Research

Human de-centered design

Spatial similarity of ISS TransHab and The Panopticon

- Efficient form
- Unit size

[not to include– unit size]

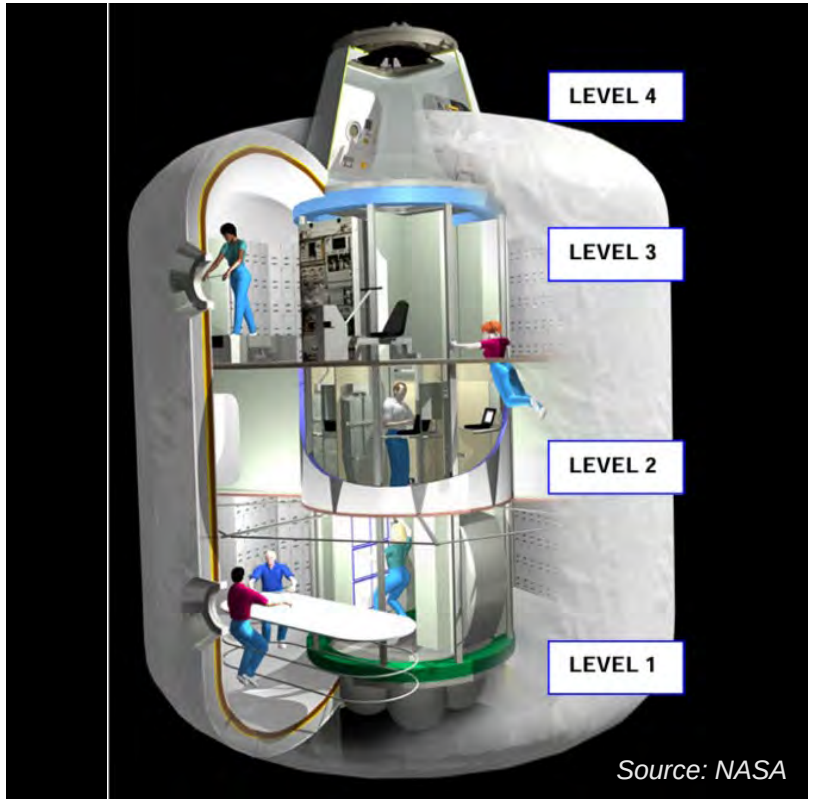
US prison standard minimum 6.5 sqm

Europe prison standard minimum 6 sqm

UK cell sharing minimum 4.5 sqm/person

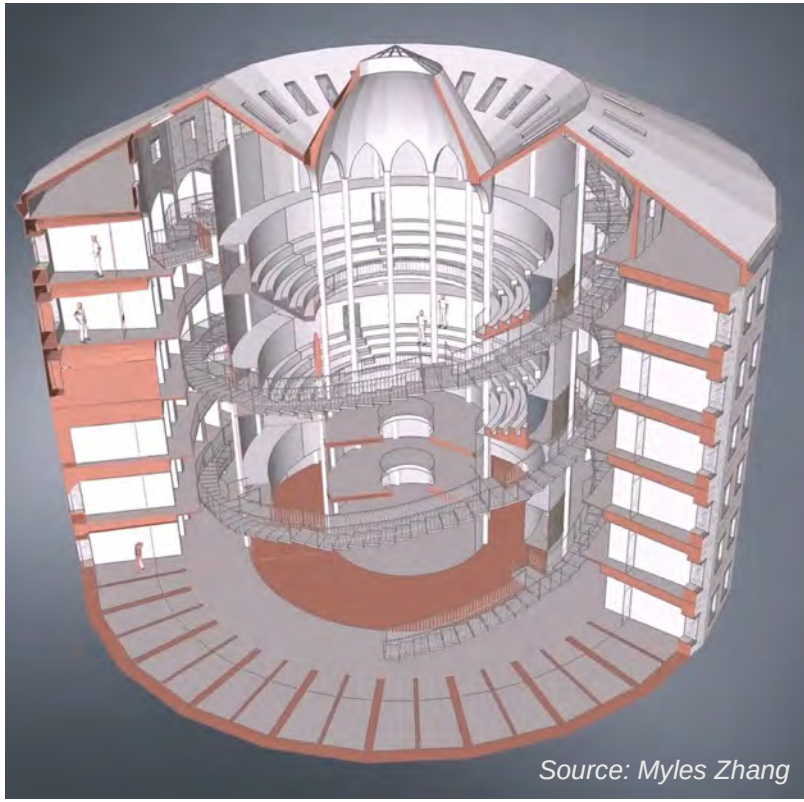
ISS sleeping quarter 2.5 sqm/person (2.5x1x1)

Recommended minimum NHV 25 sqm/person



ISS TransHab

Efficient form for transportability and environment protection (non-human actor)



The Panopticon

Form derived to enable central surveillance of every inmate's cell (inhuman, dehumanizing)

Human de-centered design

Definition

Dehumanizing architecture

- Habitat that deprives the user from positive human qualities, personality, or dignity

Adapted from Oxford and Merriam-Webster Dictionary

Example of dehumanizing architecture on urban setting: street furniture and obstacles to stop homeless people from sleeping or accessing the space.

Inhuman design

- **Inhuman styles**: Not adapted to human sensitivity, not innovative, i.e. not developed towards life or away from life, but devoid of life.
- **Becoming inhuman**: Suppress our natural reactions to our physical surroundings.

Nikos Salingaros, Anti-Architecture and Deconstruction 4th Edition, 2010

Hostile architecture

- Urban design strategy that uses elements of the built environment to guide or restrict certain behaviors in public spaces.

Jordana Rosenfeld, in Britannica, 2024

Dehumanization of architecture

- Tendency towards abstraction, to purify architecture, to foreground the aspects taken to be true objects of aesthetic interest: e.g. form of a building and how that form relates to its function.

Rafael De Clercq, The Dehumanization of Architecture, 2022

Human de-centered design

Limited private spaces

Stress from trying to be inclusive of all crew members in all activities.

Private time is difficult due to lack of auditory privacy, even leading to frustration.

Flashline Mars Arctic Research Station 11, 2007 (100-day mission).

Hi-SEAS Research Station. Very open, nowhere to hide

Human de-centered design

Failure in design for human behavior in ICE environment

"The history of space exploration is full of reports about mishaps."

David J. Shayler in Disasters and Accidents in Manned Spaceflight, 2000

"If something is going to stick out and make a nice handhold, it's going to be used for a handhold."

Gerald Carr, Skylab astronaut, 1974

Destiny module, ISS. Broken air hose due to extended use for grabbing.

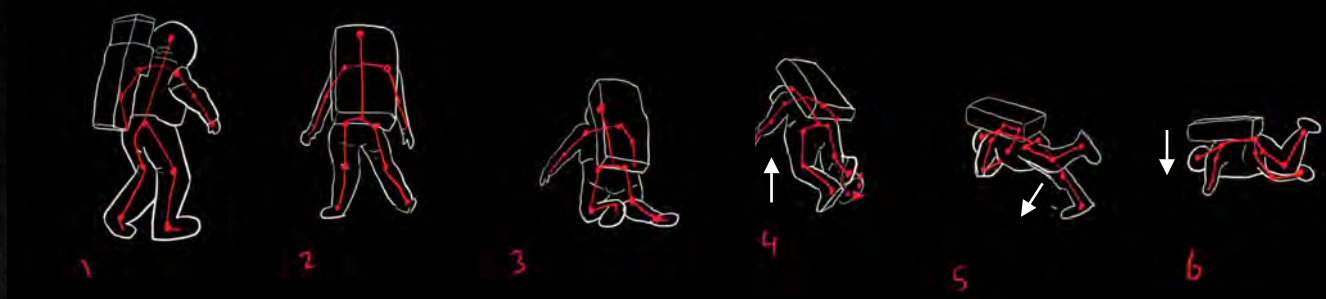
Limitations & Assumptions

Limited data on actual human experiences on moon

- Data comes from orbiting space station (ISS), short-term lunar expeditions in 1960s-1970s, and analogue missions.

Speculations on future technologies & research. Project is set in 2080, assuming:

- Availability of in-situ resource utilization (ISRU) and advanced construction methods.
- Feasibility to live with lunar environment, especially lunar dust and low gravity, with proper mitigation.
- Working with developing technologies and current research → based on assumptions and discussions with experts



Lunar Movement Analysis
Based on Astronauts Falling on the Moon (1972), NASA Archive, Apollo 17 Video Library

Condition	Outer Space	Moon	Design Implications
Gravity	0 g	1/6 g	Object does not float on moon
Enclosure (pressure, radiation, temperature, debris control)	0 bar (vacuum) -270°C – 200°C Exposure to space radiation, Micrometeoroids, bright light & glare	~0 bar (almost vacuum) -233°C – 123°C Exposure to space radiation, Micrometeoroids, bright light & glare	Both need enclosed vessel → confined boundary, highly controlled environment
Length of day	N/A	28 Earth days (14 days light / 14 days dark)	Site selection
Dust	Minimal	Pervasive & potentially toxic, electromagnetic cling, lofts above surface	Need dedicated dust cleaning area
Grounded surface	N/A	Lunar surface & underground	Take advantage of lunar morphology as natural protection

Source: Architecture for Astronauts, with modifications

*How to incorporate **user-defined spaces** based on **human-centric design principles** in designing long-term lunar habitation that **balances social interaction and private boundaries**, for the psychosocial well-being of the inhabitants?*

Human-centric design theories

using human experiences as data and human preferences as design guide

Phenomenology

human experience and perception as basis to design spaces

Proxemics

privacy gradient

mitigate confinement through setting spatial adjacencies based on privacy gradients

Third Place Theory

essential to form community

creation of a third place (between work and home) → the social/leisure space

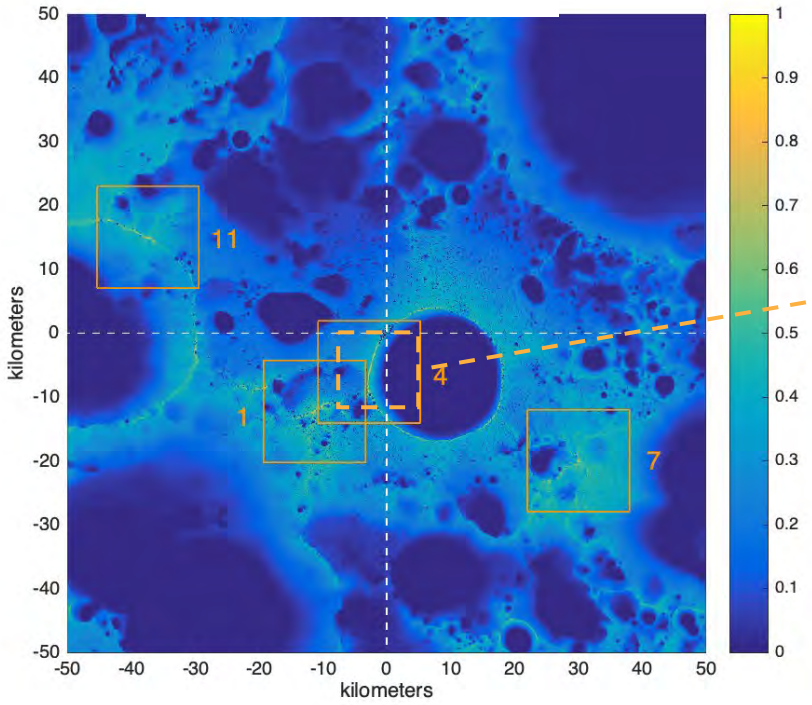
Affordances

visual cue to an object's function and use

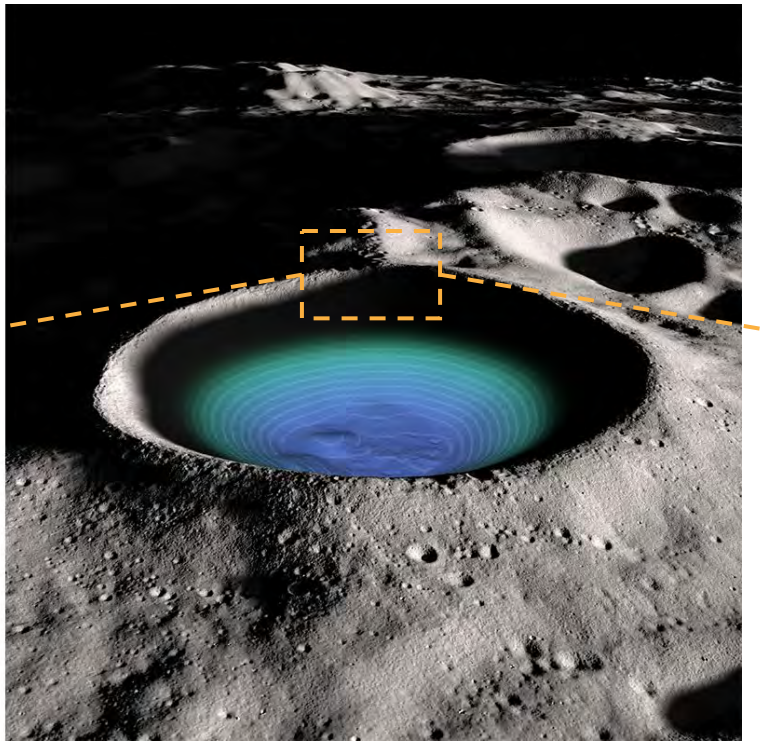
Site Selection

Sun and Earth visibility

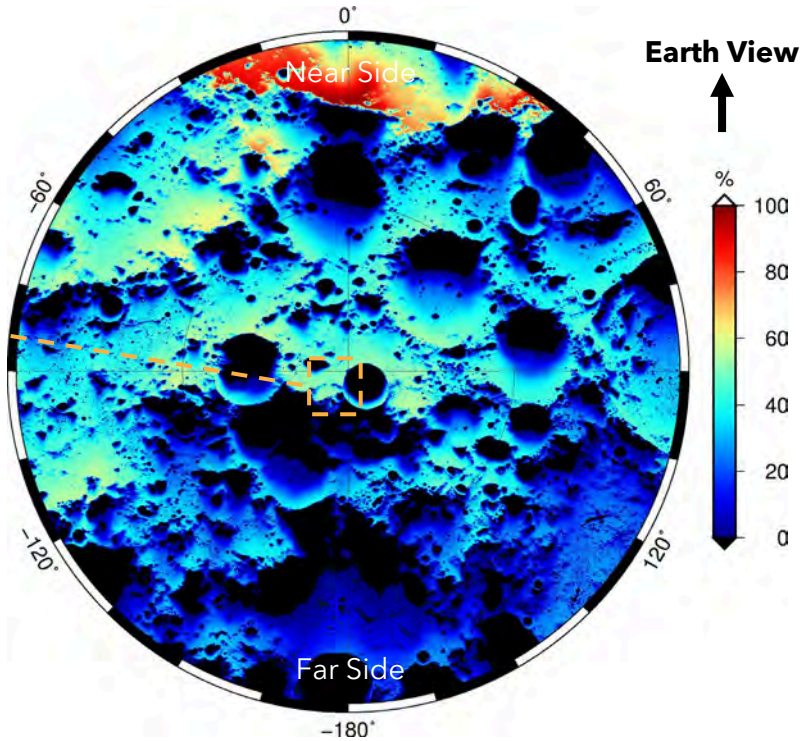
- Eternal sunlight areas (illuminated >80% of the time) as energy source and daylight utilization
- Earth view to alleviate potential homesickness
- Design potential from eternal sunlit to permanent darkness area



Average Sun Visibility



Shackleton Crater



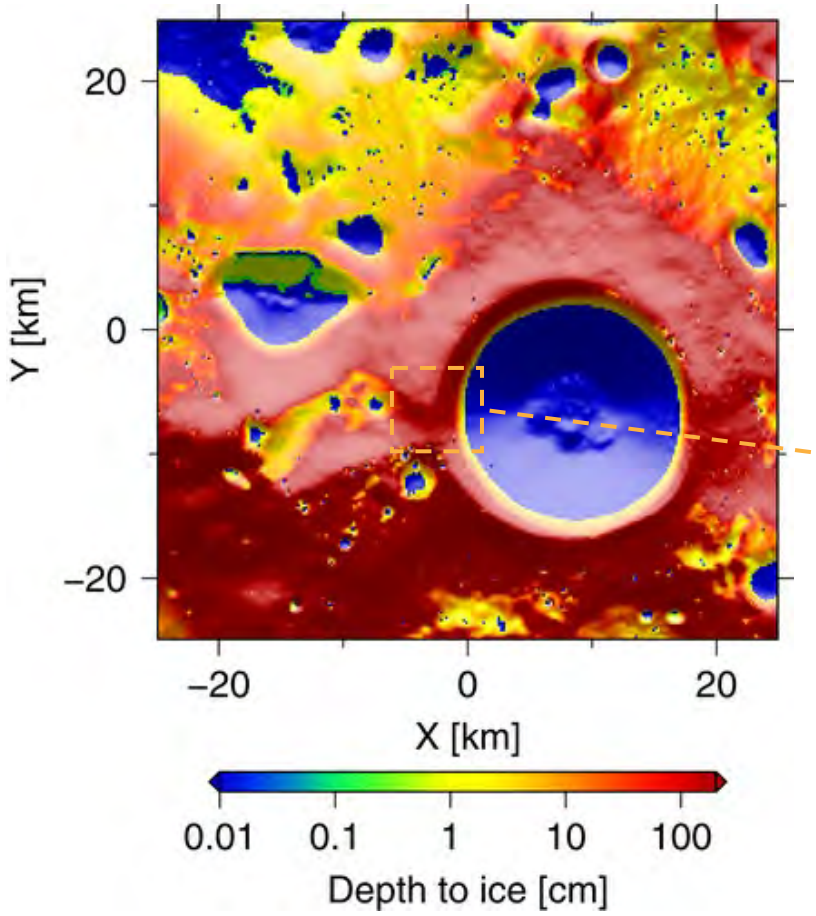
Average Earth Visibliity in 85 °S - 90 °S

Source: NASA Goddard

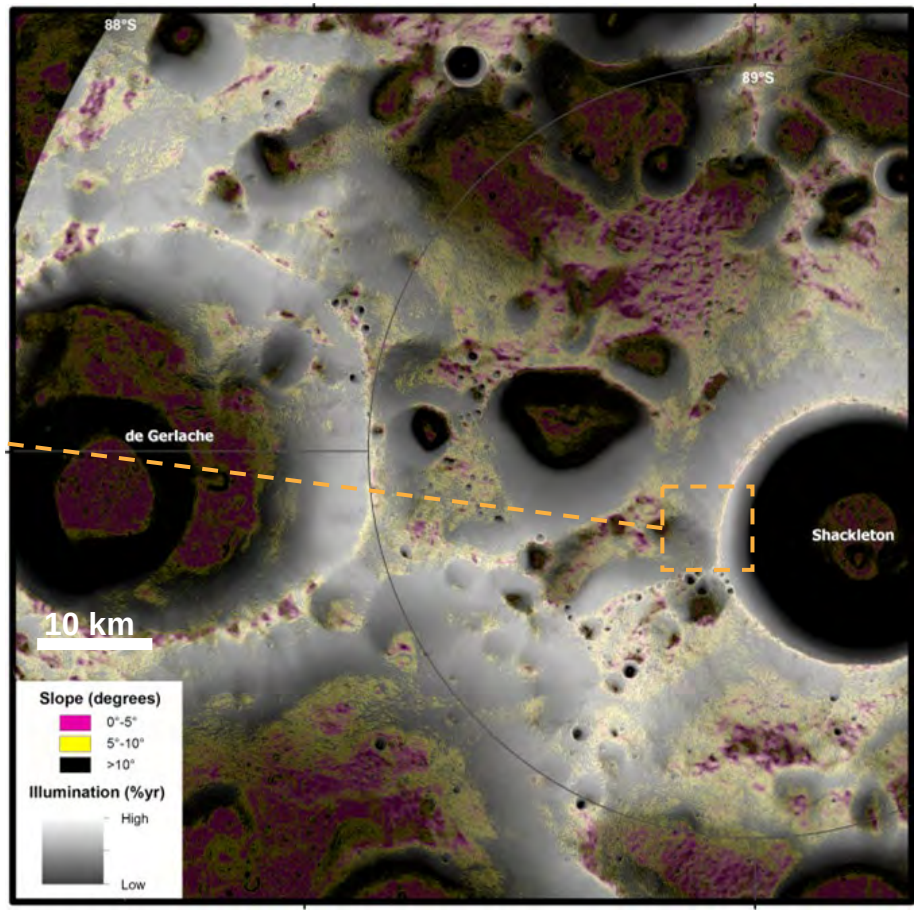
Site Selection

Resource

- Permanently shadowed areas provide abundant resources
- Water-ice → possible water collection system and water for in-situ material
- Fossil records of hydrogen, water-ice, and other early Solar System volatiles → lunar base in proximity to research materials



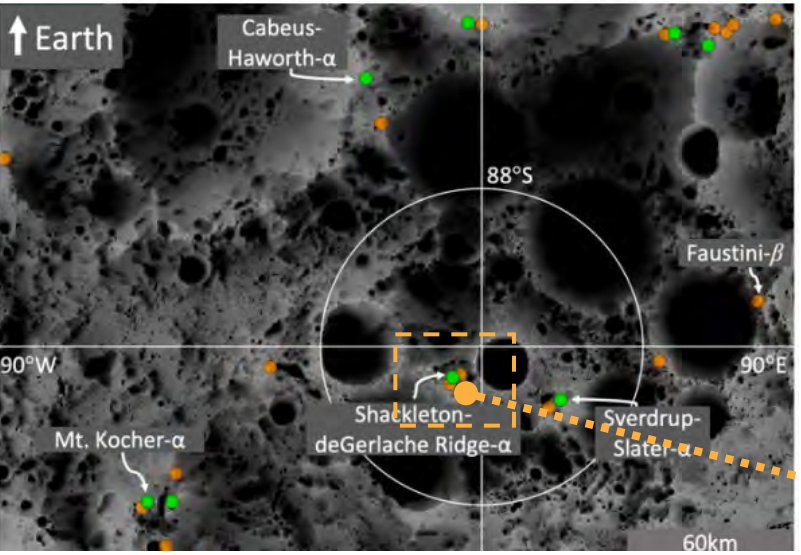
Water-ice in Lunar South Pole, Philipp Glaser et. al.



Annual Illumination and Topographic Slope of Lunar South Pole Ridge Polarsteregoraphic Projection

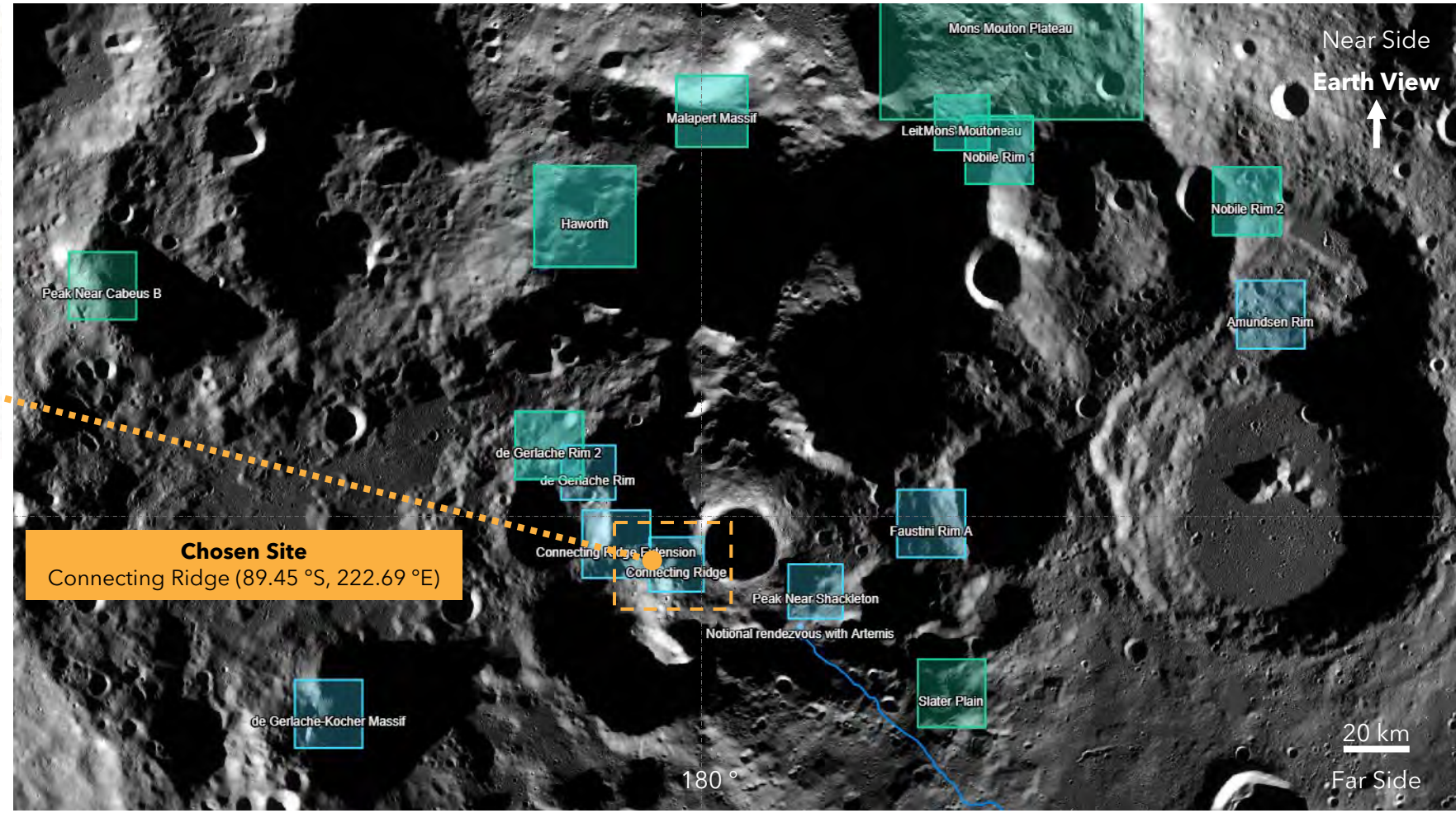
Site Selection

Importance of Lunar South Pole



Artemis Candidate Base Camp Sites
University of Chicago

- Well-researched
- Abundant resource
- Potential lunar base → epicentrum of lunar civilization



