Reflection

Master of Science Architecture, Urbanism & Building Sciences

Personal information	
Name	Jonathan Jonathan
Student number	5955998

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

Graduation project	
Title of the graduation project	Lunar Playscape: Designing a Climbing-based Habitat for Body and Space Interaction

Reflection	
1.	<u>What is the relation between your graduation project topic, your master track (A, U, BT, LA, MBE), and your master programme (MSc AUBS)?</u> The introduced graduation project about lunar habitat aligns with the broader MSc AUBS track by presenting complex questions that cross technological innovation in architectural research and design process with human-centric design. Particularly, the project exploration towards the idea of playscape habitat does not only delve into the functionality and comfort of living spaces, but also reconceptualise lifestyles that moon surface might require while living in a confined environment under low gravity. The foundation of forming the new architecture is through promoting the idea of spatial design as mediator of human behaviour and experience, where the approach would primarily be fitting into habitats and workspaces for both off-/on-Earth conditions. By basing the research and design process on body movement, postures and speeds; the project challenges societies creation to engage and appreciate bodies while moving in proofing how different it could be to go against the norm of living in standardised spaces as what typically experienced in on-Earth buildings. The project also extends to the increasingly vital necessity of adaptable interior spaces where role of architecture shall go beyond provision of envelop as shelter in accommodating body postures and movements to actively create playful spatial systems. Thus, the design direction of the habitat emphasises the interaction between human bodies and lunar gravity where this study would propose the idea to include body ergonomics

	evaluation in both furniture and architecture scales, so that they could suggest valuable insights to off-/on-Earth environments in contributing to the perpetual in-progress conversation about relationship between space and body in the general field of Architecture.
2.	<u>How did your research influence your design/recommendations and how did the design/recommendation influence your research?</u> The project falls into a theme that is rather new in the field, which naturally makes iterative and interdependent process between research and design stages as the main flow of the project development. The research done throughout the initial phase delves into astronauts behaviour, analog missions and expert commentaries which establish a set of knowledge necessary for understanding the physical and psychological challenges to live on space. This initial spark is crucial in informing the creation of problem statement and design direction as a base framework of the entire graduation project. These points are then adjusted along with a deeper examination into the extreme conditions of lunar environments such as radiation level and low gravity, which eventually turn into inspiring aspects to work with in the design proposal. A technical approach which is materialisation workshop is arranged to be quite early in the project development process which results as a helpful research machine in imagining the design steps, also in providing a hands-on experience before entering into a specific design direction. The research and design intersection come clearer with empirical studies on human movement on Earth in combination with excursion to lava tube which provide a first-hand immersive interaction between body and space. The pronounced profile of lava tube ultimately bears the idea of living with the landscape as a crucial theme that has a great potential to generate new questions along the research line. Subsequently, the project's design iterations start with the schematic exploration of daily activities with unusual postures that follows not as final products but rather a provocation that motivates specific spatial arrangement in the architectural design.
3.	<u>How do you assess the value of your way of working (your approach, your used methods, used methodology)?</u> The project methodology is essentially a combination of empirical research and design through speculative technologies which discusses human bodies interaction with space. In this matter, experiencing or observing the subject empirically through body mapping exercises and lava tube excursion maintains the tangibility of the project as a lived experience. Furthermore, with the aid from computational design, the research and design processes progress responsively and adaptively in translating the theoretical narrative with spatial imagination into physical manifestation. The strength of the methodological approach also roots from the widely comprehensive framework and requirements of the graduation thesis project which has enabled the exploration to engage to the completeness in multiple scales

