ISCTE-Lisbon University Institute
Department of Architecture

A Dissertation presented in partial fulfillment of the
Requirements for the Degree of Master

Cheila Cordeiro Arruda

Final Project of Architecture

Pratical Aspect

Roman Villa of Freiria: Interpreting the Past

Tutor
Professor Dr. Architect Pedro Mendes, Assistant Professor, ISCTE-IUL

Theoretical Aspect

Houston, we have a problem. How to design for Mars?

Advisor:
Professor Dr. Architect Alexandra Paio, Assistant Professor in ISCTE-IUL

October, 2019

Houston,
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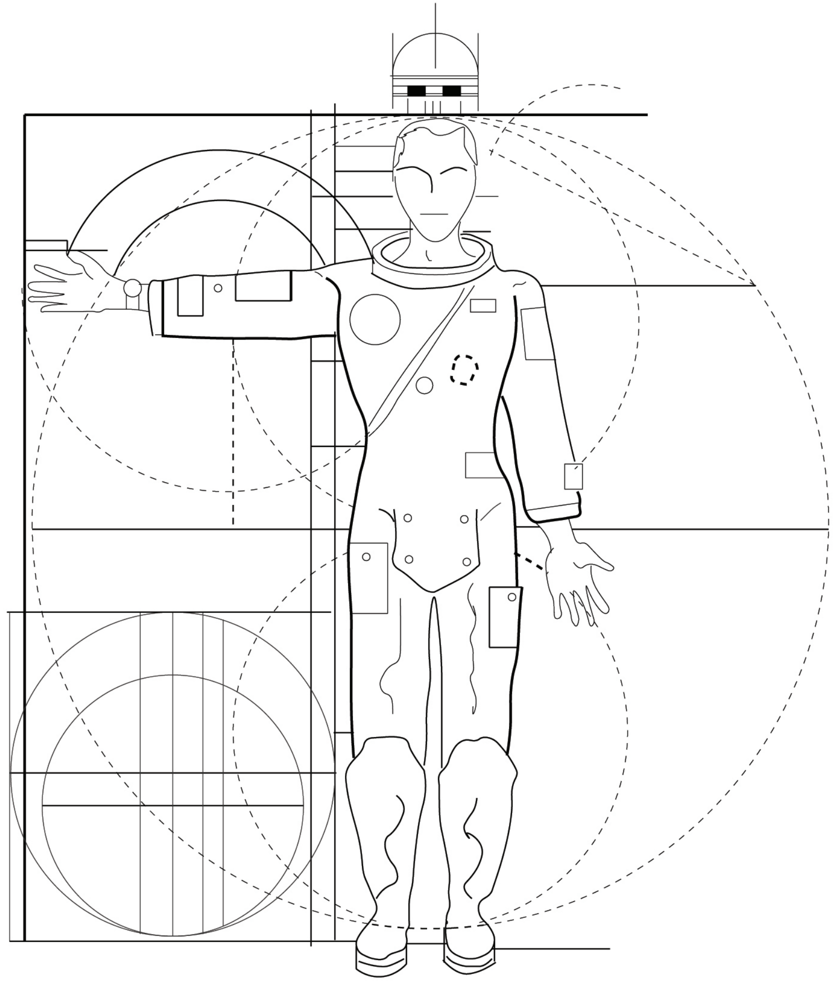

(Raymond Loewy Sketch)

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Acknowledgments

In loving memory of my Grandmother Silvina, who inspired me to always work hard for my dreams.

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To all, I'm grateful.

Resumo

Uma história de fascinação com milhares de anos: O Homem e o espaço.

Neste século passado, observou-se uma evolução tecnológica tão extraordinária que se conseguiu por o Homem no espaço, vivendo nele por longos períodos de tempo, e até estamos a celebrar o 50º aniversário da Aterragem da Lua em 1969. A questão é: Qual é o próximo passo?

Ideias de viver no espaço são abundantes no século XX e XXI, representando diferentes cenários e diversas maneiras de habitar, especialmente representado em filmes, tanto com visões utópicas como distópicas. Devido ao interesse renovado no espaço, arquitetos também estão a desenvolver designs de habitats e futuras colónias no espaço, na Lua, Marte.

Com um ambiente completamente novo, é importante que os futuros Arquitetos Espaciais percebam as adversidades que têm que ser ultrapassadas e definir linhas-guias para a "nova" Arquitetura vernacular, para uma colonização humana de sucesso.

Palavras–Chaves: Utopias, Arquitetura Espacial, Marte, Habitat;

Abstract

A story of fascination with thousands of years: Man and space.

During the last century, we have witnessed a technological evolution so extraordinary that we accomplished placing man in space, living in it for long periods of time and we are now to celebrate the 50th anniversary of the moon landing in 1969. The question is: What is the next step?

Ideas of living in outer space have been abundant since the twentieth century, picturing different scenarios and diverse types of living, especially represented in films with both utopian and dystopian views. Due to the renewed interest in space, architects are also developing designs for habitats and future colonies in outer space (Moon, Mars, and Space).

With a completely new environment, it's important for the future Space architects to understand the adversities that need to be surpassed and define design guidelines for the "new" mars vernacular architecture, for a successful human colonization.

Keywords: Utopia, Space Architecture, Mars, Habitat;

"The future of the past is in the future
The future of the present is in the past
The future of the future is in the present"

John McHale, 1965, in AD 2000+, February 1967

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Acronyms

AIAA	American Institute of Aeronautics and Astronautics
CIAM	Congrès Internationale architecture Moderne
ESA	European Space Agency
EVA	Extravehicular Activity
GCR	Galactic Cosmic Rays
IAA	International Academy of Astronautics (IAA)
IAC	International Austronautical Congress
IAF	International Austronautical Federation
ICE	Isolation, confined and extreme environments
LEO	Low Earth Orbit
NASA	National Aeronautics and Space Administration
Sci-Fi	Science Fiction
SPE	Solar Particles events (SPE)
WWI	First World War
WWII	Second World War

Chapter 1 - Introduction

“We are all . . . children of this universe. Not just Earth, or Mars, or this System, but the whole grand fireworks. And if we are interested in Mars at all, it is only because we wonder over our past and worry terribly about our possible future.”

Ray Bradbury et al., Mars and the Mind of Man, 1973

1.1. Introduction

Since ancient civilization, humans have always been curious about Space, looking up to the sky and wondering on what is out there. Now, with a deeper knowledge and the technological advancements in the last century, we look up and wonder: how would we live outside our planet?

This wonderment has been represented in movies in the past century. Architects have taken inspiration and inspired even some of them, since after all film is a way for architects to explore and expose visions and ideas (Utopian or not). These visions and ideas are not stagnant, they evolve with new inputs from science and technology, architecture movements, and even due to political agendas.

Architects have been active in the Space Industry for quite some time, starting in 1964 with Galina Balashova. These architects who have specialized in Space design are called Space Architects, and have since 2002 organized a group presenting 'The Millennium Charter', specifying what this new discipline is and what does it evolve.

Architects have unique skills that help plan and design a habitat for outer space, after all they have experimented with designing habitats for extreme environments here on Earth, on places like Antarctica or even underwater; An extra-terrestrial habitat would go a step further, but still inside the scope of work that an architect could do.

Now it's the 50th anniversary of the Moon Landing, and NASA just announced the program Artemis to go back to the moon (to stay) as early as 2024. Architects took the opportunity to start designing hypotheses for a habitat to settle both the Moon and Mars. Space Agencies such as NASA and ESA seem to understand how architect skills are valuable in planning this future habitat and started to look for collaborations with architects.

1.2. Motivation

People have manifested their dreams of a futuristic city for centuries. In our timeline, we have grown up watching futuristic cities in Space on our screens, such as Star Wars, 2001: A Space Odyssey, Interstellar, amongst others. And not only imagining it, we have in fact succeed in accomplishing scientific and technological evolutions to the point where sending people off to space started to be conceived as normal.

We are now facing a renewed interest in space, and the cause of this is perhaps due to private companies that are making the space industry boom – such as SpaceX. The companies have promised the colonization of Mars as early as 2030 (being this feasible or not). Their biggest accomplishment until now was to rebuild an interest in space. They have made people dream, wonder and imagine. They have inspired people.

Architects are well known for being able to take inspiration from everywhere. All over the world, architects have taken this hypothetic situation as a challenge. Small and big companies such as BIG and Foster + Partners got their hands on this new and exciting endeavor. Foster + Partners admitted in IAC18 that their project of imagining a 3D Printed Habitat on Mars (and Moon) was their most successful project in social media by far. This shows how people are interested in the subject.

Imagining our life in outer space, being it in general Space, Moon or Mars, raises fundamental questions: How to start a city from scratch? How will we confront this extreme environment? How can we prolong our stay in a healthy way?

So, why Mars?

Last year, the space community had a change of heart, which was the decision to delay plans for Mars and look with renewed eyes to the Moon. There are arguments for both sides, either defending to go to Mars or focusing on the Moon and both raise interesting questions. This dissertation focus on Mars habitats since in the author's opinion, it represents a bigger challenge to humanity due to, primarily, its distance, but in another account, Mars shows more promise for a sustainable future.

The concept of Mars as home is about overcoming all the boundaries that are made to our race.

> *"In the past on Earth, exploration has been the most rapid and successful when explorers have established continuously when explorers have established continuously occupied bases on the new lands, and have used local resources for the bulk of their activities. The same pattern would appear to apply on Mars. Clearly, if Mars were habitable and hospitable world, such a pattern of exploration would be followed there. However, the absence of breathable air and water has seemed to prevent this. (…)" (Powell, 2001)*

Extraterrestrial colonization was, until now, something reserved for science-fiction movies and TV shows. Plans are being made and technology is advancing in a fast pace. In no time projects and dreams will become reality. Architects should have a say and participate in this upcoming future.

> *"Few places on Earth exist that have not been subjects to the aspirations of architects, but perhaps the greatest conceptual challenge is the space beyond our own planet, even if until the 20th century it was beyond our reach, but even inaccessibility of location hasn't stopped the speculating of how the places will look." (Leach, 2014)*

Developing this future isn't limited to engineers and scientists. Architects are dotted with a unique set of skills that can make space livable in the long run. With this need for architects to become a part of it, there is an emerging profession deriving of architects (such interior architects, or an urbanist), the Space Architects.

1.3. Objectives

This dissertation has varied objectives that can be summarized in:

1. Overview of Mars habitats/cities represented in films/movies. Critical Analysis of futuristic utopia views of extraterrestrial cities in 2001: A Space Odyssey and the first Star Wars Trilogy;

2. Understanding the influences from utopist views on films on architecture and vice-versa;

3. To assert Space Architecture as a discipline;

4. Understanding the extreme Martian environment and how to overcome it and what are the best design approaches;

5. Define guidelines to design a human-friendly environment, adequate for a long stay;

6. Analyzing case-studies of different design approaches, using the guidelines.

1.4. Methodology

The methods for conducting the research are based on:

1. Research works of science-fiction which idealized and imagined extraterrestrial cityscapes in cinema from 1902 to 2017, analyzing the type of habitat (orbital or settlement), level of development and contextualize the year of the film with scientific development, social issues and architecture movements of the time.

2. Study Mars as a building site, using different sources to establish a baseline of environmental and mental factors that could influence the living of humans

3. Analysis of case studies with design proposals of a habitats, chosen from the Nasa's 3D-Printing Habitat challenge. Among some projects are the Mars Ice House, Mars Ice Home, MARSHA, Mars X HOUSE V2.; This analysis is done using previous guidelines from other authors.

4. Participation in a SAS – Space Architecture Symposium.

5. Interviews with: Space Architect Brent Sherwood, Astrotect Michael Morris, Astronaut Mike Massimino and talks with other professionals of the area.

6. Writing of a paper for IAC 2019 about the first Space Architect.

Chapter 2 - Space Architecture: The New Frontier for Design Research

‘Between the stars and the darkness we have imagined utopias beyond the reach of our travel technologies, colonizing space with our fantasies”

Armstrong, 2000

“Utopia has long been another name for the unreal and the impossible. We have set utopia over against the world. As a matter of fact, it is our utopias that make the world tolerable to us.”

The Story of Utopias (1922), Lewis Mumford, Gloucester, MA: Peter Smith, 1959, p. 1

2. Space Architecture: The New Frontier for Design Research

'*Space Architecture: the new frontier for design research'* was the title of AD (Architectural Design) magazine November/December 2014 issue, where it features the latest developments of Space Architecture. The plans of space colonization and travel, projects of space habitats, the importance of space tourism and the role of a Space Architect. It also discusses the importance of fantasy /science fiction in informing design.

In this context, this chapter can be divided in two parts – the first part gives a background describing the evolution of the ideas surrounding the living on Mars, Moon or a fictional place located in outer space. On the second part, we leave the world of utopias and take an empirical approach to the subject of Space Architecture, introducing the subject.

To begin it is important to explain several concepts: Utopia, Dystopia and touch the subject of Science Fiction. Then its proceed by explaining the evolution of the vision of extraterrestrial cities in movies starting as early as 1903 until 2018. How does the vision and knowledge on Mars/Space influence movies? How does architecture influences movies? How movies have influenced on architecture?

To answer these questions a timeline was created from 1900 to the present (and some predictions of the future) to be able to understand the economic, scientific developments, social, political events, architectural movements and buildings. Movies were also studied surrounding the course of Space Architecture

throughout time to understand the context evolving the movies and architecture projects.

While imagining (and designing) extraterrestrial habitats has been done throughout time, only recently have we formalized the profession that would be responsible to do so - Space Architecture. We focus on how it became a discipline separated from architecture, focusing on the Manifesto of the Millennium Charter. The chapter concludes with the current visions and research being made.

2.1 Utopia e Dystopia

Utopia

Utopias are part of human history since the beginning of times. The first utopic known writing is Plato's "The Republic" in 380 B.C. (Knutz, Markussen & Christensen, 2014), but the first to use the term 'Utopia' only appears much later with Sir Thomas More in 1516 with his book of the same name. Published in a time when men's imaginations were stirred by the sudden enlargement of their concept of the World, (More,1997). "Utopia", is a conversation between the author and a Portuguese sailor named Raphael Hythloday, an adventurer, whom had traveled around the world. The highlight of the book is Raphael's description of an island named Utopia, its fifty-four cities, and its society (Fernandes & Silva, 2014).

To touch the subject of Utopia, the best is to start by explaining the term itself. While Oxford Dictionary states that the word has a Greek base ou-topia, meaning not-place. On the other hand, Lewis Mumford in his book The Story of Utopias, (1922), points out that Utopia is a mock name/pun for either Outopia, which means no-place, or Eutopia –which means good place. More's neologism is certainly linguistically ambiguous, and many have pointed that this pun signals on the ideal and perfect society: "the happy and fortunate place, the good place, is no place – no place, that is, except in imagination". (Grosz, 2001, p.135). Utopia can be defined as an ideal community or an imaginary society or place that is highly desirable and perfect. A pleasant, comfortable and happy place, where you can relax and have fun. A place of freedom, (Knutz, Markussen & Christensen, 2014).

Fig. 1 – Illustration from Utopia (1515) by Thomas Moore.

Dystopia

The terrors of the twentieth century played a great part to a genre of Dystopia in literature to emerge (Moylan, 2000). Dystopia, mostly like Utopia, is an imaginary society set in a speculative future, but with opposite qualities. It's a "place" that makes you feel uncomfortable, bad and is unpleasant. It's where you are dehumanized or even fearful for your live. Dystopias are critiques for our own society (Knutz, Markussen & Christensen, 2014). Sometimes the boundary between utopia and dystopia isn't clear, they can even be used together on projects, by involving utopian qualities with the intention of being critical, (Knutz, Markussen & Christensen, 2014).

Architects always had a close relation with Utopias, per Coleman, (2005). Architectural projects themselves, are a kind of fiction comparable to utopias. Drawings (plans, sections, elevations) are how architects propose their own utopias in the hope that it becomes a reality. "Utopia is an almost inescapable companion of architectural invention." (Coleman, 2005, p. 48).

2.2 Mars Throughout Time

William Sheehan, an astronomer and perceptual psychologist divides the history of planetary studies in three Eras. The first one refers to the naked-eye observation (until early seventeenth century); The second era is due to the terrestrial telescope (1609). Lastly the Space era, in which cameras and telescopes operated outside of Earth's Atmosphere and could send back higher quality and detailed images (Crossley, 2010).

With the division of eras in mind, we can affirm that for thousands of years Mars was a nameless blood-red dot in the sky. The first recorded mention of Mars appears early in the 2nd millennium BC by the hands of Egyptian astronomers calling it Har décher, the Red One. Later, other civilizations associated the red color "star" (not yet understood to be a planet) with warfare and bloodshed, the Babylonians named it as Nergal, the Star of Death, the Greeks as the Fiery One, or the God Ares, which you could find also in Roman culture as god Mars (God of War) (Sheehan, 1996).

The first telescopic observation of Mars was by Galileo Galilei in 1610 which surged tremendous enthusiasm at the time. After that moment, numerous works started to be published about Mars.

If we could pinpoint a moment where Mars turned into an object of fascination in fiction, it would be when Giovanni Schiaparelli in 1877 started mapping and naming areas on Mars inclusive of its "seas" and "continents" (dark and light areas) with

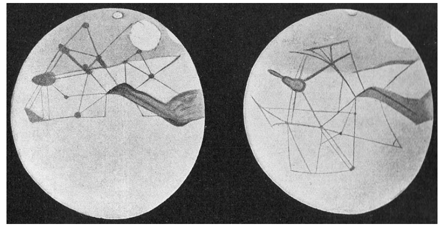


Fig. 2 – Lowell's depictions of the 'Canals of Mars'

York Times.

GUST 30, 1907.—SIXTEEN PAGES.

MARS INHABITED, SAYS PROF. LOWELL

Declares the Planet to Be the Abode of Intelligent, Constructive Life.

THE RECENT OBSERVATIONS

Changes in Canals Confirm Former Theory—Splendid Photographs Were Obtained.

Fig. 3 - New York Times, Pg.1, August 30, 1907.

Fig. 4 - Illustration of Jules Verne from his book "From Earth to The Moon" 1865

names that originate from historic and mythological sources. He observed channels naming them "canali" which were later mistranslated as "canals" implying artificial constructed structures which sparked the people imagination. Later, in 1894, Percival Lowel also affirmed the existence of these canals mapping hundreds of them. He believed they were created by intelligent Martians with the function of carrying water from the polar caps to the equatorial regions, (Dunbar, NASA). Writers have continued to pay homage to Lowell by naming Martian cities and spaceships after him and by crediting him with awakening their imaginations, (Crossley, 2010).

In the nineteenth century analogies between Mars and Earth were made in an evolution and ecological level, especially after the argument of possible life on Mars, which was theorized based on the supposed canalli and how they were probably constructed to respond to drought issues (at the time severe draughts were happening in India, Africa, Brazil and China). This raised issues of resources exhaustion, scarcity and social disintegration to our own planet (Markley, 2005). Some went far to see Mars as the possible future of Earth.

Up until now the visions/history mentioned above were based only on scientific research and observation with the means and knowledge that were available at the time. There are other important influencers in this interest in Mars that didn't restrain themselves in only scientific findings (even though there is clearly an influence of ideas) but mostly in the use of imagination, especially represented in science-fiction literature.

The most influential authors in this area were certainly H.G. Wells and Jules Verne. They certainly were responsible for the popularization of the genre of Scientific-fiction. For example, in Jules Verne's writing "From the Earth to the Moon", published in 1865 influenced later the film "Voyage Dans la Lune" (1902) which was also influenced by H.G. Wells "The First Men in the Moon" (1901).

The importance of Jules Verne´s fictional books is that it had several "predictions" and thoughts on the used technology. For example, on the journey back to Earth from the Moon of Apollo 11, Neil Armstrong references Jules Verne:

> *"This is the Commander of Apollo 11. A hundred years ago, Jules Verne wrote a book about a voyage to the Moon. His spaceship, Columbia, took off from Florida and landed in the Pacific Ocean after completing a trip to the Moon. It seems appropriate to us to share with you some of the reflections of the crew as the modern-day Columbia completes its rendezvous with the planet Earth and the same Pacific Ocean tomorrow".*[1]

As a last reference, Architects also explored these themes by rethinking architecture and technology. An important reference is from the avant-garde group Archigram, which envisioned technological utopias where science and technology were the answer to all the human problems, (Coleman, 2005). They were active between 1960 and 1974, with projects such as with projects such as "Plug-in-City" by Peter Cook and the "Walking City" by Herron, 1964.

1 "Apollo 11: Technical Air-To-Ground Voice Transcription" Houston. July 1969

These visions, as inspiring as they were, couldn't only live on words. There was a need to materialize these words to something tangible and that's where cinema comes to concretize these visions.

Fig. 5 -Archigram Waling City, (Herron and Harvey, 1964).

2.3. Timeline Review

Mars has successfully become an object of fascination, being made a set for hundreds of science-fiction novels and films. This fascination is closely related to science and its successive visions of Mars, (Hendrix, et al. 2011) seen previously. Due to that, it was not only important to understand the different visions but also to frame them in a timeline, contextualizing what was happening in the scientific area, social level, and in parallel, the architecture movements of the mentioned times (Table I).

All this concentration on the timeline from the beginning of the 20th century to present-day (2019).

When analyzing the timeline, there are there are some events that overlap and evidently relate. After all, quite often the creation of visionary art (of any form) and architecture appears after being influenced by cultural, political or technological origins that impose restrictions on creative works, especially with films. Films provide us a way to escape reality, to react to political situations and it reflects the economic, cultural and political standards of the society of the time, (Boake, 2008).

For instance, the Danish silent movie Himmeelskibet (1918) was released before the end of World War I and it translates to the need for a peaceful society. In the movie, Mars has an Utopian society, contrasting with the conflicts and horrors that were happening in the battlefield of Europe at the time. It was made in a way to analyze society and hope for a more peaceful future (Scheib, n.d.).

In Aelita's, Mars is habitable because at the time, the views of the geographic markings in Mars were thought to be an ancient canal system, which would indicate not only the presence of water but a hospitable world. In terms of society this film has the purpose to do a parallelism between the film's society and the Soviet society at the period. In the film the protagonist from Russia convinces the Martians to stage a communist revolution. The Queen of Mars (Aelita) ended up sabotaging the revolution. Notice that the film was produced in a time of political insecurity, after Lenin's death in January 1924. The objective of the novel and later the film, was to assert a pro-Lenin stance, meaning that a 'change in the means of ownership of production will lead to a new society.' A new culture would be born as result of having the proletariat come to power', against an anti-Bogdanov stance that says 'that a cultural revolution had to be achieved among the proletarians before a successful revolution could be waged' (Christensen, 2000).

The year of 1986 was marked by tragedy, the crash of the space shuttle "Challenger". This diminished faith in the space industry (same year of the Chernobyl disaster which diminished faith in technology in general). Because of this, funding was lacking. All this explains the gap in content between 1986 and 1998 in which we've seen little more than ''Total Recall' (1990). This gap ends with beginning of the assembly of the International Space Station.

There was also a time, during the "space race" where scientific realism saturated the audience, explaining at some point the success of Star Wars, that was a gush of fresh air at the time. But, taking into consideration the recent years, scientific realism has done a comeback with films such as 'Interstellar', 'Passengers', 'Bring Him Home', Space Between Us', starting the renewed interest on Space in general.

Overall, you can make connections of the events in the timeline throughout the century. It is an exciting time for the industry.

Houston we've got a problem. How to Design for Mars?

Timeline
Space Exploration in context with World events - From 20th Century to Present.

- Society
- Architecture
- Space Architecture
- Science Advacements / Discoveries
- Analyzed Films
- Other

2.4. Vision of Extraterrestrial Cities Represented in Movies

Cinema has a way to influence Architecture and Architecture has a way to influence the cinema. They feed off each other. With cinema as a tool, the architect can envision worlds, cities and ways of living. Per Glancey, (in 2003, as cited in Afonso and Eloy, 2014), “Cinema remains the best place to experience the architectural imagination at full”.

Throughout the twentieth century fictional travel in space was a recurring topic in films (Garcia, 2012). This experience offered thrilling guides on how our world might look (Glancey, 2003 as cited in Afonso & Eloy, 2014). In fact, one generation’s fantasy can emerge as reality for the next generation (Chamberlain, 2014).

The popularity of science fiction reflects cultural fascination with the potential for science and technology (Chamberlain, 2014. We can be certain that Mars has been a reoccurring object of this fascination, especially since Percival Lowell thought he discovered canals on Mars (1906), and the popular imagination flew toward the belief that a technical civilization existed on Mars, now or in the past (García, 2012).

To analyze cities and habitats that were materialized in the cinema, a sample of movies was selected. While most of them are with sets on Mars, a few are set on the Moon, or even a made-up planet/asteroid. The selection go as early as 1903 until 2018, each regarding outer space habitation. The widespread of time was to understand the evolution of the idea of a habitat outside of Earth. As an exception, the first mentions are the two first movie ever made on the subject: 'La Voyage Dans Lune' (1902), followed by 'A Trip to Mars' (1910), while these two films don't have a habitat they mark a beginning of the interest on this topic.

The analysis starts in 1918, when the first type of habitats start to appear with Himmeelskibet (1918), followed by Aelita (1924), Woman in the Moon (1929), Just Imagine (1930), 2001: A Space Odyssey (1968), Solaris (1972), Star Wars – A New Hope (1977), Star Wars Episode V - The Empire Strikes Back (1980), Total Recall (1990), Escape from Mars (1999), Red Planet (2000), Race to Mars (2007), Red Faction: The Origin (2011), John Carter (2012), The Last Days on Mars (2013), Interstellar (2014), Guardians of the Galaxy (2014), Bring Him Home (2015), Jupiter Ascending (2015), Passengers (2016), The Space Between Us (2017), and finally Valerian and the City of a Thousand Planets (2017). Overall, remakes were avoided, as well as films portraying real events (eg. Apollo 14) and sequels (except for Star Wars, which the first trilogy is analyzed due to its rich inventory of sets).

With the overview from the movies is was possible to compile a chart where you see the evolution of the idea of an extraterrestrial habitat. The analyzed criteria where: the year, the outer space location, if it considers Gravity/Radiation/Atmosphere. Finally, it studies if there exists a habitat or city. If so, there was an architect behind the concept. Even if it wasn't possible for every movie, it also tries to describe the type of Habitat and its configuration.

For a deeper analysis, the author chose two of the biggest references in the movie industry with the theme of space travel. '2001: A space Odyssey', a film that has been a reference not only in the film industry, but also for architects - for its futuristic sets; and 'Star Wars' (general view of the first trilogy), which has been inspiring the last generation of people working in spa-related areas and also architects.

Fig. 6 - Sill from ‘Voyage dans la Lune’ 1902.

2.4.1. Overview

In 1895, with the Lumière Brothers in Paris, the art of movie making starts. Within six years, the iconic first science fiction movie, illustrating a journey beyond the Earth (in this case to the Moon) was made. “La voyage dans la Lune” of George Mélies in 1902. (Garcia, 2012) This movie was based in Jules Verne novel and it shows no consideration on gravity and atmosphere, but , its importance comes from being the first to create an outer-space scenario (Fig. 6). This film marked the beginning and it’s considered the first science-fiction film. It was followed by ‘A trip to Mars’, on 1910, a silent short film where a scientist invents an anti-gravity powder and uses it to float to Mars, only finding a dense forest and monsters (Fig.7).

The next one appeared during WW1, in 1918 “Himmeelskibet”, It’s the first to have a more serious approach on a trip to a distant planet and critique the society at the time. In the film, a crew goes to Mars and they encounter a human-like utopian pacifist society, dressed in togas. In their eyes, the humans from Earth are the barbarians. In terms of a Habitat/Settlement, there is a city that concentrates in a unique building, resembling Greek architecture.

Fig. 7 - Still from Himmeelskibet, 1918.

In 1924, Aelita premiered in the Soviet Union and it presents Mars, a world with harsh environment, but even so, with a breathable atmosphere and with gravity equal to Earth’s (Bloake, 2008). It sets the humans from Mars apart from humans from Earth using scenarios designed in the constructivist style and the same with the character’s costumes (designed by Isaac Rabinowitch) (Cornea, 2007). Even though the Mars city only appears once throughout the movie, we can see that it’s a fully developed metropolis (Fig. 24).

In some films, there is no habitat but rather only their method of transportation (be it a 'rocket', 'projectile' or Ovni-shaped spaceship), but even so present ideas about space travel: Woman in the Moon (1929), "Just Imagine" (1930), and 2 decades later "Abbott and Costello Go to Mars" (1953).

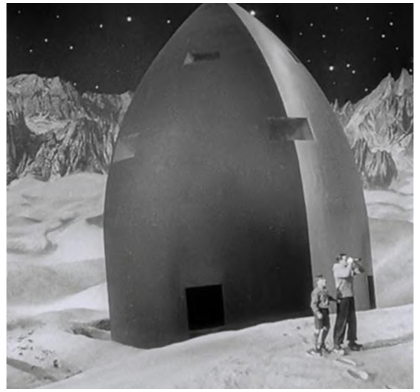


Fig. 8- Still from 'Woman in the Moon', 1929.

