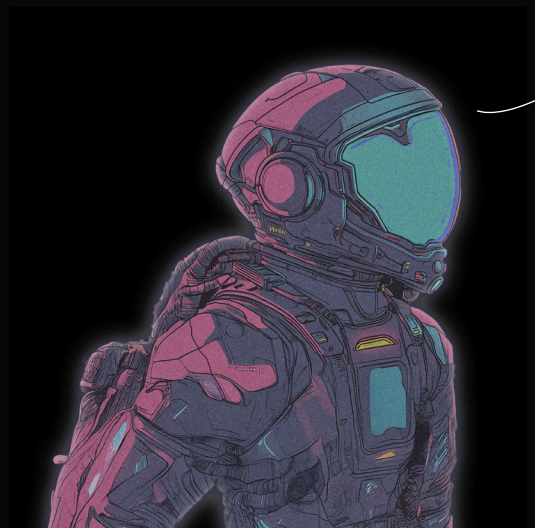
LUNAR PLAYSCAPE

Design for Playfulness in Lunar Habitat

Lunar Architecture and Infrastructure
Jonathan 5955998 | AR3A010 Research Plan
Design Tutors: Henriette Bier, Arwin Hidding
Research Plan Advisor: Aleksandar Staničić
Graduation Project 2024-2025 TU Delft BK

LIVING ON THE MOON?

to work?
to play?
to commune?



CONTENTS

Fig. 1 Earth view from lunar surface, photograph from Apollo 17

I. INTRODUCTION

Interest in space exploration especially on lunar colonisation displays opportunities of intriguing portrayals of lifestyle beyond the Earth. Recently, projects like Artemis by NASA and International Lunar Research Station (ILRS) led by China have shown rigorous studies on building permanent habitats on the moon.[1] These existing space stations and developed concepts of lunar habitat primarily depict spatial intervention by addressing only functional and environmental challenges, while one critical aspect of human value which is the nature of playfulness often gets disregarded.[2] Playing is an inherent culture in human bodies and societies as highlighted by Johan Huizinga in his book Homo Ludens.[3] It serves as a medium of social interaction, creativity and mental health which hints that playfulness is inseparable from habitat design for humans to live in. In earlier NASA's Apollo missions, astronauts who experienced lunar surface were spontaneously engaged in playful activities which suggests an intrinsic desire of playing and recreation even within the brief period of staying.[4] Consequently in long-term habitation, absence of intentional conception of play space or playscape risks formulating environments that are overly practical/utilitarian which would impact negatively in the moon settlers productivity and well-being. This signals the need to explore leisure aspect on the design of off-Earth habitats in incorporating playfulness spatially. Thus, the project raises a question about how the playscape is designed as a habitat in lunar environment to foster work productivity, social interaction and overall well-being among mooners in a long-term setting.

[1] 'NASA's Artemis IV: Building First Lunar Space Station - NASA', accessed 27 October 2024, https://www.nasa.gov/general/nasas-artemis-iv-building-first-lunar-space-station/; Andrew Jones, 'China Is Taking a Keen Interest in Lava Tubes as Possible Lunar Habitats', *SpaceNews*, 9 September 2024, https://spacenews.com/china-is-taking-a-keen-interest-in-lava-tubes-as-possible-lunar-habitats/.

[2] 'Concept for a Moon Base', ESA, accessed 27 October 2024, https://www.esa.int/Science_Exploration/Human_and_Robotic_Exploration/Imagining_a_Moon_base.

[3] Johan Huizinga, *Homo Ludens: A Study of the Play-Element in Culture* (Boston: Beacon Press, 1955).

[4] Haym Benaroya, *Building Habitats on the Moon* (Cham: Springer International Publishing, 2018), 248, https://doi.org/10.1007/978-3-319-68244-0.

II. THEORETICAL FRAMEWORK

Designing a lunar habitat involves both physical and social challenges which conceptually will be addressed through the design of playscape in this project. Firstly, social perspective will be seen through Huizinga's Homo Ludens; secondly, physical demand will be discerned from conditions at existing space stations; and lastly relationship between physical and social values have been elaborated in theoretical project of Constant's New Babylon.

A. Humans and Play

It extents logically that moon presents an empty social state like a blank canvas: no existing culture and societal structures except for those brought within astronauts' mind from the earth. Meanwhile, according to Johan Huizinga (one of the pioneers of modern cultural history) in his book Homo Ludens a study of the play element in culture, humans (including astronauts) are naturally playful, and "play as a given magnitude" has existed "before culture itself existed".[5] He added that play personifies as "special form of activity" that embodies significantly "as a social function" and forms itself a "social construction."[6] It is clearly reflected that culture always "has the play-character", thus playscape holds a crucial role in defining social bonds when we are talking about creating a new society in lunar habitat.[7] This statement connects to the fact that humans are social creatures, thus social interaction within playscape could reasonably counterbalance the sense of isolation and dullness of living off-Earth.

