Orbital Space Architecture

Quantifying recreation in nature in order to artificially fabricate it in a habitat in outer space

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Abstract

In today's world, the way we live has had major influence from technology. Since the industrial revolution, technology is shaping our lives. The new technologies are focusing more and more on the body. This study projects the human into the future of the technological advancements in the built environment to the moment where we are occupying outer space and living in the machine itself, the space station.

Architects have already begun investigating designs of alien typologies beyond Earth. There are two challenges with those proposals. Firstly, the more thoroughly researched ones are based exclusively on a planetary surfaces, either the Moon or Mars. This is practical because of the local soil's mass for protection against lethal radiation and the available in situ materials for construction and life support. However, it is more expensive and harder to escape their gravitational wells and there is no guarantee that the gravity is enough to keep the human body healthy. Secondly, the proposals predominantly suggest an outer shell with an obscure volume and later populate the interior with a regular layout and program that is identical to those on Earth (fig.1, fig.2). This does not take into account human factors in relation to isolation, enclosure, and reduced gravity.

Outer space is a harsh environment, yet in its function, it is ultimately undefined. There are no established typologies or styles. This gives the opportunity for architects to begin thinking about space habitats with the human as the center of the design. The design process can be entirely from the inside out or as we would say on Earth - 'bottom-up'. This research proposes a design approach that has the human and their experience as a starting point. In an isolated and extreme environment, the need for social interactions and recreation become vital to the mental health of people. The focus is on the human experience on Earth - the interaction with nature in a public park and the tools we use in that environment to rejuvenate and replenish our spirit. This experience is itemized with a focus on the human body. The result from the analysis is divided into three chapters on different aspects important to the experience - body motion, views of the surrounding environment, and sounds.

*Fig.1 Moon village design for the 2021 Venice Architecture Biennale by SOM (*Ghinitoiu *2021). It features a spiral staircase with riser same as on Earth, while the gravity on the Moon is significantly lower.*

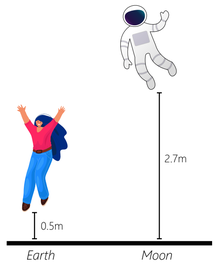


Fig.2 Comparison of the average hight to which a person can jump on Earth and on the Moon. On Earth a person can jump to 0.5m and on the Moon to 2.7m (Bright Side 2021). This shows that, for example, staircases in the two situations do not need to be the same.

Relevance

Could you live here for 5 years?

Fig.3 Expedition 59 flight engineers (from left) Anne McClain, David Saint-Jacques and Christina Koch inside the U.S. Destiny laboratory (n.d. 2019).

The human in space - Why should we think about settling space?

Our species has advanced from cavemen to a worldwide civilization for the past several hundred thousand years. We have gradually developed tools and methods to tame the wilderness in hot, dry, wet, and cold climates to make it safe and comfortable, as Gyorgy Kepes (1956, 18) phrased it - "In times of self-confidence, man was able to domesticate the worlds and gradually bring it into his human scale." The 'human scale' being the physical or imagined borders that frame parts of the planet and make us feel comfortable there. The physical borders could be a house or town walls. The imagined borders are territories that we have a mental map of and could navigate with ease. This also has allowed us to operate in and take advantage of our environment. Today there is another area that we strive to grasp - the technological advancements with which we attempt to keep up. We could accept that a single person is unable to comprehend all the world's information or land, but, as a whole, humanity is capable.

Our journey to outer space has a comparable dynamic. Once we felt sufficient confidence, as a result of industrialization and technological advancement, we took the next step and traveled beyond the atmosphere. A universe opened before our eyes and we saw more clearly than ever our place within it, both literally and figuratively. Our expansion on Earth is limited but beyond it, we are liberated. Earth is but a speck on a cosmic scale. Should we stay here forever?

The settling of outer space is the act of bringing parts of it into our human scale. That act will make us feel comfortable to go further. By increasingly larger and more complex space stations we are adapting to the way of life in outer space and we begin to grasp its vastness and hostility. It is the next island to settle. Gradually, the space habitat will become a settlement and people will stay for longer periods of time and they will define the future of how we live there. Based on this line of thinking this thesis assumes that the future of humanity is in space.

Space promises to bring us economic, political, sociological, scientific, and environmental benefits (O'Neill, 1997, 36-38). The energy sector, for example, will advance significantly as a result of the newly revived space interest. Space stations require to be designed as circularly as possible in resource usage. This teaches us lessons for efficient living on Earth. Additionally, plans are being proposed for solar power to be produced in space and used on Earth. The utilization of asteroids rich in precious materials will reduce pollution from mining and manufacturing here. The extraction of resources from asteroids will require a human colony. Wherever people go there will be a habitat and as architects, we can add value to the lives of the inhabitants. Architecture in outer space is a design challenge guided by different restrictions to what we are used to and yet it is still built form for future people and it is still architecture.

The architect in space - What value can we add as architects to the current space station design?

The current space habitat where people coexist for a significant period (6 months at a time) is the International Space Station with a habitable volume of 388m^3 (Garcia 2021) (fig. 3). If we build settlements for people to occupy for 5 years, it will have to feel like home (Connors, Harrison, and Akins 1985, 82-85). It will have to suit both the basic needs of residents and provide numerous leisure activities that will form communal life. What would those activities be and how might we begin to define the conditions required for them to occur in outer space? How would they differ from the ones on Earth, if they are not justified by culture or context? Here is the point at which this research embarks.

The International Space Station is the ultimate machine for living. It was designed and built by engineers to be compact and as easy as possible to assemble. Is space station design a field entirely reserved for engineers? Probably for the near future, it is. As architects, we grapple with big questions for the past, present, and future of humanity. We put people at the forefront of our thinking. Wherever people go architects follow to construct the environment to be inhabited.