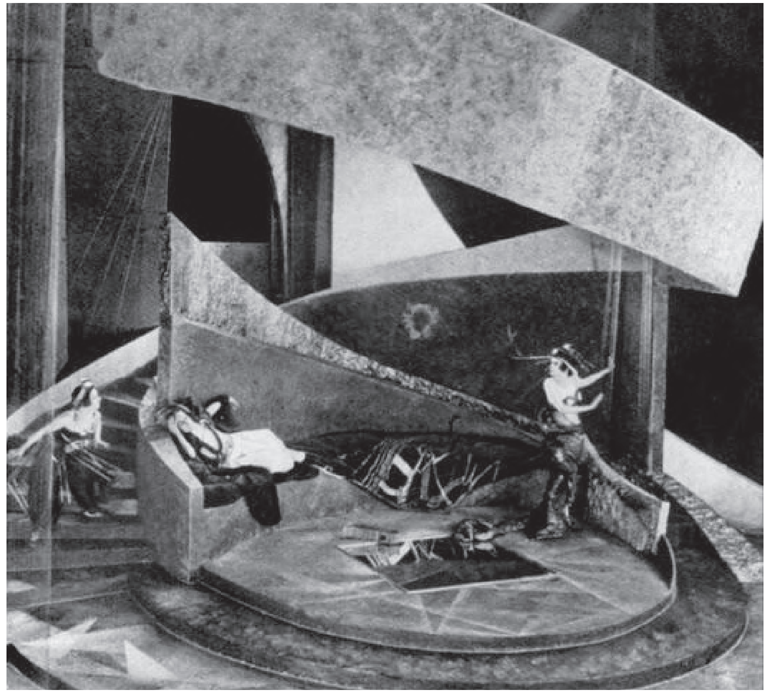


Fig. 11 - Sill from Aelita, 1924

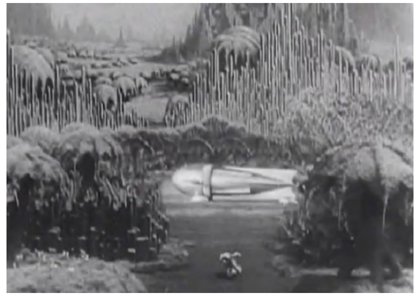


Fig. 9 - Sill from 'Just Imagine', set on Mars, 1930;

Fig. 10 - Still from Abbot and Costello Go to Mars (1953).

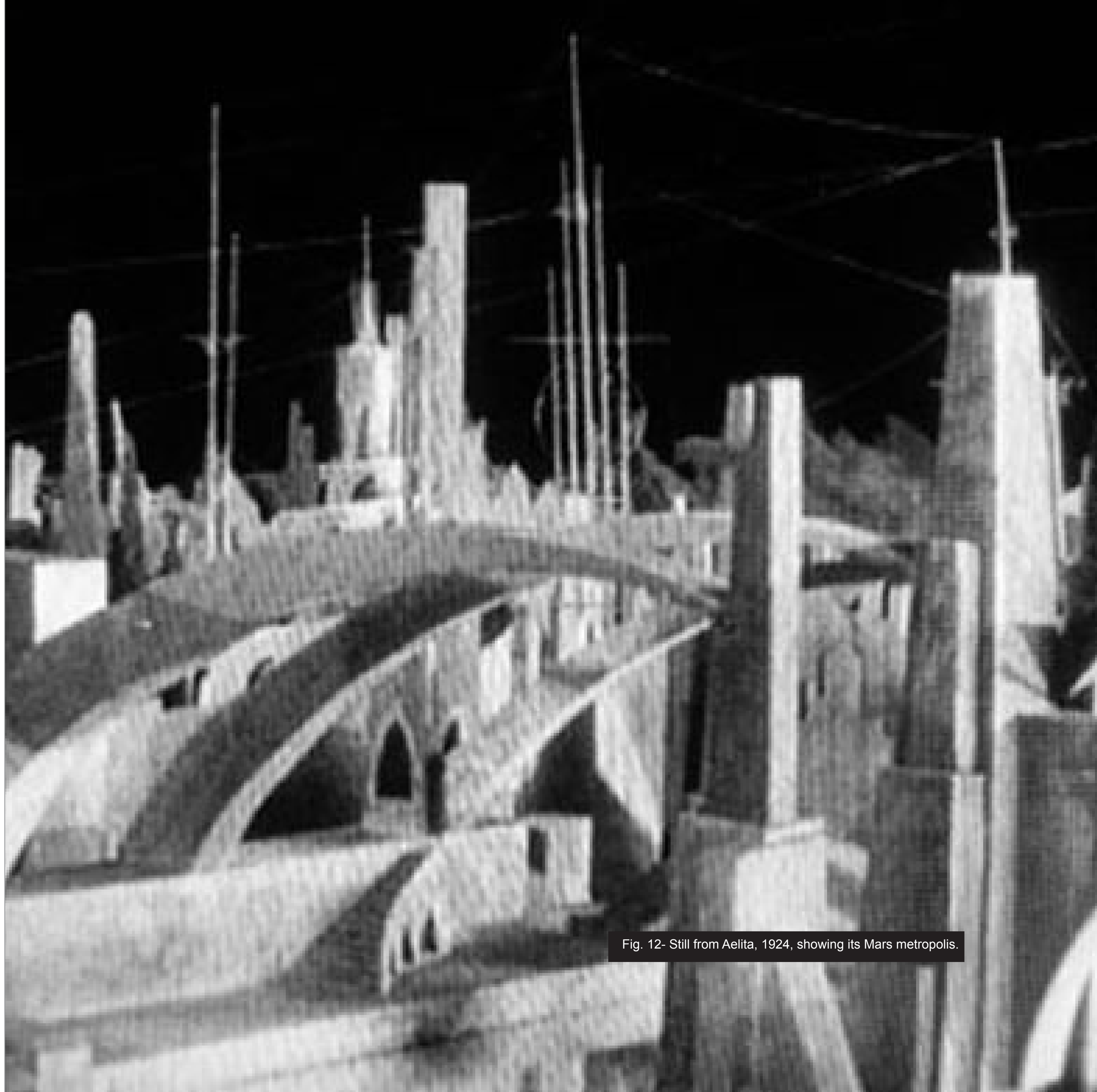


Fig. 12- Still from Aelita, 1924, showing its Mars metropolis.

One movie that came to revolution the space film industry was 2001: A Space odyssey, (analysis on pg. 40), in 1968, just a year before the Moon Landing. It was followed by some equally disrupting movies - Star Wars (analysis on pg. 44).

On the movies that have a more technological and scientific approach we tend to see two situations relating to its habitats: Mars (or other) become a sort of Industrial city, such as Total Recall (1990) where part of it happens on Mars. Critics cite numerous scientific errors regarding its representation (Bloake, 2007), but even so in Mars set, see a fully developed industrial city. There is also a high conscious of the dangers of radiation. The same happened with the movie 'Avatar', (2009), (situated in the fictional world of Pandora), that by observing the human colony, we immediately think of an Industrial City. Red Faction: The Origin (2011) presents a terraformed Mars, with also a fully developed industrial kind of city. It becomes some sort of pattern when humans colonize – industry and resources are a big developing factor on these cities.

Fig. 13 - Still from 'Total Recall' set on Mars, 1990.

Fig. 14 - Still from 'Avatar' colony in 'Pandora', 2009.

Fig. 15 - Still from 'Red Faction: Origins, 2013.

The second situation is a more of a first-time explorer and their initial habitats, normally pre-fabricated. This is the case of movies such as 'Red Planet' (2000) that has a very scientifically approach, since it had guidance from NASA. You can see its influence on the Habitat "HAB" in the movie (Fig.16), also it was used real images of recent missions to it (García et al., 2012).

A few of the same genre follow, becoming more and more scientifically aware. Race to Mars (2007) (Fig.17), Last Days on Mars (2013) (Fig.19), 'Interstellar' (2014), (Fig.18), 'The Martian', 2015 (Fig. 21) and 'Space Between Us', 2017, (Fig. 20) all show habitats that can be said to be somewhat similar.

Fig. 16 -Still from HAB in 'Red Planet', 2000.

Fig. 17 - Still from 'Race to Mars', 2007, MARSHAB ATLANTIS.

Fig. 18 -Still from Interstellar', 2014.

Fig. 19 - Still from ‘Last Days on Mars’, 2013.

Fig. 20 - Still from ‘Space between Us’, 2017.

Fig. 21 - Still from ‘The Martian’, 2015.

Some space movies have only (or mostly) sets on the spaceship/space station. It can be an orbital habitat or a transport vehicle but is still very technically/scientifically conscious. Some examples of this are movies such as Solaris (original in 1972, American remake in 2002); Interstellar, which was mentioned previously and also had a large on-screen time spent on the space station 'Endurance'. And finally, 'Passengers' (2016), which had quite the unique design. Its Starship, named Avalon, designed by Guy Hendrix Dyas, who thought meticulously about space travel issues. He addressed gravity by creating an artificial gravity-enabled exterior with the same principles seen on the 2001: A Space Odyssey station. The starship was designed for 5000 people, as a luxurious space, with big open spaces, full of entertainment with different activities: a mall, cinema, a VR room, pool, a bar amongst other things (Fig. 16, Fig. 17).

Fig. 22 - Outside view of the Starship Avalon. Passengers, 2016

Fig. 23 - Interior of 'Avalon', Passegers.

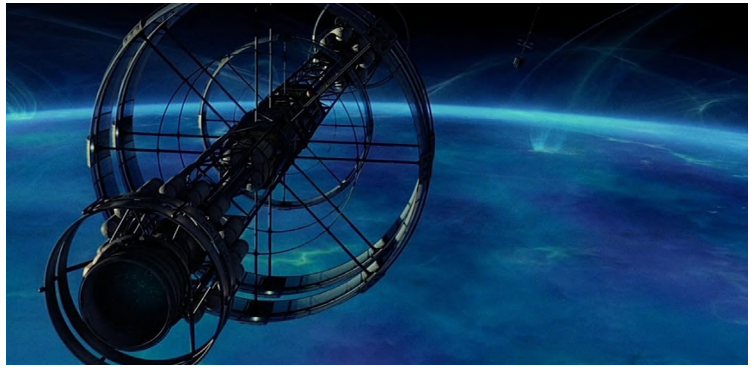


Fig. 24 - Spaceship Solaris

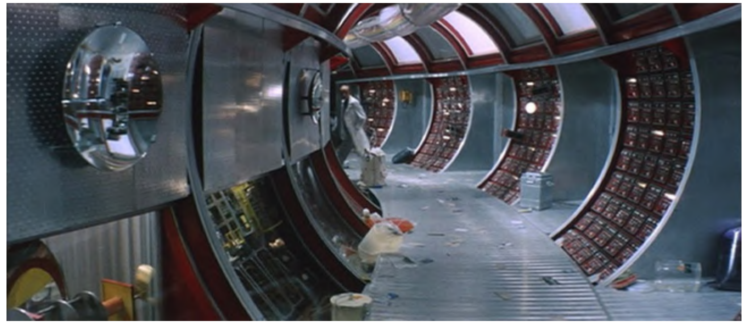


Fig. 25 - Solaris, interior.

Furthering from technological limitations, (and especially inspired by the Star Wars franchise), are movies with a fantasy base. One example of that is the movie John Carter (2012), which is set on Mars and presents a unique city 'Zondanga' (Fig.20), a mobile city that resembles a walking refinery the author notes certain similarities between it and Archigram's 'Walking City'.

Similar, there is also 'Jupiter Ascending' (2015), 'Guardians of Galaxy' (2014), and 'Valerian and the 1000 Planets' (2017) which presents an ever-growing metropolis called Alpha, a cluster type of cities which was originally the International Space Station.

Fig. 26 - John Carter, 2012. City In Barsoom (Mars). Mobile City Zondang.

Fig. 28 - Still From Jupiter Ascending, 2017

Fig. 29 - Valerian An The City Of A 1000 Planets, 2017. The Alpha (Metropolis).

Fig. 30 - Still From Guardians Of The Galaxy, 2014.

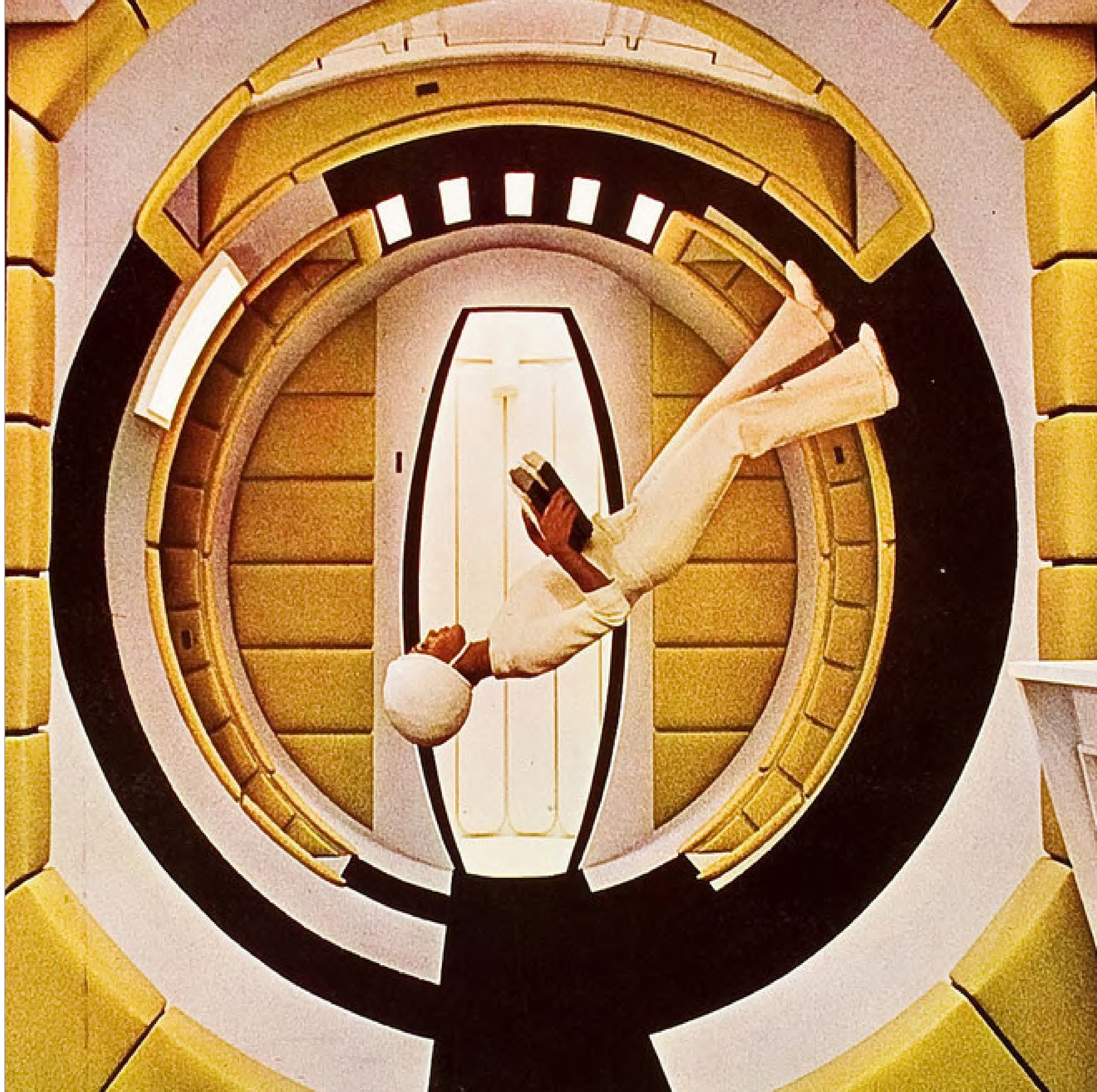
2.4.2. *2001: A Space Odyssey*

The world was taken by surprise by '2001: A Space Odyssey' in 1968, directed by Stanley Kubrick, just a year before the Moon Landing. It became the classic of Space travel, and one of the biggest references in the movie industry. It was based in the book of Arthur C. Clarke "The Sentinel" (1951) (Golder et al. 2017). One thing that sets this movie apart, was the fact of Kubrick receiving constant consultation from NASA's scientist and engineers during is development (García et al., 2012), resulting in being the most scientifically accurate feature film ever made (Geppert, 2018). It has some memorable sets, such as the Space Station V which works as an international space station and as an orbital hotel (Hilton). The Clavius Base (Fig. 32) situated in the Moon, and the spacecraft Discovery One used for the Jupiter mission.

Regarding the design of Space Station V (Fig. 33), the idea of a wheel shaped spinning volume was to mimic the Earth's gravity (García et al., 2012) since it created artificial gravity. It was inspired by German rocket engineer (and space architect) Werner von Braun and his S1 (1946) and S2 (1955) stations that further inspired Arthur C. Clarke's famous space station (AD: Design in Space). The station works both as an International Space Station and as an Orbital Hotel.

A novelty in terms of design was the new relation between the floors – ceiling, (except for the rotating spaces), the floor remains the floor, the ceiling remains the ceiling and the walls the walls. There are more durable materials placed on the the other surfaces (AD: Design in Space) to differentiate. ception to this can be

Fig. 31 - (Right) Still From 2001:Space Odyssey, Interior.



seen on Fig. 31 when a member of the Discovery crew is bringing a meal on board using a platform that connects the different levels.

Clavius base (Fig.25), is a research station, self-sustaining, and able to house 1,100 people, with each person having their single compartments of ~3,05 m by ~1,8 m wide and ~2,43 m in height. Equipped with hi-tech amenities, and adequate furnishings, to make the living accommodations as comfortable as possible. In terms of urban design the base takes a radial shape (Clarke, 1968).

Fig. 32 -Still From 2001:Space Odyssey, Clavius Base;

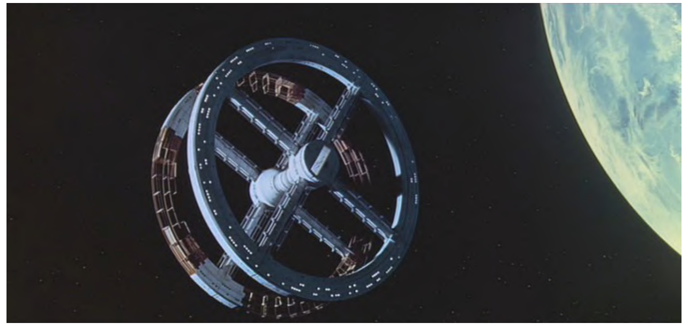
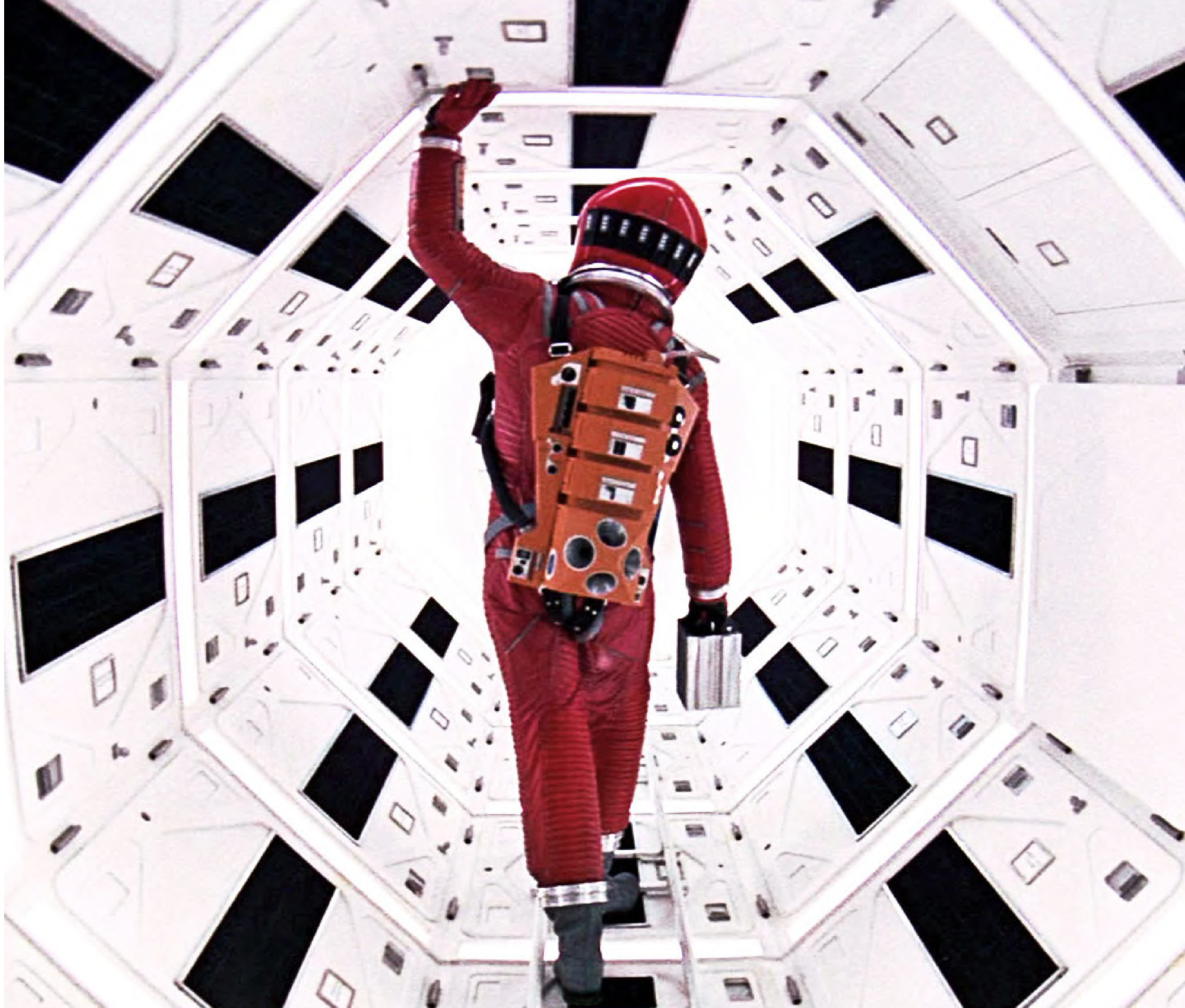


Fig. 33 -Still from 2001: A Space Odyssey, Space Station V;

Fig. 34 - (Right) Still From 2001: A Space Odyssey, Interior.



2.4.3. Star Wars (First Trilogy)

In a complete different route of 2001: Space Odyssey, was the Star Wars franchise, an American space opera created by George Lucas, a worldwide success. The first trilogy was composed by "Star Wars IV - A New Hope" in 1977, followed by Star Wars: Episode V - The Empire Strikes Back, 1980 and Episode VI - Return of the Jedi in 1983.

Since the Star Wars universe shows numerous Worlds and cities, on galaxies far far away, the range in architecture explorations can go from ancient temples to futuristic floating cities (AD Editorial Team, 2016). Having different historical, cultural and geographical backgrounds results on distinct architecture styles, for example, Coruscant, home of the Republic (Fig. 36) is a dense urban settlement with its skyscrapers, busy air traffic and high level of population, a true megalopolis. Naboo (Fig. XX) has a more rural calm feeling and Tattoine (Fig. 35) is more of a primitive desert planet (Erk, 2003).

The movies also broke a trend in ascetics of the new and pompous that you see in previews movies related to space, the director explained that the secret of the set not being a set, was to make it look like they have been inhabited for long, give it a worn-out look (Dufour, 2011), avoiding the pompous and clean looks viewed in previous movies (such as 2001: A space Odyssey).

Doug Chiang, chief artist for Star Wars: Episode (1999) discussed in an interview the need to not just make something up when designing these worlds but rather based it on existing architecture:

Fig. 35– Theed. Planet of Naboo. Image from Star Wars,

Fig. 36– Coruscant. (Starwars.com)

"(...) In order to make these new worlds believable, we had to anchor them in reality. We researched the eclectic architectural style of Venice for Naboo. The Art Nouveau movement, particularly the work of Gaudi, was used for the Gungan city. Frank Lloyd Wright's Marine Country Civic Center served as inspiration for the blue domes of Queen Amidala's palace. Hugh Ferriss and Albert Speers' monumental buildings influenced Coruscant. And lastly, Djerba architecture from Tunisia inspired the slave quarters of Tatooine"

The vision on living in outer space has certainly developed, while in the first films the destination was mostly filled with scary jungles full of monsters, where you had to escape quickly. The vision changed to being a land of opportunity for both industry and research. The development of science and technology certainly paved a hand on this evolution. Table 2 has a resume of the films presented above.

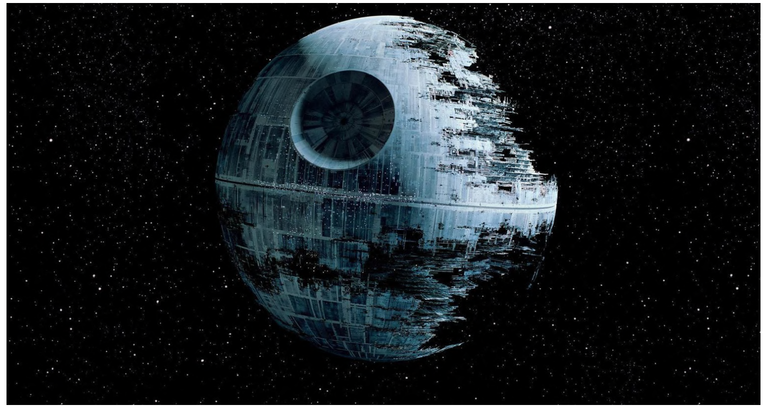


Fig. 37 – Death Star (starwars.com)

Fig.38 - Stills from Star Wars Episode V – The Empire strikes back. Bespin. Cloud City. Gas Mining Colony. (Irvin Kershner, 1980)

Fig. 39 - Stills from Star Wars Episode VI –Return of the Jedi. Mos Espa Tatooine 1983. (starwars.com)

2.4.4. Resume of Analysis

The following table was developed for and easier visualization of the representation of habitat in films – from 1903 till 2018.

As mentioned before, it enumerates basic information such as title, date, image, if it considers: gravity, radiation, atmosphere; if it has a representation of a habitat, or city.

Known collaboration with architects will also, be mentioned.

Regarding the Habitat, in the possible cases of this type of analysis, it t describes the type of habitat and its configuration.

Since some information is not accessible, or doesn't exist reference to it will be represented in blank spaces.

In cases where a film shows multiple habitats/ cities, the author selected only one.

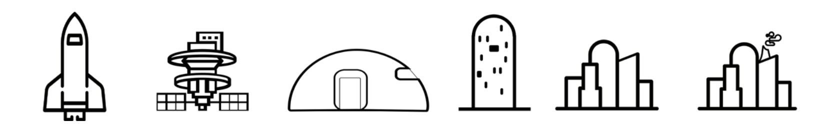
Houston we've got a problem. How to Design for Mars?

		La Voyage dans la Lune	Himmeelski-bet	Aelita	Fau im Mond	Just Im-agine	2001: A Space Odyssey		Solaris	Star Wars IV - A New Hope	Star Wars: Episode V - The Empire Strikes Back	Star Wars: Epi-sode VI- Return of the Jedi	Total Recall	Red Planet	Race to Mars	Avatar	Red Faction: Origins	John Carter	The Last Days on Mars	Interstellar	Guardians of Galaxy	The Martian	Jupiter Ascending	Passengers	Space Between Us	Valerian and the City of a Thou-sand Planets
General	Year	1902	1918	1924	1929	1930	1968		1972	1977	1980	1983	1990	2000	2007	2009	2011	2012	2013	2014	2014	2015	2015	2016	2017	2017
	Director	Georges Méliès	Holger-Madsen	Yakov Protazanov	Fritz Lang	Stephen Goosson	Stanley Kubrick		Andrei Tarkovsky	George Lucas	Irvin Kershner	Richard Marquand	Paul Verhoeven	Antony Hoffman	George Mihalka	James Cam-eron	Michael Nankin	Andrew Stanton	Ruairi Robinson	Christopher Nolan	James Gunn	Ridley Scott	Lana and Lilly Wachowski	Morten Tyldum	Peter Chelsom	Luc Besson
	Location	Moon	Mars	Mars	Moon	Mars	Moon	Space	Space	Tatooine	Bespin	Coruscant	Mars	Mars	Mars	Pandora		Mars (Barsoom)	Mars	Edmunds	Knowhere	Mars	Cerise	Deep Space	Mars	Deep Space
	Representa-tive Image																									
	Scenario / Type	First Trip to the Moon	Pre-existing civi-lization on Mars	Pre-existing civili-zation on Mars	First Trip to the Moon	First Trip to Mars	Research Base	Orbital Hotel	Research Outpost	Alternative Universe	Alternative Universe - Mining City	Ecumenopolis	Year 2084 in Mars	First Mission to Mars	First Mission to Mars	Established Colony for Industry	Mars colony in the year 2145 - terra-formed	Pre-existing civiliza-tion on Mars - Moving city	First Mission to Mars	Saving the human species	Alternative Universe	First Mission to Mars	Distant Planet	2 (active) inhabitants	First Mission to Mars - Colony	Future of ISS space-traveling city
	Name	-	-	-	Friede	-	Clavius Base	Space Station V	Solaris	Mos Espa	Cloud City	Galactic City	-	HAB	MARSHAB ATLANTIS	-	-	Zodanga	Tantalus BasE	-	-	The HABitat	Kalique's alcazar	Avalon	-	Alpha
Considers	Gravity	No	No	No	Yes (launch)	No	Yes		Yes	-	-	-	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	-	Yes	-	Yes	Yes	Yes
	Radiation	No	No	No	No	No	Yes		Yes	-	-	-	Yes	Yes	Yes	Yes	Yes	-	Yes	Yes	-	Yes	-	Yes	Yes	Yes
	Atmosphe	No	No	No	No	No	Yes		Yes	-	-	-	Yes	Yes	Yes	Yes	Yes	-	Yes	Yes	-	Yes	-	Yes	Yes	Yes
Architecture	Habitat	No	Yes	Yes	Yes	No	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	City	No	Yes	Yes	No	No	Yes		No	Yes	Yes	Yes	Yes	No	No	Yes	No	Yes	No	No	Yes	No	Yes	Yes	No	Yes
	Type:																									
	Design input	-	-	-	Hermann Oberth	-	NASA		-	-	-	-	-	NASA	-	-	-	-	-	-	-	Arthur Max	-	Guy Hendrix Dyas	NASA	-
	Inspiration	Jules Verne	Novel by Sophus Michaelis	Soviet Constructivism			NASA	Wernher von Braun		Djerba Architecture (Tunisia)																Sci-Fi comics series Valérian and Laureline

Table 2
Evolution of Space Habitats- A vision since 1903, based on cinematography.

Types of Outer Space Habitats

(a) Rockets
(b) Spaceship
(c) Unit (or multiple)
(d) City condesed in a building
(e) City
(f) Industrial City



(a) (b) (c) (d) (e) (f)

2.4.5. Influence of Films in Architecture

The same way architecture influences film sets, film sets can influence architecture, not only by inspiring futuristic architecture but also by developing technology and new design concepts.

Arnold Hauser (2005) writes “The film signifies the first attempt since the beginning of our modern individualistic civilization to produce art for a mass public. As is known, the changes in the structure of the theatre and reading public, connected at the beginning of the last century with the rise of the boulevard play and the feuilleton novel, formed the real beginning of the democratization of art which reaches its culmination in mass attendance of cinemas.”