Additionally Huizinga explained that the "sacred play-forms" have been flawed in the contemporary society (on Earth) where humans focus to compete with a mindset of high "material interest".[8] The introduction of "technology, publicity and propaganda" has caused 'play' to become a "secondary characteristic" which contradicts human nature.[9] This is an intriguing idea to interpret that the blank-state of lunar society could revive the significance (and purity) of playscape through the application of playfulness as basic form of humanity. Therefore, the novel lifestyle on the moon through the lens of playscape means the re-activation of fundamentals of play that are in fact universal in humans but not necessarily sensitive anymore on Earth due to the distractions of complex societies.

B. (Outer) Space and Play

Play as closely connotated with leisure has rather distinct reality when it applies to off-Earth missions, especially in physical sense. As observed in the schedule of outer space missions, daily life on moon is likely to remain highly work-oriented.[10] It is also shown that the short allocated time of leisure has to cover the heavy physical requirement, which is to conduct two-hour daily workout (Fig. 2), not to say that the entertainment on space stations has only featured passive media such as magazines from Earth.[11] This has inherently misled the psychology of play or leisure physically as implied by a Salyut astronauts, Valery Ryumin, that the working out routine in space is "boring and monotonous."[12]

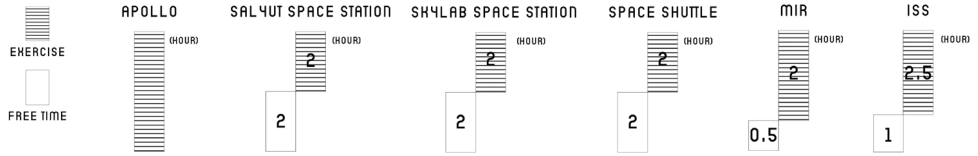


Fig. 2 Definition of leisure time (daily) in past and current space missions

5 Huizinga, *Homo Ludens*, 4.

6 Huizinga, 4.

7 Huizinga, 52.

8 Huizinga, 199–200.

9 Huizinga, 200.

10 Sandra Häuplik-Meusburger, *Architecture for Astronauts* (Vienna: Springer, 2011), 50, https://doi.org/10.1007/978-3-7091-0667-9.

11 Häuplik-Meusburger, 50; Sandra Häuplik-Meusburger, Manuela Aguzzi, and Regina Peldszus, 'A Game for Space', *Acta Astronautica* 66, no. 3 (1 February 2010): 605–9, https://doi.org/10.1016/j.actaastro.2009.07.017.

12 Häuplik-Meusburger, *Architecture for Astronauts*, 267.

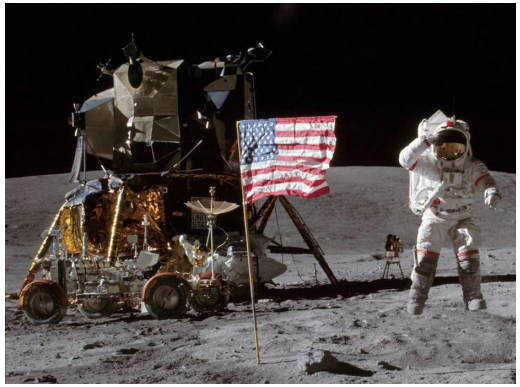


Fig. 3 Alan Shepard (Apollo 14) playing golf on the moon
Fig. 4 David Scott (Apollo 15) doing hammer and feather experiment
Fig. 5 John Young (Apollo 16) jumping for mid-airsalute photo

Meanwhile, the nature of playing – by physically engaging body with the lunar conditions such as gravity has occurred in several cases of Apollo missions, outside of the strict tasks and schedule that astronauts had to follow (Fig.3, 4, 5).[13] With the gravity that is just 1/6 of the Earth, a natural playful urge is claimed by astronaut Charles Duke from Apollo 16, "we got excited and we were going to do the high jump, and I jumped and fell over backwards. That was a scary time…"[14] These phenomena evidently ask for the provision of playscape in the future lunar habitat to enable the settlers to physically blend into immersive lunar environment. More importantly, the playscape shall address the physical workout requirement that could be demanding and tedious which would answer the query on how lunar gravity could be integrated into daily movements of lunar settlers.

C. (Architectural) Space and Play

The discussion of relationship between work, leisure and physical dynamics in a society has been presented in visionary framework of Constant's New Babylon (Fig. 6) which emphasises critics on spatial limitations and rigid society that pre-determines someone's life with "obligation to labour" to live.[15] Constant reimagined if "we are freed of the tyranny of labour of obligation" and let the technology of automation to meet the basic needs, we would be able "to play" to satisfy human's playful nature which would create "culture that is for everyone".[16] Significant idea from this work is relevant to lunar habitat design where work and play forces at the playscape will need to intersect in forming a new culture that is fundamentally shaped for lunar physical condition.