Artemis III potential landing regions 2022 (approx. 15x15 km)

Artemis III potential landing regions 2024

LROC WAC Mosaic Lunar South Pole
Polar Stereographic, 300 mpx

Site

Charged regolith:

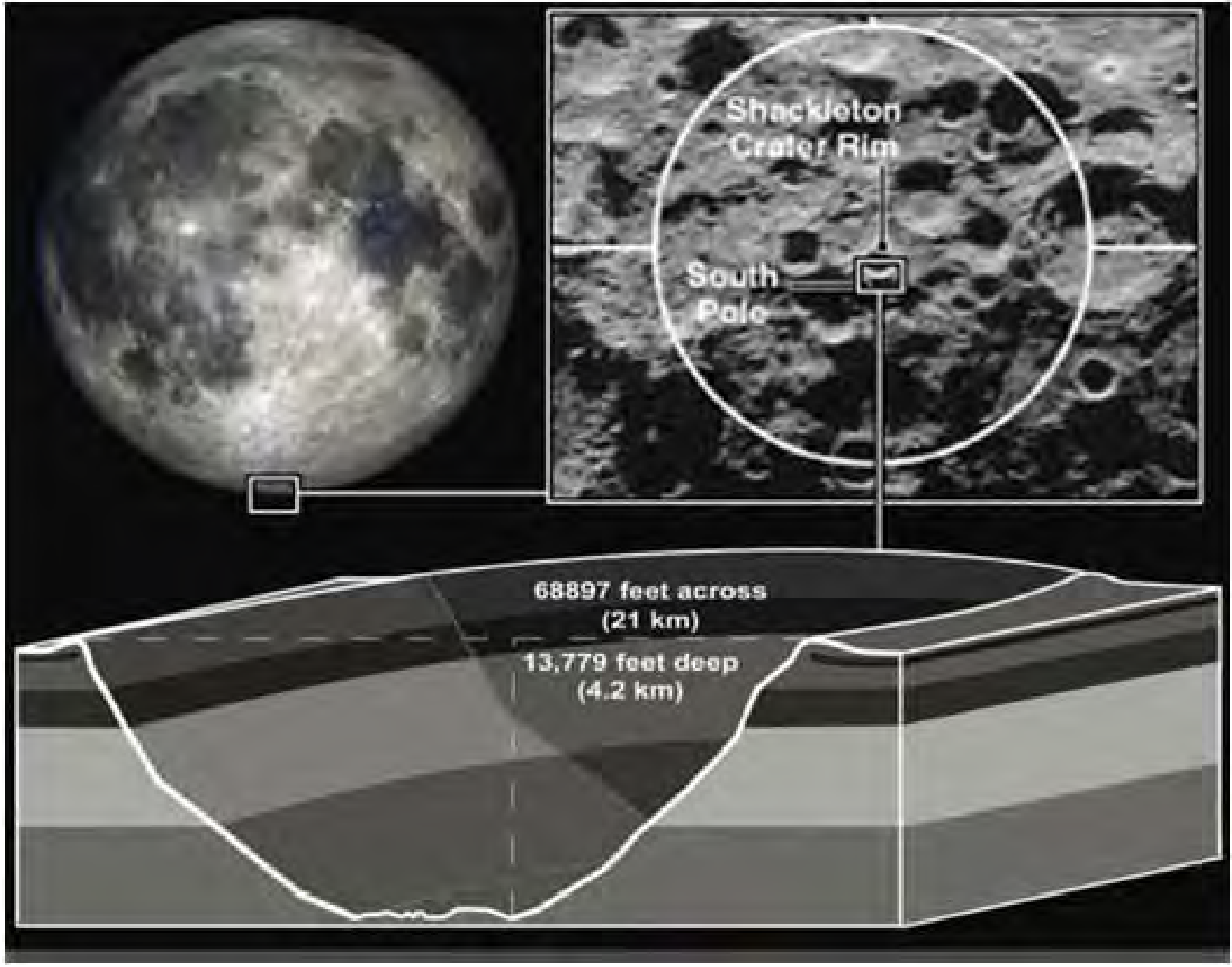
Sunlit regions, near landers

Face side

- 14/14 day night cycle
- Lava tubes
- Micrometeorites

North/South Pole

- Eternal sunlight areas (South Pole)
- Seasonal constant sunlight areas (North Pole)
- Eternal darkness areas in craters
- Deep craters protect from micrometeorites



Shackleton crater location and data, Olga Bannova, 2012.

Shackleton Crater (South Pole)

Pros

- Well researched
- Permanently shadowed areas provide resources: water-ice, fossil records of hydrogen, water ice, and other early Solar System volatiles (for research purpose)

Which part of crater? The rim

- Provides eternal sunlight
- Gradient from sunlit to shadowed areas

Full interior illumination

Partial interior illumination

Rim

Permanent Settlement

when visible from surface

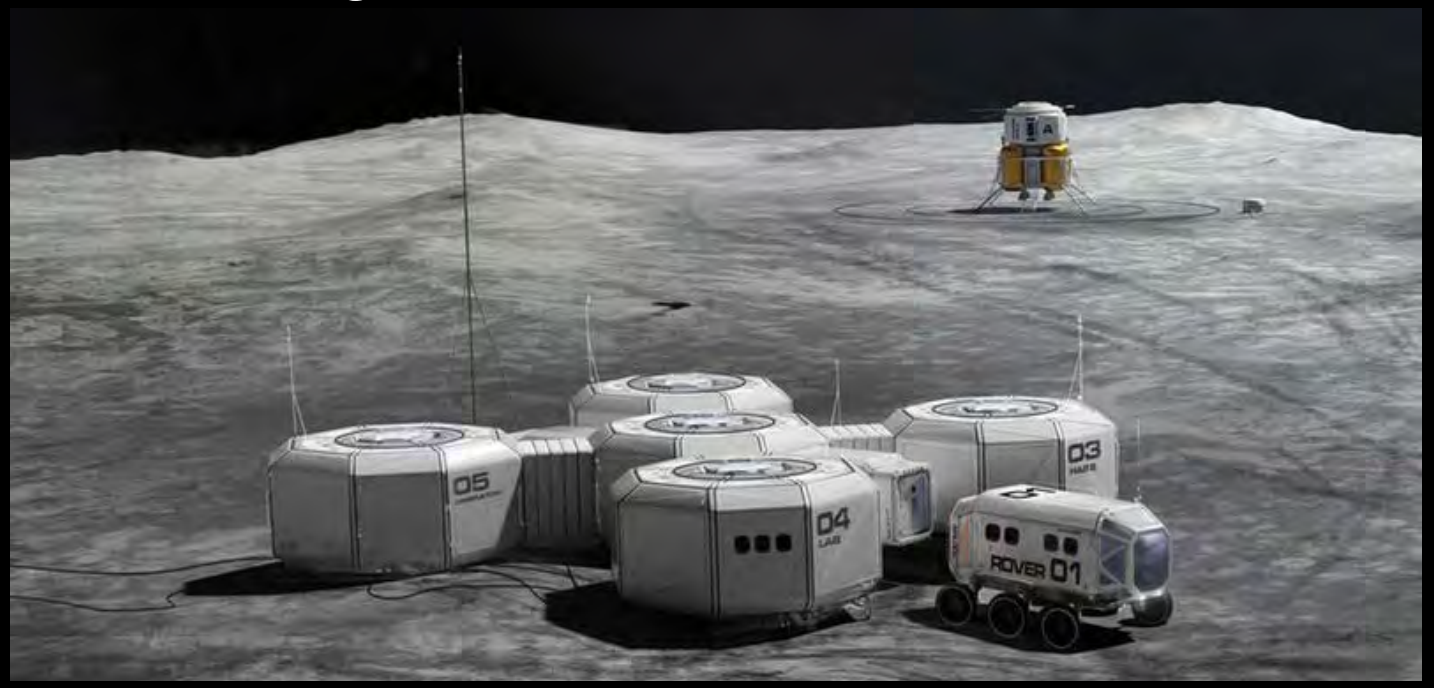
- Indicates permanent human presence → safety & reduce unfamiliarity
- Integrated with landscape
- Humanize / terraform the landscape

Ganti ke sketch

Ini showing more than ur telling

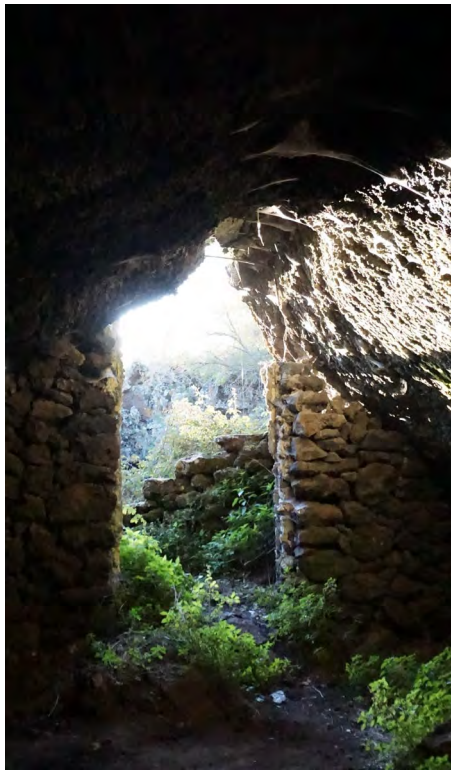
Temporary Settlement

- Indicates human presence
- But may “leave” any time”→ alien-ness



Interface of infrastructure & nature

unfamiliar - familiar



vernacular

locally integrated structure → natural & man-made

Reference_Situated Interface

Permanent: the user adjusting to the space

Surface for seating

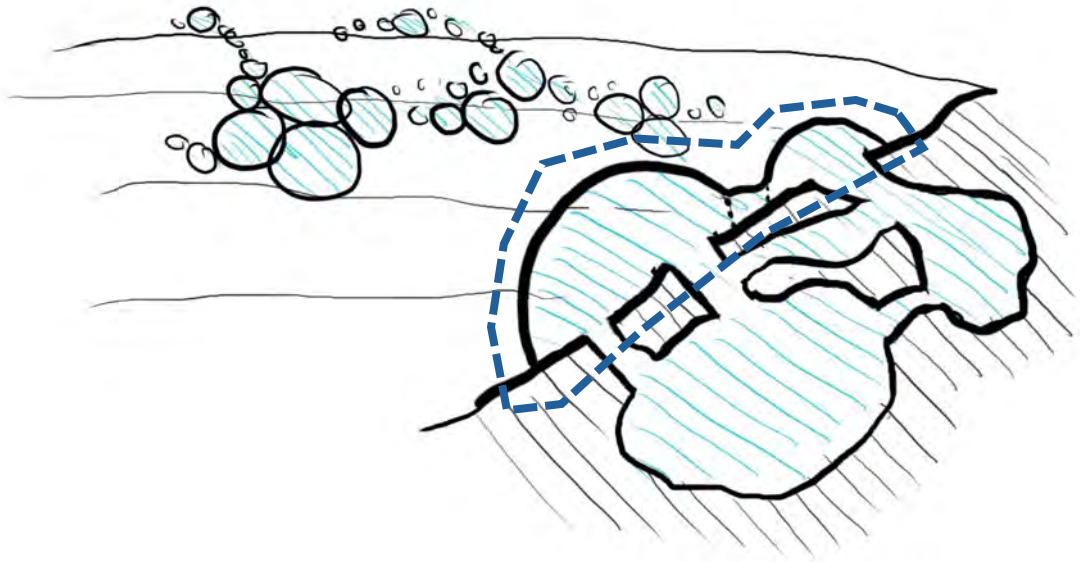
Grotto Intraleo, Sicily, Italy

Space for ritual

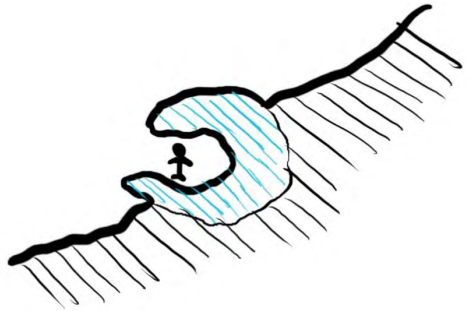
Grotto Intraleo, Sicily, Italy

interior

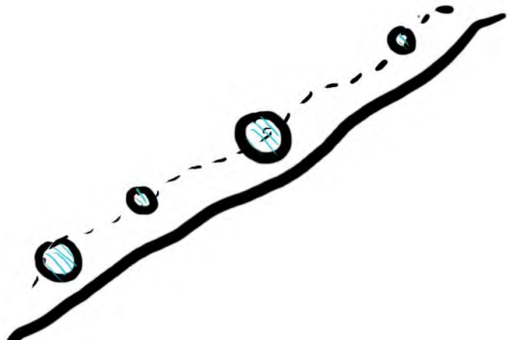
the “outside”



shelter

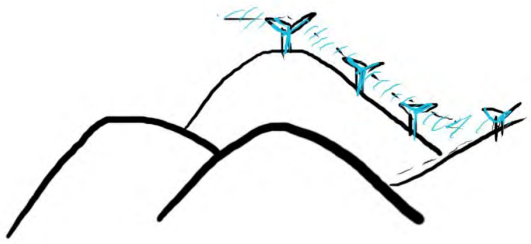


ascent



entrance

infrastructure



Analog Mission

Importance of tradition

- Hi-SEAS IV (HM12) created their own ‘‘Martian’’ holiday, dubbed *Le grand jour de la tomate*, which celebrated their first harvest of habitat grown tomatoes.
- Creating spaces for tradition → building civilization

Design direction: (micro scale)

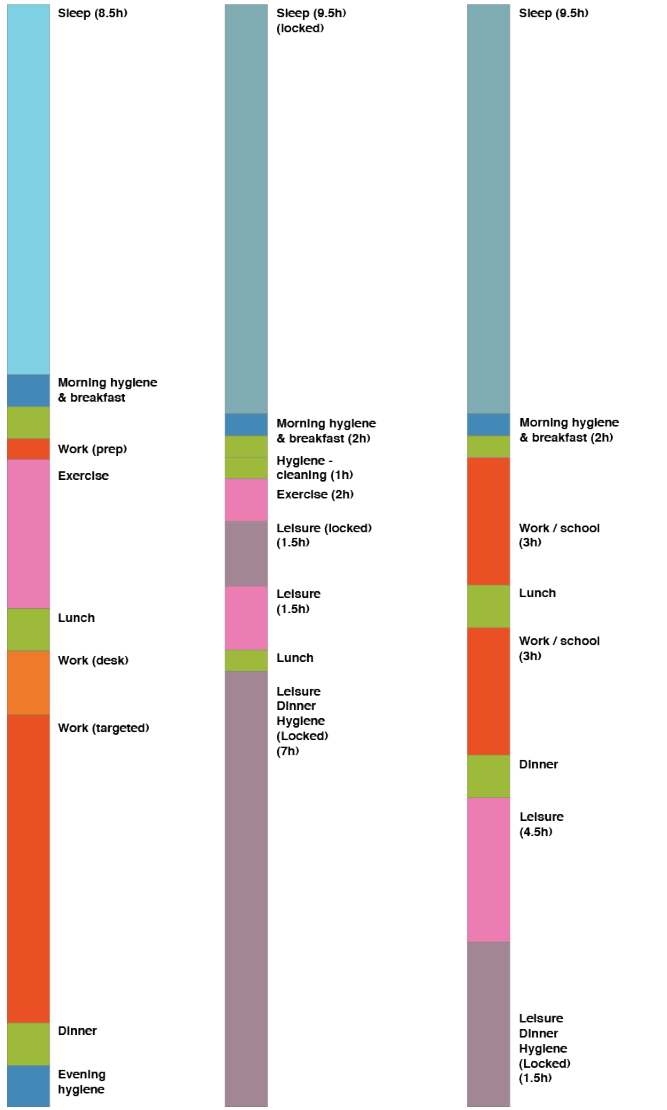
- Wall of memories
- Food experiment station
- Informal gardening areas

- Accessible garden

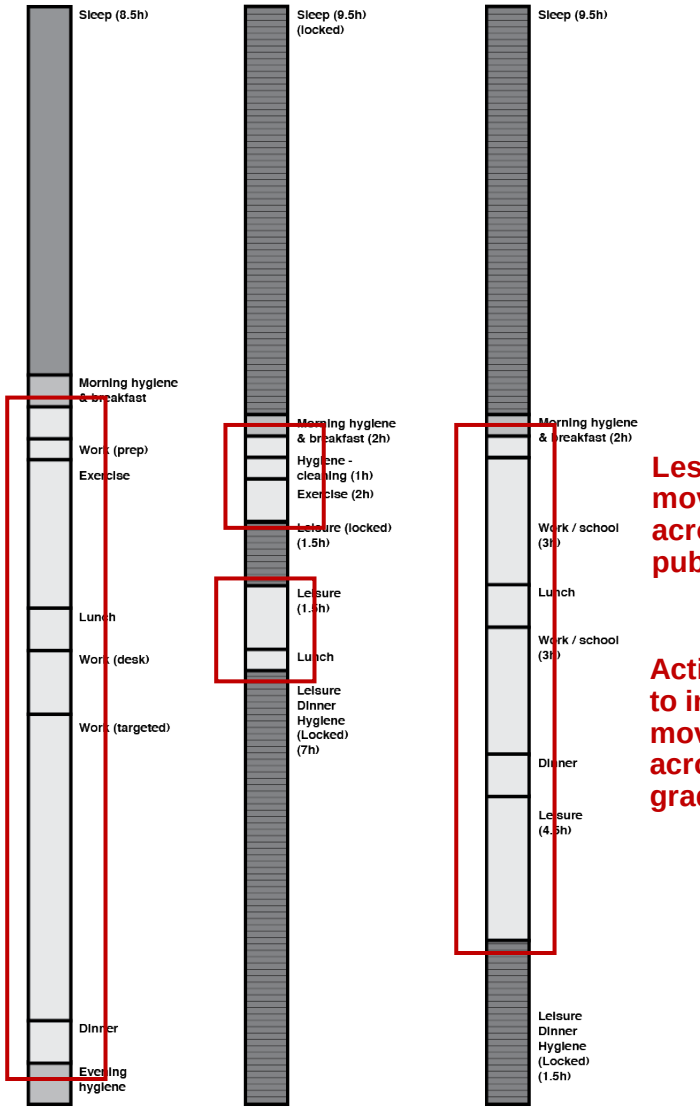
HM8 during Christmas

Living in isolated environment

Space station vs prison "day in my life" comparison



ISS | Atlanta Prison | Norwegian Prison



ISS | Atlanta Prison | Norwegian Prison

Less movement across public space

Activity mapping to inform movement across privacy gradient?

Halden Prison, Norway

La Palma Correctional Center, Arizona, USA

Arizona State Prison USA

Isolated Habitat

Communal activity schedule

- Activities with varying amount of participants
- For longer missions, there is decline in holistic participation of group activities over time
  - Evening gathering time turned into private schedule on the last quarter of the mission
  - E.g. dancing only for first 5 months
- Formation of social cliques over time

Design direction

Provide spaces with varying privacy gradient

Entire group activity

Entire group activity turned to partial

Partial group activity

Schedule for Hi-SEAS Mission II (4 months)

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
						Joint breakfast	
Morning	EVAs (3-4 times per week)						
	Joint lunch						
Afternoon		HI-SEAS	HI-SEAS	HI-SEAS		HI-SEAS	
	Workout					Chores + Workout	
	Dinner (6:30 pm)						
Evening	TV shows (on 3 or 4 out of 5 nights)					Movie or game	

Schedule for Hi-SEAS Mission III (8 months)

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Morning	(Geology EVA)	(Geology EVA)	(Geology EVA)			Rest	Debrief meeting
Afternoon		HI-SEAS	HI-SEAS	HI-SEAS		HI-SEAS	
	Workout					Workout + chores	Yoga or rest
	Dinner (6:30 pm)						
Evening	Games, Movies or TV shows						

Schedule for Hi-SEAS Mission IV (12 months)

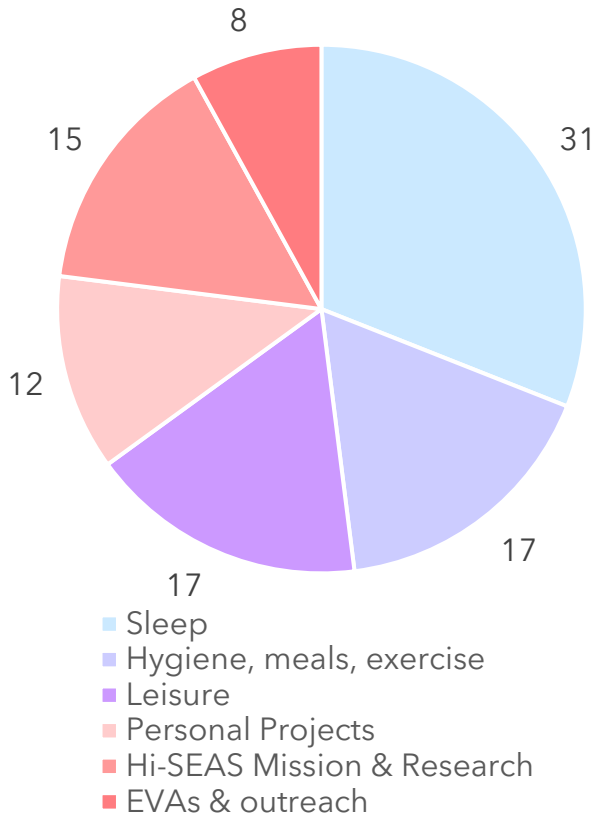
	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Morning		Media + Outreach	EVA			EVA	Brunch
Afternoon		HI-SEAS	HI-SEAS	HI-SEAS	(Chores)	HI-SEAS	Chores
	Workout						
	Dinner (6:30 pm)						
Evening		(Dancing)	Game night		Movie night	(Dancing)	Debrief meeting

Isolated Habitat

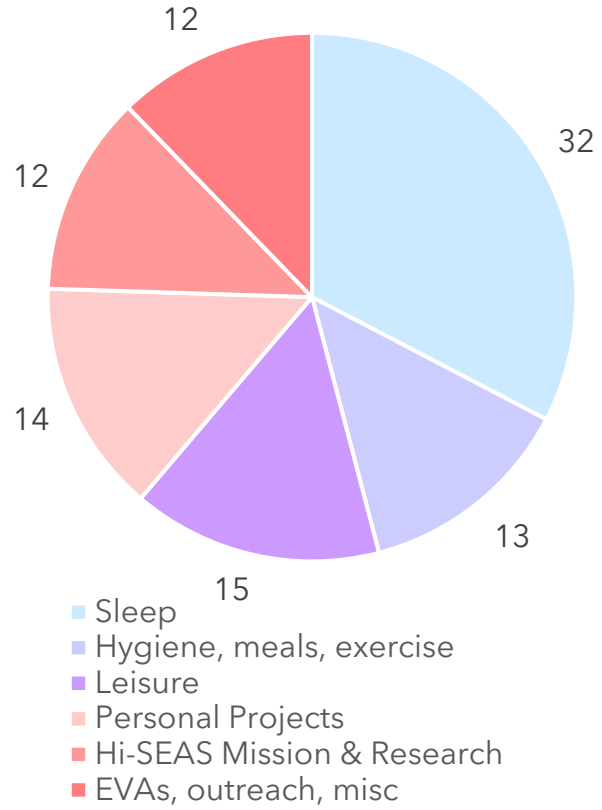
Autonomy on schedule

Almost equal time for:

- Personal
- Social
- Work



Hi-SEAS I, 4 months mission



Hi-SEAS IV, 12 months mission

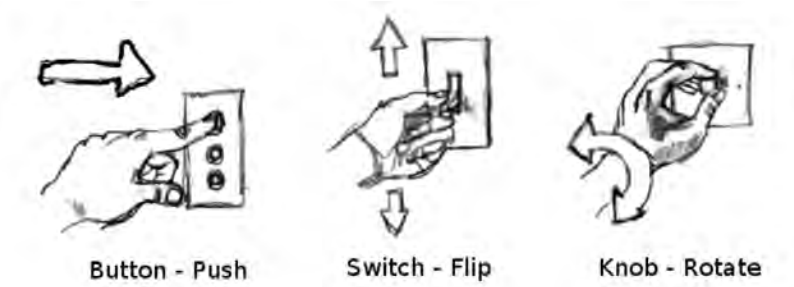
Different analog mission showing similar activity distribution

Speculative systems for the moon

Close-up view of salt accretion in scaled prototype, GEOtube Tower

Close-up view of lunar regolith with Apollo 11 Buzz Aldrin, NASA

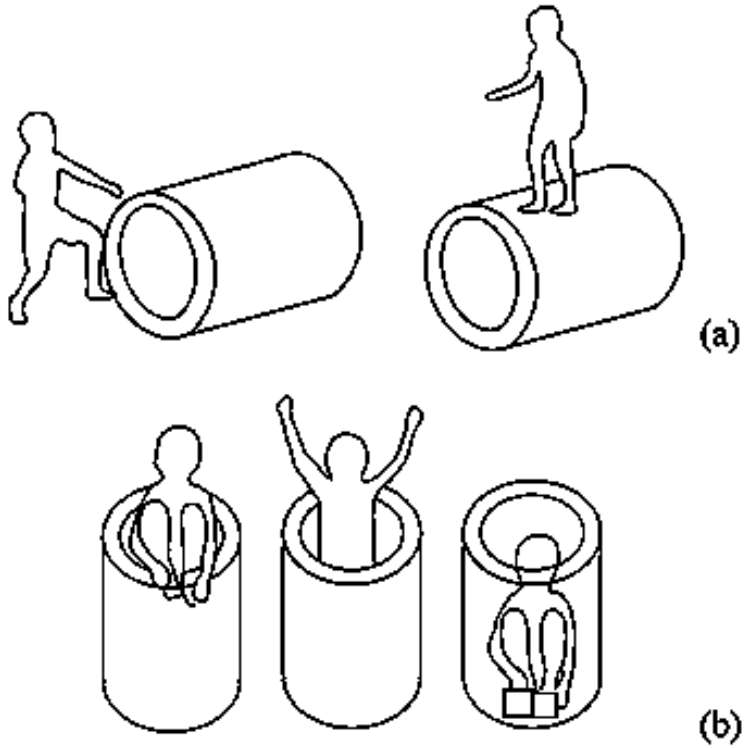
	Earth precedents	Moon
• Attraction	Seawater passing through structure	Regolith electrostatically attracted
• Compaction	Evaporation by wind	Regolith sintering
• Production	Salt harvesting	Harvesting charged regolith
• Structure	Resistant to salt corrosion	Electro-conductive
• Location	Near sea	Radiation-exposed areas → lunar surfaces