Architects such as Norman Foster, Jean Nouvel, have been influenced by films such as Stanley Kubrick's 2001: Space Odyssey (1968) or even Star Wars, some more heavily and direct than others. On Fig. 42 we see “Casa da Música “of Rem Koolhaas which has a striking similarly to architectures found in Star Wars - sandrcrawler (Fig. 43). Jean Nouvel's project the Louve of Abu Dhabi resembles the Galactic Senate Coruscant, also from Star wars.

In terms of architecture influencing films, some had direct input from architects like ‘Frau du Mond’ and others have been influenced by projects. For example, nowadays when we think of an extra-terrestrial habitat we probably evoke the idea of a Geodesic Domes, this architectural typology is due to the Geodesic Dome patented in 1954 by Buckminster Fuller who later presented the concept with 'Biosphere' in Expo 67, Montreal (1967). Even tough this idea has evolved, its still quite present in the solutions designed on analog/projects habitat too, which can be seen in following chapter (eg. HI-SEAS).

Sometimes tt becomes quite hard to define exactly who inspired whom, since architecture can be born of relationship between literature references, drawings, films, and even other architectural projects.

Fig. 40 - Louvre Abu Dhabi , 2017, Jean Nouvel, located on the lagoon island of Saadiyat. (medium.com)

Fig. 41 - Galactic Senate - Coruscant (newatlas.com)

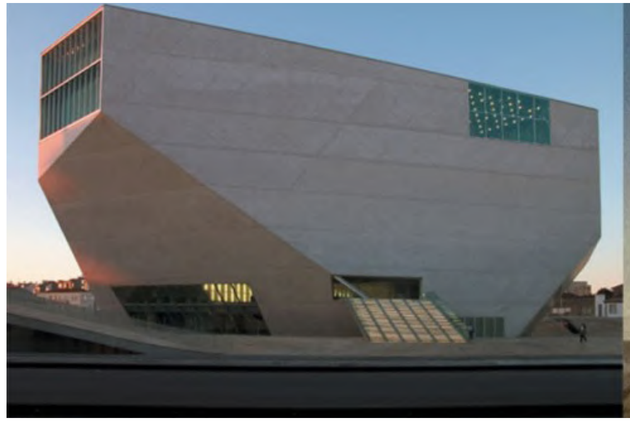


Fig. 42 - Casa Música, Porto, 2007, Rem Koolhaas

Fig. 43 - Galactic Senate - Coruscant

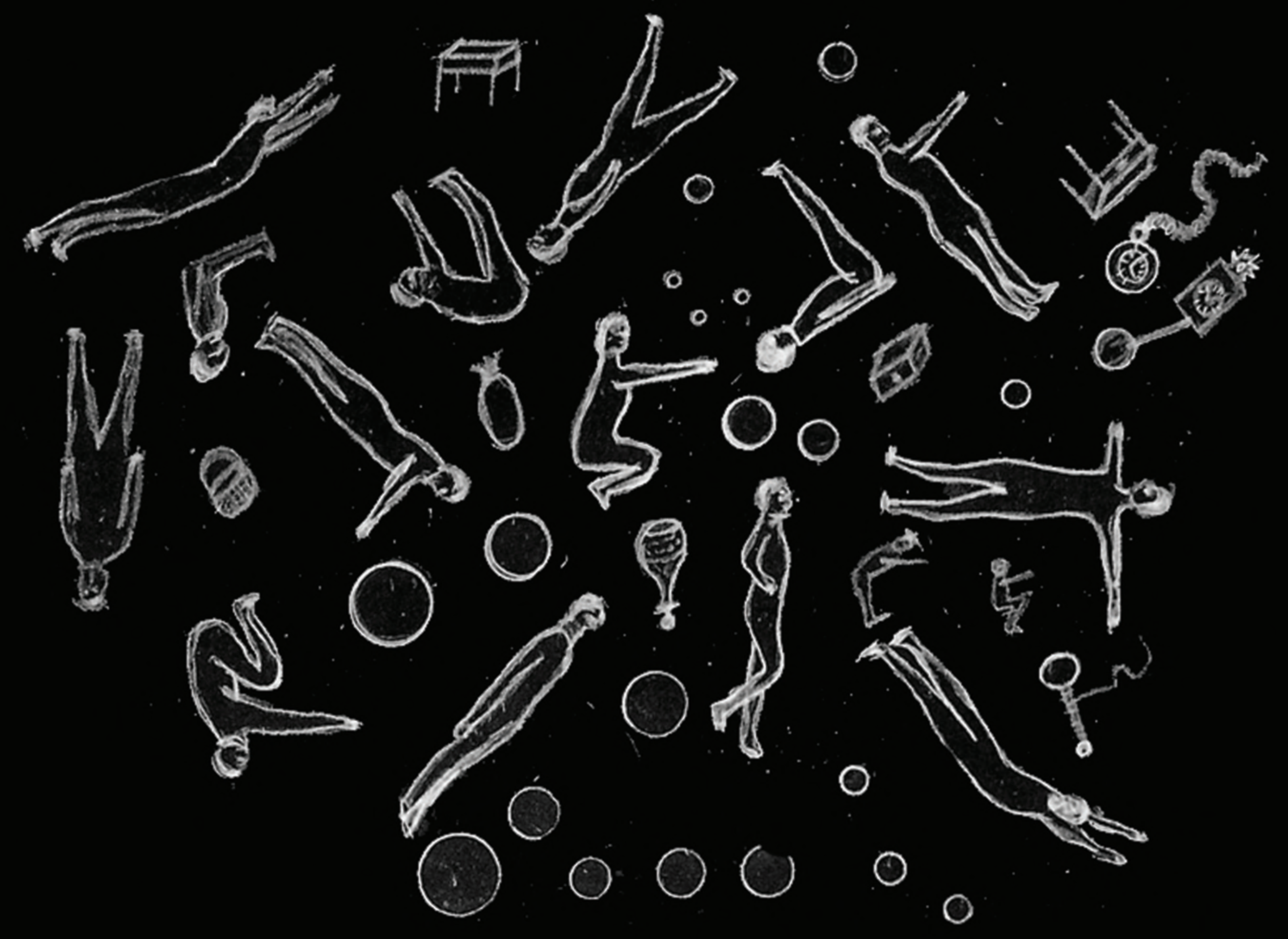


Fig. 44 - Konstantin Tsiolkovsky drawings - People in space.

2.5. Space Architecture

With the previously studied points, we already touch the basis of literature and films that culminate in inspiring people, which would later invent, imagine and draw possible hypotheses for living somewhere outside of Earth.

Space Architecture as a discipline isn't new, even though there may be some overlapping with fiction at first. There is an abundant history of early design contributions to space projects by architects and designers, (Bannova & Hauplik-Meusburger, 2016). Unfortunately, there is a misconception that Sci-Fi Architecture is the same as Space Architecture, resulting in this subject still not taken very seriously (Wong, 2003).

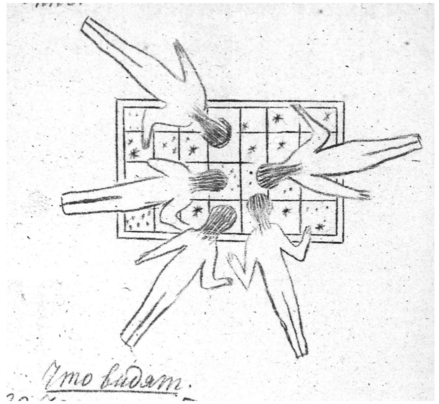


Fig. 45 -Konstantin Tsiolkovsky drawings - lookout in space.

<u>How did Space Architecture come to a discipline?</u>

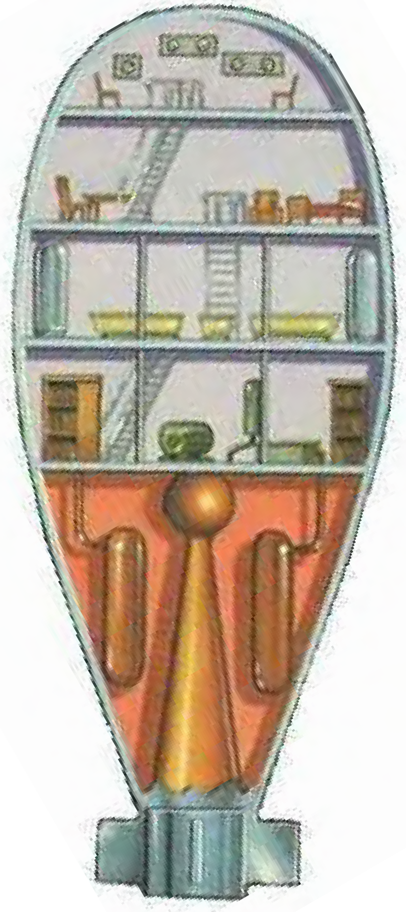


Fig. 46 - Konstantin Tsiolkovsky design of a space projectile.

If we point to which was the first serious theoretical work published on space travel, by means of rocket power, it was by the hands of a Russian math teacher and inventor Konstantin Tsiolkovsky (1857-1935), the Father of Rocketry. While investigating aerodynamics, he was inspired by Jules Verne's stories of space travel and he first began to write sci-fi stories. Gradually he went from those stories to writing theoretical papers. His most important work was published in 1903 "Ex*ploration of Cosmic Space by Means of Reaction Devices"* in which he concluded that only rockets or "reactive vehicles" would serve to explore the outer space. To be kept in mind that this work was published on the same year of the Wright brothers' first flight (McLaughlin, 1999).

He acknowledged the influence of Jules Verne's novels pointing out that his rocket propulsion was a significant advance over Verne's use of canon as a launch method.

Tsiolkovsky then published *Plan for Space Exploration,* in 1926, where human civilization could outlive its dying sun and settle the universe. It was based on rocket-powered airplanes, the use of plants for life support, and solar radiation to grow food and supply energy. He predicted the need to use pressurized suits when leaving the spacecraft, and envisioned the construction of large orbital settlements (Reznikova, 2015). He also developed some designs for space travel in a rocket. His famous quote shows his view on outer space exploration:

"Earth is the cradle of humanity, but one cannot remain in the cradle forever."

Another person who also takes part on this journey of space exploration, also an avid reader of Jules Verne novels, was Hermann Oberth (1894 – 1989) (Wong, 2003), a German physicist and engineer, one of the fathers of rocketry and astronautics. One of his most famous works was his thesis 'The Rocket into Planetary Spaces' (Die Rakete zu den Planetenräumen) in 1923, which dealt with Space travel, presenting mathematically analyzed concepts and designs. At one point, he even acted as a scientific advisor for the film Frau im Mond (1929) (Tietz, 2014).

Later Wernher Von Braun (1912–1977), a student of Hermann Oberth, is responsible for the earliest credible work on expandable (inflatable) space habitats in 1946. He could see the advantages of collapsible and expandable structures, (Howe & Sheerwood, 2009). Wernher published his architectural visions in a series of articles for Collier's magazines, which became very popular and so it was expanded to three books (Fig. 49): Across the space frontier, Conquest of the Moon, and The Exploration of Mars. Walt Disney created a three-part episode based on his books where the programs described and dramatized each of the major steps of the von Braun architecture: space taxi (shuttle), space station, Moon tug and Mars mission, (Spudis, 2012).

His vision of a station (S1 in 1946 and S2 in 1955) was inspired by Arthur C. Clarke's famous space station in the film 2001: A Space Odyssey (1968) (AD, 2014) The particular shape seen in Fig.50 was made for spinning which would accomplish an artificial gravity.

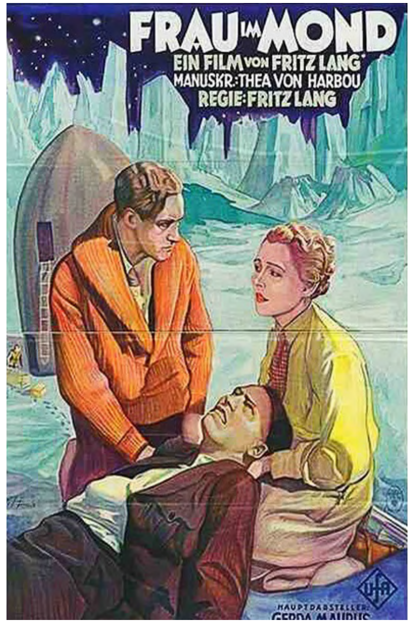


Fig. 47 - Poster Frau im Mond, 1929.

Fig. 48 -Dr. Wernher von Braun and Professor Hermann Oberth are honored by the Berlin Technical University 1963.

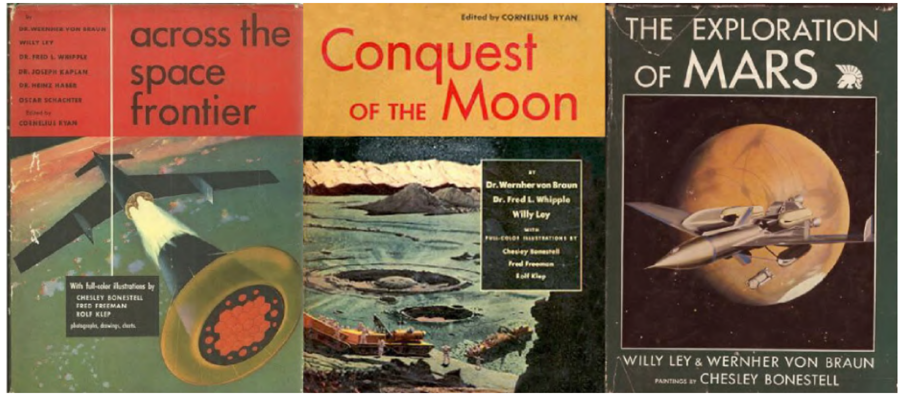


Fig. 49 - Dr. Wernher von Braun and Professor Hermann Oberth are honored by the Berlin Technical University 1963.

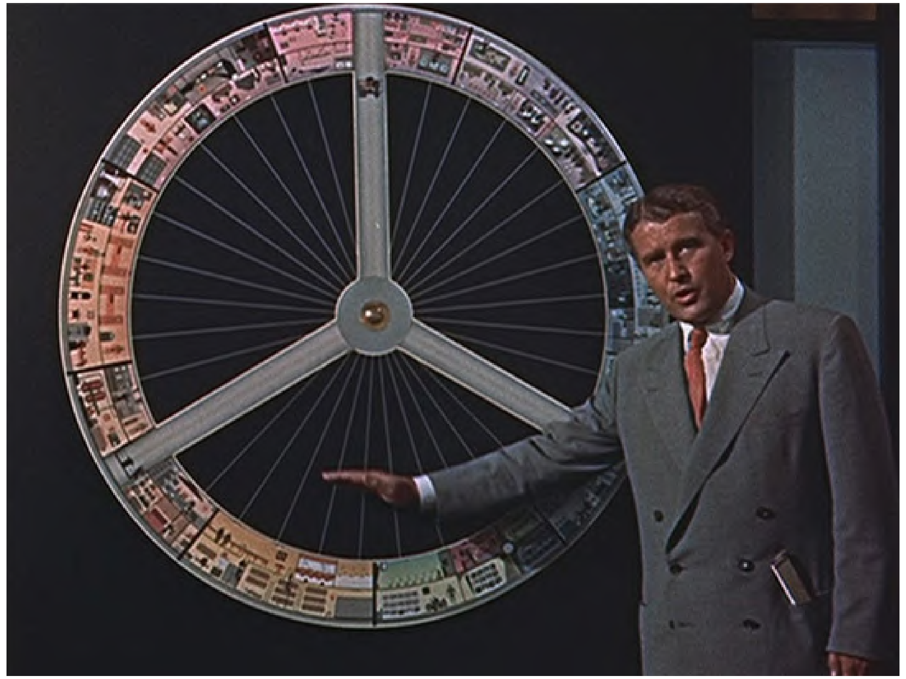


Fig. 50 - Dr. Wernher von Braun and Professor Hermann Oberth are honored by the Berlin Technical University 1963.

A commonly agreed person as the first Space Architect would be Galina Balashova, (1931 -). She was the interior architect for the Soviet space program in charge of the designs for the major Soviets space program projects. She led the sphere of design of zero gravity and micro gravity interior design for three decades (Meuser, 2015). She started in the 1960´s working on the interiors of the Salyut 6 and 7 spacecraft. Following a series for the Soyuz Orbital Spacecraft project, launched in 1966. Until then, she worked only on projects that were a single-chambered space capsules and rockets (Meuser, 2015).

The Mir Space Station, another project that she participated in, was different by itself since it was crafted out of multiple modules and dealt with micro gravity and not zero gravity. It marked a further development in long-term space habitation, it was launched in 1986 (Meuser, 2015). Her last work was for the Buran Shuttle, and some aspects of her work inspired the design of the cockpit and living quarters of the International Space Station. She retired in 1990 (Giuliani, 2017).

Galina Balashova is the acknowledged leader in the design of non–directional free compositions. She introduced the use of color for orientation: Green for “floors” (for psychological effects) and yellow for “walls” (which assisted the visibility of controls). She always had the objective in her designs to make the spaces more humane, harmonious and comfortable (Meuser, 2015). In her projects, she worked on material selection and development, furnishing, work areas, toilets, and sleeping quarters. As an accomplished painter, she presented her space ship designs in beautiful watercolor renderings. She created an art program for the

Fig. 51 -Galina Balashova in the space shop's interior (Galina Balaschova/DOM publishers)

Fig. 52 -Galina Balashova's watercolours of interiors.

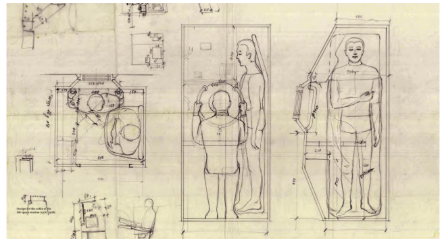


Fig. 53 - Galina Balashova Sketches - Astronaut sleeping

Mir Station that consisted of Russian landscapes and fauna, designed for their calming effect and to remind the cosmonauts of the Russian homeland (Hinchman & Yoneda, 2016).

At that time, Galina Balashova's American counterparts were Raymond Loewy and his protégé Constance Adams. A difference between the Russian and the American space interiors is that the Russian attitude (due to Balashova) focused on creating a living environment while the Americans favored functionality; Both relied on the modernist interest in modularity, (Hinchman & Yoneda, 2016).

There was also a contribution from Architect Maynard Dalton in 1967, where he was part of “Advanced Spacecraft Technical Division”, later in 1968 Dalton and Reymond Loewy, world renowned

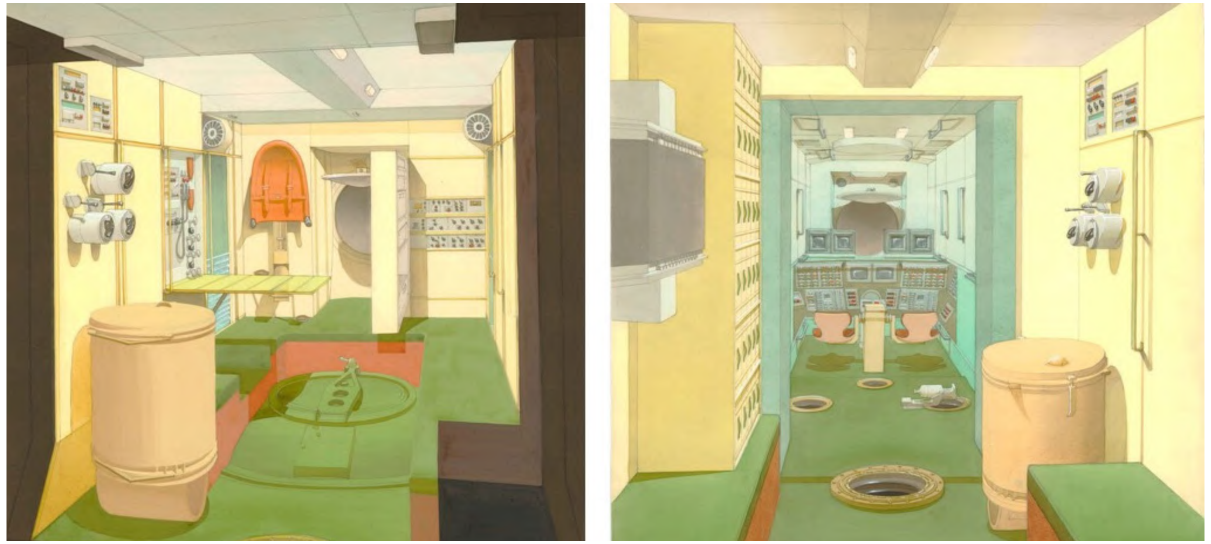


Fig. 54 -Galina Balashova's watercolours of interiors.

industrial designer, worked together on the Saturn-Apollo and Skylab projects contributing with several improvements on the existing layout, (Bannova & Hauplik-Meusburger, 2016).

> *"The interior of the workshop was poorly planned; a working area should be simple, with enclosed and open areas "flow[ing] smoothly as integrated elements . . . against neutral backgrounds." While they found a certain "honesty in the straightforward treatment of interior space," the overall impression was nonetheless forbidding. The basic cylindrical structure clashed with rectangular elements and with the harsh pattern of triangular gridwork liberally spread throughout the workshop. The visual environment was badly cluttered. Lights were scattered apparently at random over the ceiling, and colors were much too dark. This depressing habitat could, however, be much improved simply by organized use of color and illumination."*[1]

They recommended a neutral background of pale yellow, with attention to adding brighter accents for variety and for identifying crew aids, experiment equipment, and personal kits. Lighting was also thought of. It should be localized at work areas and substituting the cold fluorescents lights used for lights with a warmer spectral range. They also suggested creating a wardroom which was destined to be a space for eating, relaxing, and handling office work. The floor plan should be made flexible using movable panels, so that different arrangements could be tested. Evaluating a single layout wouldn't add much information about the design of space stations.

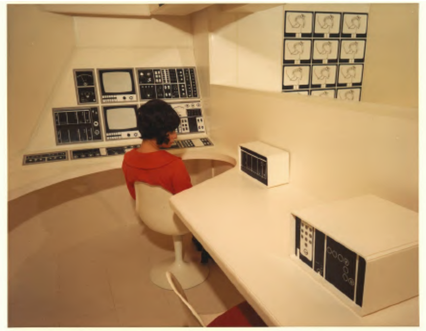


Fig. 55 -Full-scale mock-ups for an "artificial-G, shuttle-compatible space station interior", Raymond Loewy, NASA.

1 SP-4208 Living and Working in Space: A History of Skylab.

The biggest achievement at that date was including an observation window in the Skylab orbital laboratory. It meant the introduction of the human psychological dimension to spacecraft design. The window was a challenge, even though it was agreed that it would be very nice to have, it posed one of the toughest problems a spacecraft designer could face. It was not only expensive, it would weaken the structure, and it was not essential to mission success. But Loewy defended that its recreational value alone would be worth its cost on a long mission (Compton & Benson, 2011).

Skylab was used from May of 1973 until February of 1974. Even so, the Design of Skylab was far from perfect, some design philosophies were flawed or even negligent, but it was a way to learn a collect valuable data for a better design in the next try. It was there collected the knowledge of 'local vertical' – orientation references of up and down, circulation patterns and many first-hand experiences by the astronauts were critical for the future space stations design (Wong, 2003).

One of the biggest achievements was certainly the ISS (International Space Station). Its design is a compilation of all the learned lessons from previous space stations, achieving being very versatile and efficient. It also took into consideration physiological and psychological factors. In comparison to Mir, or Skylab, it provides a more generous and comfortable space (Wong, 2003).

2.5.1.Publishes

Fig. 56 - Covers of magazine AD, 1967, 2000, 2014

The architecture magazine AD: Architectural Design has published about Space Architecture for three times now, appealing to architects to this very specific branch of architecture. The earliest publication was in February, 1967 with "2000+", where it focused in technological aspects of Space, accompanied with photos of Space vehicles, rockets and astronauts.

In March, 2000, after 33 years, the magazine AD revisits the subject with "Space Architecture", to challenge architects to design for space.

> *"Architects of these new habitats will need to reflect on the comfort, health and survival of their occupants. Such speculation on the direct link between the body and its architectural surroundings may inspire traditional architects to think the unthinkable, becoming involved in the design of the currents embryonic projects. It is to be hoped that in the near future, architects and students may discard their terrestrial prejudices, leave behind the convention of gravity and join the engineers, designers and citizens who are working to realize the first determined attempts to live beyond Earth." (AD: Space Architecture, April 2000).*

It points to the lost competitive incentive of the space race as a reason to the lost momentum in the space industry development, and the importance of Space Tourism for developing since it would be an economically rewarding industry. It also thinks about the influence of Sci-Fi film visons during the Space Age in had in that generation of architects.

Most recently, it published the issue named: "Space Architecture: The New Frontier of Design Research" in 2014, which gives the name of this chapter. It answers the question "what is a Space Architect?", the architecture of other planets and how to proceed on missions and colonizing Mars. It thinks about methods of construction in another planet (3D-Printing), the challenges of growing food and the troubles of dealing with gravity.

This magazine was successful in anticipating events, '2000+' came out two years before the Moon landing, and 'AD: Space Architecture' a year before the first Space tourist went to Space.

2.5.2. What is the Space Architecture?

What is the Space Architecture? A concrete answer to this question first appears in 2002, with the Millennium Charter Manifesto. "Space Architecture is the theory and practice of design and building inhabited environments in outer space", A definition that was agreed by over fifty professionals in the Millennium Charter Manifesto, (2002). In short: The central focus of space architecture is designing to support human activity, (Howe & Sherwood, 2009).

Architects, due to their education and training, often acting as a mediator of most diverse disciplines – engineering, esthetics, social sciences, psychology and so on. In the space industry, space architects often take up the role of the integrator of design team, juggling more than a dozen experts from different fields of expertise. They also have the responsibility to give a holistic view of the project, acting as a communication bridge between the different experts, (Wong, 2003). This is a highly valuable skill that becomes even more useful in the field of Space Architecture, due to its interdisciplinary nature.

In the Diagram 2 ts possible to visualize the relationship between Space Architecture and other disciplines. Space Architecture receives information from Theory Architecture, Art and Sci-Fi Architecture. It bases itself in the input of Science, Engineering and the Space Industry. Business, Management, Policy and Law also are taken into consideration.

"This is no longer science fiction, but science and engineering facts. (...) Designing spacecraft and space and planetary habitats for humans requires knowledge spanning a range of disciplines: engineering, medical, psychology, human factors, life support system, radiation protection/space weather, and other extreme space environment, at minimum. These disciplines must result in an integrated human-centered system, which should also be reliable, safe and sustainable. This is space architecture." (Dunbar. 2016)

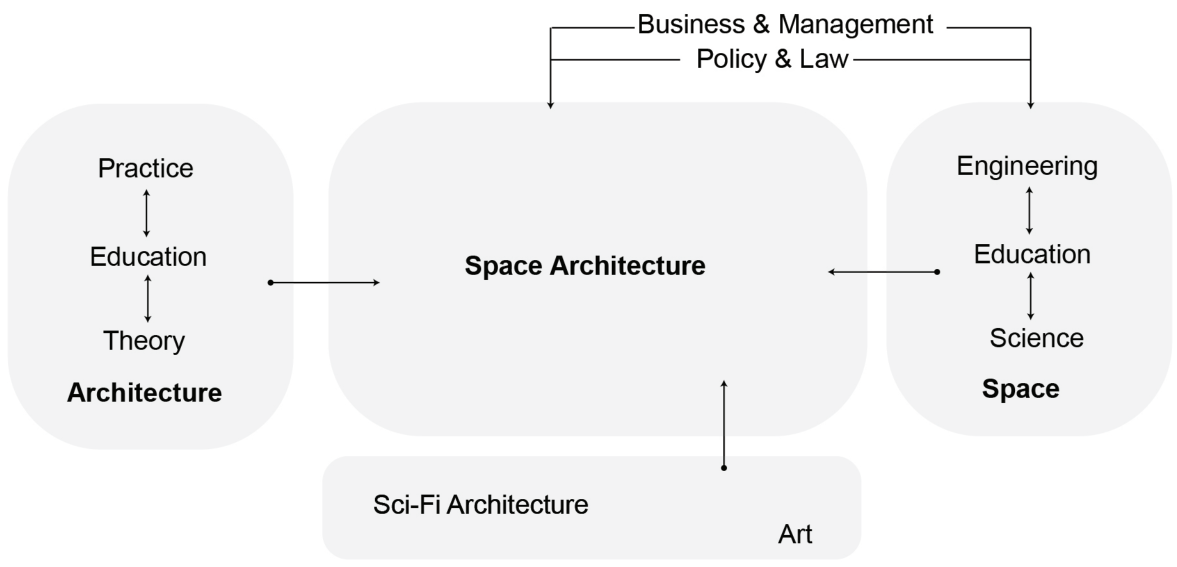


Diagram 2 - Relationship diagram between Space Architecture and other disciplines. (From Space Architecture – An Overview and its relationship with General Architecture Profession. (Wong, 2003).

The path from imagining a scenario to a final Habitat design requires the involvement of different expertise areas: Psychology, Medicine, Ergonomic, Industrial Design, Space Science, Engineering and Architecture. They partake input in different phases of the development of the project.

In the first phases Engineering, Space Science and Psychology have a more active role in the developing and tracing of the scenario, requirements and objectives. Later on, the roles of Medicine, Ergonomics, Industrial Design and Engineering come to part. In the meanwhile Architecture is the only area that requires high evolvement from the beginning stages of the Scenario throughout the final design. It's possible to visualize this on Diagram 3.

Researchers of the field distinguish the Architectural Methodology and Engineer Methodology with the Space Architecture Methodology. While the first is centered around humans and their needs, the engineering approach tends to focus on a particular problem at hand, (for example designing the HVAC system), resulting that in the end when you join the work of the HVAC with another from other system, it often ends up needing to compromise by reconsidering essential aspects of the solution (Bannova & Bell, 2011). The (Aero)Space Architecture approach "combines engineering thinking with criteria related to habitability and human factors" which are considered in the architecture and industrial design, plus other disciplines such as medicine and science (Bannova & Hauplik-Meusburger, 2016).