Engineers have a fundamentally different approach to solving problems. They are given a mission, which they divide into separate goals that have to be achieved for its success. These goals come with their sub-tasks and problems that have to be resolved by discrete teams, and in the end, the different parts are integrated within one system (Hauplik-Meusburger and Bannova 2016, 12-13). Meanwhile, architects ask overarching questions about the mission itself - why do we do it and what makes sense to be a priority of a construction project for people in outer space?

There is more to be gained from architects designing for space. As we know, a new place with new constraints opens our minds to new ways of approaching a topic or problem. We might question norms and rules that are followed here on Earth. For example, if we do not walk in microgravity, why do we need floors? Simple situations in outer space might have many thought-provoking conundrums that will stretch our perception of what is vital to us, our values, and, ultimately, how we do architecture here on Earth. Space architecture perhaps could be of greatest interest to the research of two major streams of thought - the human-machine interaction and the human-environment interaction. On one hand, there is the space station's shell and services- a habitat machine, a living organism, built into the nothingness of space. It will be the epitome of smart living and the eventual consequence of our attempts to make our smart homes and cities here on Earth. On the other hand, is the human utilizing their environment created within the space station and the purposeful designing of that environment for positive affordance. The question of how the body occupies its setting in different gravity levels than the one on Earth is essential to designing an efficient habitat that supports a person's health and comfort. This research focuses on the second of the two major topics identified here although their courses are related.

Important part of future space stations - Focus on recreational activities.

In order to give form to an environment for people in outer space, where there is no context, we can begin by thinking about the personal experience of a resident of a future colony. What might they need if they live there for 5 years at a time apart from the essential life support systems? Probably that person would expect to be able to enjoy a similarly comfortable life as they did here on Earth. A balanced fulfillment of duties and relaxation is the way we normally spend our days. The daily habits and rituals are important to us. We will have to provide an environment that allows those to occur. There are behaviors on several timescales that are part of our lives. Adapting the theory of behavior by Atelier Bow-Wow to the discussion purely focused on a single person, we can frame life into four timescales (Tsukamoto and Momoyo 2012, 9-10). On the smallest scale is the daily routine, which is characterized by waking up, regular meals, children going to school, traveling, working, interacting with colleagues, meeting friends, communicating with family, and sleeping. This takes up most of the time of an average adult with a family. On the weekly scale, a person might spend time with a group of friends, go to a restaurant or a bar, go to the park, practice sports, or go to a church. On a monthly scale, they might visit relatives, have important meetings, or visit their children's school. On a yearly scale, happen the holidays and traveling to visit new places. These vary from person to person. With such a model of human habit on Earth, we can begin to focus on what should we accommodate in a habit in outer space.

Consequently, we can derive that the larger the time scale the larger the area that a person covers on Earth and the larger the community of people involved. With the growth of the scale, it also becomes increasingly harder to imagine how it can be compacted into an artificial and enclosed environment. Generally, we could say that we have captured the smallest, daily, one within the built form in our cities already. What about the weekly activities? Those begin to happen in areas that are slightly more complex and involve larger numbers of people. Here, we also find a large number of vital leisure activities. Recreation plays an important role in health and happiness. It is something that we will most definitely have to build into a future space colony for occupants to strengthen communities and develop a sense of belonging to the place - essential for them to feel at home. This is the scale that we shall dive into in the current study.

The public park is one of the first steps from a city to the wider environment at our disposal on Earth. It is outdoors and brings wildlife and biodiversity to the city. Communities evolve within it. It houses a vast range of activities and can be adapted to many uses. The park instills calmness that rejuvenates us by reducing anger, stress, and anxiety. Our built environment is enriched by it. With so many positives, such a feature would be a necessary addition to the habitat for extended occupation. The goal of this thesis is to study the human experience in a public park in order to create an artificial environment that yields such a mode of recreation.

Research question

How can we simulate the spatial experience of recreation in nature?

What does one minute during a picnic with friends in a public park look like? How do the surroundings facilitate the experience to have a rejuvenating and invigorating effect on people? What is the dynamic of the human body in relation to its surroundings and other people? What objects does the body interact with? What effect do those have on the person's experience? How would that experience happen without gravity?

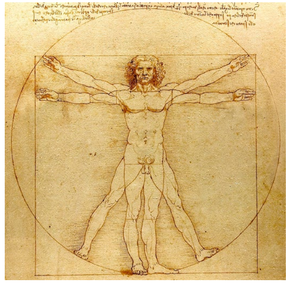


Fig.4 Vitruvian man (Da Vinci 1485-90)

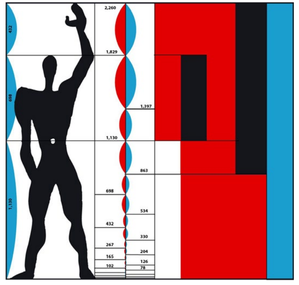


Fig.5 The Modulor (Le Corbusier 1958, 57)

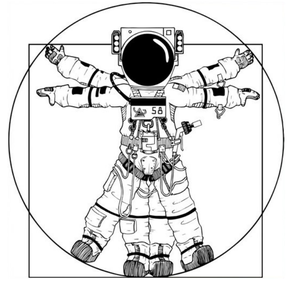


Fig.6 Vitruvian astronaut (Araiza n.d.)

