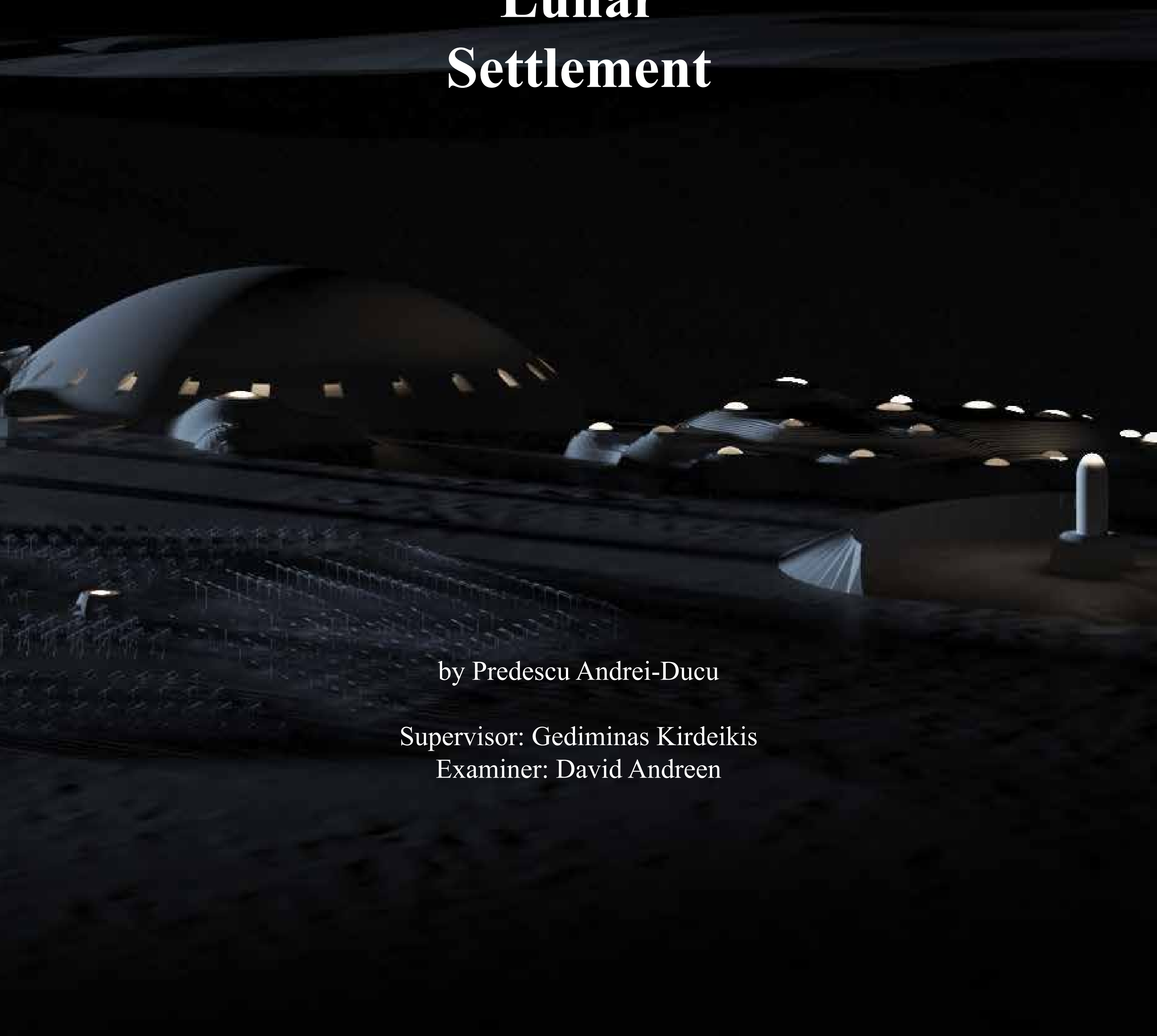

Multi-Corporate Lunar Settlement

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Preface

Throughout the last 50 years a great deal of proposals dealing with Lunar habitation have been published, however many of these deal with this problem through a very engineered perspective and ignore many aspects of living a fairly "normal" life within this environment.

The project at hand seeks to offer an utmost realistic vision, given current knowledge, into what a lunar settlement built in support of creating a place just a step away from home could look like and function. The project comes as a support for developing a thriving community of more than 300 individuals. Through the investigation of human physiological and psychological needs it establishes a series of design principles and revolves around the development of architectural solutions dealing with public and private space within the Lunar context.

It does not explore lunar construction techniques but respects principles already proposed in this field.

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Introduction

Lunar settlement has been a hot topic in recent years, and is seen as the next leap in the history of humankind. Although many proposals have been made with regards to lunar living, most of these deal with small-scale habitats, focusing on technological aspects of building and pure survivability in this harsh environment. Such projects deal with a small number of colonists and ignore many human psychological needs, such as isolation and the idea of developing an actual lunar community.

The project at had tries to look at the problem of lunar colonisation from a different perspective, by proposing a solution of long term rotational living (3-5 years) for a constant, reasonably high population of minimum 3oo scientists researchers and technicians as part of a corporate initiative in colonising and exploiting the rich rare minerals found on the lunar surface.

The project looks at transforming the idea of living on the moon from a sterile, isolationist engineered ordeal into near home experience. By proposing a social architecture which could mitigate the effects of extraterrestrial living and transforming life support essentials into amenities.

The project proposes a series of architectural solutions resulting in an ecosystem capable of sustaining life while at the same time dealing with human physical and psychological needs.
It is crucial that the inhabitants of the facility feel as comfortable as possible during their stay, as well as ensuring good physical and mental health, thus facilitating a quality of living resulting in a productive environment.

From food production to public space encouraging interaction between individuals and physical activity to water recycling systems that have multiple functions ,transforming life support essentials into amenities.

In order to successfully colonise the surface of the Moon we first have to develop a suitable living environment which seems but just a step away from home.

Hypothesis

“ In order to successfully inhabit\colonise the Lunar Surface and mitigate the negative aspects of this environment an architectural solution covering all physiological and psychological needs of humans, mimicking Earth’s conditions needs to be developed. ”

Part I

A brief history of the Moon

The following chapter is a short investigation of the relationship between humans and our closest celestial body, the Moon. From the first moment humans gazed at the night sky to our most recent endeavours and proposals for Lunar habitation. It seems the apropriet point in starting this project.

We start by looking at how humans began to acquire the first information regarding the moon. From early attempts in understanding its movement and size. We then take a brief look at the first attempts at mapping the lunar surface and speculations around it's geography.

We will try to understand the motivation behind the fascination with this celestial body generated in the 20th century and how pop-culture becomes a catalyst for begging to dream about a lunar civilization.

In this chapter we will also look at the first attempts of exploring the Moon from close up, and how the political environment was the main cause in humans traveling to the moon as well as examples of different concepts developed by various entities which tackle the idea of lunar habitation.

fig.1 Sumerian Representatioon of Moon

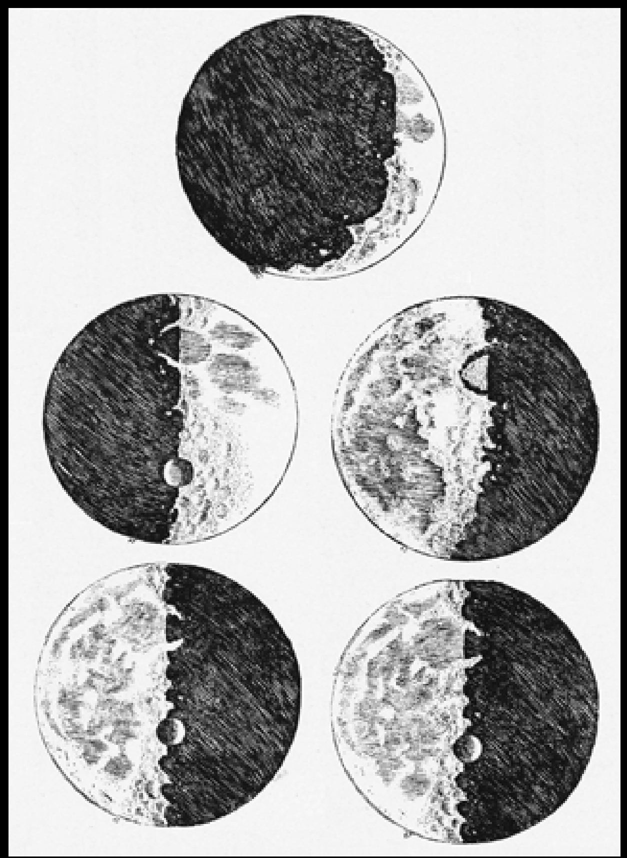


fig.2 Galileo drawings of the Lunar Phases

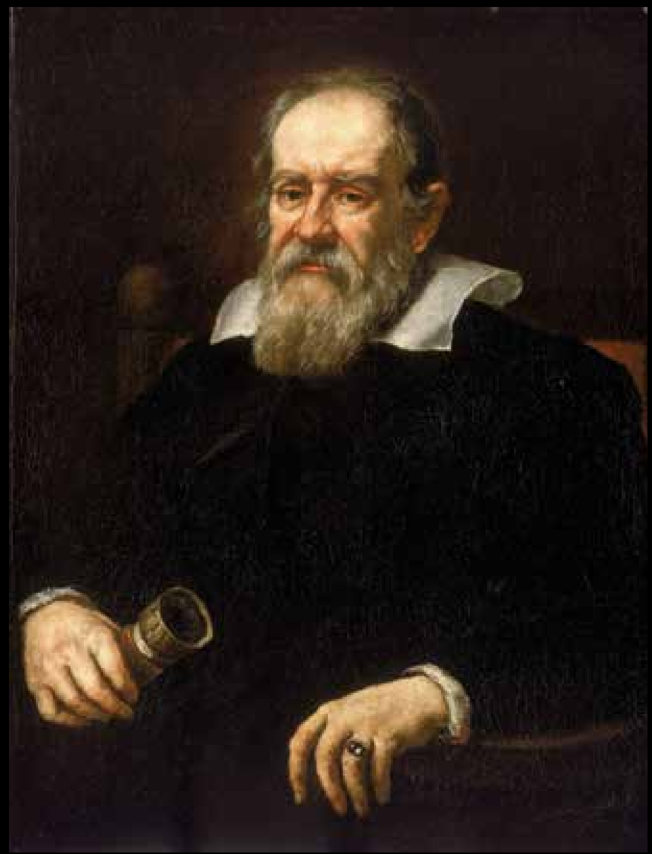


fig.3 Portrait Galilelo Galilei

First Knowledge

Some of the first depictions of the Moon date back to the 3 millennia BCE. In a multitude of prehistotic and ancient culturesthe Moon has been depicted as a deity or a supernatural phenomenon.

It was only around the 5th century BCE, when Babylonian astronomers began to study the Moon and its movement establishing the Saros cycle of lunar eclipse.

Around the year 428 BCE, the greek philosopher Anaxagoras claimed that the Sun and Moon were giganti spherical rocks. This was the first attempt at understanding the form of the Moon as well as the phenomenon of Moonlight.

In the 2nd century BCE, it was theorized by Seleucus of Seleucia that tides were the result of the Moon's attraction, and that their height corresponds to its position in relation with the Sun.

It was also during this time that the first attempt to calculate the size of and the distance between the Moon and Earth. These calculations were further improved several centuries later by Ptoly (90- 168 CE) and to a remarkable degree. He speculated that the mean distance was approximately equivalent to 59 times the radius of Earth and the diameter of the Moon was 0.292 of Earth's size. These calculations were remarkably accurate for the time, as do to our current knowledge the correct ratios are 60 and 0.273.

During the Middle Ages the idea that the Moon was a sphere began to gain more and more traction, however it was believed that its surface was perfectly smooth.

With the Invention of the telescope this all changed and in 1609 Galileo Galiei used this new invention to make a series of drawings of the Lunar surface and publish them in his book Sidereus Nuncius.

While the 17th century was the beginning for the exploration of the lunar surface, in the following 2 centuries several publications were made, most notably Der Mond ((1837) by Wilhelm Beer and Johan Heinrich Madler contained Mappa Selenographica, the first trigonometrically accurate study of lunar features. In 1870 Richard Protoc proposed that the Lunar craters were the results of impacts and not of volcanic nature as it was believed until that point.

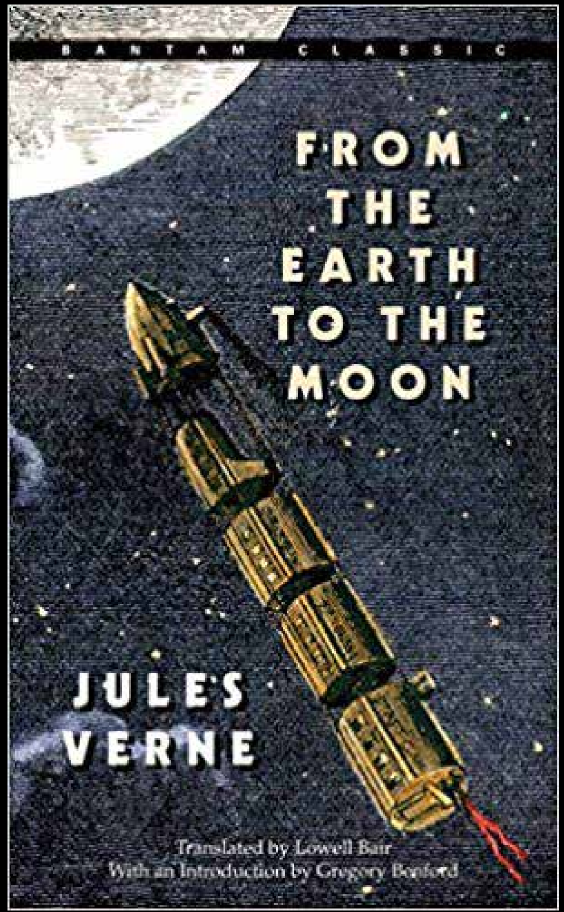


fig.4
Original Cover of Jules Verne's
"From the Earth to the Moon"

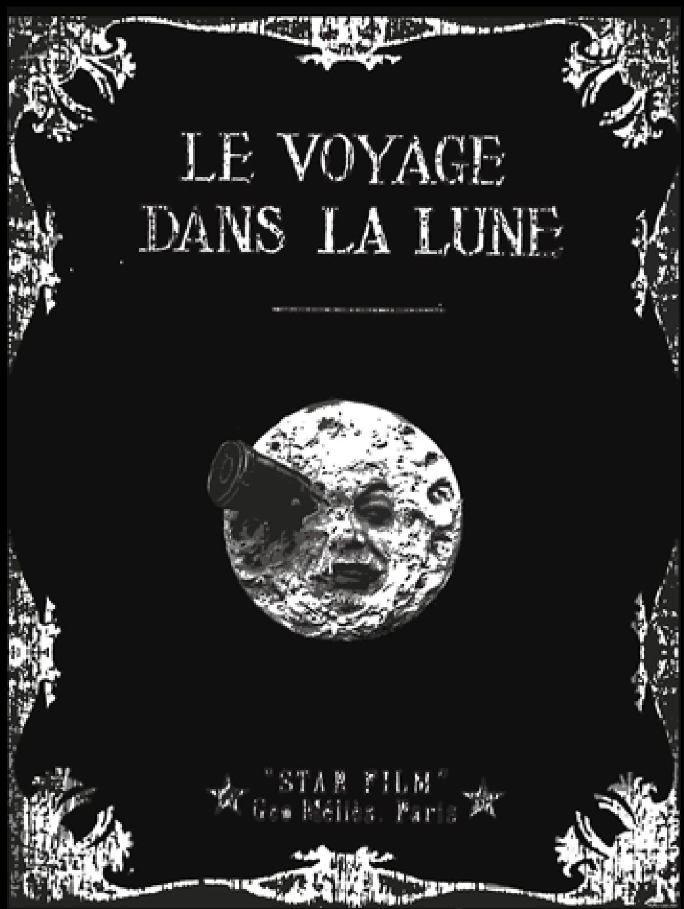


fig.5
"Le Voyage Dans La Lune"
Advertisment Poster

The Moon and Pop-Culture

Throughout the ages, The Moon has been a great source of inspiration for different creative works. It has been a recurring motif in different artistic fields. In the mid to late 19th century the interest in the Moon was sparked again through works of Jules Verne, "From Earth to the Moon" (1865) and its sequel "Around the Moon" (1870). It is through his works that the author manages to capture the imagination of the public, and a new idea, that of traveling to the Moon becomes part of popular culture.

At the turn of the century the interest in the Moon was further rekindled. It is in 1901 that the concept of the Moon being inhabited by another species was introduced by H.G. Wells in "The First Man in the Moon" (1901). One year later using a new, rising, artistic medium George Melies, introduces the world to "Le Voyage dans la Lune" (1902) , a silent film, inspired by the writing of Verne, and becomes the new sensation of the time, and becoming a science fiction cult classic.

Slowly but surely the fascination of traveling to the Moon krept into the mind of the general public, becoming a fascination for many or the dream of an impossible future for others.

Throughout the 20th century more and more "outlandish" ideas rose from the minds of science fiction writers, as well as the other artistic mediums.

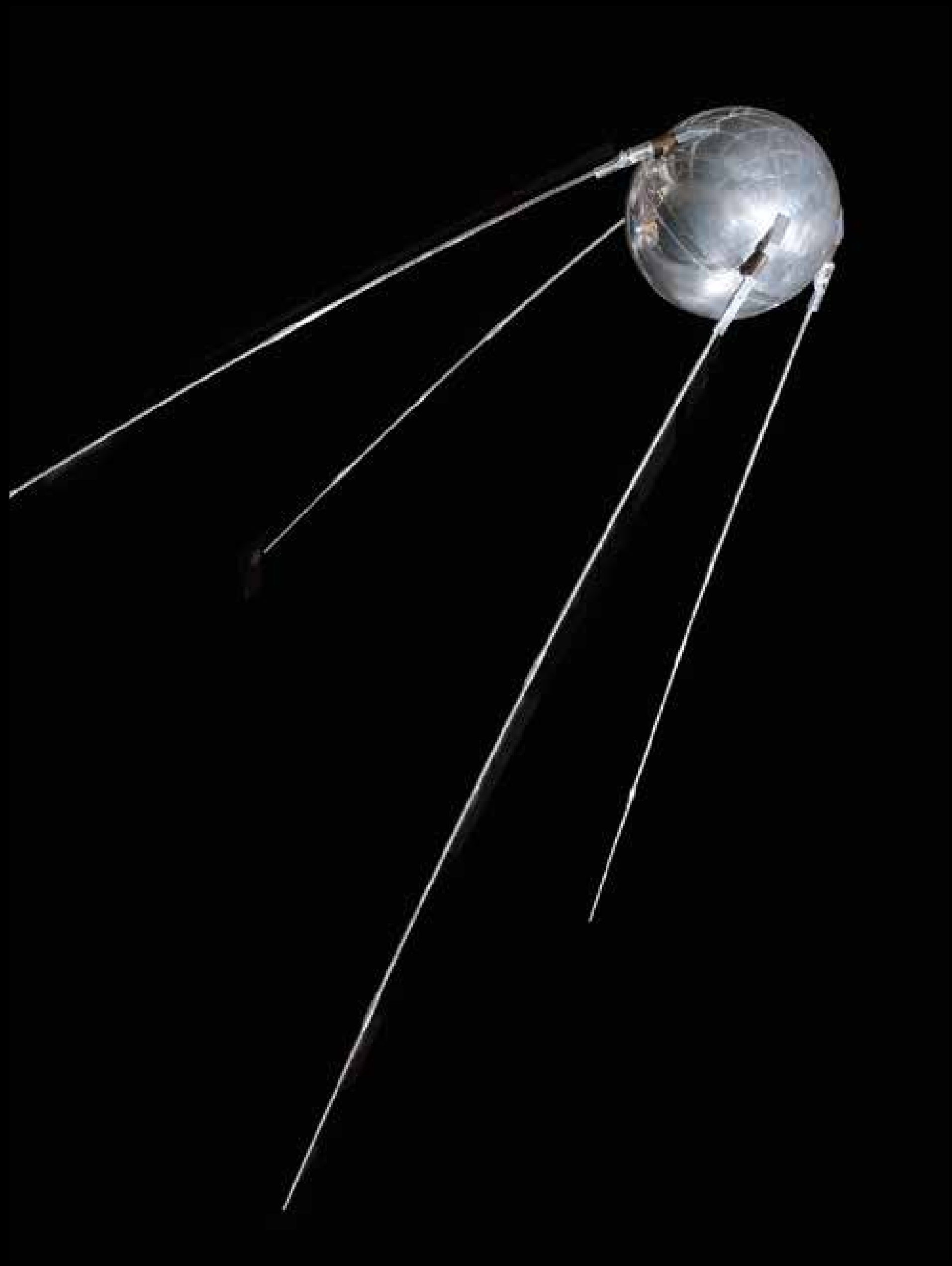


fig. 6 Sputnik 1 was the first artificial Earth satellite. The Soviet Union launched it into an elliptical low Earth orbit on 4 October 1957, orbiting for three weeks before its batteries died.

The Space Race

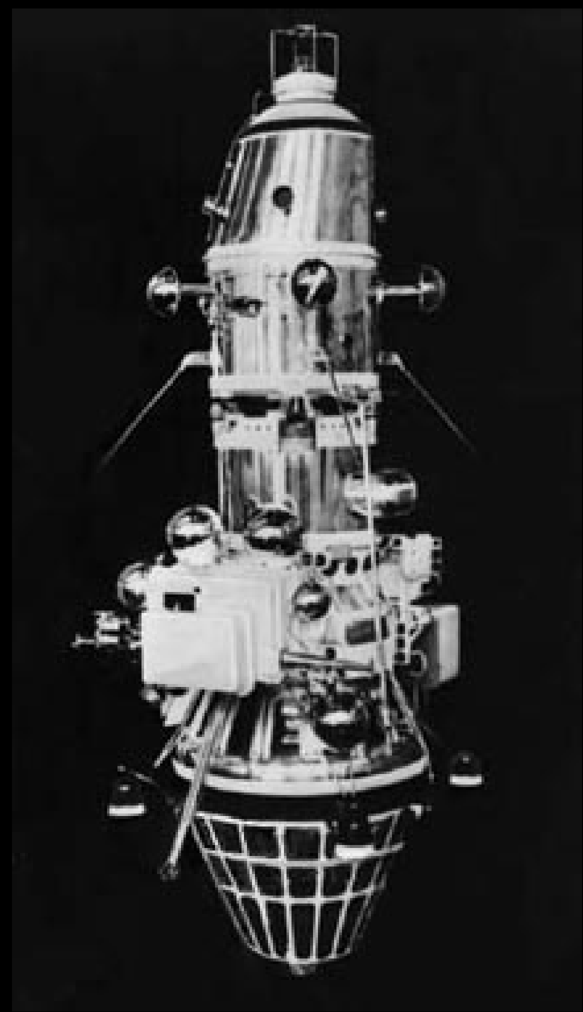


fig.7 Luna 2 Robotic Probe

With the end of the Second World War two geopolitical superpowers had emerged, representing very different ideologies, the USSR and the USA, thus launching the "Cold War". With its origins in the ballistic missile arms race, the so called "Space Race" was an ongoing competition starting in 1955 between the two nations in achieving superior spaceflight.

The lead was taken by the USSR, with a series of impressive achievements. Two years after the "Space Race" had officially begun, on October 4th 1957, the Soviets achieved the first successful launch of an artificial satellite, Sputnik 1. This was followed by the Luna program and on 14th of September 1958 the Luna 2 robotic probe was the first man made object on the surface of the Moon.

The Soviet Union's success did not stop there, but continued by sending the first man to space with the orbital flight of Yuri Gagarin on 12th of April, 1961. The USSR demonstrated an early lead in the race with these and other firsts over the next few years, including the largest Earth orbital lift capability, flight durations measured in days instead of hours, the first multi-person crewed spaceflight, and the first spacewalk.

fig.8 J.F.K. Photograph at the 1962 Congress adress

We Choose To Go To The Moon

Prior to Gagarin’s flight, US President John F. Kennedy’s support for the American space program was lukewarm at best, considering it to be an unjustifiable expense to the american public. However the success of the USSR was perceived in Washington as a humiliation, many US citizens fearing the soviet lead in this field.

At the time, when considering up-staging the Russians, the primary two options taken into consideration were the establishment of an Earth orbital station and that of a crewed landing on the Moon. Due to the lead held by the Soviet Union in rocket lifting capabilities, it was concluded that much more was needed in reaching a leadership position when considering the first option. A crewed landing would be far enough into the future to allow the U.S. to frog-leap the Soviet achievements.

Kennedy will ultimately decide to pursue what will become the Apollo program, and on 25 of May 1961, addresses the U.S. Congress for support in the “Cold War” with the speech titled “Special Message on Urgent Needs” In September of the following year he will address the nation and rally popular support with his “We choose to go to the Moon” speech.

In 1963 Kennedy proposed to Soviet Premier Nikita Khrushchev a joint lunar landing. The Soviet government is inclined to accept, however due to Kennedy’s assassination one month later and the lack of trust in the new Johnson administration, the offer is declined.

Lunar Landing

Seven years after Kennedy announced to the world the intention of the US, to send a crewed mission to the Moon and to return them safely. On July 20th 1969, Apollo 11 was the spaceflight which first landed humans on the Moon. Commander Neil Armstrong was the first man to step on to the surface of the Moon followed 19 minutes ater by the lunar module pilot Buzz Aldrin. They spent a little over 2.5 hours on the lunar surface collecting a total of 21.5 kg of lunar material to bring back to Earth.The preparation in overcoming the technical challenges of such a feat, had been a gargantuan task for all the people involved in this project.

The lunar landing site was selected from a list of 5 potential locations. This was the result of two years of studying high-resolution photography of the lunar surface provided by uncrewd probes of the Lunar Orbiter program. It was imperative that the site would be close to the lunar equator in order to minimize fuel requirements. It needed to be as flat as possible to minimize the maneuvering required and to simplify the task of the landing radar. There was no scientific consideration when choosing the site,only safety.

The event was televised in 33 countries and millions of people listened to the live radio broadcast. Thus opening a new chapter in humanity's dream of conquering the stars.