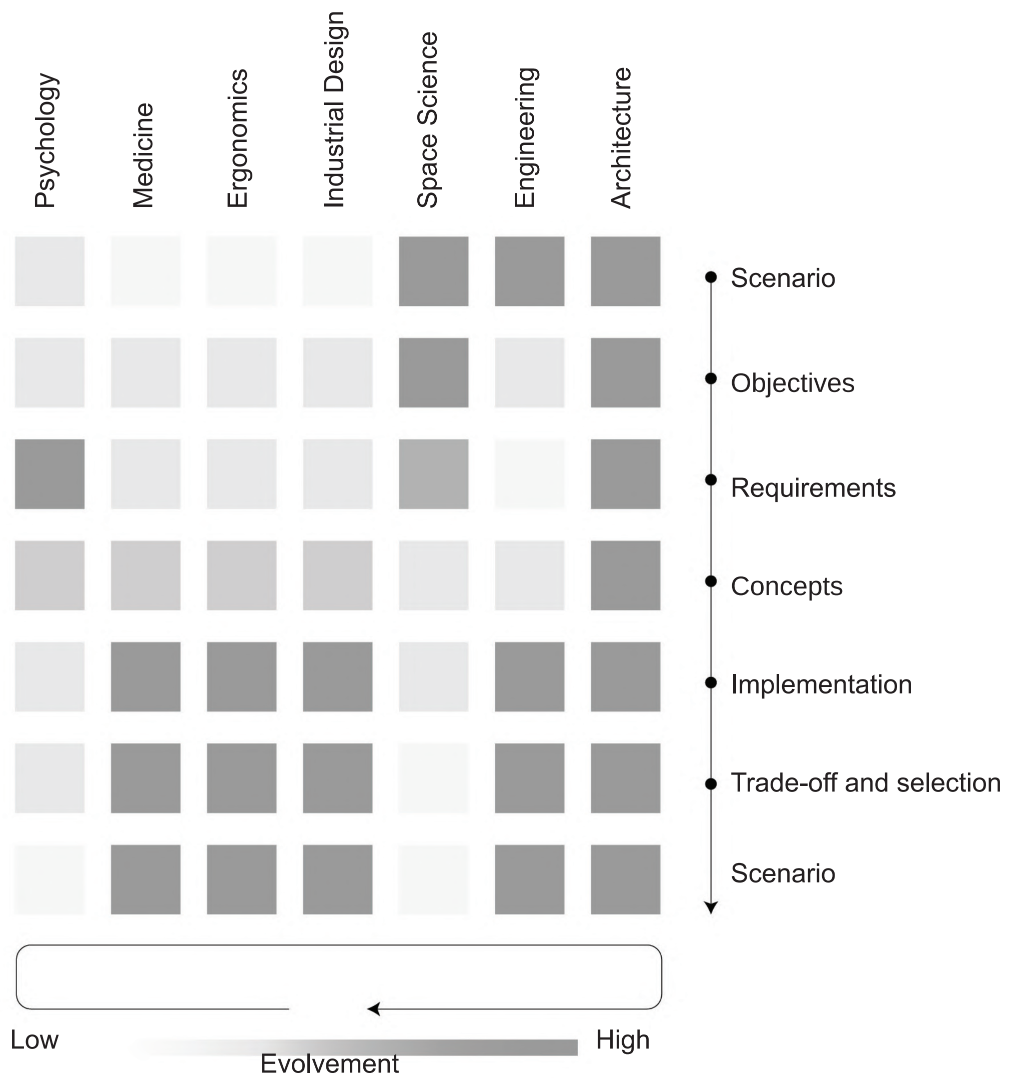


Diagram 3 – Scheme of a disciplines relationship synthesized approach diagram. Taken from 'Space Architecture Education for Engineers and Architects' (2016) p.17

2.5.3. Space Architecture Manifesto – Millennium Charter

The first International Space Architecture Symposium took place at the World Space Congress in Houston, on October 12 of 2002, and it closed with a final draft of "The Millennium Charter", a manifesto of Space Architecture. It was the first attempt to recognize the discipline of Space Architecture, (Wong, 2003). Defining it, as early stated: Space Architecture is the theory and practice of designing and building inhabited environments in outer space."

According to Cohen (2018) in his "Memorial to Constance Adams – Space Architect", Constance Adams played a lead role in organizing the "Team 11/ Millennium Charter Workshop". She chose the name for this in any random way. It is not only connected with the presence of 11 members of ASASC involved in organized the Symposium and Workshop but also by suggesting an inheritance from team 10 (or team X). The intention was to revive the CIAM as the only and truly international precedent of architects working as an organized, political body to craft a sense of relevance and understanding between our profession and the world at large (Adams, 2002).

The intention was to follow a tradition that the Swiss Architect Le Corbusier and leading Modern Architects did first in 1928, with the Congrès International d'Architecture Moderne (CIAM), that resulted in the Athens Charter on its fourth congress (CIAM4) in 1933. This Athens Charter was an idealistic vision of the extension of Modern Architecture to modern Urban Planning. The Team 10 appears later in 1953 founded by group of 10 younger architects.

Fig. 57 - New York Times, Pg.1, August 30, 1907.

After the dissolution of CIAM in 1959, they kept advocating the cause of Modern Architecture and Modern urban planning until 1981, where the last formal meeting took place in Lisbon.

In ambition to connect with the architecture movements and history, one of the participants invited was Waltrude "Val" woods, one of the last surviving participants in Team 10 activities and wife of Shadrach Woods, one of the Team 10 founders.

The whole point was to write the Millennium Charter about Space Architecture, just as CIAM wrote the Athens Charter in 1933 (Cohen, 2018).

It joined enthusiast and experts of the field from all over the word, with a special focus on Constance Adams, Marc Cohen, Brent Sherwood, Sandra Hauplik, A. Scott Howe, Barbara Imhof, Kriss Kennedy and the non-attending Buzz Aldrin.

The Millennium Charter laid out the parameter and values that space architecture takes into consideration (Wong, 2003).

The 11 fundamental principles evolved were: Sustainability, Human Interaction, The User, Human Factor, Human Condition, Social Aspects, Environmental Conditions, Education, Life Cycle, Humility, and Benefits.

"1. Sustainability
As in earth architecture sustainability is multidimensional and encompasses the following areas: Ecology; Technology; Economics, Social; But in the context of space architecture it requires greater flexibility to adjust to unknown situations.

2. Human Interaction
Space Architecture is influenced by the interaction between: Human – Human; Human – Machine (product); Human – Universe;

3. The User
Because user needs and well-being are critical components of mission and vehicle design, user contributions are indispensable in the practice of space architecture.

4. Human Factors
Human requirements for inhabited space systems are fundamentally similar to our requirements for daily life on earth.

5.Human Condition
Space architecture is concerned with the continuum and the future of the human condition.

6.Social Aspects
Community life, communication and interaction among space voyagers are important considerations for space architecture.

7.Environmental Conditions
Space architecture must respond to a wide range of different environmental boundary conditions (orbital, interplanetary,

8. Education Space
Architecture uses a multi-disciplinary approach to manage the complex nature of space projects. From the start of each project, success is derived from collaboration.

9. Life Cycle
The Life Cycle of architectural elements is an essential aspect of mission planning and design.'

10. Humility
Architecture involves forging harmony around the human system, balancing culture, biology, planetary knowledge and technology in counterpoint to the unknowable.

11. Benefits
The involvement of space architecture from project onset provides great benefit to space development and exploration: measurable savings in cost, time, maintenance and extended usability. Knowledge and Technics derived from the practice of space architecture can improve the sustained quality of life on our human mothership, the Earth."

Space Architecture debates and works on designing living and working environments in outer space (being on Space, in Moon, Mars or other celestial bodies). It doesn't only include planetary habitats and space stations but also space vehicles and required infrastructure. Earth analogs may include Antarctic, airborne, desert, high altitude, underground, undersea environments, and closed ecological systems (Häuplik-Meusburger & Bannova, 2016).

2.5.4. Colonizing Mars: Current Vision and Research

It is an exciting time, being the 50th anniversary of the Moon Landing. After many disappointments and letdowns in the Space Industry, it looks its finally moving forward.

On the 68th IAC, in September 2018, Elon Musk announced his plan to establish a self-sustaining city on Mars, allowing humans to become a multi-planetary species. Their stipulated timeline is optimistic, targeting for the first cargo mission in 2022, and a crewed mission in 2024, and we will see more about this plan in the case study on the next chapter.

On 2023, on a project called “Dear Moon”, SpaceX will do a private Lunar Mission with a Japanese entrepreneur Yusaku Maezawa, taking 6-8 artists from around the world, from different fields including painters, musicians, fashion designers, photographers, film directors and architects.

In May 2019 after the announcement of Mike Pence, Jim Bridenstine, current NASA Administrator declared:

> *“President Donald Trump has asked NASA to accelerate our plans to return to the Moon and to land humans on the surface again by 2024. We will go with innovative new technologies and systems to explore more locations across the surface than was ever thought possible. This time, when we go to the Moon, we will stay. And then we will use what we learn on the Moon to take the next giant leap - sending astronauts to Mars.”*

With the program Artemis (named after the sister of Apollo in Greek mythology), NASA is looking to establish a sustainable human presence on the Moon by 2028. A platform is also being planned – Gateway (Lunar outpost)- that will stay in orbit, around the moon, to do deep-space experiments. It will be able to move between orbits.

The success of this mission would pave the way for a human on Mars by 2030s and even further deep-space missions.

In terms of architect’s involvement, we have also seen a change. The challenge to build in outer space sparked interest renowned firms, such as BIG, and Norman Foster to think deeply on the subject.

Another way to keep architects dwelling on this subject is through competition. In 2015 NASA promoted design contests for the explorations of habitat concepts. NASA wanted proposals of how humans might one day live on Mars. The projects needed to corporate 3D-Printing Technology to design sustainable housing solutions for space. There have been a few editions, and the objective is to 3D Print a habitat, to research possible habitat design for the Moon/Mars base and even building them at 1:1 scale. Teams were judged on many factors, including architectural concept, design approach, habitability, innovation, functionality, Mars site selection and 3-D print constructability.

In terms of education, it’s now possible to have a master’s degree in Space Architecture, at the University of Houston (since the 2001/2002 academic year). This was a huge step forward in terms of recognition to the discipline.

Fig. 58 - 1st, 2nd and 3rd place in the 3D-Printing Habitat Challenge. Mars Ice House, Gamma, LavaHive. 2015 edition (NASA)

There are exciting years ahead in the space exploration, and in space architecture. Being able to not only work internationally but successfully work interdisciplinary makes us (as humans) come closer to our objective, to work/live in outerspace, Moon, Mars or even beyond.

3. Chapter III – How to Design for Mars?

"Space architecture is a manifestation of humanity's desire to explore, to journey out into the universe, and to change the new spaces that we find there into new places for us to be. As for any journey, there is a departure from the well known and familiar; a movement into new and potentially challenging areas, combined with a willingness to engage with change. "

Christ Welch in "Space Architecture for Architects and Engineers", 2016

Chapter 3 – How to Design for Mars?

As any other architectural research for a project, we first study the site of future intervention. We try to understand our restrictions and requirements to satisfy the programed needs of the client. Being out-of-earth wouldn't change this very programmatic/ pragmatic approach to architecture. In this chapter, we deepen our knowledge about the different characteristic of Mars – the Atmosphere, Temperature, Radiation, Gravity, and overall environment in comparison to our own Planet, Moon and Space. The objective would be to resume the knowledge that space architects need to take into consideration when projecting for this new space.

On the second part, we create different analysis criteria, to later apply on Study Cases. This factors will be analyzed and resumed into guideline on how to Design for Mars. The research to define this guideline, are based on the work developed by Donny Donoghue (2016) in Urban Design Guidelines for Human Well-being in Martian Settlements, where he sets some guidelines concerning different scales, both the community and Site Design, and added guidelines developed through the scientific studies of various sources, with more focus on "Space Architecture Education for engineers and architects".

For the final part, the author analyses 4 case studies, winners of Nasa's Habitat Challenge. Mars Ice House, Mars Ice Home, MARSHA, Mars House X V.2. For sake of a more complete review on works done currently some mentions follow: Space X, Mars Science City from BIG, and the participation of Foster+ Partners also in the contest.

3.1. The Millennium Guide 2.0

The forms of settlements are determined by factors and influences, and are called by A. E. J. Morris as "Urban form determinants". These have two different origins: The first ones derivate from geographical "natural world" attributes of the settlement location such as the climate, the topography and the composition of the site (materials available).

In the other hand, there are also "man-made" determinants. (Morris, 1994) By "man-made", Morris refers to determinants such as economic, political, defensive, Religious, Aesthetic, Legislations, urban infrastructure, social, religious and Ethnic Grouping, and Leisure.

However, in the context of living in Mars, in exchange for those determinants, the form of the new settlements would be based on determinants that responded to the crucial needs for human life. The determinants would be based on solving problems as how to grow and store food, how to protect ourselves from radiation and massive dust storms, how to get breathable air and how to keep our health and avoid loss of bone structure. Also, how to fight effects in a psychological level, such as the feeling of confinement and isolation and give comfort and warmth to the habitants.

More than any other city on earth, planning is crucial for a successful Martian Colony. "On Earth a building is a building. And to make a city you need a conjunction of buildings with diversity on its functions, such as residential, services, civic, and of employment.

All these buildings are connected through exterior areas such as streets, parks, plazas. But on Mars we will see a different situation. A building is a city. There will be no "outdoor space" to connect building or access other areas, so the interior environment alone must provide the range of function and benefits that a city can offers." (Donoghue, 2016)

So, first, it's important to understand the different characteristic of Mars compared to Earth and understand the different design approaches to solve the different problems that will appear due to this new environment.

3.2. Environmental Conditions

Atmosphere

Mars atmosphere is composed by 98% of CO2, which makes it impossible to be independent of the habitat without proper support (suit). An artificial atmosphere must be provided within the habitat.

In terms of design, all habitat must be completed isolated. Due to the difference between outside pressure and the one inside (essential to live), the walls of the habitat must be hermetic, airtight and tensile resistant (Kozicka, 2008).

There should also be special attention to the areas reserved for agricultural purposes. Since plants can't take water from the ground due to the low pressure on Mars, it should be placed in a special hermetic and strong constructions, with a higher pressure (Kozicka, 2008).

Temperature

Daily and yearly temperature fluctuations are high in Mars due to the thin atmosphere. The surface temperature can reach to about -120ºC as minus and -25ºC as maximum temperature (Sherwood & Howe, 2009). The habitat must be completely isolated from the exterior to provide a habitable space, providing heat. The material used for construction must be resilient to temperature fluctuations, and insulation of extreme importance.

Winds

Even with a thin atmosphere, strong winds are a regular occurrence in Mars, it's able to lift dust storms that takes months to settle. The average speed is 36 km/h but may achieve 100-160 km/h in the larger dust storms (Kozicka, 2008).

Martian winds are not dangerous due to the thin atmosphere of Mars, but when designing the habitat base it should be taken into consideration the direction of the strongest winds, determining the safest entrances and location of windows. In regards to the location, since winds depend on the latitude and shape of the ground, open flat planes are to be avoided (Kozicka, 2008).

The outside of the habitat should be as smooth as possible to prevent the settling of dirt, especially on windows. The outer layer should also be of high electrical resistance due to the electrostatic of dust particles in the air (Kozicka, 2008).

Water

Various water sources have been recognized: permafrost, seasonal fluxes with liquid water called recurring slope linear (David, 2016). Regarding its influence on architecture, the planned base should be located as close to this resource as possible. Ice could also possibly be used as a building material (explored for example by Ice House Mars) since it even protects against radiation.

Gravity

Mars has a diameter of 6794 km, and a density of 3.9 g/m3, resulting in 3.7 m/s2 of gravitational force. In comparison to Earth, which is almost double the size, Mars has only 38% of Earth's Gravity. Gravity levels have an important impact on the design of all space facilities. It affects individual performance, human-equipment interaction, and engineering design. There are different types of gravity: Partial gravity (eg. Moon and Mars), Microgravity (Low Earth Orbit and Phobos/Deimos); and Artificial gravity (centripetally induced). All those different gravity conditions have impact on the human body (Häuplik-Meusburger & Bannova, 2016).

The influence of the gravitational force on architecture can be pointed in three major areas. First, due to the lower gravitational force of Mars, the construction can achieve higher heights and be more massive. Less Gravity means less working the muscles which could lead to atrophy – exercise would be crucial to lessen the effect of the gravity (Kozicka, 2008).

Gravity, of course, also influences the way people move around, so new ergonomics should be applied and learned. Though most studies were done on Earth's gravity, in Mars these studies wouldn't apply so we have to base our studies on previous experiences in Space and on the Moon. NASA already did some prediction on its MSIS STD-3000 for microgravity and some of those clues can be adapted to Mars Habitat Design (Kozicka, 2008). With no exact ideas (but some perceptions) the first designs could (and probably will) have design failures so we have to go on a trial basis and we will fail many times until one day we can have a study as complete as Neuferts.

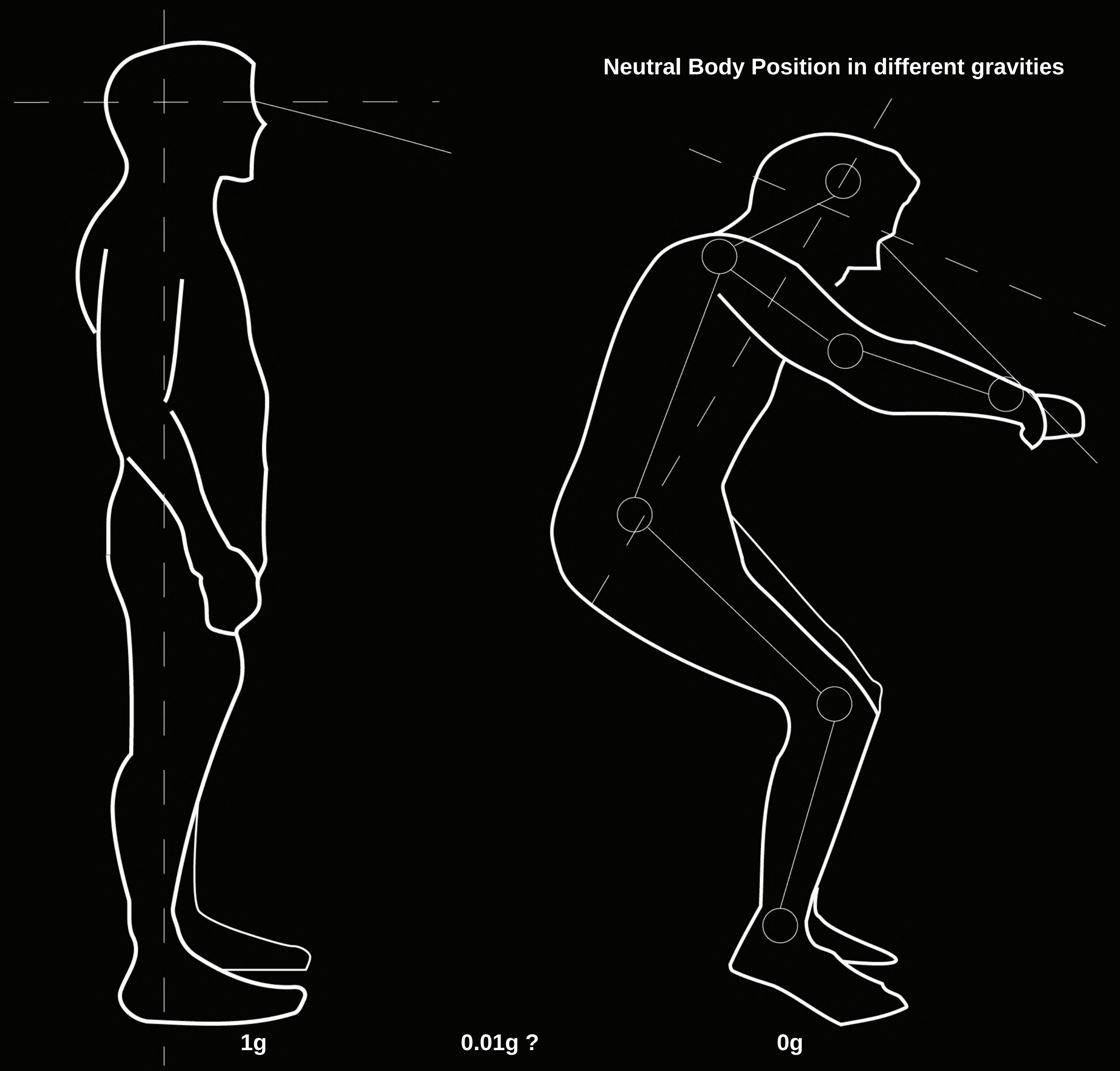


Fig. 59 - Comparison between the neutral body orientation on Earth and the one in micro- gravity. (NASA, 2010)

Terrain

The selection of the site for a future colony needs to be strategic, taking into consideration the resources available, the objectives (scientific or otherwise) and the constraints of the place. Ideally, it would be finding a relatively smooth and flat terrain and searching for a place with natural landscape protection from the environmental hazards (Häuplik-Meusburger & Bannova, 2016).

Radiation

Outside of Earth's magnetic field and atmosphere, we will become exposed to ionizing and non-ionizing radiation. In deep space exploration, astronauts will be exposed to Galactic Cosmic Rays (GCR) and Solar Particles events (SPE), which is radiation that is extremely hazardous for the human body and may cause equipment failure or malfunctioning (Häuplik-Meusburger & Bannova, 2016).

On Mars this is accentuated due to the low density of the Martian Atmosphere. Radiation is a key factor to consider when designing for outer space. It is understood that there should be ways to block UV radiation and to limit its reachable amount into the habitat. Regarding the Solar Flares, which are the source for the Solar Radiation (that is fatal), they only happen from time to time. Its sufficient to either have purpose built shelters (with enough room for every habitant) or that all parts of the habitat be protected with permanent or temporary barriers, that are easy to fold (Kozicka, 2008).

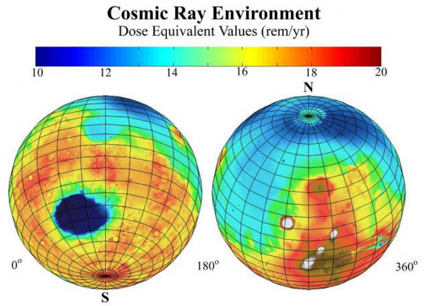


Fig. 60 - Dosage of Cosmic Radiation reaching the surface of Mars surface In mepag.jpl.nasa.gov/topten.cfm?topten=10

Joanna Kozicka also adds that the location of the building site is fundamental for success since it is different from region to region, with more intensity in mountains. The image XX, shows that the lower the altitude, the lower the expected dose, because the atmosphere provides shielding.

Regarding radiation, it will have influence on the chosen material for the habitat, since highly energetic radiation may cause cascade radioactive radiations. For that reason, the building materials need to be made from light elements such as hydrogen, oxygen or carbon. A protective external shield should also be made from materials that can limit radiation dosage (such as water).

In the scheme below, it shows possible ways to balance between having light, and connecting with the exterior more directly, or burying the structure, prioritizing the blockage of radiation. BIG suggests that there should be a balance between those two factors, idealizing a solution with buried structure and a protective shield.

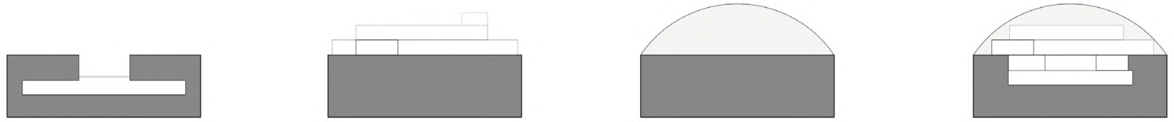


Fig. 61- Radiation shielding options. Based on BIG explorations

Comparison between habitats.

	Earth	Mars	Moon	Outer Space
Gravity	9.8 m/ s²	3,711 m/s²	1,62 m/s²	Microgravity
Temperature	15ºC Min: -89ºC Max: +60ºC	-60ºC Min: -87ºC Max: -5ºC	-20ºC Min: -233 ºC Max: +123ºC	Min: -270ºC (CGR) Max: +200 ºC (RE)
Atmosphere Pressure	1 bar	0,01 bar	0 bar almost vacuum	0 bar vacuum
Atmosphere Composition	nitrogen, oxygen, argon, others	98% CO2	n/a	n/a
Radiation	Natural Protection (Earth Atmosphere), equivalent to 1000 g/cm3	Atmosphere shields about 30 g/cm3. Mass of planet gives "half shielding"	Exposure to SPE and GCR. Mass of the surface gives "Half shielding"	Exposure to SPE and GCR.
Days (Period of Rotation)	23h and 53 min	24h and 37 min	672h	n/a
Year (Period of Revolution)	365 days	670 Sols	28 days	n/a
Presence of Water	Abundant in all forms.	In ice form, buried.	Water in the deep, permanently shadowed craters at the poles	n/a

Table 2 – Comparison on values: Based on table 5.2 – Space Architecture for Architects and Eng. Pg. 168

Fig. 62 -Human Body (author's illustration)

3.2.1. The Human Body Outside of Earth

Radiation: The biggest liability of space travel is the high levels of radiation. It increases the risk of cancer, alters cognitive and motor functions and causes heart and circulatory diseases. Intracranial pressure variations also cause vision problems.

Blood Pressure: Blood without gravity tends to move to higher areas. There is, thus, a redistribution that causes swelling of the face and thinning of the legs.

Immune system: The immunological system is weakened during stays in space, increasing the risk of suffering infections.

Kidney Stones: Due to dehydration, and the increased levels of calcium found in the blood, due to the loss of bone mass, Kidney stones are more probable to happen.

Urinary tract infections: Prone to urinary tract infections, (especially in women).

Muscle Atrophy: Muscle Mass can be reduced up to 5% weekly.

Bone loss: On earth we experience the loss of 1-1.5% per year. On Mars, we produced the result of losing around 1% density per month.

3.3. Human Factors

The definition of Human Factors (or ergonomics) by the International Ergonomics Associations is: “the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design to optimize human well-being and overall system performance.”

No matter how far from Earth, the human psyche is always dependent to our surroundings. Per se if we control our environment, we will be able to control to a certain level our psyche (Szocik, 2019).

Human Factors	
Psychological	Territoriality, Withdrawal, Privacy, Depression, Anxiety, Anger, Hostility, Fear, Ego, Homesickness, Demotivation, Loneliness;
Social	Privacy, Conflict, Love, Sex, Groupism, Cohesion, Tension, Competition, Aggression, Rebellion, Disagreement, Family Emergencies, Leisure, Conflict;
Sensory	Visual, Tactile, Auditory, Olfactory, Gustatory, Cognition, Real/Virtual;
Spatial	Cramped Volume, Linear Configuration, Interiors, Outfitting, Movement, Orientation, Outdoor Access, Windows/Windowlessness, Technologized Spaces;
Work-Related	Overload, Not enough Work, Scheduling, Fatigue, Monotony, Boredom, Not enough time for real science, Not enough time for Exploration, Emergencies, Team Dynamics
Habitation-Related	Illumination, Temperature, Noise, Odor, Air/Water Quality, Food, Sleep, Health, Hygine, Exercise;

Table 4- Overview of an adverse and complex array of human factor issues that gateway can help counter Taken from Moon Life Handbook, (Framis, 2010)

Privacy

Privacy is one of the fundamental human needs – to have a space that is your own, and that you can escape. Privacy is a main concern when designing the settlement, and it's more than a provision of private spaces. A privacy gradient should be applied so that each transect should complete the transition gracefully from public to semi-public to semi-private to private. (Donoghue, 2016)

Privacy can also be identified differently, depending on a person's social and cultural background (Häuplik-Meusburger & Bannova, 2016) but the need to keep a private place is one of the fundamental needs of a human being; some space belonging to the individual only, where nobody can enter without permission. The size of such place is suggested by Stuster as a minimum 2.4 m2. The longer the mission time the greater is the need of a larger private area place. (Kozicka, 2008, Pg. 102)

Adding to the private cabins, there should be rooms for silent reflections, psychical rest, and private work – that can be used by every member of the crew – for example a library (Kozicka, 2008, pg. 102). The best architectural strategy to guarantee gradient privacy would be to design with compartmentalization (as shown in analogue Habitats experiments) (Donoghue, 2016).

Personal Space

Personal space regards to the space around us, that we like to be kept “clear”, so we can be comfortable – it's not a fixed distance since it can change due to the person's upbringing, culture, gender or even mood (Donoghue, 2016).

The best strategy for the mission on a Mars Colony would be compartments, a space to many smaller rooms, this way it would have less people in comparison to an open space room with lots of people (Szocik, 2019).

Territoriality

Humans have the need to "mark their territory", it's intersected in our biology, to be able to assert ownership and dominance over an object or area. As such, it is important to prevent interpersonal aggression as the Mars Colony continues to grow. This can be done by clearly demarcated "territories" early on, even on shared personal quarters (who can use that drawer, that table or that closet) (Szocik, 2019).

Brown (cited by Szocik, 2019) also suggests the separation of territories: primary (living quarters that are individual to a person), secondary territories (such as workplaces), and public territories which are completely unrestrained, as a way to decrease interpersonal conflicts in Mars.

Boredom

Imagine being in the same place, with the same people, never changing views doing the same things for two years or more. Repetitive tasks cause boredom, and this boredom can have a result negative affect (Vakoch, 2019).

Humans need stimulants. Good planning can help with it since architecture on Mars Habitat should be able to offer various forms of entertainment. Imagine a room that could transform into being a cinema, into a gaming area or virtual "world". Diversification is key here.

Isolation and Confinement

Any future habitat on Mars will be considered ICE (Isolated and Confined Environment) which causes the feeling of isolation and confinement. This causes severe psychological and social consequences. This is a topic of continuous study in the ISS astronauts, but there will be a deeper infliction of the Mars exploration due to the larger distance.

While on missions to Space and the Moon, the crew have a visual connection with our planet, but on a mission in Mars, there is no blue dot in the sky. It is leaving behind everything and everyone you know. Settlers will have this understanding that there is no escape. No Rescue and Help is quite limited (with 40-min delay). These feelings accumulated can cause neurotic reaction, stress, sleep disorders, anxiety, depression and loneliness (Donoghue, 2016).