From body to architecture

In order to understand how to use the body's experience as a design guide for future habitats, it would be of use to position the research within the wider view of architecture as it has been advanced in the past by similar notions. By doing this, we would hope to extrapolate not only a logical continuation of a branch of an established theory in architecture but also a method used to study the body and its environment. Primarily we analyze 20th-century avant-garde art and architecture in the industrial and technological context. This thesis' topic is similar to the questions asked a hundred years ago because it positions the person and body in a new scientific societal revolution - the one of building the future mode of living in outer space. It is argued that personal experience should be the inspiration for the new built environment.

What brings together, under the same functional laws, vernacular architecture from across the world is the human body that occupies them. It is its size and capability that transcends cultural influence to make a living space practical and safe. In Europe, the human body's scale and proportions have been a conscious fascination of architects already since the 1st century BC. Vitruvius' (1960) 'Ten Books on Architecture' define the perfect ratio of body parts, which was then translated into a building's proportions. Famously, the 'Vitruvian Man' by Leonardo da Vinci draws on the notion of ideal proportions and relates the person to the world. Later, Le Corbusier devises the Modulor following the golden ratio. This returning to the fundamentals of the body attests to the persistent presence of the body as a central role in the theory of architecture.

From craftsmen to industry

In our contact with the complete reorganization of stuff and labor, which was the industrial revolution, the classical model for art and architecture became nonrepresentative of the change in the social and demographic conditions (Artists Network Staff, n.d.). At the time, art movements questioned and reimagined the aesthetics, scale, ornament, form, and function of architecture and art. After an initial nostalgic grip of the past, Art Nouveau (1890s) and Art Deco (1920s) slowly explored ways of expressing the spirit of the industry-oriented society (Artists Network Staff, n.d.). In that context, the human body was seen as part of the masses, as a unit. Yet, in the common everyday worker's life was what architecture should be about - clean and functional.

Mechanization of the world dominated all facets of life, changing norms and status quo. Designers slowly learned how to use the new methods for production and out of their work with new materials came the new look for our homes, both for exterior and for furniture (Giedion 1969, 489-507). The new look was derived from the way factories manufactured products along an assembly line, instead of simply attempting to mimic old ornaments and forms.

The human body was the focus of the study for functionality and efficiency. Chairs, airplane cockpits, kitchens, and other spaces or objects were based on basic human ergonomics. The body was studied in motion as well as in rest. It was traced in its movements in order to map patterns and devise efficient user-oriented experiences. Étienne-Jules Marey's methods for photographing and mapping bodies in motion benefited our understanding of nature and the world. Studies of the efficient movements of people became what factories needed to optimize their production lines and increase output (Giedion 1969, 32).

The strive for functionality was implemented into every aspect of living. The 'Frankfurt kitchen' by Margarete Schütte-Lihotzky was an outcome of the analysis of the workflow in the kitchen (fig.7), which was then translated to an arrangement of the hardware and appliances to reduce the movements required (Bois 2020). Ernst Neufert and others in Bauhaus sought the human scale in all its typical activities in daily life and use of furniture and architecture and devised the Architects' Data, which is used until today as a rule of

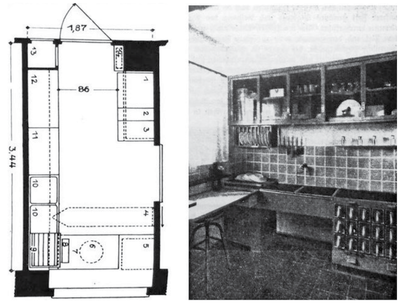


Fig.7 Frankfurt kitchen by Margarete Schütte-Lihotzky (May 1926).

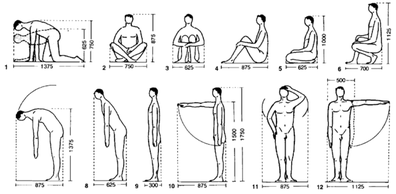


Fig.8 Body measurements (Neufert 1936, 9)

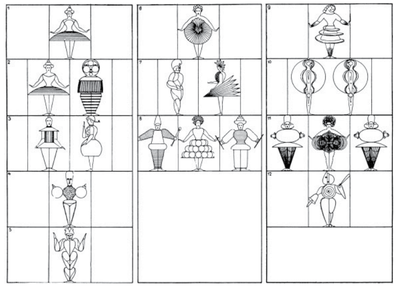


Fig.9 Abstract of the triadic ballet (Schlemmer 1961).

thumb (fig.8) (Neufert 1936). This has become the standard for architecture throughout the world based on living in a mechanized society.

In that regard, Bauhaus represented a fundamental step towards the practice in architecture today. The collectivization of people was also the union between architects, artists, and craftsmen. With common thinking, they would be able to design the whole spectrum of modern life - imagery, objects, furniture, and architecture (Gropius 1919). That ambition led to the question of the place of people in their environment both physically and consciously.

Oskar Schlemmer's work in the theater portrays robot- or doll-like masks and costumes that were inspired by the industrial period. The dances in the Triadic ballet were also inhuman (Triadisches Ballett von Oskar Schlemmer 2013). The human body was only capable of restricted balance and athletics. It has its natural limits in the Earth's environment. The body could only be obstructed and challenged further and not be liberated by its fundamental obstacles. Only a robotic figure could defy the natural laws. Schlemmer took these ideas as inspiration for his costume design. He abstracted the body in proportions, form, and movement to challenge the perception of how we inhabit our surroundings (Schlemmer et. all, 1961, 17-19). He used the cubical and oval forms to outline the different parts of the body (fig.9) and exhibit their proportions. Through these methods, Schlemmer expressed his view of people in the industrial age, the new look, and the style of regularity and repetition.