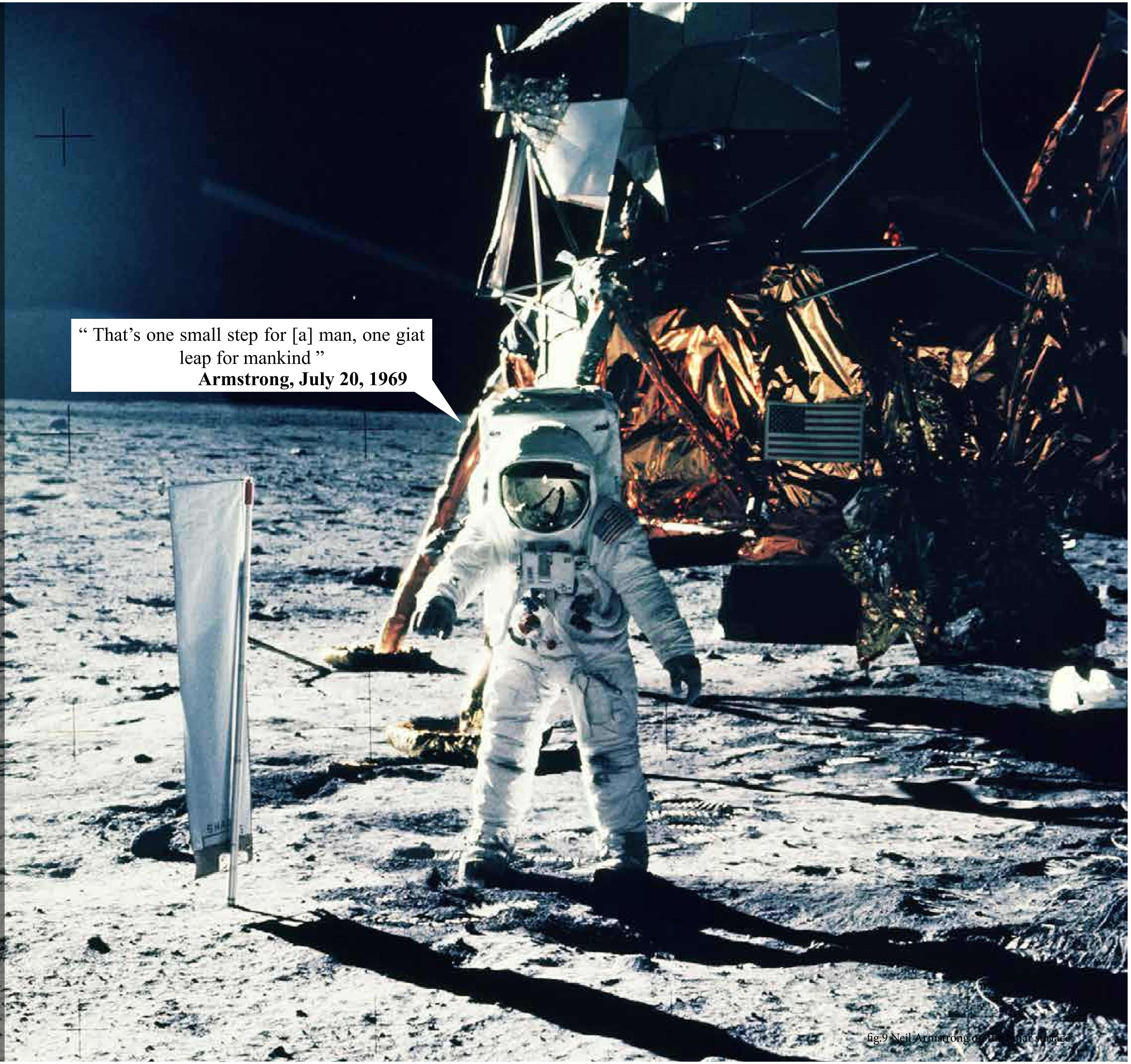


fig.9 Neil Armstrong on the lunar surface

fig. 10 NASA Lunar Colony, NASA 1970 Concept

fig. 11 NASA 90 Day Study Lunar Outpots, 1989

fig, 12 Norman Foster - Lunar Habitat - 2013

fig. 13 SOM- Moon Village - 2019

Lunar Base Concepts

The concept of inhabiting the Moon dates back to the early 1950s, proposing an array of potential solutions for the development of such a project, in 1954 Arthur C. Clarke envisioned inflatable igloo-shaped habitats covered in regolith.

The earliest proposals came from the U.S. Army whose ambitions revolved around the so-called Project Horizon. The army wanted to build a “space fort” crewed by 12 people, as early as 1967, with an estimated cost of around $6 billion to complete. Through the past 50 years many space agencies around the world have expressed interest in the development of a permanent settlement on the lunar surface.

Most recently NASA and the ESA have been exploring the conceptand both have produced their own methods for turning lunar regolith and other resources into usable materials. For example, since 2013, the ESA has been working with the architectural design firm Foster + Partners to design their International Moon Village. Their proposed method for building this base consists of placing inflatable frameworks on the surface which would then be covered with a form of concrete made from lunar regolith, magnesium oxide, and a binding salt. NASA has proposed a similar method which calls for robotic workers using “sintered” regolith to 3D print bases. This consists of melting regolith by bombarding it with microwaves, then printing it out as a molten ceramic.

In 2019 the architecture firm SOM in partnership with MIT, unveiled the Moon Village concept. The project proposes a Masterplan relying on a modulal configuration of habbitable structures. The design of the modules is a hybrid of rigid-soft system composed by a rigid composite perimeter frame and an inflatable structural shell.

When proposing an architectural solution for the current project we will rely heavily on these proposed construction techniques. However the project will look at the development of a concept aming to host a much bigger population than any of the aforementioned proposals, as well as drastically increasing the quality of life which is expected in such an environment.

Part II

A Comparative Study of the Earth vs. the Moon

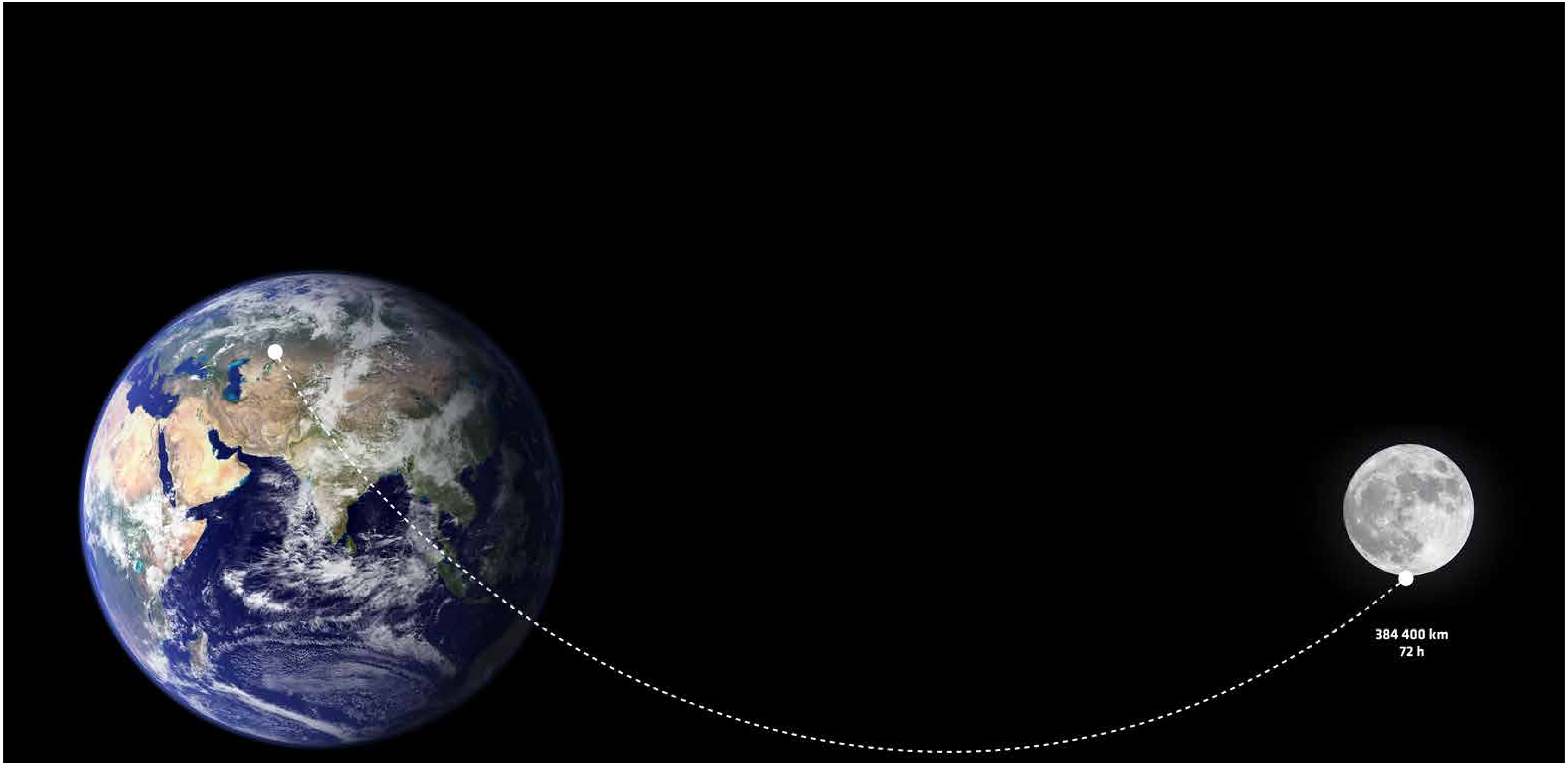
In order to design a habitat suitable for the Lunar surface, which offers similar safety conditions and comfort for our lunar colonizers, we first have to understand the conditions found in this new environment.

As such a comparative study between Earth and the Lunar environment was done so that the project could respond in an appropriate manner to these differences. Each of these differences influence design decisions in the project.

From the different sizes of the celestial bodies and implicitly very drastic gravitational conditions , to their axial rotations and axial tilt, from their internal makeup to their very different atmospheric conditions.

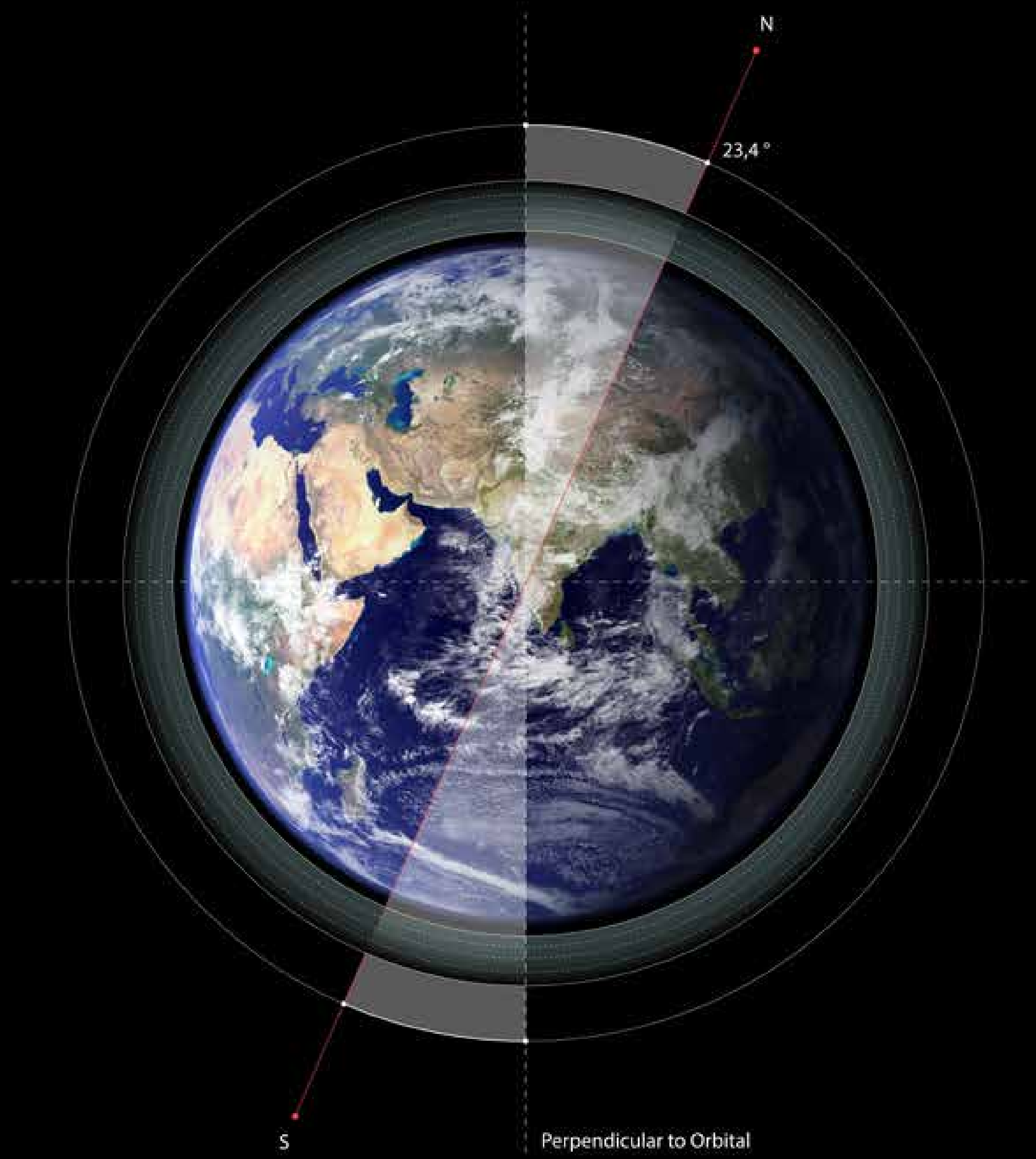
These aspects cascade into a very different landscape of conditions, very different from those found on Earth, hence resulting in a series of design principles that accumulate into a guideline for a potential solution in driving the emergence of a, however speculative, lunar vernacular architecture.

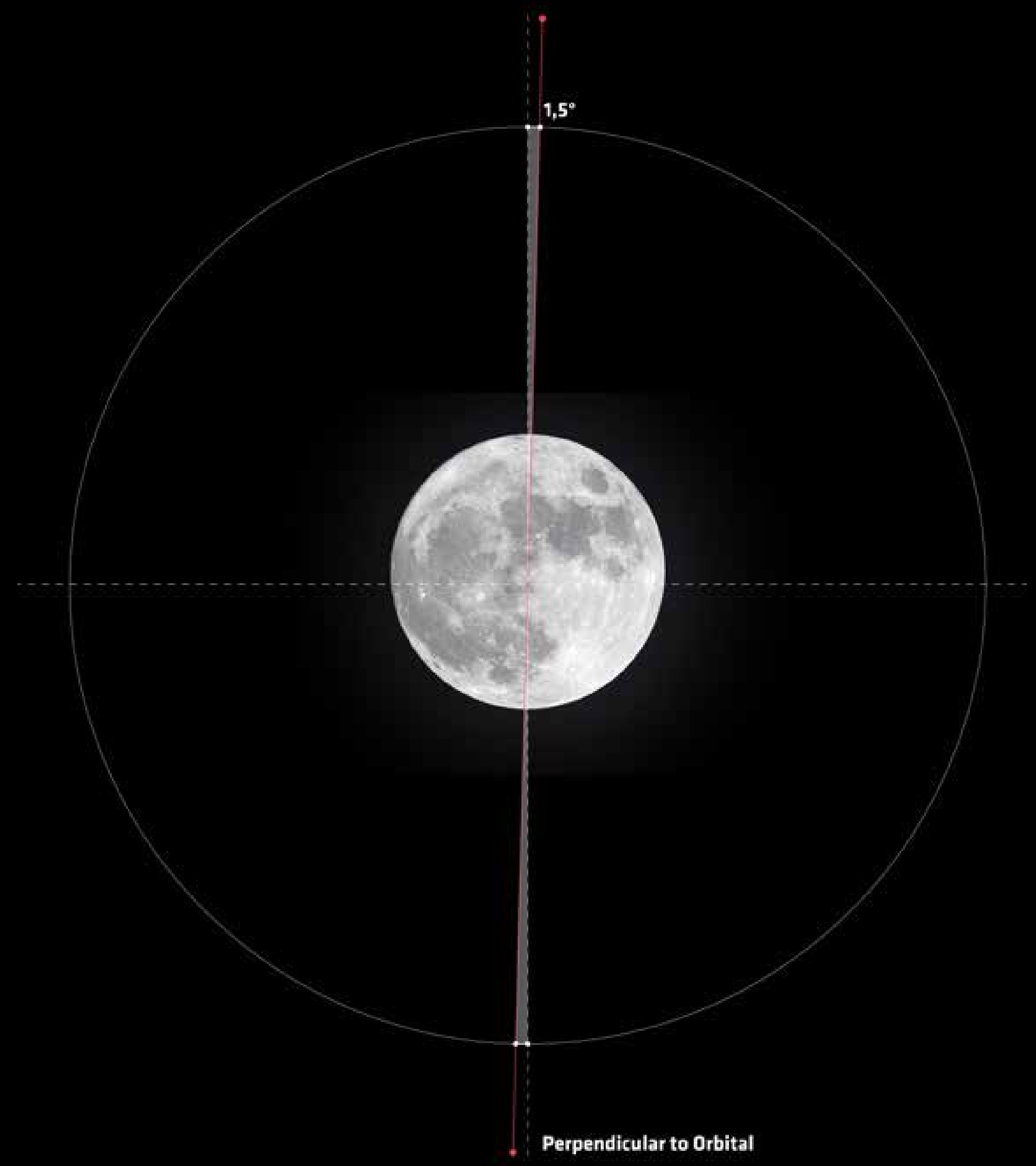
Much of this information could be considered trivial. Having said that, I believe that the whole of this knowledge is greater than the sum of its parts, and a crucial part in the development of a safe and highly quantitative living environment. Thus achieving the premise of a home away from home in our quest for colonising the Moon.



Distance to Moon

The moon orbits the Earthe aproximatly every 27 in a syncronoius rotation at an aproximate distance of 384,00 Km. It is the only Earth's only natural satelite and our closest celestial neighboar. A confortable maned journey to the moon would take around for days, however the fastes mission to fly past the Moon was New Horizon which only took 8 hours.



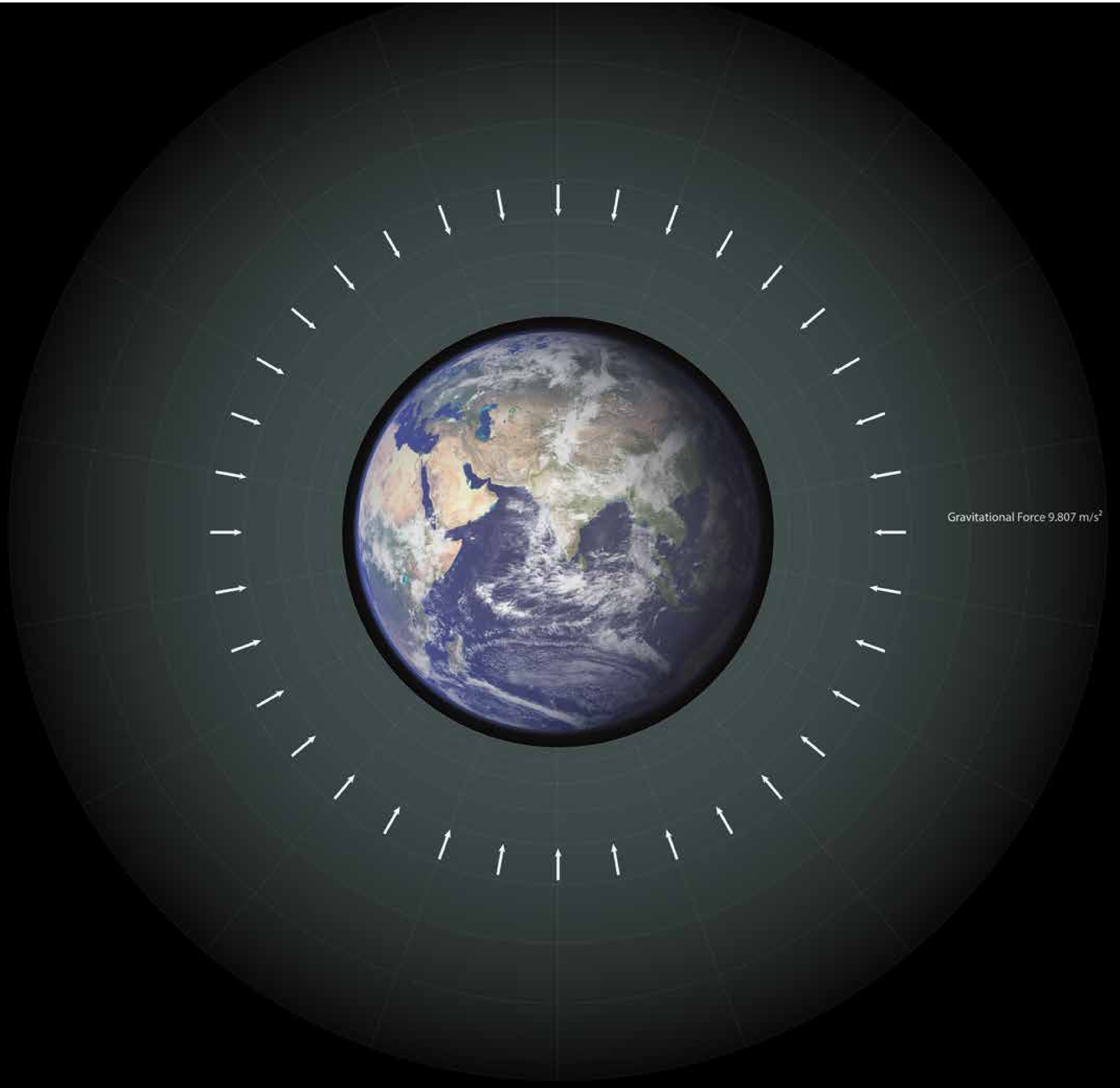


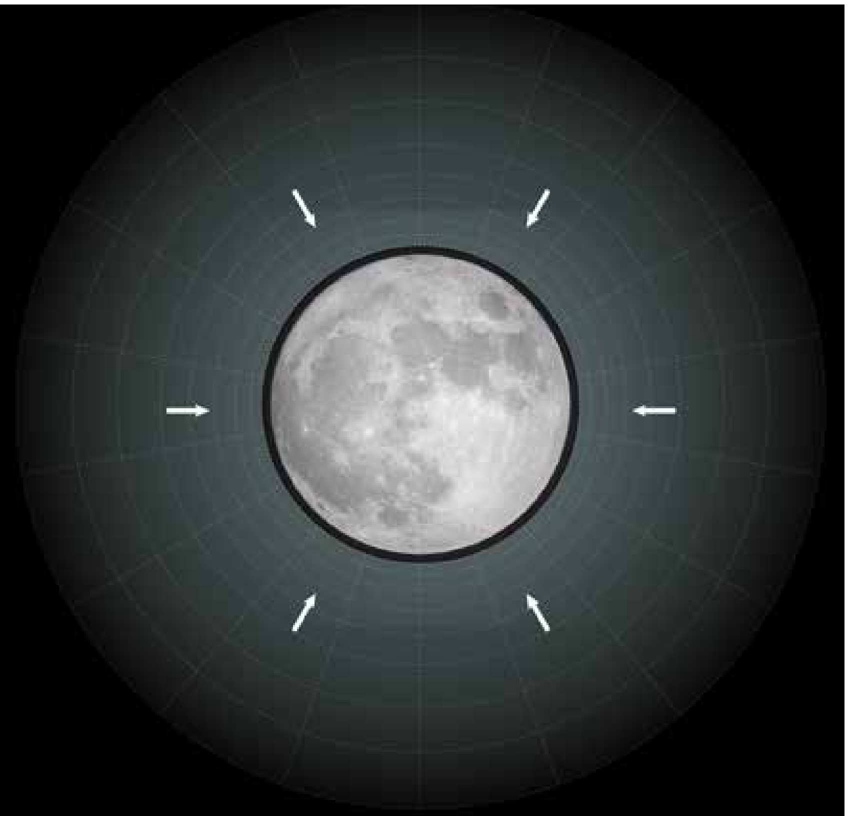
Axial Tilt

The two celestial bodies have very different axial tilts, while the Earth has an inclination of aprox. 23,4 degrees, resulting in seasons and Polar Night and Days that last around 6 months, the Moon only incliens around 1,5 degrees. As a result Polar Lunar Night\Day cycle is only 13.5 days long.

Size

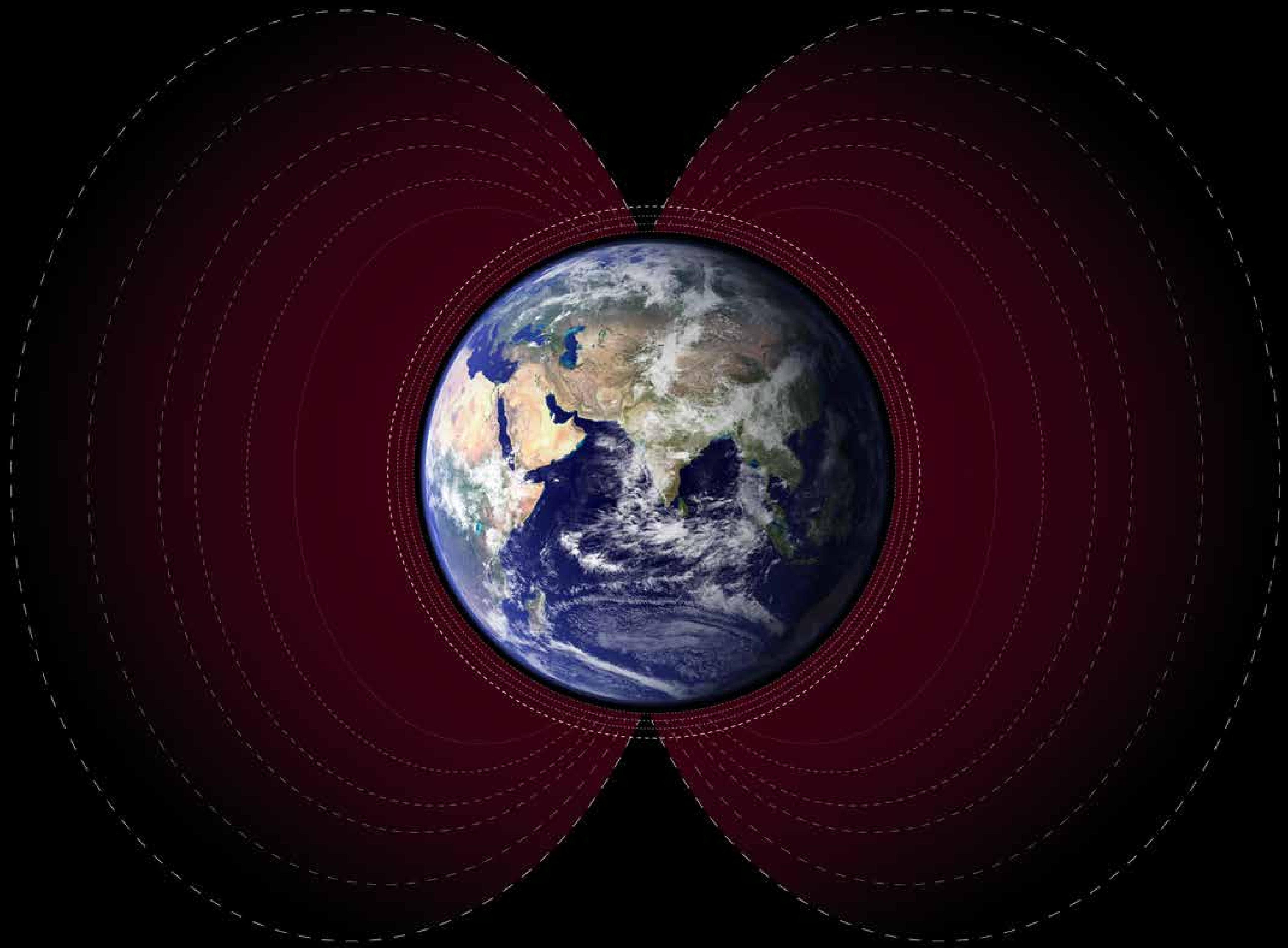
While Earth has a circurferince of 40,075 km our closest neighboar sizes up only to 10,921. The Moon is aproximatly 27 % of Earth's size, this has many implications from the obvious gravitational pulls exerted by the two bodies, to the horizon line which will play a very important role in the search of our Lunar Settlemnt Site.





