Graduation Reflection

Master of Science Architecture, Urbanism & Building Sciences

Personal information	
Name	Regina Tania Tan
Student number	6010881

Studio		
Name / Theme	Lunar Architecture and Infrastructure	
Main mentor	Henriette Bier	Architecture
Second mentor	Ferry Adema	Building Technology
Third mentor	Arwin Hidding	Robotics

Graduation project	
Title of the graduation project	Terraforming Moon: Humanizing Lunar Habitat through Human-centric Design
Research question	How to incorporate **user-defined spaces** based on **human-centric design principles** in designing long-term lunar habitation that balances between social interaction and private boundaries for the psychosocial well-being of the inhabitants?
Design direction	Designing a long-term lunar habitat with heterogenous spaces that is user-defined, with the aim to balance between social interaction and private boundaries, within the isolated nature of space habitat.

Graduation Reflection

1. **What is the relation between your graduation (project) topic, the studio topic (if applicable), your master track (A,U,BT,LA,MBE), and your master programme (MSc AUBS)?**

My graduation topic of exploring human-centric design for a more humanized lunar habitat is directly connected to the studio topic, which is Lunar Architecture and Infrastructure. The project scale itself is architectural, thus directly relates to my master track architecture. The project is carried out in the MSc level, such a way that research is informing the design and design serves as a test of the concept. Concept, schematic, and design development follows through a methodical approach that is driven by the research question.

2. **How did your research influence your design/recommendations and how did the design/recommendations influence your research?**

<u>Initial Research & Concept Design</u>

In-depth research was carried out in the early phase of the project to determine the design guideline and requirements. Analysis is done to extract aspects in relation to the research question. Since this project centres on human-centric design, the research is built upon the experiences of astronauts and crews on analogue mission. A common frustration point is the lack of diversity of social spaces, which inform the design direction of the project.

Other sources are also consulted to support the project holistically. Guidelines and Best Practices inform the baseline requirements of the habitat, which is the starting point for the form study in Concept Design. Literatures, lectures, and symposium on current space technologies as well as 1:1 prototype fabrication workshop gave insights on construction, materialisation, and building physics concept, due to the speculative nature of the project. Literatures on human-centric design theories help to guide the design method, giving insight on methods to balance social interaction and private boundaries.