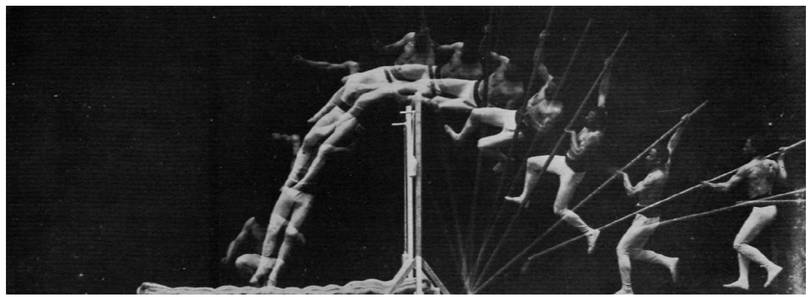


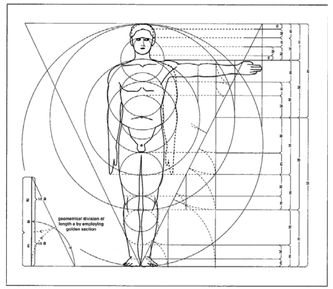
Fig.10 A man jumping over an obstacle (Marey 1890)

From idealized body to environmental affordance

More recently the idea that the body and its scale could be the basics for a functional design has been challenged. A field of research has been done using James Gibson's (1986) 'The Ecological Approach to Visual Perception' as a basis for affordance study of environments in which we operate. It is theoretically different from focusing solely on the body because it sees the relationship of the body to its surroundings as inseparable. The study of the way bodies can take advantage of objects goes beyond the purely single purpose, 'perfect design', according to a single size measurement of the body (Souza 2020). Partly the argument stems from the fact that the standardized body type, used for measuring how tall a chair should be, does not communicate the variety of the body's shapes and sizes. Environmental affordance focuses on the surroundings and the opportunities it can provide for a body. Thus the design directive of the concept comes from a test and evaluation process, rather than the body itself as the starting point.

Our attempts to tame the character of the machine world and become synonymous with it have kept falling behind the progress of technological advancement. The adjustment of society to the technology of the 20th century was a continuation of industrialization. "Rapid expansion of knowledge and technical development have swept us into a world beyond our grasp" (Kepes 1956, 19). Sciences have dealt with this by reducing fields into smaller, more precise specializations, each one drifting apart from the others.

Through art, we have attempted to capture a more complete understanding (Gropius, in Kepes 1956, 94). Yet, science has continuously advanced and changed our lives even with the lack of our capability to overview the entirety of its growth. It seems that our system has a natural way of fitting subparts, which grow in isolation, into a coherent whole. It could be said that this study is complacent about subdividing topics by focusing on an extremely particular research situation for the sake of scientific rigor. However, this research attempts to focus on a fundamental starting point for thinking about a new way of living not only in outer space but also on Earth. It falls back on the principles explored at the beginning of the 20th century when lifestyle had to be redesigned - it explores the human body and its environment to extract spatial insights. Similarly to what has been the fascination of Étienne-Jules Marey (fig.10), Ernst Neufert (fig.8), and others from the end of the 19th and early 20th century, here the human body is studied so that the new advancements in the built environment will be based on the fundamentals of functionality. Additionally, we will analyze the external factors that afford the habits of the body. Our presence in our surroundings is what defines them for us and what gives them meaning.



a.

Standardization

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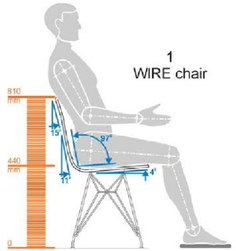
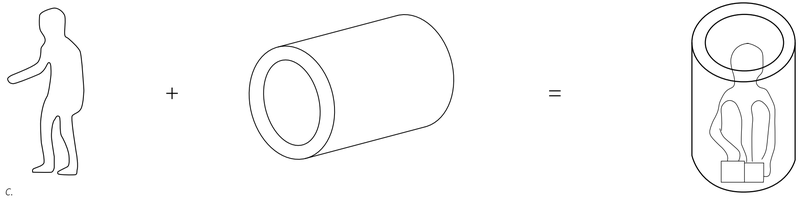


b.



c.

Affordance

Fig.11 Comparing approaches of standardization and affordance.
Diagram adopted from:
a. The Universal Standard (Neufert 1936, 9)
b. Sitting positions for the Wire, Plywood LCW, Rocking, Diamond and Tulip chairs (Cionca, Muscu, and Bartha 2013).
c. Multiple affordances of an object (Atmodiwirjo 2014)

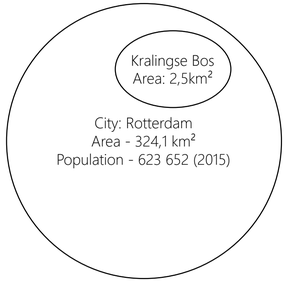


Fig.12 Kralingse Bos, Rotterdam (Algemeen Dagblad n.d.)

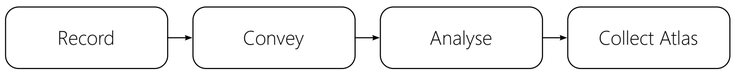
The methodology for this thesis is derived from previous examples of ways the body was studied to influence architecture for a change. In the same way, multiple times in the past to rethink norms and functionality, architects have gone back to observe the basic principles of the body in its environment to produce architecture that answers the basic fundamental requirements. To do this, the study focuses on the activity of recreation in nature. More precisely, the activity of sitting with two other people in a park, having beer and snacks. The specific park targeted for the study is Kralingse Bos, which is the largest city park in Rotterdam, the Netherlands (Fig.12).