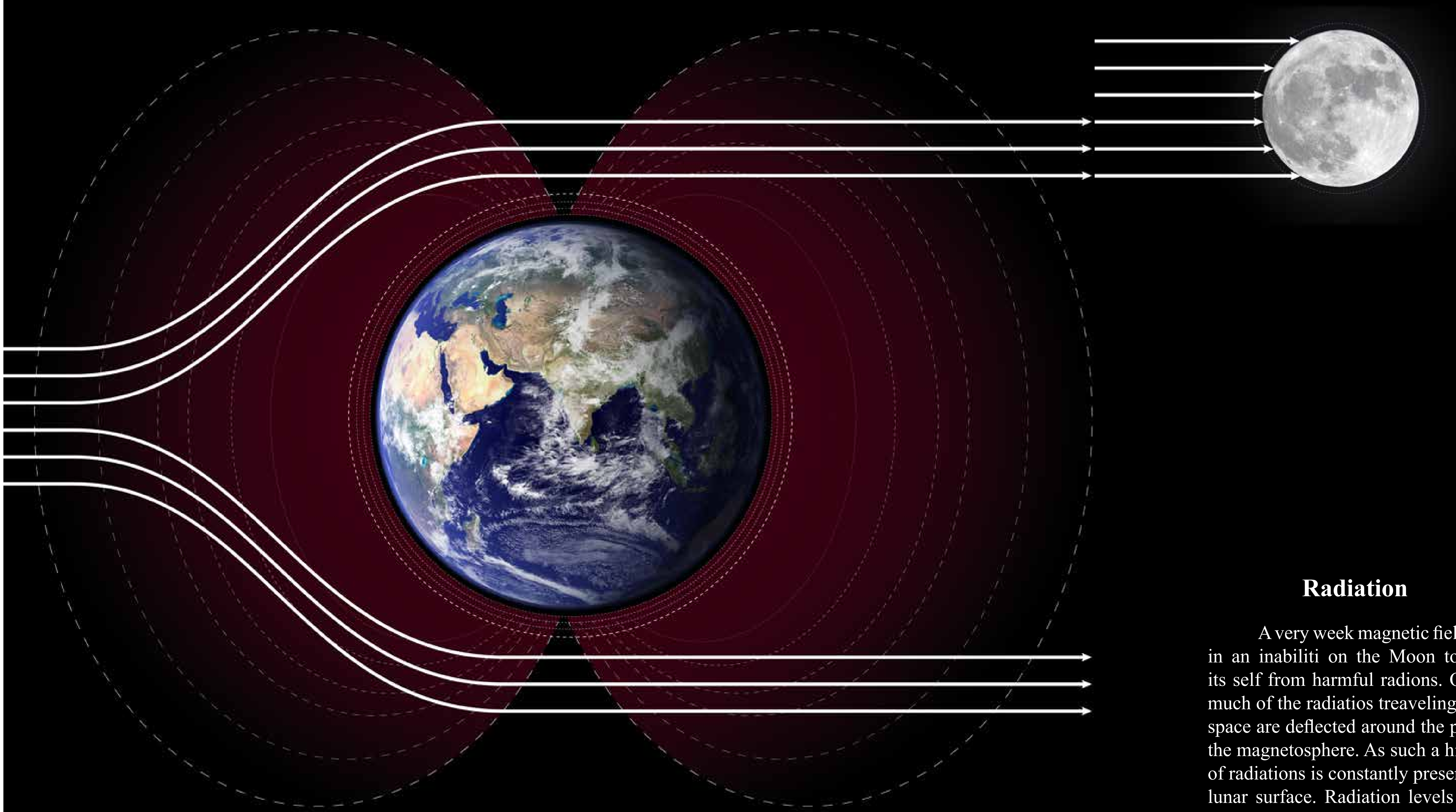
Gravity

Earth's average surface gravity is about 9.8 meters per second per second, whilethe Moon's surface gravity is about 1/6th as powerful or about 1.6 meters per second per second. The Moon's surface gravity is weaker because it is far less massive than Earth. This aspect has a very serious impact in designing the structure of our habitat as well as potential heath implications for our settlers.



Magnetosphere

The magnetic field of the Moon is very weak compared to that of the Earth. The moon does not have a dipolar magnetif field due to the lack of an active molten core. A rough estimate might be that on the Moon can be registered around 5 microtesla compared to that of the Earth's 50. This has several repercutsions on the lunar enviroment.

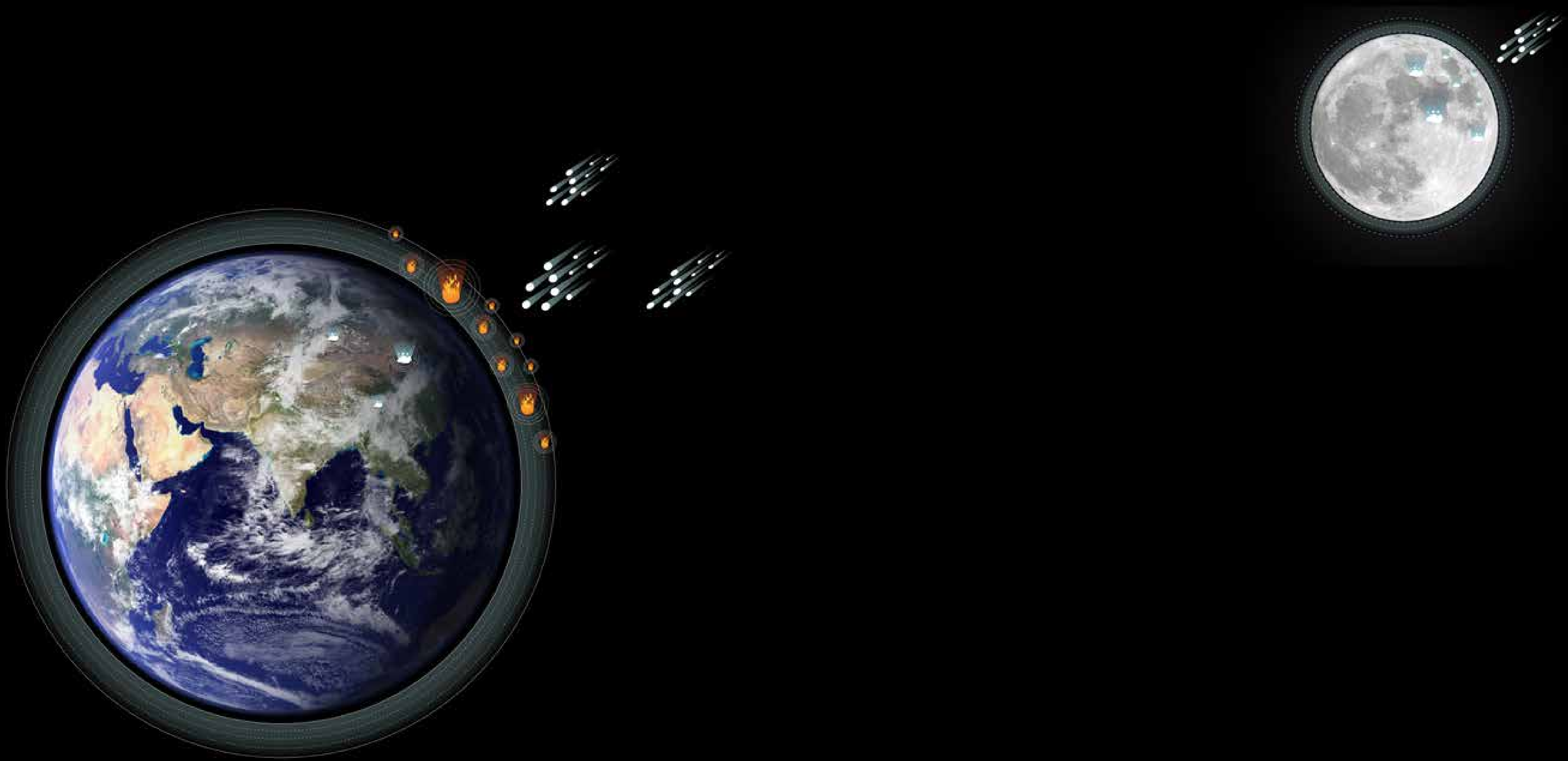


Radiation

A very week magnetic field results in an inabiliti on the Moon to protect its self from harmful radions. On Earth much of the radiatios treaveling through space are deflected around the planet by the magnetosphere. As such a high level of radiations is constantly present on the lunar surface. Radiation levels can be from 200 to 1000 times more then those found on Earth's surface and 2.6 times more then what astronauts on voard the Internatioanal Space Station are experiencing.

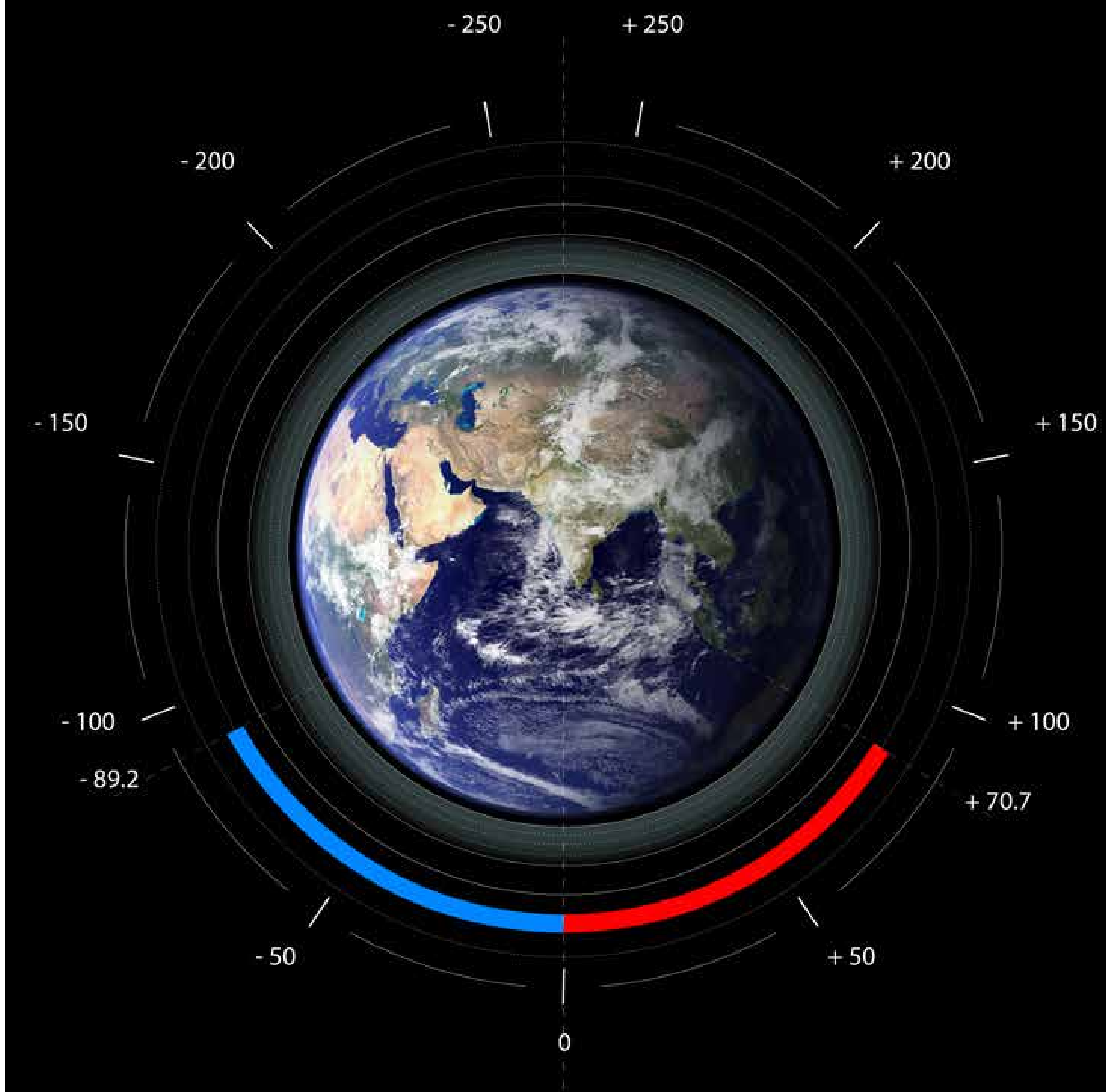
Atmosphere

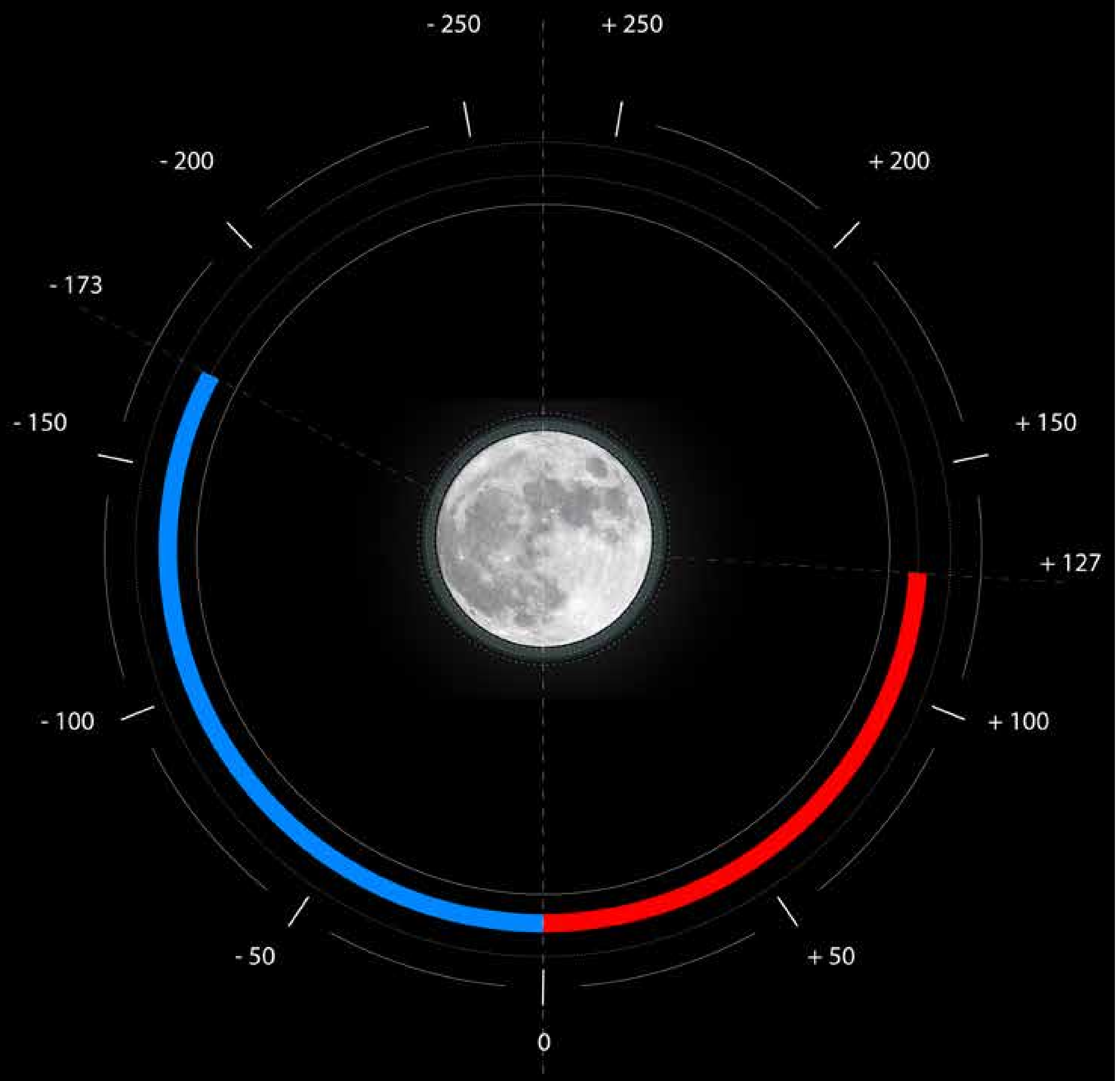
For most practical purposes, the Moon is considered to be surrounded by vacuum. The elevated presence of atomic and molecular particles in its vicinity compared to interplanetary medium, referred to as “lunar atmosphere” for scientific objectives, is negligible in comparison with the gaseous envelope surrounding Earth. The pressure recorded on the Moon is around 0.3 nPa compared to Earths sealevel pressure of 101325 Pa.



Meteorite Impacts

Due to it's very thin atmosphere the lunar suface is highly vulnerable to meteorite and micro-meteorite impacts. On Earth most of these space travelers burn out, explode or shatter in the thick atmop-shopere of the planet. This is not true for the mun and as such the proposed shelter needs to be able to withstand such mi-cro-impacts.





Enviromental temperature

Due to its atmosphere the Earth surface temperature sits at a relatively comfortable mean temperature of 14 C, while extremes range from - 89.2 C, in the arctic regions and up to 70.7 C in the deserts of Iran.

Temperatures on the moon are extreme, ranging from boiling hot to freezing cold depending on where the sun is shining. There is no significant atmosphere on the moon, so it cannot trap heat or insulate the surface.

When sunlight hits the moon's surface, the temperature can reach 127 C. When the sun goes down, temperatures can dip to -173 C. Permanently shadowed area on the lunar crates can reach temperature down to -224 C.

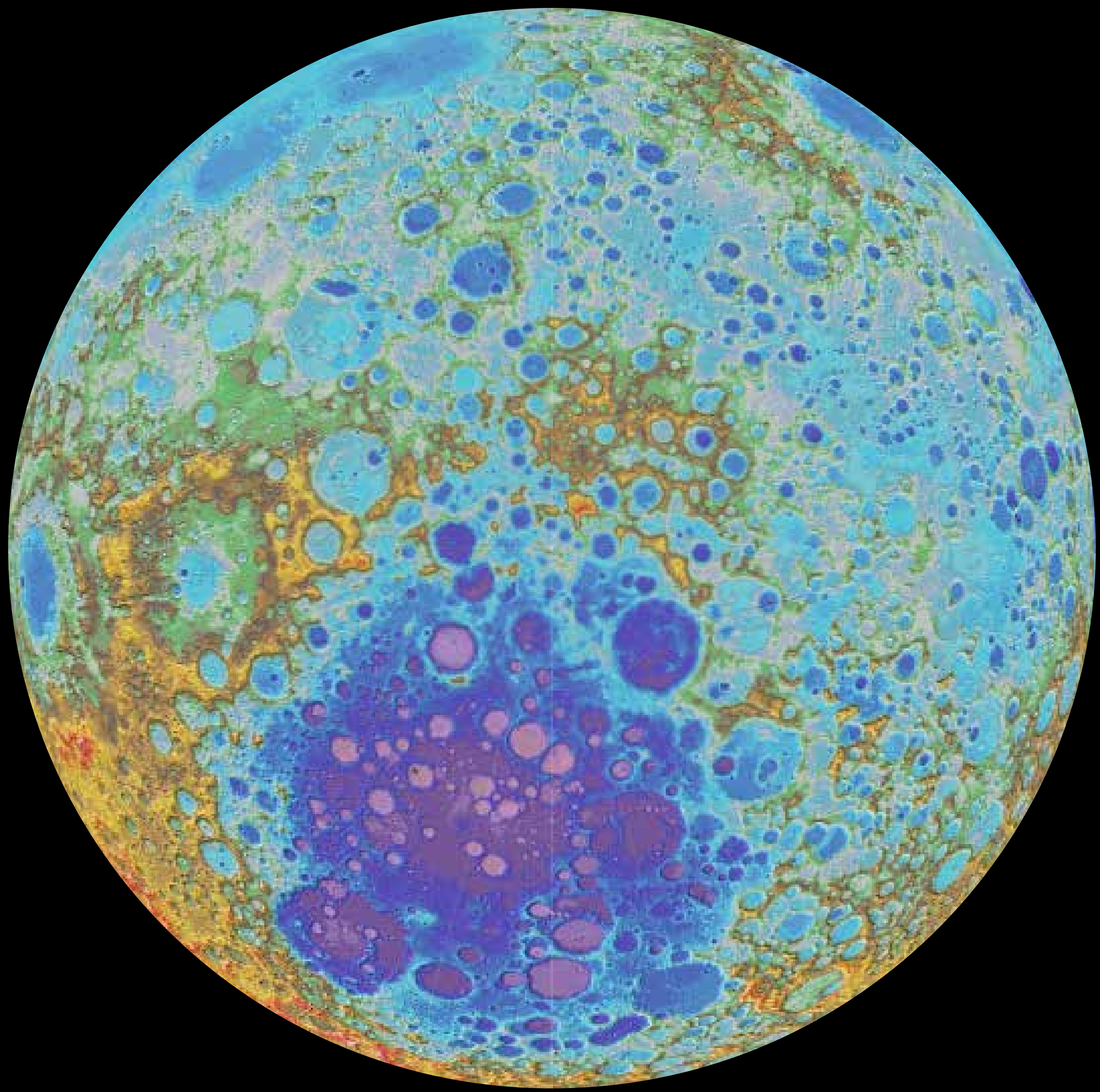


fig. 14 Depth Map of Lunar South Pole

Part III

The Site

The first design chalange any Architect faces when designing a project is the site. In our case our site is the Moon. But this is a big place where exactly we should go and why?

The surface of the lunar south pole is of high interest to many scientists particularly due to the fact that in permanently shadowed areas, according to several satellite surveys, the presence of water in the form of ice has been confirmed. Along with this vital resource the craters in the area are cold traps which are believed to contain a fossil record of hydrogen and other volatile gases dating from the early Solar System.

These resources could be used in ensuring the survivability of our proposed colony as well as creating the scientific and economic incentive for people to inhabit this area of the Moon. One such economic incentive could come from the exploitation of the highly sought after Helium-3.

Numerous references suggest that the most suitable place for a Lunar settlement could be the Lunar south pole.

Just like the poles back on earth, here "days" are extra long. However there are 3 very interestings factors contributing to a unique phenomenon in this region of the moon. The first one is a very small axial tilt of the moon along with it's small size, and the local topography of the Malapiri Range, which rises high above the lunar platouse give birth to the "Peaks of Eternal Light".