Architecture certainly plays a roll to mitigate these issues, for example there are studies that show that those who live and work in isolation require more personal space to be comfortable, as such, the design needs to be a large scale spatial organization of habitat complexes. Taking in attention maximizing the perception of its space. Other positive guidelines would be to minimize negative adjacencies and the sensation of being trapped, and one of the most important: Provide space for social interaction. These become a new center of activity and interaction (Donoghue, 2016).

It would be positive to also create connections to planet Earth, especially in providing ways to communicate frequently with loved one. Another way the author imagines would be to have an integration of a "fake" window in the inhabitant's private spaces, that could "live stream" (even with the delay associated with it), the view from a window of your house back on Earth, or even views of the settler favorite places.

Another problem related to isolation is social isolation. The group of people that will adventure to Mars are an 'artificial micro-society' as Kozicka (2008) puts it. However well they get along, feelings arise, irritably, feeling of antipathy, and as such there is the need to be able to escape, withdrawing yourself since 'lack of relaxation and separation time from the same people is a great physical burden for an individual' (Kozicka, 2008).

Noise

Noise can affect a person physically (even able to cause nausea and headaches) and psychology, causing stress (Szocik, 2019).

It's important to design thinking about how much noise each function makes, associating places that produce high levels of noise with social spaces, and design private space with silent retreats (eg. private quarters).

Odors

Unpleasant smells can increase aggravation and stress (Szocik, 2019), good ventilation is essential, and separate areas that cause most odors eg. Kitchen, lab, Hygiene Unit.

Stress

Being somewhere strange, isolated is stressful, all the factors mentioned above increase stress and deteriorate the crew's health rapidly.

Kozicka affirms that one of the biggest threats to a successful Mars exploration mission would be reasons associated with socio-psychology. For a successful mission architect, must design ways to counter such effects. A good planning of the habitat can successfully mitigate factors mentioned previously.

Sleep & Circadian Rhythms

Sleep will be challenging because of noise and the desynchronized circadian rhythms, which is due to longer days, lower levels of light, and poor lightning on Mars These can have consequence from. Moodiness, depression, and even cognitive dysfunction (Donoghue, 2016). Light studies can subdue this effect, creating cues, of the different times, inside the habitat.

3.4. How to Design for Mars?

A basic tool for architects are site plans, in the case of a Mars a settlement won't, and can't grow organically, so a site plan that addresses dimensions and relationships between spaces is fundamental, since it also will control the settlement maturation. The success of this avoids "inefficiency or unsatisfactory accommodation or haphazard growth that would lead to them" (Sherwood & Howe, 2009, pg.299).

Sherwood in "Out of this World" talks about a 4-step process to design for the Moon, the same applies to Mars.

1) Define the site's "architectural program" (predicted activities, objectives, and aspirations);

2) Define site elements: everything that can give deeper view of the site such as geographical, topographical and geological information of the site, or have a more specific nature – hardware systems, site works, space needed between buildings;

3) Identify connections between elements, constraining how they need to be arranged in the site.

4) Generate diagrams that intent do represent the importance of each element (by sizing) and shows connection/proximity between elements, resulting in a base for a site plan;

3.4.1. Systems of a Space Habitat

Without going into depth on the subject, its important to mention the systems required in a Space Habitat.

These systems are essential and need to be thought in the process of designing a habitat. The systems that support human life have the basis on: Environmental Control & Live Support System (ECLSS), Active Thermal Control, Command and Data Handling, Power System, Communications, habitability systems, (human accommodations), and crew Health Care Systems (CHeCs) (Kennedy, 2002). The habitat also needs to connect with the outside using an airlock (EVA).

On Fig. 63 we are able to visualize the habitat functional relationships, between the different systems.

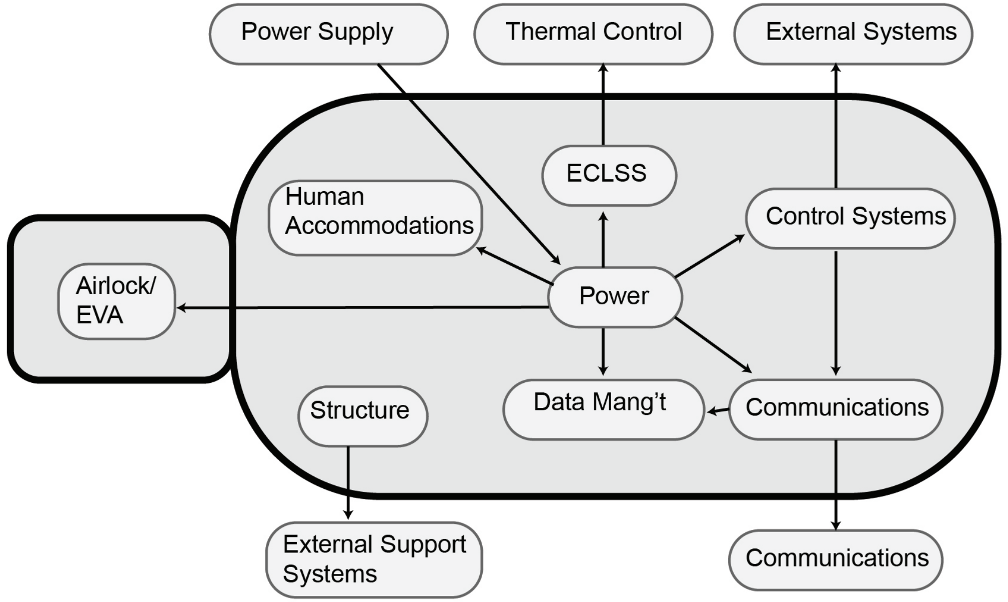


Fig. 63 - Relationship between Systems of a Space Habitat, (Howe and Sherwood, 2009)

3.4.2. Design Guidelines

Form

Due to the difference between the atmosphere of planet Mars and the artificial atmosphere inside the habitat, the gas inside will be pressuring the walls. To avoid wearing off the construction and materials due to uneven pressure points, it is best to choose from a close to spherical form (optimal pressure dispersion), as such sphere, cylinder, torus, domes (Fig. 64) or derivatives of those forms are the ideal (Kozicka, 2008).

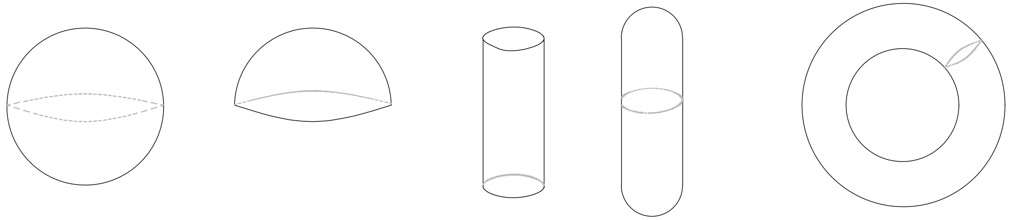


Fig. 64 - Basic shapes: Sphere, Dome, Cylinder, Onlong shape, Torus

Configuration

Configuration is the first stone that sets how people will live, so a careful approach to the different conceptual physical layout of inhabitable modules is necessary.

The ideal configuration is unique to each case, since it's based on objectives, requirements and technology. To be more specific it will depend on mission objective and crew size, the specific site and its conditions, and preparation requirements (excavation/infrastructure). The methods for construction, assembly and material used can also influence (Häuplik-Meusburger & Bannova, 2016, Pg. 223) the final form. The objectives in long term regarding the habitats evolutionary growth also need to be taken into account, since there are configuration options that are more optimal for growth. Donoghue (2016) adds that the configuration should have as a goal to enable physical separation of different uses and embed an overall wayfinding logic.

On the Fig.65 we are presented with a series of possible configurations from a simpler one as a unique unit to more of a complex structure such as a Hybrid Structure. Each type would have different potentials. For example, the Homogeneous, gridded and linear modules have higher potential for a smaller population, since they are efficient, organized and easily reproducible (up to 30 people). Radial, Cluster and Hybrid have more potential for a higher number of population, since it needs more complex network to accommodate the different uses (Donoghue, 2016).

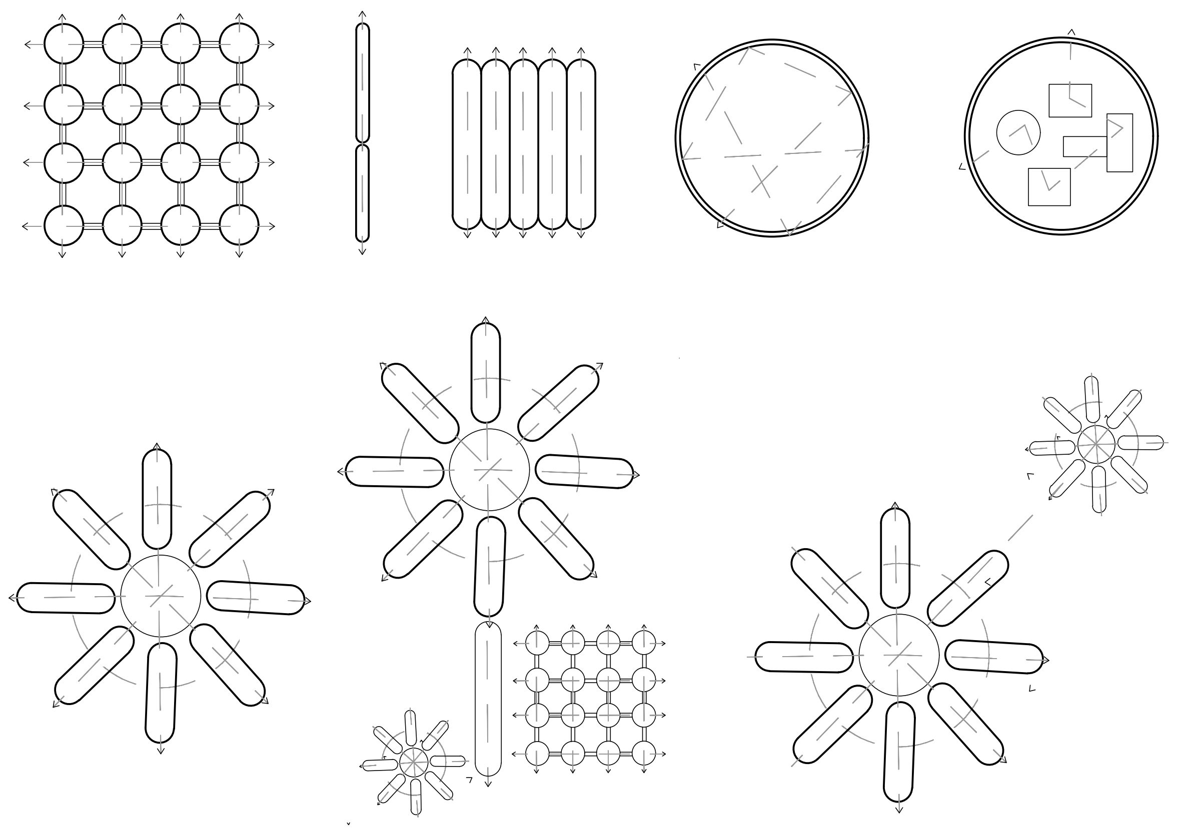


Fig. 65 - Possibility of configurations: (from right to left) gridded, linear, juxtaposed, single unit, multiple units under dome, radial, hybrid, cluster. Based on Donoghue, 2016; Kozicka, 2008

Scale

As previously mentioned, the lower gravity of Mars could potentially allow the construction of much higher buildings than here on Earth, however it is human nature to only trust things that they experience before, this includes factors of scale, distance and even form (Donoghue, 2016). Mars as unfamiliar enough as it is, the habitat is a excellent starting point to build the relationship of the unknown (environment) to what's familiar (habitat).

In terms of scale, Jan Gehl in a City for People (2010) states that building communicates excellently with their surrounding (in this case Mars environment) up to 2 floors, and feasibly from the third, fourth and fifth floor. As such the limit in Mars habitats should be 5 floors above ground.

On Fig.66 we observe three different situations: The first is a high-rise building where lots of space is wasted on vertical communications, the same happens of situation C – since a lot of space is wasted on horizontal communications – corridors. The preferable choice here would be B: with 2 -5 floors, adequate to human scale. It's also favorable to minimize the sprawl without sacrificing the appropriate density for civic life (Donoghue, 2016).

In terms of height, the building should consider the much lower gravity from Mars, and mentioned in the Gravity overview, the habitat need to accommodate a different type of movement that the 0.1g will implicate in the human body. But since there will be no data until we are there, it will be mostly trial and error.

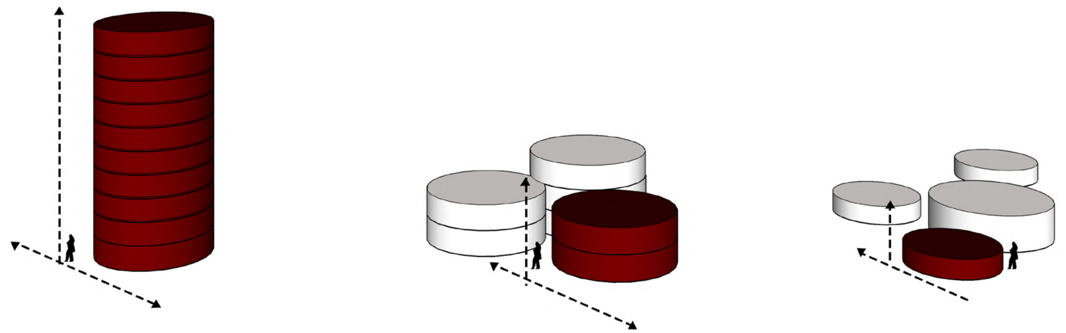


Fig. 66 - Possibility of configurations: (from right to left) gridded, linear, juxtaposed, single unit, multiple units under dome, radial, hybrid, cluster. Based on Donoghue, 2016; Kozicka, 2008

Volume

There still isn't specific information and rules of how much volume should be provided for each crew, but the volume needed is directly influenced by the crew size; mission, functional and operational requirements. (Bannova & Häuplik-Meusburger, 2016).

Food is a bit more of an exact science. For a crew 4 people, to grow all the food needed it will be needed 200 m3 of space (Cohen &, Häuplik-Meusburger, 2015).

Lighting and Illumination

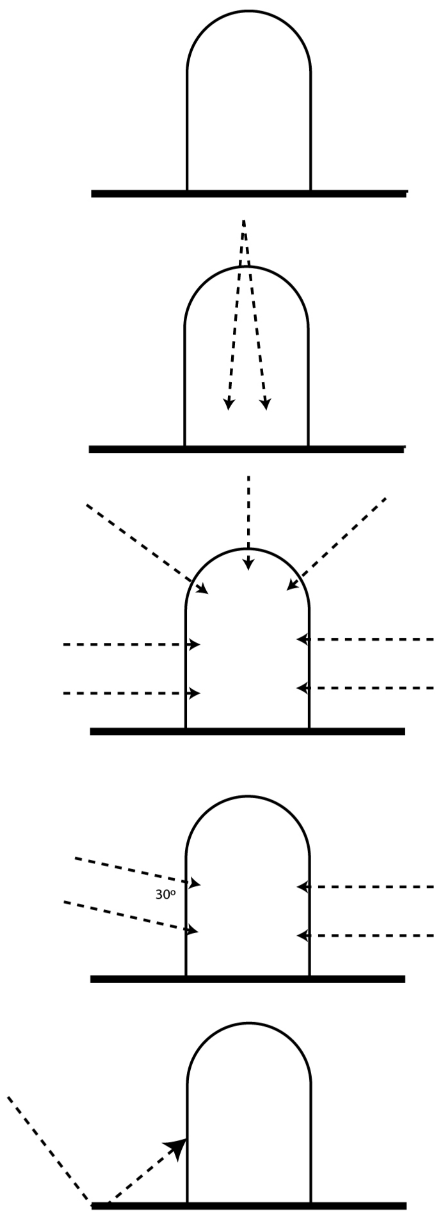
Light can be either natural or artificial. In terms of natural light, it has been mentioned before, that Mars receives a lot less light than Earth, and with dust storms occurring, people can be without natural light for months.

Humans are a species that are very dependent on light since it influences our sleep and Circadian Rhythms. Outside of Earth, natural lightning may not be available sometimes (Moon – 14 days, 14 nights), or not be available in the desired times (Häuplik-Meusburger & Bannova, 2016), having completely different cycles, non-adaptable for human cycles, (ISS orbits around Earth every 90 min).

Windows are a topic that has been in discussion since the beginning of spacecraft design. While everyone agrees that it is a nice thing to have (Attachment A – Q & A Mike Massimino), it is not entirely necessary, and it's a vulnerable spot in the structure. But of course, its use can be very beneficial for the inhabitants since it connects them with their environment.

Multiple windows and transparent walls to illuminate the inside isn't the best solution, since it would leave the habitat without the necessary anti-radiation coating (Kozicka, 2008).

Kozicka also suggests that It would also be possible to increase the intensity of visible radiation with mirrors, or some sort of reflective surface. She suggests the use of it inside of the habitat, but possibly it could be used also outside the habitat to direct light in.



Finally, it would also work as a system to avoid radiation. Regarding artificial lightning (color, intensity) it also needs to be a factor considered in future habitat designs. Different activities require different levels of lighting, and good planning with light is even able to offer comfort to the crew (Häuplik-Meusburger & Bannova, 2016). Some of the 'standard' types of lights can be found in NASA's 'Human Exploration of Mars Design Reference Architecture 5.0' (2009).

Fig. 67 - Types of light entrances, (from author)

Functions

Orbital Habitats have shown the importance of a careful planning regarding spatial relationships in a crammed place. On Mars the same applies, there is will be no escape and limited space, as such not every function will have its own personal space. That decision will be made by analyzing its cost-benefit (Donoghue, 2016).

Each function has their characteristics, they can be more Social, Individual, Noisy or Quiet it's important to understand which category each function falls into and design taking into consideration of joining functions with similar characteristic. On Graph 67 it shows this principle. Functions are also scaled differently depending on the area they need, and it has a major impact on the layout. On Fig. 68 we can observe a reference of a scaled proximity analysis for an interior configuration (Sherwood & Howe, 2009).

Donoghue approaches the subject of zoning proposing three different types of relationships between space: Buffer, Adjacency and overlap, (other authors only mention the concept of adjacency). The analysis of adjacency relations, determines which activities prefer to be next to each other, which should be separated, or that are indifferent (Häuplik-Meusburger & Bannova, 2016). On Fig. 70 shows an adjacency matrix for guidance on the functional proximity.

Analyzing the adjancency graph its possible to come to a conclusion to which functions can overlap, which is when two functions

are beneficial or even neutral to each other. The same space can be used for different types of function, either at the same time, or using it on different times of the day. The use can also depend on the user and necessities at the time, an example of this is the dining and social spaces that can correlate easily. Greenhouse and restorative spaces can also have this symbiotic relationship since humans find green spaces calming. Greenhouse could also be paired with Leisure (Donoghue, 2016).

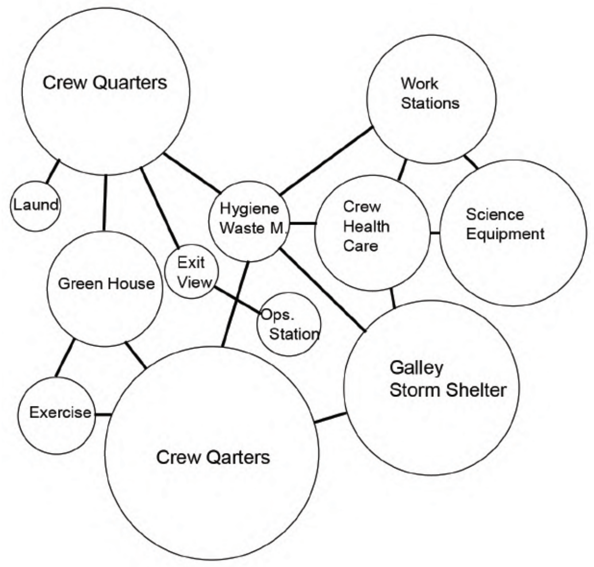


Fig 68 - Scaled proximity analysis is the basis for reference interior configuration. Taken from Sherwood & Howe, 2009, pg. 127

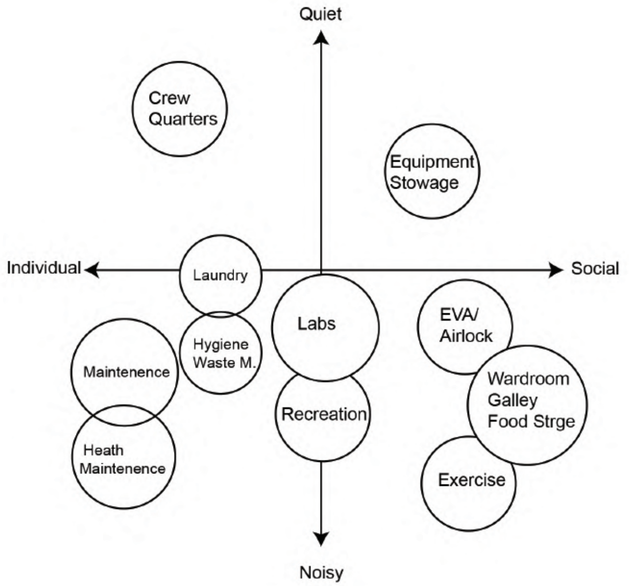


Fig 69 -Diagram used for the principle zoning of areas (Häuplik-Meusburger & Bannova, 2016), There also should be areas dedicated to be buffers between functions 'when one function is inherently detrimental to the vitality of the other (Donoghue, 2016). Donoghue refers that this detrimental can take form as invasion, intrusion, or even contamination (such as vibrations, or noises). Buffers can be considered as physical, psychological, sensory barriers, or simply as a complete separation/ isolation of the space (eg. Work and escape, exercise and dining).

In 'Architecture for Astronauts' (2011), Sandra Häuplik-Meusburger develops a method to analyze the relationship between function in orbital habitats, it can also be applied to projects or even analogues to understand functions relationships between spaces (Fig. 71).

As a last note on the subject, the final layout is a juggling process that also takes to account other factors: volume, mass, cost, technology all are taken into consideration (Häuplik-Meusburger & Bannova, 2016), as such some sacrifices need to be made in consideration of other factors.

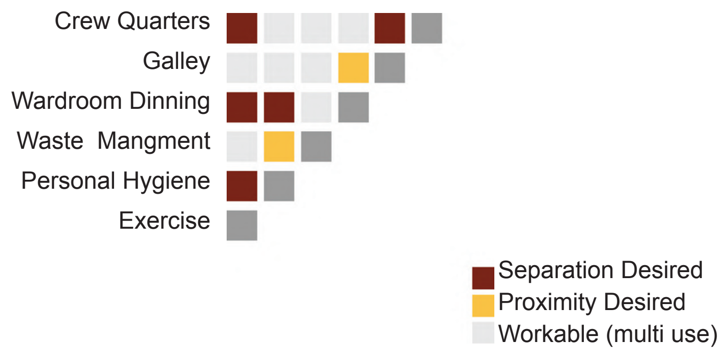


Fig. 70 - A functional adjacency matrix. (Häuplik-Meusburger & Bannova, 2016),

Spatial Allocation of functions

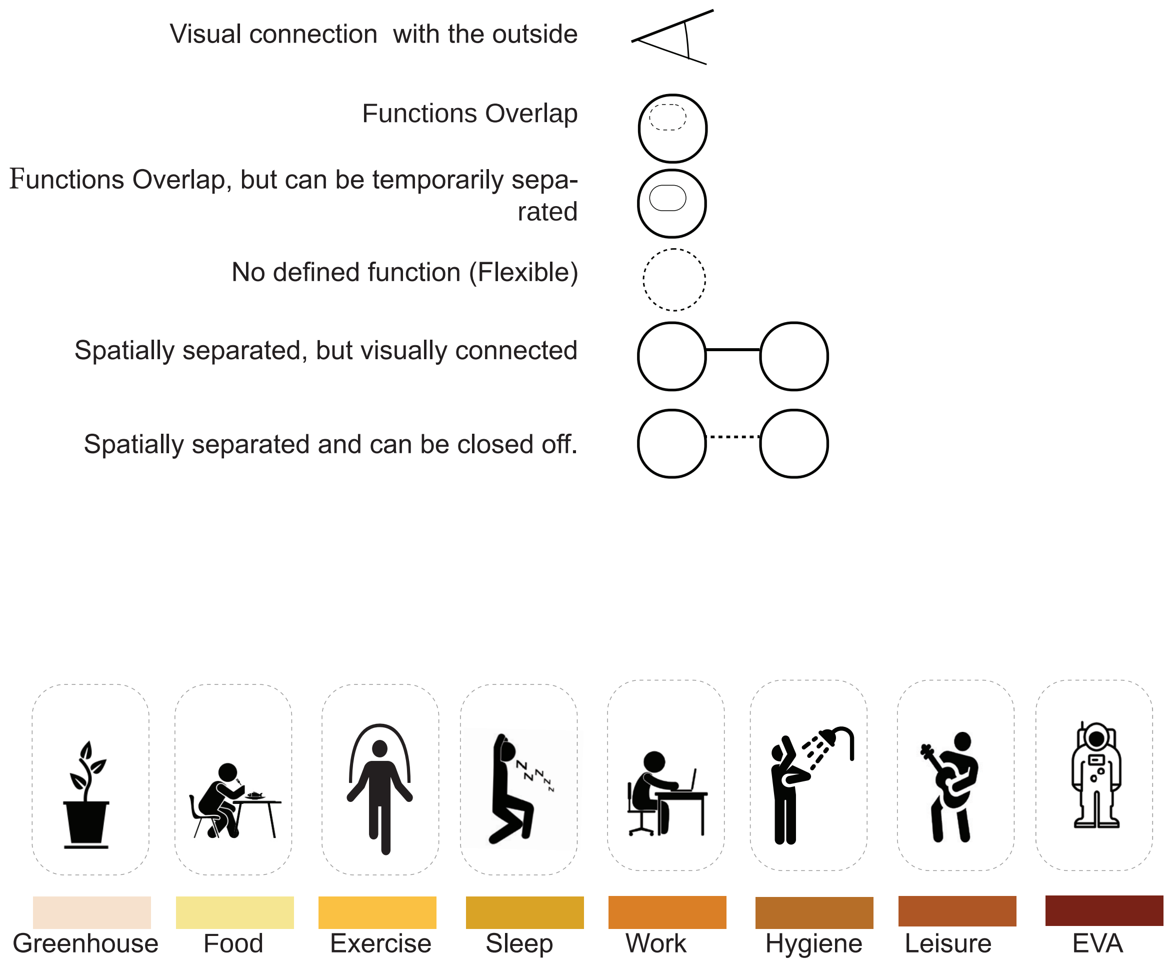


Fig. 71 - Spatial Allocation on human activities analysis, developed by Sandra Häuplik-Meusburger, 2011

Privacy Gradient

The best way to maintain a healthy psychological atmosphere is to design with conscience, providing spaces with different levels of privacy that can be adjusted (Häuplik-Meusburger & Bannova, 2016).

This gradient would start with Public, the spaces of communal occupation, fading to semi-public, this spaces to semi-private which are shared space that belong to an implied sub-group, and finally Private space that are space used exclusive to the user/owner (Donahue, 2016).

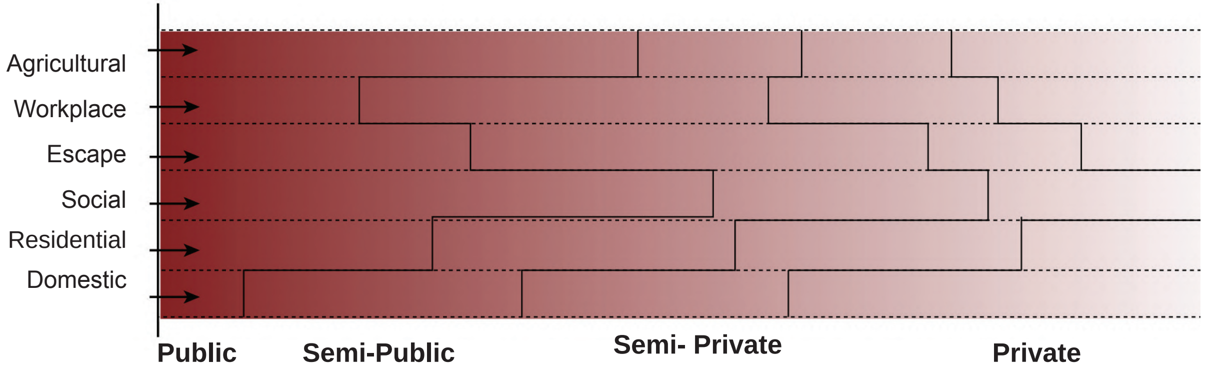


Fig. 72 - Gradient from private to public in relation to functions; (from Donghue, 2016)

Flexibility

Flexibility is important to take into consideration since it can save space, and resources. Per Sherwood & Howe (2008) flexibility has three components: adaptability, the power to accommodate off nominal conditions; resilience, the ability to adjust to failure; evolution and the power to adapt overtime to different requirements. Spaces need to adapt and change when needed. Fig 73 presents a scheme of how flexibility can be applied to space, how functions change over time. Also, being flexible means it can adapt to future expansions, as Kozicka (2009) states: "The habitat must be planned as a flexible space. Then, and only then, it may survive the trial of time.