Kralingse Bos (Kralingse Bos n.d.):
- total area = 2,5 km²
- water = 1 km²
- forest = 1 km²
- open areas = 0,5 km²

In the setting specified above, a set of recordings shall be made during one minute of the experience of a person. The motion of the body, surroundings, direction of gaze, sounds, and interactions shall be documented (Diagram 1). The means of capturing those aspects of the experience will be:

- stationary video
- wide-angle video
- microphone - sound recording
- personal notes
- temperature
- sky overcast

The result of these recordings is then visualized into sequential diagrams, charts, and sketches to turn data gathered into a design tool, but also to study and pick out details that might relate to the recreational experience of the person (Diagram 2). When we talk about recreation what is meant is the act of doing something for pleasure. It does not involve any aspect that is related to what we might consider as work. It also does not include exercising. Leisure in this case does involve contact with other people in a natural environment with water, trees, grass, and park furniture.
With these methods, the research tries to gain insight into what is considered the most important aspects of a person's experience in a particular environment. The goal is to extract insights from what are the constituent elements of that environment that add to the positive, leisure, relaxing, enjoy being in nature. The natural vegetation and life of the park are key for this study because it is something that might be perceived as hard to be encapsulated and captured as an experience in a room.



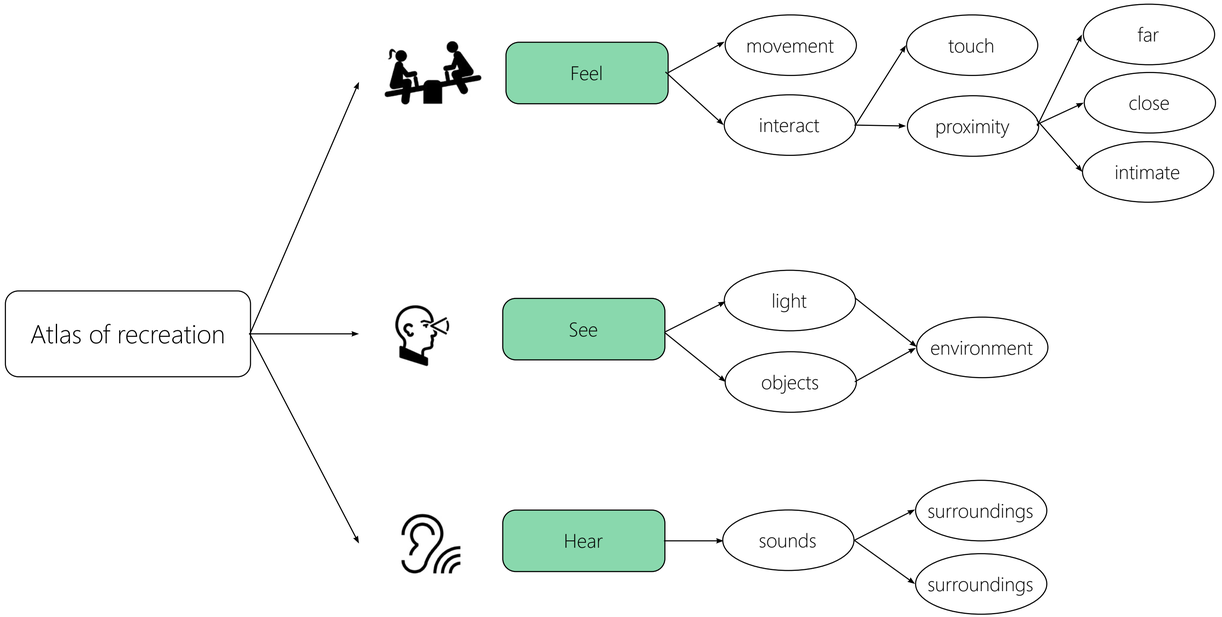


Diagram 1 *Diagram of the different aspects of the experience that will be recorded during the study.*

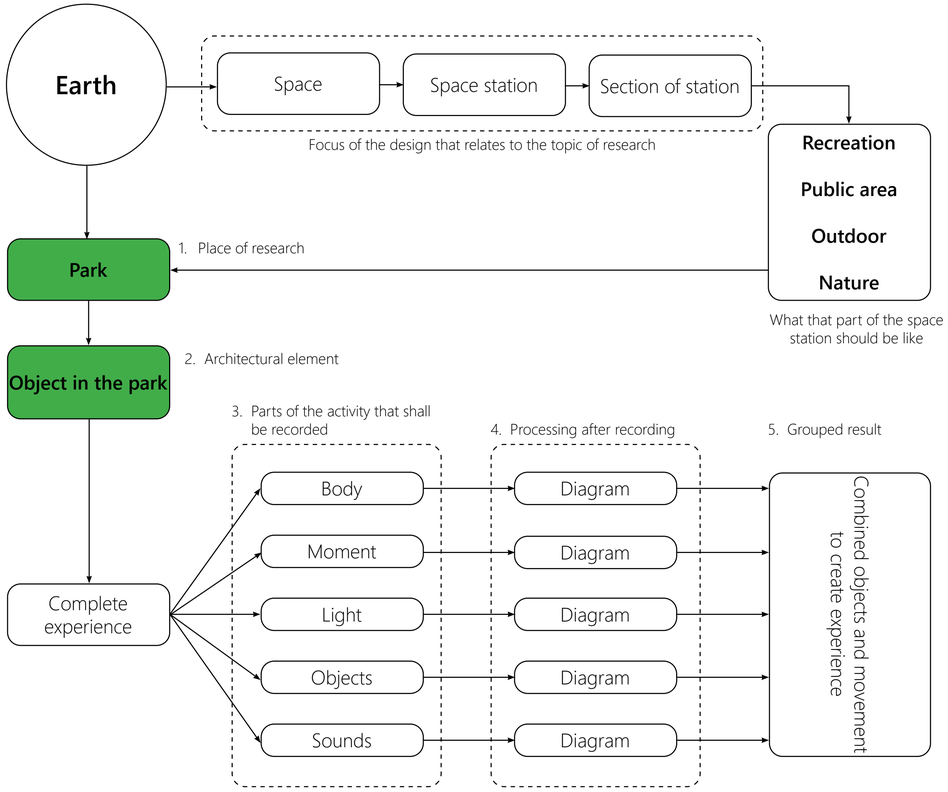


Diagram 2 *Methodology*

This diagram is showing how the methodology of analysis on Earth relates to the specific design of a recreational facility in a space colony in outer space. The research method takes 5 major steps that can be seen here.