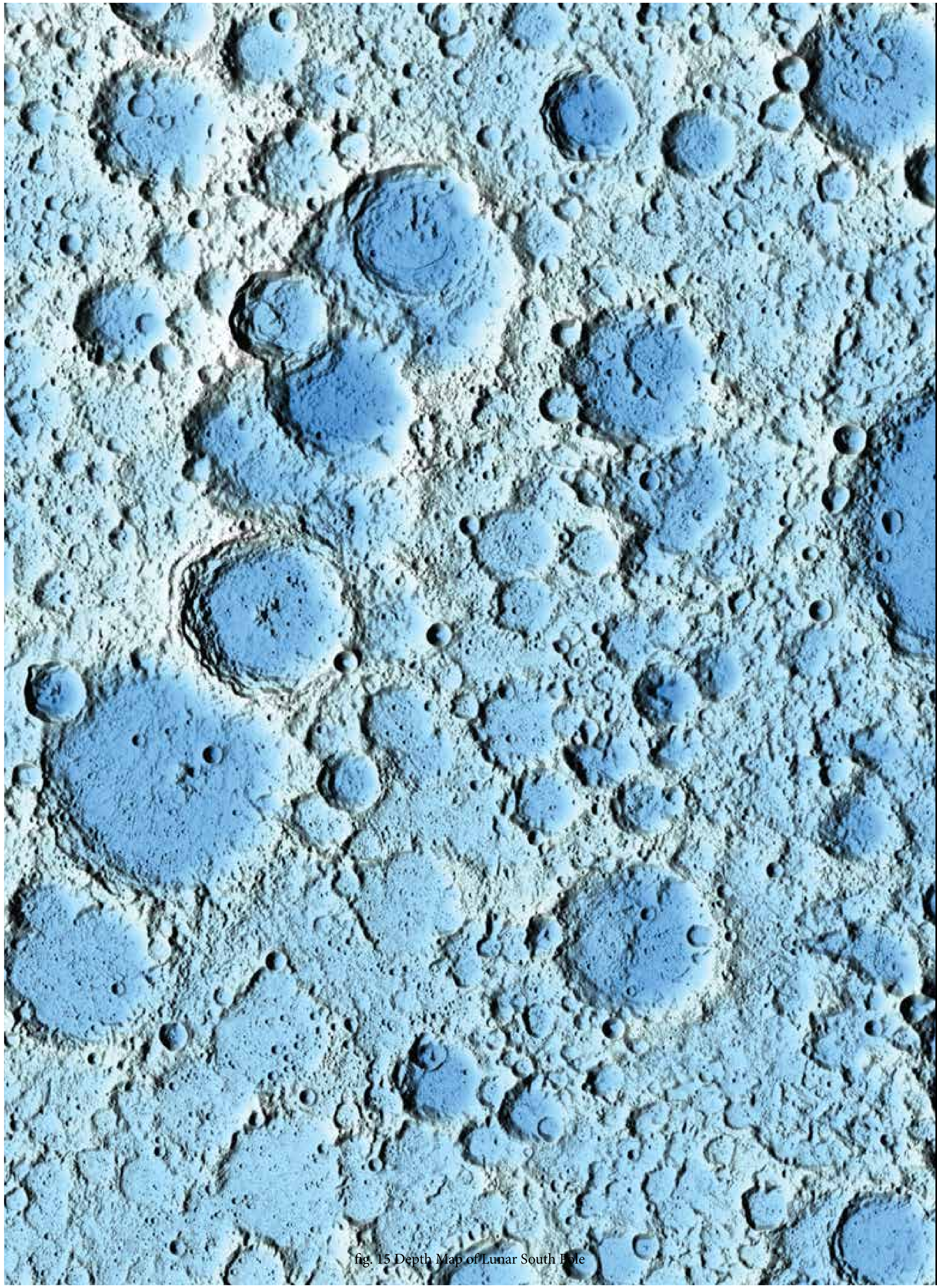


fig. 15 Depth Map of Lunar South Pole

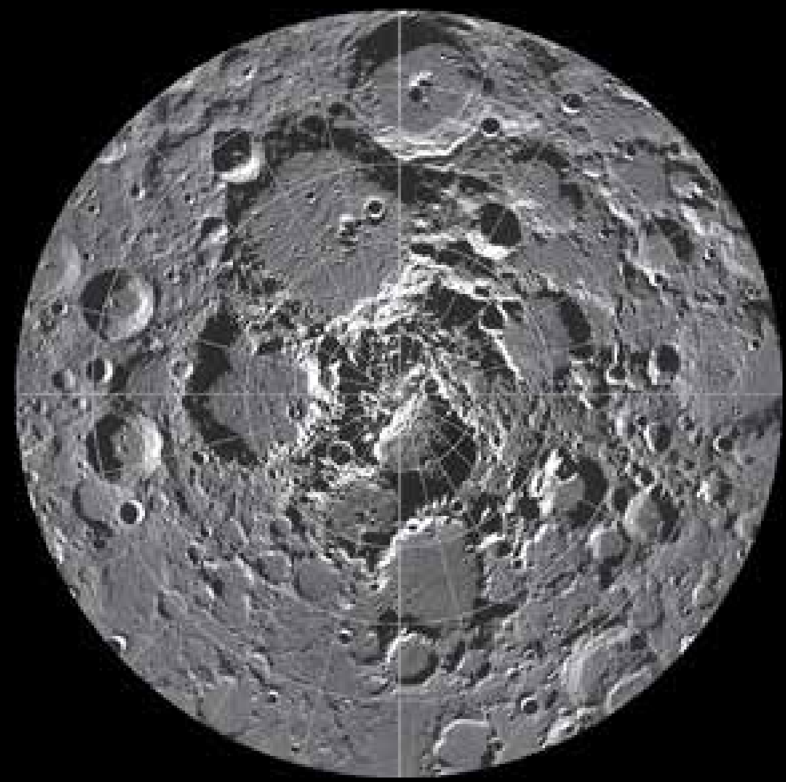


fig. 16
Depth Map of
Lunar South Pole

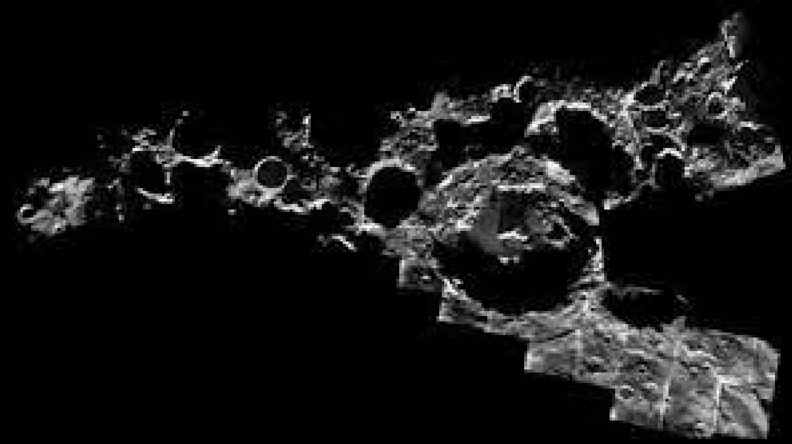


fig. 17
Collage of Light Maps
in proximity to
Shackelton Crater

fig. 18
Eternal Peeks of Light

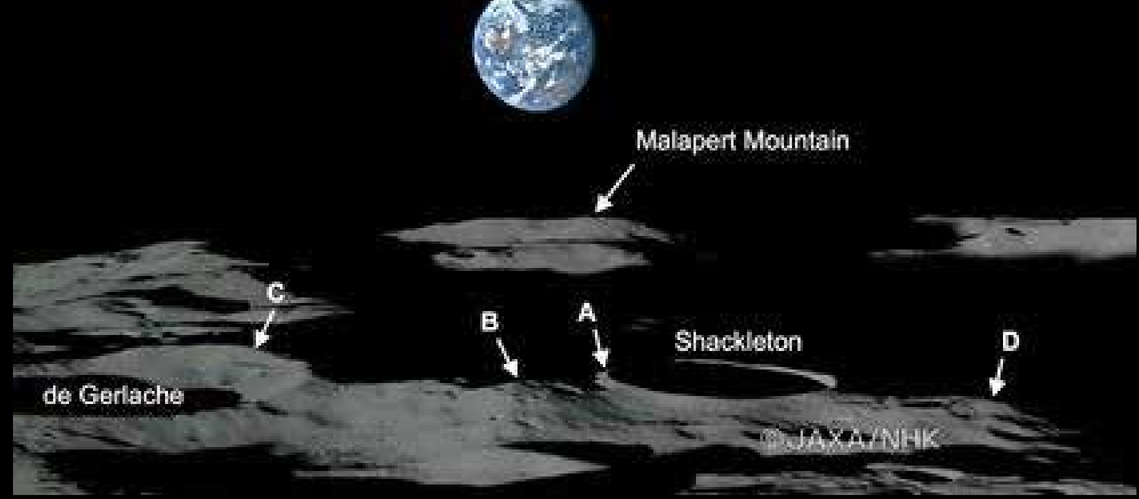


fig. 19 Image of Shackelton Crater

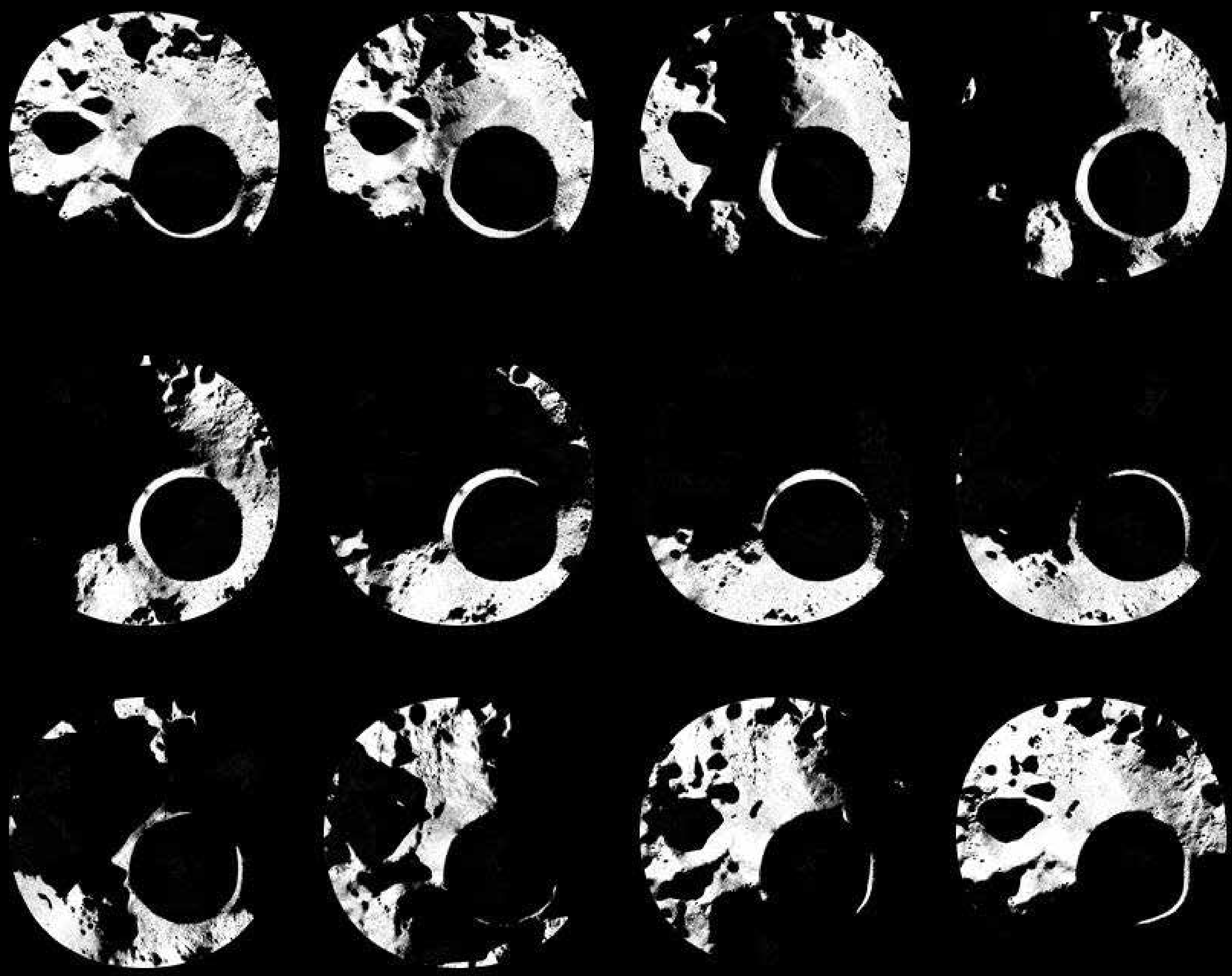


fig. 20 Shadow Map of Shackelton Crater over a period of 12 days.

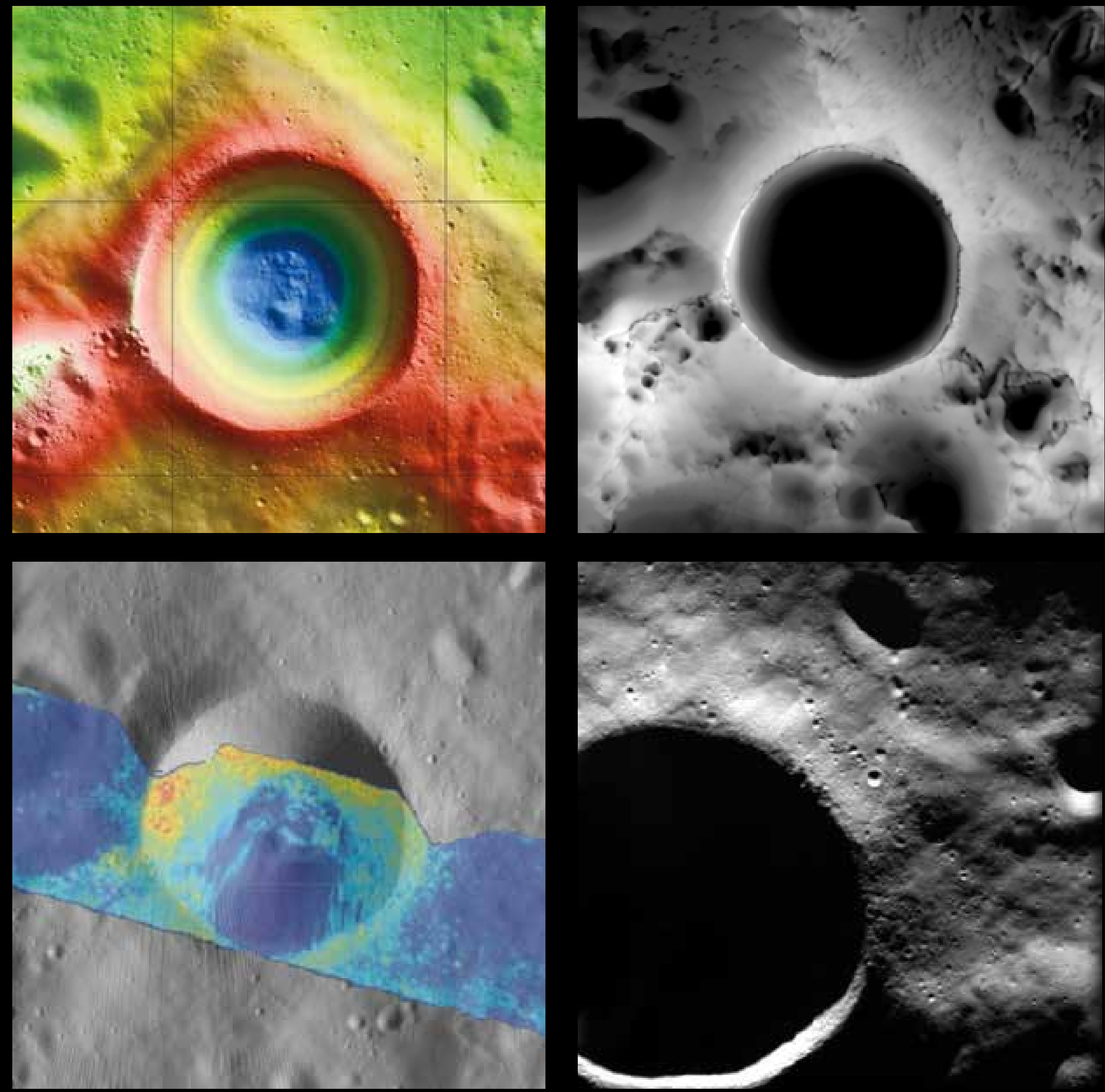
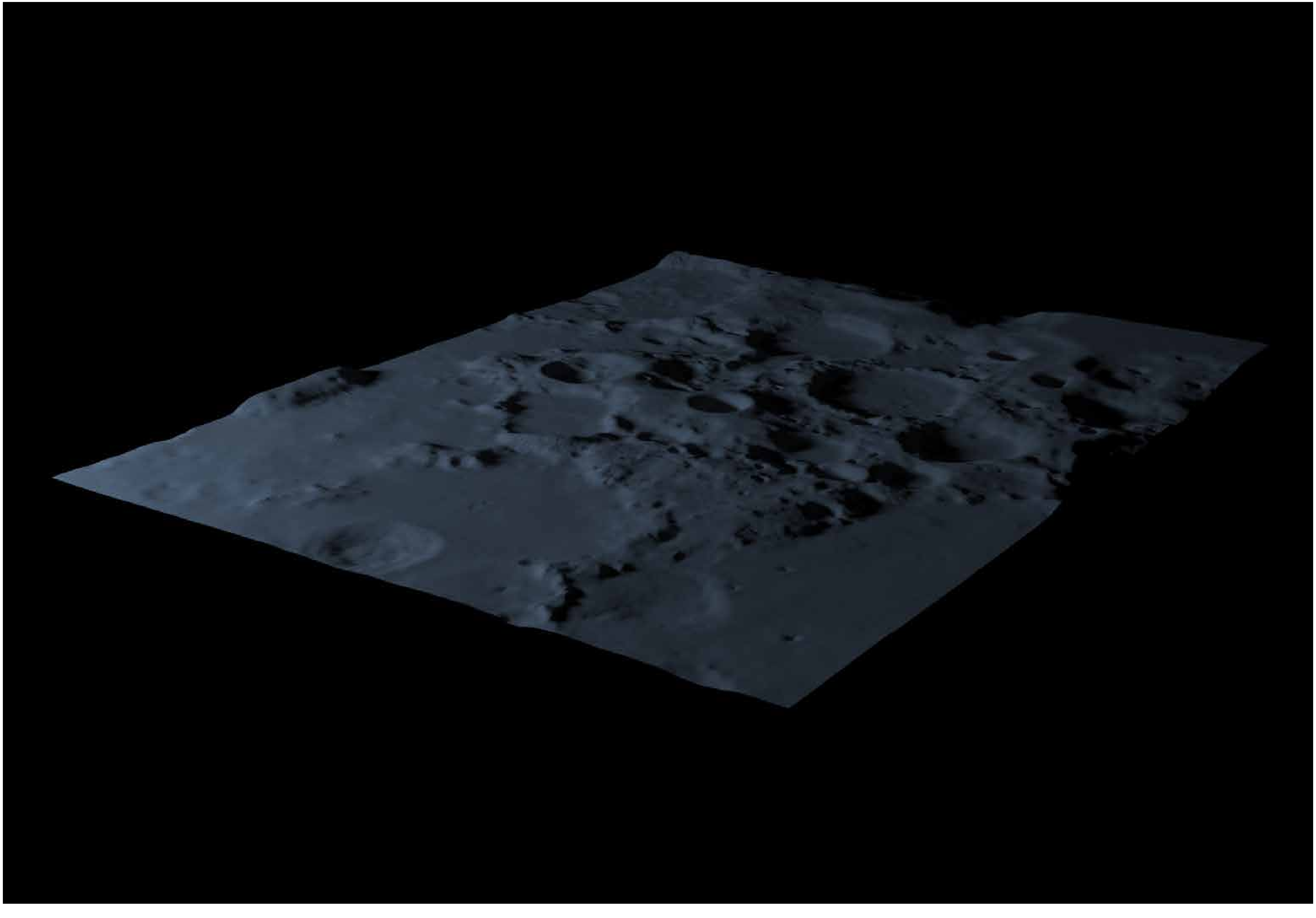


fig. 21 Different Layers of information about Shackelton Crater

These are places on the Lunar surface that get Sunlight more the 80% of the time. This being a crucial aspect in generating the required electrical energy in sustaining a large colony without resorting to nuclear power.

The impact place of a large meteorite, the crater, Shackleton Crater spans 20 km in diameter and it is nearly 6 km in depth. Ironically as its edges are in almost permanent light it's interior is in permanent shadow, making it one of the coldest places in the solar system. However satellite imagery shows us that a great deal of water in the form of ice can be found here, thus making it the ideal "watering hole" for our future colony.

Another aspect in choosing this location is due to a magnetic anomaly found in the area, this is due to the presence of remnants of iron emplaced by the impact that formed the South Pole basin. Such an anomaly could hypothetically aid in the protection of a habitat against radiation.

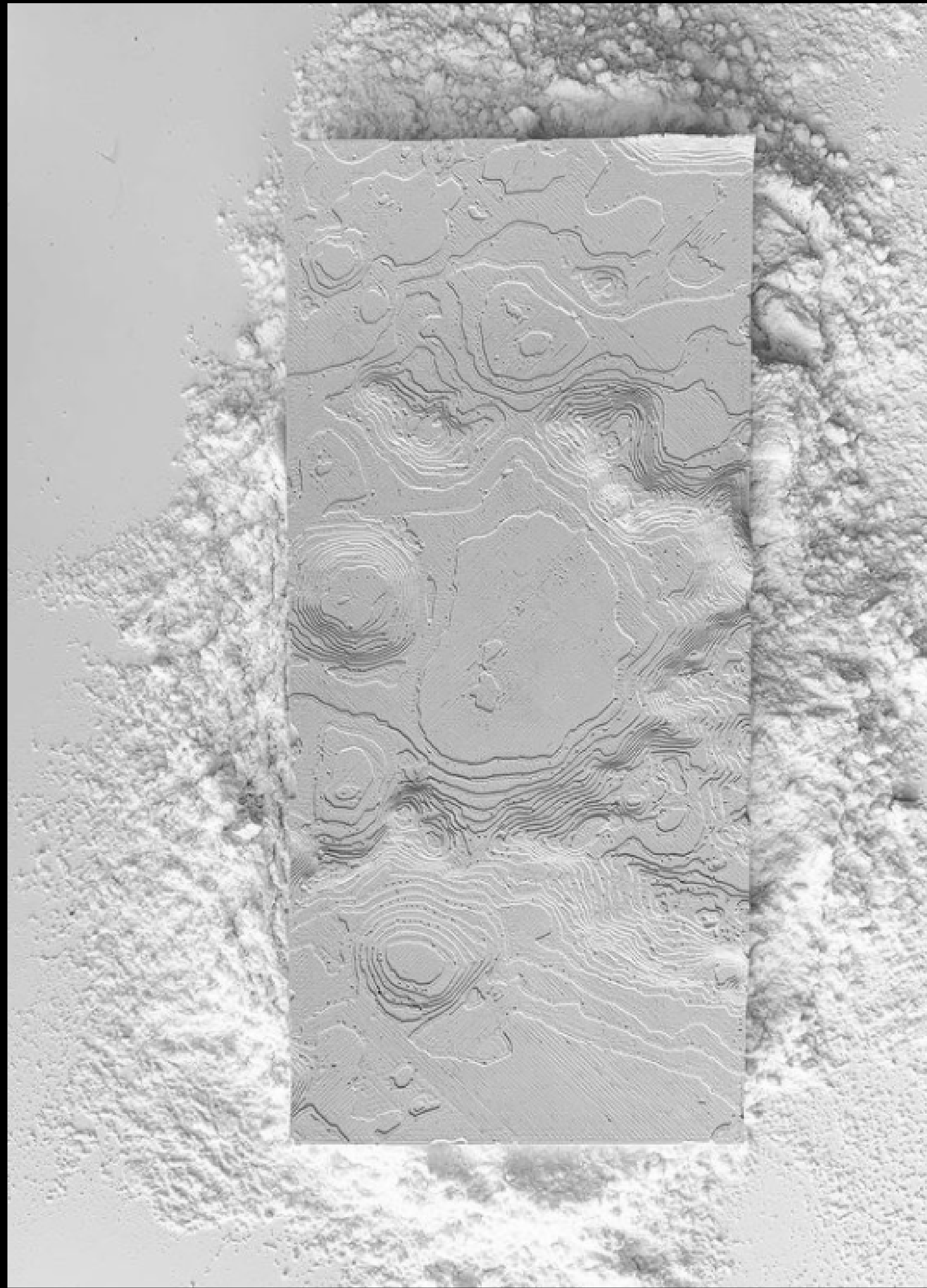


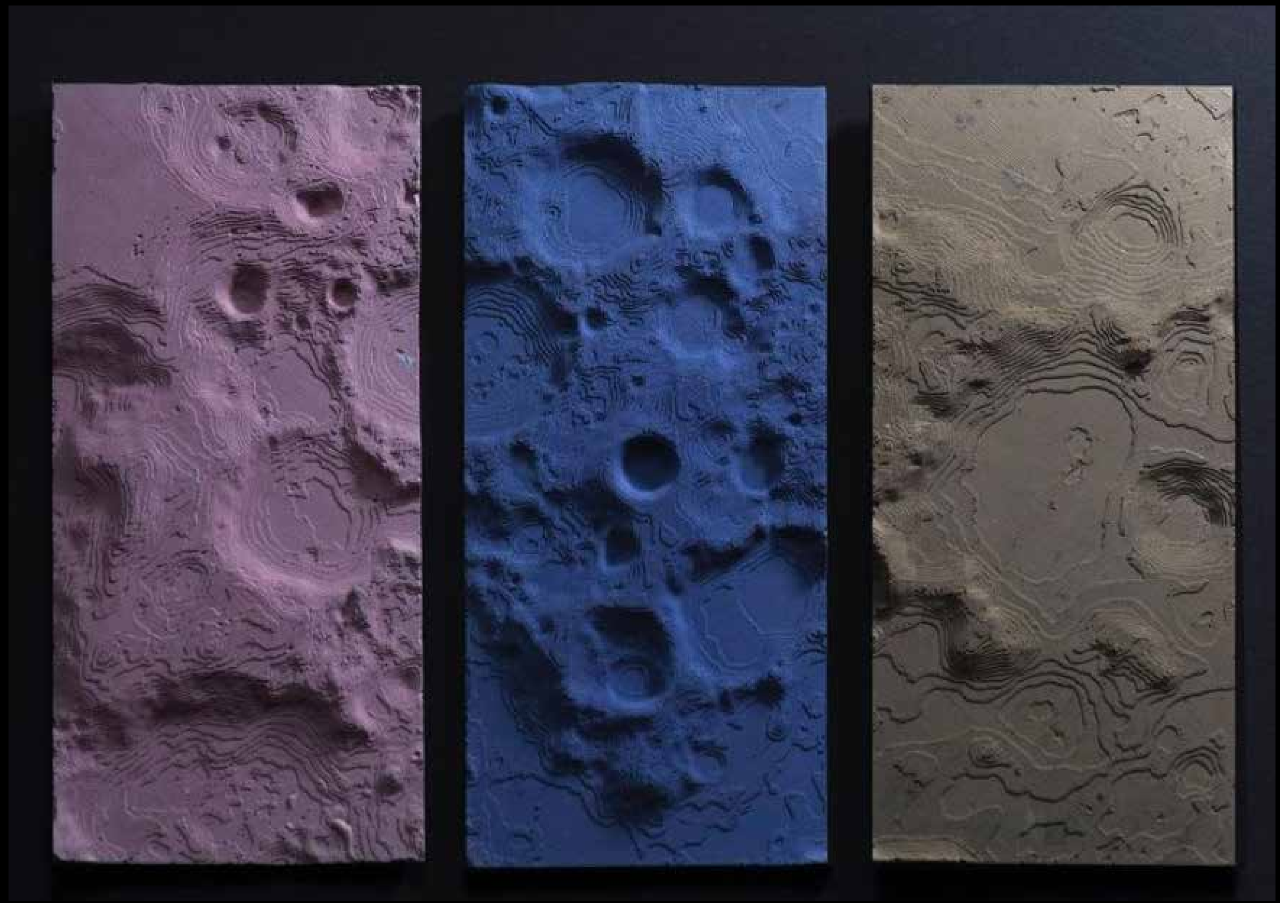
While doing the investigations for a potential site in grounding the my architectural proposal, I developed a fascination for the lunar landscape.

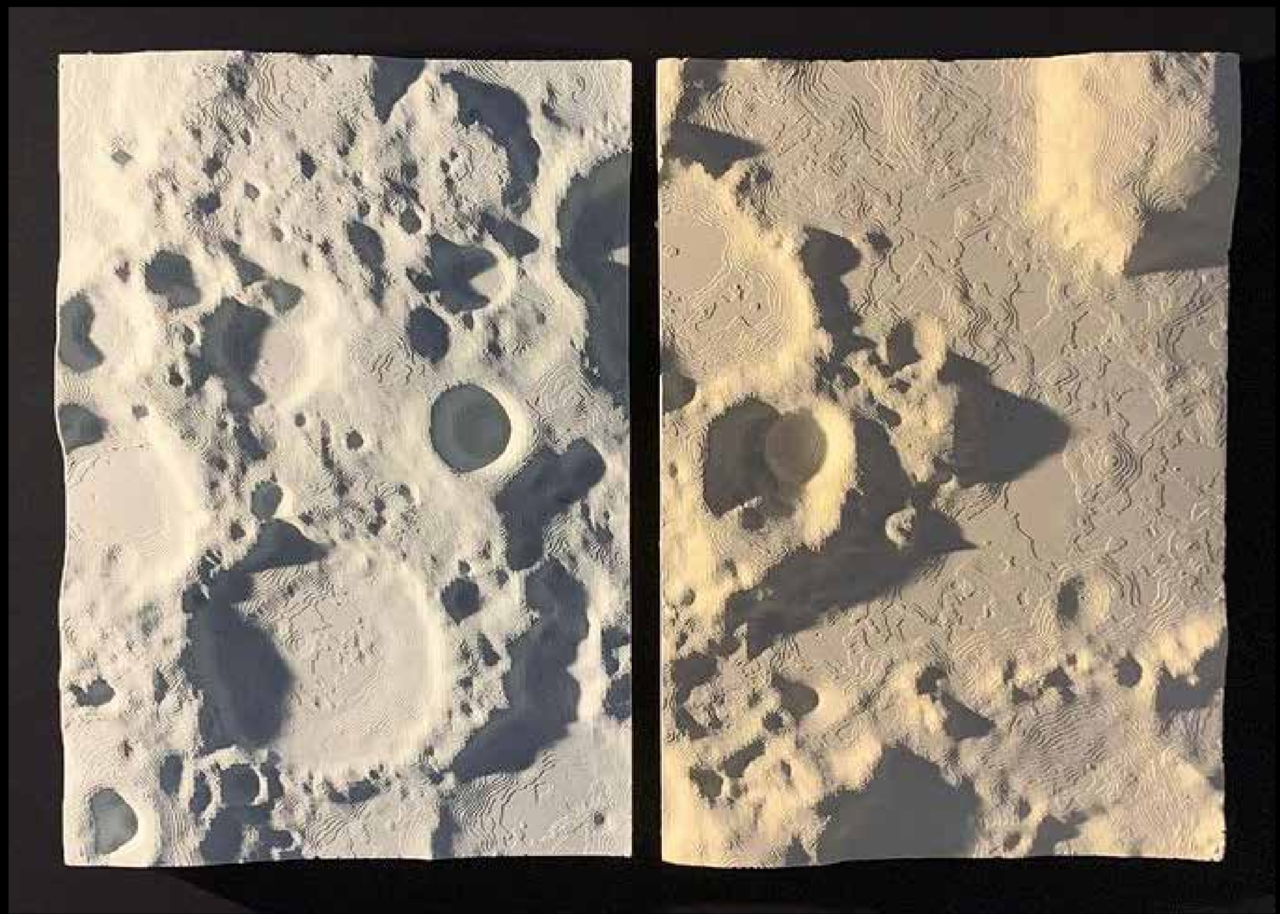
I wanted to be as thorough as possible in understanding the topography that I had to work with in the context of an architectural proposal. Using lidar data from the LOLA satellite, publicly available from NASA, I managed to transform the this data set into a topographical section of the Lunar South Pole, this was done through the development of a relatively simple Grasshopper script that would help in reproducing the geometry of the surface of the Lunar south pole.

