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:

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
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

Benaroya, Haym. *Building Habitats on the Moon*. Cham: Springer International Publishing, 2018. https://doi.org/10.1007/978-3-319-68244-0.

Cervone, Angelo, Henriette Bier, and Advenit Makaya, eds. *Adaptive On- and Off-Earth Environments*. Springer Series in Adaptive Environments. Cham: Springer International Publishing, 2024. https://doi. org/10.1007/978-3-031-50081-7

ESA. 'Concept for a Moon Base'. Accessed 27 October 2024. https://www.esa.int/Science_Exploration/Human_and_Robotic_Exploration/Imagining_a_Moon_base.

'Explore - ESA - ESA's Missions - ISRU'. Accessed 27 October 2024. https://lunarexploration.esa.int/ explore/esa/233?ia=418.

Häuplik-Meusburger, Sandra. *Architecture for Astronauts*. Vienna: Springer, 2011. https://doi. org/10.1007/978-3-7091-0667-9.

Häuplik-Meusburger, Sandra, and Olga Bannova. *Space Architecture Education for Engineers and Architects: Designing and Planning Beyond Earth*. 1st ed. Space and Society. Cham: Springer International Publishing AG, 2016. https://doi.org/10.1007/978-3-319-19279-6.

Hewes, Donald, Amos Spady, and Randall Harris. 'Comparative Measurements of Man's Walking and Running Gaits in Earth and Simulated Lunar Gravity'. NASA Technical Reports Server (NTRS), 1 June 1966. https://ntrs.nasa.gov/citations/19660019917.

'Human Integration Design Handbook'. National Aeronautics and Space Administration (NASA), 5 June 2014. https://www.nasa.gov/organizations/ochmo/human-integration-design-handbook/.

Pickering, A. 'MOON VILLAGE Conceptual Design of a Lunar Habitat'. ESA, September 2020. https://esamultimedia.esa.int/docs/cdf/Moon_Village_v1.1_Public.pdf.

Rappaport, Margaret Boone, and Konrad Szocik, eds. *The Human Factor in the Settlement of the Moon: An Interdisciplinary Approach*. Space and Society. Cham: Springer International Publishing, 2021. https://doi.org/10.1007/978-3-030-81388-8.

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

	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	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%