[13] 'The Apollo 15 Hammer-Feather Drop - NASA Science', NASA, accessed 11 November 2024, https://science.nasa.gov/resource/the-apollo-15-hammer-feather-drop/; 'Apollo 14: Shepard Hitting Golf Ball on Moon', 1 January 1970, https://ntrs.nasa.gov/citations/19950023897; 'John W. Young's Lunar Salute - NASA', NASA, accessed 11 November 2024, https://www.nasa.gov/image-article/john-w-youngs-lunar-salute/.

[14] Benaroya, *Building Habitats on the Moon*, 248.

[15] *Constant. New Babylon* (Madrid: Museo Nacional Centro Reina Sofia, 2015), 274, https://issuu.com/museoreinasofia/docs/constant._ingl__s.

[16] 'Constant Nieuwenhuys', Nieuwe Instituut, accessed 11 November 2024, https://nieuweinstituut.nl/en/projects/work-body-leisure/constant-nieuwenhuys.

Furthermore, Constant explained that designers task is to "invoke the fantasy of human playfulness" instead of dictating the "playful or inventive behaviour" of society.[17] This statement may suggest architectural interpretation that inspires design strategies to find impactful and healthy habitat although inhabitants have to live in a sealed interior space. Several most relevant points are to utilise "mechanized devices" in reconfiguring artificial landscape that would promote physical dynamics; to personalise "material and climatic conditions" according to users preference; also to refine connection between interior and exterior.[18] Most importantly, New Babylon relates to the reimagination of a new society of how if humans are "less rational and a little less selfish" by rooting back to their playful nature.[19] This notion is applicable in lunar society that is self-sufficient, as an adjustment from the materialistic society in contemporary Earth.

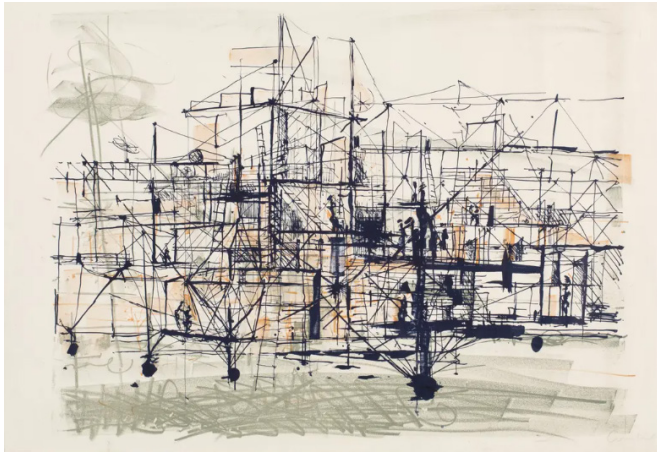


Fig. 6 New Babylon by Constant

[17] 'New Babylon 1956-1974', Fondation Constant Stitching Constant, accessed 11 November 2024, https://stichtingconstant.nl/constant/periods/new-babylon-1956-1974.

[18] Marco Ferrari, 'New Babylon - L'utopia Nomade Di Constant', *Artwort* (blog), 23 June 2015, https://www.artwort.com/2015/06/23/architettura/new-babylon-lutopia-nomade-di-constant/.

[19] Ferrari.

III. METHODOLOGY

This design research combines speculative and phenomenological approaches: understanding the physics and technical challenges of lunar construction is limited to the current technology advancement that leaves some aspects speculative. Besides, designing habitat means to think from the lived experience perspective by deriving concepts from some lunar phenomena, for instance the lunar gravity. This leads to study like lunar ergonomics on how differently physical movements on the moon could form a special social identity for the lunar settlers.

A. Lunar Surface (Conditions and Materials)

Moon has notable physical attributes compared to what humans are accustomed to on Earth which becomes the first thing to understand before designing lunar habitat. Conditions such as lunar gravity that is mere one-sixth of the Earth gravity, and physical threats like radiation and micro meteorites set critical requirements of the habitat design.[20] Another priority would be familiarisation towards available materials and fabrication methods to answer logistical challenges in transporting materials from Earth. Lunar construction is expected to benefit mostly from In-Situ Resource Utilisation (ISRU).[21] Regolith or lunar soil (Fig. 7) is one instance of in-situ material that has a great potential as main building material with effective radiation protection degree and promising potential to be 3D printed in bulky size.[22] Further exploration of available materials on lunar surface will consequently introduce more design opportunities in the lunar habitat.

[20] Benaroya, *Building Habitats on the Moon*, 42–47.

[21] 'Explore - ESA - ESA's Missions - ISRU', accessed 27 October 2024, https://lunarexploration.esa.int/explore/esa/233?ia=418.