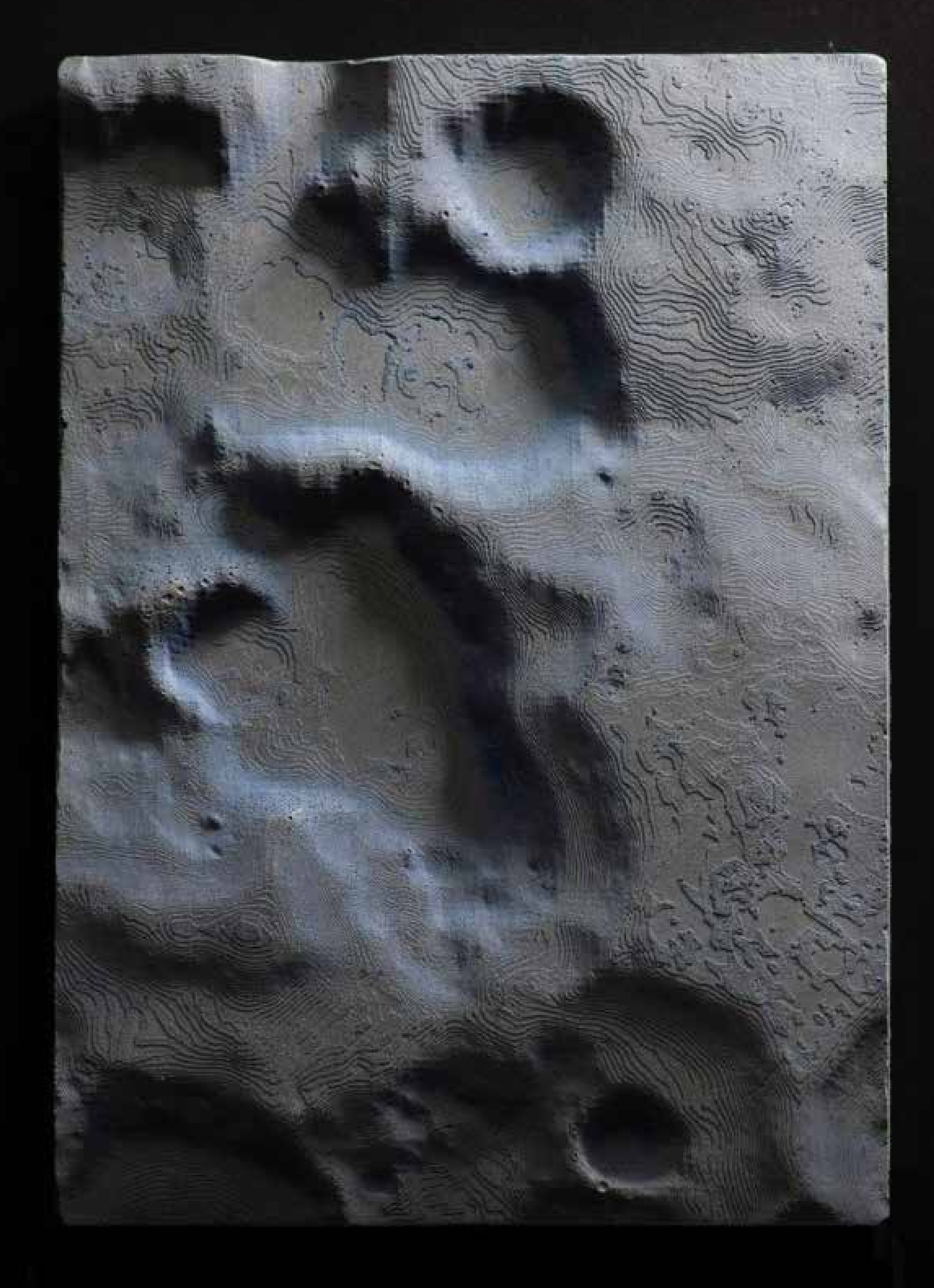
Having a working geometry I started to 3D print different sections of the original topography, experimenting with different scales, in the pursuit of developing an architectural model. The 3D prints acted as positives and were further used in casting durable silicon molds that would help do castings in different materials, from plaster to resin and from concrete to porcelain.

The 3D printng layer lines helped in further giving an intentional understanding of the topography as well as an interesting aesthetic. I also did many experiments in terms of coloring of the materials in order to further play with this look. This side of the project has take a life of its own and notw manyfests as a business known CassiniLab.









Part IV

Human Requirements

The next part of the research focused on human physiological needs such as air and water intake, food and energy consumption as well as waste management. Human psychological needs are also of crucial importance and developing a successful habitat as such they must be thoroughly understood and used as design principles within the architectural proposal.There are also other factors and parameters to take into consideration which a habitat must provide in order to support human life and activity.

On Earth these needs are fulfilled either due to the environment of Earth or by an infrastructure which has been in place for decades or even centuries. However this is not the case for the moon, as we have seen in previous chapters this environment is truly inhospitable to human life, or any life according to our current knowledge.

As such the chapter is an attempt to gather enough data which can help in understanding the infrastructure needed to build and sustain long term living and growth on the lunar surface.

We will also look at what is the anthropological background for a successful colony in terms of numbers and social structure as well as the context in which such a community could exist.

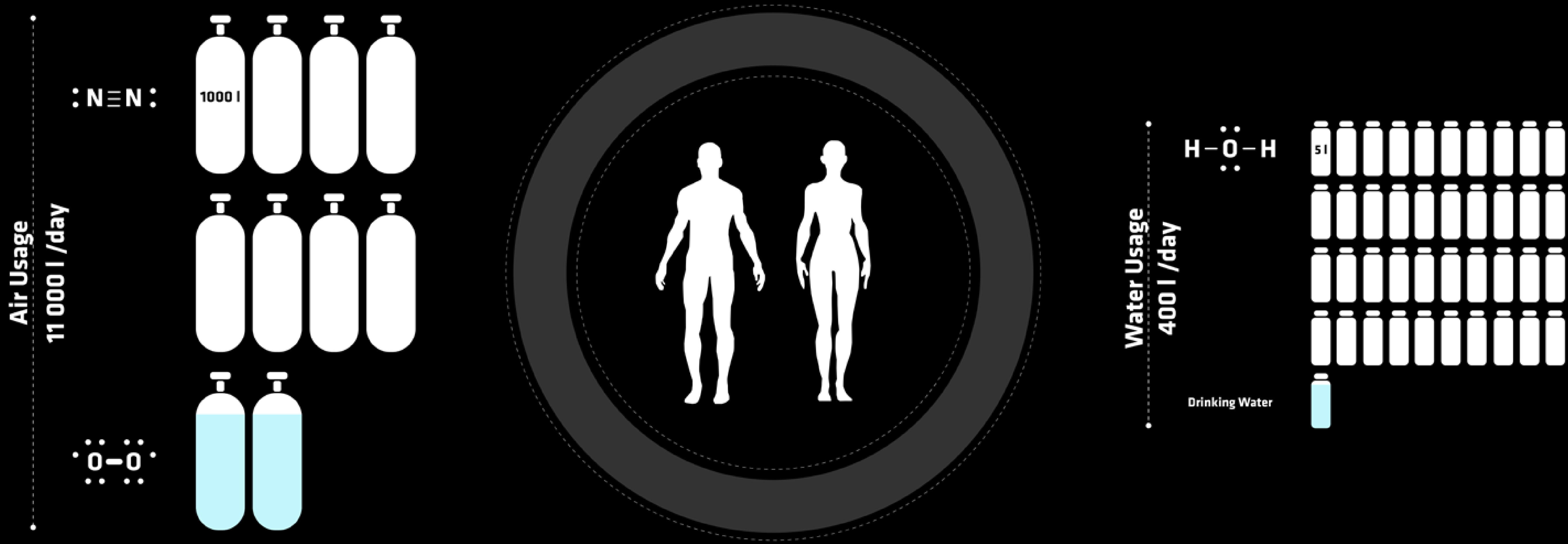
By establishing a preliminary quantitative analysis of the resources needed for an individual, we can further extrapolate and deduce the requirements of the programmatic scheme in developing an architectural solution catering to a larger community. Finaly we ge an overview of the social context in whic such a colony could exist.

Air Requirements

Air is the most vital resources of all. without it life on the Moon can be fairly short. The most common mixture of gases required for human breathing are Nitrogen 78% and Oxigen 22%. The average human inhales and exhales a volume of around 11.000 L\Day.

Water Requirements

The second most important resource is water. Luckly on the Moon we can find plenty of it. It can also be used in the production of Oxigen used for breathing and Hydrongen as fuel. Humans drink on average 2-5 L of water a day, however the average U.S. household uses up to 400 L.



Nutritional Requirements

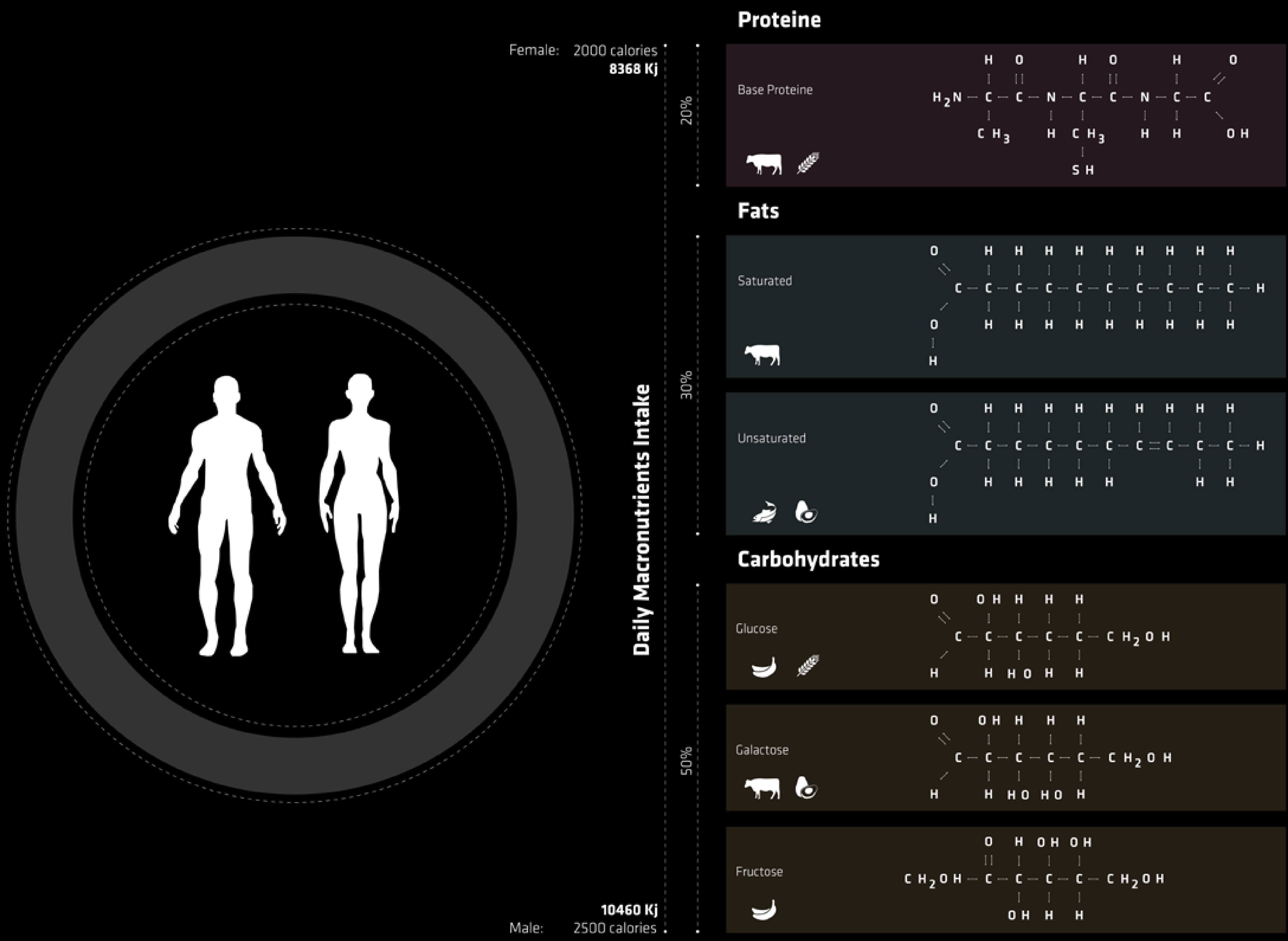
In order to achieve a healthy and happy population, food production in the colony is of utmost importance. The amount of each nutrient needed in our diets is called nutritional requirement.

Each nutrient has a function in the human body and some nutrients are needed in larger quantities than others. Individual requirements are related to a person's age, gender, level of physical activity and state of health.

In order to have a self-sustaining colony we need to introduce the idea of farming, which is able to locally produce food and feed the entire population.

With this indent in mind a breakdown of the average human diet was done. This will help in developing a comprehensive understanding of these needs and further help in establishing the space requirements needed in producing the amount of food needed. On earth the average male consumes food summing up to around 2400 Calories while females consume only 2000 Calories. However we should remember that physical activity plays a crucial role in the amount of energy required by individuals, knowing the Moon has only 1\6 of Earth's gravity means that the aforementioned quantities needed might actually be half.

Nutritional requirements are broken down into its components, proteine (20%), fats (30%) and carbohydrates (50%), in order to establish potential food sources, such as crops and livestock.

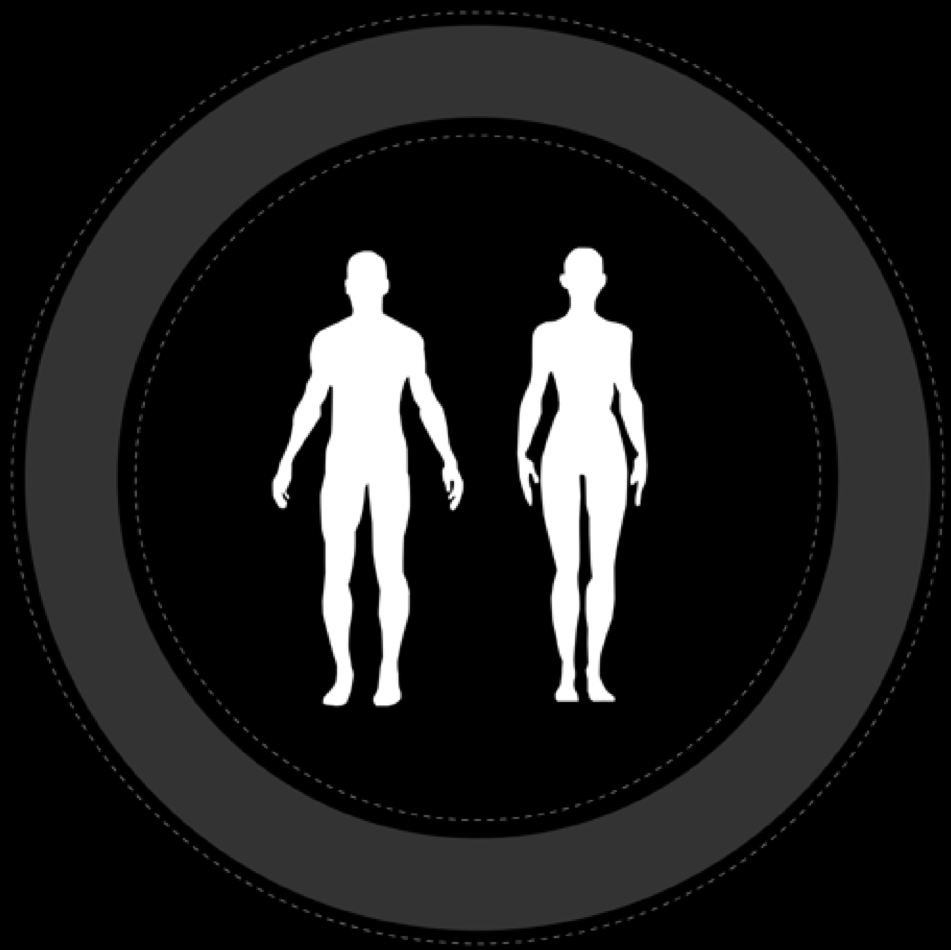


Human Waste

Humans generate on average around 400-500 g of solid waste daily and with a healthy intake of water they can produce up to 2L of urine. The by-product of human living can be seen as a resource and recycled, by producing compost used for agriculture as well as feed for livestock.

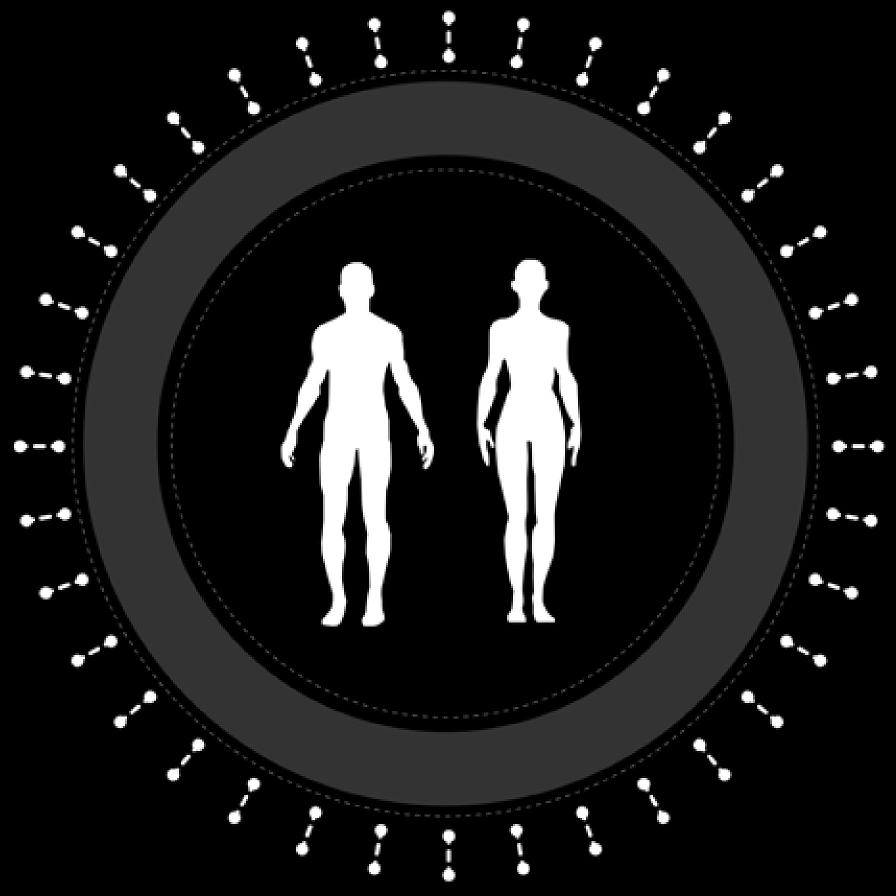
Energy Usage

According to the EIA, in 2017, the average annual electricity consumption for a U.S. residential home customer is 28.9 kWh. We will half this number in order to account for multiple members of a household. Even though this might be an overestimate we need to have into account energy usage of life support systems



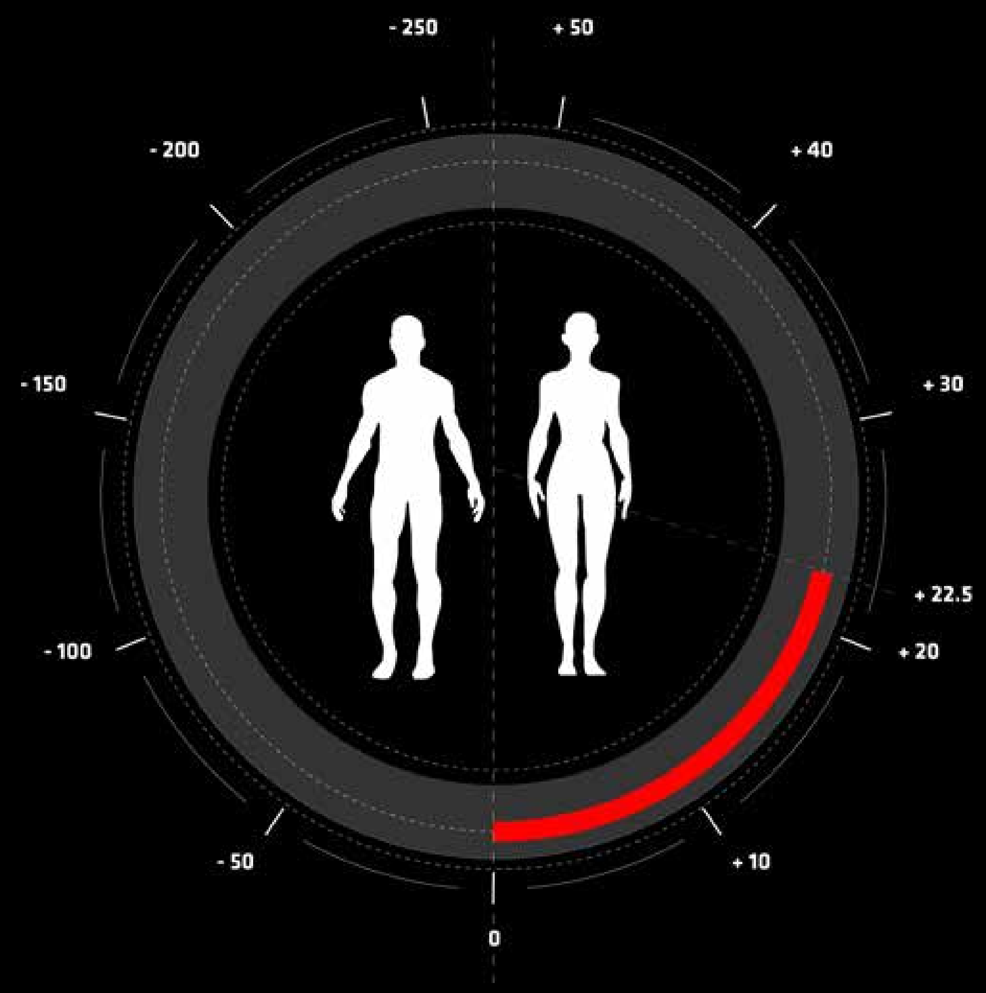
Radiation Requirements

Radiation registered on the surface of the Moon is of a very high level and represents a threat for human life. In order for our colonists to live a healthy life the habitat must provide adequate shelter. The NRC regulates members of the public to 1 mSv per year.



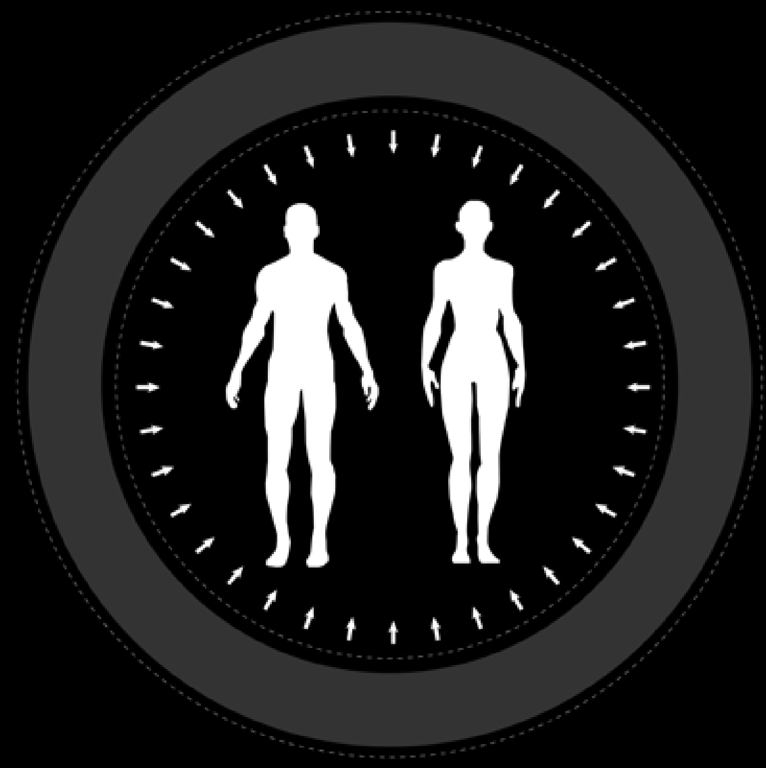
Temperature Requirements

Humans can live in a wide range of temperatures, however an ideally, comfortable temperature, for humans to be in is around 22.5 C.This means that the habitat needs to have a sufficient thermal mass and other thermal regulatory systems capable of maintaining the aforementioned level with constancy.



Pressure Requirements

Humans are able to survive in a wide range of pressured environments from 6300 to 700,000 Pa. The earth’s pressure at sea level is 101,325 Pa, and seems to be the most comfortable for human activity. The habitat needs to have the structural rigidity to withstand the pressure difference between the outside environment (vacuum) and it’s inside.



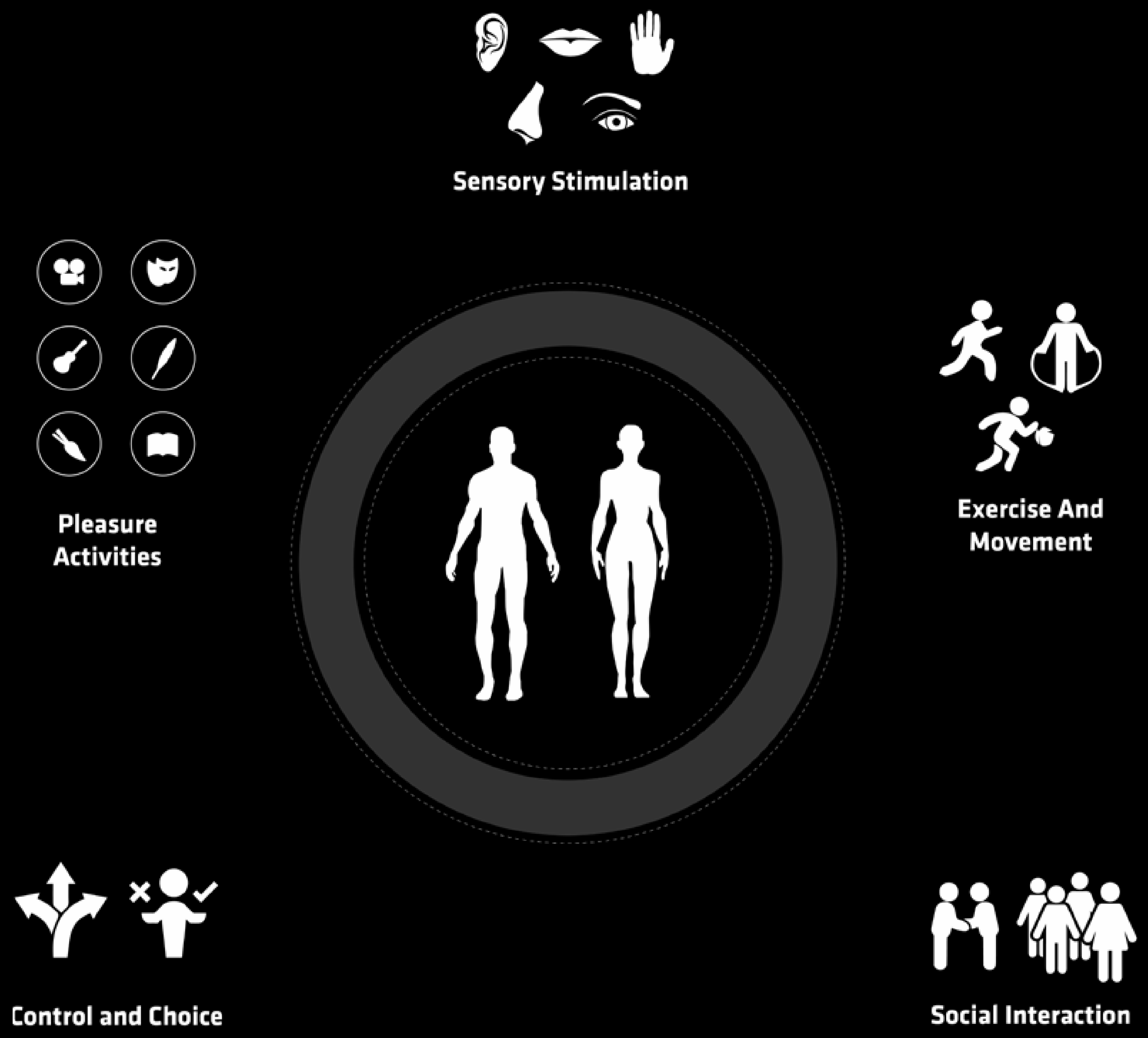
Phycological Wellbeing

Besides fulfilling the physical needs of individuals, psychological needs must also be addressed. As such there are many factors which contribute to the fulfillment of such needs, some can be taken into consideration when considering an architectural proposal and some can not. However the purpose of this investigation was to establish those for which solutions can be set in place.