	across the architectural design and product. While gaps are evidently still present due to the nature of progressive field especially in the specific procedure of construction and detailing, these are consciously acknowledged as research in progress. Thus the proposed design outcome is an adaptable and logical system that can be applied not strictly to mimic a specific interface, but rather a design framework that could be followed and modified according to advancing research contexts. This ensures that the proposal does not only serve as a single or one-end construction, instead provides a reflective and continuous strategy that stays influential in the future practice of extraterrestrial architecture.
4.	<u>How do you assess the academic and societal value, scope and implication of your graduation project, including ethical aspects?</u> Designing a habitat on moon surface is personally an atypical architectural project, where high degree of nuanced societal force is still absent unlike the situation on Earth. A benefit that this state has would be that the project could truly represent the sensitivity on the connection between architectural design and one aspect of human factor as the users. In this case, with the focus on human bodies, this project aims to reposition bodies as an active/ defining physical actor that is essential in architectural design process to create a more physically conscious and engaging environment, especially in an enclosed environment with low gravity like moon surface. The main idea provokes the conversation where human bodies are often regarded as a passive input for architectural dimensions while the architecture itself does not interact physically with the users which are humans. In practice, when the architectural dimensions are translated, they typically promote repetitive movements such as climbing stairs and walking on rather flat surface; or the knowledge of ergonomics are applied into furniture scales which result in sedentary society that is widely found on workspaces on Earth up to these days. While the project's academic objective is to propose an imagined lifestyle on off-Earth habitat through playful physical engagement, it is also hoped that this project could serve as a reminder and implication on how we have conceived human-centred design on Earth and how sedentary lifestyle has greatly affected our physical and mental health. On the technical side, the project highlights the idea of limitations breed creativity where constrains on lunar surface motivate the exploration of construction methods and effective uses of materials that could boost sustainable practices on Earth. This procedure prompts for vernacular architecture that respects local contexts of the building where materials are collected from the surroundings (equivalent to In-Situ Resource Utilisation/ ISRU) which inform contextual quality of the site out of material performance and climate control while maintaining high decency of building performance to be functional and energy efficient which ethically advocates for a step forward of human civilisation in the facing of ecological urgency.

5.	<u>How do you assess the value of the transferability of your project results?</u> Extraterrestrial colonisation is a cutting-edge field that is calling for multidisciplinary collaboration from highly renowned academic stakeholders and industry professionals which direct the practice to be a catalyst of technological advancement where innovation and development are pushed beyond the typical boundaries and pace, allowing a greater potential for significant breakthroughs especially in the intersection of robotic design and production with underlying aspect of human-centred design. In the long run, the related tests/ simulations done on Earth will interact with the implementation off Earth and subsequently the discovered knowledge will generate feedback loop that is beneficial for human civilisation and application towards future works in both conditions (on-/off-Earth). For instance, technological advancement in large-scale 3D printing is growing rapidly not only because of its automation feasibility as widely proposed for off-Earth construction method, but also with several other qualities that could be advantageous for on-Earth application. To name some, the material efficiency nature of 3D printed structures with minimal amount of required formwork, thus leading to a cleaner construction that minimizes construction wastes. Additionally, a relative fast construction is also a character of 3D printing where this nature could be utilised strategically to overcome challenges on Earth, such as construction for post-disaster resilience and housing crisis. In this project, moon regolith is chosen to be the main building material due to its abundance on site as well as the possibility to reuse/ upcycle the material by re-printing it. The idea of circular use of the material could be applied on Earth with the rising popularity of bio-based materials for printing furniture, which in the future might grow into larger scale, such as shelters/ habitats. Upon the successful execution on the moon, the project would perform as an exemplary result that could be followed by communities on Earth as an effort for achieving holistic sustainable goals in multiple layers. On the larger scale which is to manage towards clean construction, also on the community/ personal scale in adopting a closed-loop life support management system in reproducing food, water and oxygen that lunar inhabitants would strictly require to carry out as studied by European Space Agency in their project called MeLiSSA (Micro-ecological Life Support System Alternative). From human perspective, the project promotes an extended narrative to counter customary sedentary behaviour, suggesting the exploration of different postures and movements in daily activities. The knowledge could be translated revolutionarily in reforming offices, schools and even rehabilitation centres to include a new/ more engaging environment on a certain level. Besides, the project working approach also demonstrates a feasible scenario to work with speculative technologies and inaccessible site by designing a framework that merges existing knowledge in the general field of