[22] Angelo Cervone, Henriette Bier, and Advenit Makaya, eds., *Adaptive On- and Off-Earth Environments*, Springer Series in Adaptive Environments (Cham: Springer International Publishing, 2024), 39–56, https://doi.org/10.1007/978-3-031-50081-7.

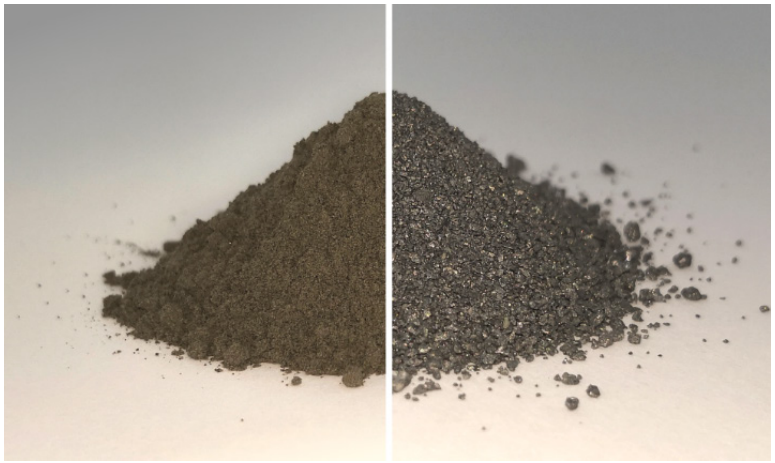


Fig. 7 Regolith (lunar soil) and metal extracted from the regolith

B. Human-Robot Interaction

Human activities on the moon will be closely assisted by robotic systems including habitat construction which requires designers to be familiar with the human-robot interaction process and to integrate the steps into the design process. A project called Design to Robotic Production Assembly (D2RP&A) is an example of human-robot interaction technology that is advanced in Delft Technological University (Fig. 8).[23] This project may inform designers how fabricating and combining building components on lunar surface works through prototyping in speculated materials and conditions closely mimicking the lunar surface. More specifically, foam blocks are used to imitate regolith weight on moon; they are milled by an autonomous drilling robot into certain geometries that have been previously coded; then stacked to create a structure using robot hand while being assisted by humans' hand.[24]

[23] Cervone, Bier, and Makaya, 20-36.
[24] Cervone, Bier, and Makaya, 20-36.

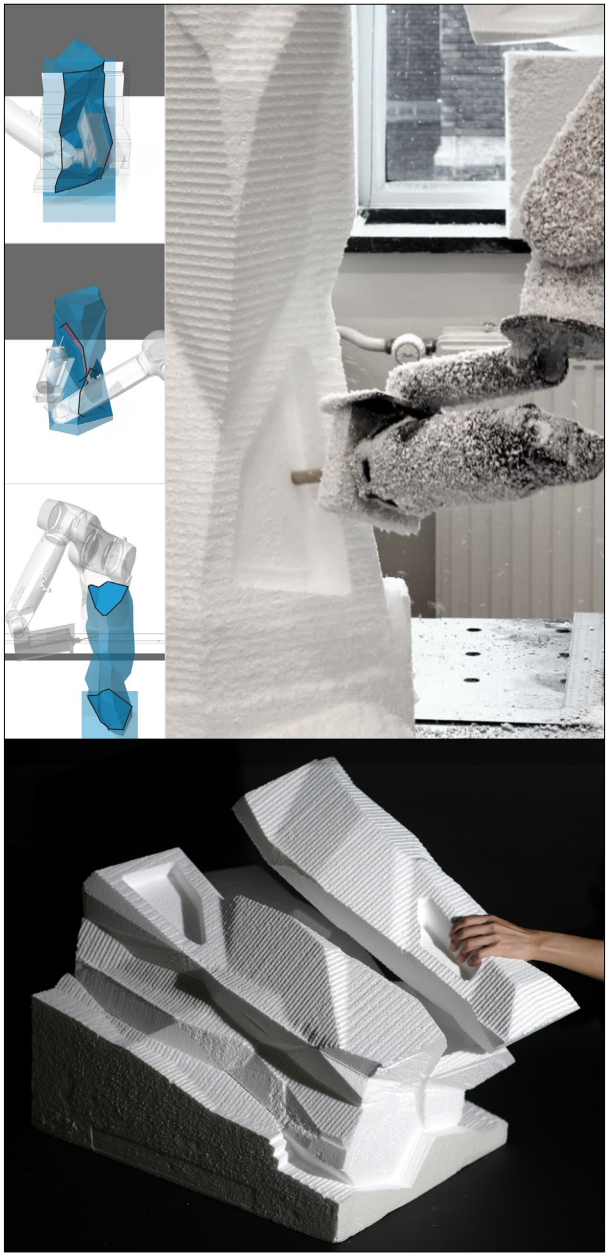


Fig. 8 Design to Robotic Production and Assembly (D2RP&A) workshop in TU Delft to familiarize with existing technology of autonomous construction