As any living organism, humans have a series of senses through which they navigate and understand the world, it is through these senses that we can either enjoy or be displaced by our environment. Sensory stimulation is an important factor when discussing psychological well being.

An environment providing pleasant stimulation to our senses is desired. From this perspective, our design solution must deal with visual stimulation by providing a dynamic visual environment. We must create an environment in which our senses of taste and smell are stimulated potentially through the use of diverse species of vegetation. Within the design solution we must also embed a strategy allowing for a diverse and tasty diet. Our sense of touch must be stimulated through the textures of materials individuals interact with on a daily basis, and for our sense of hearing a pleasant audio-scape must be present.

It is a well documented phenomenon that exercise is of great benefit not only to our physical health but also to our mental



one. Regular exercise can have a profoundly positive impact on depression, anxiety. It also relieves stress, improves memory and boosts overall mood. The design needs to take this aspect in consideration not imply from a physiological perspective but also a physical one. Due to the lower gravity of the Moon there is a relatively high risk for human health if a high level of movement is not embedded in the design proposal.

As a social species human beings rely on social interaction and group bonding. We rely on cooperation for our ability to survive and thrive. It is mandatory to promote social interaction in order to build a successful community that could grow and further develop over the years. Private and public spaces as well as circulation are design aspects that must not be neglected when tackling such an issue.

Another psychological need is that of choice, people need to be able to choose, be it, where they work, relax, eat, walk and so on. This is a relatively need but it is one that can be understood as the ability to provide versatility in the design and community at hand.

All humans need to rest, and enjoy themself, this can be achieved by implementing a variety of entertainment and recreational opportunities,through different amenities.

Population Size

Some of the earliest studies of groups in sociology revolve around their size. In 1922 Cooley described how people are universally members of primary groups which are small in size, face-to- face, highly intimate, cooperative and enduring. Prototypes of such groups include family units and groups of friends. As group size increases, groups tend to adopt a more direct and organized approach.

The intent in our case is to generate a lunar community both in it's archaeological sense of a settlement as well as in its sociological sense of a group of people living near one another who interact socially. In The Different Drum: Community-Making and Peace (1987) Scott Peck argues that the almost accidental sense of community that exists at times of crisis can be consciously built. Peck believes that conscious community building is a process of deliberate design based on the knowledge and application of certain rules.

If we are to consider multi-generational living for our new colony, from the perspective of a viable population, the starting number of individuals should be similar to that of a small village of 80 individuals, this number would ensure the minimum necessary genetic diversity, however more conservative views consider that the ideal number should be 160 individuals.

From an anthropological point a view Dunbar's number is a suggested cognitive limit to the number of people with whom one can maintain stable social relationships—relationships in which an individual knows who each person is and how each person relates to every other person. In his studies, Dumbar found a correlation between brain size and average group size of primates. By using the average human brain size and extrapolating from the results of primates, he proposed that humans can comfortably maintain 150 stable relationships. Since the publication of this theory alternative studies have been made suggesting that this number could be as high as 290 individuals.

Anthropological studies of the Amazonia tribes ranging in size from 150-300 people also suggest that a stable social structure can be achieved in these communities without the need of a rule enforcement apparatus. Having known all of the above mentioned, the population size of our colony should be around 300 individuals.

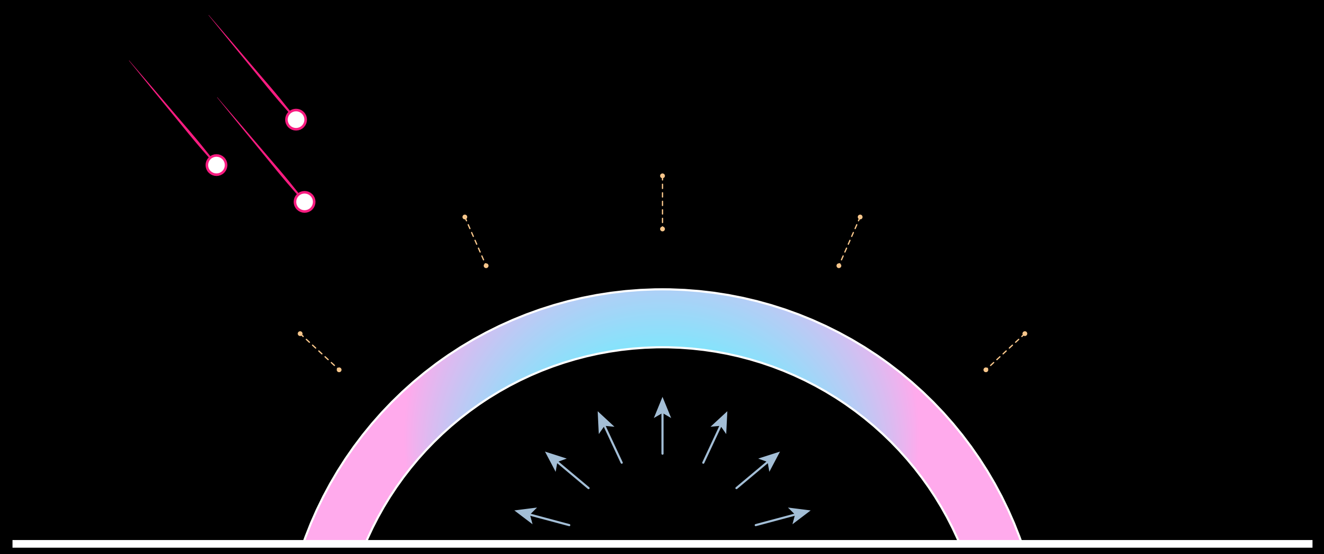
Social Context

The context in which such a community and project exist would be similar to that of a company town. In our case a multi-national, multi-corporate conglomerate which has an interest in pursuing research as well as undergoing rare minerals extraction operations on the surface of the Moon.

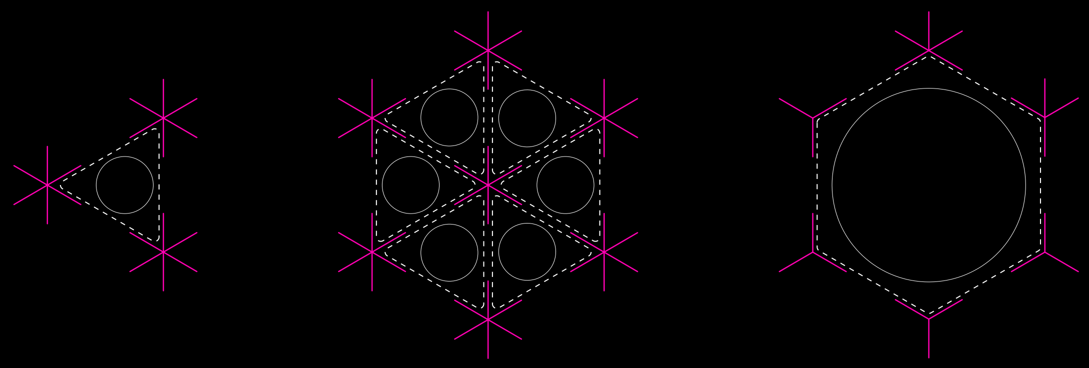
Traditional settings for company towns were where extractive industries had established a monopoly franchise. Dam sites and war-industry camps founded other company towns. Since company stores often had a monopoly in company towns, it was often possible to pay in scrip through a truck system, although not all company towns engaged in this particular practice. In the Soviet Union there were several cities of nuclear scientists known as atomgrad.

Even though this is an fairly old concept which hasn't had much success in the past, due to the monopolised nature of the endeavour, I believe that a multi corporate environment would facilitate the social mobility required in order to prevent unethical practices within the social body. As such scientists, researchers and technicians would come to live in the lunar settlement based on a 3-5 year employment contract, either alone or accompanied by their family.

Through the establishment of a permanent presence and the introduction of a special economic zone, different industries would become incentivised to partake in the further development of the colony.



Maintain radition levels under 1 mSv.
Withstand presure difference from 1 -0 atm.
Withstand the ocasional Micro-Meteriorite Impact



Part V

Geometry and Growth Strategy

Among structures, domes carry the distinction of containing a maximum amount of volume with the minimum amount of material required. Dome structures have been used from the very beginning of humankind. By comparing domes to rectangular structures of equal height and volume, we can quickly see that the structural properties are a great advantage when considering the harsh conditions of the lunar environment.

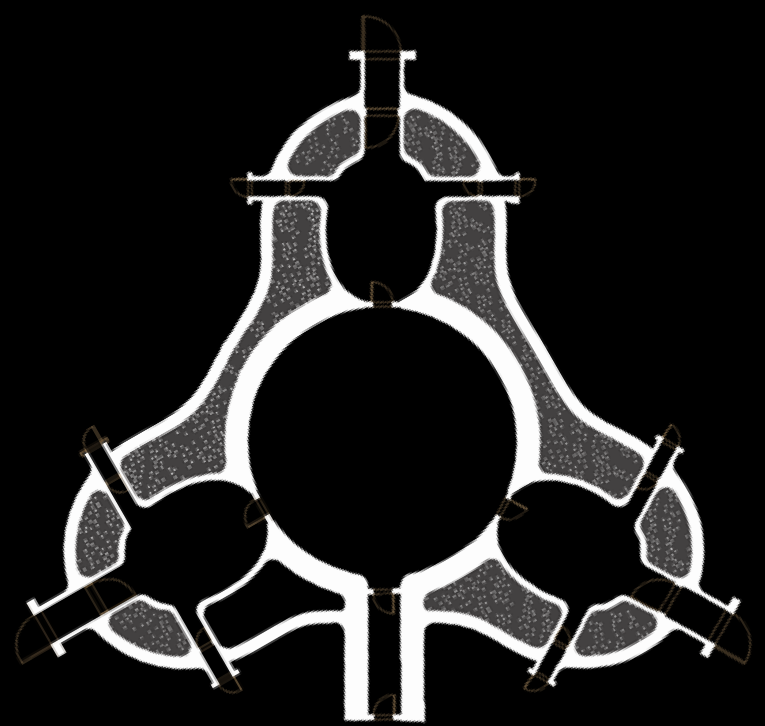
One of the main factors contributing to choosing this geometry has to do with the internal pressure loads required for habitation. As humans need an atmospheric pressure of 14.6956 psi. The pressure difference between the inside and the exterior of the dome equals 1 atm, which results in a great stress upon the structure. The dome structure is ideal for dissipating in an equal manner both internal and external forces.

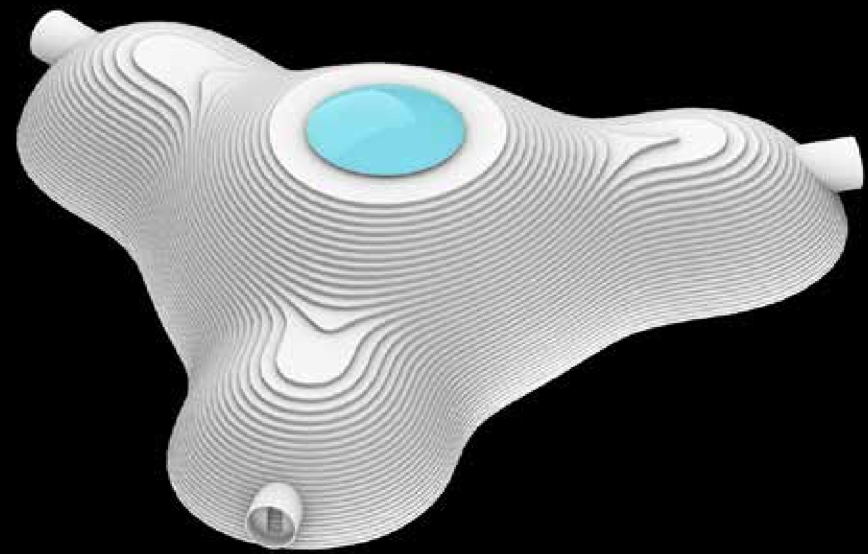
The need for the structure to be buried under a very thick layer of regolit so that its inhabitants would be protected from radiation and the occasional micrometeorite impact is further motivation for using a geometry which is well suited for dealing with diverse loads.

From an architectural perspective domes are also suited for creating large open spaces, which could allow for an architectural solution which does not seem claustrophobic.

The next aspect had to do with the growth potential of such a structure, I opted to create a plot strategy which would be able to allow for the interlocking of the different domes as well as allowing for different dome sizes. This needed to take into the consideration the additional space required for burying the structure.

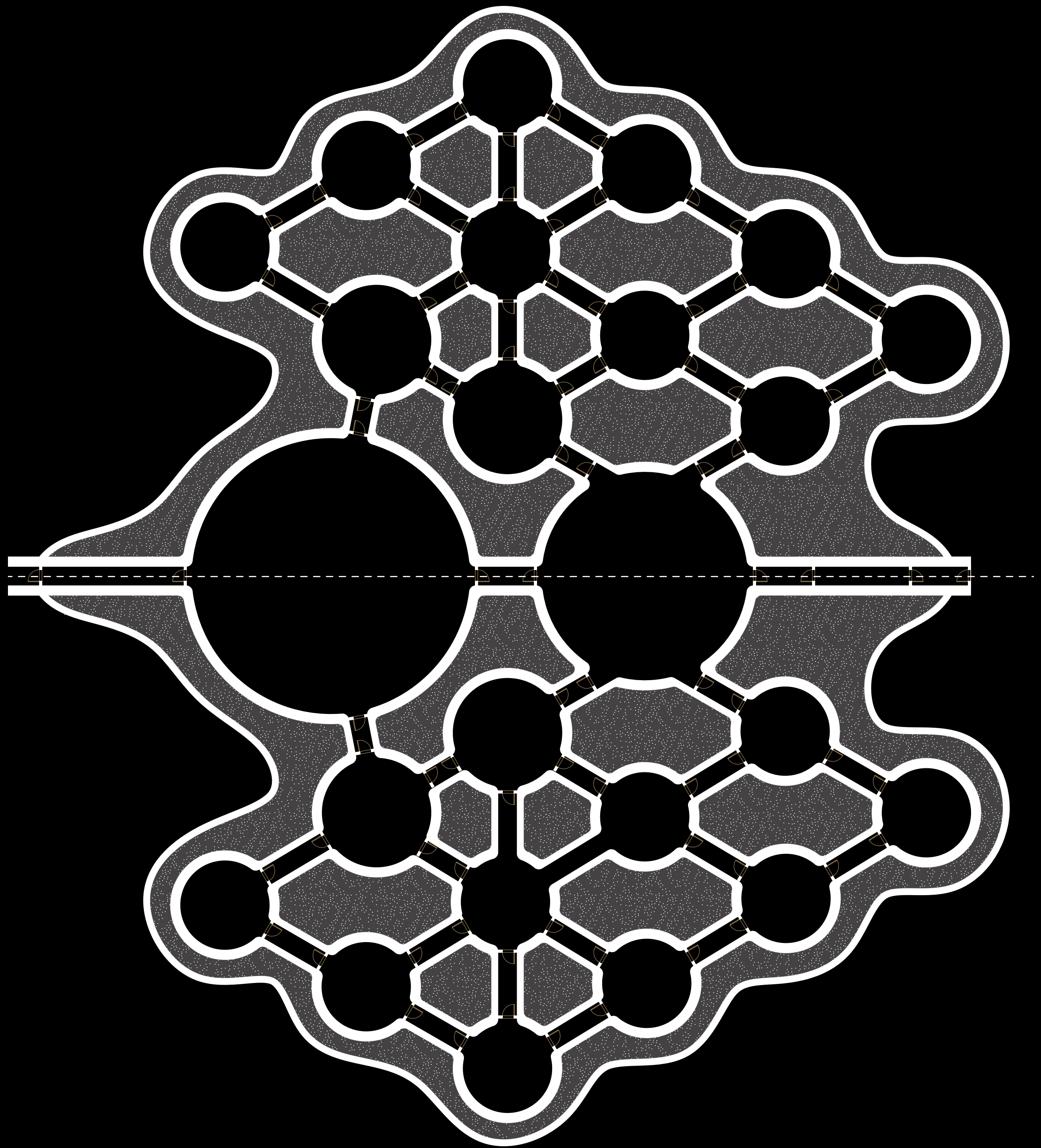
As such a developed a triunghiular grid system which would allow for multiple configurations of dome aggregates. The triunghiular grid cells can be combined to allow for different sizes of the domes as well as different configurations between domes of different sizes.

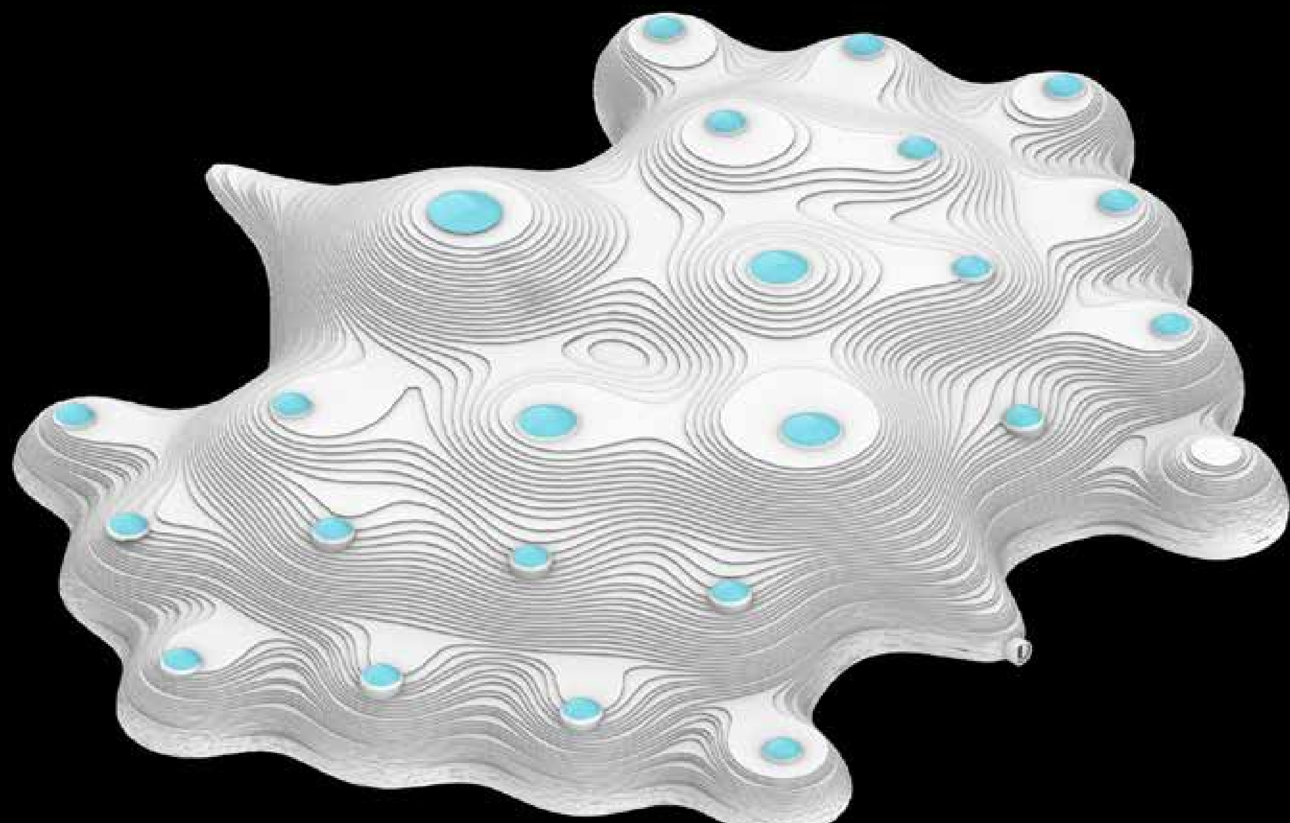




Typology A

I started from a small cluster of inflatable connected domes that would be encased by a masonry shell built using robotic means, which later would be covered with regolith.

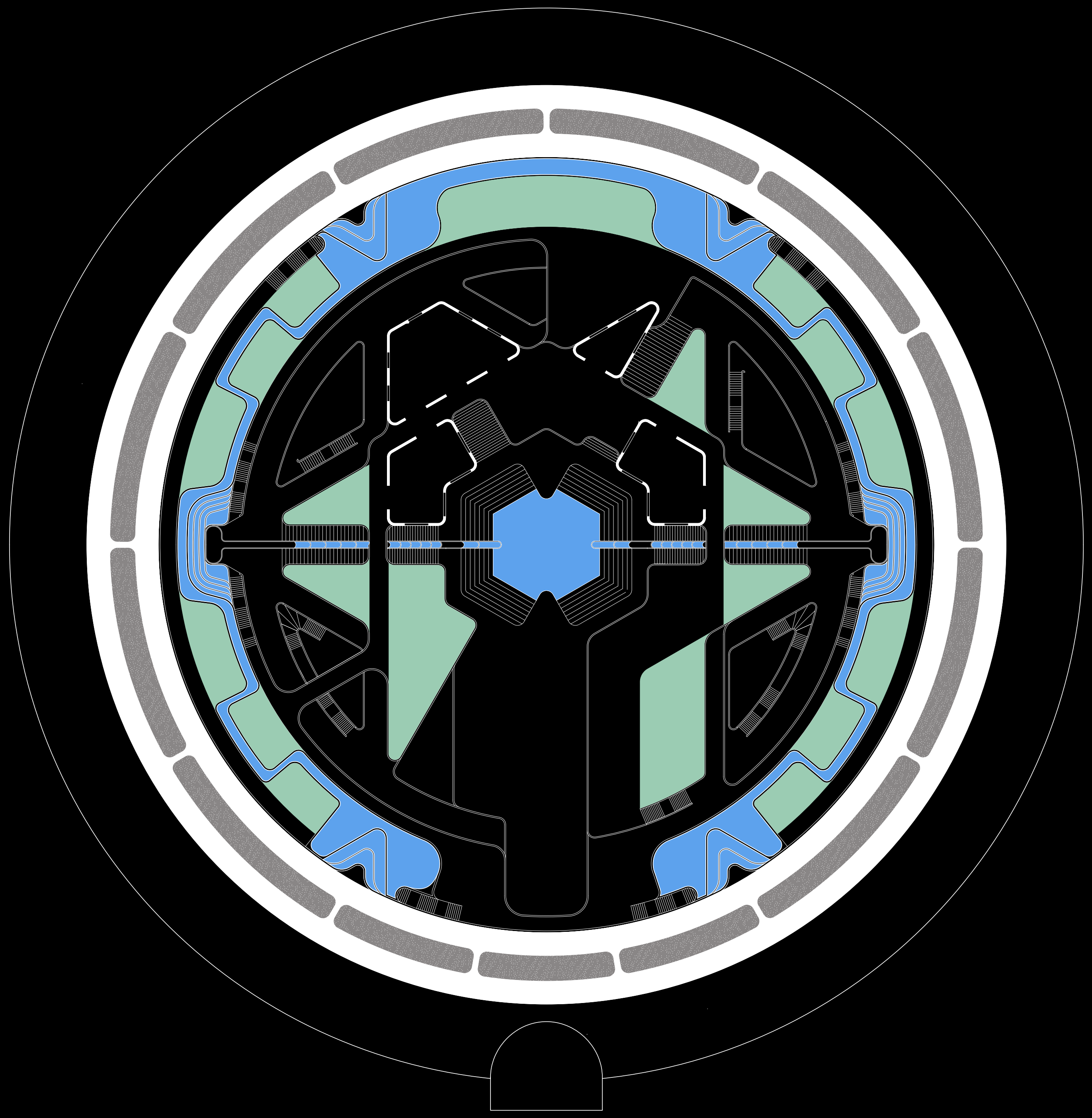




Typology B

I then further moved in expanding the idea to larger clusters which would comprised from different sizes of domes which would fit within the proposed “grid” system.

However in order to facilitate a thriving micro-society I came to the conclusion a third typology was needed.



Typology C

The idea behind the main habitat dome is to create an environment not much different from living on earth.

A small city centre fitted with amenities. Parks and lakes, runing tracks, small public plazzas a chapel and other eterntaiment where people could feel just one step away from home

Part VI

Masterplan Development

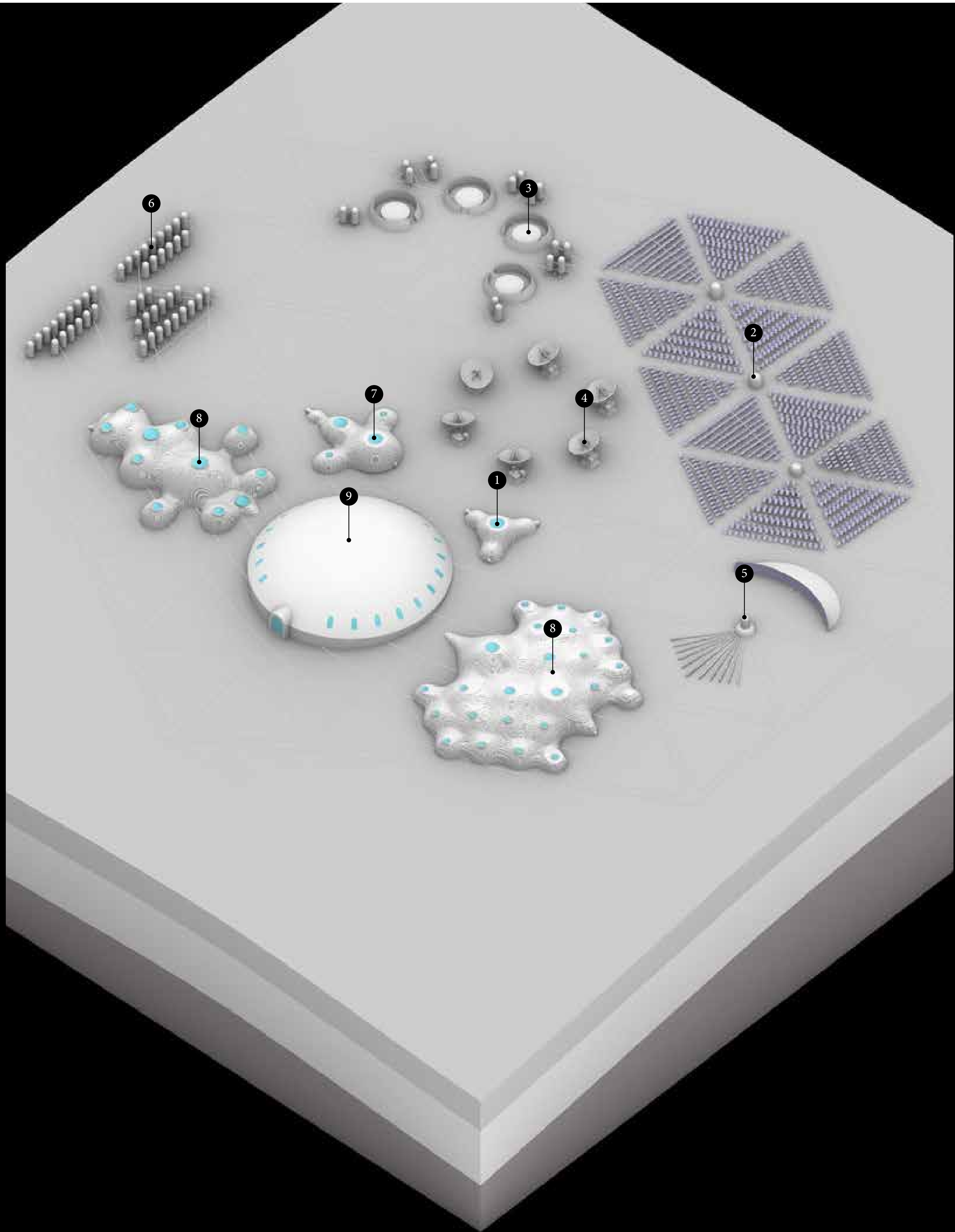
The Matesteplan is developed as a result of the previous investigations, it aims to present a growth strategy that would take into consideration all infrastructure needed for building and sustaining the colony.