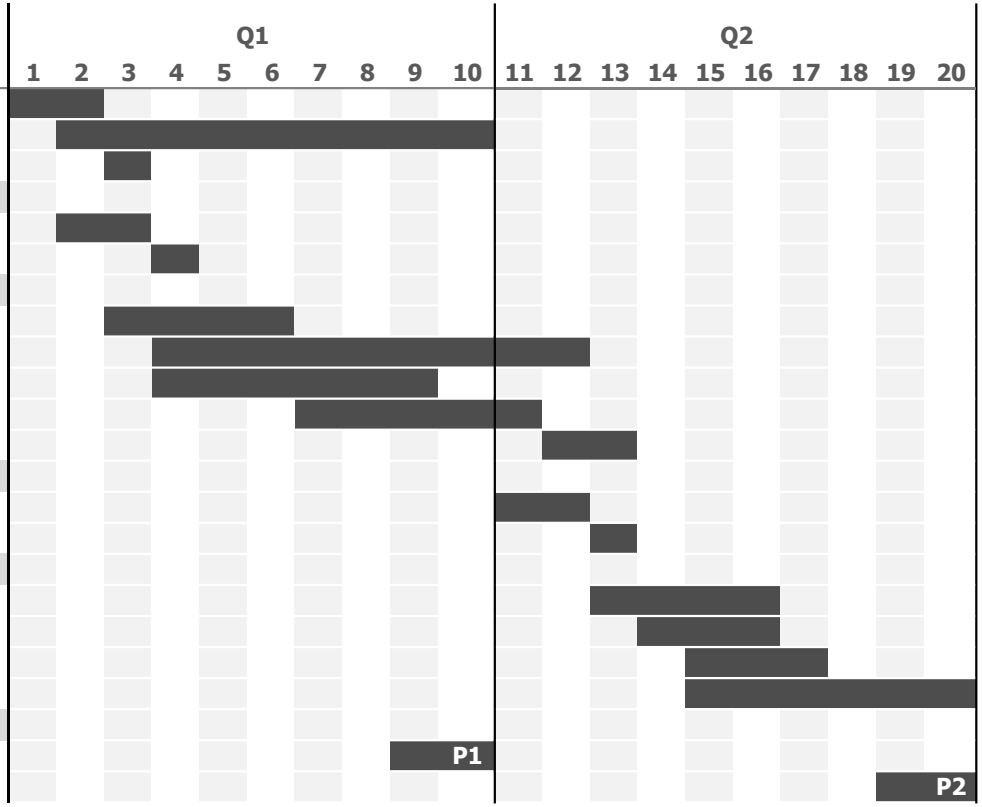
	extraterrestrial exploration, empirical research on human bodies and iterative computational design. The learning process suggests a fruitful manner towards development of personal skill in understanding of automated construction and in applying parametric design on human-centred design that are highly relevant and insightful for future profession.
6.	<u>What are the strengths and weaknesses of using computational design methods particularly in this project?</u> Computational design is known to be powerful as a design-aid tool in generating experimental spaces that could make experientially intriguing three-dimensional spaces that traditional or more manual methods could not easily achieve, which is suitable to be used in this project to certain degree. However, the speed and variety of results that computational method could generate might be a double-edged sword in the design process, since the easiness of generating new results is not as simple as assessing them. During the reviewing process, one may quickly get disoriented in the computational control and be overwhelmed with the geometrical complexity that the results present at once, for instance Voronoi geometries that are used mainly in this project, which could directly replace the focus on architectural senses into an endless computational play and trivial micro tweaks, or even worse physical challenges following an extensive engagement with the computational process. After experiencing a constant use of computational design, I would argue that computational output is different from design output. The iterations generated from computational scripts or models would need to be reviewed attentively and critically, since the swift results from machine means that designers would not immediately be aware of the qualities of each edges or corners of the geometries generated. Especially, in the specific case of this project that focuses on human-centric aspect such as human bodies engagement into posture and movements, thinking computationally which is generally useful for building performance enhancement, might at times seem to be quite distant and less intuitive in translating specificities that human bodies actively suggest in architectural forms. Therefore, it should be acknowledged that computational design could be regarded as a part of the methodological design which does not necessarily provide a holistic literal spatial answer, and any results would need to be carefully assessed and sharply rebuild to fit into precise design intention.
7.	<u>How does lunar habitat project affect your view towards habitat and habitability?</u> Lunar habitat project personally recalls the situation of global pandemic that undoubtedly has a great impact towards at that time hyper-active civilisation on Earth that was forcefully turned down into isolation/ confinement where the trends "stay at home" and "work from home" have changed little or