C. Humans Bodies Ergonomics VS Gravity

A significant impact of lunar gravity is experienced directly towards humans' body which affects ergonomics differently from Earth which calls for further study. Conventional Earth movements and specific postures of running, walking, sitting and exercising could be irrelevant on the lunar surface where it is found that humans walk and run 40 per cent slower on moon (Fig. 10).[25] This phenomenon proposes the design of playscape through rethinking of necessary movements under lunar gravity and incorporating physical activity with architecture elements. For instance, climbing could be adapted as new ergonomics and promoted extensively into daily movements of the lunar settlers. It might also serve as alternative of the time consuming and monotonous workout as it endorses postures that actively stress different parts of human bodies (Fig. 9).[26] As translation to the architectural design, components like net suspensions and climbing walls could be utilised in defining spaces that also support the playful and dynamic movements of the lunar settlers.

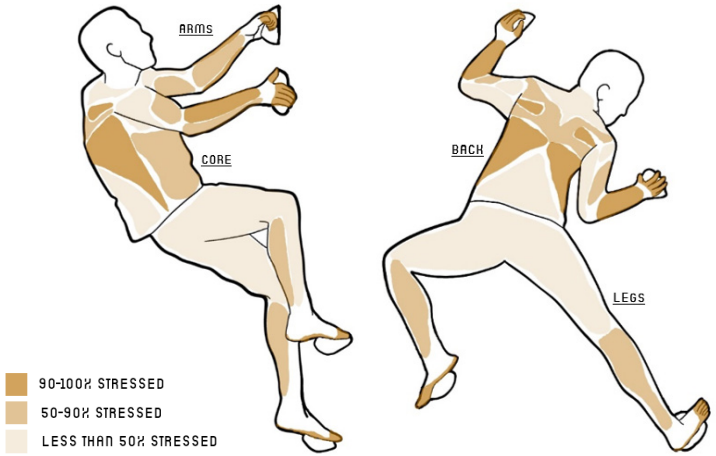


Fig. 9 Muscle activation on humans' bodies in climbing action

[25] Donald Hewes, 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), 7, https://ntrs.nasa.gov/citations/19660019917.

[26] Mirjam Boss, 'Muscles Used In Rock Climbing: What Groups Does It Work?', 24 July 2021, https://www.thewanderingclimber.com/muscles-used-in-rock-climbing/.

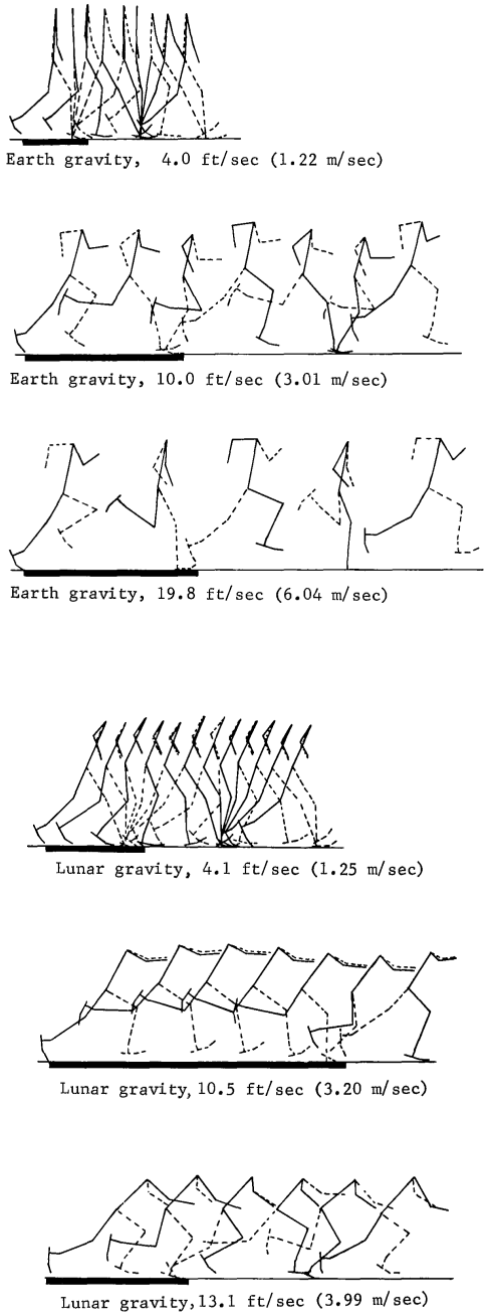


Fig. 10 Study by NASA of typical walk and run on earth and moon, the result shows that humans move 40% slower horizontally on the moon compared to earth.