The solution encompases an area for energy production, resource and management and processing, communication array and landing area, as well as the different habitats.

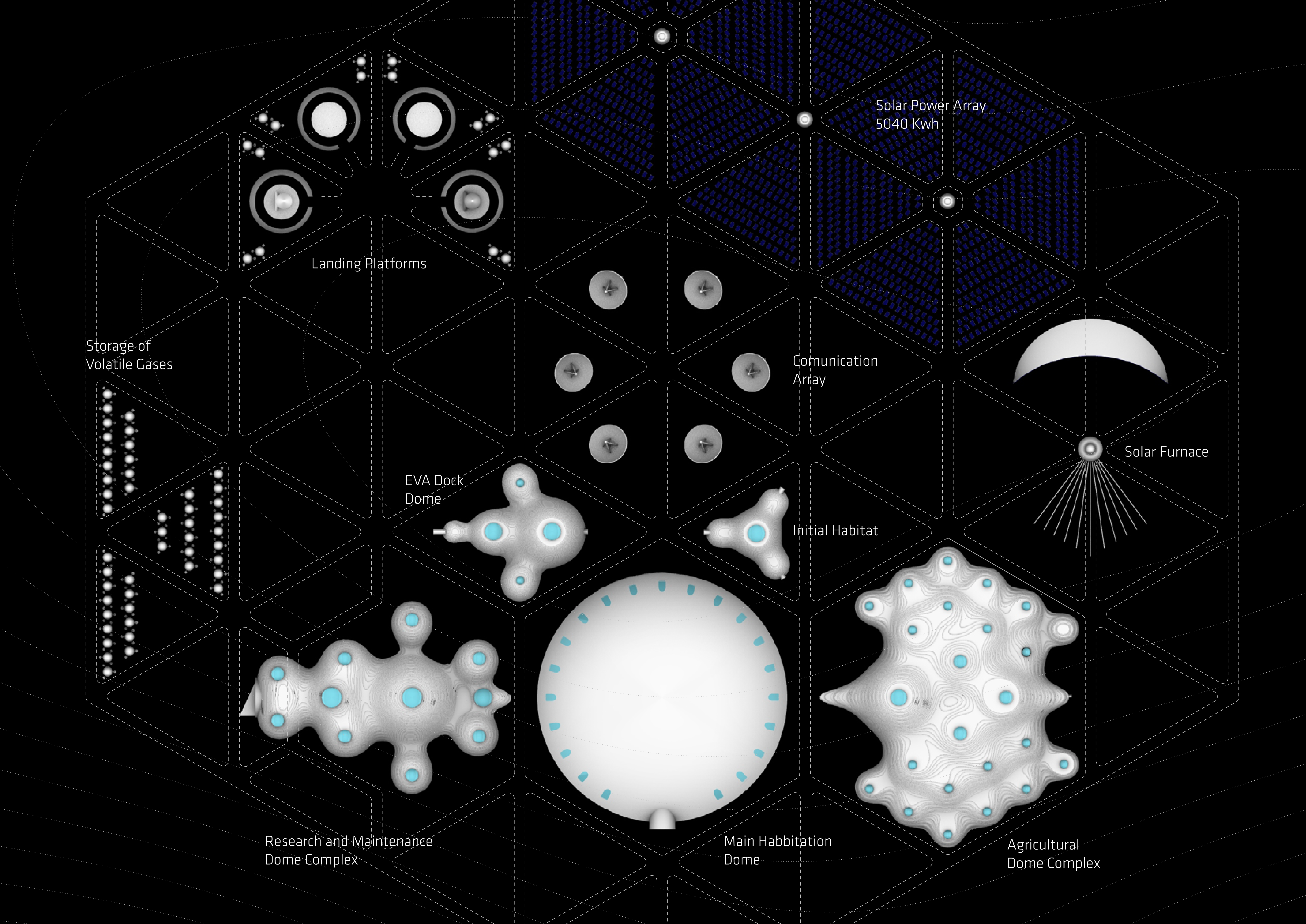
The proposal is presented as a moment in the development of the colony, a picture frozen in time, however it takes into account the future growth of the colony, by establishing different infrastructure zones. It also proposes a road system which respects the proposed grid structure. By having developed the different habitat typologies we can now embed them in the Master Planning proposal.

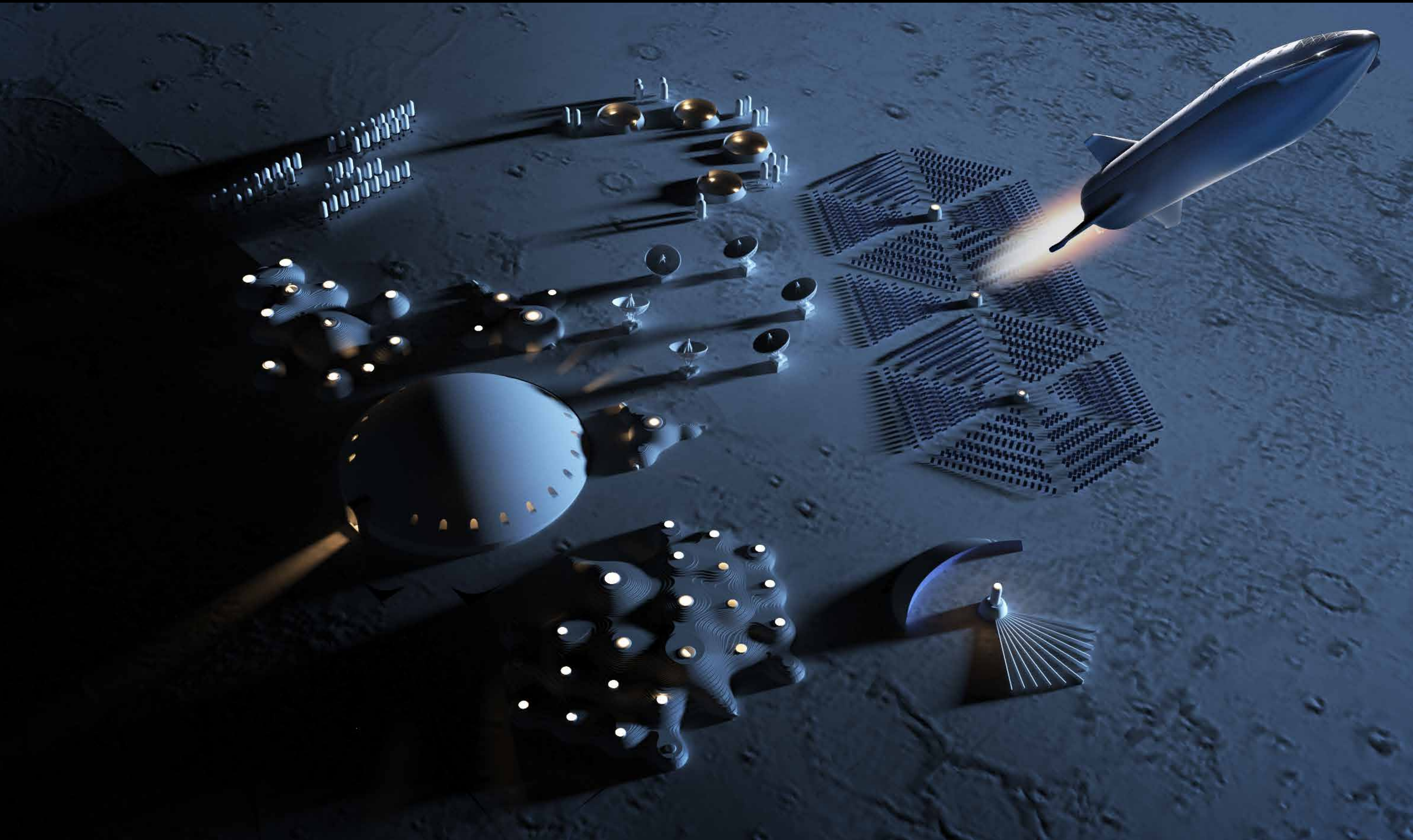
Development Stages

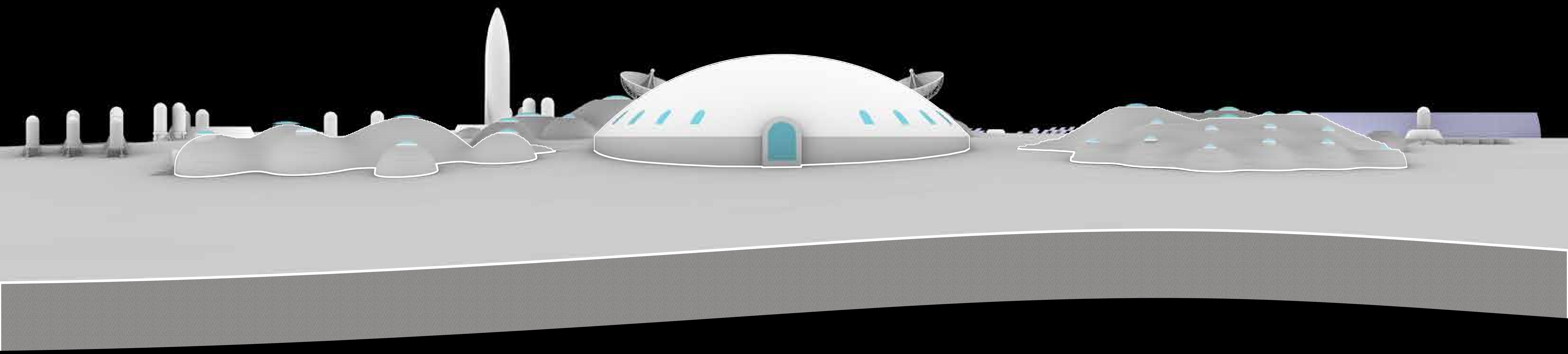
The complex would grow over time, starting from an initial habitat which would house a small group of individuals. Their tasks would revolve around the development of the settlement.
This habitat would be a class II structure, meaning that it would be an inflatable structure, around which later a masonry shell would be built, as soon as the infrastructure to allow that would be in place. At this predominantly physiological needs are taken into consideration, air, water and food are provided by routine supply missions.
Part of the solar array needs to be set in place as soon as possible in order to provide the energy for the initial habitat as well as to provide power for the robots needed in further developing the colony.
The next step would be the development of a landing platform, thus mitigating the risks in the resupply missions. A crucial aspect in allowing the development of the colony is communication with Earth as such a communication array would need to be developed. This would need to be brought in from Earth.
At this point the established settlement would be ready to beggin resource extraction operations, processing plant would be needed. As such a solar furnace would be constructed using parts shipped from earth as in situ construction. The furnace would allow for the processing of regolith and water ice, allowing for the harvesting of volatile gases as well as the production of brick like basaltic glass masonry elements which would be used in further constructing the settlement. Storage would be needed for many of the gases and rare minerals, as such containers would be required for shipping them to Earth.



The next step would be development of a habitat which would be build in situ using locally produced materials. It would function as an intermediate living situation, and allow for additional research functions.
Continuing the development of the colony would be the creation of a facility that would allow for the development of much of the required equipment and maintenance of existing equipment, as well as providing additional housing. At this stage the colony would move into the development of typology 2 habitats, where large clusters of domes having different functions would be developed. It is in this stage that agriculture is introduced to the system.
Following these steps the colony would grow to a significant number of individuals, it is at this point that a population critical mass would be formed, and psychological needs need to start being addressed through the architecture. Thus introducing the 3rd and final Typology.
Throughout this expansion all other infrastructure would be expanded.
The further development of the settlement would revolve around a slow cycle of growth through clusters of habitats (typology 2) which would be followed by a fast expansion(typology 3). Many of the spaces in typology 2 clusters could then be converted to agricultural or other functions, as their inhabitants would be relocated to more appropriate living conditions


Solar Power Array
5040 Kwh
Landing Platforms
Storage of
Volatile Gases
Comunication
Array
Solar Furnace
EVA Dock
Dome
Initial Habitat
Research and Maintenance
Dome Complex
Main Habbitation
Dome
Agricultural
Dome Complex





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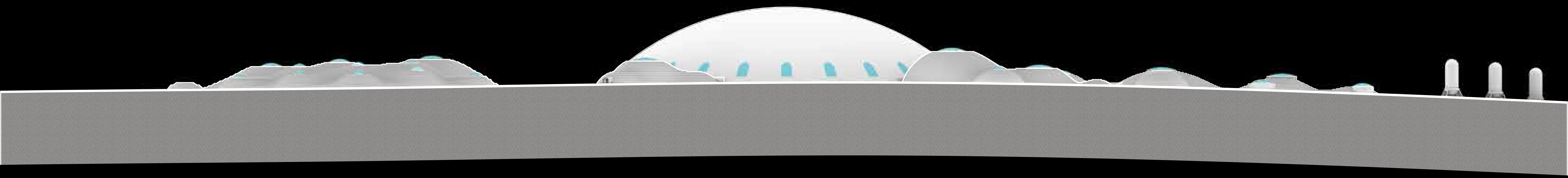

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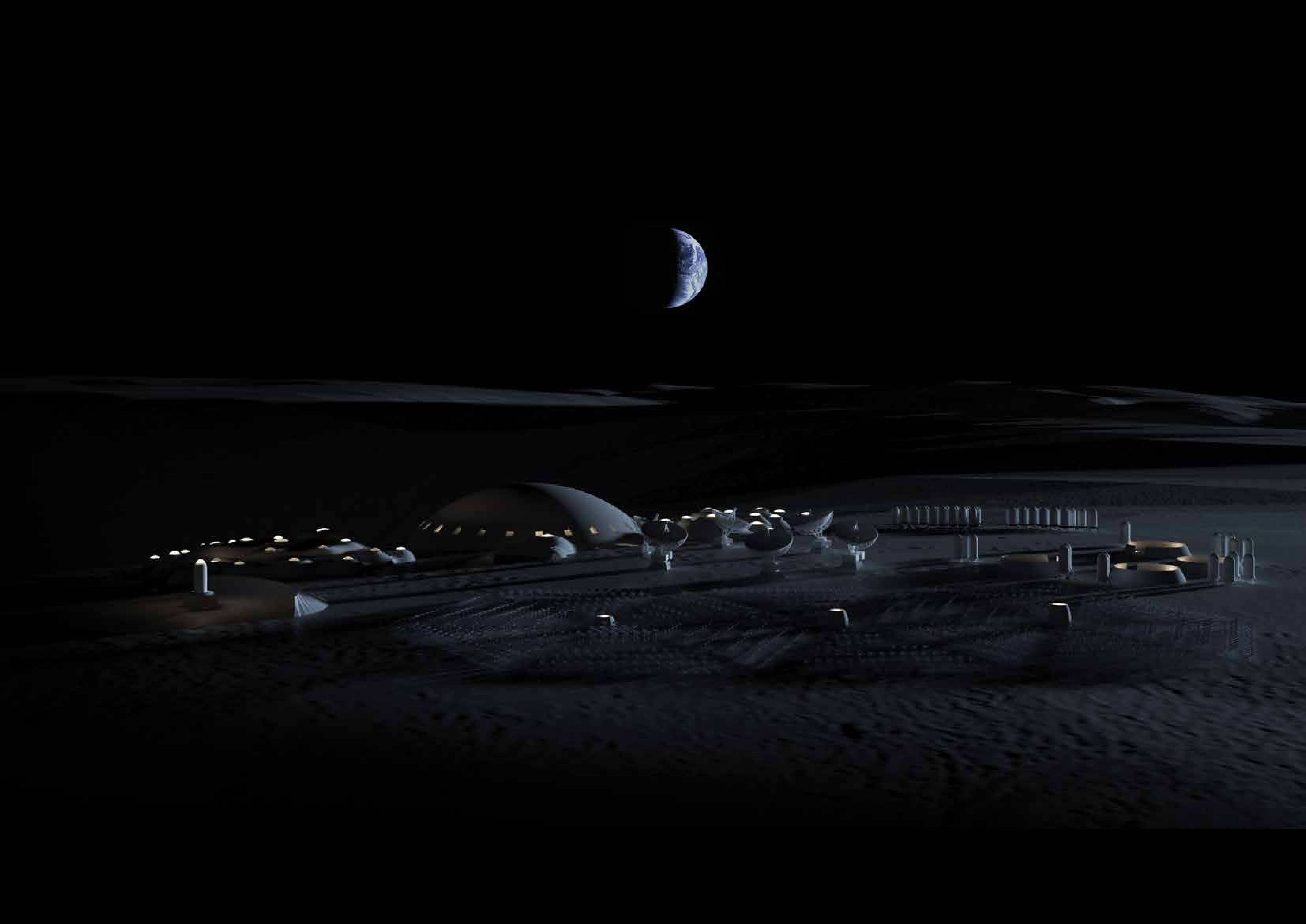

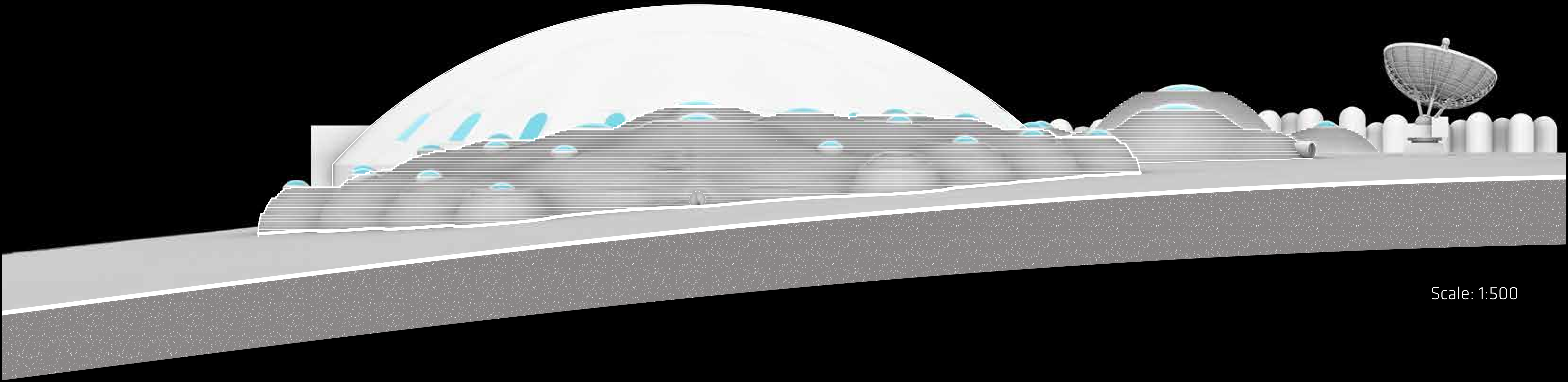

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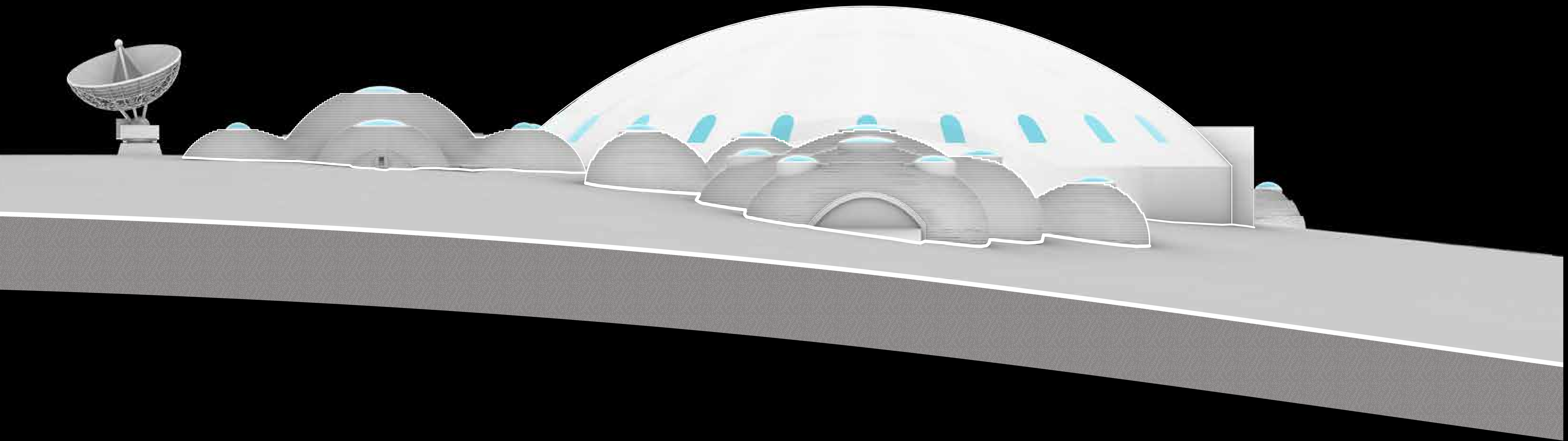

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Part VII

Development of Main Habitat

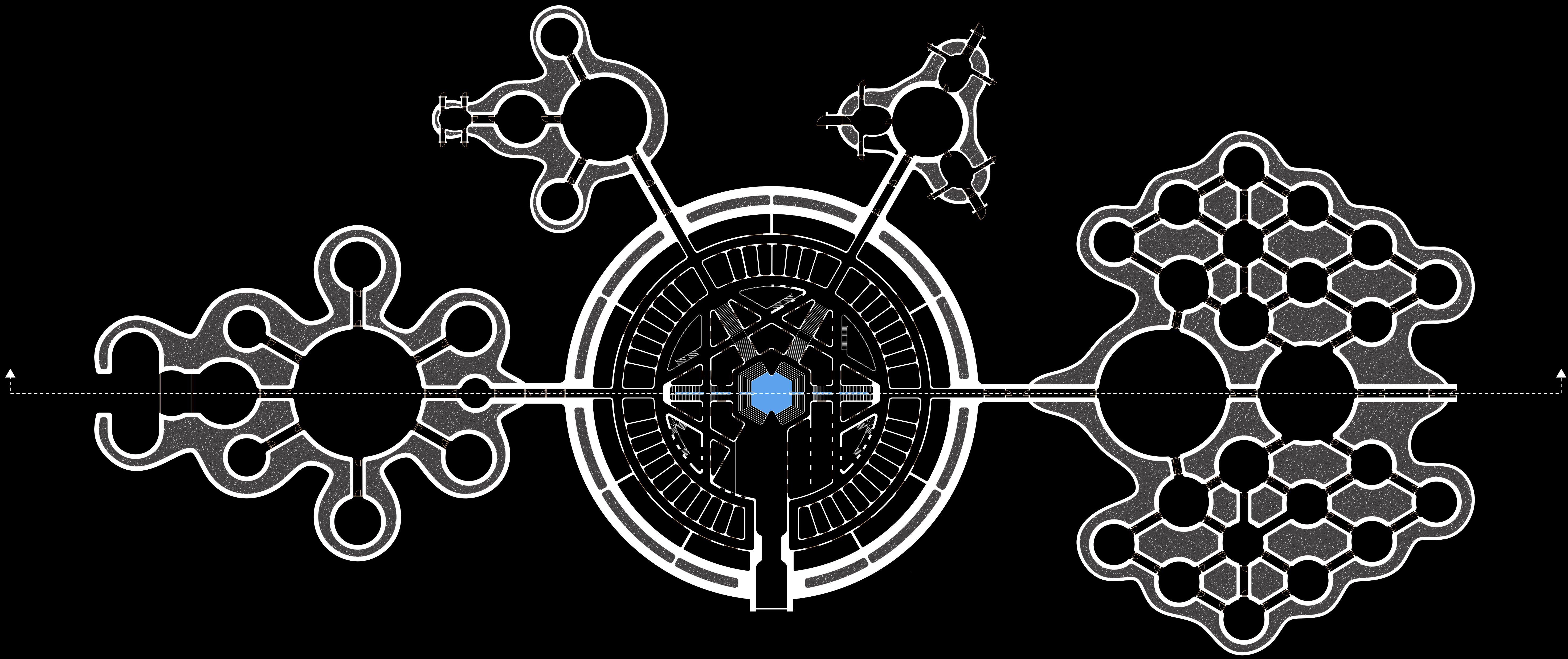
When developing the main living habitat, humans were at the centre of the design. The physiological needs of humans are the first that are taken into consideration, however the architecture proposed focuses intensively on satisfying psychological needs.

As such sensory stimulation is one of the first aspects taken into consideration. This is done through the development of a dynamic visual environment,creating a tactile experience through the use of apparent material and urban furniture, an audioscape which is dominated by the sound of a moving body of water, and olfactory stimulation generated by the plots of greenery. The last aspect in sensory stimulation refers to the integration of a circadian lighting solution in the form of an artificial sky which would mimic Earth's illumination conditions.

The following physiology refers to the need for physical activity. As well as maintaining physical fitness this also plays a crucial role in the mental well being of the inhabitants. Movement is promoted through the development of an architecture which promotes movement, such as the use of numerous stairs in the circulation of the structure.
The design tries to take into account social interaction, as such the layout revolves around creating different pockets of activity at different scales. From more private areas to a large central plaza.

One of the most difficult , and rather abstract psychological needs is that of control and choice, I believe that the proposed layout crates numerous choices from navigating the space to the different activities that can occur in the design. By allowing inhabitants to be part of the processes of sustaining the colony such as food production, a sense of control can be achieved.

However considering the context i believe this is one of the most challenging aspects to consider when developing the architecture in this environment. It is also important to understand that the architecture tried to be as demorcratic as possible, when considering the social context of the colony offering different living conditions to the inhabitants might be a cause for unrest.
Lastly the colony could offer a wide range of pleasure activities, through the use of the proposed parks and common area.



Design Priorities:

Primary design principles in developing the main habitat focused around the ideas:

- Generating a visually dynamic environment which encompases lots of green areas, as this is one of the main criteria in mitigating the psychological impact of living in an isolated environment.

- Integrating the need for physical activity as much as possible in the design is also critical thus the preserving physical health.

- The use of a circadian lighting solution improving wellbeing.