	Rooms	Size					Activity			Privacy			Movement		Protection			
		Vol for 1 (m3)	Factor	Vol for 6 (m3)	% vol	%	Category	Cross-function	Detail	Personnel	Visibility	Audio	Speed	Arrangement	Duration	Garment	View outside	Access outside
PQ	Private Quarter 1 (Single)	15.0	4	60.0	6.99%	12.52%	Personal	Work	Sleep, work, personal leisure	Individual/Couple	Enclosed	Soundproof	Slow	Flexible	>8 h	Clothed	Optional	No
	Private Quarter 2 (Couple)	22.5	1	22.5	2.62%		Personal	Work	Sleep, work, personal leisure	Individual/Couple	Enclosed	Soundproof	Slow	Flexible	>8 h	Clothed	Optional	No
Bath	Bathroom	5.0	5	25.0	2.91%		Personal		Hygiene	Individual/Couple	Enclosed	Soundproof	Slow	Fixed	< 1 h	Naked	Optional	No
Collab	Collab room	2.5	3	7.5	0.87%	0.87%	Social	Work		Small groups (2-3)	Enclosed	Soundproof	Moderate	Semi-flex	1-8 h	Clothed	Optional	No
Kitchen	Kitchen	10.0	2	20.0	2.33%	2.33%	Social	Personal	Food prep, communal	Small groups (2-3)	Open	Neutral	Fast	Semi-flex	1-8 h	Clothed	Optional	No
Living Room	Dining table	5.0	6	30.0	3.49%	10.66%	Social	Work	Communal, team meeting, game night	Large groups (4-6)	Open	Neutral	Moderate	Flexible	1-8 h	Clothed	Optional	No
	Exercise area (3 equipments)	8.0	3	24.0	2.80%		Social	Personal	Combined with adjacent 26.8 m3	Small groups (2-3)	Open	Neutral	Moderate	Flexible	1-8 h	Clothed	Optional	No
	Open area (misc)	5.0	6	30.0	3.49%		Social	Work	Communal, informal meeting, Group exercise min. 11.8 m3	Large groups (4-6)	Open	Neutral	Moderate	Flexible	1-8 h	Clothed	Optional	No
	Observation	2.5	3	7.5	0.87%		Social	Personal	can be integrated in other functions	Small groups (2-3)	Optional	Neutral	Moderate	Fixed	1-8 h	Clothed	Essential	No
Green-house	Greenhouse 1 (food lab)	7.0	6	42.0	4.89%	48.57%	Support	Social	Each person oxygen 20m2 vegetation/year; crops 67m2	Large groups (4-6)	Optional	Neutral	Moderate	Fixed	1-8 h	Clothed	No	No
	Greenhouse 2 (oxygen)	62.5	6	375.0	43.68%		Support	Social	Remaining area to achieve 50% area of the habitat for vegetation	Large groups (4-6)	Open	Echo	Slow	Semi-flex	1-8 h	Clothed	Essential	No
EVA	Airlock (EVA prep)	10.0	3	30.0	3.49%	3.49%	Work			Small groups (2-3)	Enclosed	Neutral	Fast	Fixed	1-8 h	Suited	Essential	Yes
Medical	Medical bay	10.0	2	20.0	2.33%	2.33%	Work		1 bed + minimum storage	Small groups (2-3)	Enclosed	Neutral	Moderate	Flexible	1-8 h	Clothed	Optional	No
Lab & Research	Lab	12.5	6	75.0	8.74%	12.23%	Work		Geology & biology lab	Large groups (4-6)	Enclosed	Neutral	Moderate	Flexible	1-8 h	Clothed	Optional	No
	Open workstation	5.0	3	15.0	1.75%		Work	Social	6 desks open plan	Large groups (4-6)	Optional	Neutral	Moderate	Semi-flex	1-8 h	Clothed	Optional	No
	Focus workstation	5.0	3	15.0	1.75%		Work	Personal	Monitoring, call to Earth, command control	Small groups (2-3)	Enclosed	Neutral	Fast	Flexible	1-8 h	Clothed	Optional	No
Storage	Personal storage	2.0	6	12.0	1.40%	1.40%	Support			Storage	Enclosed	Neutral	Fast	Semi-flex	< 1 h	Clothed	No	No
	Food storage area	2.0	6	12.0	1.40%	1.40%	Support		Service	Storage	Enclosed	Neutral	Fast	Semi-flex	< 1 h	Clothed	No	No
	Lab storage	2.0	6	12.0	1.40%	1.40%	Support			Storage	Enclosed	Neutral	Fast	Semi-flex	< 1 h	Clothed	No	No
Service	Maintenance	8.0	1	8.0	0.93%	2.80%	Support		System maintenance	Storage	Enclosed	Neutral	Fast	Fixed	1-8 h	Clothed	Optional	No
	ECLSS	8.0	1	8.0	0.93%		Support			Storage	Enclosed	Neutral	Fast	Fixed	< 1 h	Clothed	No	No
	Waste management	8.0	1	8.0	0.93%		Support			Storage	Enclosed	Neutral	Fast	Fixed	< 1 h	Clothed	No	No
	Outside						Work			Large groups (4-6)	Open	Neutral	Fast	Flexible	1-8 h	Suited	Essential	Yes
	TOTAL			858.5	100.00%													
	Total green			417.0	48.57%													
	Total non-green			441.5														
	NHV per person	171.00																

Figure 1. Programme of requirements: research informing design.