Affordances

definition

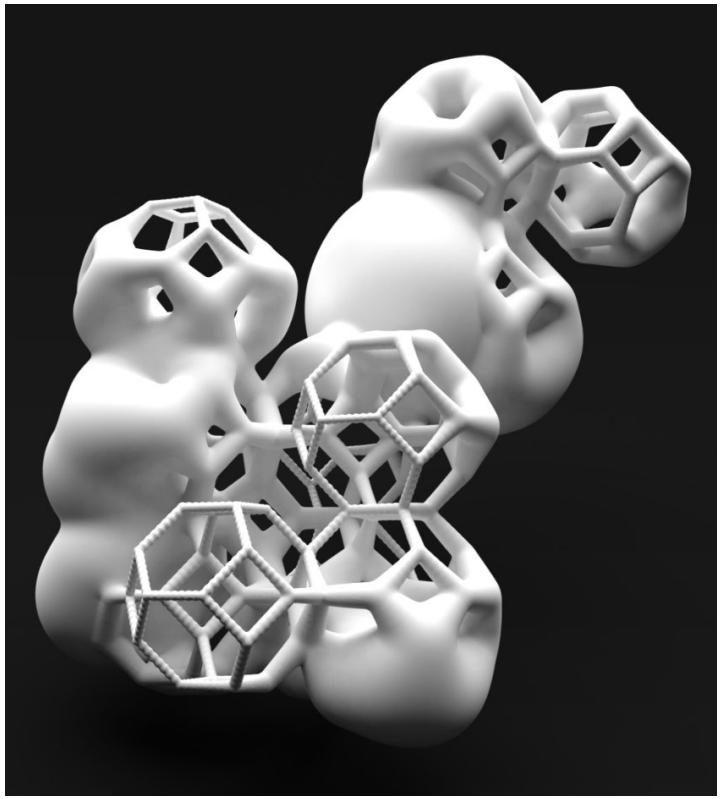
the design aspect of an object which suggest how the object should be used; a visual clue to its function and use.
- Norman 1988



Design for separation – controlling porosity

Variable structure/surfaces

controlled structure / variable surface

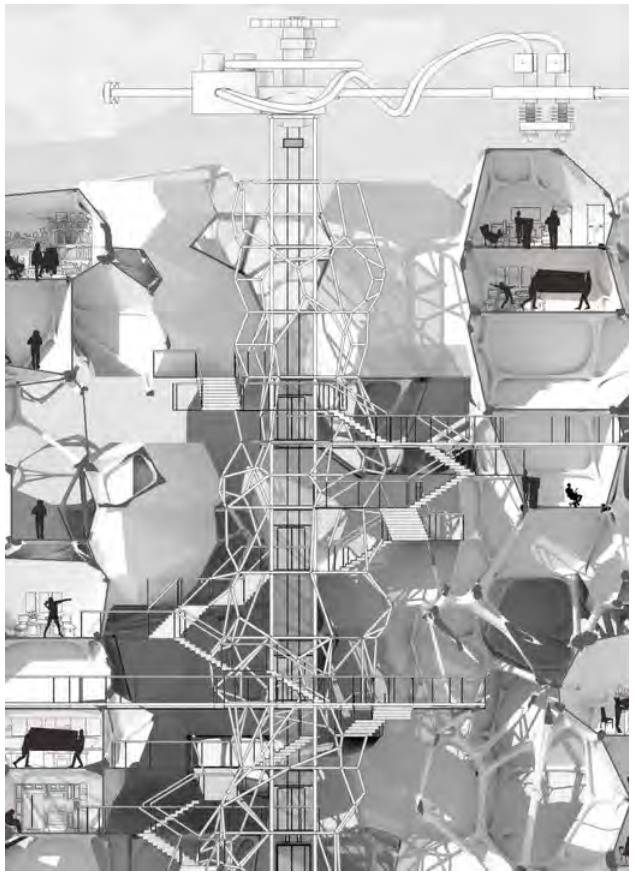


Metaballs

variable structure / variable surface

Robotic + Substances, Francois Roche, New-territoties

variable structure / controlled surface

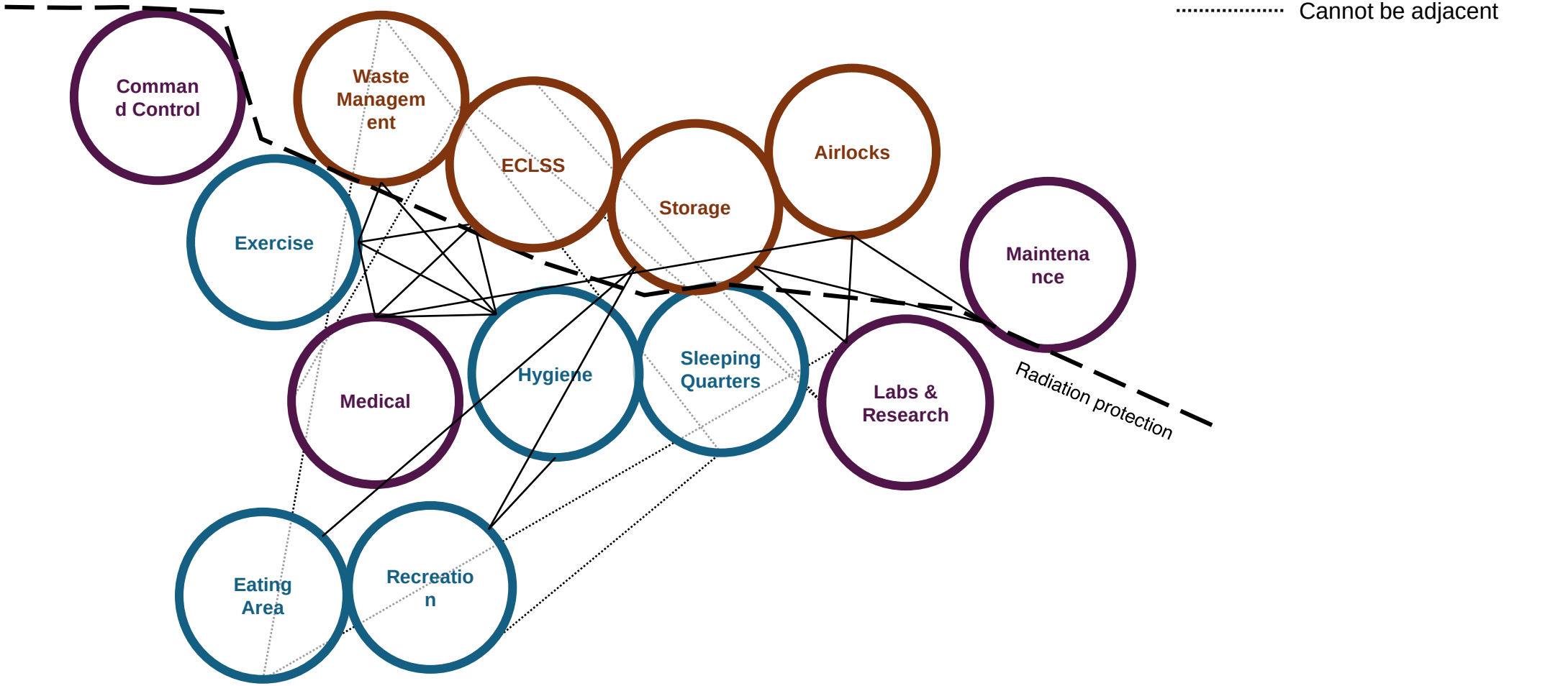


Stay Plastic, Renjie Huang, 2014, RCA

Design

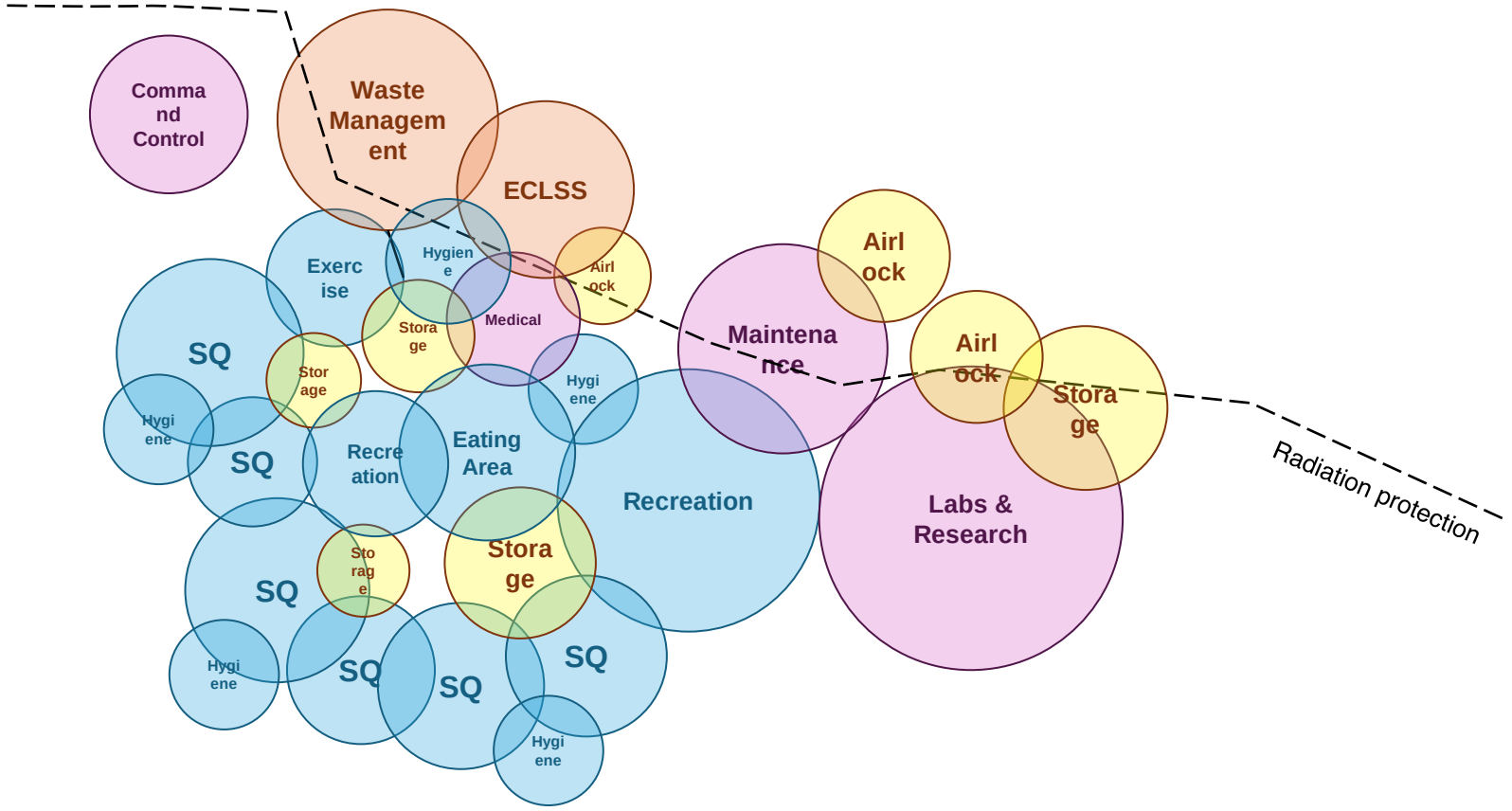
Spatial distribution

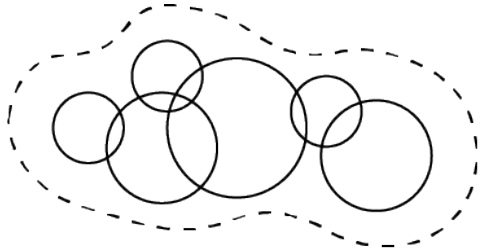
Interior schematic diagram (adjacencies)



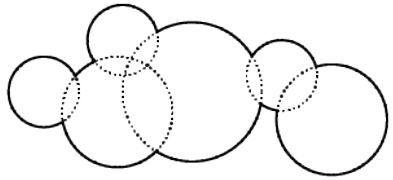
Spatial distribution

Interior schematic diagram

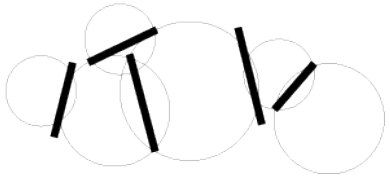




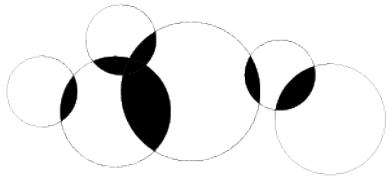
thresholds



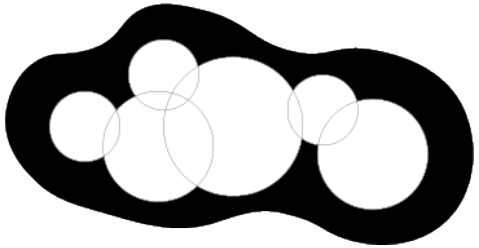
walls



transitional space
- interior



transitional space
- exterior



redefining wall, corridor, program overlaps

transitional space

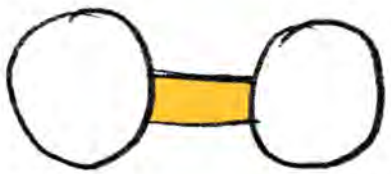
threshold space

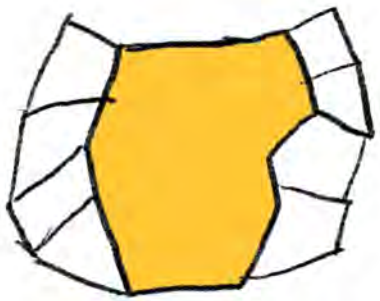
interstitial space

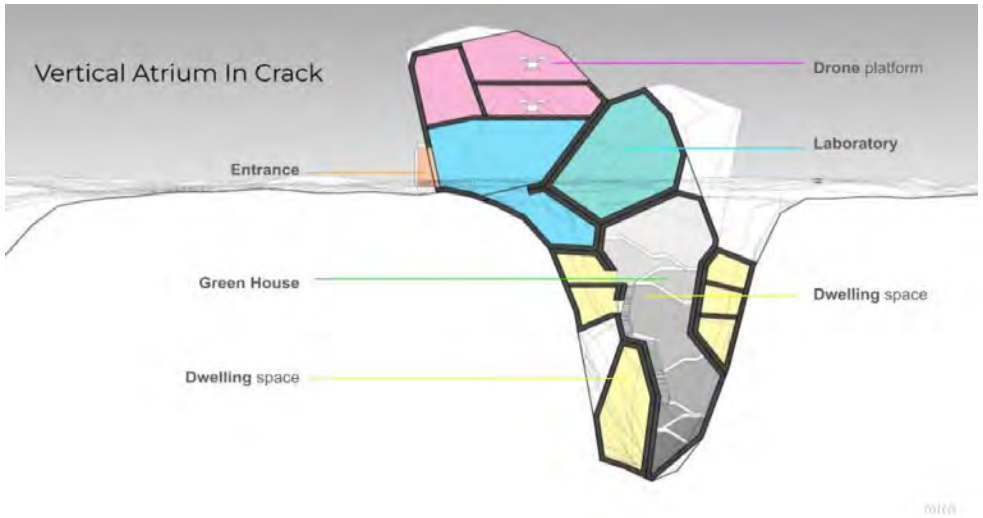
separation adjacencies transition

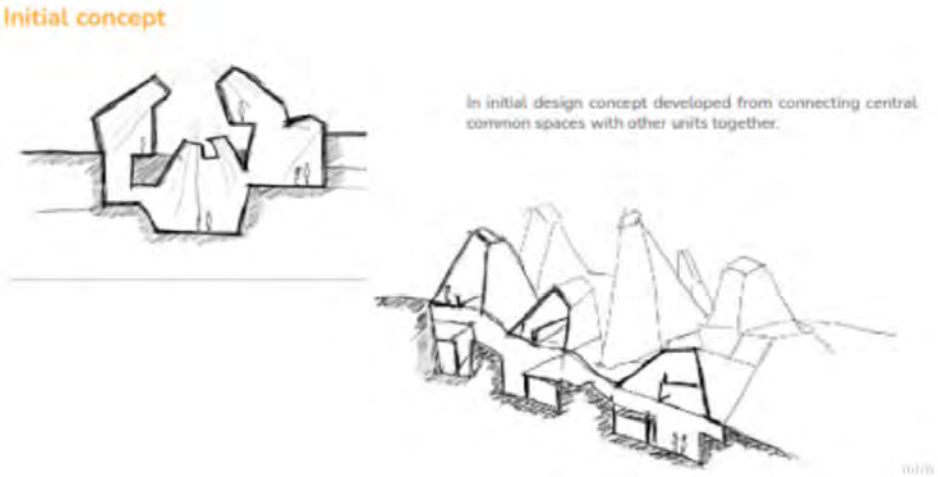
Transitional space as community activator

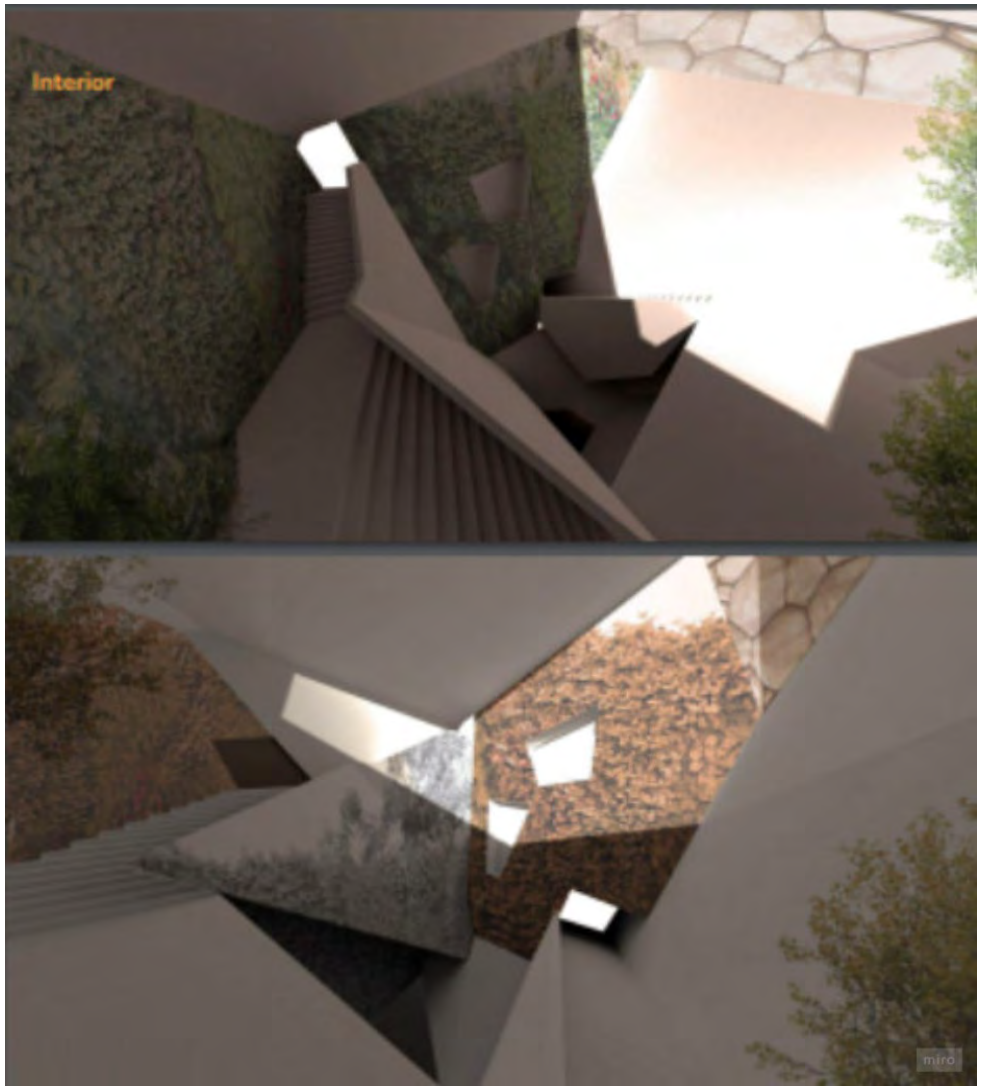
from corridor to atrium






Vertical Atrium In Crack
Drone platform
Laboratory
Entrance
Green House
Dwelling space
Dwelling space

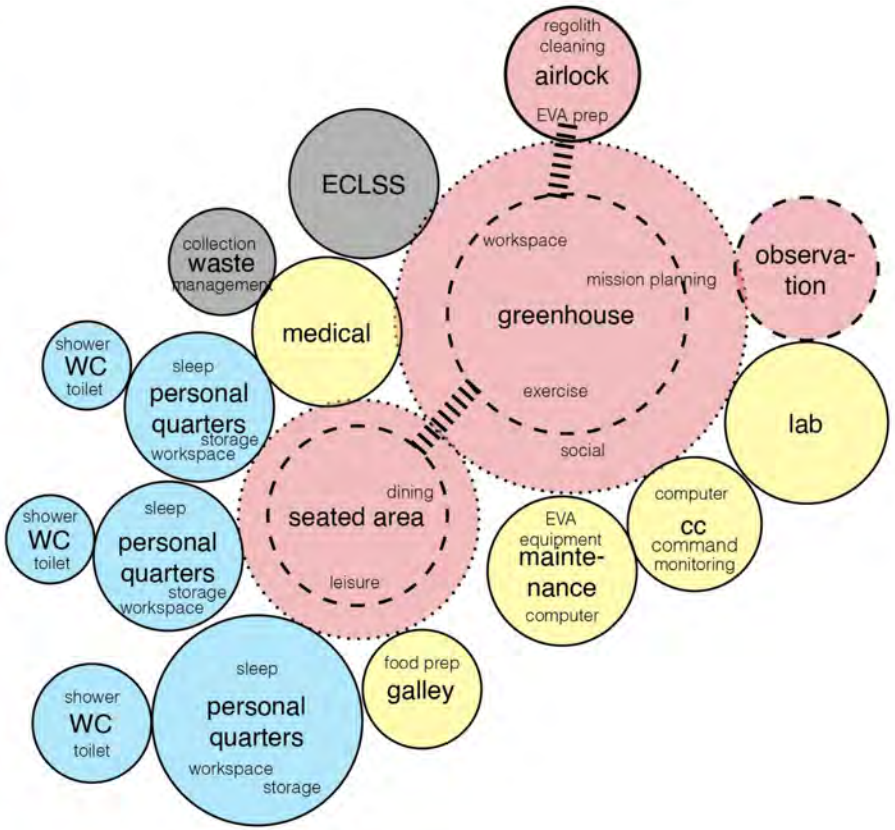

Initial concept
In initial design concept developed from connecting central common spaces with other units together.


