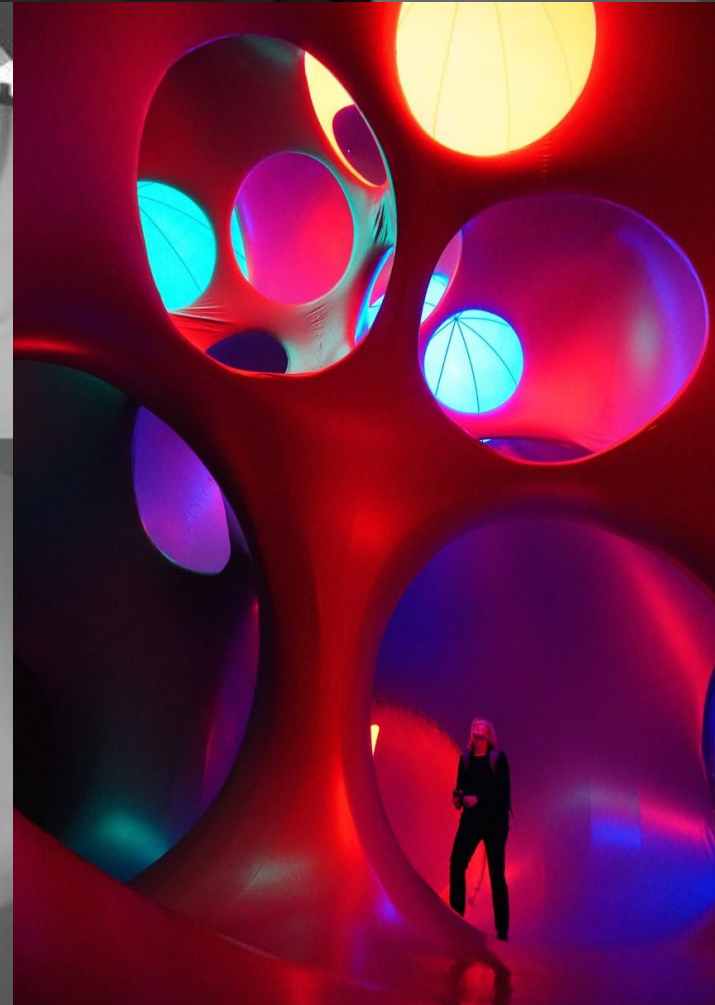


Lava tube mission: sketching



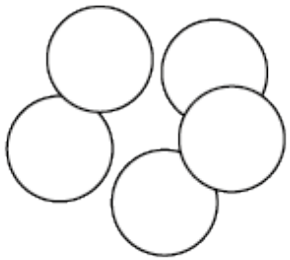
Spatial connection: 3D

- Visually connecting spaces– decreasing confinement
- Dynamic views
- Big atrium that branches out



Porosity: computational script

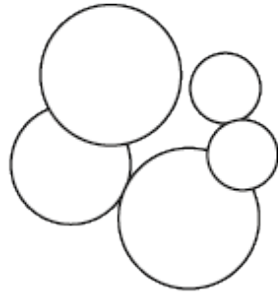
1. Create spheres



Variables:

- Manual adjustment of position

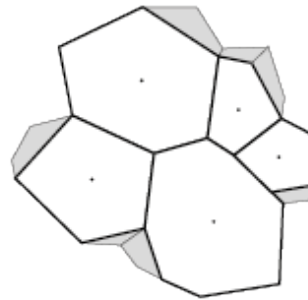
2. Adjust volume to function



Variables:

- Volume
- Oblongness in x,y,z direction

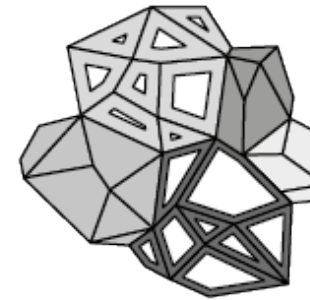
3. Create Voronoi cells



Variables:

- Neighbourhood point count
- Seed
- Sphere position

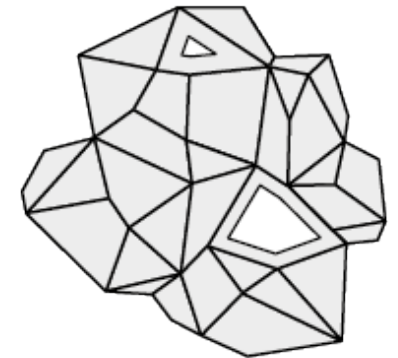
4. Adjust porosity to function



Variables:

- Porose yes/no
- edge offset openings
- selecting specific faces requiring a diverging porosity

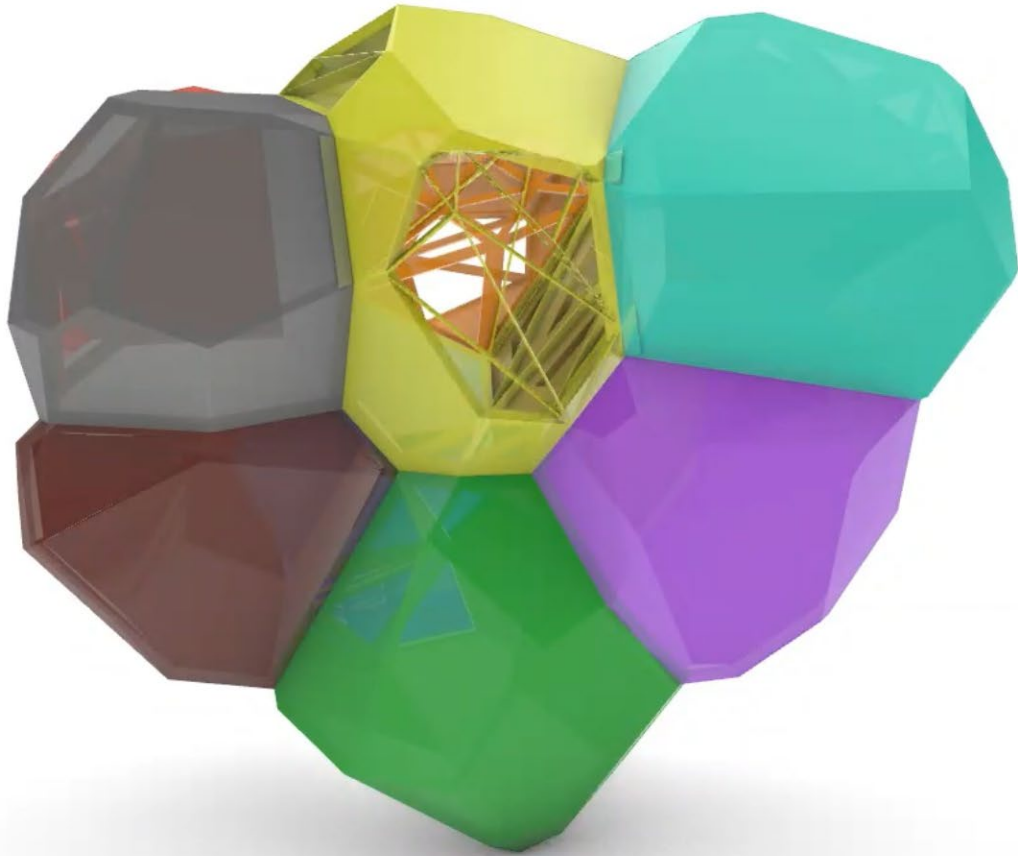
5. Create outer shell



Variables:

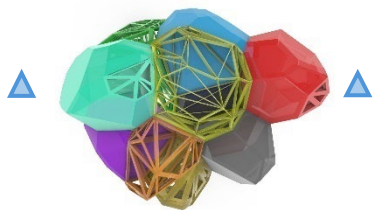
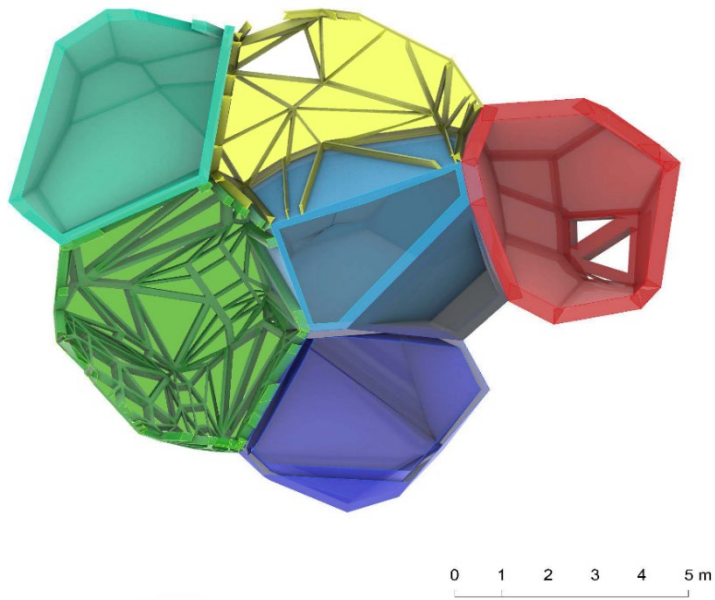
- Shell thickness
- selecting specific faces requiring a divergence of porosity
- Opening edge offset distance

Porosity: Voronoi

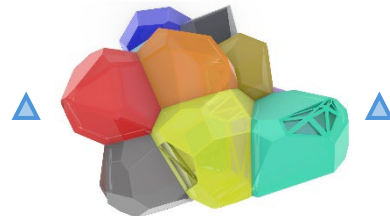
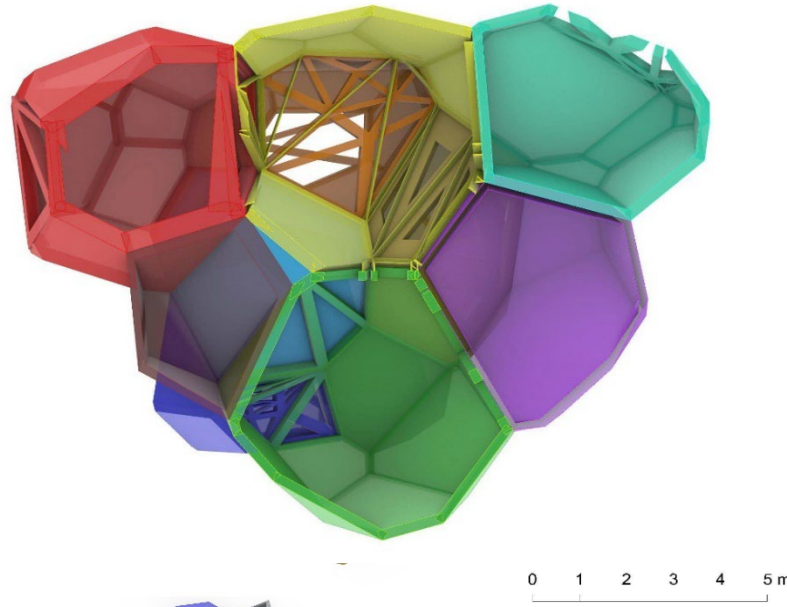


	Function	Porosity
	Living	80%
	Kitchen	62%
	Storage main	16%
	Meditation	7%
	Garden-gym	40%
	Medical	0%
	Private quarters	3%
	Bathroom	0%
	Storage private	0%
	Research	8%
	EVA chamber	5%
	Storage research	0%