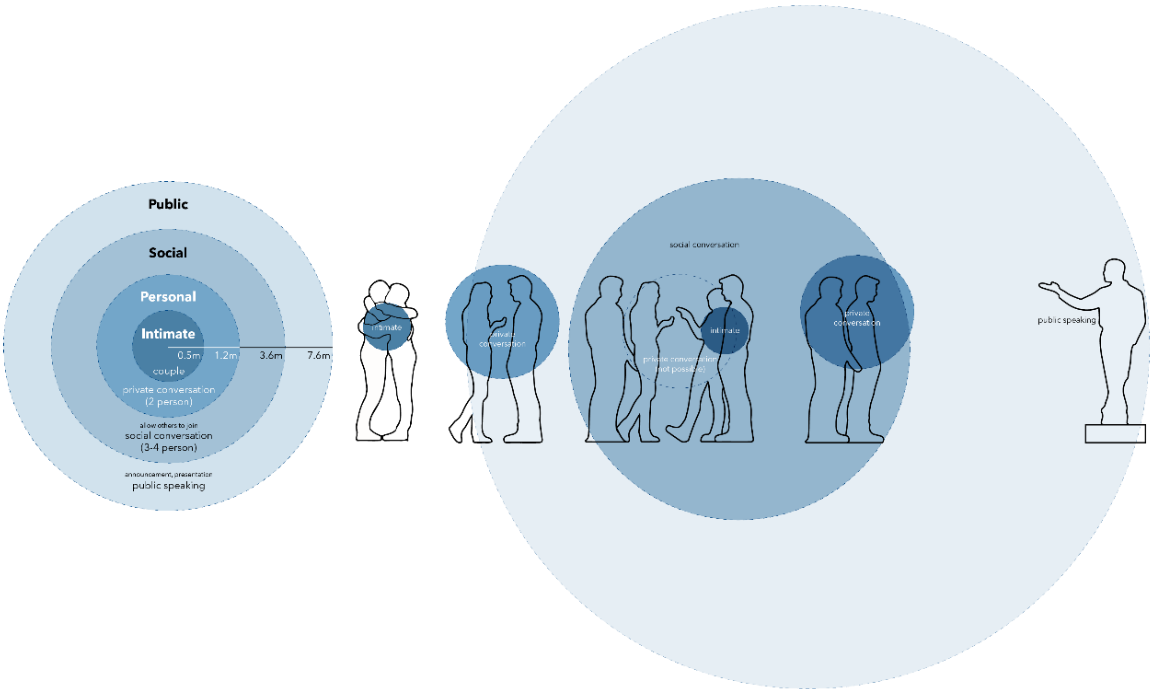

Figure 2. Proxemics: research

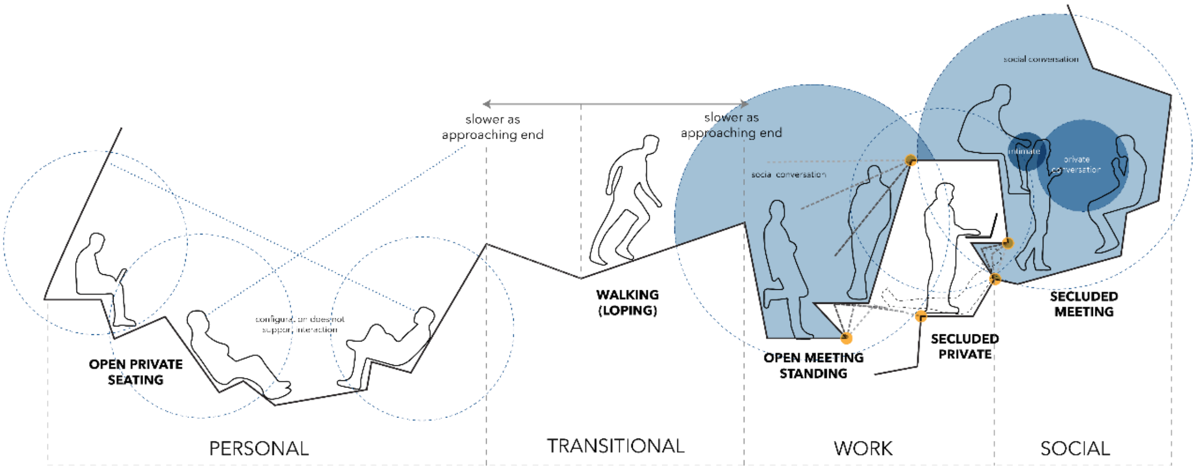

Figure 3. Proxemics: concept design

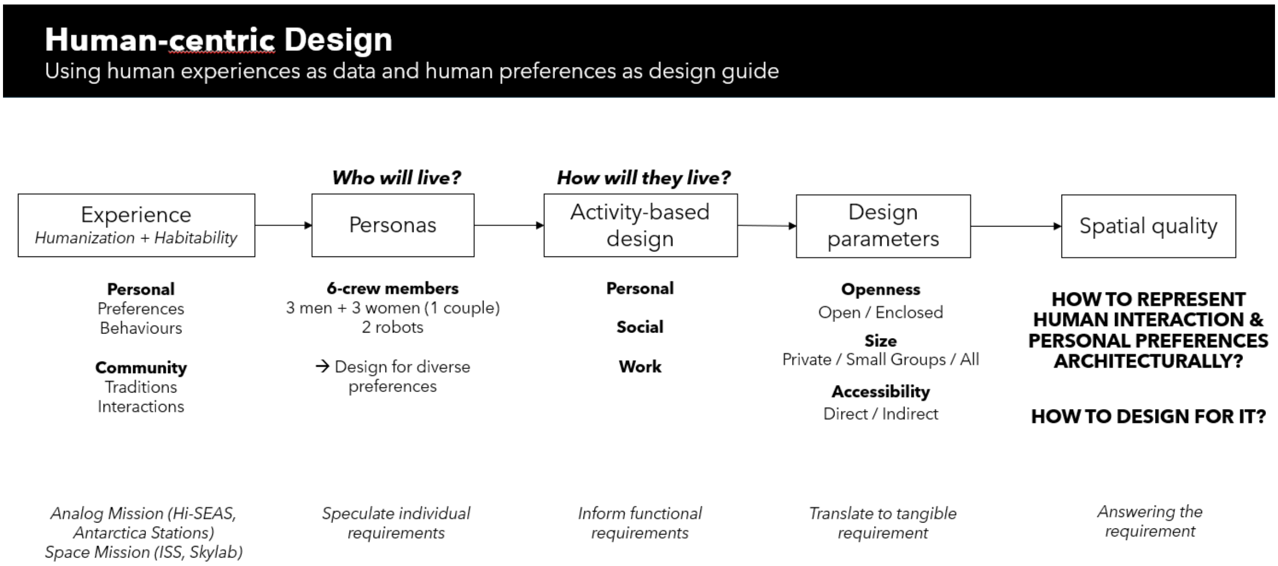

Figure 4. Research to design framework

Schematic Design & Design Development

At the later stages, there is more iterative process between research and design. Each iteration is evaluated for its advantages and disadvantages, then further study will be carried out on missing aspects. For example, the size and programme adjacencies of the early iterations are based on minimum requirements established by space agencies, which after the iteration, is found not to be the ideal case in promoting degrees of social interaction. Studies is then done on relationship between the habitat component and the human, studying degrees of enclosure and volumes relating to privacy. When moving from geometry to architectural resolution, some aspects need to be researched, such as circulation. The design iteration is used as basis of circulation study, supplemented by additional research on circulation. The conclusion is then integrated in the next iteration. Similar process is done on the materiality and structure. Structure and materialisation concept of using in-situ construction has been established in the beginning. However, further research on the structural principles come after the design explorations. After evaluating the design form, catenary principle is integrated as it complements the structural logic. The research is done to further supplement the design and resolve concepts from schematic to detail level.