Interior

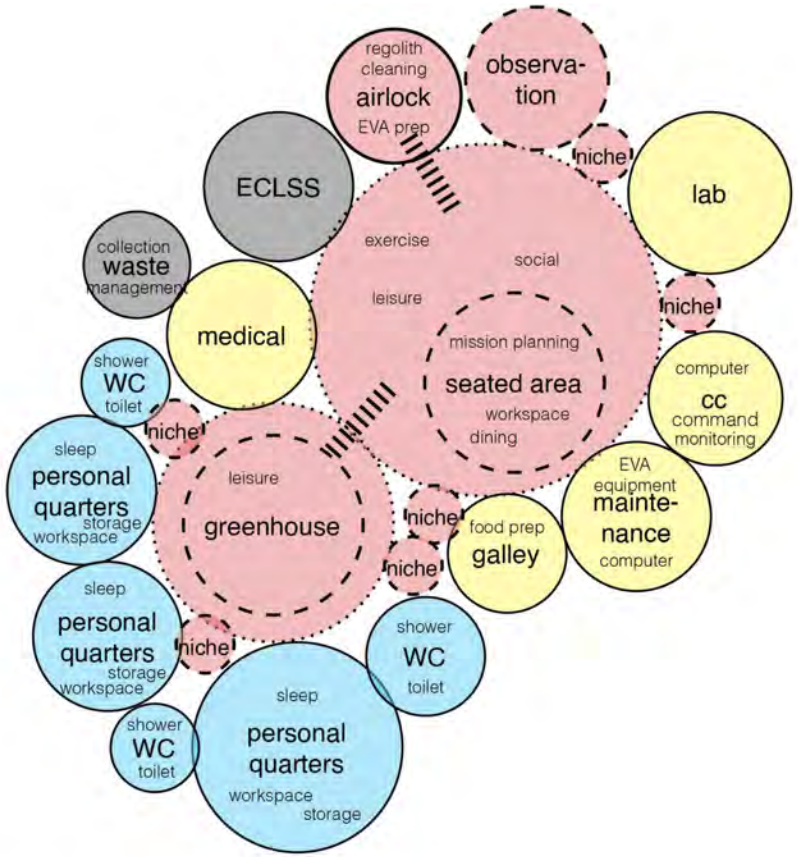
vertical transition
enclosed
zoned
open

service
work
private
communal

proposal
Transitional Spaces
activity + space
social atriums
green atriums
meeting corridors
dining niches



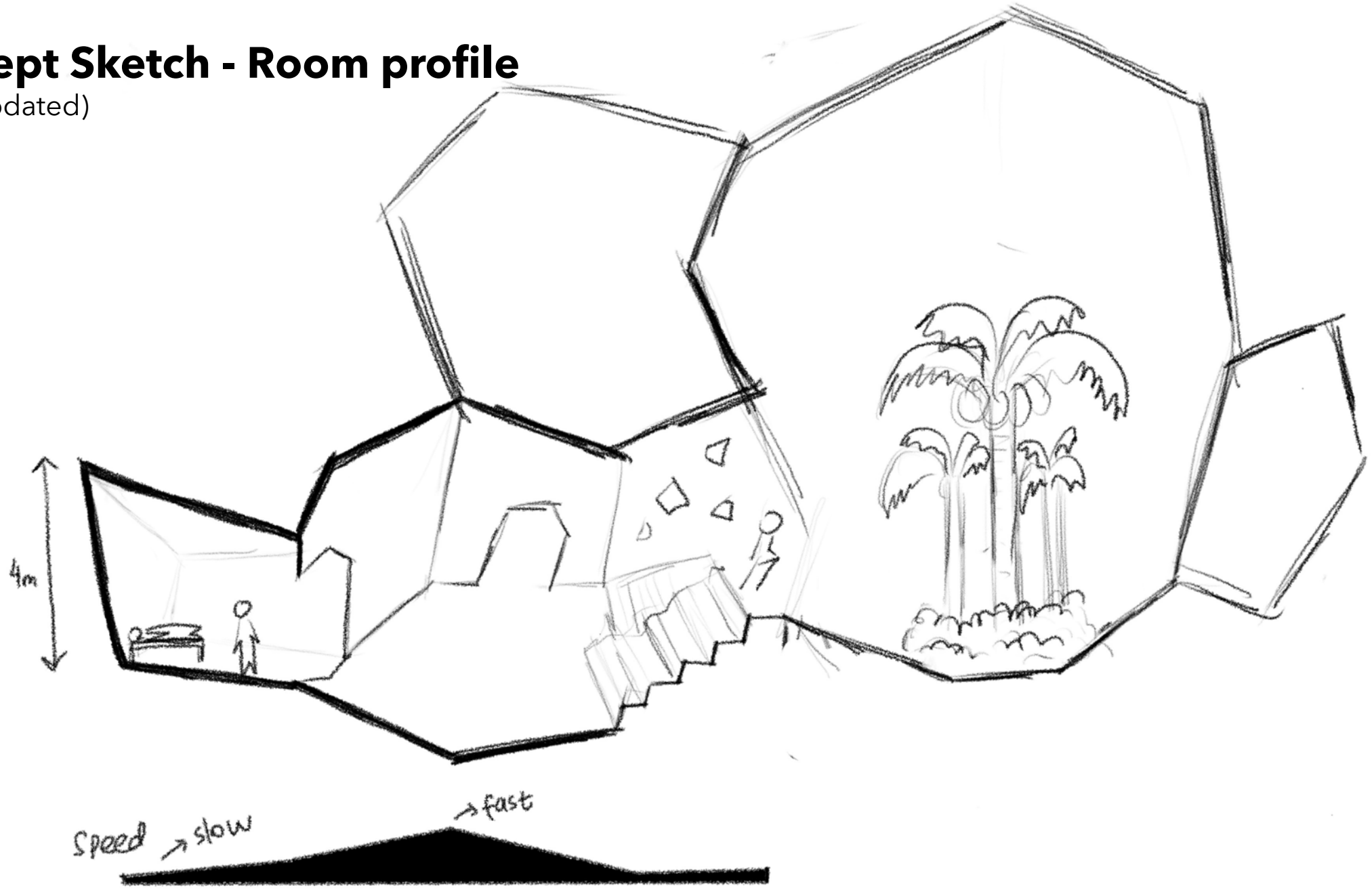
maximize communal interaction



maximize individual privacy

Concept Sketch - Room profile

(to be updated)



proposal

Transitional Spaces

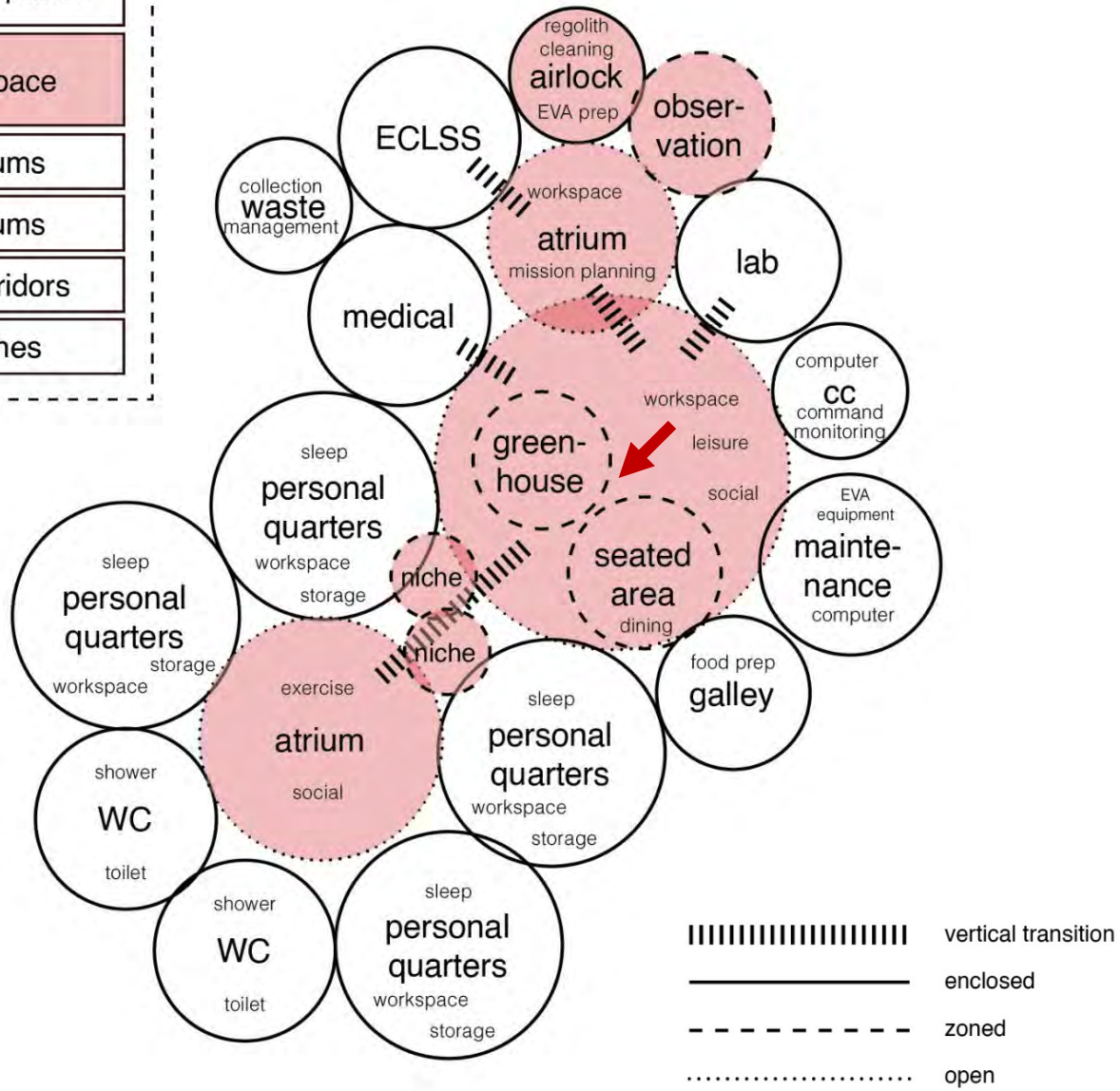
activity + space

social atriums

green atriums

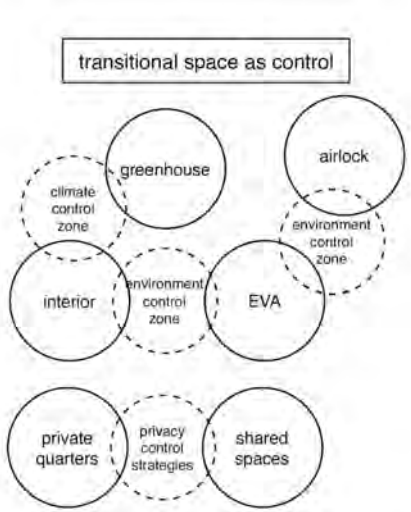
meeting corridors

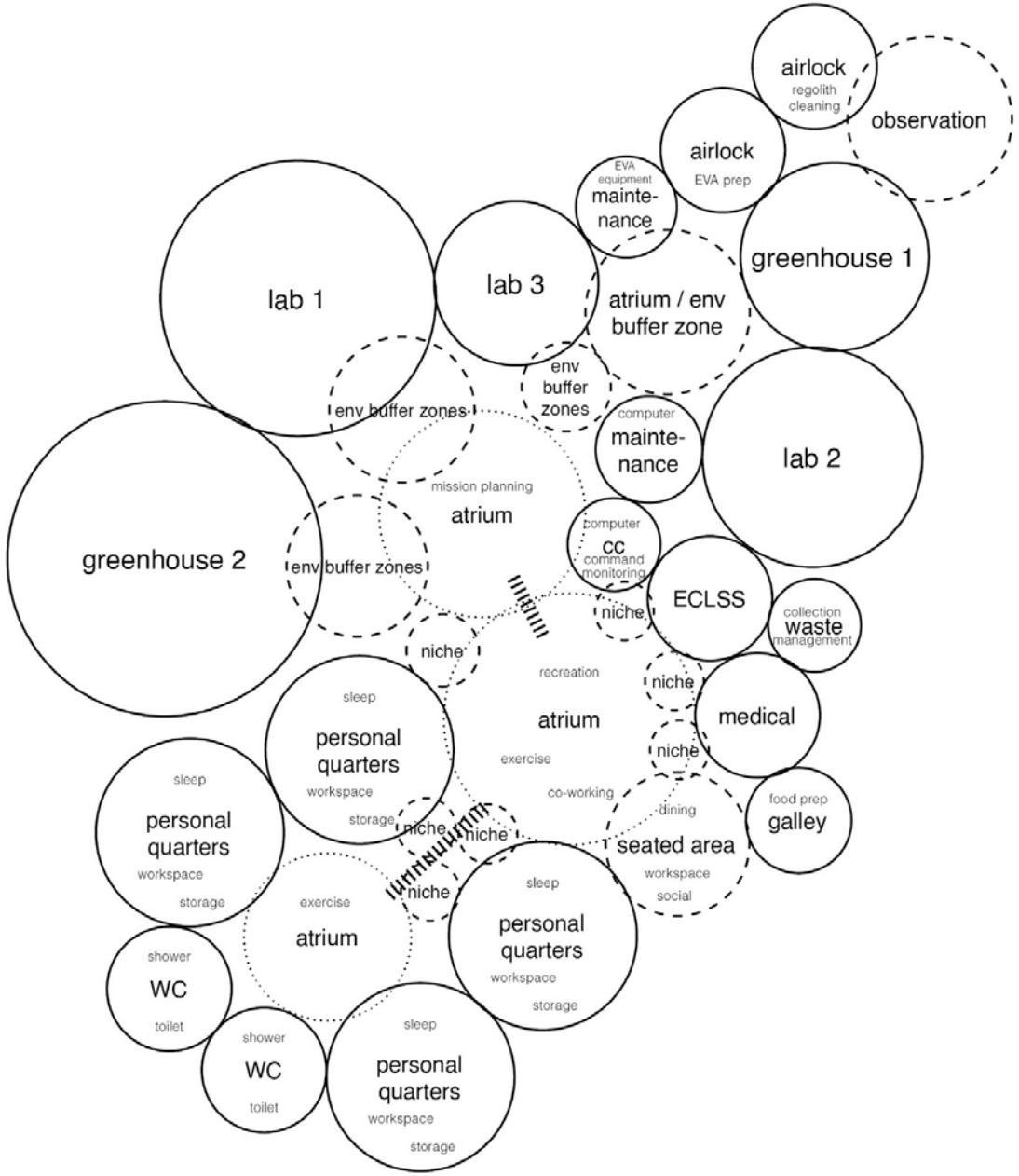
dining niches

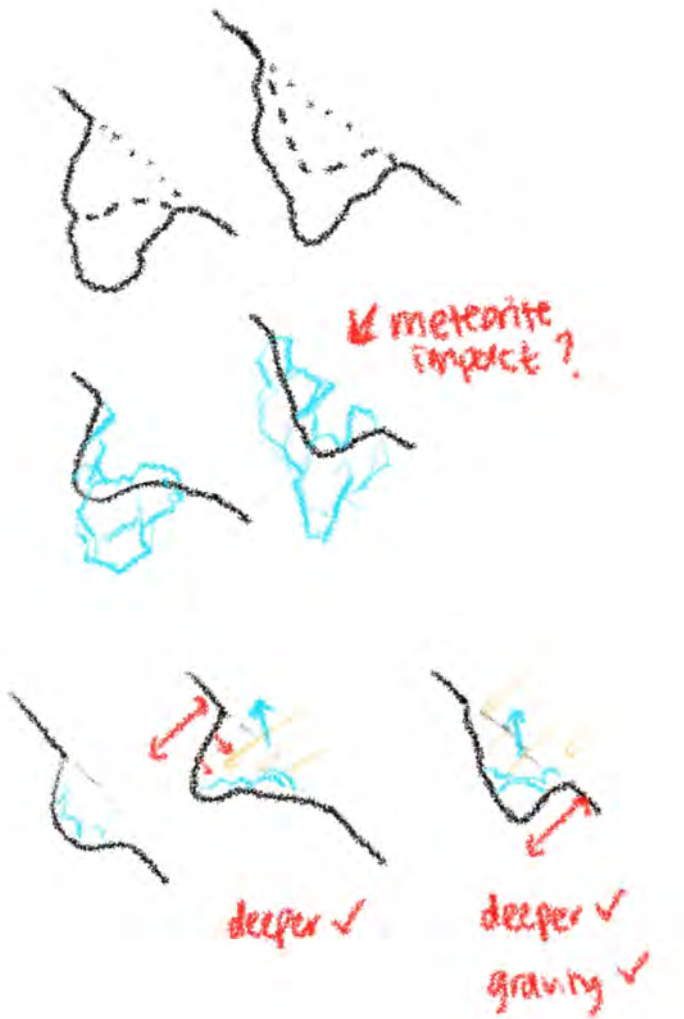


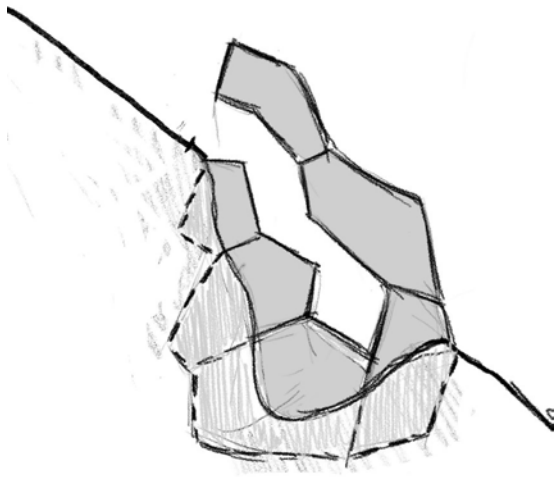
Spatial strategies

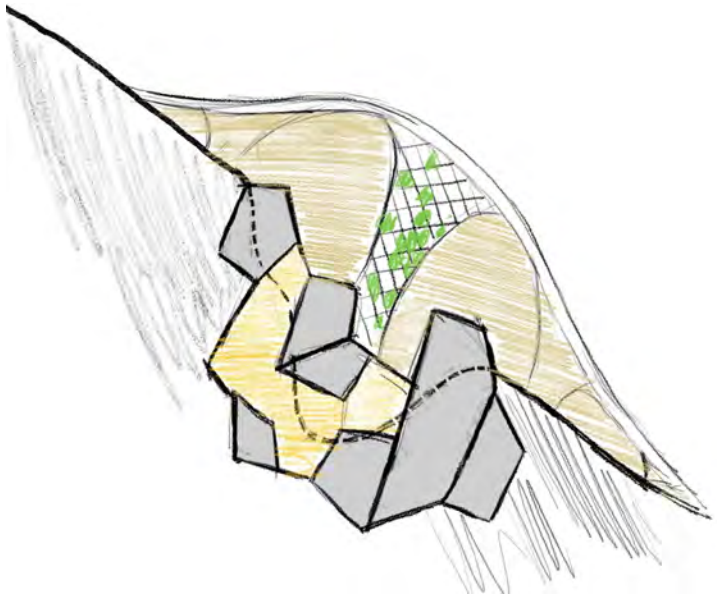
Connection and visibility

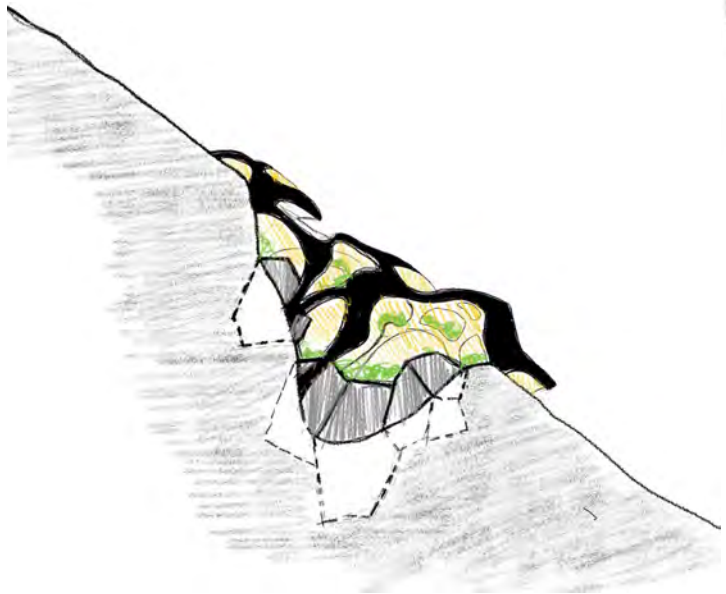


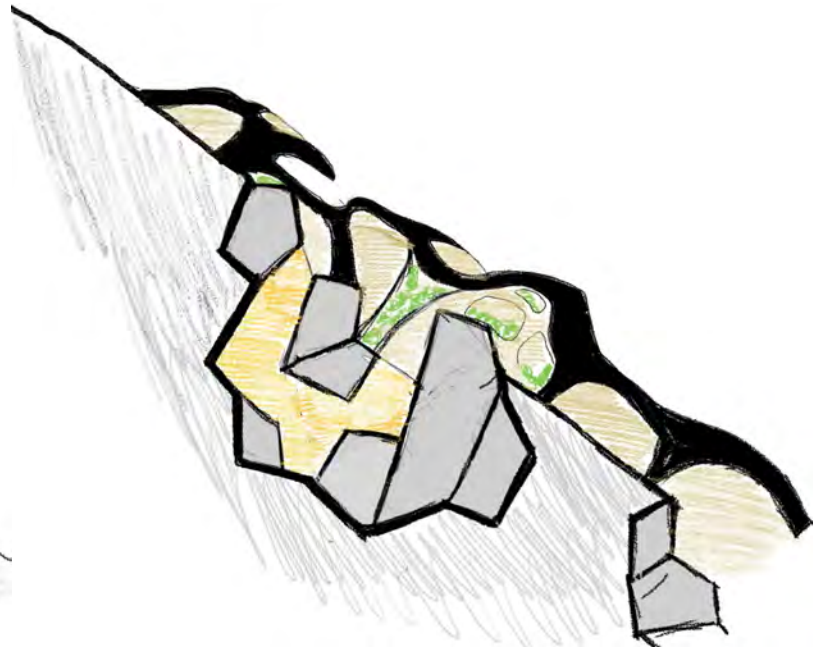



meteorite impact ?
deeper ✓
deeper ✓
gravity ✓



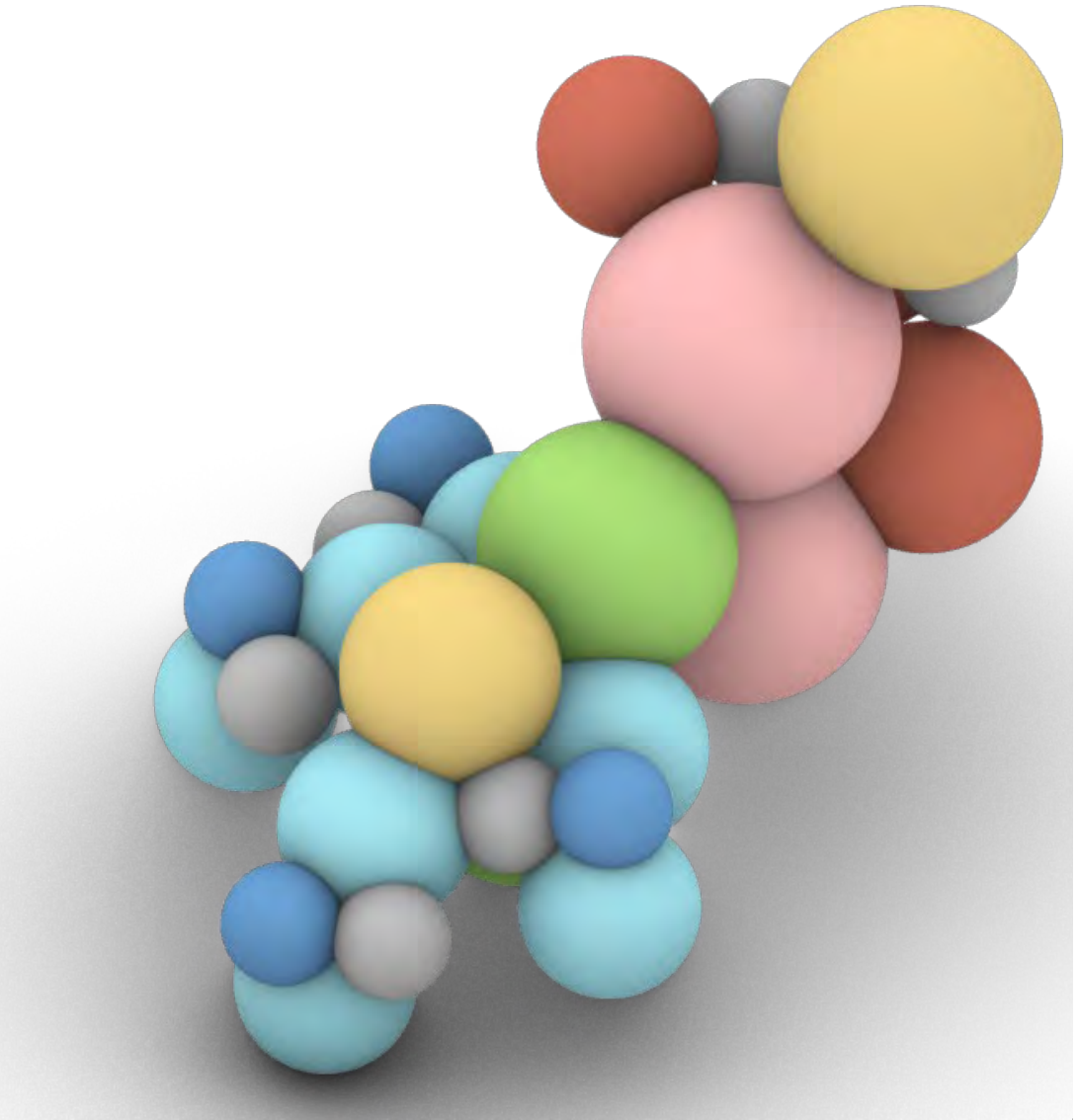




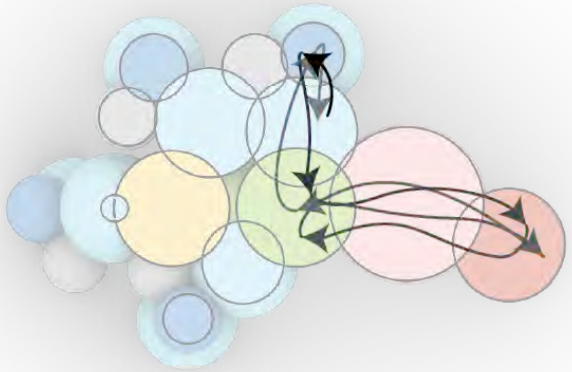


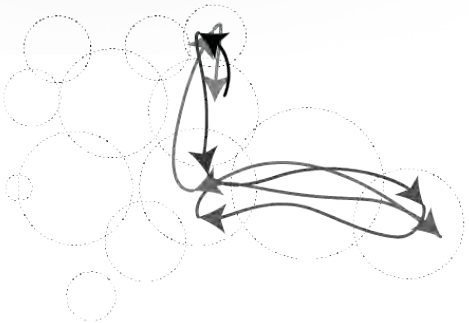
Spatial distribution

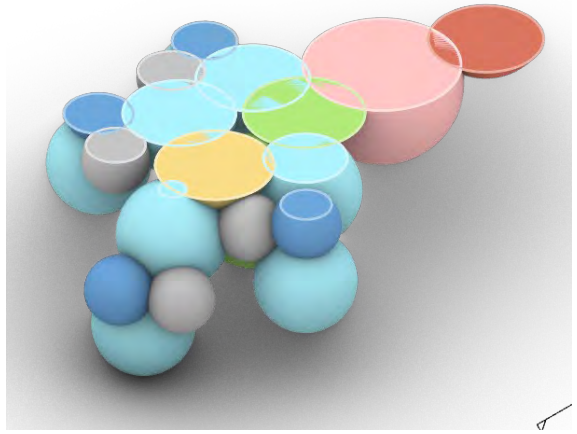
Interior schematic diagram

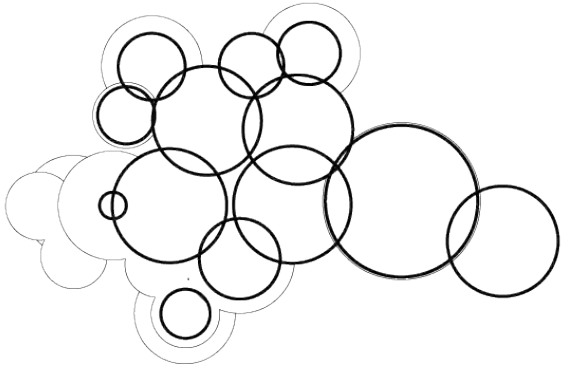


Category	Programs	4 crew (m3)
GENERAL	Circulation (20-30%)	
	Storage (20%)	6
SLEEP	Sleeping quarter	14
	Personal workspace	17.4
	Personal storage	
FOOD	Galley - food prep	7.65
	Galley - food storage	(2 week) / Kitchen
	Table (Dining/WS)	10.1
HYGIENE	Washroom / cleansir	4.4
	Bathroom pp	
LEISURE	Recreation	18.2
	Exercise	13.4
	Plants	
WORK - OPERATIONS	Research & Labs	
	Command control (c	3.4
	Maintenance	8.2
	Medical	7
NON-ACTIVITY	Airlock	
	ECLSS 3 racks	
	Waste management	6.2
	TOTAL	115.8
	NHV per crew memb	28.95