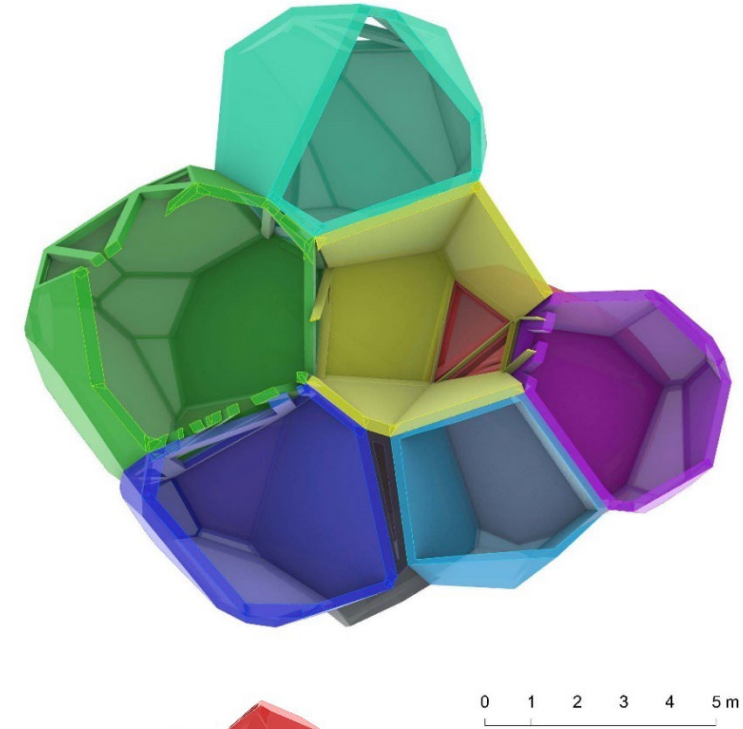
Porosity: iterations



Iteration 1:
section

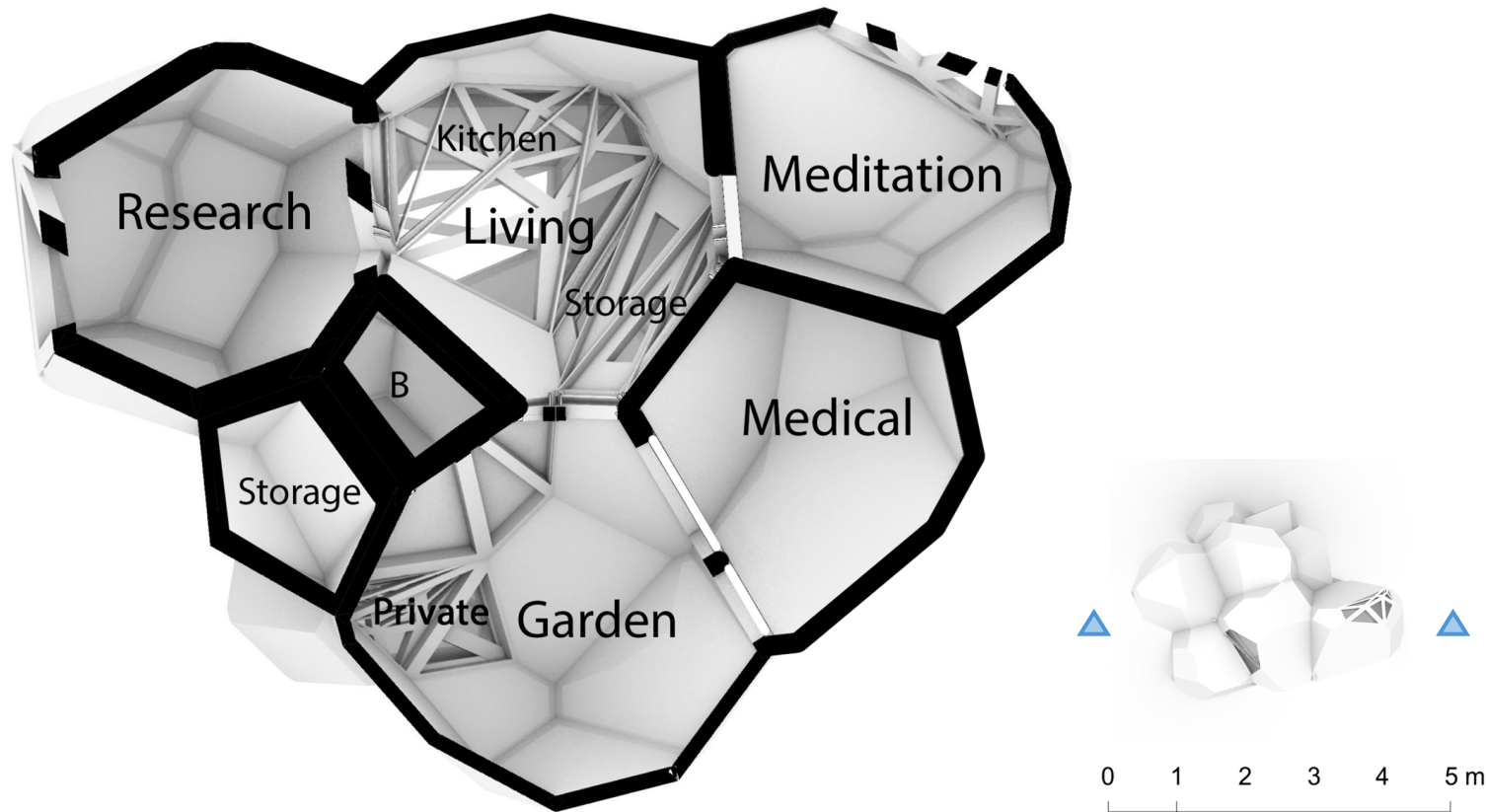


Iteration 2:
section



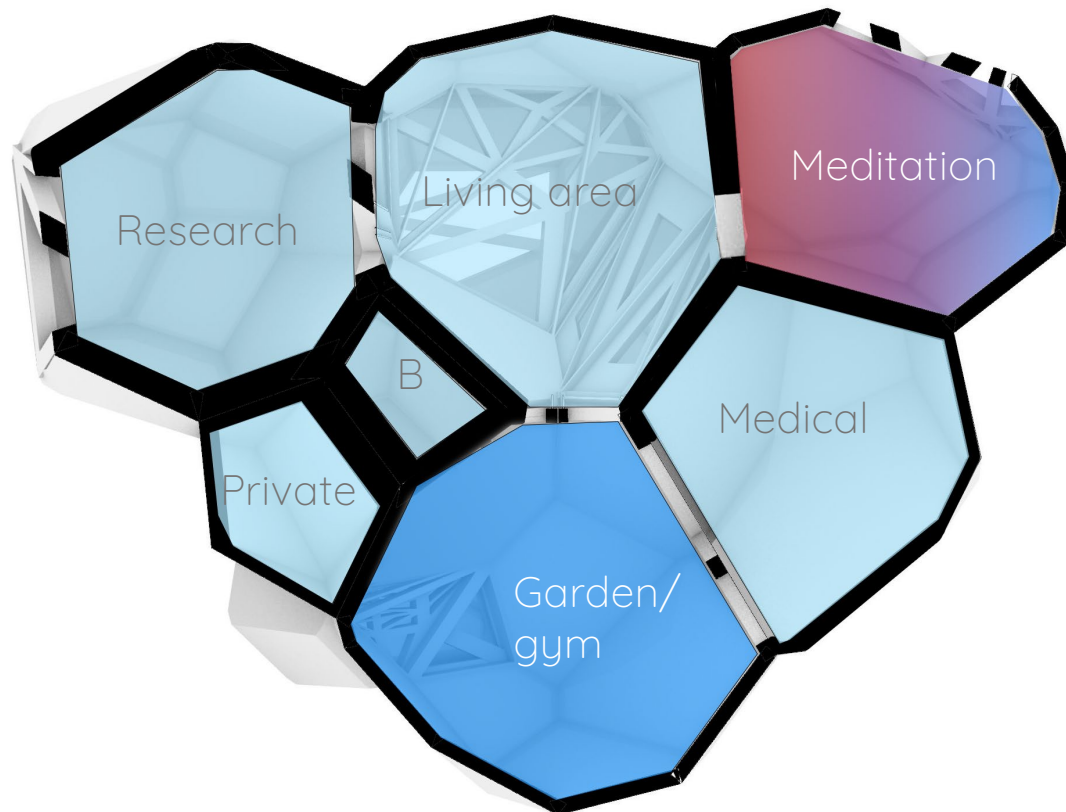
Iteration 3:
section

Iteration 2



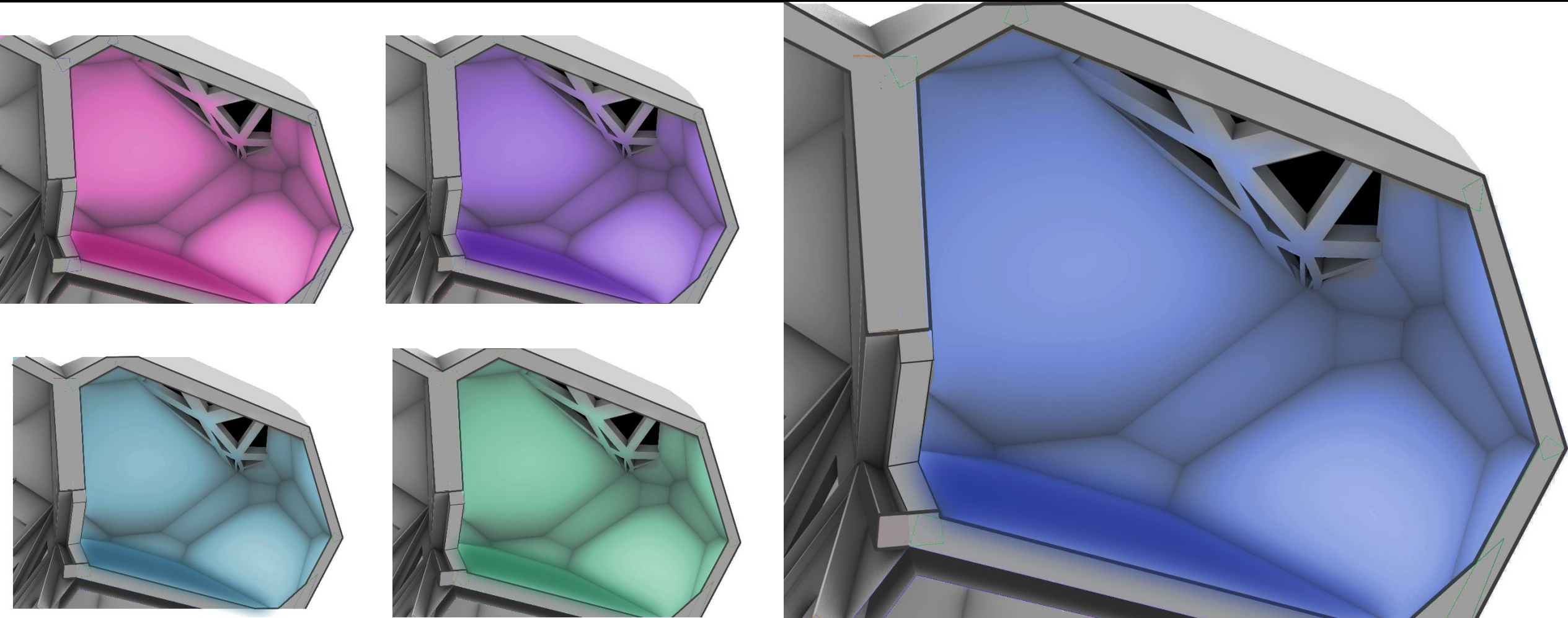
- More centred atria:
 - Garden
 - Living area
- Two levels created
 - Daytime
 - Private
- Access private quarters through garden

Interventions: light & projection

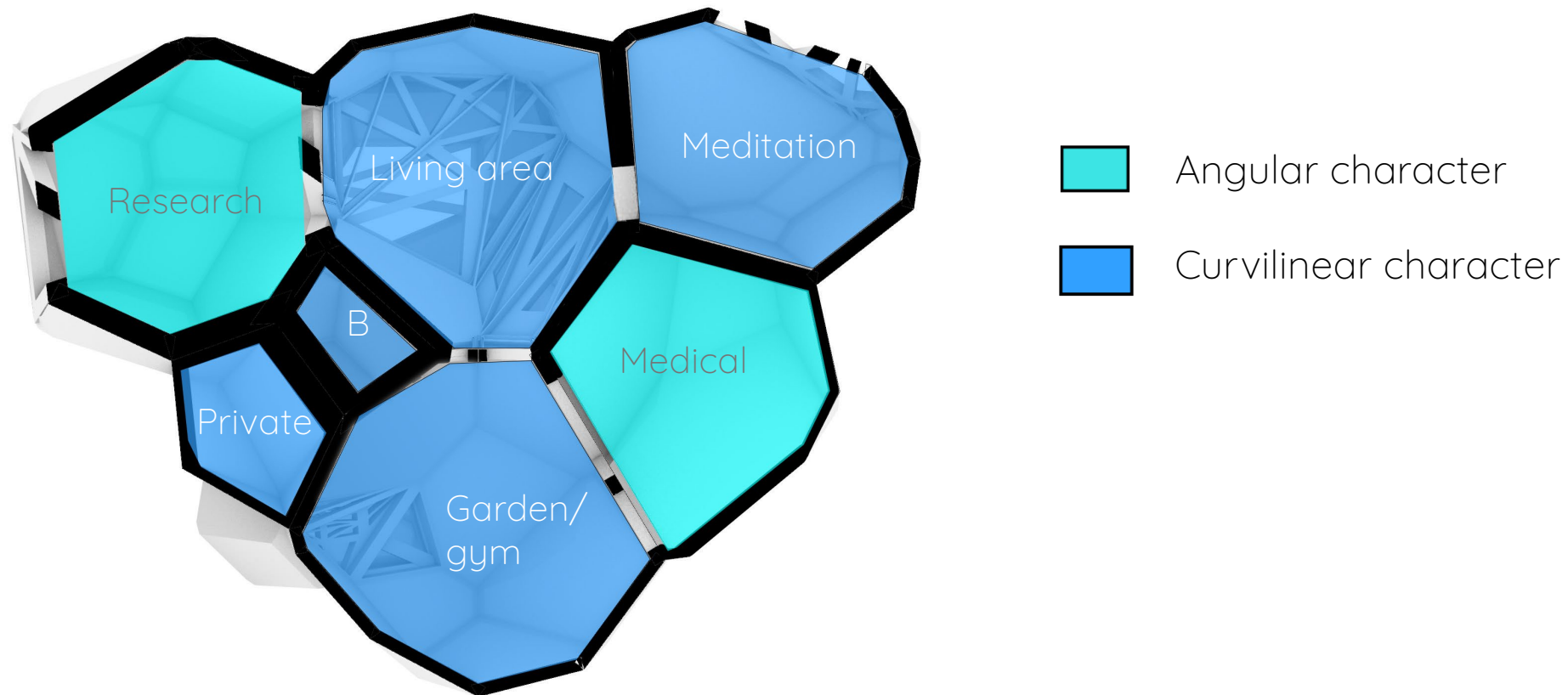


-  Daylight simulation
-  Adjustable colour projection
-  Dynamic fractal projection