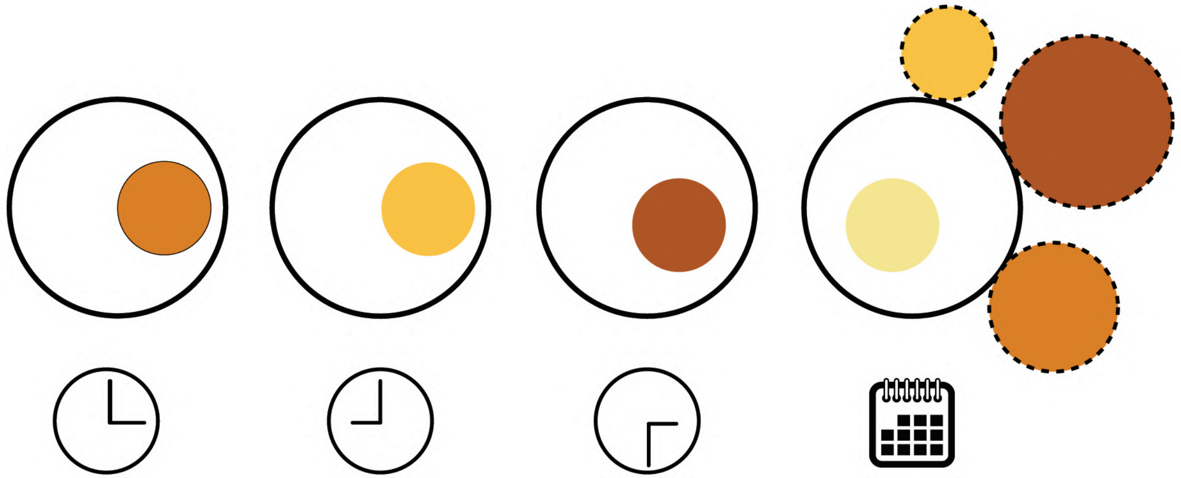


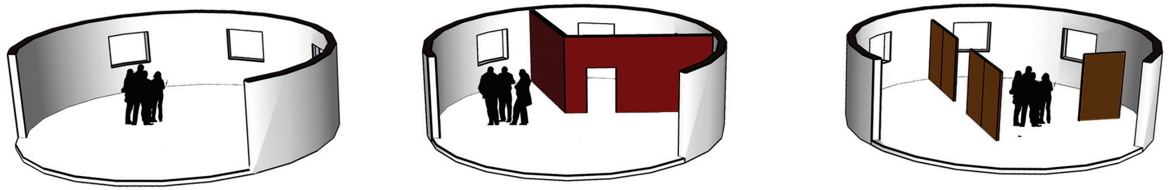
Fig. 73 - Flexibility on different times of day, and in an evolutionary sense.

Divisions

A common way to divide spaces here on Earth is by using walls. These can be fixed walls, which are permanent; or partitions which are movable and flexible structures.

In terms of how to divide space in Mars, fixed wall should only be used on permanent spaces, such as bedrooms and bathrooms (Donoghue, 2016). Partitions can be used upon need, create sub-rooms to offer temporarily privacy, a more flexible choice. It has a disadvantage of not providing the same level of privacy, and as acoustics barrier.

The choice between theses two systems of divisions, influences the flexibility of the habitat.



Open **Fixed Walls** **Partitions**

Fig. 74 - Different types of division of space - Open, Fixed Walls and Partitions (based on Donghue, 2016)

Color

Both light and color are extremely important when designing a Space Habitat since studies show that they affect body functions

and provoke emotions (Durão, 2002), following this thought manipulating color and light efficiently would lessen burdens on future crews.

A pioneer on this subject was, as mentioned before, Galina Balashova, architect behind most of the color related advancements in space architecture in the design of the Soyuz habitation module she states that: "Initially I assumed that – in light of 'weightleness' – defining the ceiling and floor of the room was irrelevant. But then it became clear that cosmonauts could be better oriented if they had a notion of above and below, even in Space." (Meuser, 2015)

She ended up using colors to differentiate the floor from the ceiling. Floors – browns, walls – beige and the ceiling in the light blue. On Mars color, wouldn't be used with the focus on solving the issues of spatial orientation but rather of psychology based issues.

> *"The isolation and confinement of space environments, where life and work may be carried out for extended periods of time, require the design planning to be sensitive to the effect that it has on the emotions as a result of the monotony of enclosure and prolonged confinement." (Durão, 2002).*

Fig. 75 - Galina Balashova explorations of color.

NASA has already defined colors (on Space) with MSIS (Man-Systems Integration Standard) document, selecting neutral and lusterless colors for workstations; black or grey for controls and its vehement of constituency (Häuplik-Meusburger & Bannova, 2016).

Construction

Pre-fabricated

Almost everything in space has pre-fabrication as its nature (Skylab, Mir, ISS modules), since it's a standard and simpler way to design and ensemble. It's a reliable method. Although as a constraint, the volume and scale is limited, to increase volume it will needed to add new units (Häuplik-Meusburger & Bannova, 2016), which need to be done on Earth and transported to the intended place. This method on Mars is not reliable in the long run, since it can't be dependent on Earth.

Inflatable

This type of method has a big advantage comparing to others, since its compactly packaged on the launch, being able to offer extra volume after deployment, which greatly exceeds a pre-fabricated module, (Häuplik-Meusburger & Bannova, 2016) making it a cheaper solution since the payload is just a fraction of more standard solutions. A great example was TransHAB, which will be studied in the next chapter.

Hybrid

Hybrid systems are a way to achieve large habitat volume, it can combine the traditional pre-fabricated with systems using textiles or even in-situ materials (Häuplik-Meusburger & Bannova, 2016).

3D –Printing

3D-Printing is the method that shows the most potential due to its flexibility. Being able to construct using in-situ resources avoiding the need to bring them from Earth is a huge advantage. Regarding the material, construction and ensemble method, the habitat can be divided in three classes (Sherwood & Howe 2009):

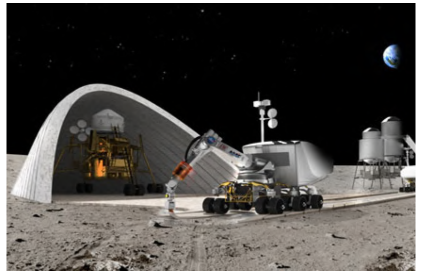


Fig. 76 - A Contour Crafting robot is shown here printing a road in front of a parabolic hangar structure housing a lunar lander. In the background, can be seen a plant intended for processing regolith that will be used in the construction process. Taken from nanowerk.com.

Class I: Pre-Integrated: Habitat is completely assembled, integrated, verified, and fully functional when delivered. Since everything is Earth bound it has constrains on volume and mass since it needs to be launched to Space.

Class II: Pre-fabricated – Space/Surface Assemble: Although it's also manufactured on Earth, the habitat needs to be assembled when deployed in space/planet surface. This has the advantage of being less restricted on launch-vehicle capability of maximum size and mass that can transport, allowing bigger volumes. The disadvantage is that it still need to be assembled.

Class III: In situ derived and Constructed: Habitat would be produced in situ using in situ materials (ISRU), allowing the largest volumes since it's not restricted to launch-vehicle.

We are currently mostly on Class I, Transhab is an example of Class II, but for Mars (And Moon) the objective is to achieve Class III in the habitat on Mars, a self-sustainable settlement, as can be observed on Fig.78 for that to happen it takes time and advancement of technology.

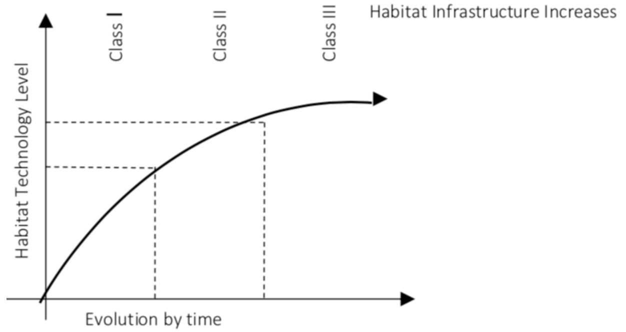


Fig. 78- Evolution of space habitat technology based on Sherwood & Howe, 2009

3.5. Case Studies

The case studies of projects envisioning to live on Mars where selected from the winners of NASA Continental 3D Printing NASA challenge, one for each phase.: Phase 1: Ice Mars House (and subsequent rework with NASA collaboration – Ice Mars Home), Phase 2: MARSHA, and phase 3. Important notice is that these projects followed the guidelines given by NASA for the contest, that came from the NASA Space Flight Human-System Standard (NASA-STD-3001, Volume 2):

> The habitat shall provide a pressure-retaining living space of at least 93 m2 with a minimum ceiling height of 2.25 m.
>
> The habitat should be designed with the intent of supporting four astronauts for one year. The interior space shall include sleeping, eating/meal preparation, sanitation, recreation, laboratory/work area, communication, as well as mechanical, electrical, plumbing (MEP) and environmental control and life support system (ECLSS) equipment.
>
> MEP and ECLSS design shall be at the "schematic design" level of development. That is, an initial design scheme that defines the general scope and conceptual design of systems including scale and relationships between components. The minimum volume required for ECLSS equipment is 1.3 m3 for each of the three ECLSS volumes.
>
> All structural component (foundation, exterior surface, load bearing/pressure retaining walls, etc.) design shall be fully developed and ready for construction.

> The exterior surface of the habitat shall, as a minimum, include the following penetrations:
>
> > One suit hatch 85 cm by 60 cm
> >
> > One view port (located close to the suit hatch) 50 cm in diameter (minimum)
> >
> > One equipment/rover hatch 1 m wide by 1.5 m tall. This hatch could also serve as a connector to a future additional habitat and should have the bottom edge located 0.5 m above the top of the foundation slab.
> >
> > Two combined communications-power-instrumentation penetrations, 75 mm diameter (minimum) located at least 1 m apart from each other. (NASA, 2018)

The analysis of this study cases, will start with a explanation of each project, acknowledging which type of habitat it can be categorized, using the previous studied guidelines, and also to apply the diagram 'Spatial allocation of human activities'.developed by Sandra Häuplik-Meusburger (in Architects for astronauts, 2011) Furthermore, for a more complete view on works done recently visioning a Mars habitat/Colony there will be some mentions of projects: Mars Science City by BIG, Space X design of Mars Colony, and the project done by Gamma from Foster + Partners. On these, the analysis will be only basic information: a brief description of project, duration of the envision mission, number of crew participants designed for, and functions found in the habitat.

3.5.1. NASA's 3D-Printed Habitat Challenge

The 3D-Printed Habitat Challenge was divided in 3 phases: In 2015 occurred phase, which the objective was for the participants to develop state-of-the-art architectural concepts. In 2017 occurred phase 2 which focused on manufacturing structural components. The third phase challenged the participants to fabricate sub-scale habitats using indigenous materials with or without mission-generated recyclables, (NASA, 2017) completed in 2019. On diagram 4 you can visualize the winners of each phase. On phase 1 there was the particularity of the contestant's winners with Ice Mars House, to do a collaboration with NASA Langley resulting in Mars Ice Home (Fig. 79).

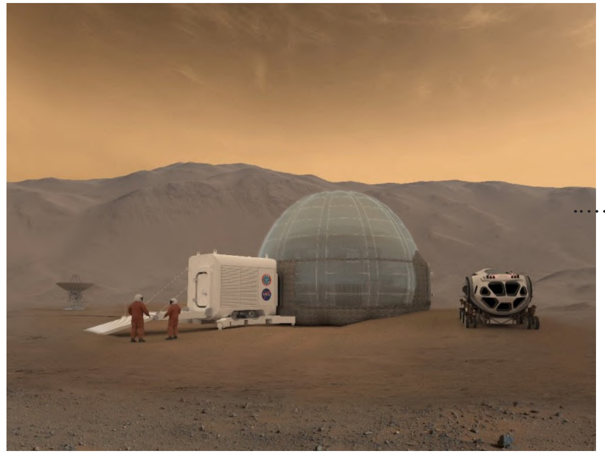


Fig. 79 - Mars Ice Home: SEArch+/Clouds AO/ NASA

2015 - Phase 1

1st

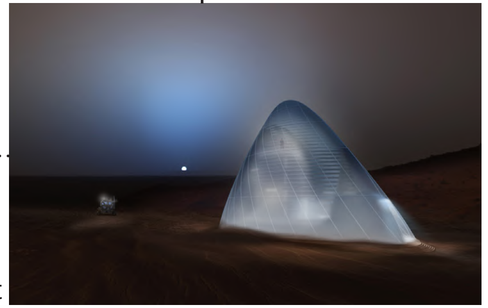


Fig. 80 - Mars Ice House: SEArch+/Clouds AO

2nd

Fig. 81 - Team GAMMA, Foster + Partners, 2015.

3rd

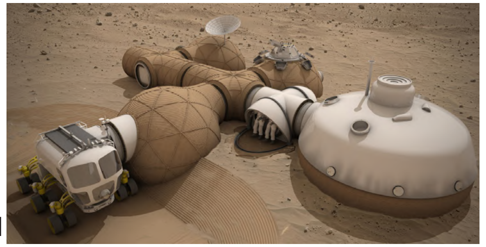


Fig. 82 - Team LavaHive was awarded third place honors for their Mars habitat design.

2017 - Phase 2

1st

Fig. 82 - MARSHA, AI SpaceFactory. habitat boasts an egg-shaped design to deal with atmospheric pressure.

2nd

Fig. 83- - MARSHA, AI SpaceFactory. habitat boasts an egg-shaped design to deal with atmospheric pressure.

3rd

Fig. 84 - MARS X HOUSE V1

2019 - Phase 3

1st

Fig. 85 - MARS X V2 HOUSE Credits: Team SEArch+/Apis Cor

2nd

Fig. 86 - Team Zopherus

3rd

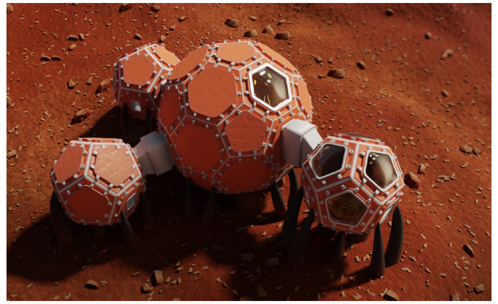


Fig. 87 - Project of Team Mars Incubator

3.5.1.1. Mars Ice House
SEArch+, Cloud
2015

Mars Ice House was one of the proposals, designed with the partnership of Clouds Architecture Office and Space Exploration Architecture (SEArch+) in 2015. They developed a clever solution with the use of in-situ material that was confirmed to exist in abundance in Mars – water. "The architecture of Ice Mars House celebrates the presence of a human habitat as a beacon of light on the Martian surface" (Rosenfield, 2019).

This appeared with the need to protect people from radiation, but contrary to other projects that tend to show buried proposal for radiation protection, it uses a 3D printed ice membrane of 5 cm that serves as protection. Ice also allows for natural light to penetrate the interior and to create visual connections with the Martian landscape. It envisions life in a single unit, that can be multiplied. A habitat classified Class III since it's assembled on site and uses in-situ material (Fig.92).

On the first level it is located the Airlock Vestibule, entry level rover connection, and the intermediate containment one. (with goes up to level 4). The functions on level two are dedicated to exercise and Medical Support, Lab, Library, Hygiene area 1, and the Greenhouse (which goes up to level 4). Level 3 is dedicated to crew, hygiene area 2; Level 4 Wardroom/Gallery and food preparation. This habitat was designed for a crew of 4.

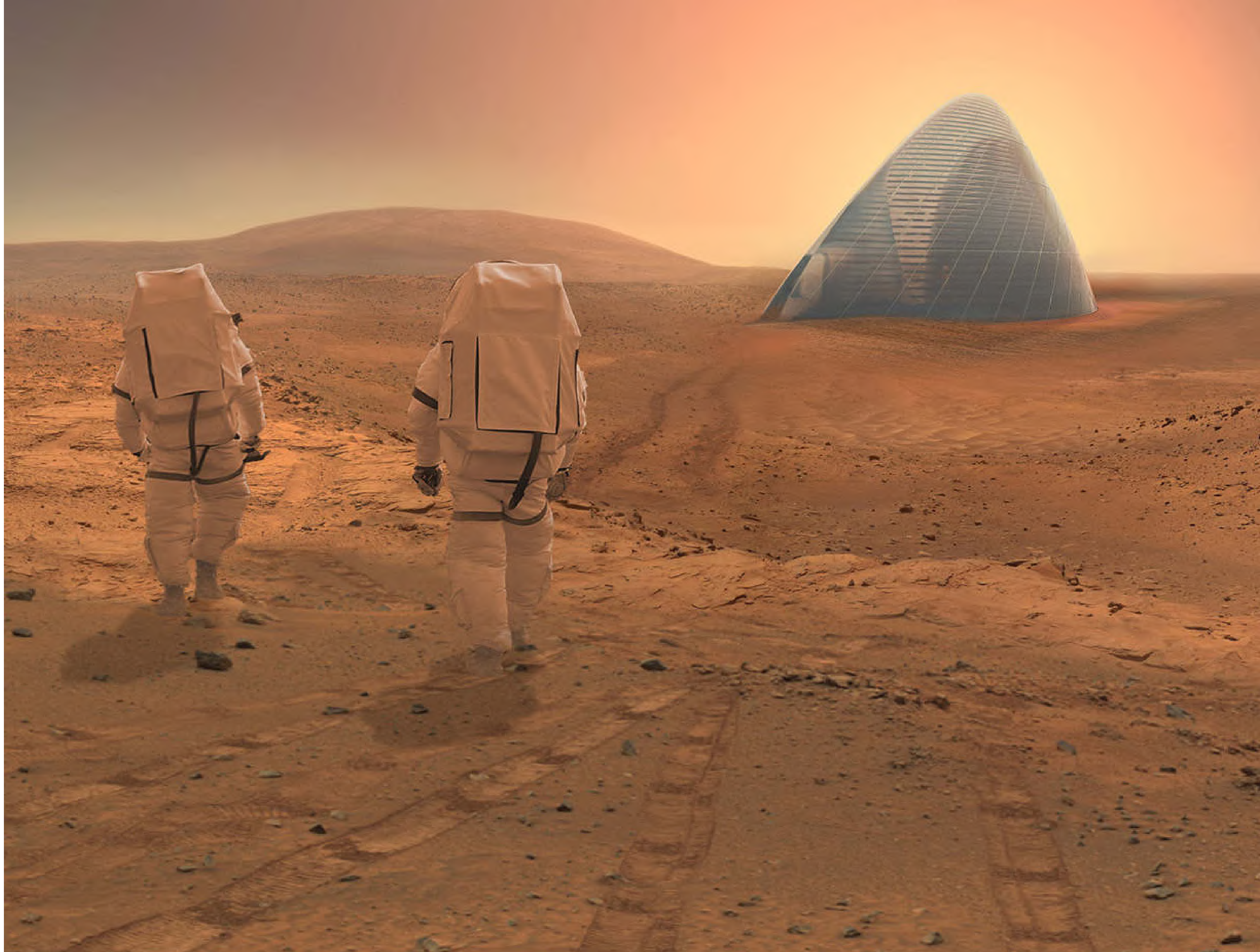
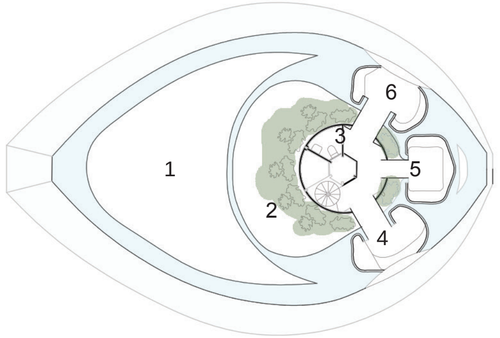
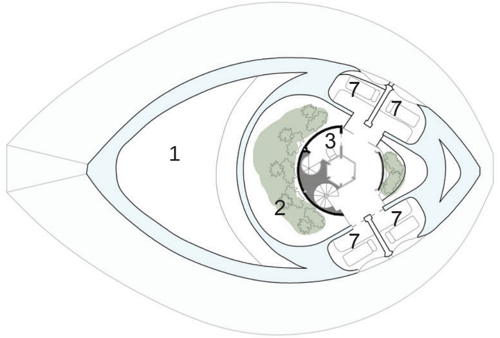


Fig. 88 - Ice Mars House, SEARch+, Clouds AO, 2015

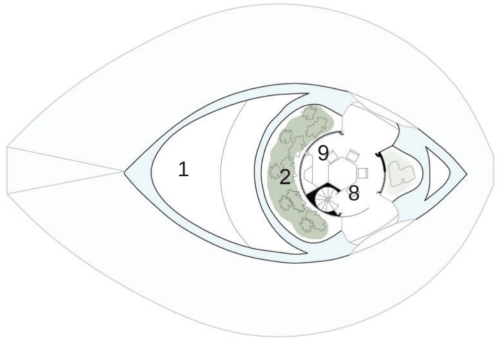
Plans and Section



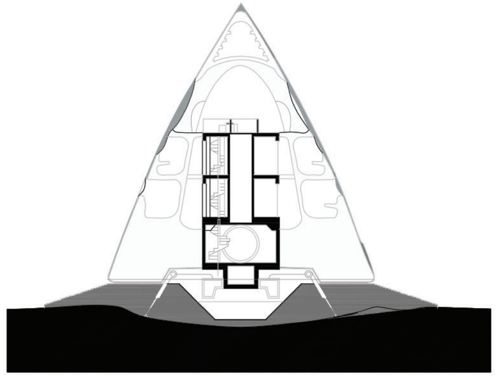
Level 2



Level 3



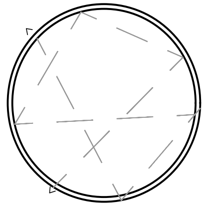
Level 4



Section

Fig. 89 - Plans of Mars Ice House. Redrawn by author some minor differences may be found. Not scaled since no known measurement

Configuration:



Type: Class III

1-Yard (Intermediate Containment Zone
2-Vertical Greenhouse
3-Hygiene Area
4-Exercise /Medical Support
5-Laboratory
6-Library / Small room
7-Crew Quarters
8-Wardroom/Gallery
9-Food Prep

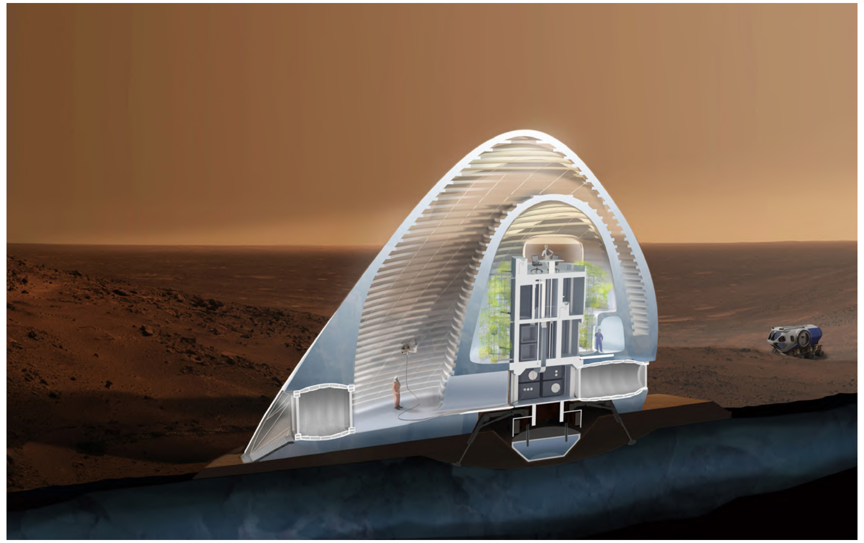


Fig. 90 - Section Ice Mars House. SEArch+, Clouds AO.

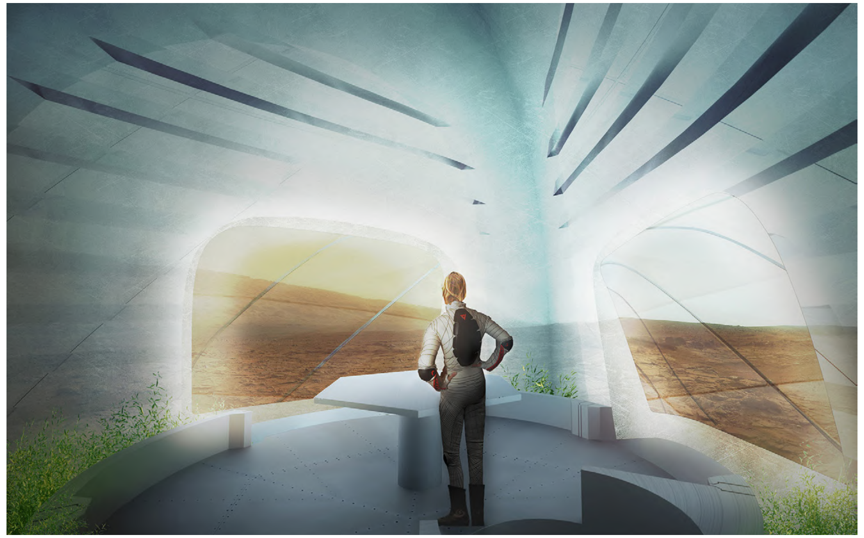
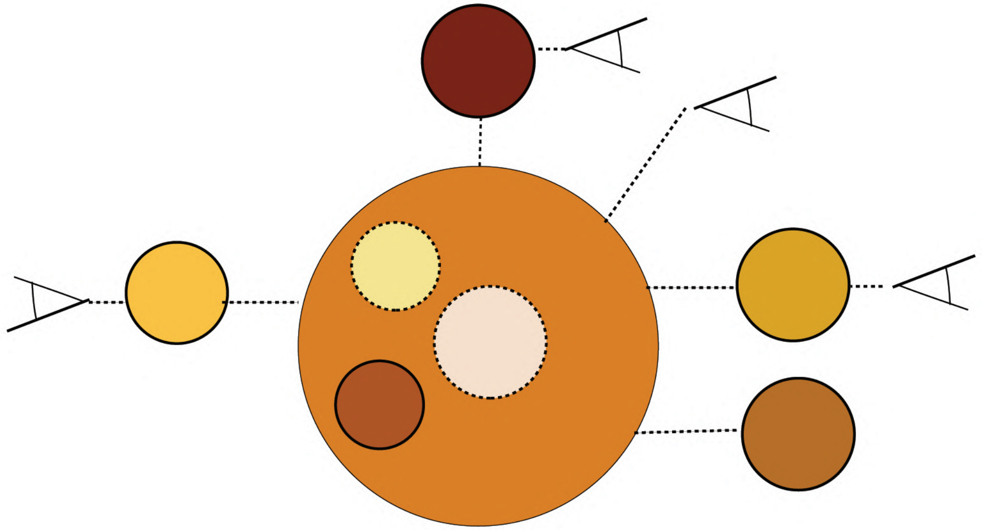


Fig. 91 - Interior of Ice Mars House - spaces ‘Hallowed-out’ of ice. SEArch+, Clouds AO.

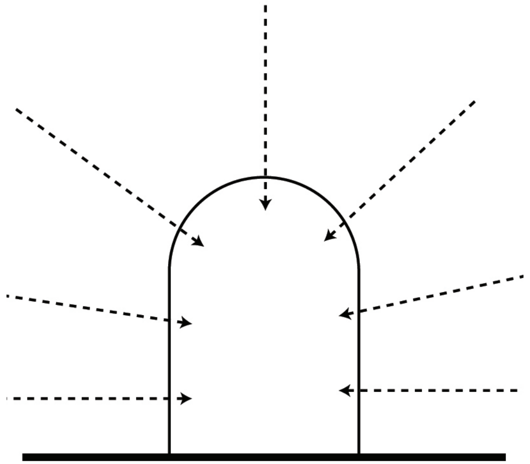
Spatial Allocation on human activities



Caption

EVA	Visual connection with the outside
Leisure	Functions Overlap
Hygiene	Functions Overlap, but can be temporarily separated
Work	No defined function (Flexible)
Sleep	Spatially separated, but visually connected
Exercise	Spatially separated and can be closed off.
Food	
GrenHouse	

Natural Light entrances:



Phases of Assemble

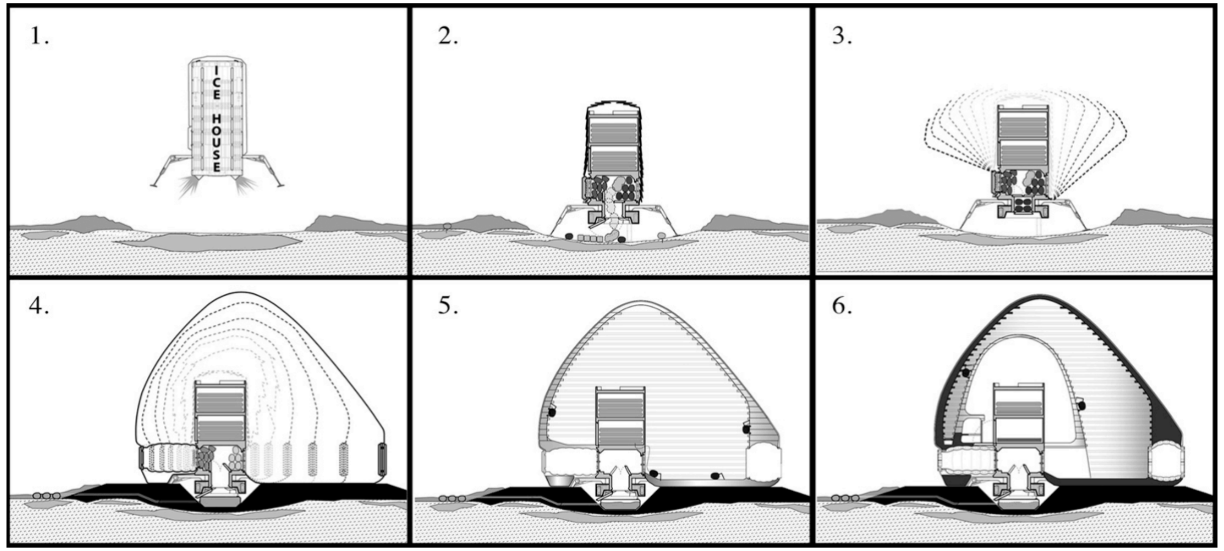


Fig. 92 - Concept of Operations and Deployment (1) Vertical Landing (2) Release of robotic water extraction (3-4) Deployment of Pressure Membrane (5-6) Interior Printing with climbing robotics. (Morris et al., 2016)

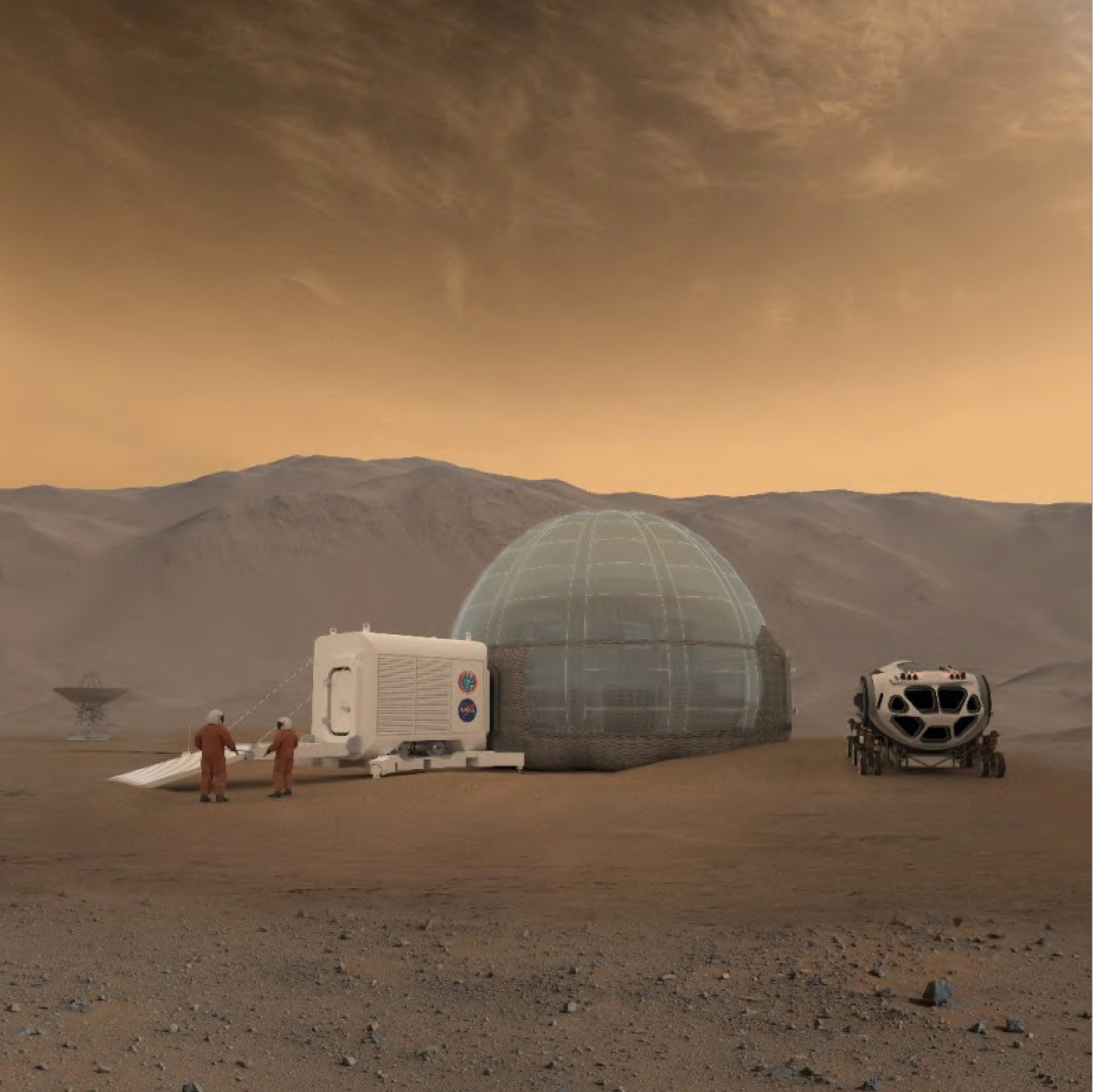


Fig. 93 - The Mars Ice Home, NASA Langley/ Clouds AO/ SEArch+

3.5.1.2. Mars Ice Home
NASA/ SEArch+/CloudsAO
2016

Mars Ice House is a collaboration between NASA Langley Research Center, SEArch+ and CloudAO in 2016, to further explore the concepts presented in the contest 3D-Printed Habitat Challenge with the previous project of Ice Mars House.