	much perception on necessity and composition of their habitats or homes. Similarly, designing for a habitat on the moon would put the mindset of thriving in a confined environment in accommodating human nature such as physical and psychological demands as well as refreshed notion of spatial and functional requirements. Stresses could be caused due to the absence of sunlight, fresh air or sensory input from nature which potentially happen in the habitat. Increased sedentary lifestyle that is often promoted by the typical furniture design that maximizes comfort as well as "work from home" that encourages stationary state also leads to physical and psychological discomforts. With that being said, environmental changes and sensory stimulations are the essential elements that habitat design should achieve by attempting to recreate dynamics and reconfiguration. "Work from home" has also exposed a problem of spatial blur between work and rest that could be problematic for human well-being to have no significant physical effort to change between work, rest or even play and eat since everything is directed to be accomplished on one similar functional surface. The idea of playscape thus emerges beyond a superficial narrative, instead working as a reaction towards the demand of body-conscious inclusivity in habitat design to fulfil survival strategy within the enclosed environment. Interaction and plays have become embedded qualities that human need in low gravity for psychological well-being. Lastly, the project has widened my perspective to grasp habitat in both on-/off-Earth conditions as a living system that should accommodate human system that lives and evolves simultaneously where upon the appearance of lunar habitat pioneer, it will have the role to serve as a radical testing foundation to connect human bodies, minds and spaces which insights should create knowledge and benefit loop towards future architecture and built environment.