D. Verticality in Lunar Lava Tube

Lava tube as a site for lunar habitat (Fig. 11) has gained popularity for its natural capability to shield radiation and meteorites.[27] Responding to its vertical structure, the playscape design would be directed likewise to represent a radical concept that contrasts to the typical structure of Earth. A powerful playscape could be achieved by exploring vertical spatial connection followed by vertical social interaction. Under lunar gravity conditions, humans could jump higher, fall slower from higher elevation, and climb faster with lighter body weight – these activities could reform a new playful lunar routine.[28] By emphasising vertical lifestyle within the lunar community through the habitat's architectural configuration, common rituals of engaging bodies vertically would proceed along with an identity formation that is vital for sustaining a society. The authenticity of the lunar settlers' lifestyle compared to a more horizontal life on Earth would naturally develop their awareness towards their bodies and the nature of playfulness.

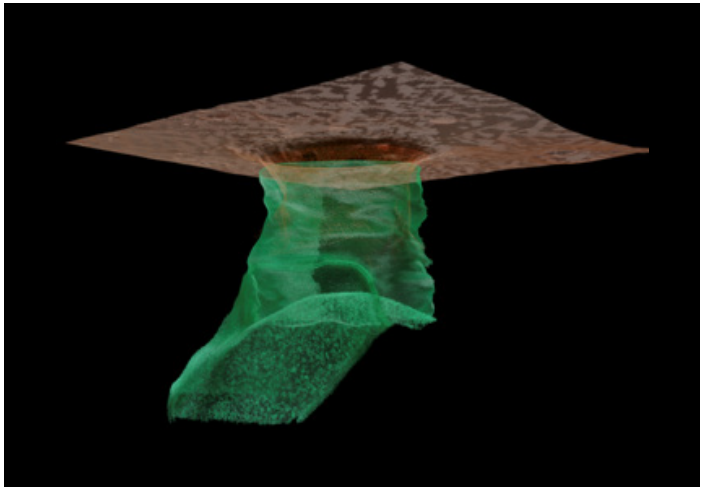


Fig. 11 Assumptive model of lunar lava tube

[27] Jones, 'China Is Taking a Keen Interest in Lava Tubes as Possible Lunar Habitats'.

[28] *The Science of Moon Hopping* (European Space Agency, 2023), https://www.esa.int/Science_Exploration/Human_and_Robotic_Exploration/The_science_of_Moon_hopping.