Impression meditation space



Interventions: spatial geometry



Transitions

Angular



Edged

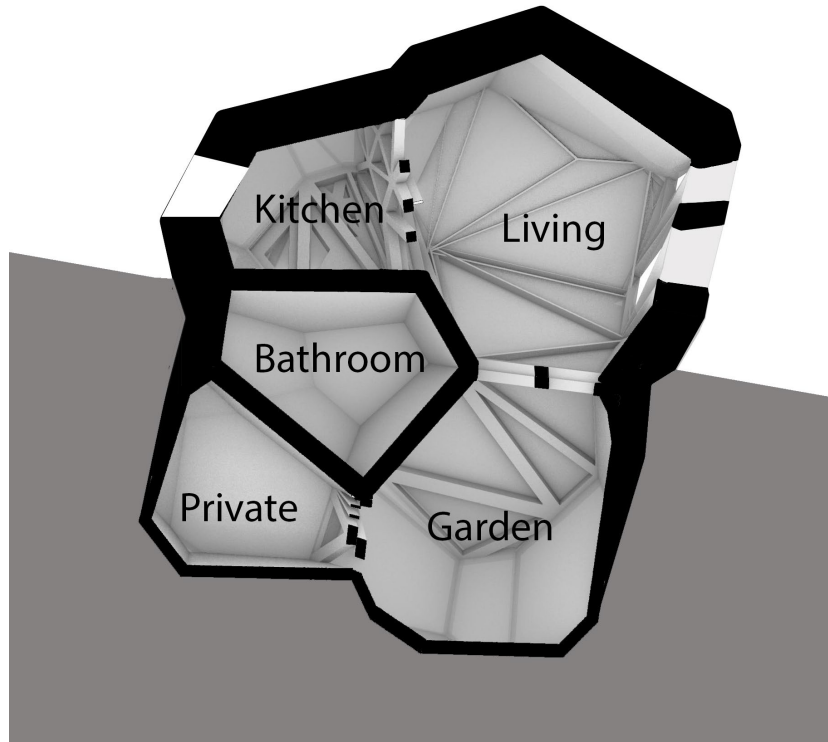


Curvilinear

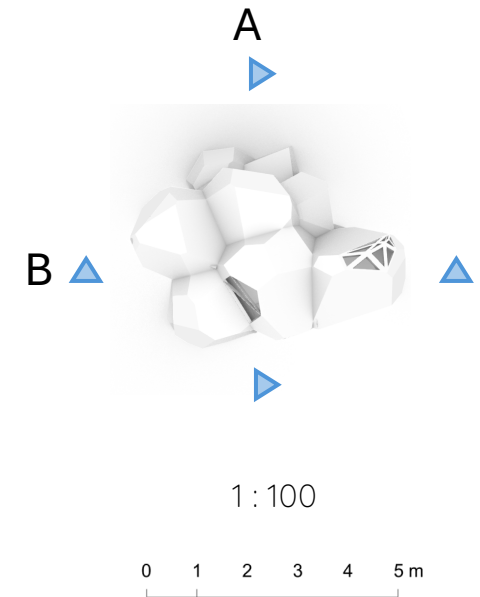
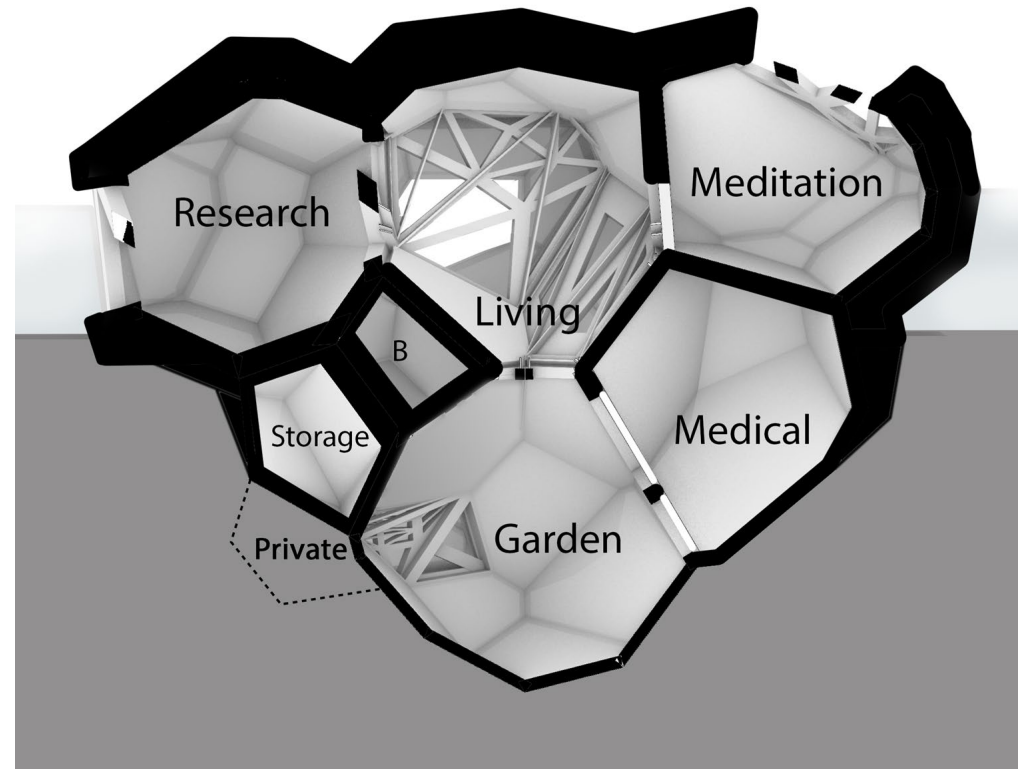