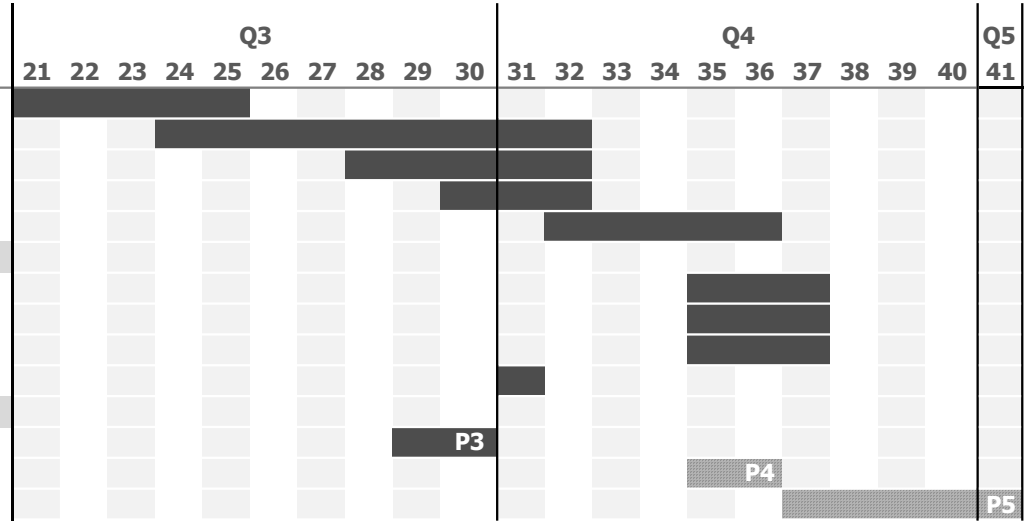
Graduation Planning Realisation

In Progress Completed

	ACTIVITY	PLAN START	PLAN DURATION	PERCENT COMPLETE
Introduction	Initial Idea Pitch	1	2	100%
	Lectures	2	9	100%
	Moonshot Symposium	3	1	100%
Workshop	Design to Robotic Production Workshop	2	2	100%
	Workshop Presentation	4	1	100%
Research	Initial Research	3	4	100%
	Data Collection	4	9	100%
	Concept Exploration	4	6	100%
	Research Plan	7	5	100%
	Body Mapping Exercise	12	2	100%
Excursion	Lava Tube Mission	11	2	100%
	Presentation	13	1	100%
Design	Design Parameters	13	4	100%
	Schematic Sketch	14	3	100%
	Computational System Development	15	3	100%
	Volumetric Schematic Exploration	15	6	100%
Presentations	P1 Preparation	9	2	100%
	P2 Preparation	19	2	100%



	ACTIVITY	PLAN START	PLAN DURATION	PERCENT COMPLETE
Architectural Design	Form Optimisation	21	5	100%
	Interior Planning	24	9	100%
	Structural Systems	28	5	100%
	Envelope Design	30	3	100%
	Furniture Design	32	5	100%
Building Engineering Systems Design	Construction & Assembly Systems	35	3	100%
	Materialisation & Detailing	35	3	100%
	Life Support, Climate Control & Energy	35	3	100%
	Components Modelling & Prototyping	31	1	100%
Presentations	P3 Preparation	29	2	100%
	P4 Preparation	35	2	0%
	P5 Preparation	37	5	0%



Appendix

1. Graduation Plan
2. Graduation Planning

Graduation Plan

Master of Science Architecture, Urbanism & Building Sciences

Graduation Plan: All tracks

Submit your Graduation Plan to the Board of Examiners (Examencommissie-BK@tudelft.nl), Mentors and Delegate of the Board of Examiners one week before P2 at the latest.

The graduation plan consists of at least the following data/segments:

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Name	Jonathan Jonathan
Student number	5955998

Studio		
Name / Theme	Lunar Architecture and Infrastructure	
Main mentor	Henriëtte Bier	Architecture
Second mentor	Ferry Adema	Building Technology
Third mentor	Arwin Hidding	Robotics
Argumentation of choice of the studio	This studio offers a unique and forward-thinking approach in architecture field by addressing unconventional/ highly innovative theme of lunar habitat. The exploration process of such a cutting-edge field provides fresh perspective in design challenges especially in extreme environments which I personally believe is intellectually and professionally enriching as compared to rather traditional studios that I have previously attended. Besides, the emphasis on intersection and application of advanced technology in architecture and construction aligns well with my aspiration to develop skill and insights in complex parametric design which is undoubtedly priceless for architects to have in the near future.	

Graduation project	
Title of the graduation project	Lunar Playscape: Designing a Climbing-based Habitat for Dynamic Human Body and Space Interaction
Goal	
Location:	The Moon (west of Shackleton Crater rim approx. 89.67^{O}S 150^{O}W)
The posed problem,	Interest in space exploration especially on lunar colonisation has been shown with the plan of building long-term habitats on the moon. However, spatial interventions and built structures on the previous missions only addressed primarily functional and

	environmental challenges, while one critical aspect of human value which is the nature of playfulness was often disregarded. Playing is an inherent culture in human bodies and societies as it serves as a medium of social interaction, creativity, and mental health which hints that playfulness is inseparable from habitat design especially when we are discussing a long-term habitation. Absence of conception of playing space or playscape will consequently formulate environments that are overly practical or utilitarian which would impact negatively in the moon settlers productivity and well-being. Besides, working schedule on moon is packed as seen from previous lunar missions, while on top of that there is still mandatory workout. At least 2 hours of daily exercise alone needs to be reserved to prevent muscle and bone density loss which leaves little to no time left for free time and leisure. Several astronauts from the previous missions also mentioned that the routine of working out with the available machines is boring and monotonous, let alone to regard it as a leisure activity. Thinking of long-term habitation, these problems imply to strategise the lifestyle of moon settlers from the architectural aspects to effectively fulfil the work, leisure and exercise requirements.
research questions and	With the problems said, an architectural response is to design a habitat in form of Lunar Playscape that raises a question on: How is the playscape designed as a habitat in lunar environment to foster work productivity, social interaction and overall physical well-being among lunar inhabitants in a long-term setting? Sub-questions: - How is lunar habitat designed to trigger humans' body interaction? - How does lunar physics (i.e. gravity) affect the architectural scale and measurements? - How do the reimagined architectural components reshape the lifestyle of the habitats' dwellers? - How are lunar materials utilised in creating play/ leisure spaces?
design assignment in which these result.	The playscape proposal shall explore possibilities in creating spaces that encourage full body movements in fulfilling the requirement of merging the physical and social demands of living on the Moon. A concept of