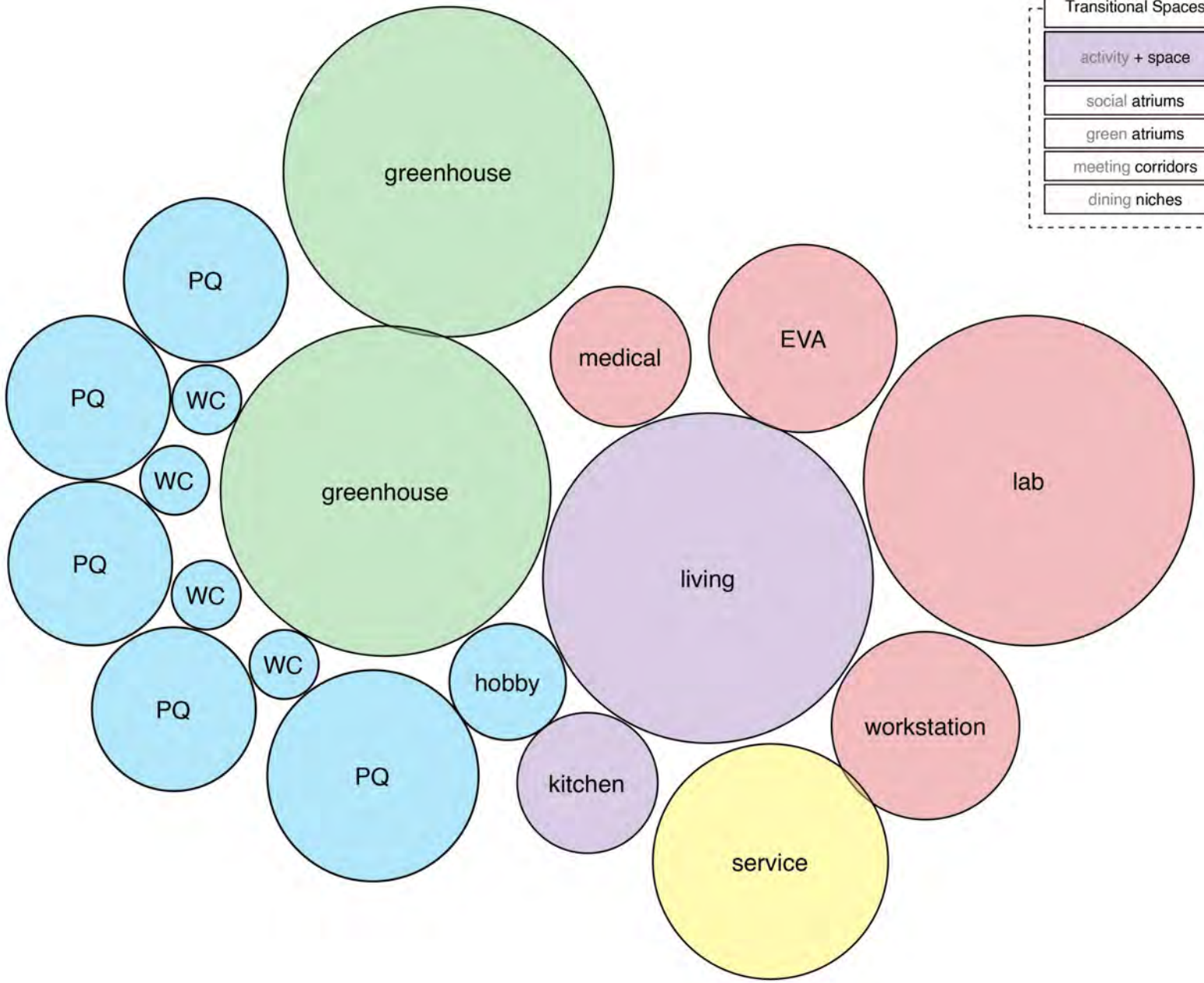








service
work
private
living

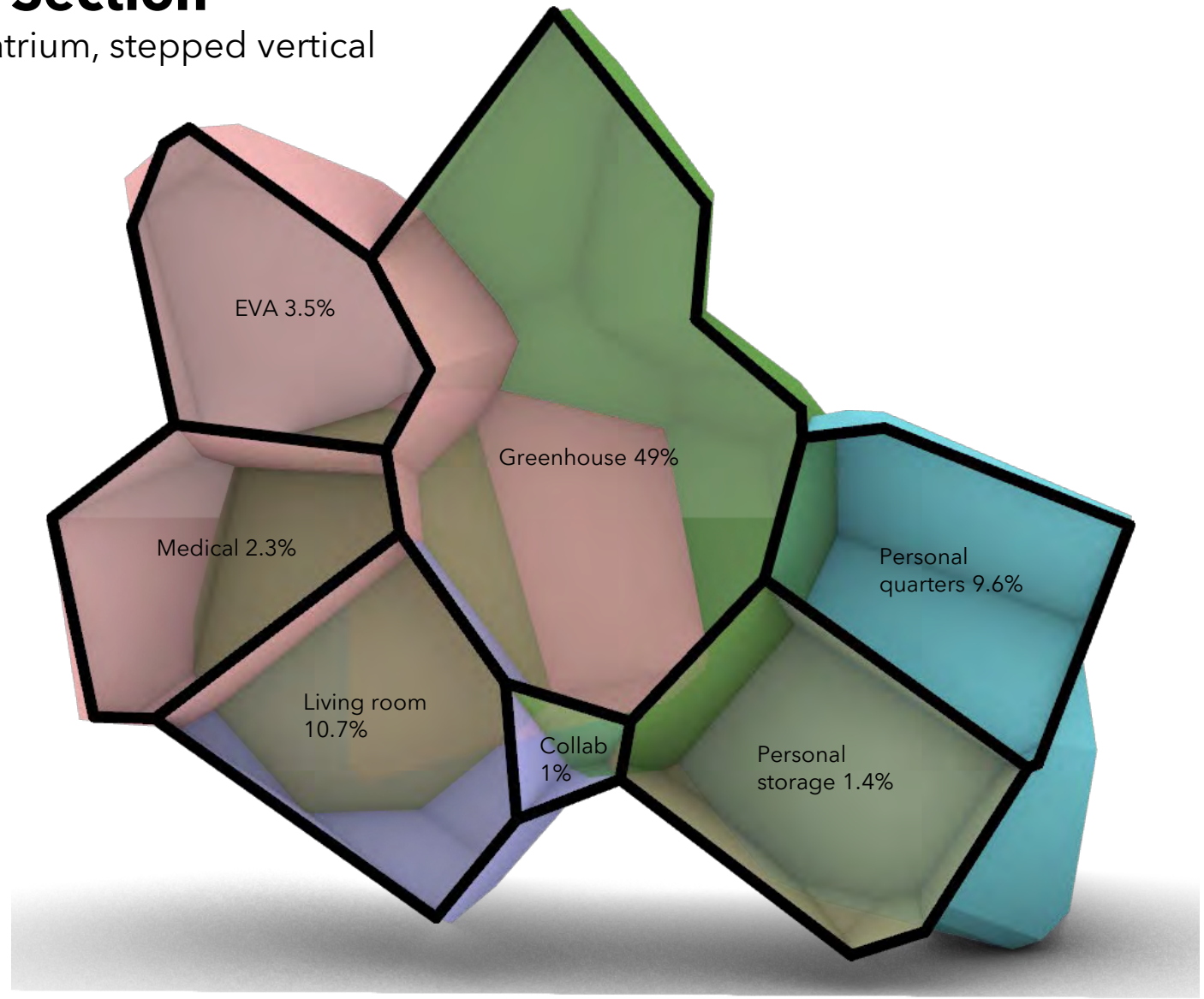


proposal
Transitional Spaces
activity + space
social atriums
green atriums
meeting corridors
dining niches

	Rooms	%
PQ	Private Quarter 1 (Single)	14.63%
	Private Quarter 2 (Couple)	
Bath	Bathroom	
Kitchen	Food storage area	4.90%
	Food prep area	
Living Room	Dining table	9.86%
	Exercise area (2 equipments)	
	Open area (misc)	
	Observation	
Greenhouse	Greenhouse 1 (food)	45.19%
	Greenhouse 2 (O2)	
Hobby	Small recording studio	0.81%
EVA	Airlock (EVA prep)	3.90%
Lab	Lab	9.75%
	Lab storage	
Medical	Medical bay	1.63%
	Medical storage	
Workstation	Open workstation	4.12%
	Command control	
Service	Maintenance	5.20%
	ECLSS	
	Waste management	
	General storage	

Schematic Section

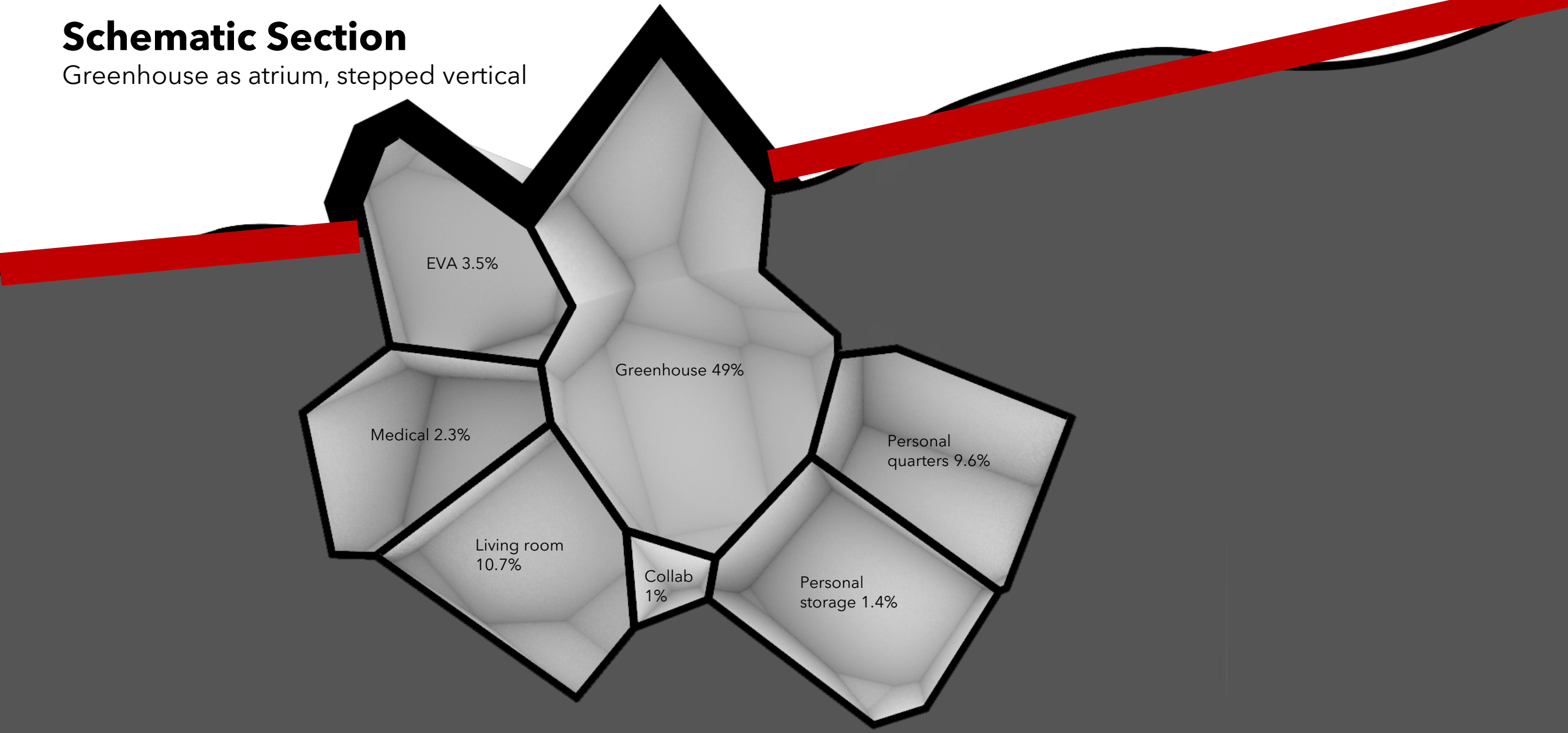
Greenhouse as atrium, stepped vertical



	Rooms	
		%
PQ	Private Quarter 1 (Single)	12.52%
	Private Quarter 2 (Couple)	
Bath	Bathroom	
Collab	Small recording studio	0.87%
Kitchen	Kitchen	2.33%
Living Room	Dining table	10.66%
	Exercise area (3 equipments)	
	Open area (misc)	
	Observation	
Greenhouse	Greenhouse 1 (food lab)	48.57%
	Greenhouse 2 (O2)	
EVA	Airlock (EVA prep)	3.49%
Medical	Medical bay	2.33%
Lab	Lab	8.74%
Research	Open workstation	3.49%
	Focus workstation	
Storage	Personal storage	1.40%
	Food storage area	1.40%
	Lab storage	1.40%
Service	Maintenance	2.80%
	ECLSS	
	Waste management	