Iteration 2 in location

Section A

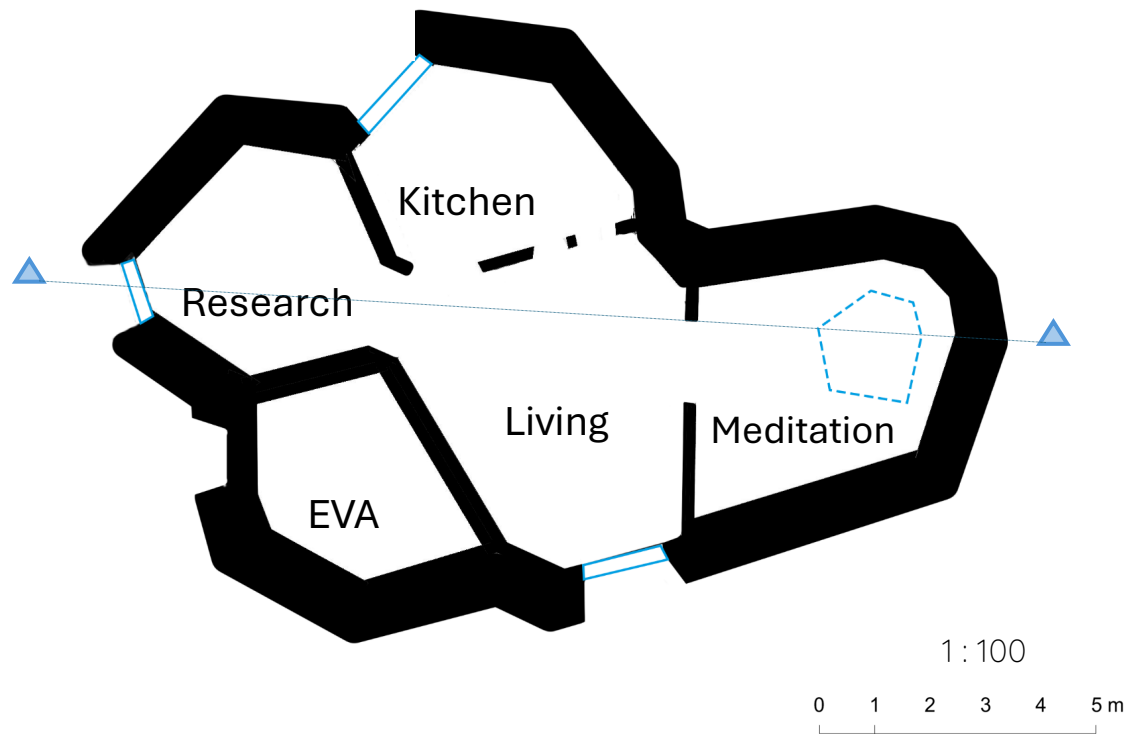


Section B

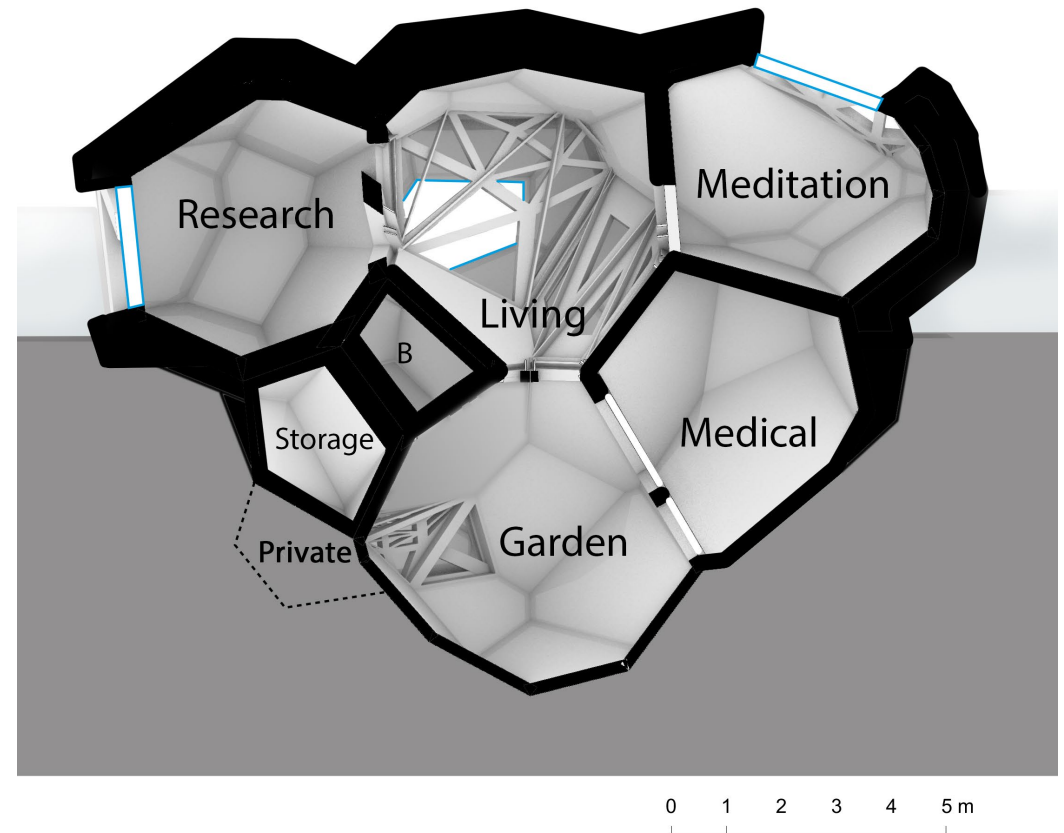


Views

Plan top level

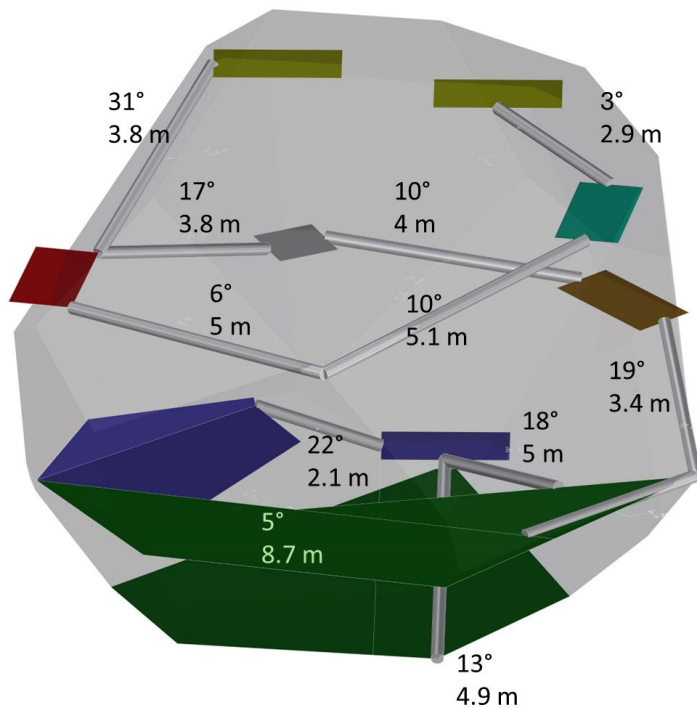


Section B

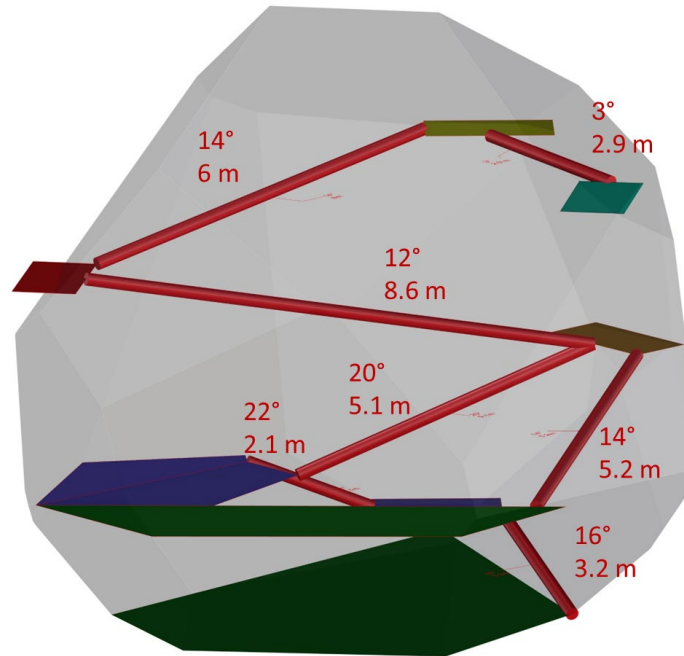


Garden: connectivity

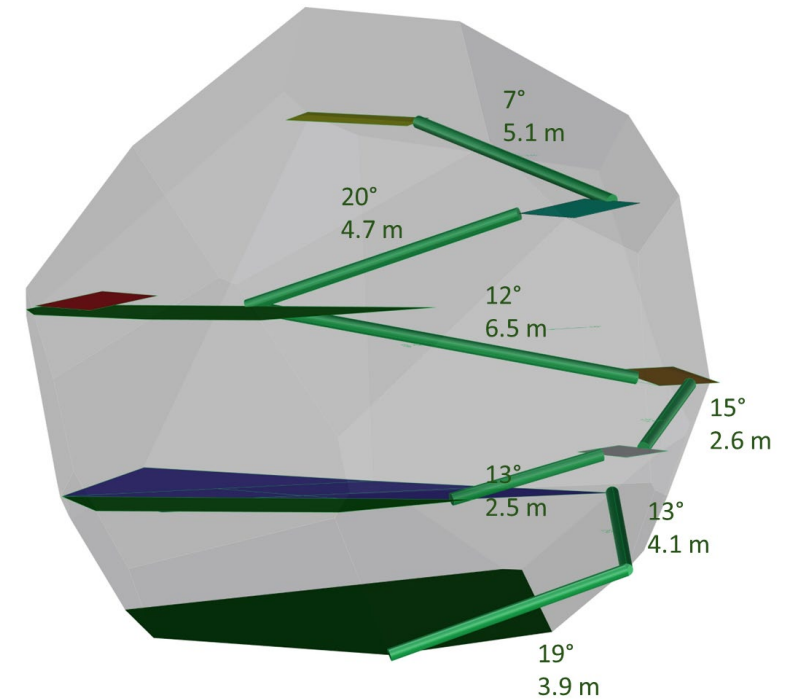
Iteration 1: spiral



Iteration 2: direct



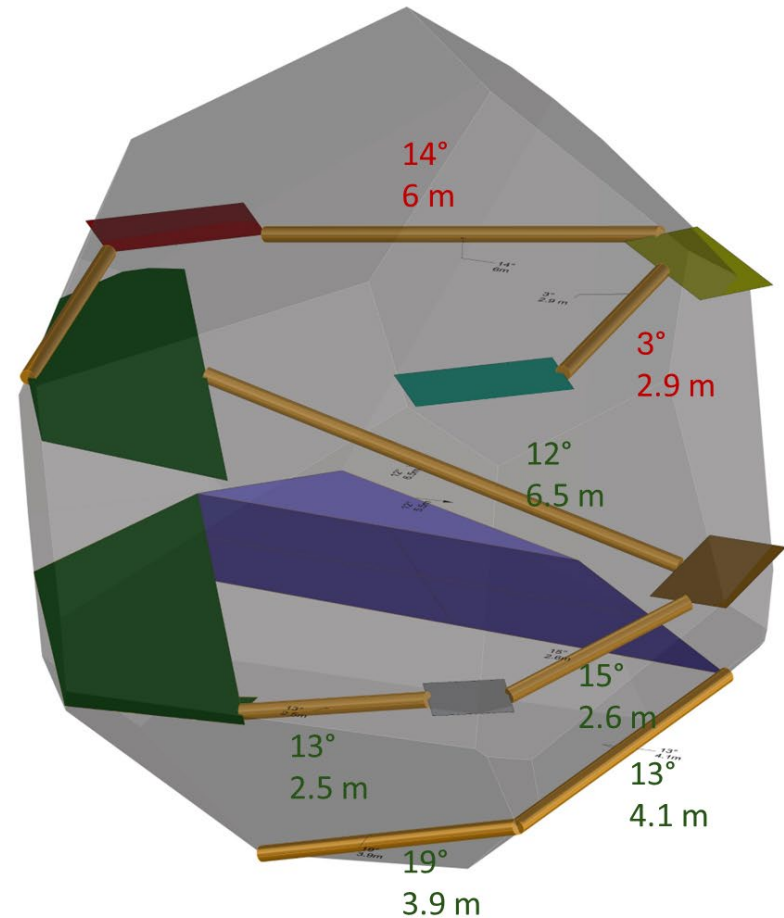
Iteration 3: plateaus



Garden: connectivity

Iteration 4: Combination of all iterations

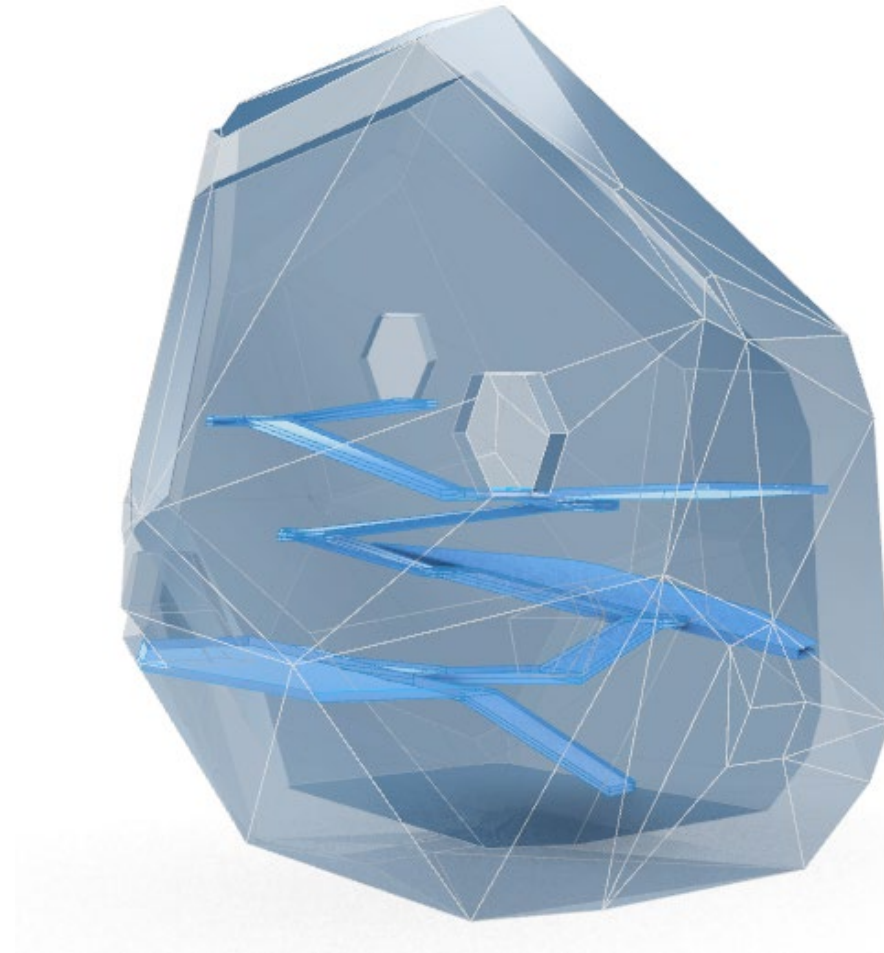
- + Manageable slopes (below 20°)
- + Average/short spans
- + Makes use of sides – for construction
- + Private quarters have a one level entrance
- + More plateaus; combining farming space with connection
- + Meditation area quiet – destination ramp
- More plateaus; closes the space off more?



Garden: adjusting

Adjustments:

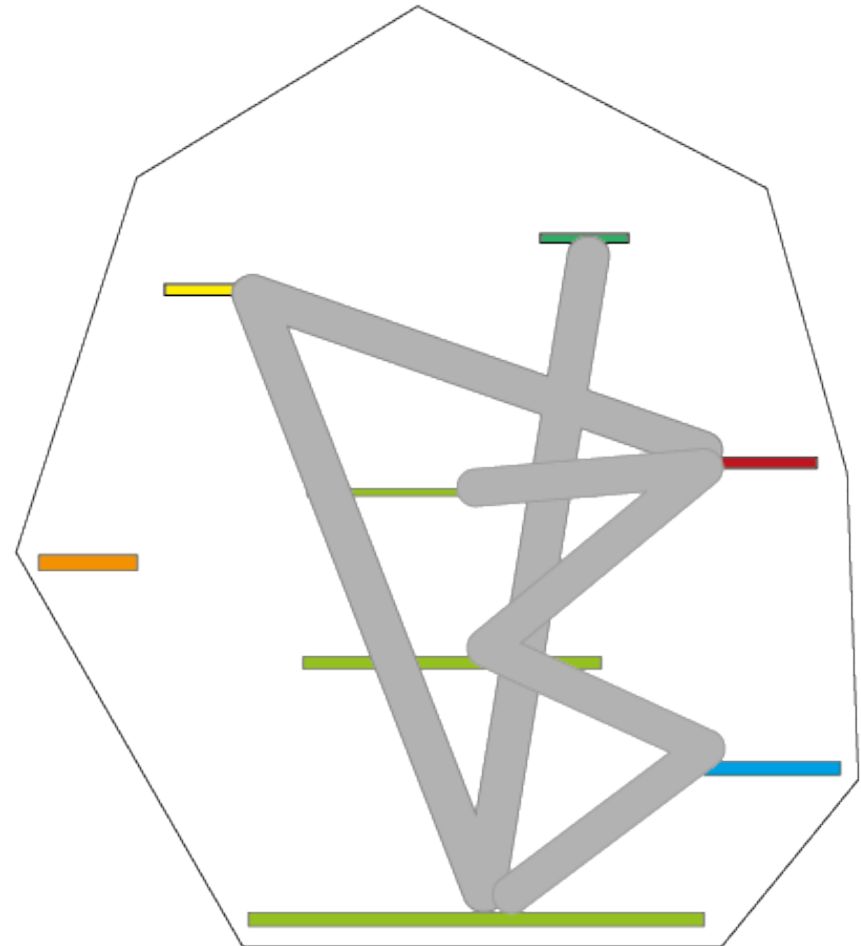
- Make ramps & plateaus
- Check walking space -> extrude
- Usable plateau space



Garden: internal views

Mapping views within the garden

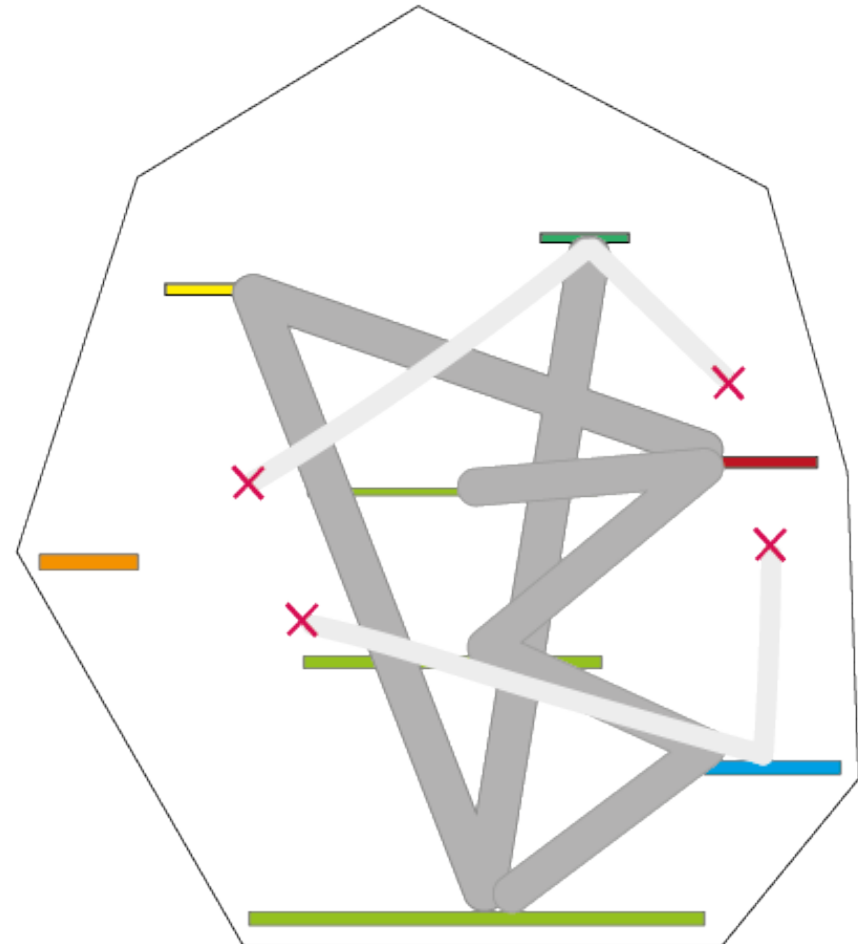
- Restful views:
 - Garden
- More active views:
 - Kitchen/storage
 - Working area



Garden: internal views

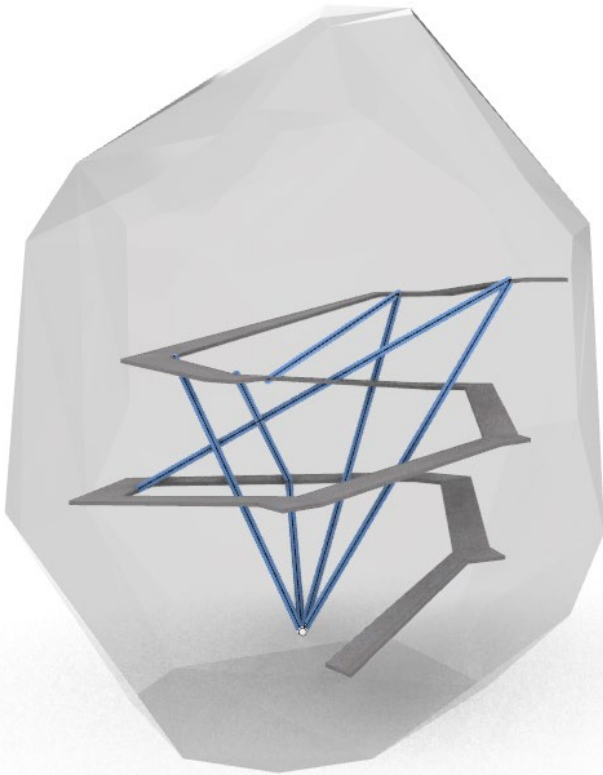
Mapping views within the garden

- Restful views:
 - Garden
- More active views:
 - Kitchen/storage
 - Working area