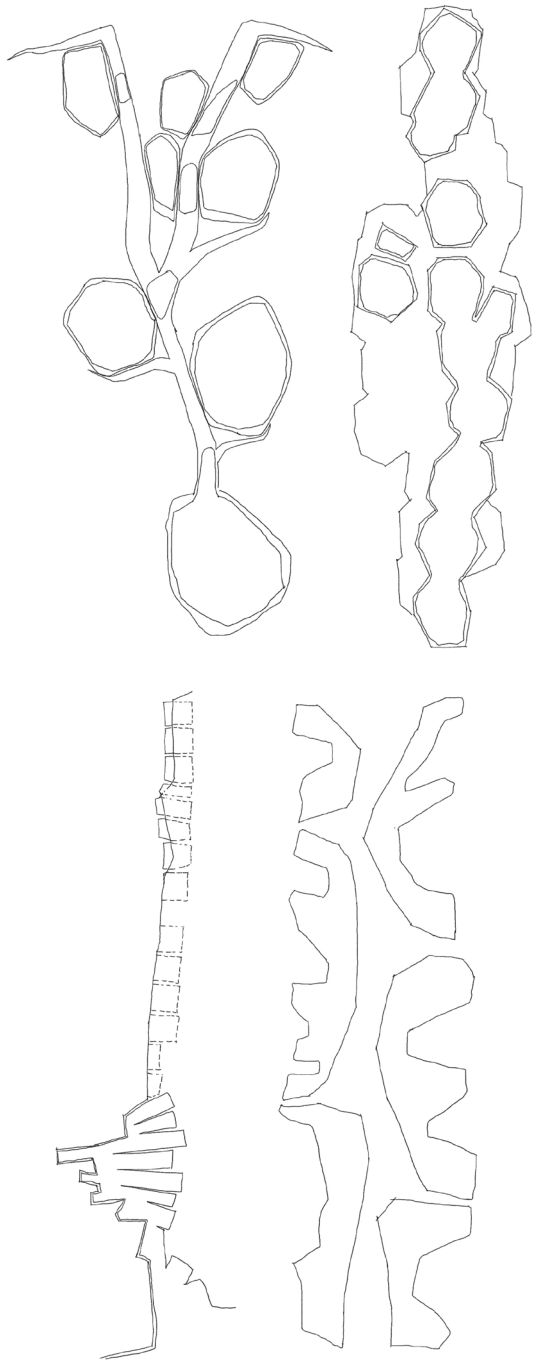


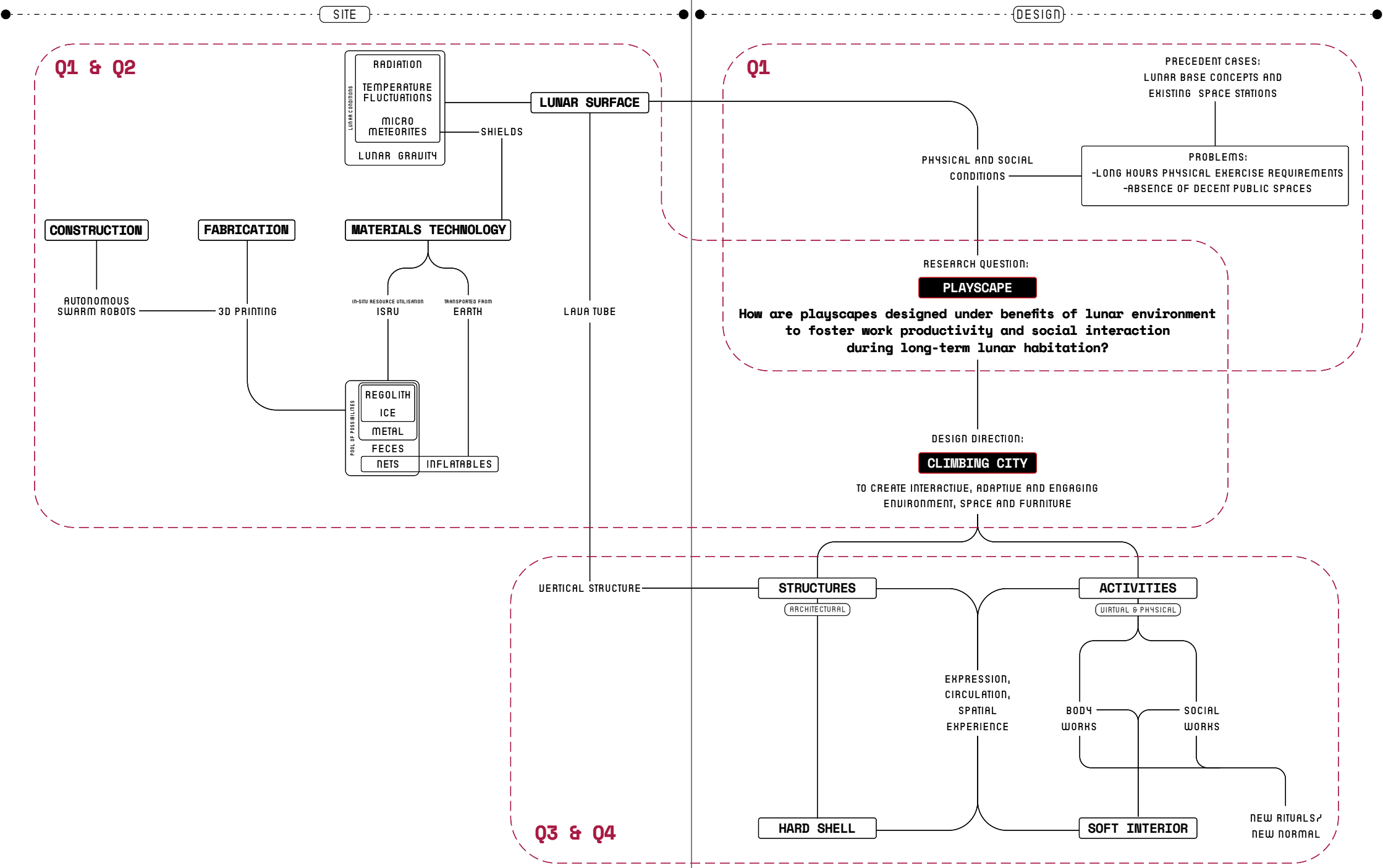
Fig. 12 Initial sketches for growing/ climbing vertical structures

IV. CONCLUSION

Lunar Playscape envisions a dynamic habitation on the moon that combines concept of playfulness and advantages of lunar condition such as lunar gravity and verticality of lava tube. By creating such environment, it is hoped that the habitat could foster physical fitness, work productivity and social interaction for the coming lunar settlers, as well as to promote several supplementary thoughts which include body ergonomics; importance of social identity; as well as reflection of a more inclusive society than the one on Earth despite the much harsher natural environment and limited resources that the moon offers. Therefore, the design of Lunar Playscape would be directed to a theme that well represents the identity of the habitat, such as creation of “Lunar Playscape: Climbing City” while simultaneously informs unique spatial quality and lifestyle that base the physical and social engagement in the nature of playfulness.

Fig. 13 Moon view and earth’s atmosphere from the ISS during supermoon August 2023

V. RESEARCH PLAN DIAGRAM



VI. BIBLIOGRAPHY

'Apollo 14: Shepard Hitting Golf Ball on Moon', 1 January 1970. https://ntrs.nasa.gov/citations/19950023897.