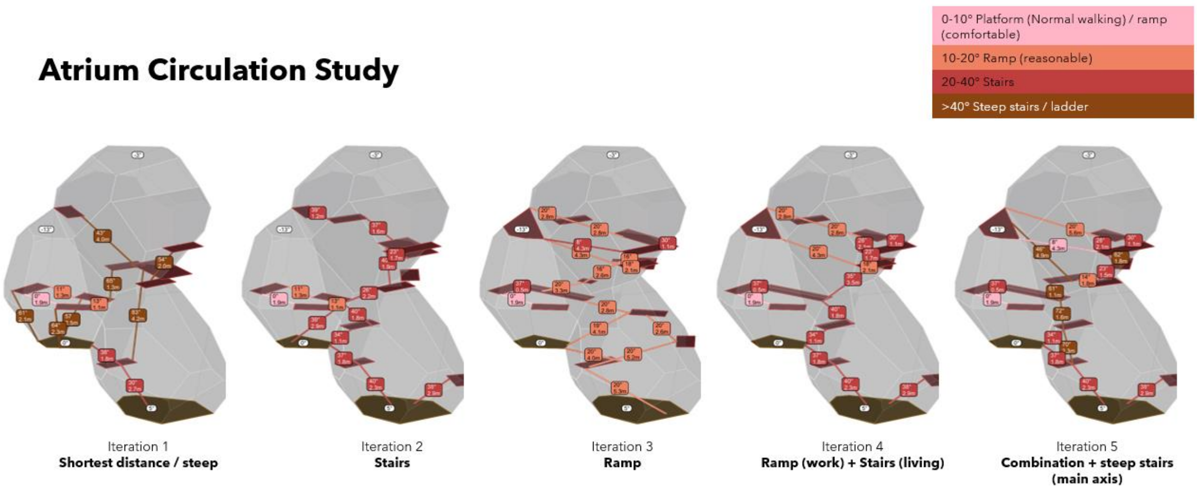

Figure 5. Atrium circulation study: design informing research

3. How do you assess the value of your way of working (your approach, your used methods, used methodology)?

The main aspect of this project is to design for personalisation and social interaction, which translates into distinct spaces that encourages different types of social interaction and catering to different personal preferences. This project adopts a bottom-up approach to address the design objective, by first establishing a system for designing spaces with varying privacy through human-scale studies. Building blocks of the spaces is then consolidated into an integrated spatial solution. This bottom-up approach is ideal when focusing on human-centric design, as it also addresses the research gap since most established studies on lunar habitation mainly departs from construction or technological aspect that tend to adopt a top-down approach for the spatial solution.

Aside from the spatial solution, building on the moon also requires an integrated approach to materialisation and construction. To achieve a systematic approach from form-finding into realisation, computational design is mainly used in the design process.

Specifically, this project adopt a Voronoi-based geometry for the form-finding process. Voronoi is chosen as it is scalable and inherently structural, which is ideal for the bottom-up approach of the project and geometry exploration. This method allows for iterative design. Due to its systemic nature, it allows coherent spatial solution to be adopted across scales.

However, the Voronoi structure is not the end result of the process. Thus, this specific computational approach alone is not sufficient because it only resulted in geometry. Further refinement is needed to transform the geometrical solution into an architectural solution. To transform the computer-generated geometry, an additive and subtractive method is applied. Going back to the theme of socially heterogeneous spaces, each iteration is evaluated by openness, accessibility, and sizes.

Throughout the process, some aspects are able to be integrated computationally such as: programme sizes and adjacencies, structure, fabrication, circulation, and form – to a certain extent. For programme sizes, transition of adjacent geometries generated by Voronoi adopts a gradual size change, thus limiting contrast in volume difference. This is refined by adding or subtracting the volumes to create contrasting sizes. For form, selective subtractive method is applied on each geometry, taking away surfaces thus transforming a solid volume into varying degrees of enclosure. The structural strategy to deal with the resulting negative spaces follows principles of inverted catenary, where loads are distributed.

In conclusion, utilising computational design generates complex geometry with some limitations in the process. Refinement is needed to simplify the geometry and address the limitations. Priorities need to be made on aspects to be automated and controlled manually.

Throughout the development, this project planned to use personas and activity-based design to guide the design parameters. Admittedly it is a valid method, however it was not as integrated during the design development process. Had it been more integrated, perhaps the iteration evaluation process could have been more precise and consistent. Regardless, the personas are utilized again in the final iterations, and hopefully can be further used as a proof-of-concept continuing forward.