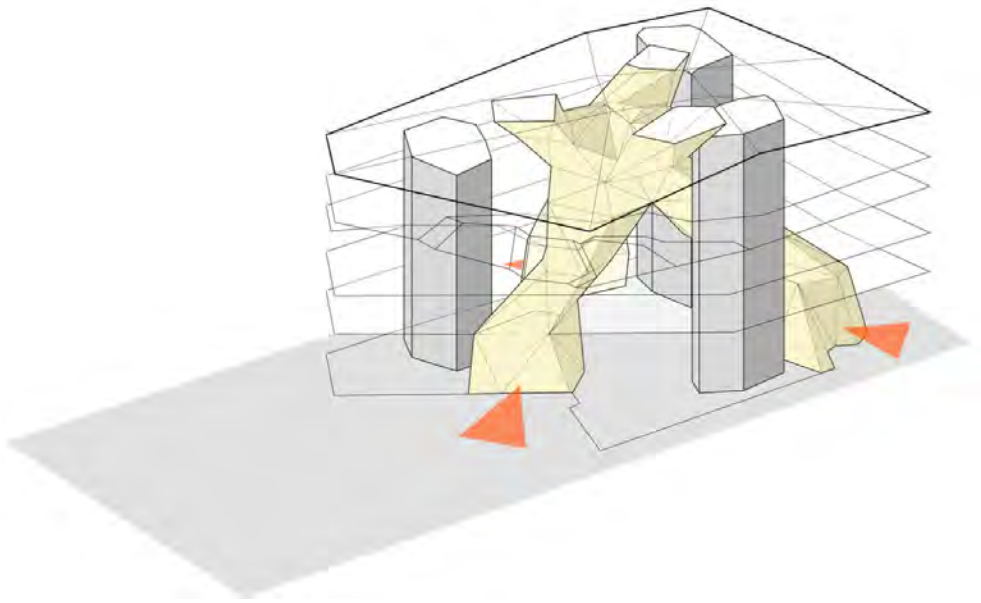
Schematic Section

Greenhouse as atrium, stepped vertical

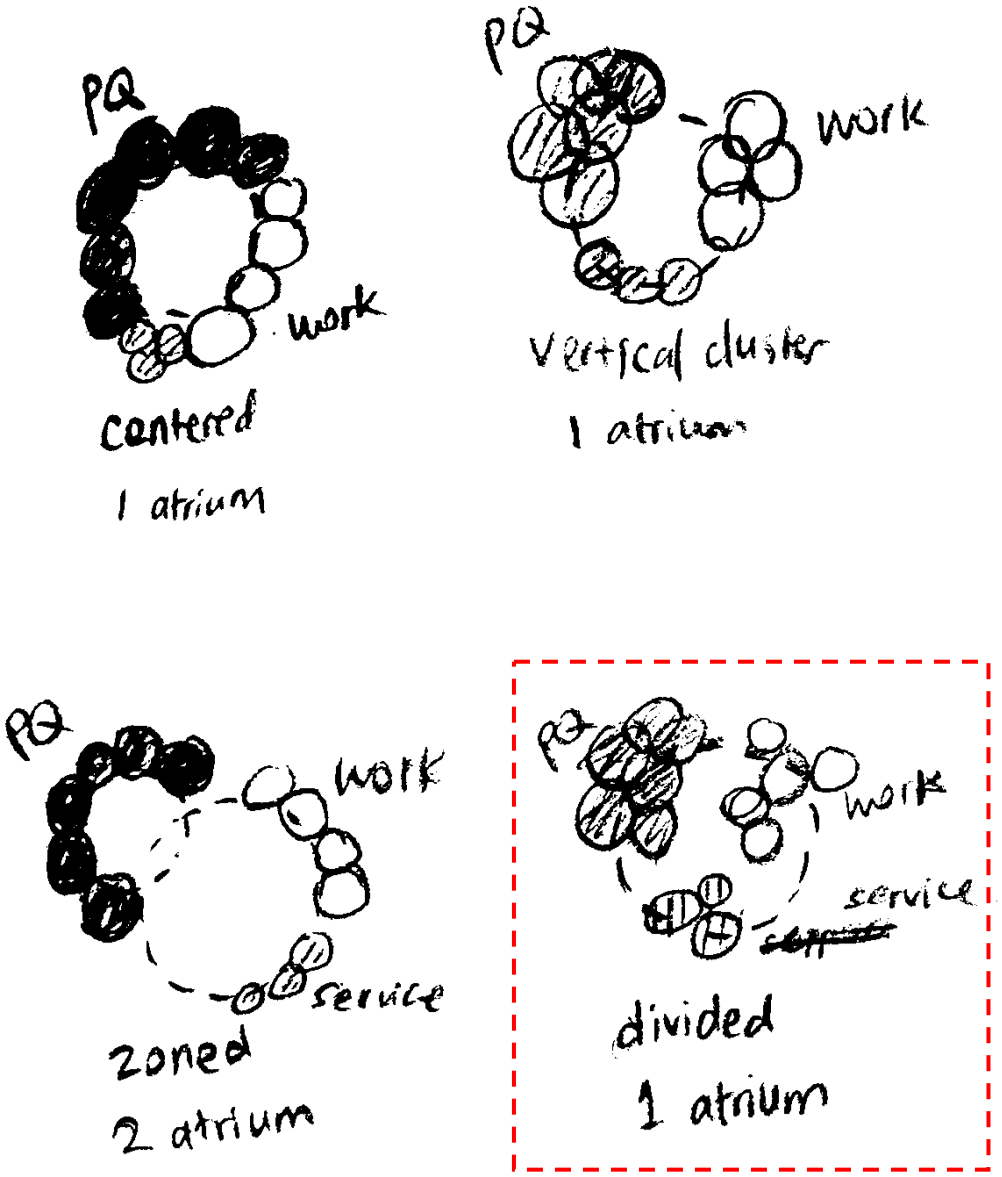


Program distribution

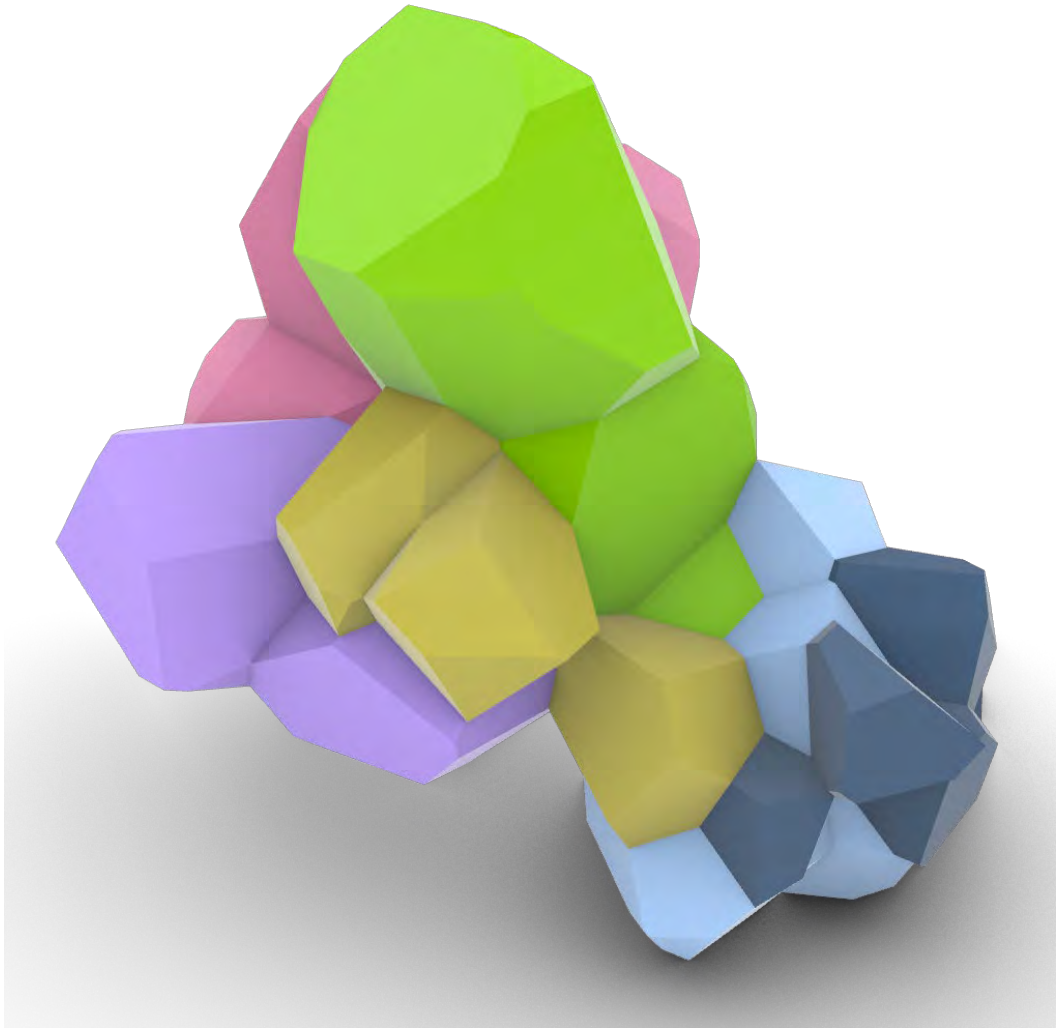
Future strategy

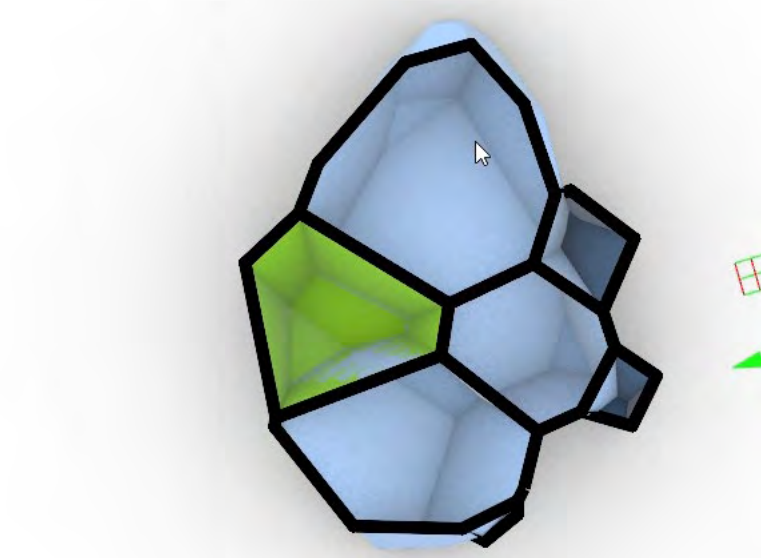


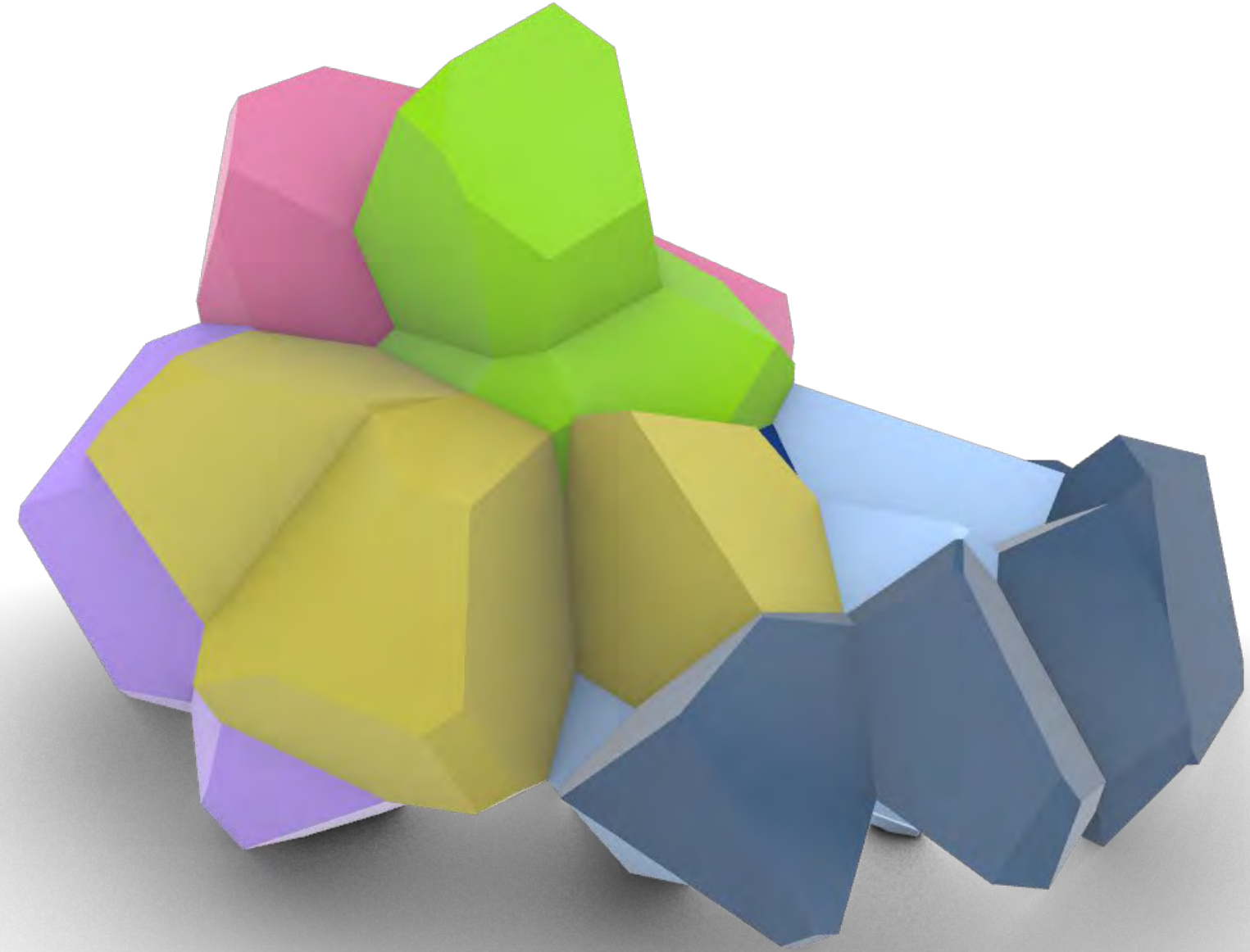
Massing of Deichman Bjorvka, Oslo

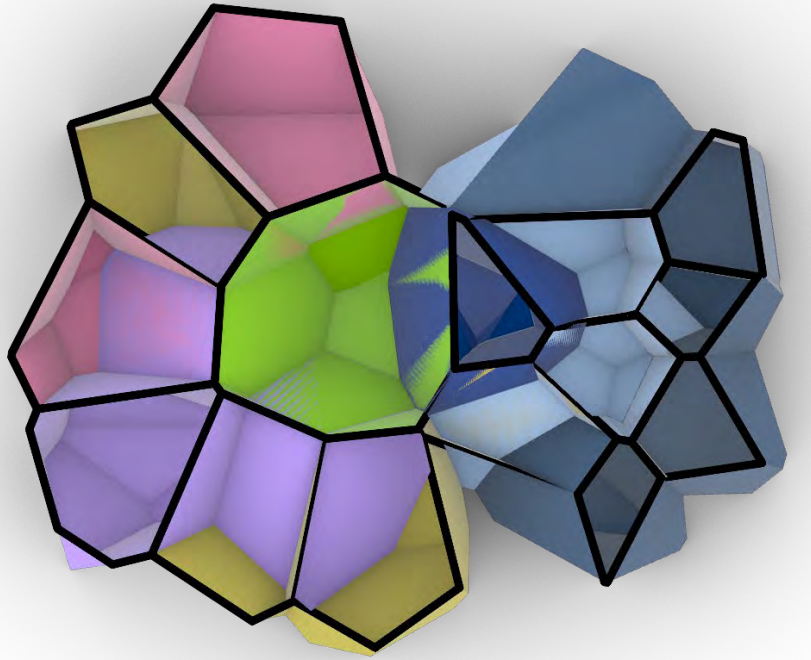


Atrium zoning

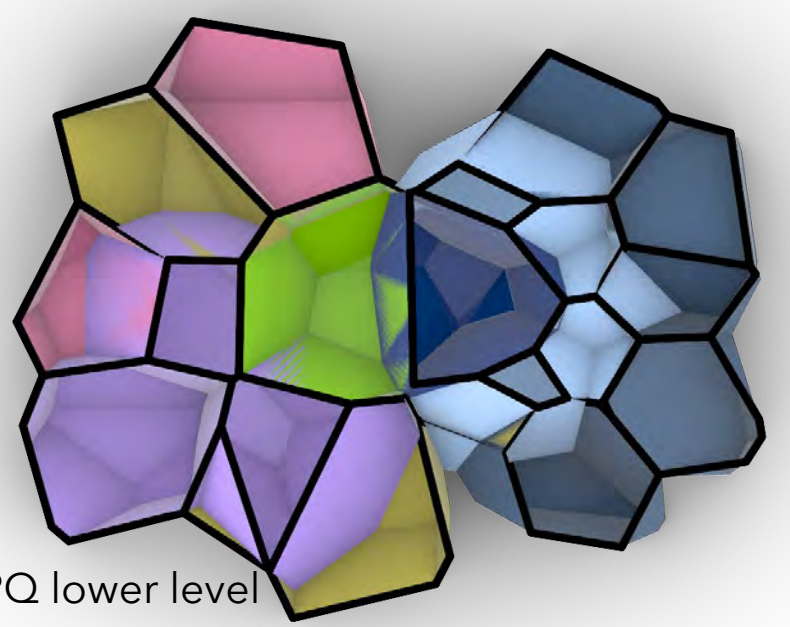




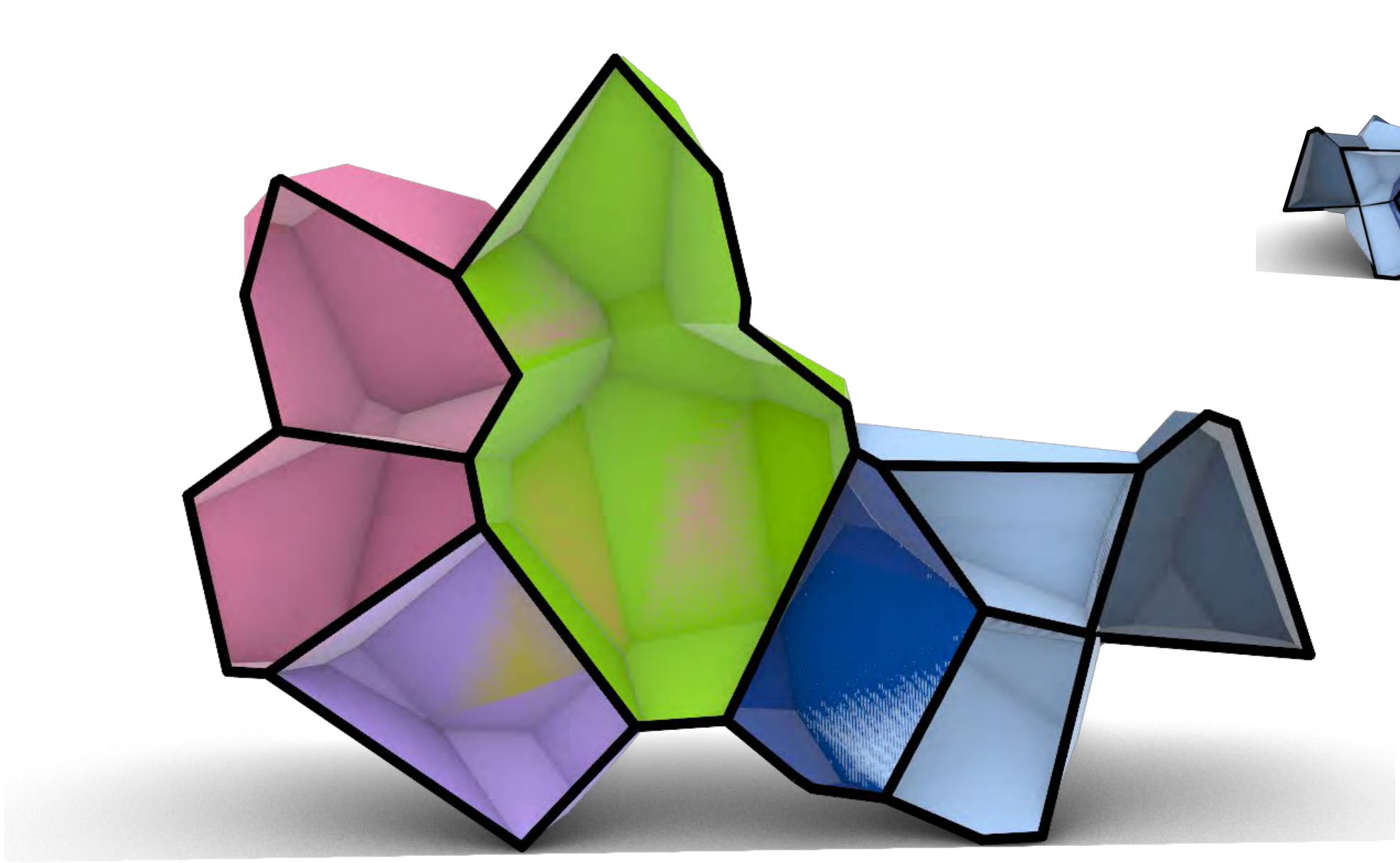


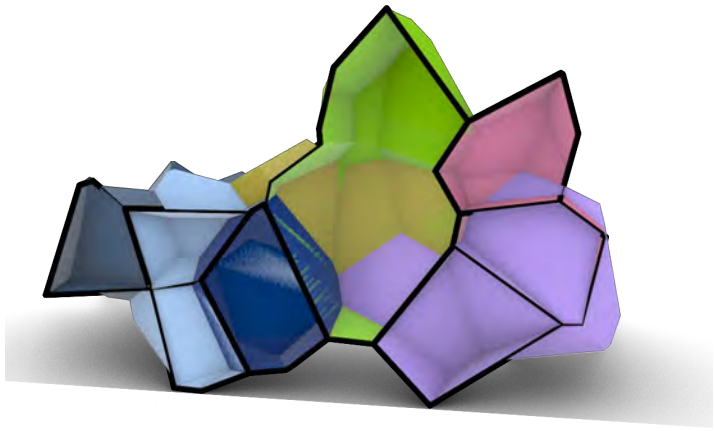


PQ upper level



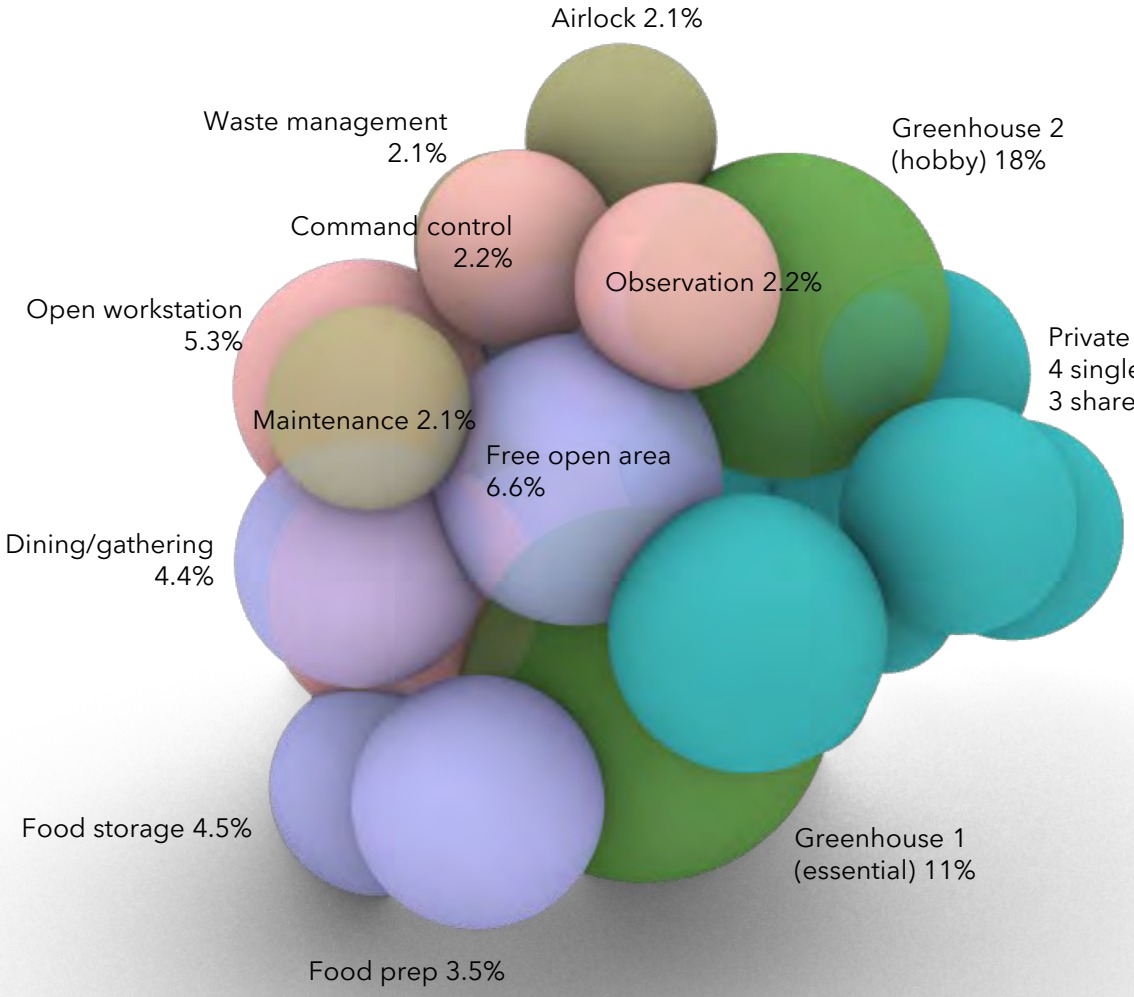
PQ lower level

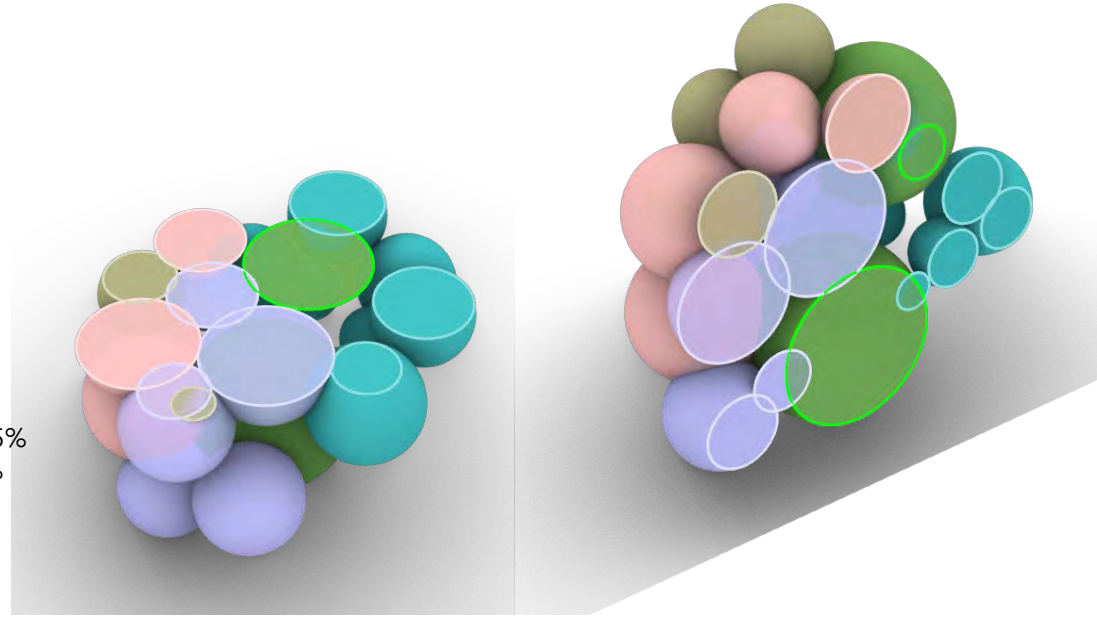


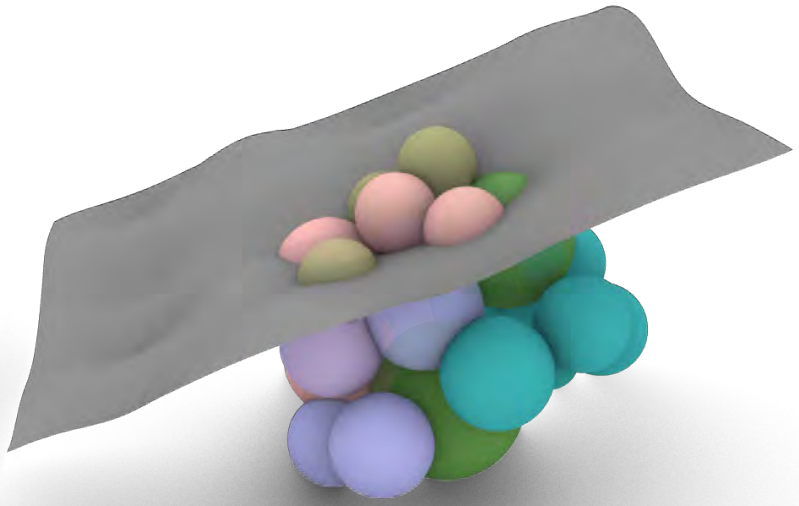


Program distribution

Slanted atrium

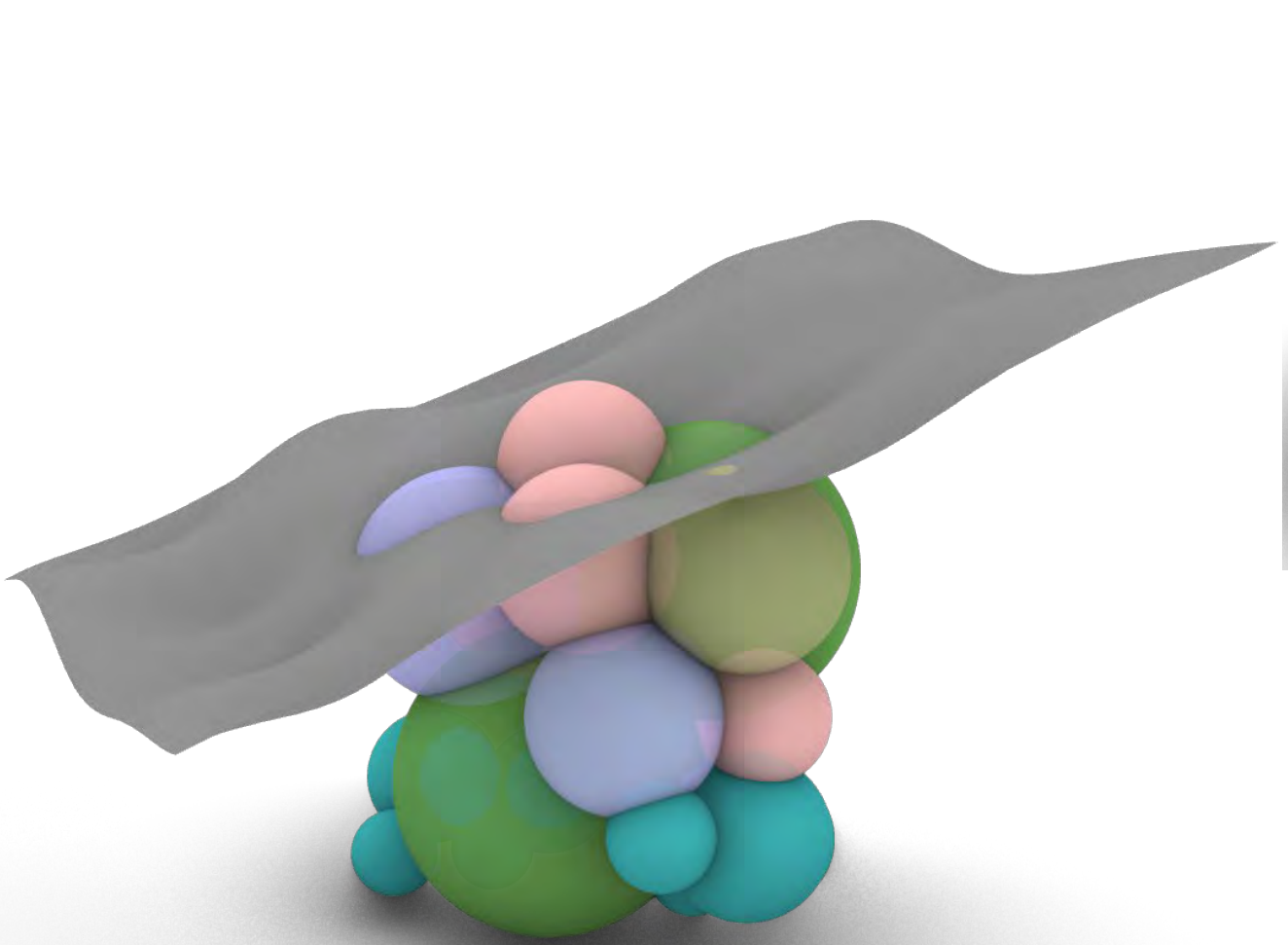


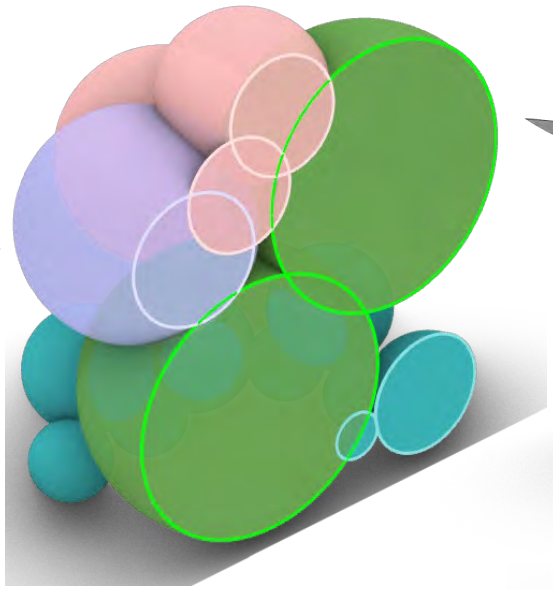


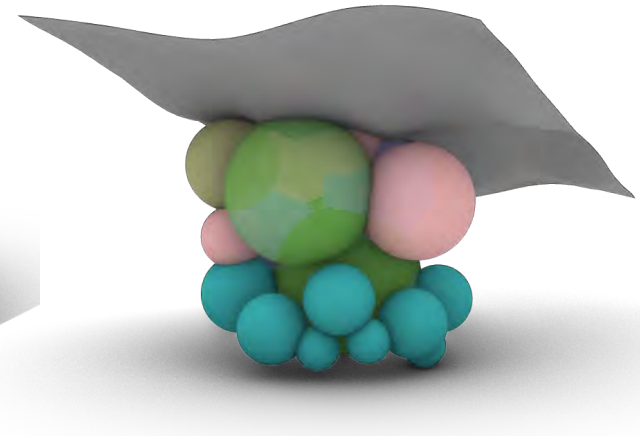


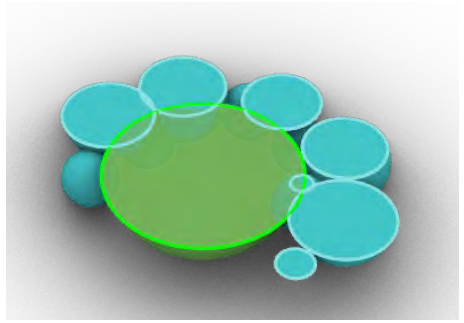
Program distribution

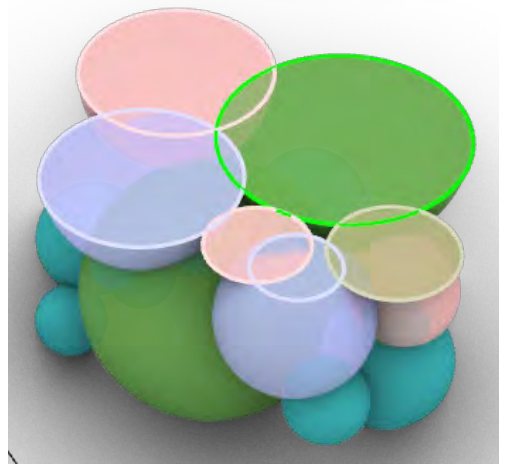
Slanted atrium







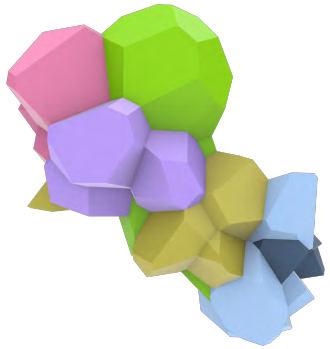
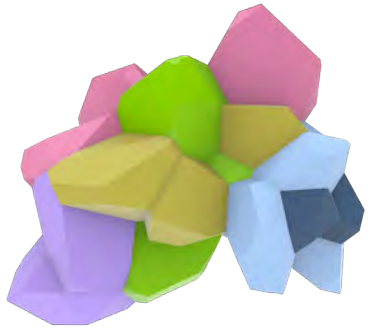
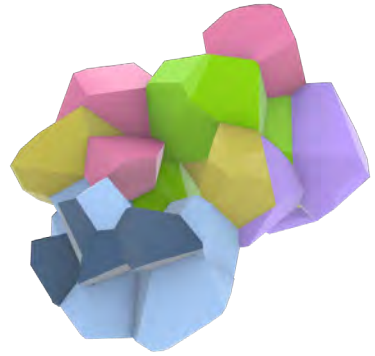
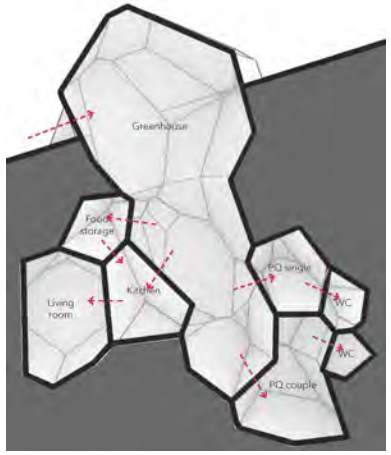
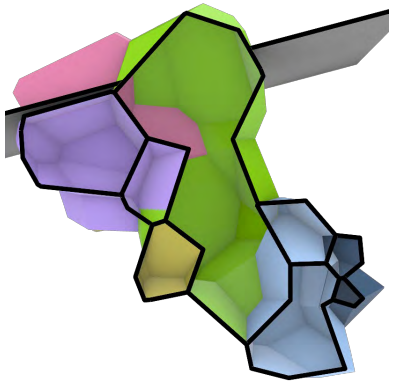
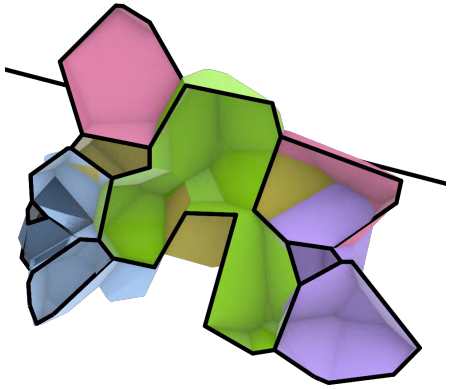
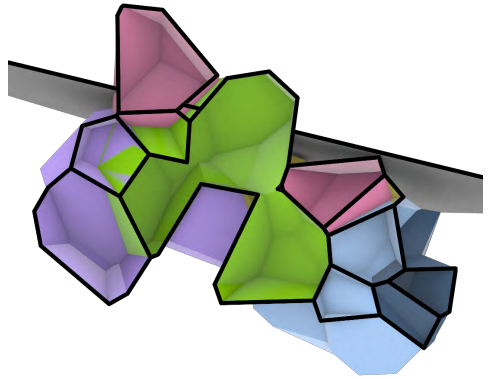
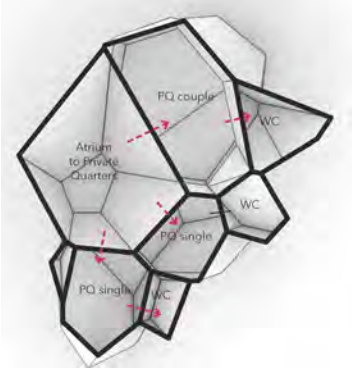
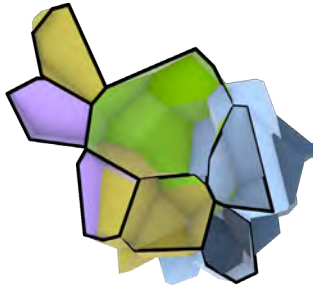
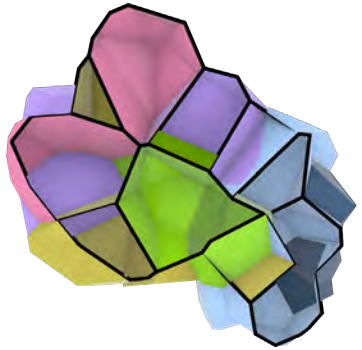
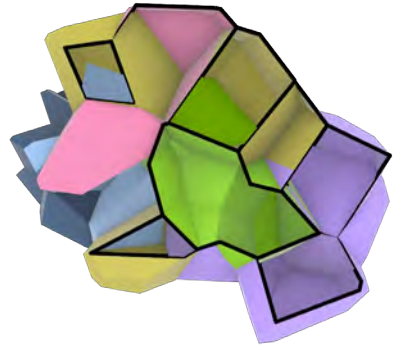