	climbing habitat is specified as central to the playscape creation where climbing is promoted as the main movement inside the habitat which emphasises natural physics of lunar environment on humans body (i.e. gravity) as benefits instead of limitations. Climbing which means moving in a considerably vertical direction will allow humans' body to be fully immersed in lunar environment which counteracts the repetitive movement such as walking or taking stairs that humans commonly encounter on daily basis living on Earth. Climbing as activity is also chosen due to its rich potential to be developed into various communal activities in different group sizes. Design of dynamic spaces that are connected vertically or diagonally with climbing walls will need to accommodate not only the required working and living spaces of the inhabitants, but also public areas for collective games and activities in the task of creating physically and socially impactful spaces in a confined interior. All needs to be achieved with a proper consideration of construction method on lunar surface, especially in the In-Situ Resource Utilisation (ISRU) or other material collection methods to ensure the functionality of the private and public spaces and to meet all technical requirements. All in all, the design assignment can be concluded to design a physically playful climbing habitat under lunar gravity that stimulates the inhabitants' body interaction with the surrounding environments and furniture in which also facilitates the community's leisure and social life.

[This should be formulated in such a way that the graduation project can answer these questions.
The definition of the problem has to be significant to a clearly defined area of research and design.]

Process

Method description

The investigation on lunar habitat topic involves several research techniques/ methods and design tools. The knowledge gathered from the initial research serves as a foundation to inform the design direction and exploration. The methods used along the process in general are as follows:

Case studies

Several types of case studies are covered throughout the research process of lunar habitat. Firstly, studies from previous space missions (even though only very few are lunar missions) provide narratives that depict closely the architectural spaces in rockets or space stations, as well as lifestyles of astronauts. The information is crucial to comprehend fundamental limitations, personal and communal desires while living off-Earth through the commentaries of the astronauts. Secondly, case studies on lunar habitat proposals have been presented pretty intensively by several architectural designers in collaboration with space agencies like ESA and NASA. From them, architectural program requirements, materials and construction methods could be observed thoroughly and rethought carefully. Thirdly, presentation by personnel from a completed analogue mission is also delivered which helps the research from a humane point of view as human psychology that illustrates matters like personal behavioural development and inter-crew relationship in a long-term confined environment.

Literature Research

Design guidelines and requirements, technical issues of space construction and materials as well as newest available technologies need to be reviewed since they will highly drive the design tasks. These are found in books and journals of relevant topics as well as news and handbooks released by space agencies such as ESA and NASA. Besides, many institutions and companies have also collaborated in developing specific items (i.e. climbing robots) and in conducting testing (i.e. concrete 3D printing).

Empirical Observation

While the Moon physical attributes are naturally different from the Earth's, it is important to conduct empirical research in humans' bodies postures and movements. Often times, humans might not pay attention closely on how they move on daily basis since they are used to the repetitive movements on earth, for instance walking. Thus, focus or familiarisation on other possible movements in other body parts (i.e. hands and core during climbing) is minimal. With that being said, body postures and movement mapping will be conducted and the results are to be combined with the knowledge of the moon physics which will be helpful in formulating a speculative parameters in the habitat design process. Besides, observation is also made during the lava tube mission where body movements are heavily challenged by the terrain of the lava tubes that aligns well with the theme of climbing habitat. Here, the interaction between body dimensions and various scales on the lava tube floor and wall interfaces are highly apparent which inspires the possible design direction by emphasising the significance of scales in body and architecture components.