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

Boss, Mirjam. 'Muscles Used In Rock Climbing: What Groups Does It Work?' *The Wandering Climber* (blog), 24 July 2021. https://www.thewanderingclimber.com/muscles-used-in-rock-climbing/.

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.

Constant. New Babylon. Madrid: Museo Nacional Centro Reina Sofia, 2015. https://issuu.com/museoreinasofia/docs/constant._ingl__s.

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.

Ferrari, Marco. 'New Babylon - L'utopia Nomade Di Constant'. *Artwort* (blog), 23 June 2015. https://www.artwort.com/2015/06/23/architettura/new-babylon-lutopia-nomade-di-constant/.

Fondation Constant Stitching Constant. 'New Babylon 1956-1974'. Accessed 11 November 2024. https://stichtingconstant.nl/constant/periods/new-babylon-1956-1974.

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

Häuplik-Meusburger, Sandra, Manuela Aguzzi, and Regina Peldszus. 'A Game for Space'. *Acta Astronautica* 66, no. 3 (1 February 2010): 605–9. https://doi.org/10.1016/j.actaastro.2009.07.017.

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.

Huizinga, Johan. *Homo Ludens: A Study of the Play-Element in Culture*. Boston: Beacon Press, 1955.

Jones, Andrew. 'China Is Taking a Keen Interest in Lava Tubes as Possible Lunar Habitats'. *SpaceNews*, 9 September 2024. https://spacenews.com/china-is-taking-a-keen-interest-in-lava-tubes-as-possible-lunar-habitats/.

NASA. 'John W. Young's Lunar Salute - NASA'. Accessed 11 November 2024. https://www.nasa.gov/image-article/john-w-youngs-lunar-salute/.

NASA. 'The Apollo 15 Hammer-Feather Drop - NASA Science'. Accessed 11 November 2024. https://science.nasa.gov/resource/the-apollo-15-hammer-feather-drop/.

'NASA's Artemis IV: Building First Lunar Space Station - NASA'. Accessed 27 October 2024. https://www.nasa.gov/general/nasas-artemis-iv-building-first-lunar-space-station/.

Nieuwe Instituut. 'Constant Nieuwenhuys'. Accessed 11 November 2024. https://nieuweinstituut.nl/en/projects/work-body-leisure/constant-nieuwenhuys.

The Science of Moon Hopping. European Space Agency, 2023. https://www.esa.int/Science_Exploration/Human_and_Robotic_Exploration/The_science_of_Moon_hopping.

VII. IMAGE CREDITS

Fig. 1 *Crescent Earth*, NASA, accessed 20 November 2024, https://science.nasa.gov/resource/crescent-earth/.

Fig. 2 Illustration by Author, information from Sandra Häuplik-Meusburger, *Architecture for Astronauts* (Vienna: Springer, 2011), 42–84, https://doi.org/10.1007/978-3-7091-0667-9.

Fig. 3 'Apollo 14: Shepard Hitting Golf Ball on Moon', 1 January 1970, https://ntrs.nasa.gov/citations/19950023897.

Fig. 4 'The Apollo 15 Hammer-Feather Drop - NASA Science', NASA, accessed 11 November 2024, https://science.nasa.gov/resource/the-apollo-15-hammer-feather-drop/.

Fig. 5 'John W. Young's Lunar Salute - NASA', NASA, accessed 11 November 2024, https://www.nasa.gov/image-article/john-w-youngs-lunar-salute/.

Fig. 6 'Constant Nieuwenhuys', Nieuwe Instituut, accessed 11 November 2024, https://nieuweinstituut.nl/en/projects/work-body-leisure/constant-nieuwenhuys.

Fig. 7 'Explore - ESA - ESA's Missions - ISRU', accessed 27 October 2024, https://lunarexploration.esa.int/explore/esa/233?ia=418.

Fig. 8 Photos and illustrations by Author

Fig. 9 Illustration by Author, information from Mirjam Boss, 'Muscles Used In Rock Climbing: What Groups Does It Work?', *The Wandering Climber* (blog), 24 July 2021, https://www.thewanderingclimber.com/muscles-used-in-rock-climbing/.

Fig. 10 Donald Hewes, 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), 7, https://ntrs.nasa.gov/citations/19660019917.

Fig. 11 'Existence of lunar lava tube cave demonstrated', UniTrento Press Room, accessed 20 November 2024, https://pressroom.unitn.it/comunicato-stampa/existence-lunar-lava-tube-cave-demonstrated.

Fig. 12 Illustration by Author

Fig. 13 NASA Johnson, *August's Supermoon*, 31 August 2023, photo, 31 August 2023, https://www.flickr.com/photos/nasa2explore/53182000082/.