Voronoi volume optimization

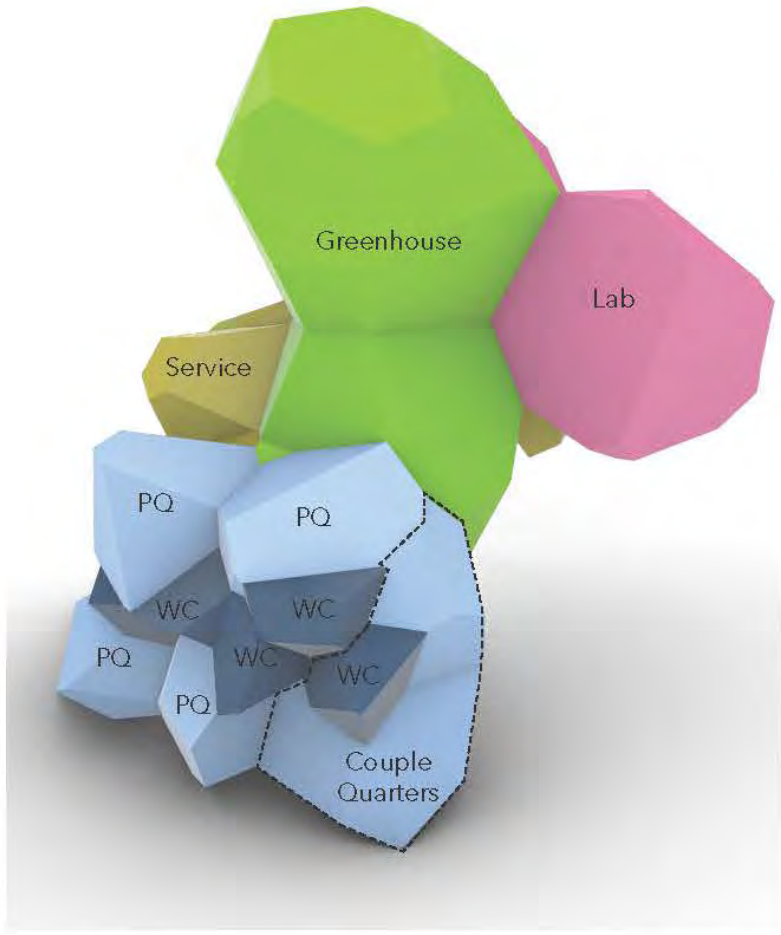
Volume details

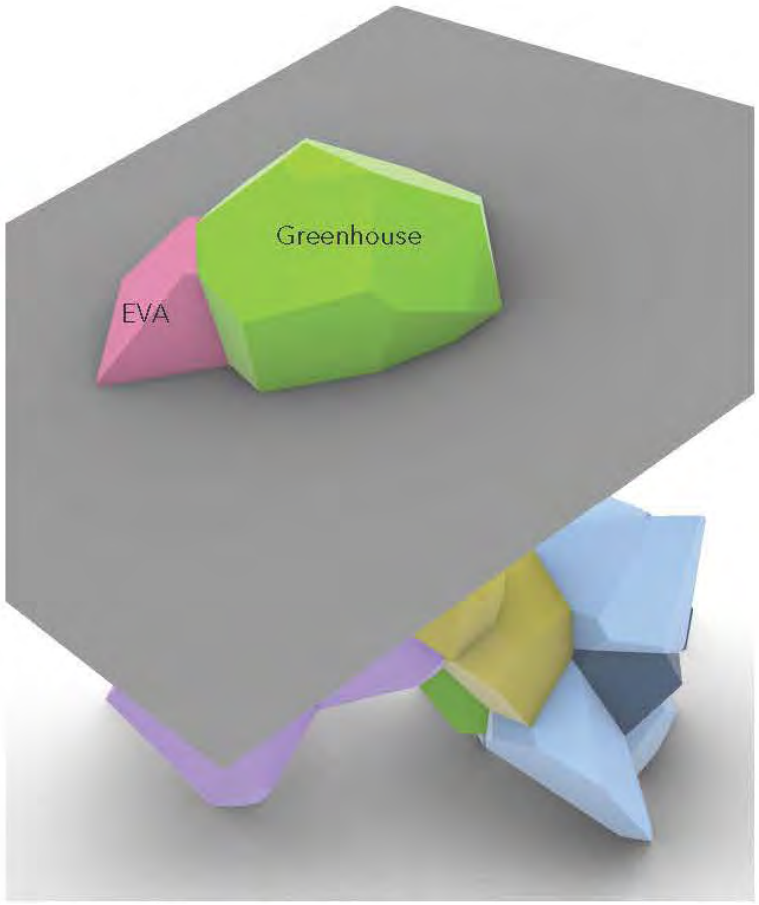
	Iteration 3.1			Iteration 3.2			Iteration 3.3			Iteration 3.4			Iteration 3.5			Iteration 3.6			Iteration 3 Manual Adjustment		
Rooms	**Voronoi (m3)**	**Deviation**	**Sum Deviation**	**Voronoi (m3)**	**Deviation**	**Sum Deviation**	**Voronoi (m3)**	**Deviation**	**Sum Deviation**	**Voronoi (m3)**	**Deviation**	**Sum Deviation**	**Voronoi (m3)**	**Deviation**	**Sum Deviation**	**Voronoi (m3)**	**Deviation**	**Sum Deviation**	**Voronoi (m3)**	**Deviation**	**Sum Deviation**
Greenhouse	308.08	0.54		233.46	0.42		187.71	0.31		197.90	0.32		242.37	0.41		274.68	0.47		251.55	0.46	
PQ	34.05	2.27		35.09	2.34		35.79	2.39		25.01	1.67		21.92	1.46		19.21	1.28		37.92	2.53	
PQ	29.41	1.96		20.45	1.36		25.15	1.68		26.31	1.75		20.57	1.37		18.10	1.21		25.39	1.69	
PQ	21.96	1.46		17.46	1.16		14.15	0.94		17.48	1.17		14.38	0.96		16.06	1.07		21.56	1.44	
PQ	20.10	1.34		19.58	1.30		28.55	1.90		28.96	1.93		27.05	1.80		19.04	1.27		27.20	1.81	
PQ couple	106.05	2.36		61.21	1.45		62.11	1.38		72.23	1.77		95.11	2.12		65.22	1.47		79.94	1.87	
WC	26.24	10.27		30.57	11.97		34.25	13.41		31.93	12.50		20.23	7.92		20.55	8.04		9.81	3.84	
WC	28.35	11.10		12.05	4.72		26.60	10.41		28.08	10.99		25.87	10.13		10.30	4.03		8.69	3.40	
WC	17.53	6.86		11.80	4.62		13.37	5.23		17.53	6.86		13.53	5.29		4.10	1.61		8.30	3.25	
WC	26.19	10.25		19.29	7.55		6.87	2.69		26.19	10.25		14.87	5.82		10.06	3.94		7.83	3.06	
WC	20.89	8.18	89.61	17.54	6.87	67.19	11.04	4.32	69.34	20.87	8.17	83.25	18.08	7.08	68.23	14.62	5.72	57.40	9.63	3.77	43.19
Living Room	61.21	0.67		69.77	0.76		62.74	0.68		112.49	1.22		61.23	0.67		103.22	1.12		110.68	1.20	
Kitchen	65.97	3.32		48.94	2.46		65.87	3.32		58.75	2.96		36.36	1.83		56.92	2.87		57.25	2.88	
Collab 1	53.83	7.25		51.56	6.95		33.92	4.57		50.58	6.82		31.56	4.25		33.21	4.48		45.50	6.13	
Collab 2	69.24	9.33		72.71	9.80		53.90	7.26		68.22	9.19		63.43	8.55		64.31	8.67		58.04	7.82	
Lab Research	100.67	1.34		85.38	1.13		105.80	1.40		117.48	1.56		81.12	1.08		121.42	1.61		116.27	1.54	
EVA	85.86	2.85		70.73	2.35		45.96	1.53		48.01	1.59		52.05	1.73		42.38	1.41		73.84	2.45	
Medical	90.31	4.55		63.73	3.21		82.90	4.17		84.68	4.26		95.59	4.81		97.89	4.93		63.90	3.22	
Storage_Lab	64.55	5.38		84.28	7.03		78.43	6.54		80.88	6.74		73.06	6.09		87.74	7.32		25.99	2.17	
Storage_Food	90.85	7.58		17.08	1.42		54.25	4.52		49.70	4.14		79.75	6.65		81.42	6.79		47.43	3.95	
Storage_Personal	62.75	5.91		52.63	4.96		62.41	5.88		46.35	4.37		42.48	4.00		56.70	5.34		31.34	2.95	
Service	77.13	3.16		60.05	2.46		73.94	3.03		48.77	2.00		47.78	1.96		56.49	2.31		26.48	1.08	

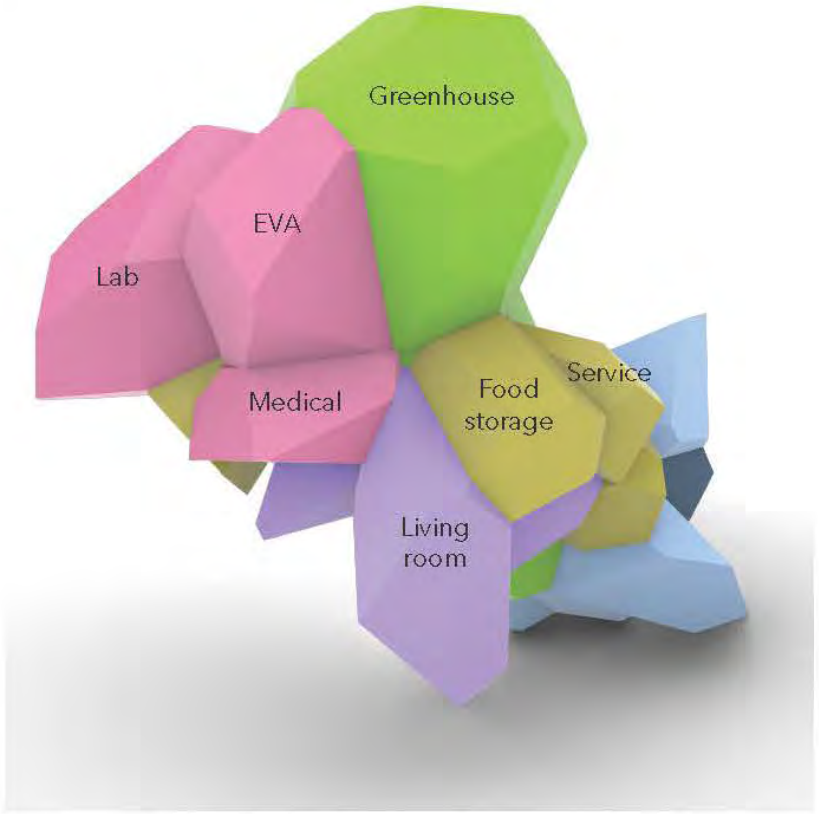
	Iteration 1	Iteration 2	Iteration 3	Iteration 4
Massing				
Section				
Plan				

Iteration 1

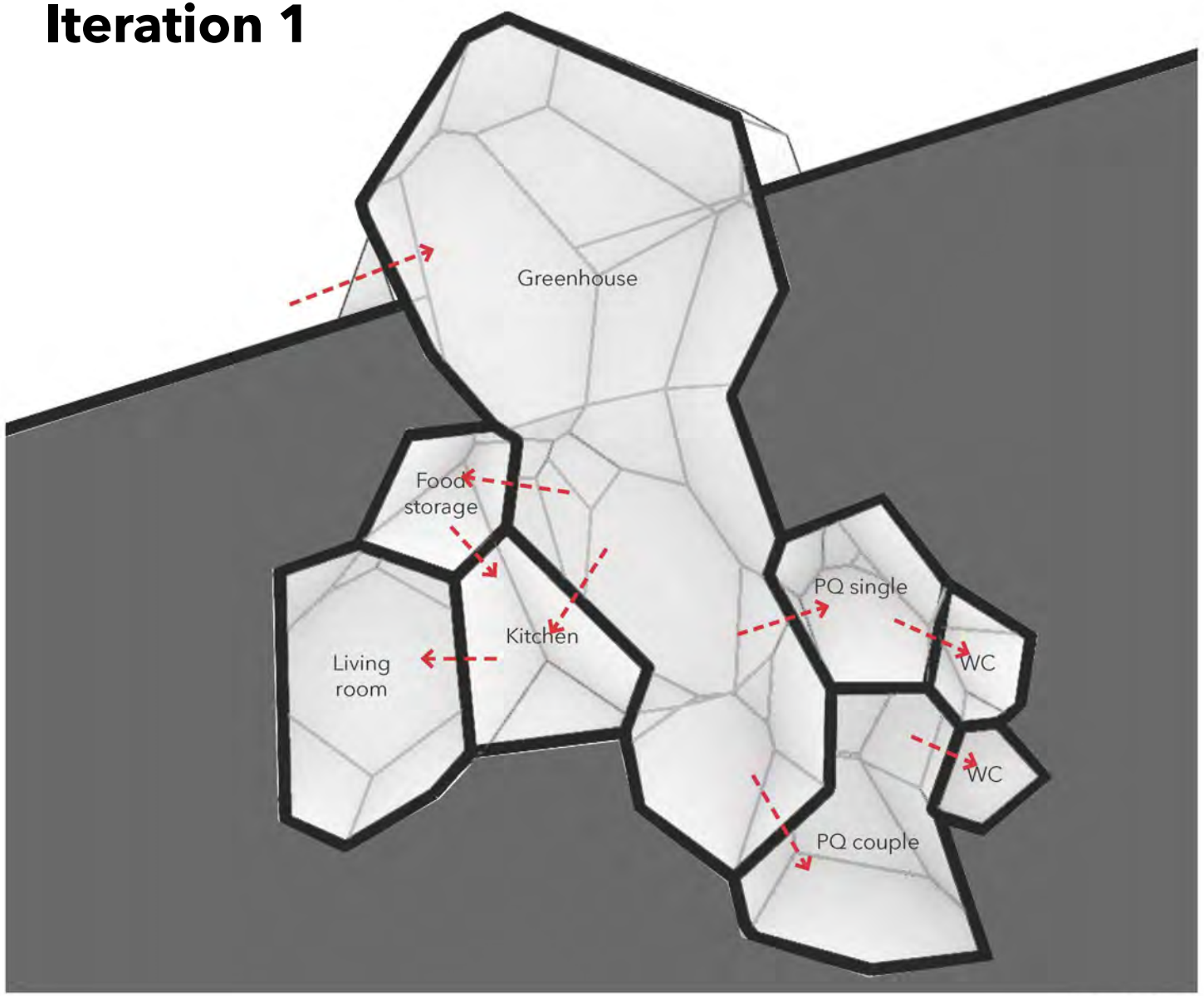

Personal (PQ, Bath)
Social
Work
Greenhouse
Support


Greenhouse
Lab
Service
PQ
PQ
WC
WC
PQ
WC
WC
PQ
Couple
Quarters

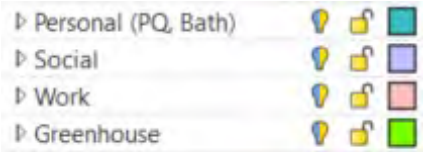

Greenhouse
EVA

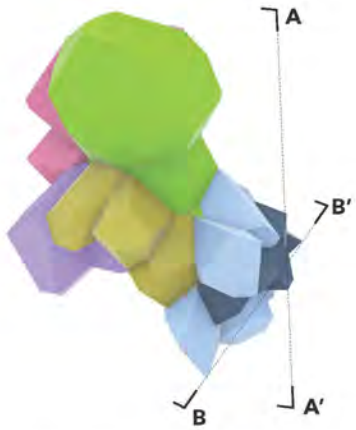

Greenhouse
EVA
Lab
Medical
Food
storage
Service
Living
room

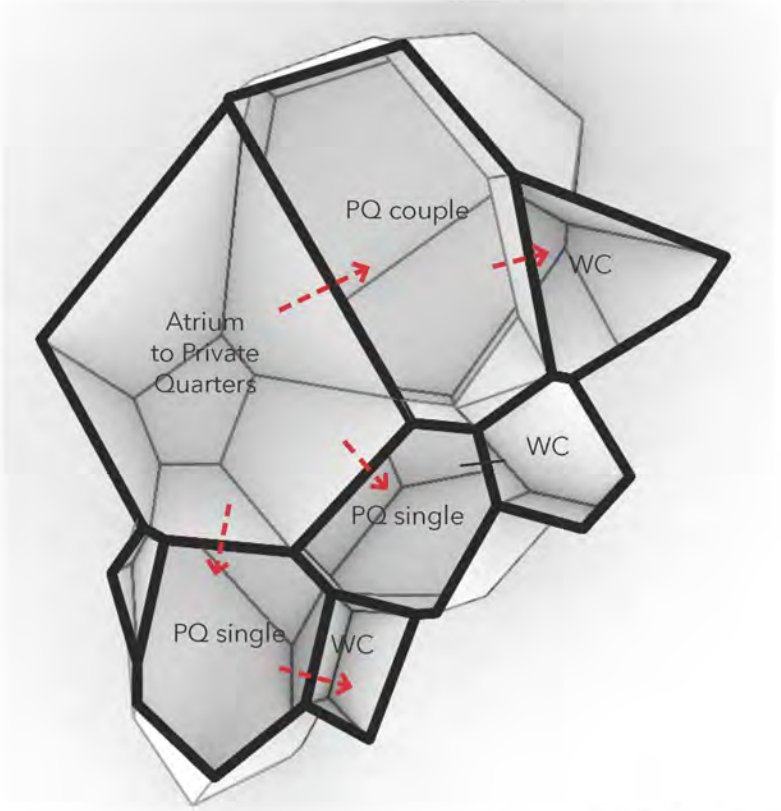
Iteration 1



SECTION A-A'
Overall Habitat Section

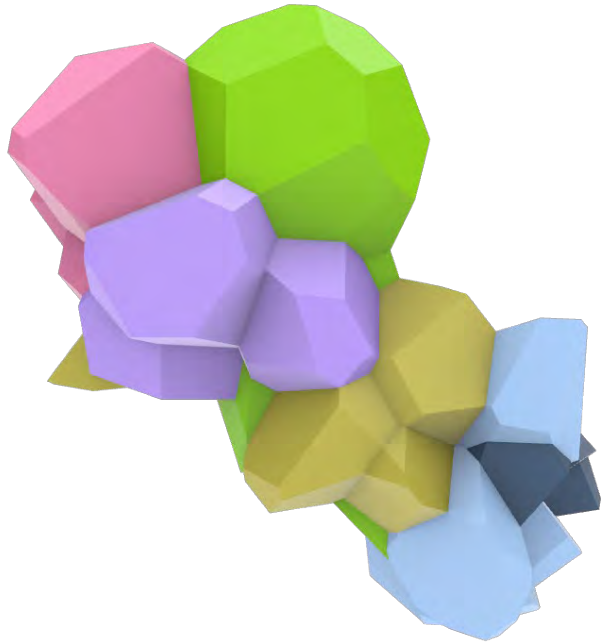


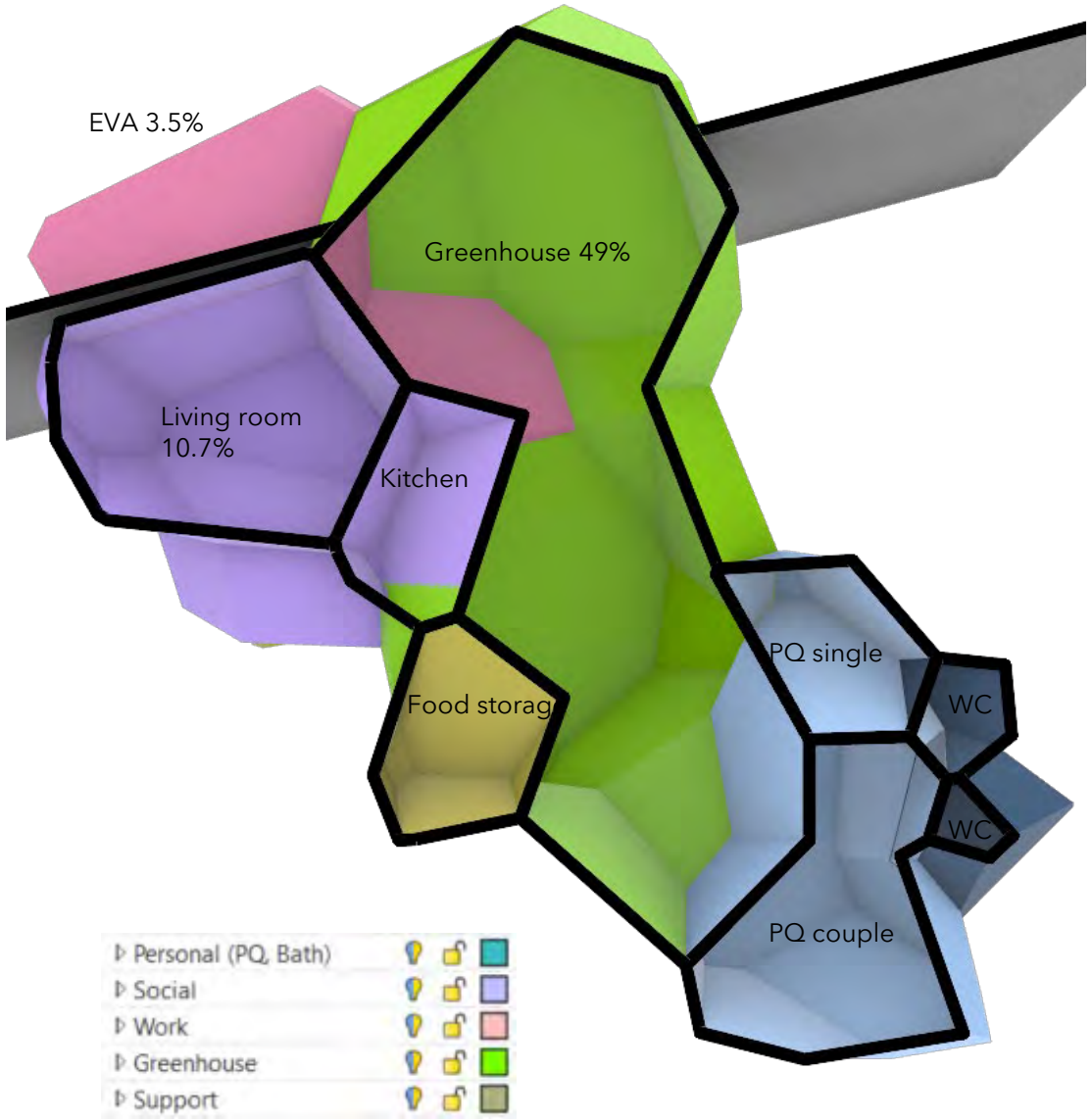


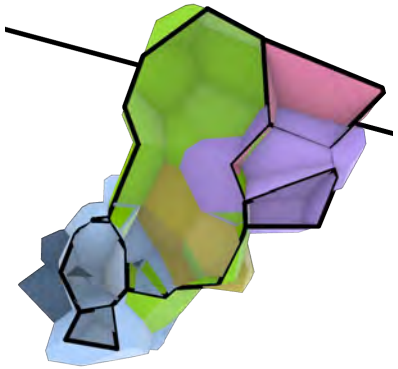


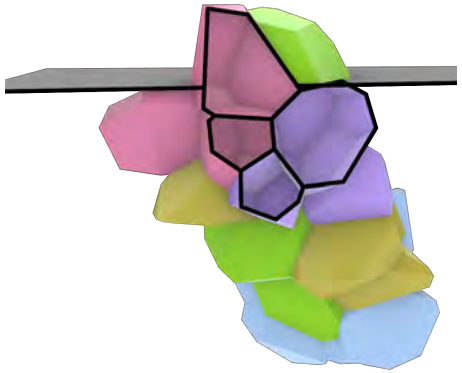
SECTION B-B'
Private Quarters Plan View

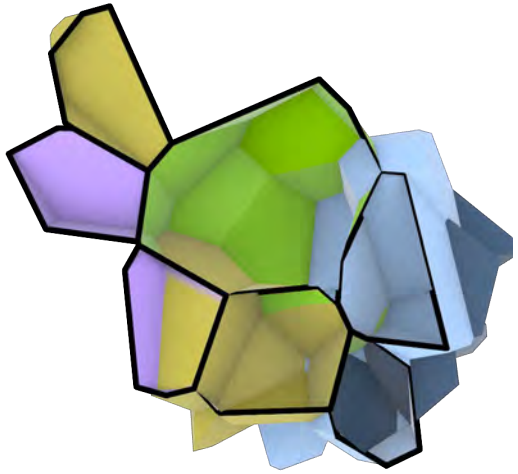
Iteration 2



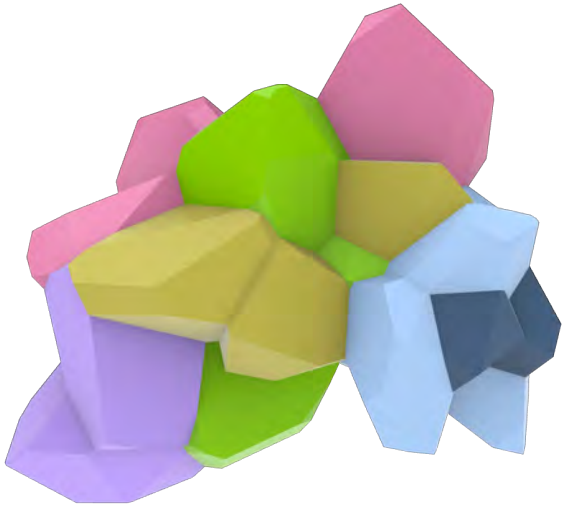

EVA 3.5%
Greenhouse 49%
Living room
10.7%
Kitchen
Food storag
PQ single
WC
WC
PQ couple
Personal (PQ, Bath)
Social
Work
Greenhouse
Support