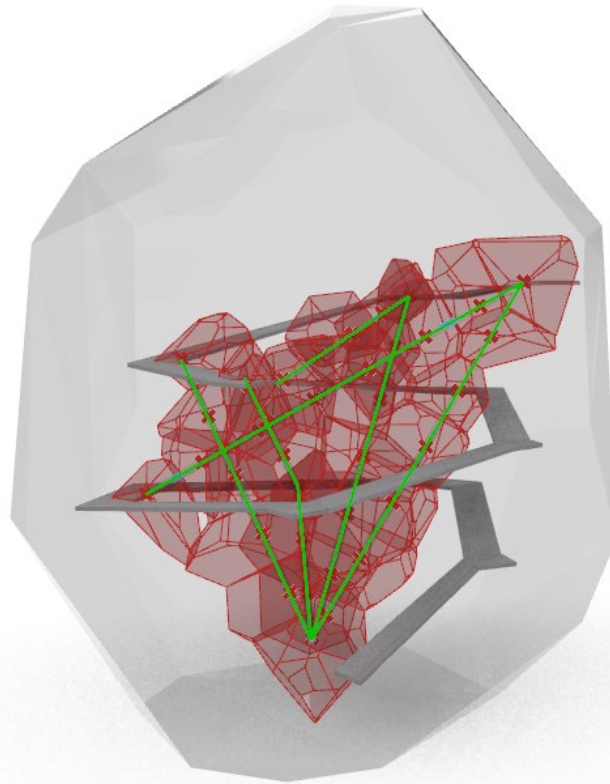


Garden: internal views

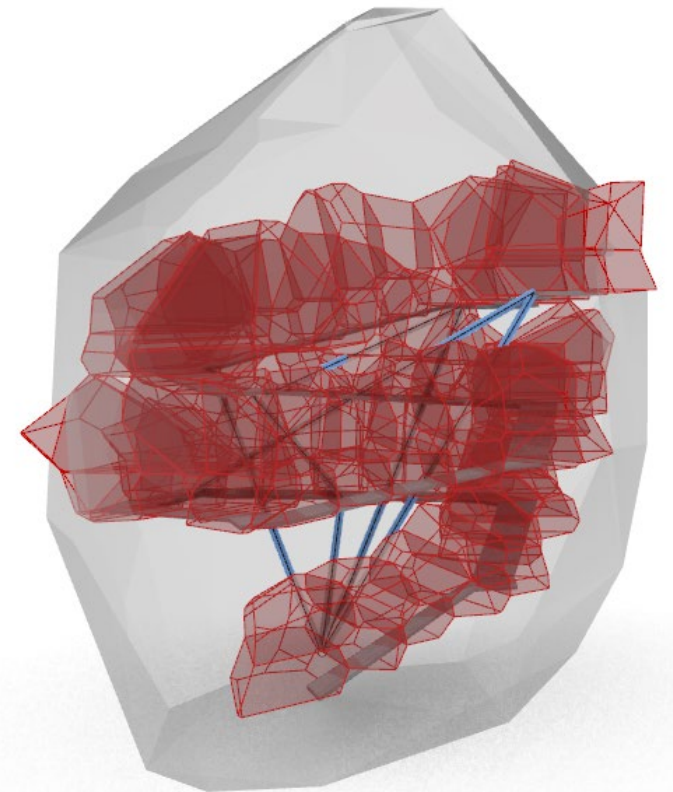
Map views 3D



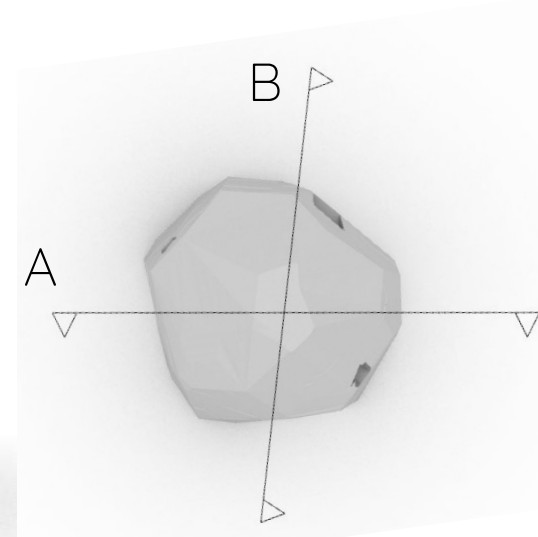
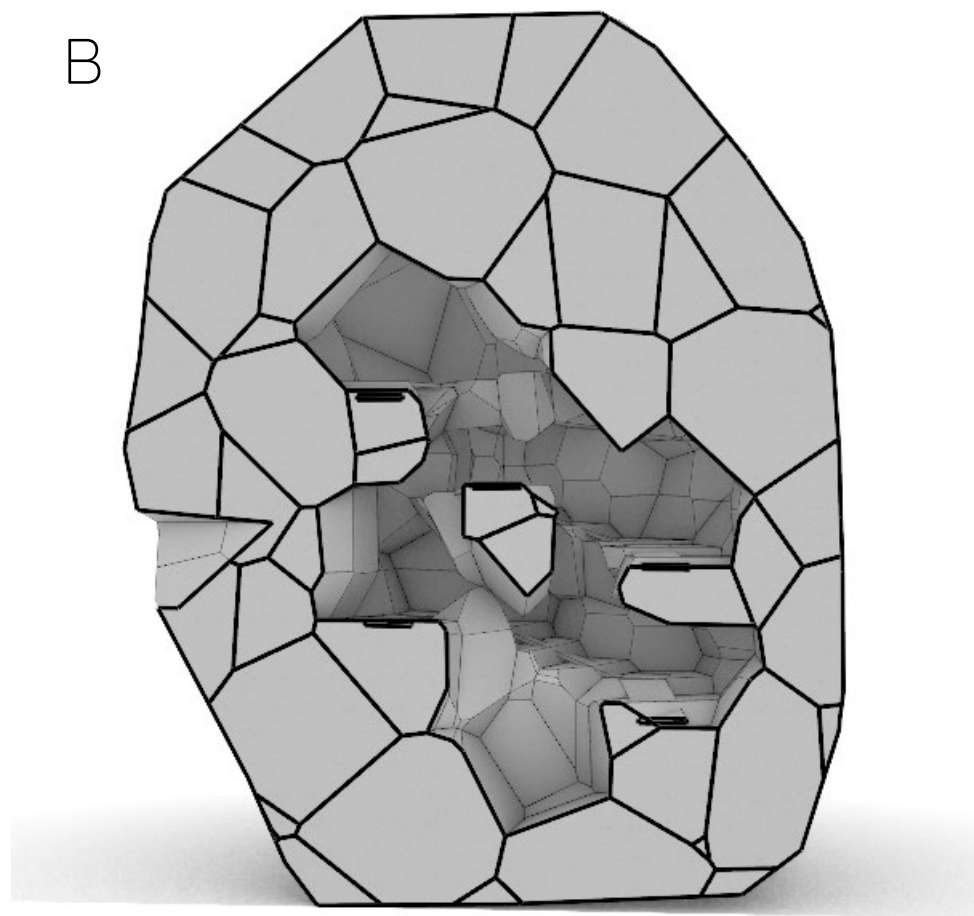
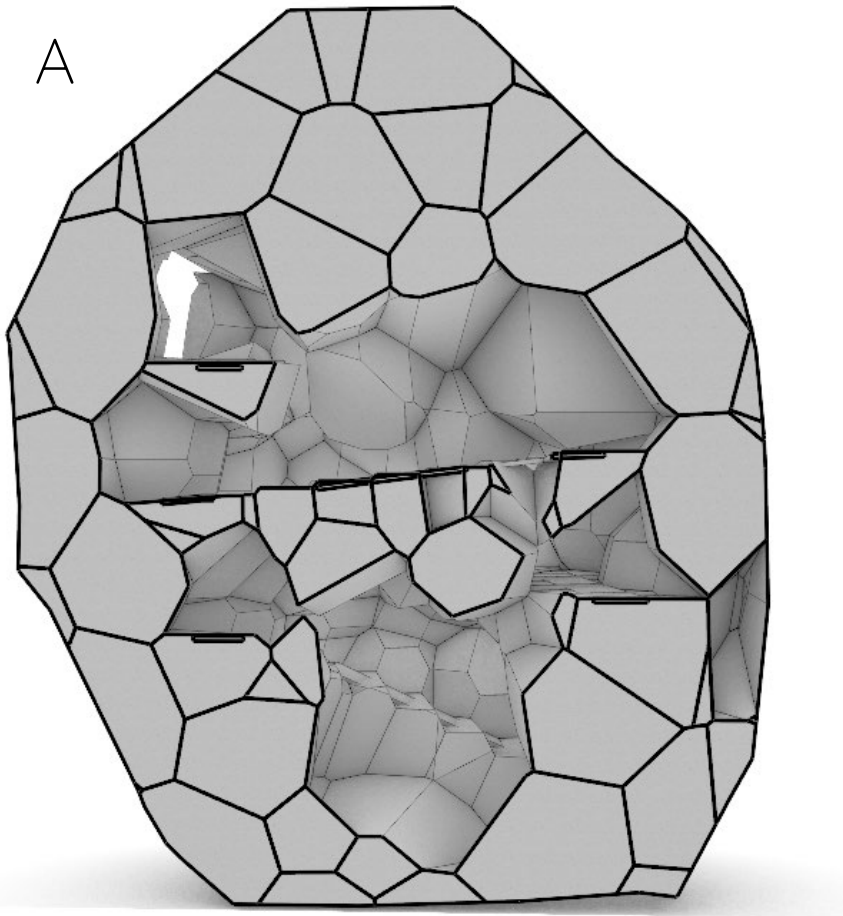
Voronoi along lines



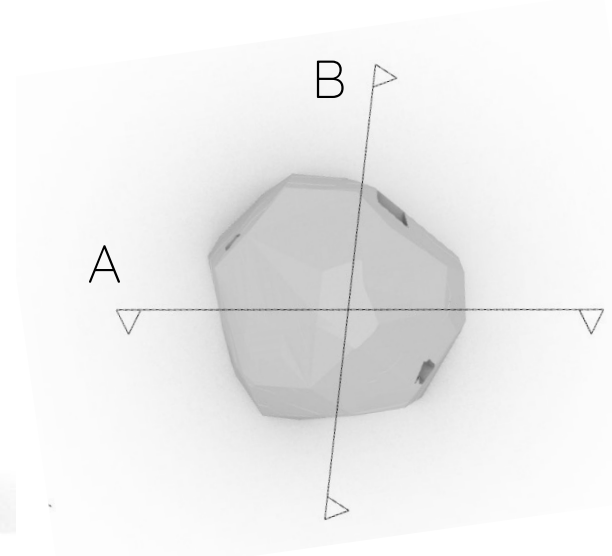
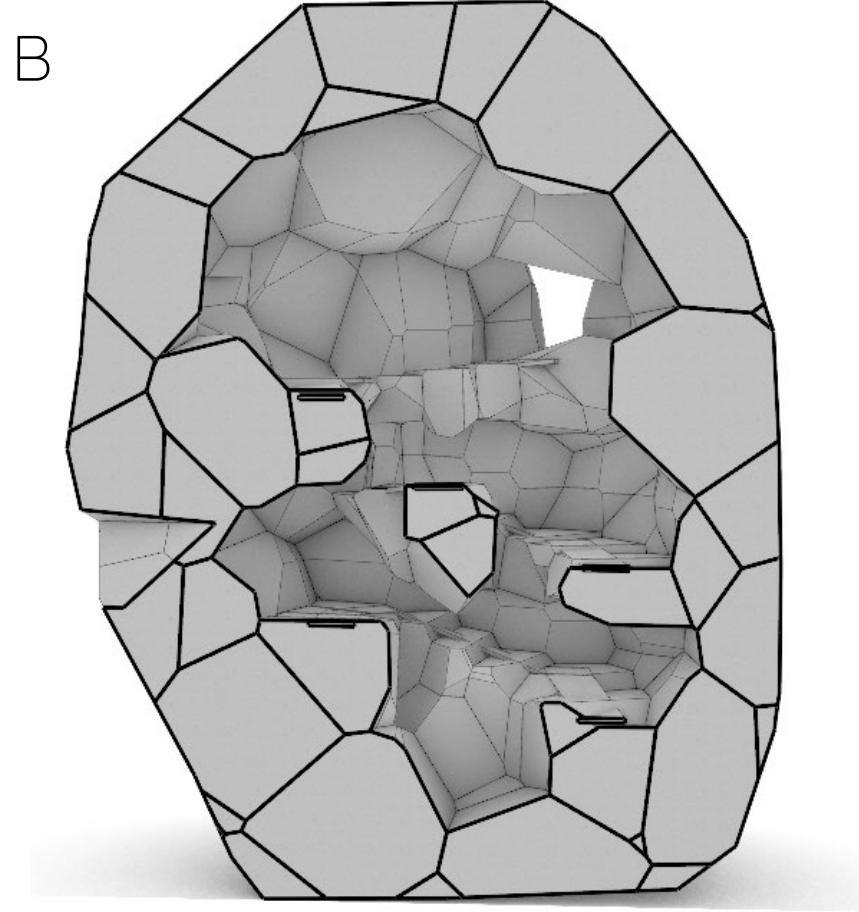
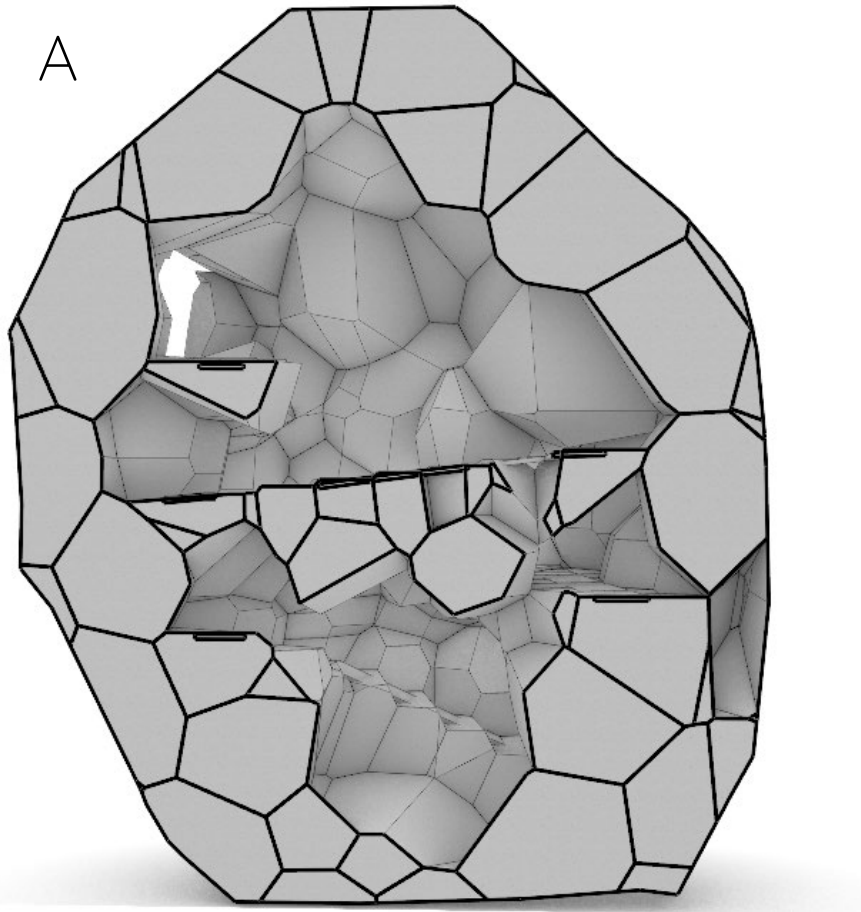
Voronoi along walking path