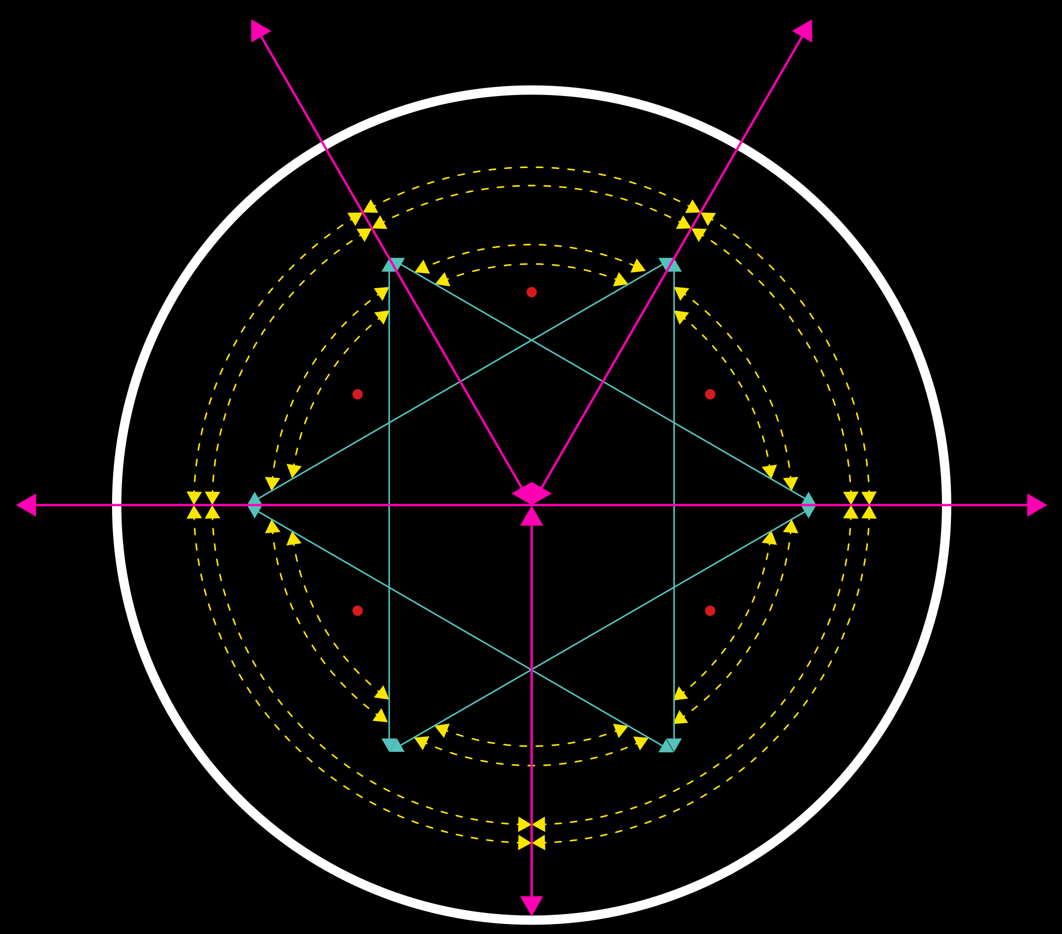
- Transforming necessities such as food production and water recycling, and air management into amenities as much as it was possible.

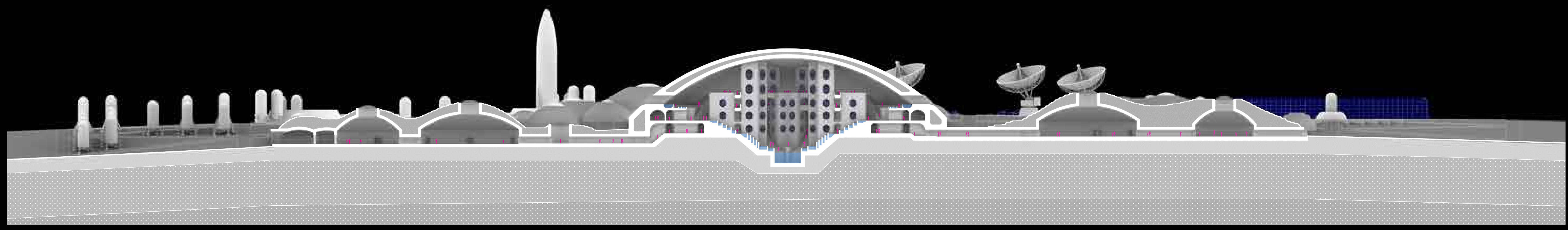
Layout Principles

The first step in achieving a dinamic visual environment was establishing a series of axis and routes in order to ensure propper circulation while at the same time generatic the potential for verious perspectives.

Due to the nature of the starting geometry a radial aproach was taken. The priciple axis folow the conections to the nearby habitats. The second layer of axis conects the primary perspective heads, while the last layer consists of a series of concetric promenades. The red dots mark vertical visual connections.

I also established the programmatic layout principles. The outermost ring would represent infrastructure such as water storage, followed by the agricultural ring, habitation, public function and lastly public area. However there would be exceptions to this rule in order to facilitate a dynamic environment.





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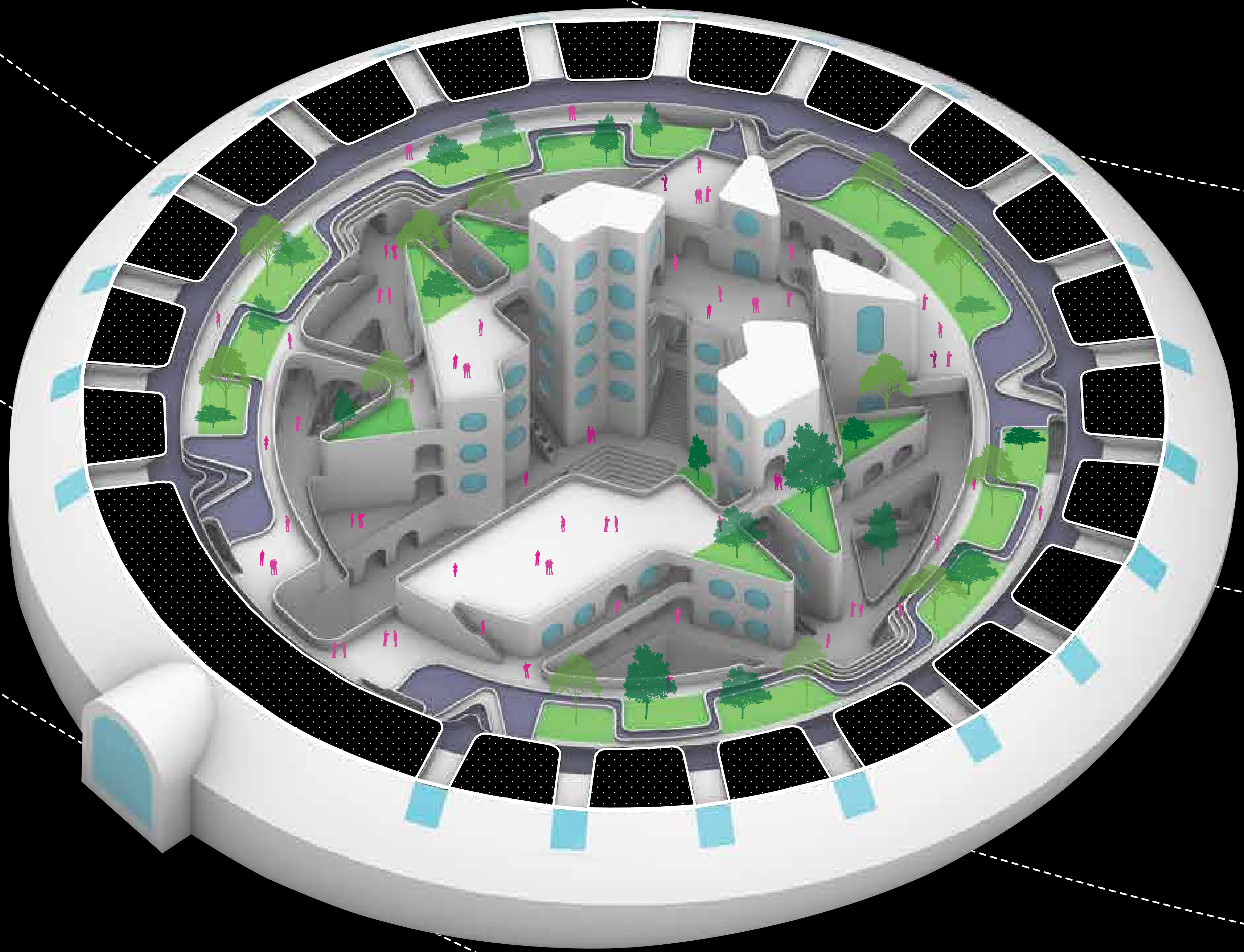
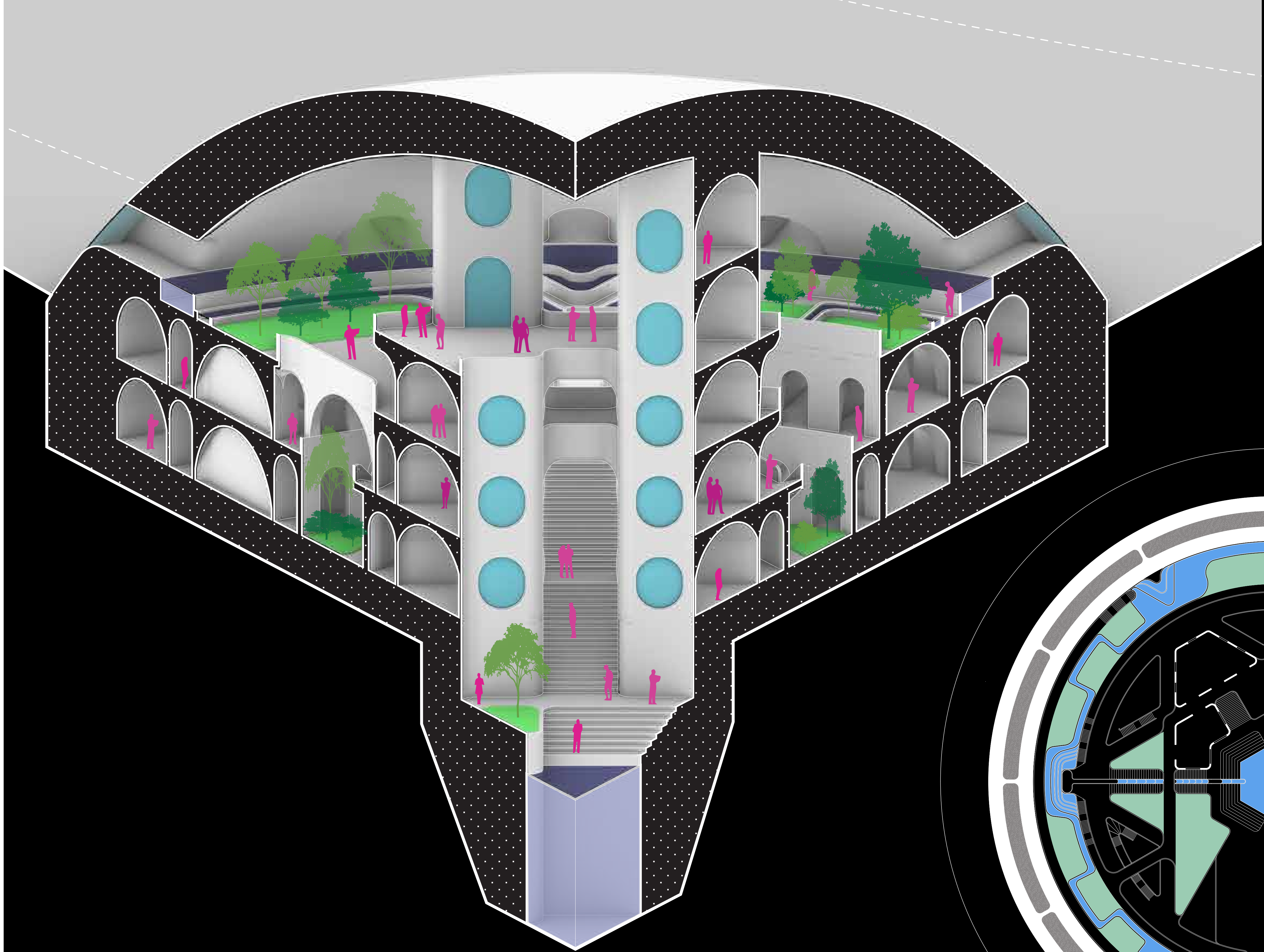


Circulation and Visual Conections

Furture more the nature of the site allows for a high level of verticaly. Takeing advange of this quality, we can design the circulation in the habitat as to further develop visual diversity, through the use circulation paths covering diferent levels in the structure.
In this manner we integrate the need of a higher level of physical activity required to maintain propper health.

The different plantforms created along allow for small scale agriculture, introducing a direct contact with greennary and food production, increasing the connection and attachment to this delicat ecosistem.



Water System

The design includes several artificial lakes and rivers. They not only have an aestetic purpose but several functional ones as well, being used as a water storage and recicling system as well as for aquaculture. The top lake is used for growing carp and other high yeald animal and plant species, while irigating and bringing nutrients to the vegetable gardens.

Level 5

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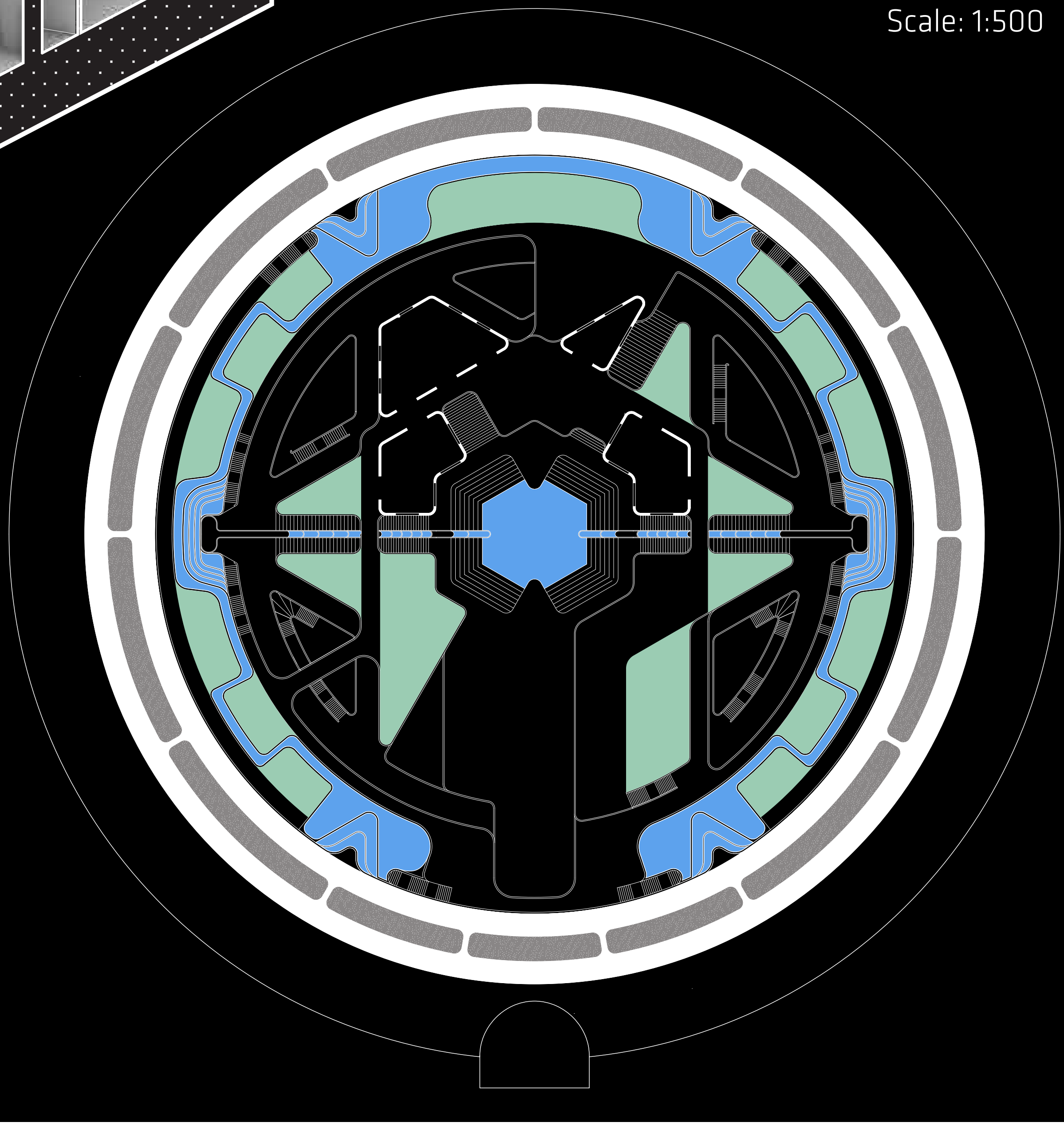
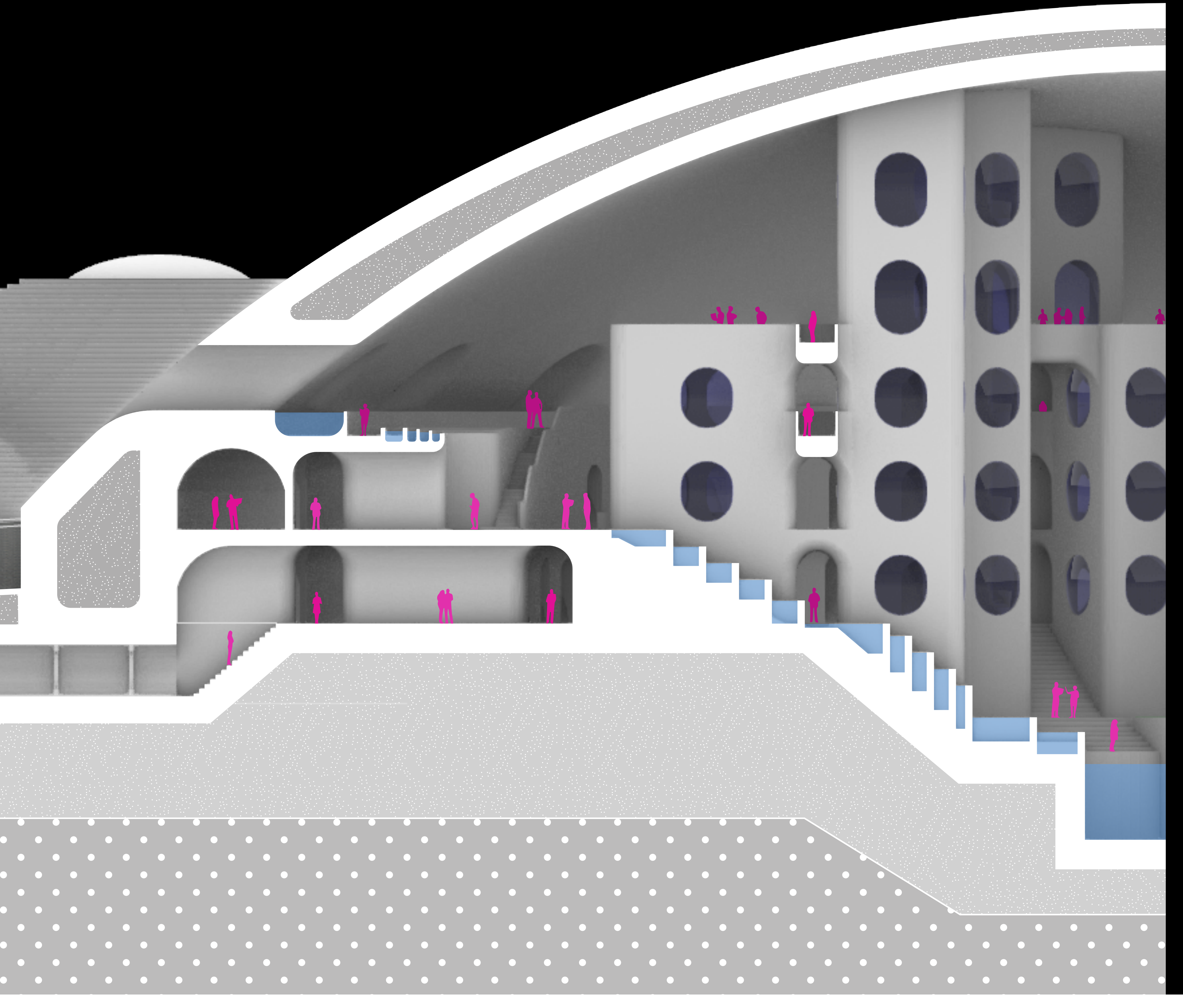


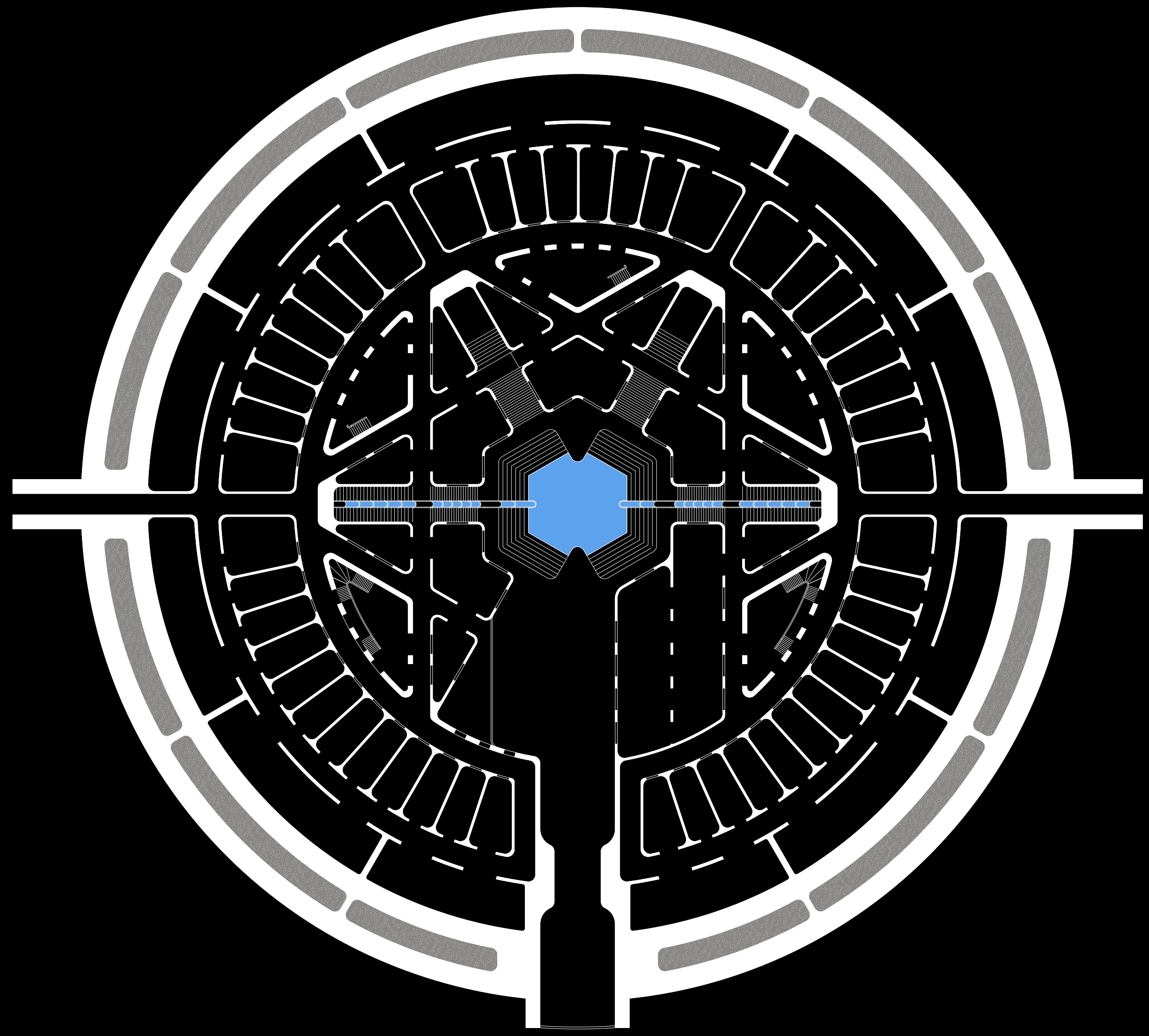


The rivers, and waterfalls act as a filtration system purifing the water, while at the same time providing a plesent audioscape. The small basin at the bottom level provides fresh clean water to the inhabitants, while helping to termo regulate the temperature inside the structure and provideing a breeze to the nearby Plaza.

Scale: 1:250

Level 1

Scale: 1:500



Level 2

Scale: 1:500

Level 3

Scale: 1:500

Level 4

Scale: 1:500

Light

The last aspect of living on the moon that we tackle is the issue of light, which will be provided by a series of light emiting pannles plating the upper part of the dome, which will mimic the Earth’s sky, while at the same time respecting the circadian rithm of humans.

References:

Iconography

fig.1 Sumerian Representatioon of Moon	https://en.wikipedia.org/wiki/Galileo_Galilei
fig.2 Galileo drawings of the Lunar Phases	https://en.wikipedia.org/wiki/Galileo_Galilei
fig.3 Portrait Galilelo Galilei	https://en.wikipedia.org/wiki/Galileo_Galilei
fig.4 Original Cover of Jules Verne's"From the Earth to the Moon"	https://www.amazon.co.uk/Earth-Moon-Extraordinary-Voyages
fig.5 "Le Voyage Dans La Lune"Advertisment Poster	https://wattsatthemovies.wordpress.com/2012/07/02/le-voyage-
fig.6 Sputnik 1	https://en.wikipedia.org/wiki/Sputnik_1#/media/File:Sputnik
fig.8 J.F.K. Photograph at the 1962 Congress address	https://www.skyatnightmagazine.com/space-missions/jfk-space-
fig.9 Neil Armstrong on the lunar surface	https://medium.com/slackjaw/its-time-nasa-returns-to-the-
fig.10 NASA Lunar Colony, NASA 1970 Concept	https://medium.com/@ikokki/moon-base-landing
fig.11 NASA 90 Day Study Lunar Outpost, 1989	https://www.researchgate.net/figure/NASA-artists-impression
fig.12 Norman Foster - Lunar Habitat - 2013	https://www.fosterandpartners.com/projects/lunar-habitation/
fig.13 SOM- Moon Village - 2019	https://www.som.com/projects/moon_village
fig.14 Depth Map of Lunar South Pole	https://greenplanetethics.com/wp-content/uploads/2011/11/
fig.15 Depth Map of Lunar South Pole	https://www.space.com/moon-ice-first-lunar-resource-solar-
fig.16 Depth Map of Lunar South Pole	https://solarviews.com/cap/moon/clmsouth.htm
fig.17 Collage of Light Maps	https://skyandtelescope.org/sky-and-telescope-magazine/
fig.18 Eternal Peeks of Light	https://en.wikipedia.org/wiki/Peak_of_eternal_light
fig.19 Image of Shackleton Crater	https://www.esa.int/ESA_Multimedia/Images/2017/01
fig.20 Shadow Map over a period of 12 days	https://en.wikiversity.org/wiki/International_Year_of_Astronomy
fig.21 Layers of information about Shackleton Crater	http://public.media.smithsonianmag.com/legacy_blog/
fig.22 Company Town	https://en.wikiversity.org/wiki/International_Year_of_Astronomy

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