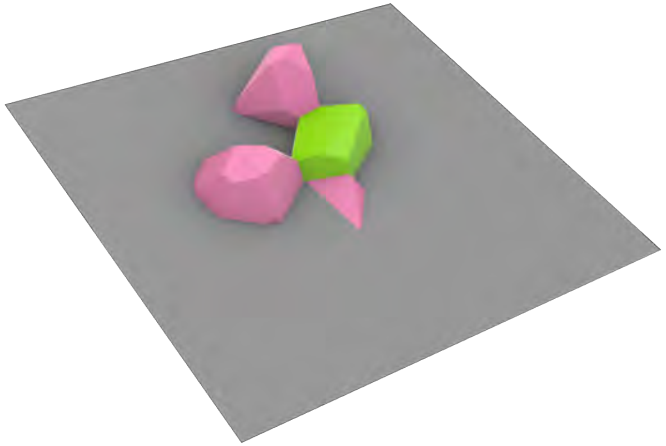


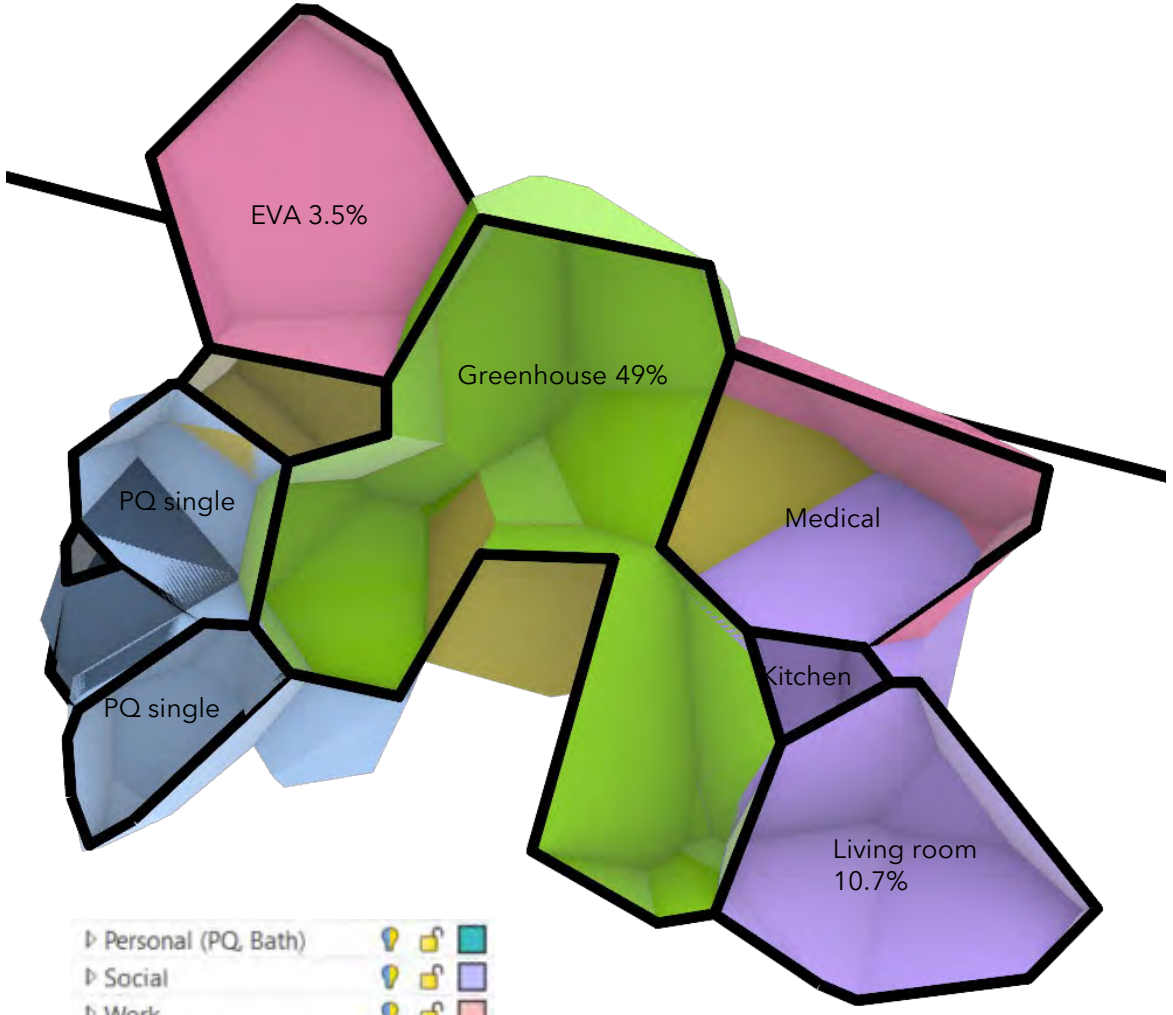


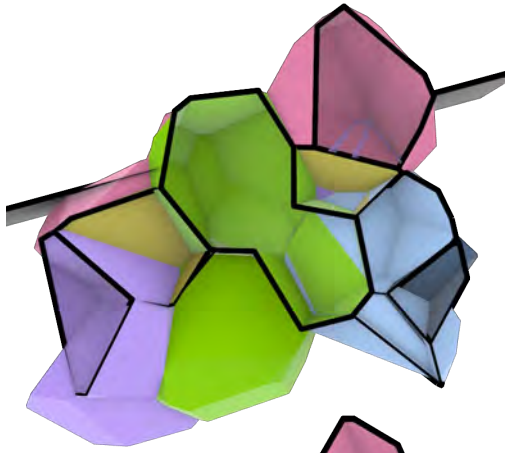


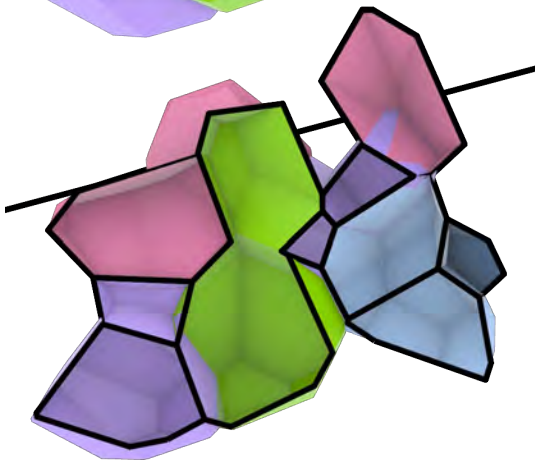
Iteration 3

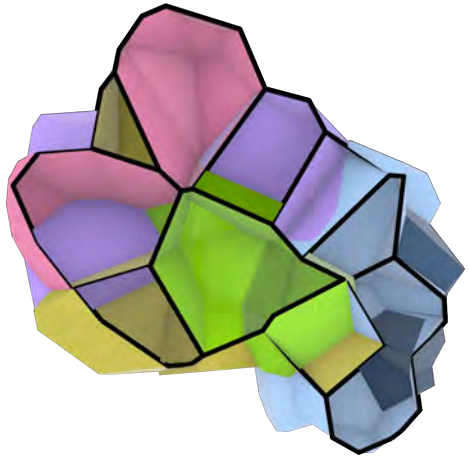




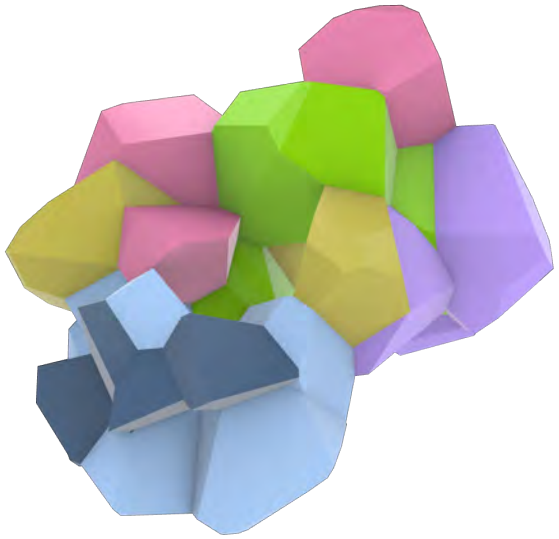

EVA 3.5%
Greenhouse 49%
PQ single
PQ single
Medical
Kitchen
Living room
10.7%
Personal (PQ, Bath)
Social
Work
Greenhouse
Support

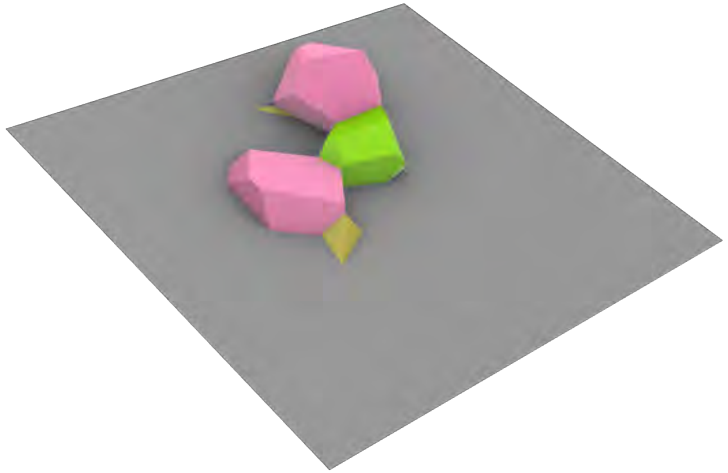


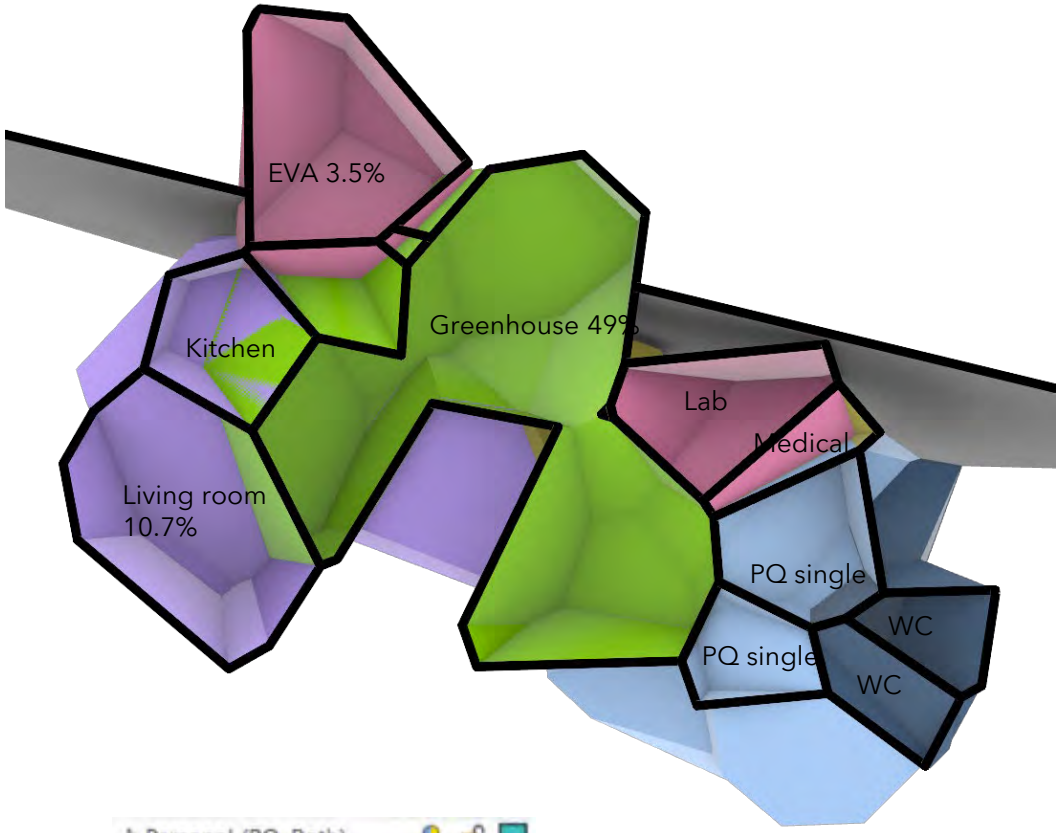


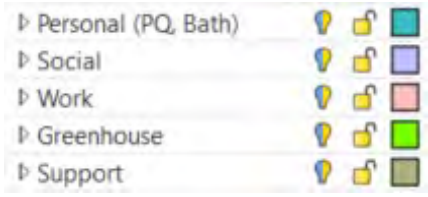


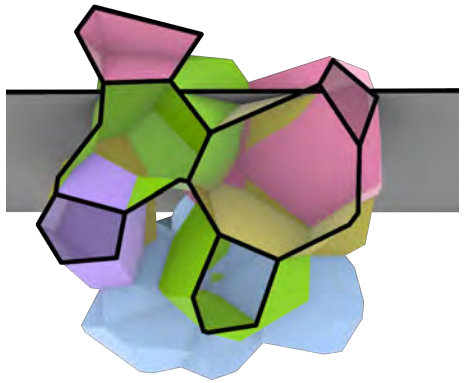
Iteration 4

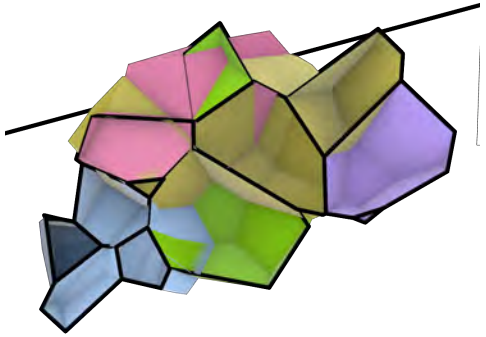


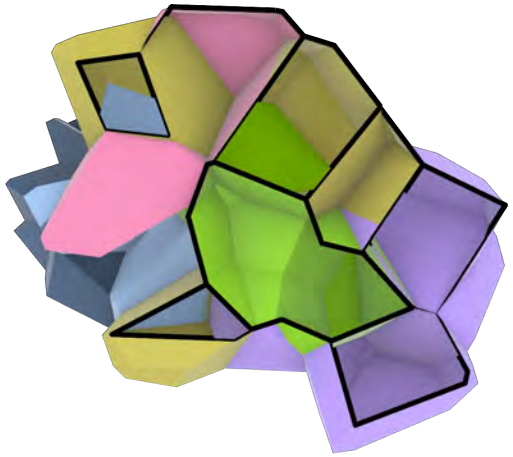


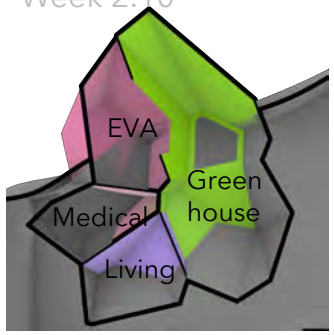

EVA 3.5%
Kitchen
Greenhouse 49%
Lab
Medical
Living room
10.7%
PQ single
WC
PQ single
WC

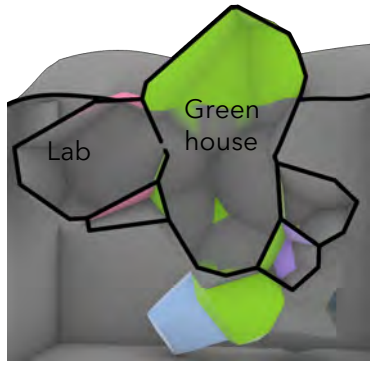

Personal (PQ, Bath)
Social
Work
Greenhouse
Support

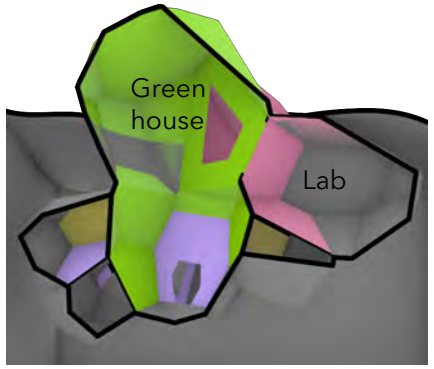


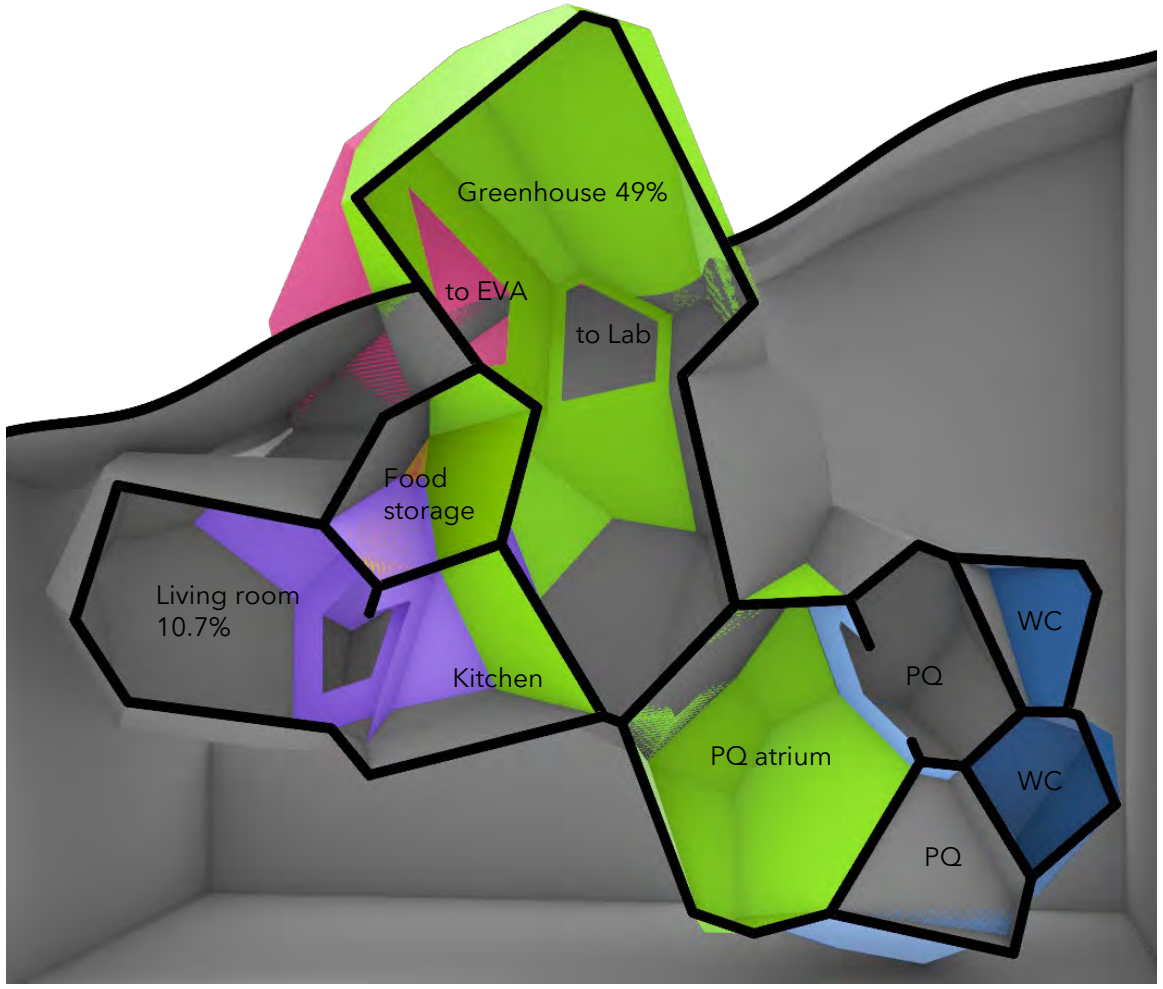


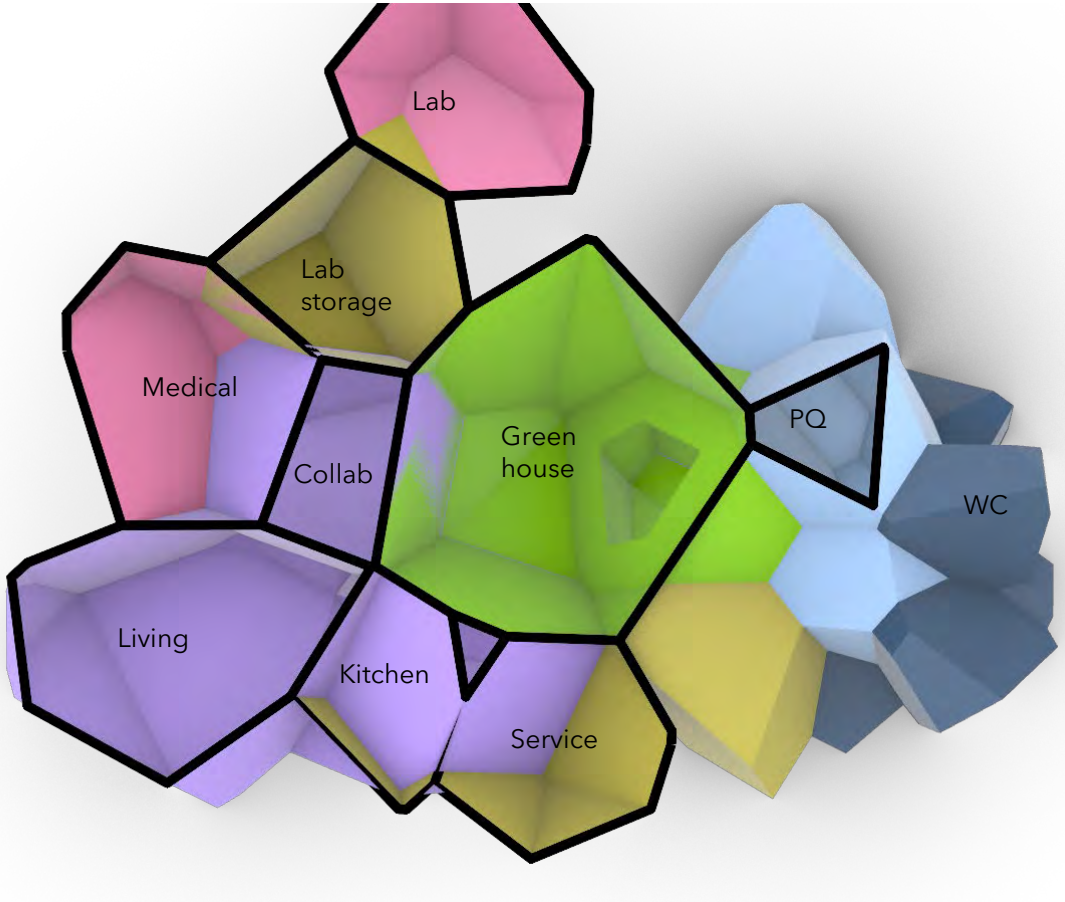



EVA
Green
house
Medical
Living


Green
house
Lab


Green
house
Lab


Greenhouse 49%
to EVA
to Lab
Food
storage
Living room
10.7%
Kitchen
PQ
WC
PQ atrium
WC
PQ


Lab
Lab
storage
Medical
Collab
Green
house
PQ
WC
Living
Kitchen
Service

Gaming at McMurdo during 6 months of winter darkness, one of the popular areas to gather. Team competitions or role playing games are some of many hobbies.
Credit: A Year on Ice

Despite weight or size restrictions, personal items purely for fun are included on the ISS, such as musical instruments. This can dramatically boost crew morale.
Credit: NASA

219. Liapi, Marianthi. Oungrinis, Konstantinos-Alketas. Linaraki, Despoina. Paschidi, Mariana. *"The Astronaut's Playscape: Supporting Creativity Through Play in Long-Term Missions Beyond Earth Orbit."* Conference Paper, 2013, pp 3
220. Kreitler, Shulamith. Casakin, Hernan. *"Motivation for Creativity in Design Students"*. Article, Creativity Research Journal, October 2012, pp 283