Garden: negative space

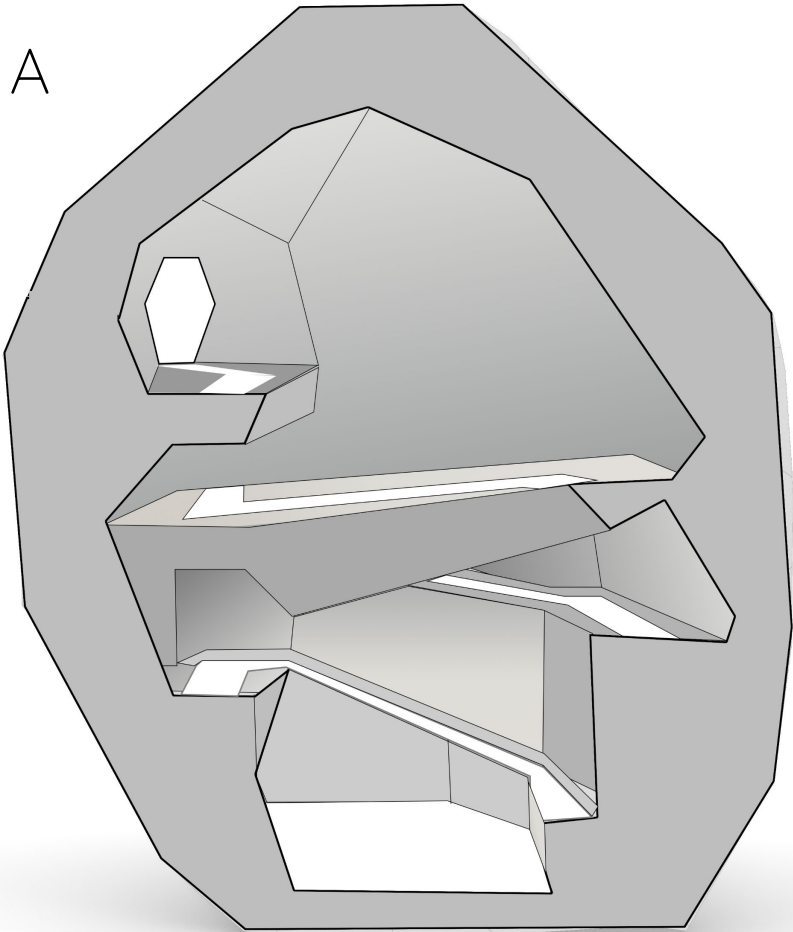


Garden: negative space

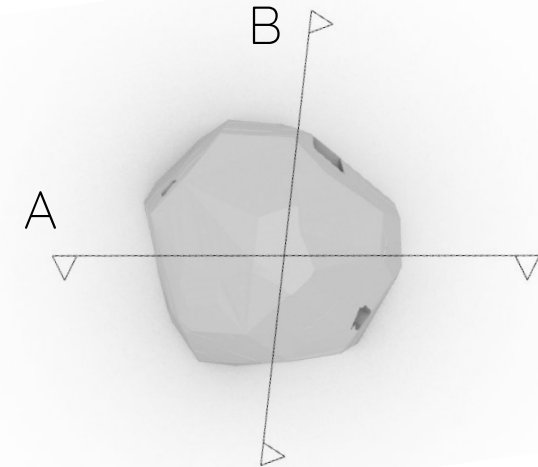


Garden: usable space

A



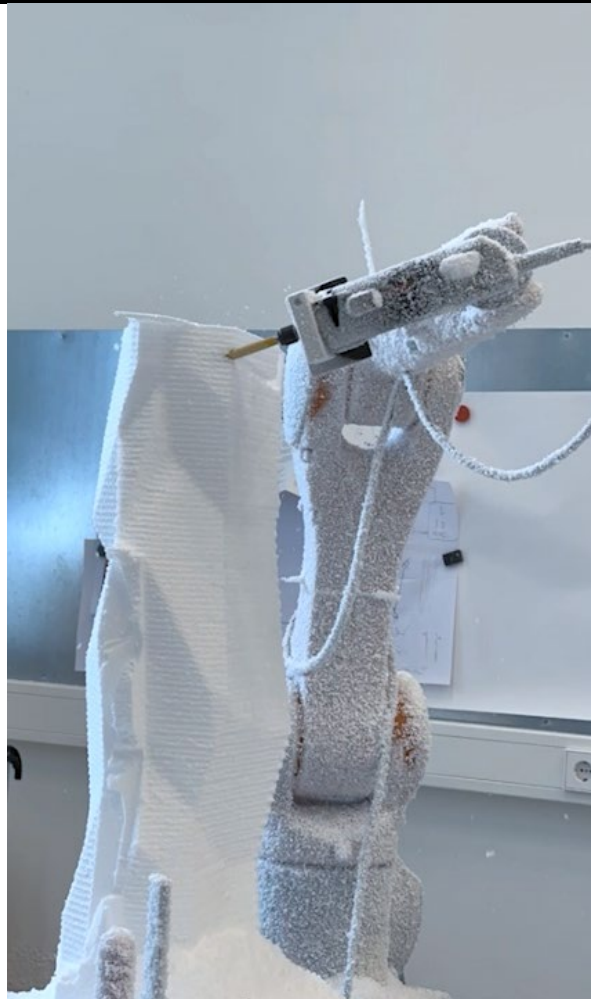
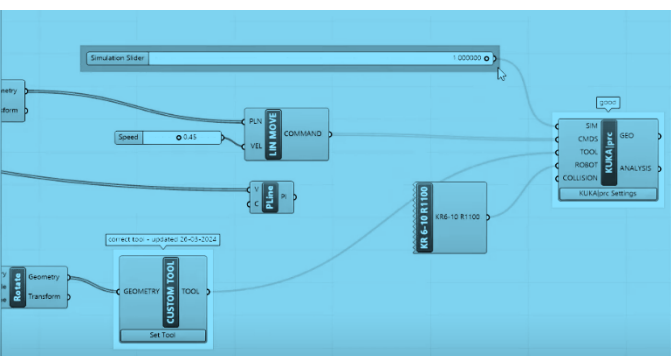
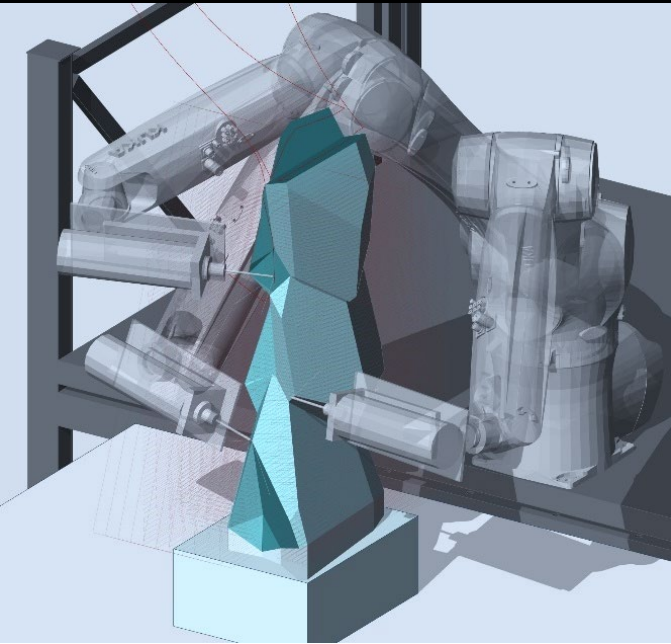
B



Constructing Lunar Architecture



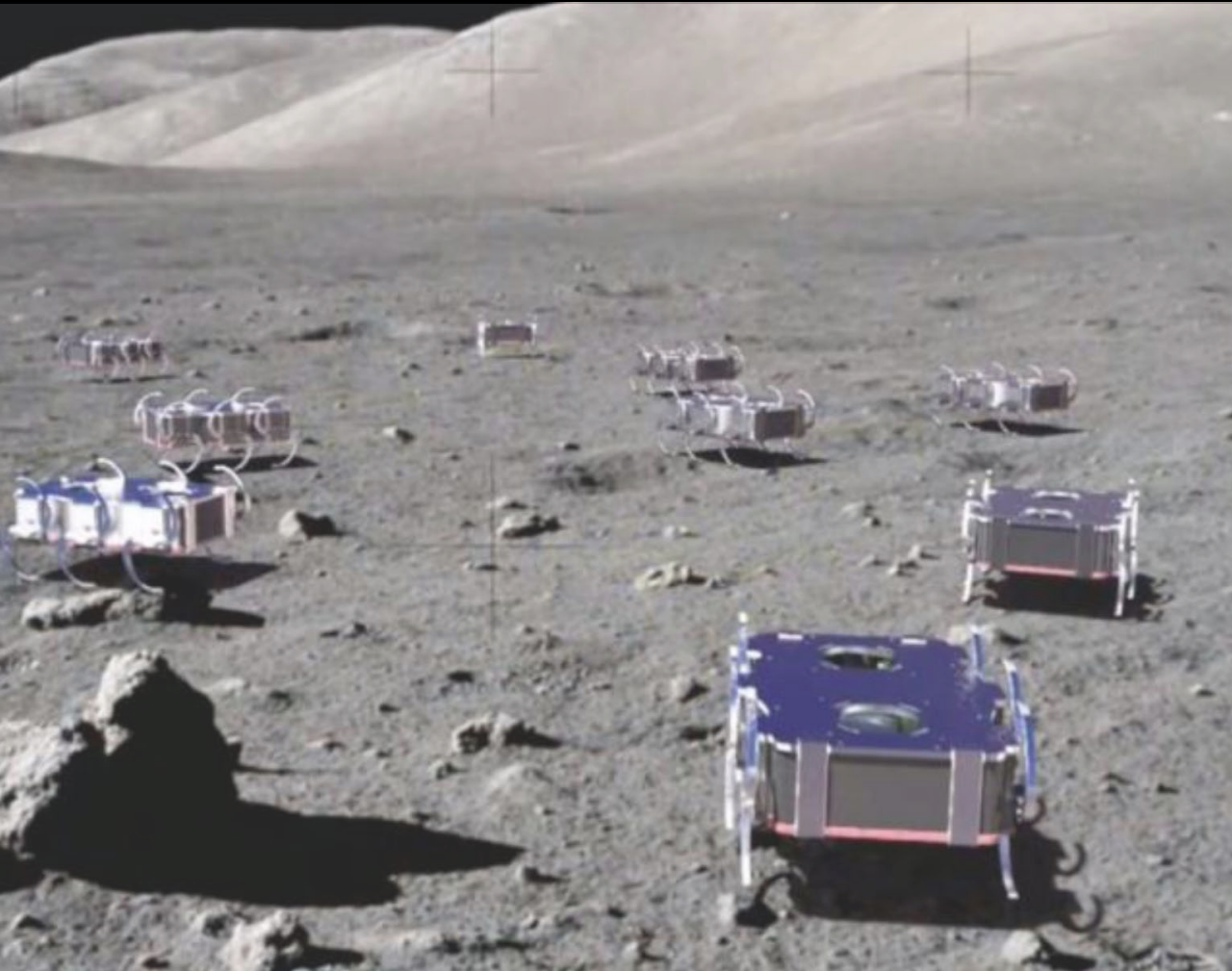
Workshop



Organic forms in design

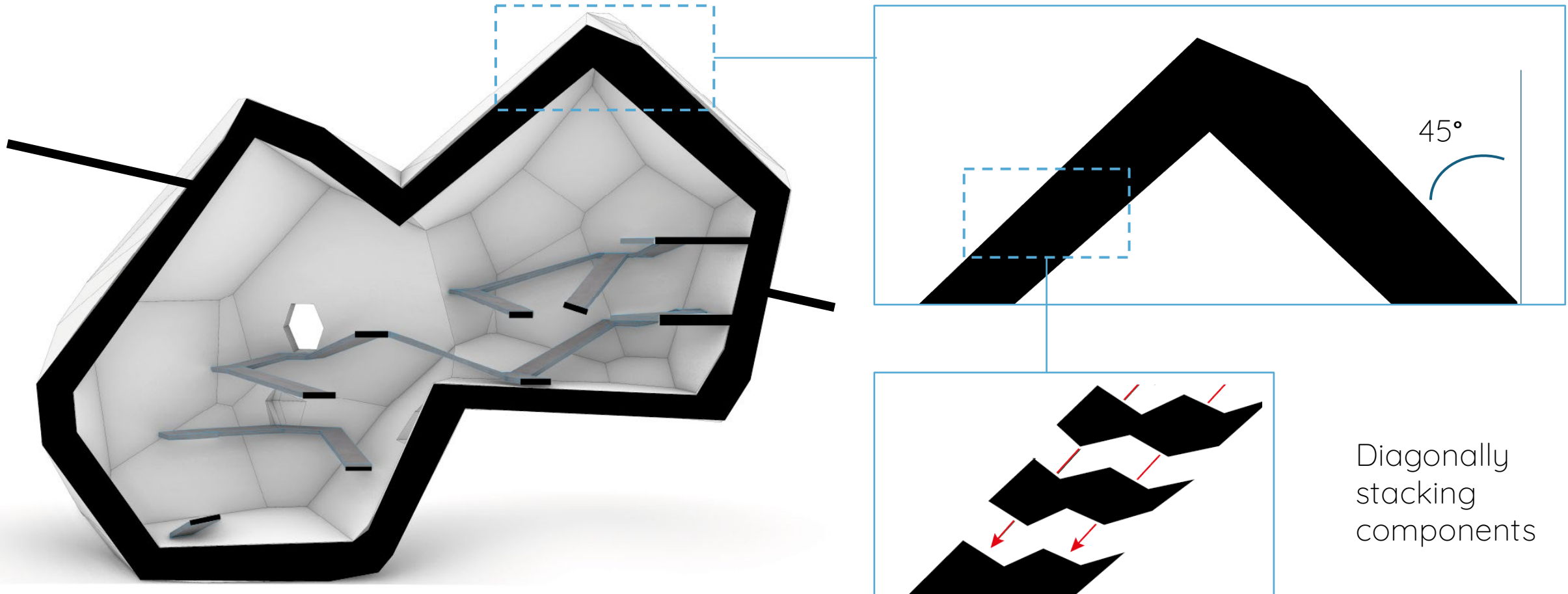
- Flexibility for room requirements mental health
 - Curved or Angular
- Voronoi: component adapted to form