As a starter, the team points to the GCR as the biggest issue for human health in space traveling, and with this, the need to find a solution increases, in order to have a successful Mars mission. They suggest the use of ice for radiation shielding and as a structural component, since its a material that can be harvested in-situ. The ice can also, being translucent, help in making natural light penetrate the habitat, making it more enjoyable, and successfully keeping occupants connected to diurnal cycles, and ensuring the inhabitants well-being.

In terms of structure it has an inflatable structure element, which water-ice would fill it and freeze within cellular pockets of the membrane.

The domed structure in terms of architecture the habitat is divided in two levels. The first floor has a library, Wardroom, food preparation area, hygiene unit, exercise and medical area, mechanical room, labs, and the hatches.

In the second floor, it concentrates on the crew quarter, the private quarters, greenhouse, storage, hygiene unit and a study. It also features various windows, around the habitat (Gohd, 2019).

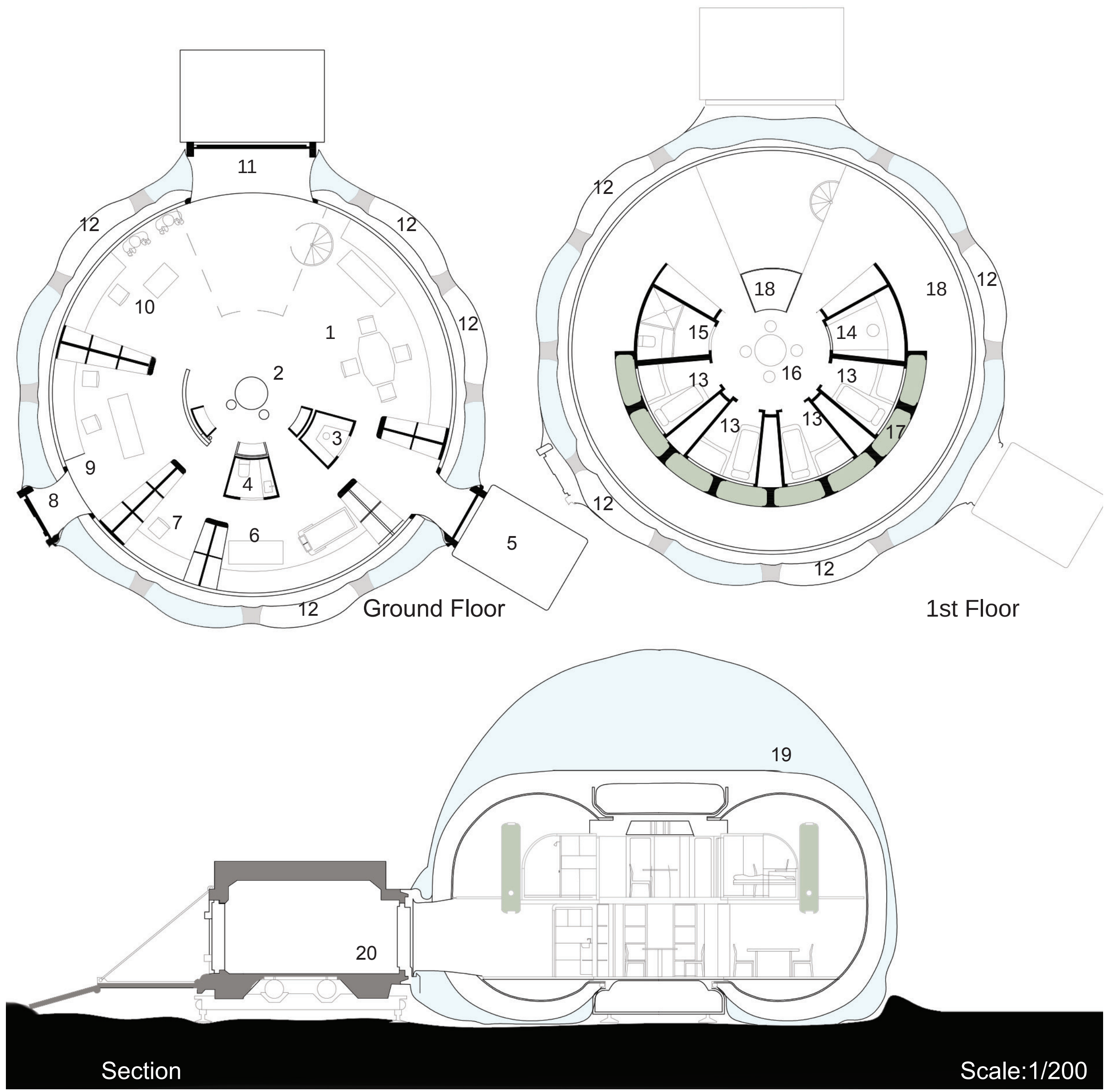
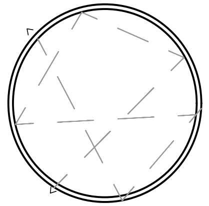


Fig. 94 - Plans and Section of Mars Ice Home. Redrawn by author some minor differences may be found. Scale: 1/200

Configuration:



Type: Class III

Ground Flor

1-Wardroom
2-Library
3-Food Prep
4-Hygiene Unit
5-Hatch 1
6-Exercise and Medical
7-Mechanical Room
8-Hatch 2 (Egress)
9-Science Lab
10-Maintennance and Repair
11-Hatch 3
12-Windows

1st Floor

13-Crew Quarters
14-Study
15-Hygiene Unit
16-Crew Unit
17-Greenhouse
18-Storage

Section

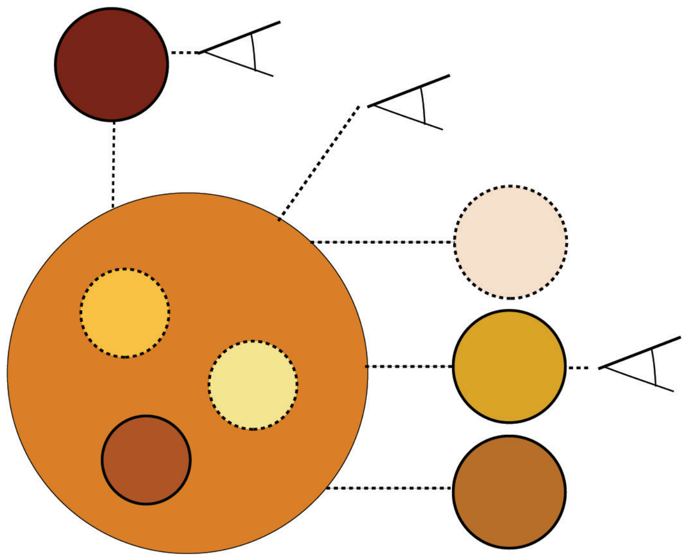
19- Ice Chambers
20-Airlock

The habitat is designed for a crew of 4 and in terms of measurements, the habitat has 10.9m of height and 13.5m. The habitat can be classified in habitat Class III since it uses local material and needs to be assembled.

Comparing to the previous project of Mars Ice House, where the walls were only has 5 cm of ice, new information became available stating that for ice to be able to protect the inhabitants from radiation it would need a minimum of 3 m (Appendix A – Interview with Michael Morris), so in this new Ice Mars Home the habitat has on top 3.5 m of ice.

Fig. 95 - Interior of Mars Ice Home. SEArch+, Clouds AO. Langley NASA.
From the rooms you have a direct view tothe vertical garden. (NASA)

Spatial Allocation on human activities

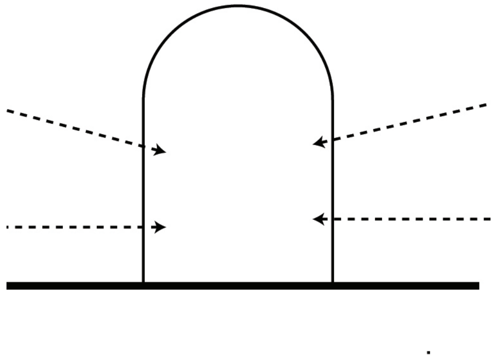


Caption

EVA
Leisure
Hygiene
Work
Sleep
Exercise
Food
GrenHouse

Visual connection with the outside
Functions Overlap
Functions Overlap, but can be temporarily separated
No defined function (Flexible)
Spatially separated, but visually connected
Spatially separated and can be closed off.

Natural Light entrances:



3.5.1.3. MARSHA
AI SpaceFactory
2017

MARSHA, stands for MARS HAbitat, developed by AI Space Factory, is an egg-shaped habitat vertically oriented with a total of four floors. Its construction would be autonomous, using 3d printing technologies and pre-assembled parts.

It is a different approach than the typified low-lying domes, or buried structures. Unlike those, this shape has the advantage of not producing unused overhead space or unusable floor area.

Regarding radiation and Mars environment protection, MARSHA, proposes a construction of a dual-shell to protect the habitat, built by in-situ materials. These two shells would be completely separated (pressure vessel –habitable space), and the space between the shells would be used to diffuse natural lighting coming from the water filled skylight.

In terms of light it has a window for each floor, being the 4 floor is by the skylight.

The shape is also efficient on separating different functions on different levels. On the ground floor it relates to exploratory activities, a supporting wet lab and a mechanical area. The 1st floor has 24 m2, and it constitutes the kitchen and dry lab, and acts as the main social hub. The 3rd floor has the most private zones such as the sleeping quarters and bathroom facilities. It also has the hydroponic garden. Lastly, the top level is used for informal recreation uses, and overlaps with exercise (AI SpaceFactory, 2019).

Fig. 96- MARSHA, AI Space Factory, 2018

Plans and Section

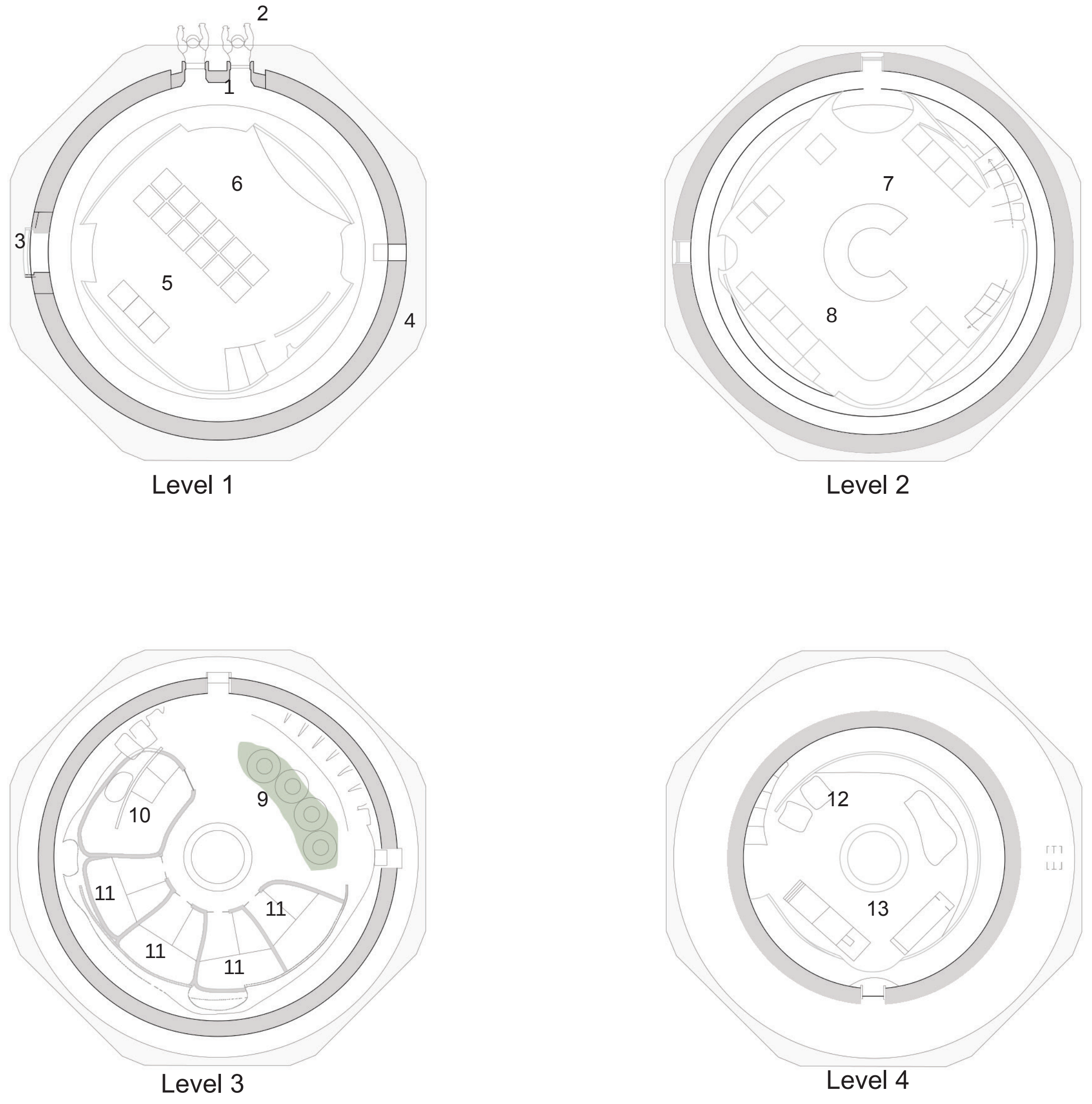
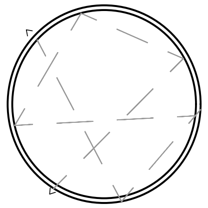


Fig. 97 - Plans of MARSHA. AI Space Factory, 2017. Redrawn by author. Not scaled since no known measurement.

Configuration:



Type: Class III

<u>Level 1</u>
1- Space Hatches
2-Space Suits
3-Rover Docking Port
4-Base Flange
5-EVA Prep
6-Wet Lab

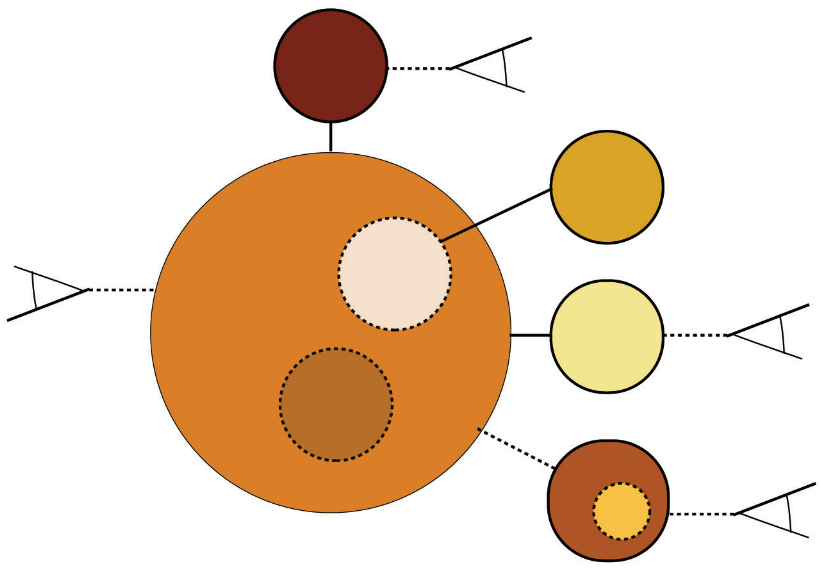
<u>Level 2</u>
7 -Kitcheen
8-Dry Lab

Level 3
9-Garden
10-Sanitation Pod
11- Sleepy Pods:
Enclosure
Work Desk
Bed

<u>Level 4</u>
12-Recreation
13-Exercize

Fig. 98 - MARSHA, interiors by AI SpaceFactory, 2017.

Spatial Allocation on human activities

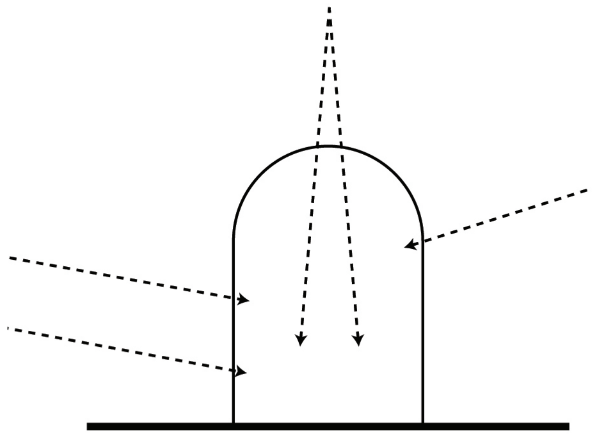


Caption

EVA
Leisure
Hygiene
Work
Sleep
Exercise
Food
GrenHouse

Visual connection with the outside
Functions Overlap
Functions Overlap, but can be temporarily separated
No defined function (Flexible)
Spatially separated, but visually connected
Spatially separated and can be closed off.

Natural Light entrances:



3.5.1.4. Mars X-House V2
SEArch+ /Apis Cor
2019

This concept was of a vertical structure with a spiral staircase on the outside around the habitat. Its construction is completely automatous, and it was inspired by a water tank. Its form is very singular, while the norm tends to go to spherical, or oblong shapes. Its hyperboloid shape is a more efficient compression structure, since it would work similar to a dam holding water.

Same as previous works from SEArch+, light continues to be crucial to maintain the inhabitants connected with their environment, and keep their circadian rhythms adjusted, but instead of ice, this project uses pre-fabricated windows all over the habitat, bringing natural light to the habitat. Windows are a weak spot against radiation, so the light can only enter by 30º from the horizon for safety. (SEArch+, 2019).

Another detail, which was also seen in Ice Mars House, is the incorporation of greenery, where a vertical hydroponic garden runs up the center of the living space. There is a visual relationship between this vertical garden and each private room, which is important since there are studies that prove benefits of being close to plants, especially in an extraterrestrial environment (Scwab, 2019).

It tries to simulate the quality of life on Earth, without sacrificing safety. In terms of radiation protection, for example, it has a multilayer exterior shell which would be 3D Printed using in-situ

Fig. 99- Render of Mars X-House V2, SEArch+ /Apis Cor, 2019.

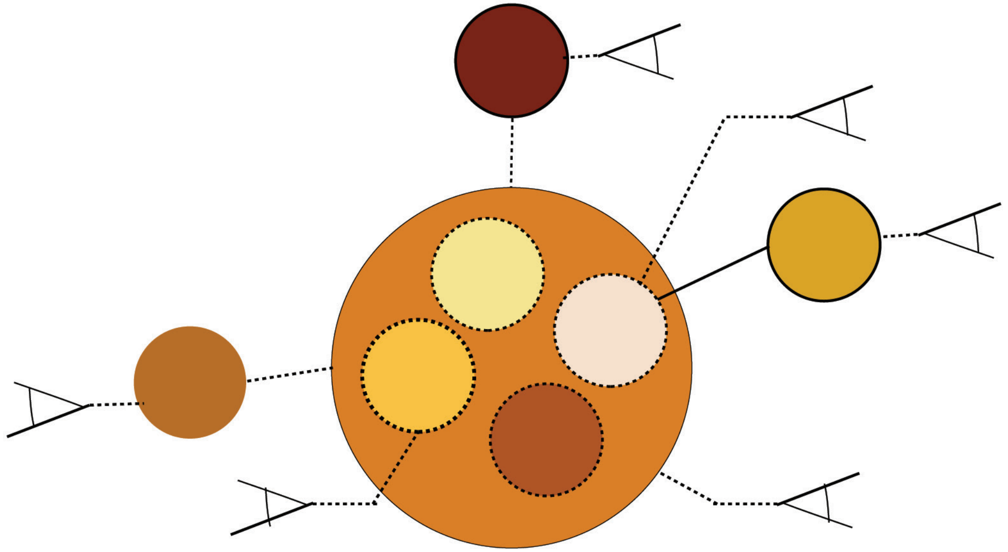
material-regolith, and a high-density polyethylene. Another precaution taken was to move the places that will be used most – labs and sleeping quarters – to the core of the habitat, meaning they are less exposed to radiation (Scwab, 2019).

The project also thinks about possible contaminants and accidents, so there are sections of the house that can be completely quarantined, and there is also an emergency staircase tunnel that goes around the habitat - an extraterrestrial fire escape. Every floor has connection to the emergency tunnel (SEArch+, 2019).

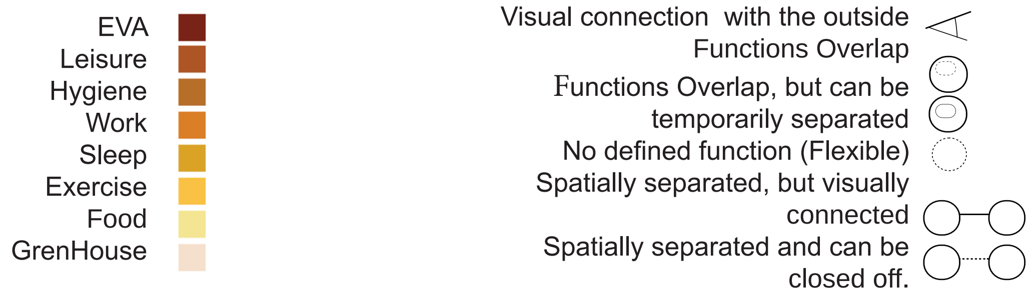
In terms of functions, on ground floor we can find an Airlock, 2 laboratories and storage. On the first floor, where the mechanical systems are located, it is dedicated to the shower and toilet. On the third floor there are two rooms, and the greenhouse. Following to the 4 floor where there are two more bedrooms, a space for relaxation and the continuation of the greenhouse. Lastly, on the fifth floor is where the kitchen, and living area are. It is also the area destined for exercise. On the top of habitat is also located a water tank.

Fig. 100 - MARS -X HABITAT V2 interiors - Private Quarters, Laboratory, social area.

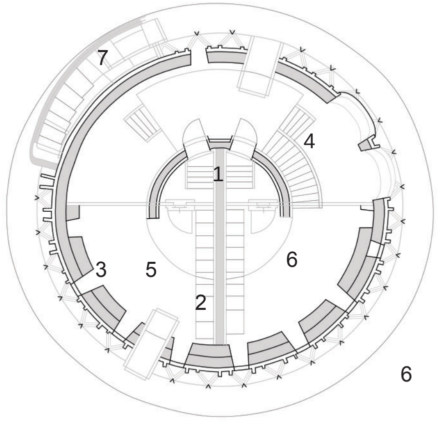
Spatial Allocation on human activities



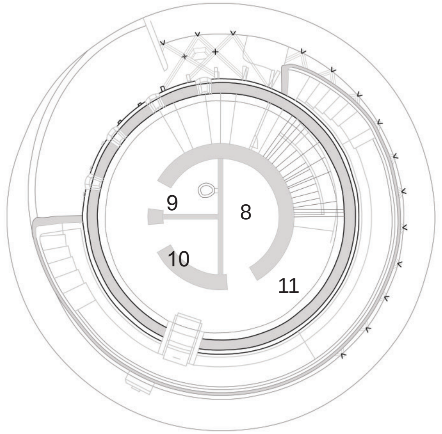
Caption



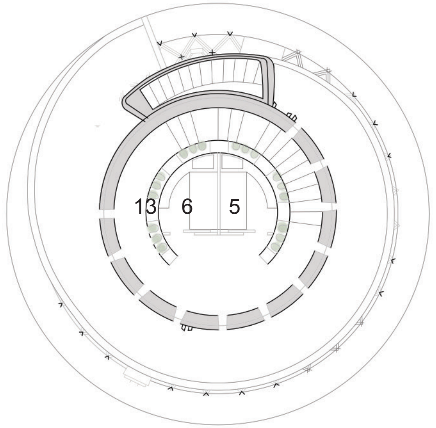
Plans



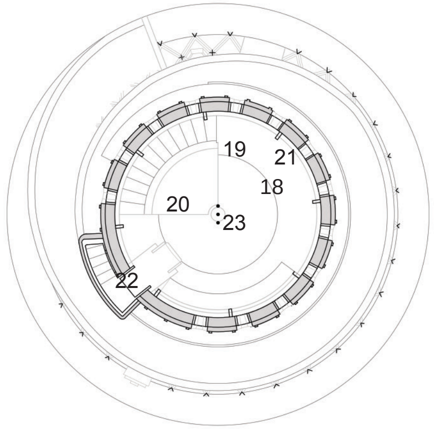
Level 1



Level 2



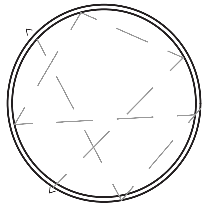
Level 3/4



Level 5

Fig. 101 - Plans of Mars X-House V2, SEArch+ /Apis Cor, 2019. Redrawn by author. Not scaled since no known measurement.

Configuration:



Type: Class III

Level 1
1-Airlock
2-Racks Experiment Systems
3-Workspace Under Windows
4-Storage Under stairs
5-Laboratory 1
6-Laboratory 2
7-Emergency exit

Level 2
8-ECLSS (Mechanical Systems)
9-Toilet
10-Shower
11-EXIT to Egress Tunnel

Floor 3
12 - Bedroom 1 and 2;
13- Harvest Area Along Stairs
14-Vertical Gardens

Floor 4
15-Bedroom 3 & 4
16- Relaxation
17- Greenhouse

Level 5
18- Herb Garden
19-Kitchen and Food Prep
20- Living Area
21-Operations/Observation
22-Entrance Emergency Egress Tunnel
23-Exercise

Natural Light entrances:

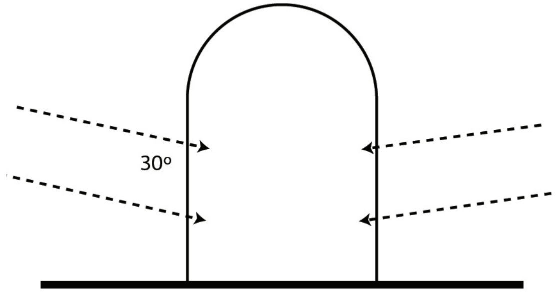


Fig.102 - Model Section of MarsX Habitat V.2 (spacexarch.com)

3.6. Mentions

3.6.1. Team GAMMA - Foster + Partners, 2015

Foster + Partners collaborated with ESA in 2013 in a project exploring design possibilities of 3D printing to construct lunar habitations using regolith as building matter. This first base was designed to house four people, offering protection from meteorites, high temperature fluctuations and gamma radiation. Its construction uses a transported (From Earth) tubular module with an inflatable dome inside of it, as the final step they would then use a robot-operated 3D printer to create the protective shell with regolith (Foster + Partners, 2013).