1. *Picking a place on Earth that creates experiences that are to be emulated in the space colony.*
2. *Picking a man-made object or architectural element from the park.*
3. *Recording people's experience in relation to that object with video, pictures, and sounds.*
4. *Analysing the recordings in diagrams and mapping of the human in relation to that architectural element.*
5. *Collecting the findings into a structured and clear form.*

Expected outcome

Chapter 1: Feel

Chapter 2: See

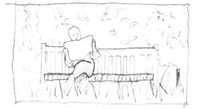
Chapter 3: Hear

Diagram 3 After studying the focus areas of the activity, the results are grouped into three chapters. Chapter 1 - for the body habits and behavior; Chapter 2 - the environment that facilitates the experience; Chapter 3 - the sounds that create the atmosphere during the activity.

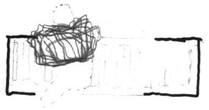
This series of studies are first attempts at representing movement and the areas around the body it occupies.
The first example is of a person reading a newspaper for 5 seconds. The situation has been sketched in 3 ways.
1. *The whole picture with surroundings*
2. *Only the newspaper being flipped in relation to the human body*
3. *4 frames per second for 5 seconds of the activity of the whole body and the newspaper outlined.*

The second example is of a man performing a fencing movement (04.). The analysis that follows is of the space the man occupies during the movement and the area he does not and the flow of movement of different parts of the body simultaneously.

00. Person reading a news paper

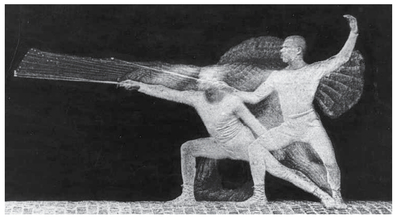


01. Complete view

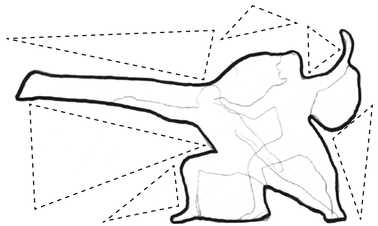


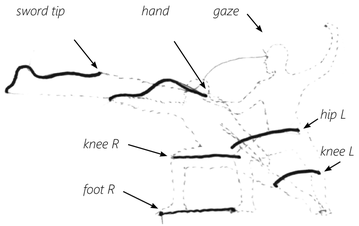
02. Only the movement of the newspaper in relation to the body