Construction: swarm robotics



1. Excavation
2. Regolith gathered by swarm
 - brought to printer
3. Components printed
4. Carried by worker robots to location
5. Placed in correct location

Vault construction



Windows

ISRU:

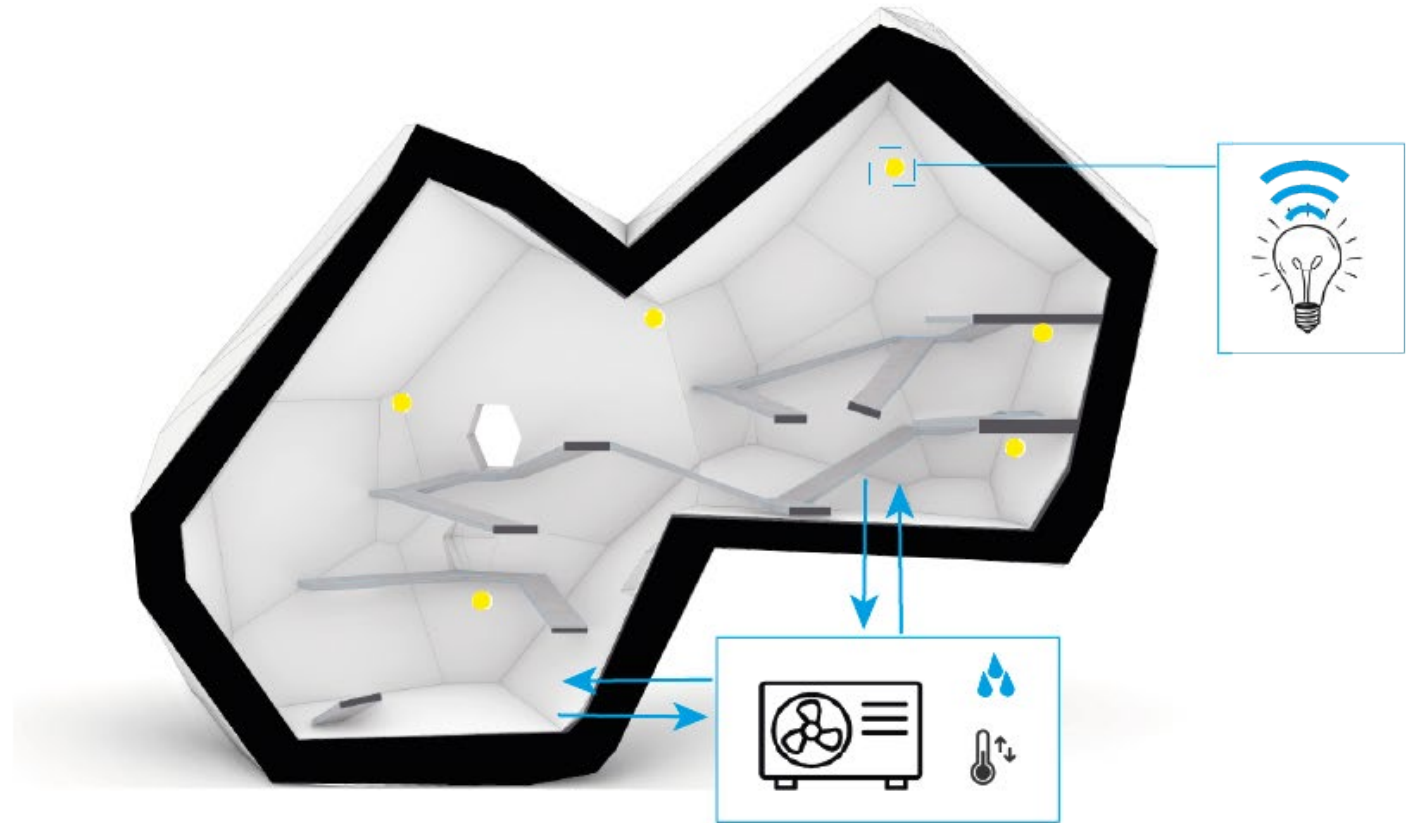
- Silica – silicon dioxide
 - Current ISS windows 4 layers of fused silica
 - Major component of Lunar Regolith: 42+%
 - extraction?
 - 3D printing windows is possible

Compound	Concentration (%)
SiO ₂	42-48
TiO ₂	1-7
Al ₂ O ₃	12-27
FeO	4-18
MgO	4-11
CaO	10-17
Na ₂ O	0.4-0.7
K ₂ O	0.1-0.6
MnO	0.1-0.2
Cr ₂ O ₃	0.2-0.4

Climate design

Communal

- **Ventilation**
 - Monitor CO2, aerosols etc
 - Humidity
 - Base temperature
 - optimal for machinery etc
- **General lighting**
 - Base setting - daylight
 - Motion sensors



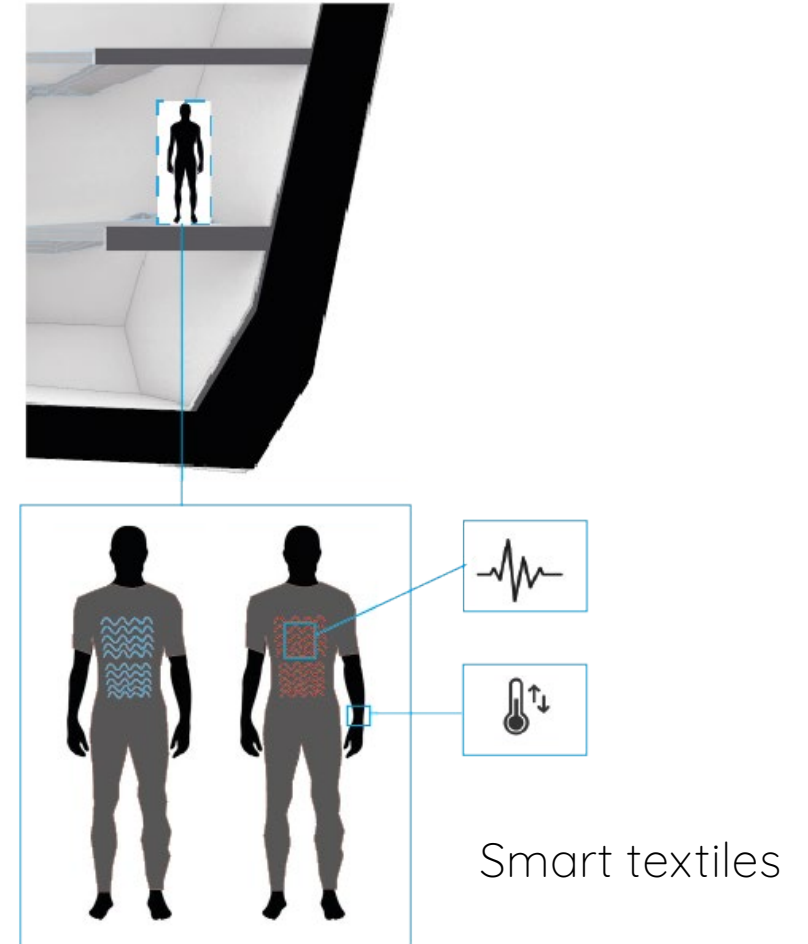
Climate design

Personal

- Heating
- Cooling
- Health monitoring and adapting schedule accordingly
 - Stress – take a break or meditate etc.
- Adapting lighting
 - Personal settings at workstation, private and meditation room

Why personalisation?

- Feeling of control in an otherwise uncontrollable setting



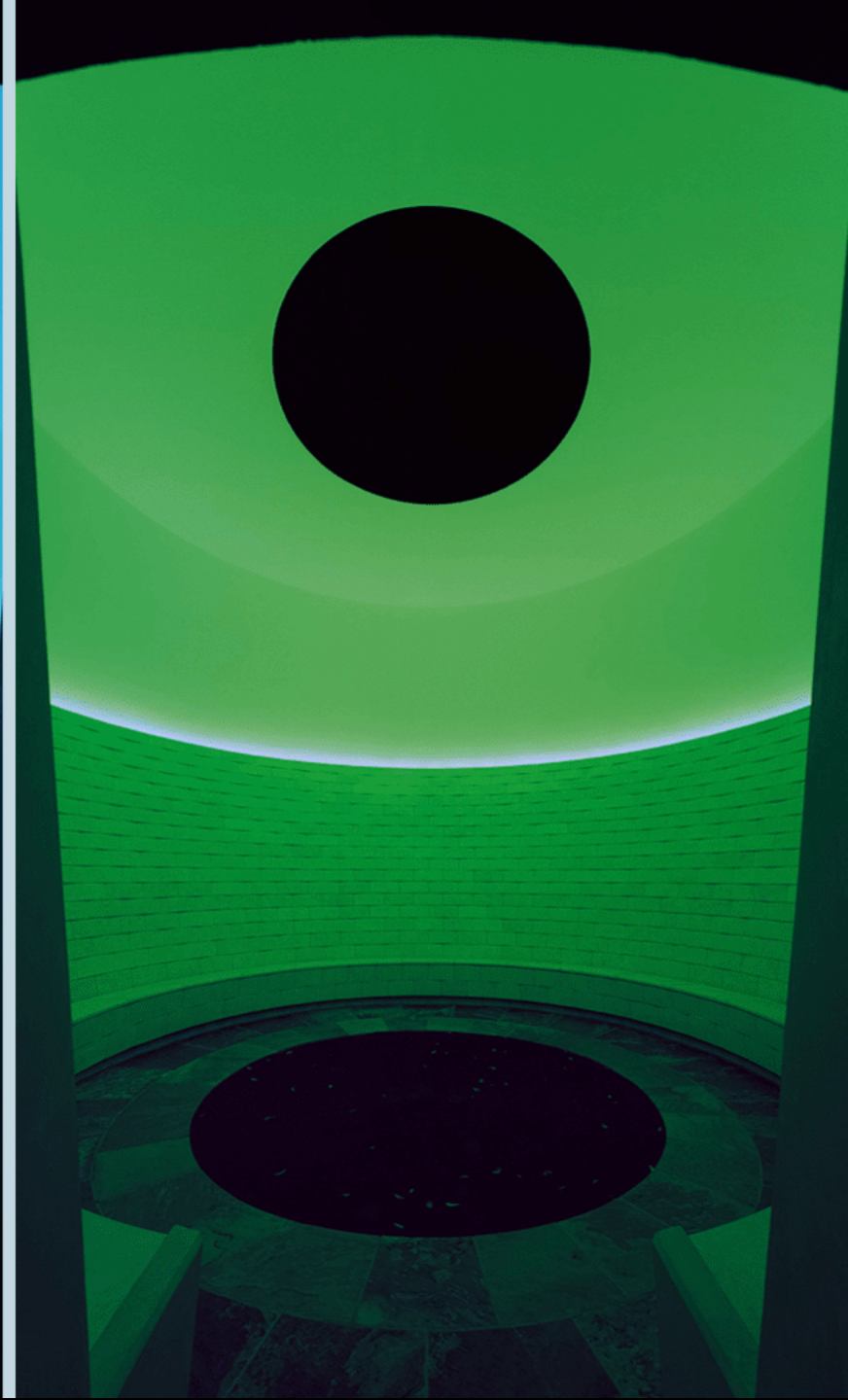
Next steps

Architectural design:

- Expand internal strategy beyond garden atrium
- Envelope design
- Integrate greenery in design
- Products:
 - Definitive plans, sections and elevations
 - Prototypes and visuals

Building technology:

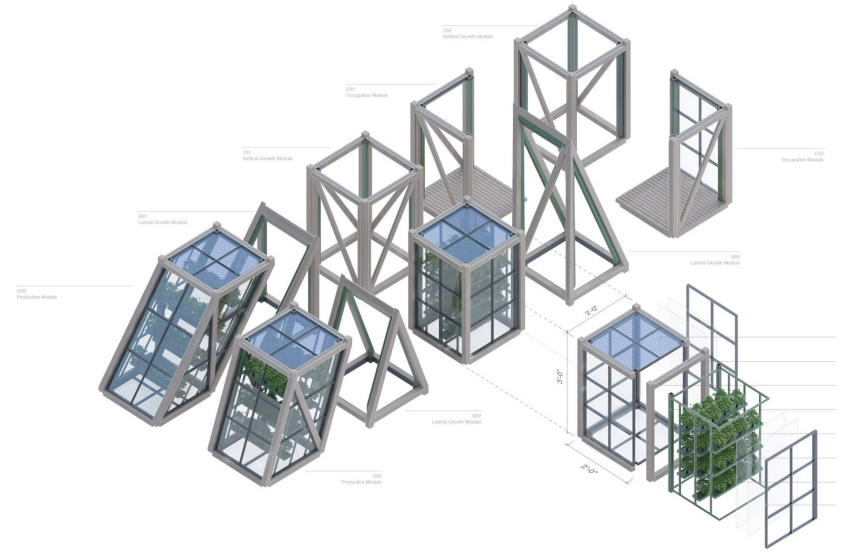
- Construction:
 - Apply workshop to own design fragment
- Detail:
 - Incorporated windows & shutters
 - Or integrated furniture
- Climate design:
 - Schematic
- Develop structural design



Vertical garden – modular small

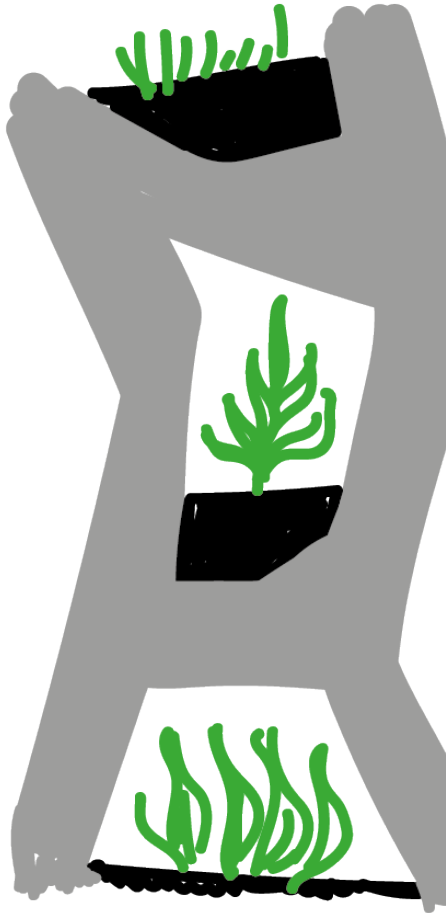
Glasi– Framlab

- Build up of greenery modules
 - Reproduced with Voronoi?
- Production Module, Growth Module and Occupation Module