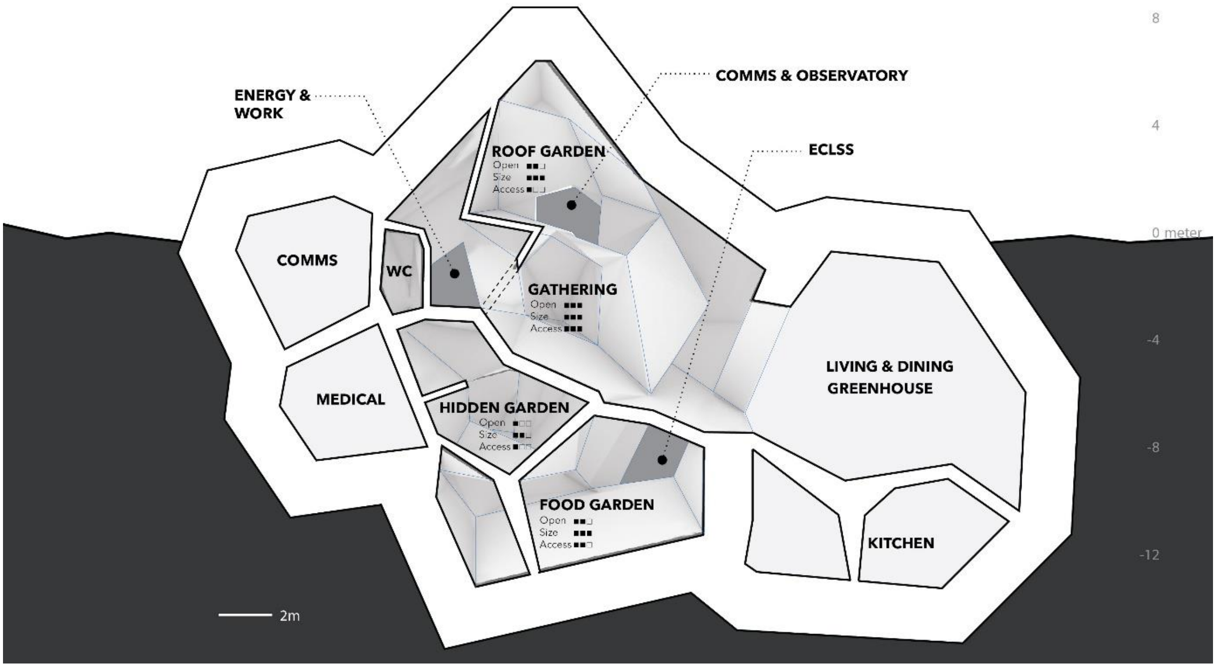

Figure 6. Section of the habitat, showing atrium in varying degrees of openness, accessibility, and sizes.

4. How do you assess the academic and societal value, scope and implication of your graduation project, including ethical aspects?

This project focuses on humanizing the lunar habitat, based on one of the common issues that is found throughout past missions: lack of variations in private space. Essentially, living in a lunar habitat means living in isolation – both from the environment and society. Any kind of human interaction relies heavily on the designed infrastructure. With the state of the space habitat research now, there are advancements in construction and technological research, yet there is still a lack of research in the architectural sector. Plans going to outer space and landing on the moon is coming towards realization now, thus it is crucial now more than ever to push the architectural research on lunar habitats – especially on the repeated problems on privacy that was overlooked, causing social and psychological distress to the astronauts. Maintaining a healthy cognitive environment is important for high-risk missions to the moon. The aim of this thesis is to contribute another possibility of approach in designing a more humanized space habitation.

The findings of this project are not only relevant for future lunar habitation studies on the moon itself, but also for identifying areas that still needs to be researched within psychological and social resilience in a confined environment while carrying out high-importance mission.

The unique limitations and conditions of building on the moon requires various technological innovations – as has been done with a lot of space exploration initiatives in the past. The scarcity of resource and limitations of human capital requires rethinking of the construction method, such as incorporation of in-situ resource utilization and close-loop system, which is currently still a developing method that has a lot of potential for circular architecture. All in all, the progressive nature of extraterrestrial construction can push novel methods of designing, which hopefully these innovation can be brought back for terrestrial applications.

That being said, there are limitations that are not being addressed in this project due to the limited graduation timeline and still evolving field of research. The focus of this project is on the architectural solution: providing a user-driven lunar habitat, that is designed to cater for varying degrees of privacy and social interaction. Aside of this scope, such as the technical aspects, this project adopts viable applications that aligns with the focus of this project. Speculations are made to a certain degree until proof-of-concept, because the realization can only happen later when humans actually land again on the moon.

Ethically, lunar habitat design ventures on designing with no social context – as there is no existing civilization. It invites us to think about colonization on a broader sense. If there is no "owner" of the moon, could we exploit the moon to our own goals? It is important to reflect on this post-anthropocentric context, the extent of our responsibility towards the environment. For this project at least, aiming for a circular, self-sustaining habitat is a step to minimize ecological footprint on the moon.