03. 5 Seconds of reading a newspaper

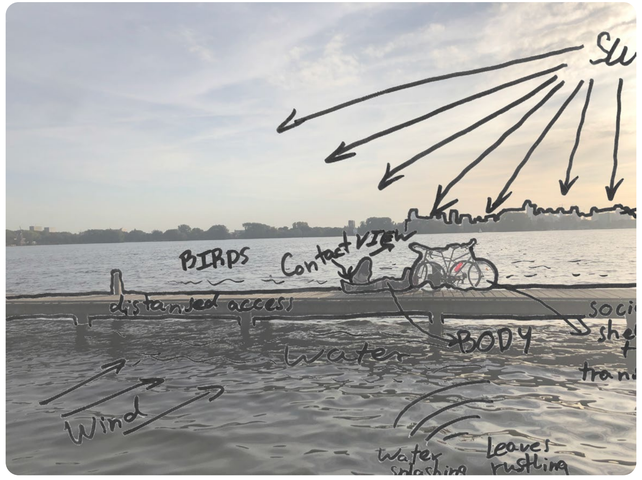


04. Stroboscopic image of a fencing movement





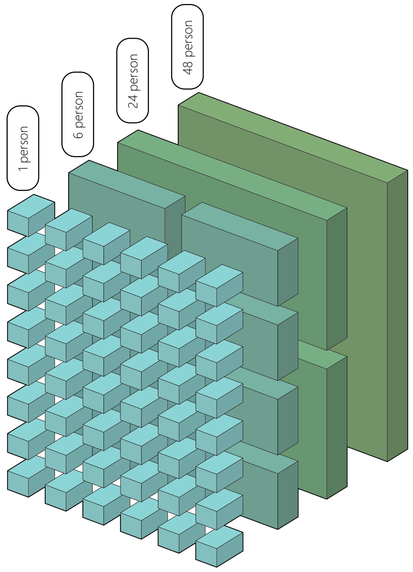
Play me



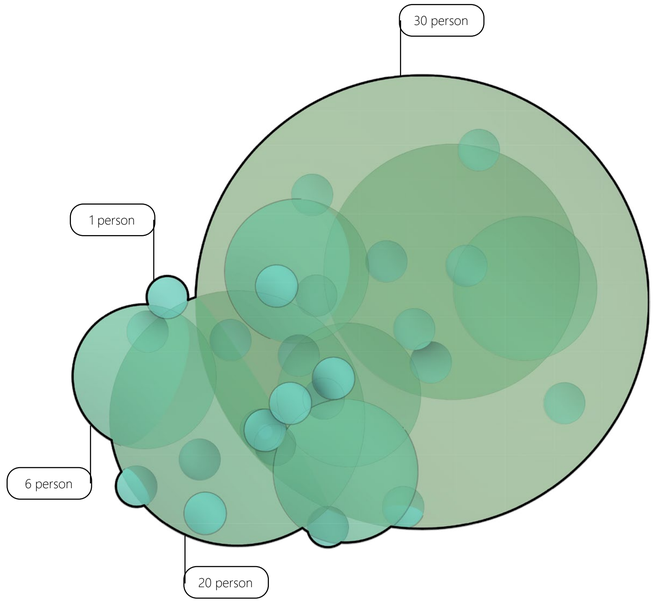
Kralingse Bos, Rotterdam (by author)

Lessons learned from initial testing: *This image shows the multitude of variables in any given 'real' situation in the public park. This is the challenge when trying to translate an experience on paper. Thus, the area of focus around the activity and the object of study will be important for the research. It will be vital for the final result to have clear boundaries on which parts of the surroundings are included both in terms categories (natural elements, light/shadow, movement, man-made objects, etc.) and rage (5/10/n m radius) from the activity.*

Design concept: Privacy in a closed community



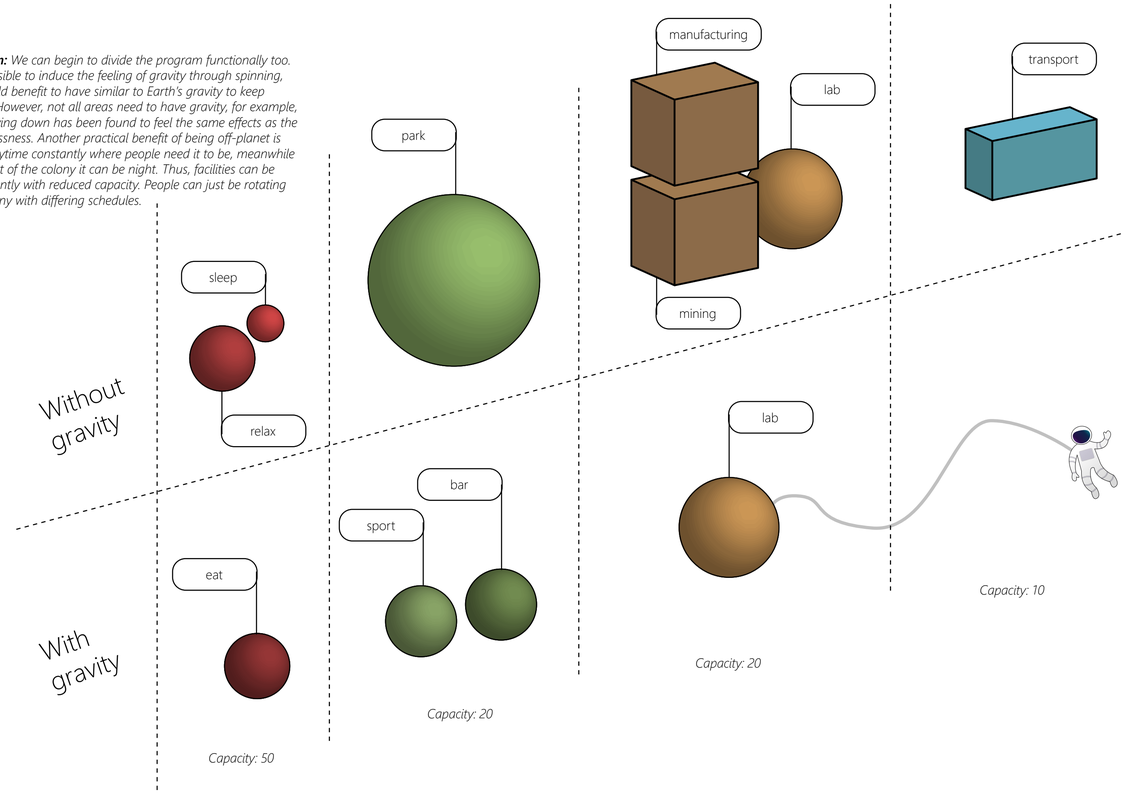
Non-communal model of private and public