Computational design

The flexibility of computational design is the main benefit that should be utilised in the design process of the habitat. The tool can be used in developing design iterations from schematic to details where architectural performances (such as structural efficiency, relationship between human body dimensions with space volumes and wall angles) can be analysed during the processes followed with immediate necessary adjustments. Besides, off-Earth architecture is a progressive

field by nature, where using computational design tool that allows habitat to grow or remain scalable is theoretically necessary for future expansion.

Workshops
The focus of workshops is in understanding Design to Robotic Production (D2RP) process of lunar habitat construction in a hands-on manner. Scale models of building components will be constructed as a continuation of the computational design step. Further, the models will be used to demonstrate the Human-Robot Interaction (HRI) in placing the building components together to simulate partially the lunar on-site construction process.

Literature and general practical references

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Reflection

The graduation topic about lunar habitat ties into the broader MSc AUBS track by addressing complex questions that intersect human-centric design with technological innovation in architectural research and design processes. Specifically, the exploration towards the concept of playscape habitat does not only cater the comfortable and functional spaces for living, but also reimagine a lifestyle that moon requires, which is living in a confined environment. This establishment of architecture would fundamentally be relevant to on-earth habitats and workspaces where creation of new societies develop along with the increasingly critical demand of adaptable and healthy interior spaces. Also, the design direction of the habitat emphasises the relationship between lunar physics (especially gravity) to human bodies. This study would recall for evaluation of body ergonomics which could offer valuable points of reflection for on-earth environments to not only seeing body ergonomics in furniture scale, but also in the design of architecture scale.

From a broader perspective, extraterrestrial habitat design is a cutting-edge field that is still calling for multidisciplinary collaboration especially on combining robotic design and production with human aspects design. This means that throughout the learning process, the skill of processing, understanding and applying parametric design on human-robot interaction is greatly relevant and highly insightful for future profession. Moreover, with the progressive nature of the field, research goals are often set to push beyond typical boundaries of other fields, so that there is a high possibility of significant innovations. With appropriate knowledge transfer, innovations that are initially conceived for space exploration will bring the benefit back to the civilisation on Earth. Lastly, there are also several knowledge that has been applied on Earth such as circular design that utilises local materials, as well as self-sustaining communities that will need to be implemented strictly on extraterrestrial habitation. The execution may serve as an exemplary sustainable lifestyle that are holistic and meaningful to the application for communities on Earth in upgrading sustainable application in many fields, including architecture and construction.

Graduation Planning

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Introduction	Initial Idea Pitch	1	2	100%
	Lectures	2	9	100%
	Moonshot Symposium	3	1	100%
Workshop	Design to Robotic Production Workshop	2	2	100%
	Workshop Presentation	4	1	100%
Research	Initial Research	3	4	100%
	Data Collection	4	9	100%
	Concept Exploration	4	6	100%
	Research Plan	7	5	100%
	Body Mapping Exercise	12	2	100%
Excursion	Lava Tube Mission	11	2	100%
	Presentation	13	1	100%
Design	Design Parameters	13	4	100%
	Schematic Sketch	14	3	100%
	Computational System Development	15	3	100%
	Volumetric Schematic Exploration	15	6	90%
Presentations	P1 Preparation	9	2	100%
	P2 Preparation	19	2	90%
Architectural Design	Form Optimisation	21	5	0%
	Interior Planning	22	6	0%
	Structural Systems	26	3	0%
	Envelope Design	26	3	0%
	Furniture Design	28	3	0%
Building Engineering Systems Design	Construction & Assembly Systems	29	3	0%
	Materialisation & Detailing	29	3	0%
	Life Support, Climate Control & Energy	31	4	0%
	Components Modelling & Prototyping	31	4	0%
Presentations	P3 Preparation	29	2	0%
	P4 Preparation	35	2	0%
	P5 Preparation	37	5	0%