On the broader realm on the contribution towards architectural discourse, this project establishes design method from the bottom-up, testing the systematic approach towards architectural design. It also invites architects to rethink social and individualized spaces in post-anthropocentric and confined contexts.

5. **How do you assess the value of the transferability of your project results? We also expect you to develop 2 reflection question yourself which relate to the content of your work.**

This project result in a habitat where the atrium performs as a social condenser, with different type of spaces catering to different degree of social interaction. Architecturally, the project addresses one of the biggest challenges living in inhabitable environment which is isolation – not just providing a dedicated private space, but designing the in-between. We have seen the importance of designing for isolation especially during COVID-19 and finding refuge in "a room of one's own" in dense urban living.

Technologically, it is transferable to terrestrial projects in extreme environments and contributes towards progression of a close-loop sustainable system in a building. The scarcity of resource and limitations of human capital on the moon reflects the construction scene in developed countries today, which requires rethinking of construction method. This project uses in-situ resource utilisation, which is a developing method that has a lot of potential for circular architecture.

6. **How does the design process adapt when working within a speculative context?**

The interesting part of this studio is the speculative context, as it is an emerging research field with many research still ongoing progress. It is also not possible to actually visit the site on the moon. Hence, understanding the lunar context depended heavily on previous experiences, research, photographs, and videos. To have a feel of living in a barren landscape of extreme conditions, there was an excursion to the lava tubes in Sicily, Italy, that provides first-hand analogue experience.

In this project, getting to know the breadth of the field in the earlier stages of the project was helpful, as it opens perspective to speculations in the later stages and having available alternatives. In the project development, consultations with experts across fields were crucial for brainstorming and developing the design, hence the interdisciplinary part of the project.

7. In what ways does designing through 3D-dominant methods challenge or complement traditional tools such as plans, sections, and elevations?

The 3D method allows creation of more complex geometry creating spatially rich form and opens up avenue for new strategies such as interlocking method of components or establishing spatial enclosure.

The challenge is complexity in translating the 2D to 3D, and vice-versa. 2D concept sketches needs to be tested in the 3D environment to ensure proof-of-concept. Likewise, 3D model needs to be abstracted for traditional representation for it to be readable.

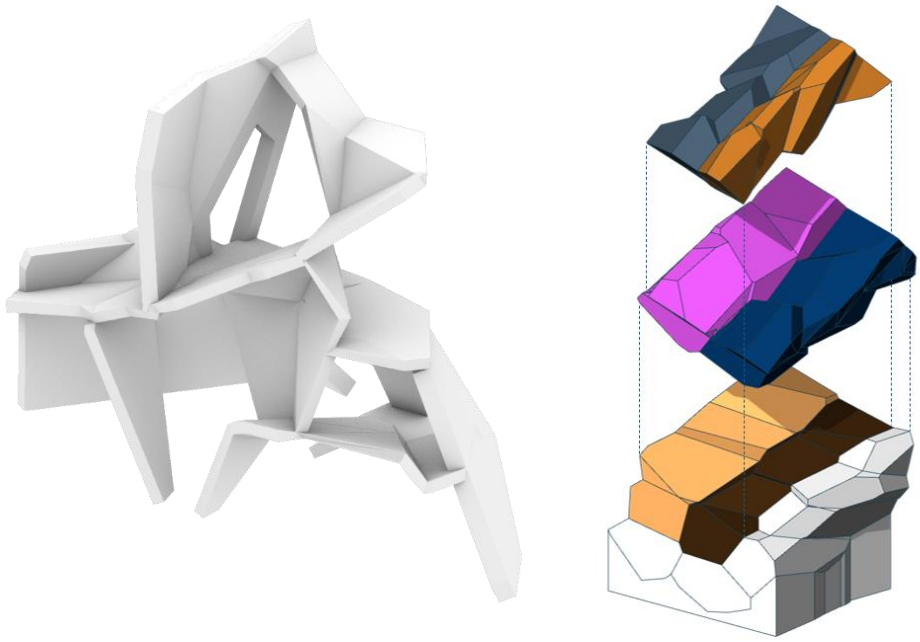

Figure 7. Spatial enclosure (left) and interlocking component (right).

8. Next steps

The project will continue to be developed, mainly on refining the representations of the project to ensure more clarity.