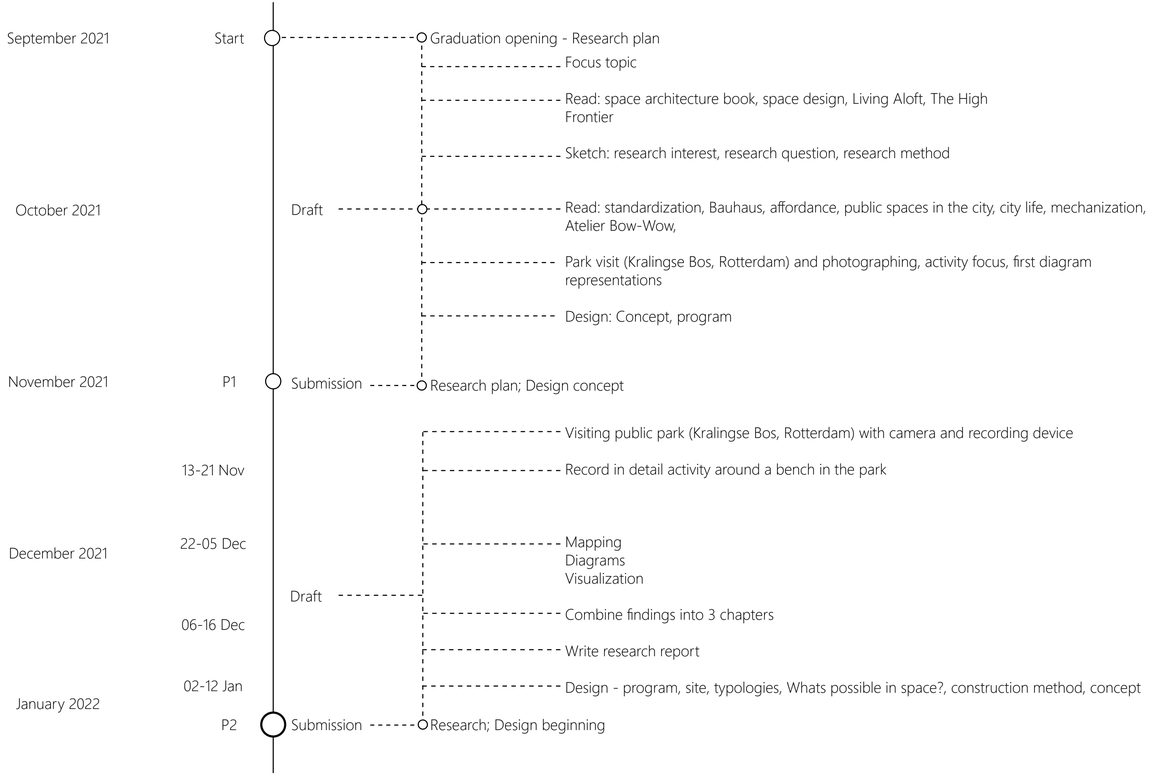
Communal model of private and public

The design concept that shall come out, as a result, will be related to the person within a closed community. If the residents in a space colony live there for 5 years, they will be sharing that habitat with 50 people with little opportunity for external diversity. How to sustain that community and provide that people maintain healthy relationships amongst one another? On Earth, we have our personal space and can choose to take retreats if we need to. We can choose to take part in public events whenever. Private and public will be a vital balance for the space community. It is fascinating to think about what privacy might be like in a closed community. We can imagine a structure in which public and private are closely knitted and personal space is available throughout.

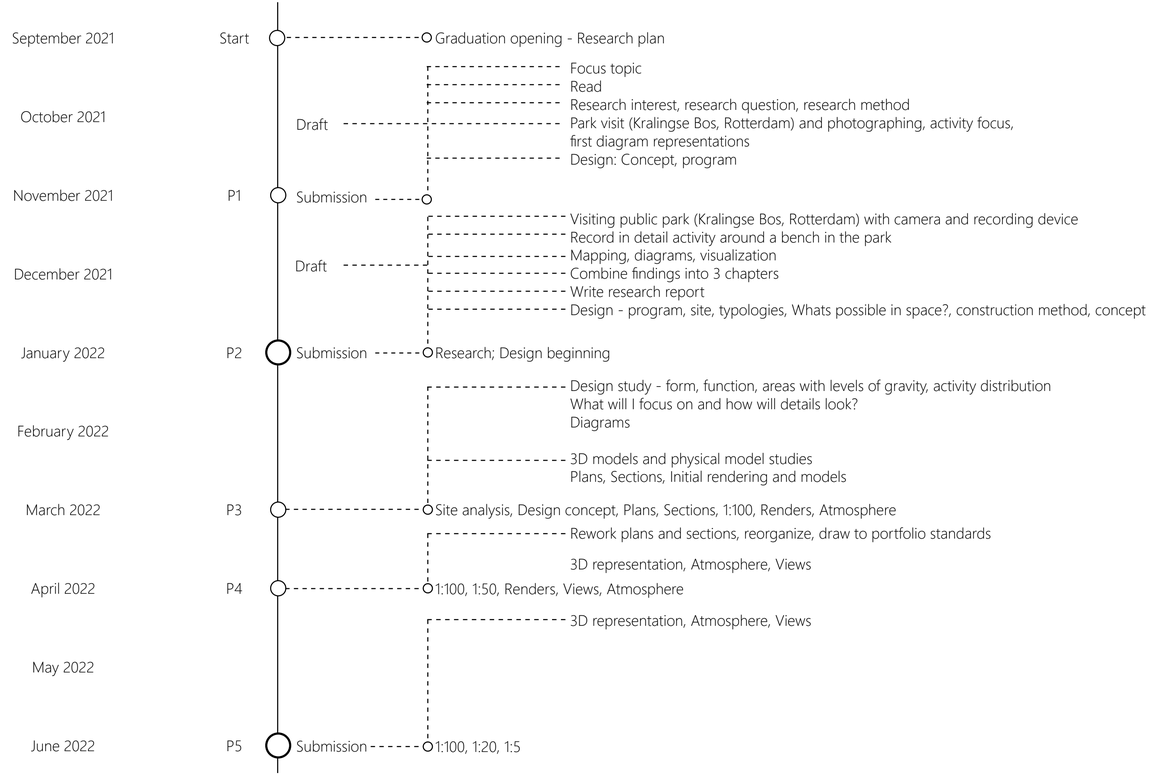
Design diagram: *We can begin to divide the program functionally too. Because it is possible to induce the feeling of gravity through spinning, some areas would benefit to have similar to Earth's gravity to keep people healthy. However, not all areas need to have gravity, for example, the body while lying down has been found to feel the same effects as the body in weightlessness. Another practical benefit of being off-planet is that it can be daytime constantly where people need it to be, meanwhile in a different part of the colony it can be night. Thus, facilities can be utilized permanently with reduced capacity. People can just be rotating through the colony with differing schedules.*



Research plan



Graduation plan



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