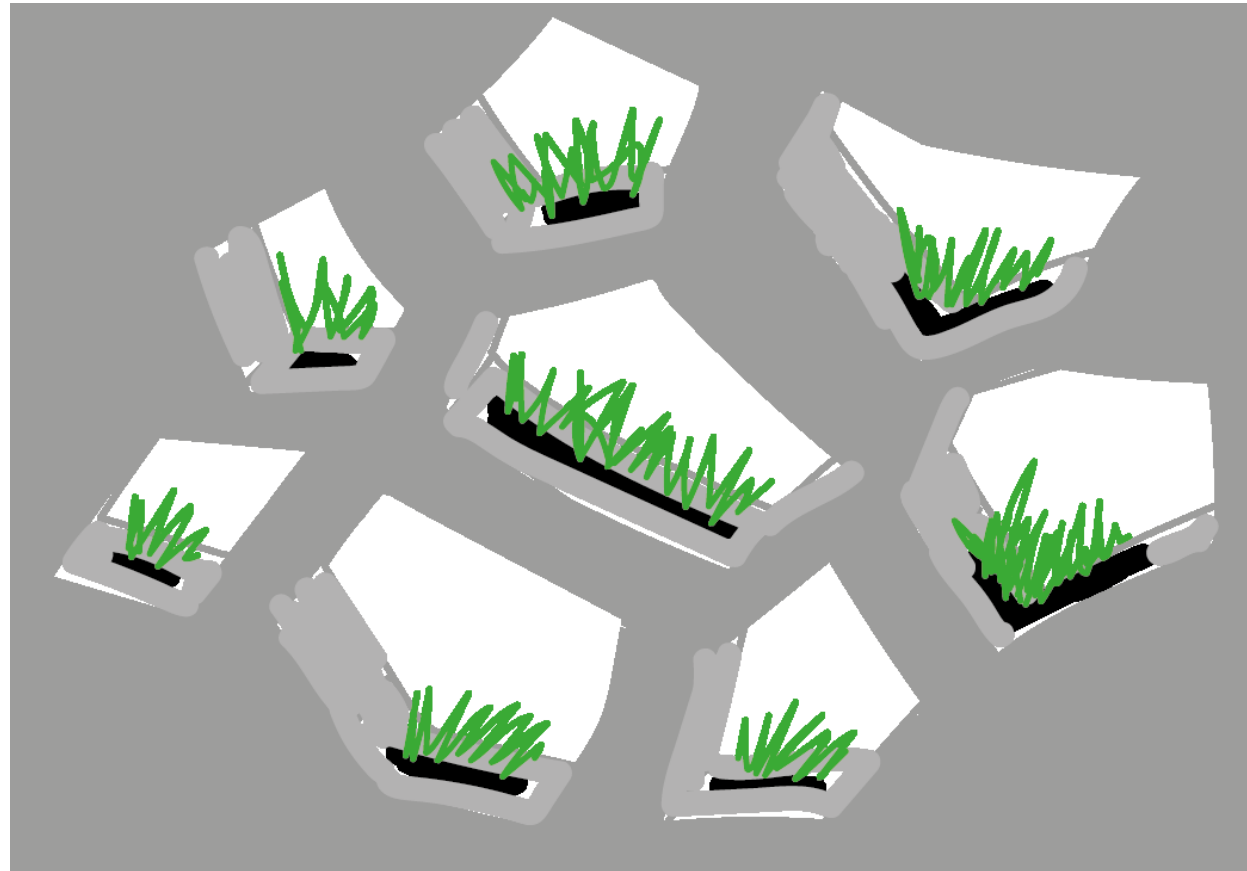


Vertical garden - sketch

Section

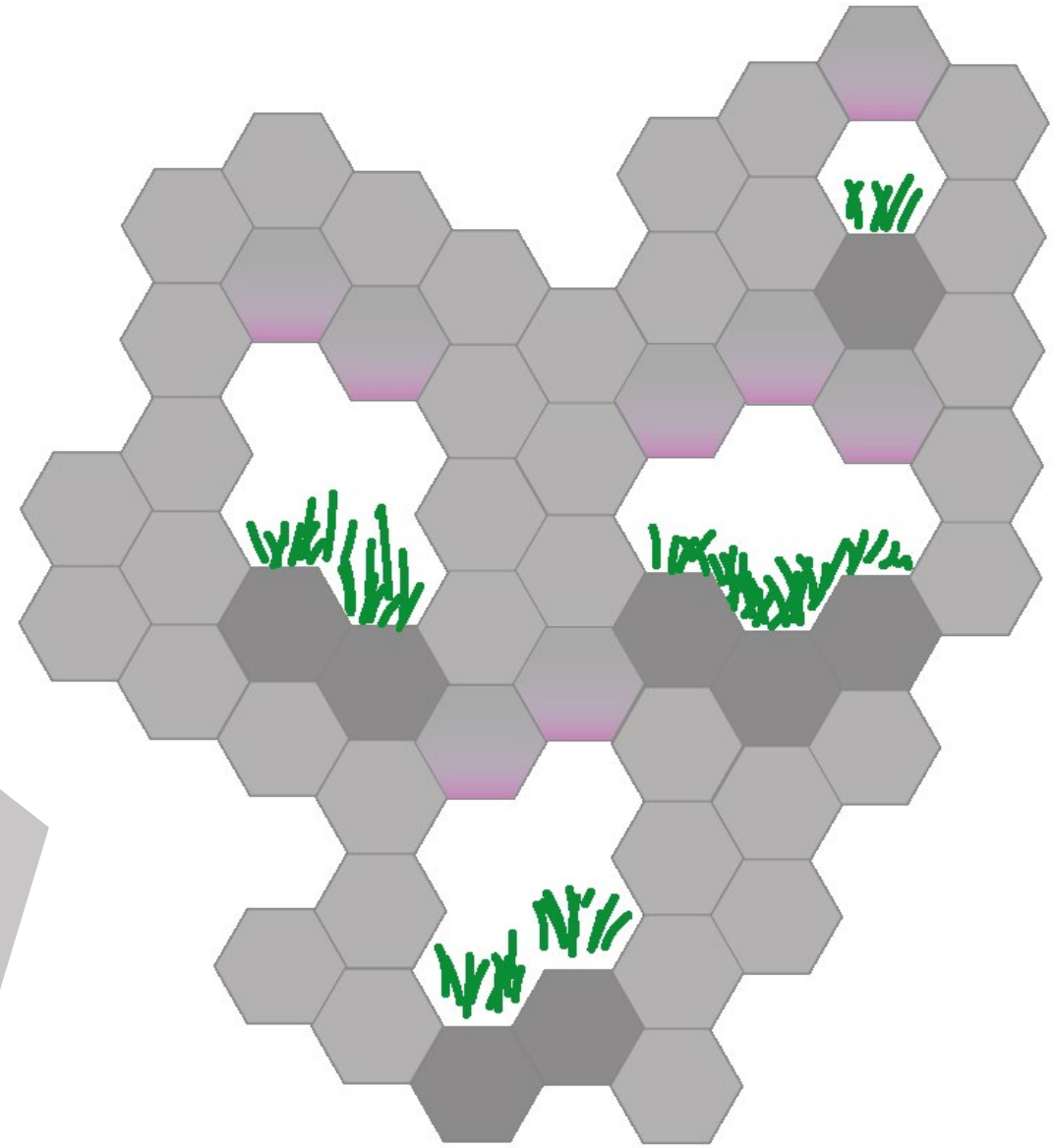
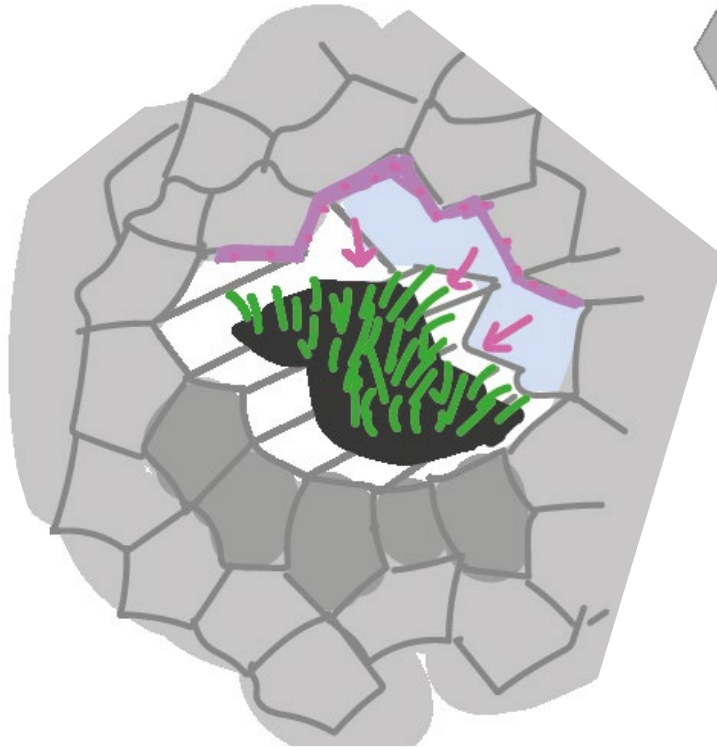
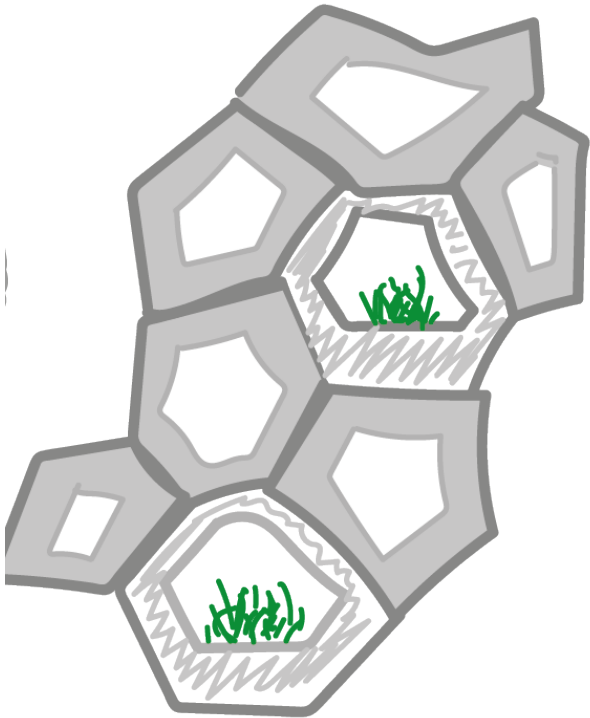


Front/ perspective

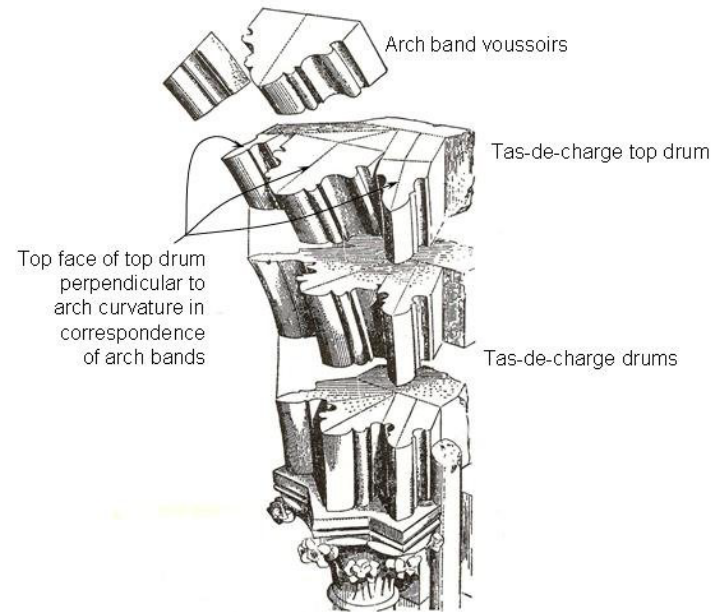
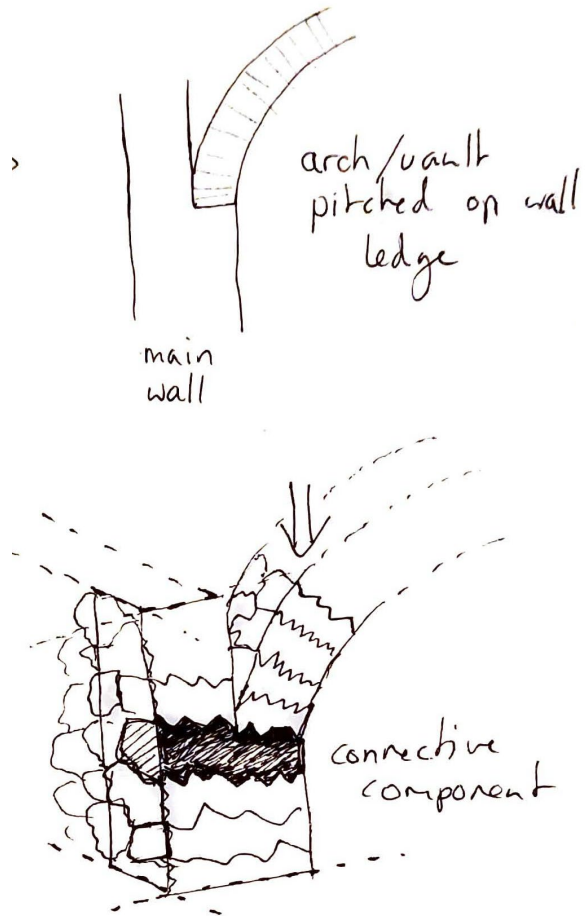


Vertical garden - structure

- Components – leave gaps
- Some components ‘planters’
 - Room for earth etc.
 - Multiple together? Or one whole component
- Others structural
- Add lights / light components?



Vault construction



Explain vault?