In 2015, with the previous experience with ESA collaboration, Foster + Partners decided to participate in NASA'S Centennial Challenges 3D-Printed Habitat Challenge, team 'GAMMA', being one of the winners.

It envisions the construction in 3 phases: first semi-autonomous robots select the site and dig a 1.5-meter-deep crater, then inflatable modules which form the core of the settlement are delivered, and finally robots assemble a regolith over the inflatable habitats module layer by layer. All of this needs to be ready before the astronauts arrival. The habitat has 93 m2 and combines spatial efficiency with human physiology and psychology (Blahut, 2015).

In IAC 2018, Bremen, (Germany) Jan Dierckx, the specialist modeling group from Foster+ Partners stated that is was their most successful design do date in terms of media attention.

Fig. 103- Vizualization. Team GAMMA - Foster + Partners, 2015

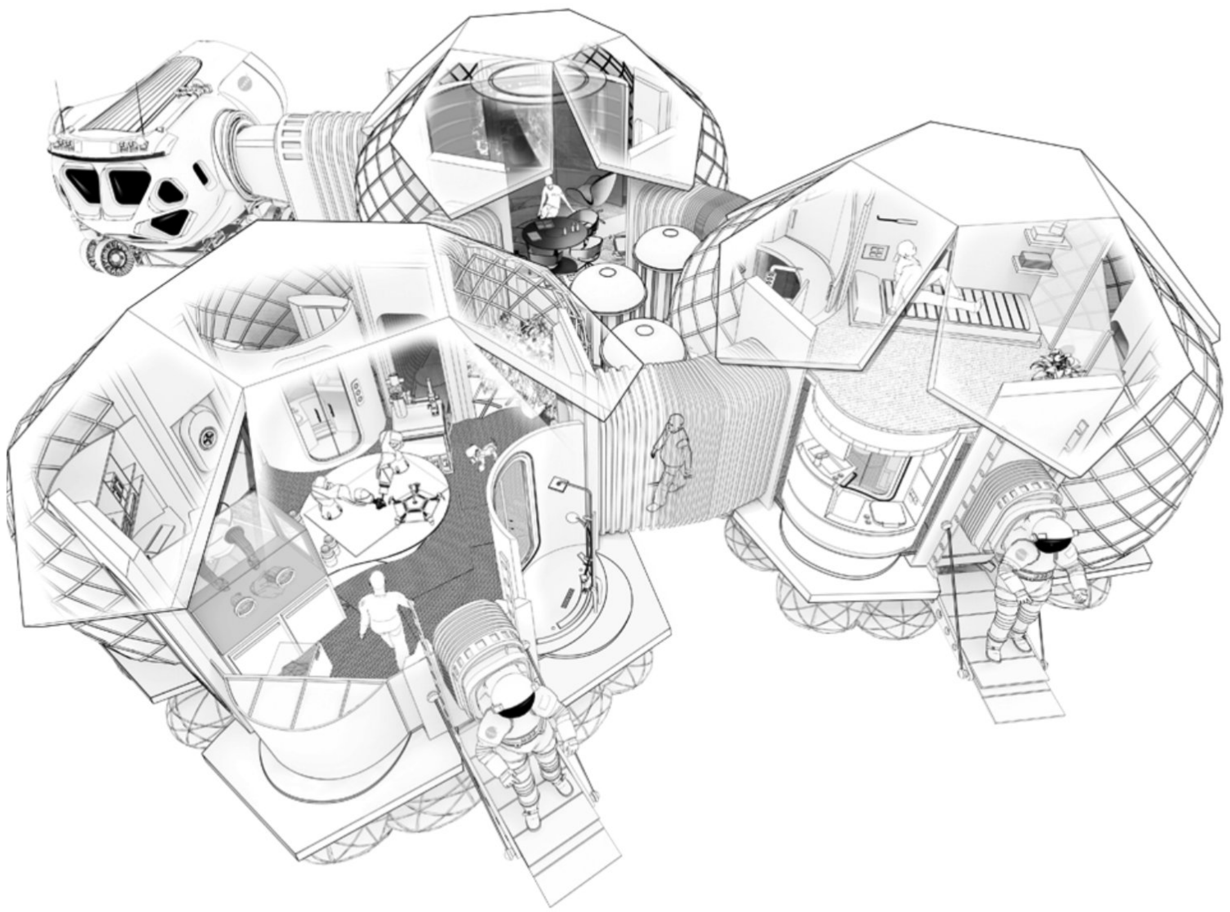
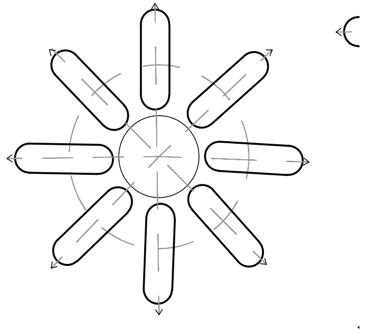
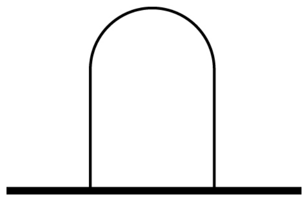


Fig. 104- Team Gamma (Foster + Partners) 3D Visualization of the Habitat, 2015.

Configuration:



Natural Light entrances:



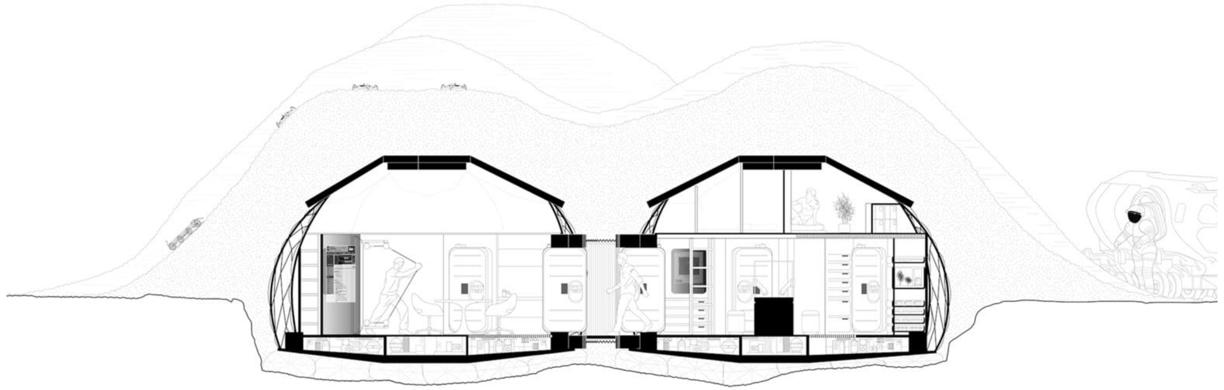


Fig. 105 - Team Gamma - (Foster + Partners), Section, 2015.

3.6.2. Mars Science House, BIG, 2017

Mars Science City was a commission project for Government of United Arab Emirates, which had the collaboration of Mohammed Bin Rashid Space Centre, the Dubai Municipality and BIG. It will be a research city that will serve as a prototype, a "viable and realistic model" for the simulation of human occupation of the Martian landscape. It part of the UAC 2117 Centennial plan. It has the size of a total of 56.810m2 and it will cost $140 million.

Regarding its program, it integrates laboratories for the study of food, energy and water, landscapes for agricultural testing and food security studies and a museum for the visitors. The areas dedicated to each function can be observed on Fig. 107. The walls of the museum will be 3D printed using sand from the Emirati desert.

Researchers would test construction and living strategies under specific Martian heat and radiation levels by partaking experimental living scenarios during longs periods of time.

> *"Building settlements on Mars will be like inventing a new vernacular architecture. Martians will be like indigenous settlers, inventing structures for the first time and understanding local materials, climates, physics, safety and comfort."*
>
> Bjarke Ingels

Fig. 106 - Mars Science City, BIG, 2017.

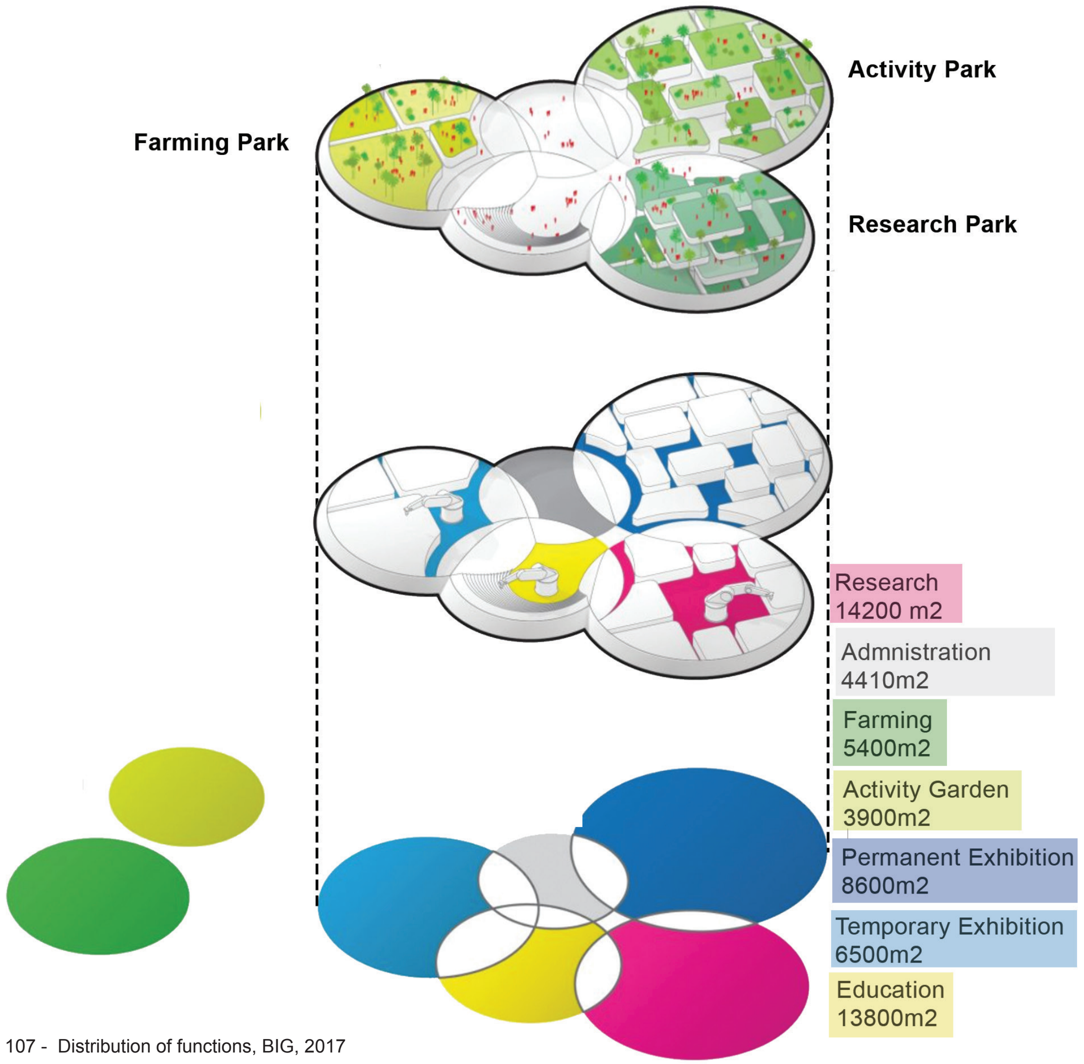
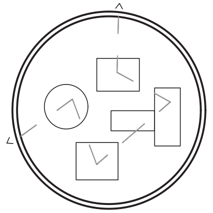


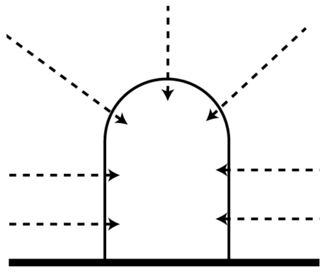
Fig. 107 - Distribution of functions, BIG, 2017

Configuration:



BIG also shows how the complex will grow (Fig. 109), showing its evolution from a single dome to a complex of domes, eventually becoming a Torus shaped cities. A single dome can hold a population of 10 people, and this prototype in Dubai would be able to host 1000 of them.

Natural Light entrances:



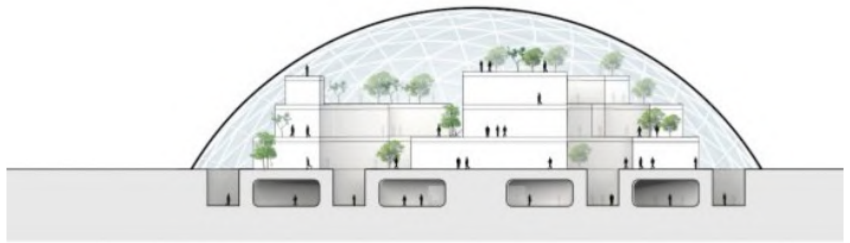


Fig. 108 - Section of a dome, BIG, 2017

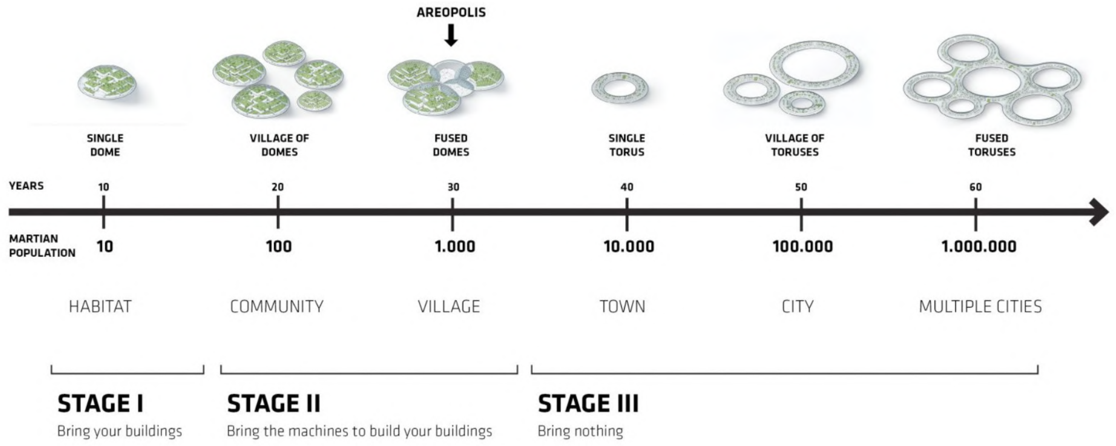


Fig. 109 - Possible growth on Mars , BIG, 2017

3.6.3. Self-Sustaining Colony on Mars, SpaceX, 2017

SpaceX is a private American aerospace manufacturer and space transport service founded in 2002 by Elon Musk. It's the one who is in the front line of the race to get to Mars, taking in account all its recent developments in the technology field. For them, the objective is to make "human a multi-planetary species".

On September 29th of 2017, at the International Astronautical Congress (IAC) in Adelaide, Australia, Elon Musk presented his talk regarding the technical challenges that need to be solved to support the creation of a permanent, self-sustaining colony on Mars, the plan (fig. 110) for a colony that would grow, saying: "The base starts with one ship, then we start building out the city and making the city bigger, and even bigger."

SpaceX is a company that focuses on the transport of people from Earth to Mars, even so they presented a Martian City design, although without too much detail of how it works, and how people would live on Mars. As such, the analysis on this case was more observational. Using the images we were able to learn some design questions that were considered.

Based on the Design Guidelines of Donoghue (2016) we identify the settlement configuration asa grid. It has different types of buildings for different functions.

Regarding its organization, we can compare it to classics cases of city organization such as a Roman city, as an east-west-oriented road. There was also the concern on the separation of functions (eg. city and travel base).

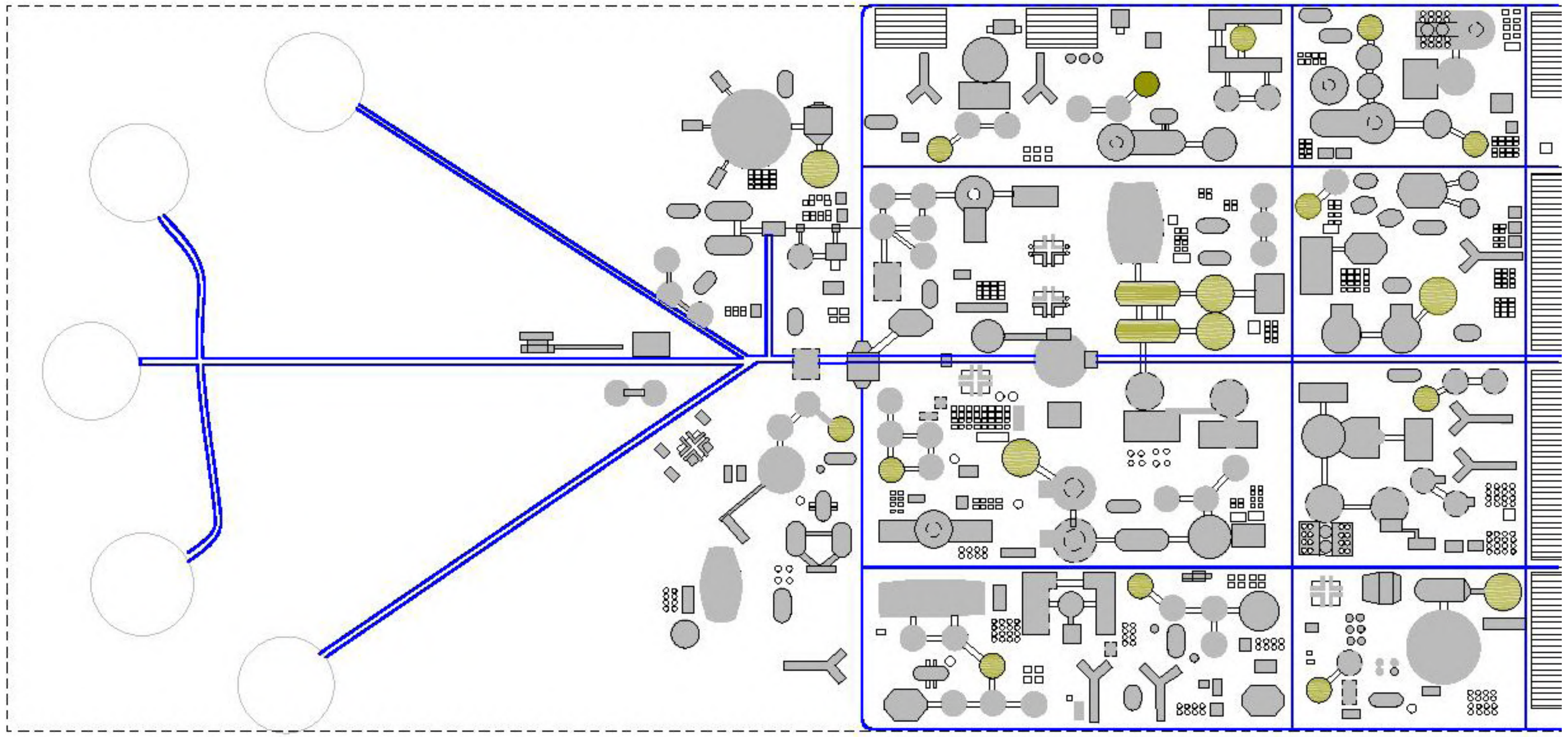
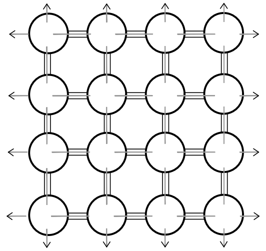


Fig. 110 - Redraw of SpaceX proposal for a Mars Colony

Configuration:



3.7. Analogue Habitats

After the development of a possible design for an extra-terrestrial habitat, the procedure is to test it on Earth. Analyse its efficiency, by creating an analogue habitat, used on an analogue mission.

Analogue missions are a necessary step in preparation for any space endeavour and must be planned and executed in accordance with the anticipated space mission goals (Häuplik-Meusburger & Bannova, 2016). The locations of these missions are chosen based on physical similarities to the extreme space environments. Some test locations include the Antarctic, Oceans, Deserts, the Arctic and Vulcanic environments. There, they test "new technologies, robotic equipment, vehicles, habitats, communications, power generation, mobility, infrastructure, and storage. Behavioural effects - such as isolation and confinement, team dynamics, and others are also observed" (NASA, 2019).

One of the first, and most known example of the analogue habitats is Biosphere 2, located in Arizona. It was designed by American engineer John P. Allen, director of Space Biospheres Ventures. Its construction started in 1986 and had as objective to 'develop self-sustaining space-colonization technology'. It consisted of an airtight glass-enclosed area, totalling 204,000 m2, containing 5 different ecosystems. It ran two missions, between 1991 and 1994, being that the first one lasted 2 years and had a total of 8 participants (Rogers, 2014).

Antarctica, since the 1980s has been considered as a "window on Outer Space'' (Salazar, 2017). Polar regions naturally create isolation and the temperatures found there resemble Mars

Fig. 111 - Biosphere 2 Areal Photo(1991-) (visittucson.org)

Fig. 112 - Halley VI British Antarctic Research Station (2005-2013)

Fig. 113 - NEEMO - Underwater Habitat, Active from 2001 until today (NASA)

Fig. 114 - D-MARS, Israel, 2018.

temperatures. As such, many analogue habitats have been developed there. (eg. Halley IV (2005-2013) designed by Hugh Broughton Architects); Concordia was another Station that opened in 2005.

Some analogues have the intention to simulate a different gravity from Earth's, and to achieve that, some habitats have been built underwater. This was the case of AQUARIUS, an undersea laboratory, located 19 m underwater close to Key Largo Florida. NASA has been using it for the mission NEEMO (NASA Extreme Environment Mission Operations) since 2001.It's designed to house 6 people for 4 weeks.

Another environment used for analogue habitats are deserts, which simulate a visually similar Mars environment – examples of these were D-Mars (Desert Mars Analog Station), located in Israel (2018) and PolAres, a field simulation in the Sahara desert near Erfound in Morocco in 2013.

Mission "Mars 500" doesn't fit on any type of environment mention before. It occurred in Moscow and it simulated a 520-day mission from June 2010 to November 2011, which focused on the psychological and physiological aspects of being in an enclosed environment for an extended period of time (ESA, n.d).

Another analogue habitat is HI-SEAS (Hawai'I Space Exploration Analog and Simulation), situated about 2440 m above sea level, in the Mountain of Mauna Noa, Hawai, a place chosen not only because of its physical isolation but also the geological similarities to Mars. It was designed by Vincent Paul Ponthieux and it has about 111,4 m2 of usable floor space (HI-SEAS, n.d.). The missions on this habitat can take up to a year and its for a crew of six.

Architects have also taken part in participating in these experiments. Arch. Alon Shikar participated in the D-Mars 01 during 4 days, (2018) in the Habitat that he designed (in collaboration with Arch Moshe Zagai) (D-MARS, n.d).

In Hi-SEAS, Tristan Bassingthwaighte, also an architect, participated in Mission IV on a 12-month mission, which culminated in his Doctoral thesis "The Design of Habitats for the Long-term Health of Inhabitants in the Extreme Environments of Earth and Outer Space" (Bassingthwaighte, 2017).

It's clear that through experimentation here on Earth we can learn and evolve in a more efficient and economical way than to test it on Space. Analogue gives us precious information and feedback on designs. Architects participation should be increased in this missions since they have a unique sensibility and vision to space.

Fig. 115 - HI-SEAS, active from 2013 - to date; (hi-seas.org/);

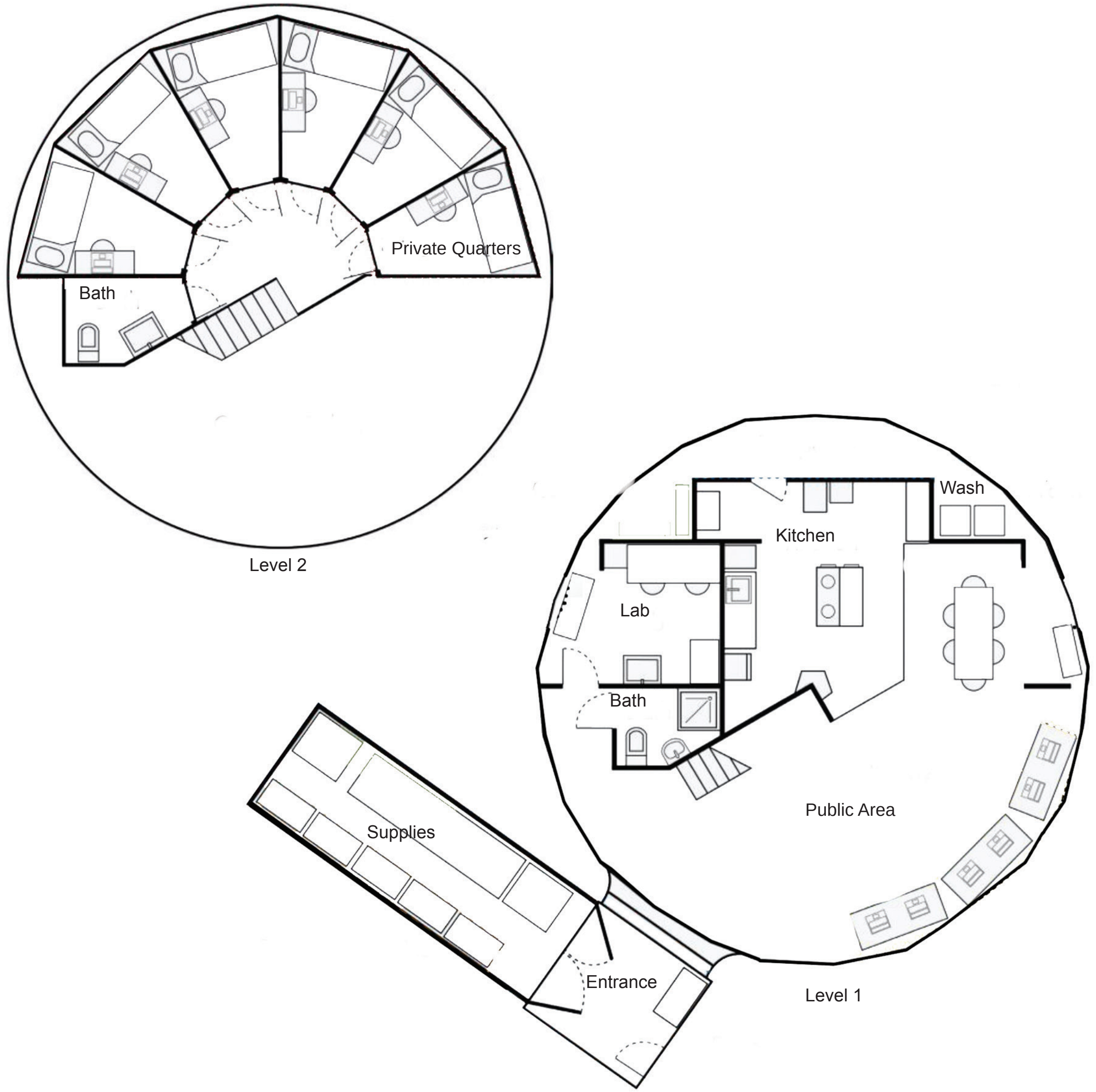


Fig. 116 - HI-SEAS, plans, level 1 and level 2 (https://hi-seas.org/);

4. Conclusion

This dissertation is summarized with 3 main ideas:

The first is that there is a clear evolution of the idea of habitat in Outer space, these ideas develop with inspiration and inputs that come from different sources: evolution of science, architecture movements sometimes even political events.

The second conclusion is the (re-)affirmation of Space Architecture as a discipline, and the acknowledgment that it actually has been around for some time, even tough it didn't use 'Space Architect' as its nomination, take Galina Balashova situation in 1964 as an example, at one point she was considered an engineer for doing the job of a Space Architect.

Conversations with Space Architects led to believe how hard to find a paying job being a Space Architect being that most of them work as ''architects by day, and space architects by night'. It's little known, but everything points to be a certifiable profession of the future.

Finally, the third idea is in relation to the guidelines, they are a great started point on developing habitats, but without real-experience, feedback of inhabitants, these will not be validated. And even after they are used, they will evolve, the same way architecture evolves and adapts here on Earth.

The program Artemis, which NASA stated they were going back to the Moon in 2024, was announced after the start of this dissertation, hence the focus on Mars and not on the Moon. But even with completely different environments some of the guidelines would perfectly apply to the Moon.

The question now is not if we are ever going to develop habitat for the Moon or Mars, but rather when. It's just a matter of time. Hopefully, Space Architects will continue to contribute to these future missions, and inspire future generations.

5. Bibliography

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6. Filmography

Le Voyage dans la lune, (1902), Georges Melies;
Himmeslskibet, (1918), Holder-Madsen;
Aelita, (1924), Yakov Protazanov;
Die Frau im Mond, (1929), Fritz Lang;
Just Imagine, (1930), Stephen Goosson;
2001: A Space Odyssey, (1968), Stanley Kubrick;
Solaris, (1971), Andrei Tarkovsky;
Star Wars: A New Hope, (1977), George Lucas;
Star Wars: The Empire Strikes Back (1980), Irvin Kershner;
Star Wars: Return Of The Jedi (1983), R. Marquand
Total Recall, (1990), Paul Verhoeven;
Escape from Mars, (1999), Neill Fearnley;
Red Planet, (2000), Antony Hoffman;
Race to Mars, (2007), George Mihalka;
Avatar, 2009, James Cameron;
Red Faction: The Origin, (2011), Michael Nankin;
John Carter, (2012), Andrew Stanton;
The Last Days on Mars, (2013), Ruairi Robinson;
Interstellar, (2014), Christopher Nolan;
Guardians of the Galaxy, (2014), James Gunn;
The Martian (Bring Him Home), (2015), Ridley Scott;
Jupiter Ascending, (2015), Lana and Lilly Wachowski;
Passengers, (2016), Morten Tyldum;
The Space Between Us, (2017), Peter Chelsom;
Valerian and the City of a Thousand Planets, (2017), Luc Besson;

Appendix

Appendix A – Interview with Mike Massimino, Ex- NASA Astronaut
Appendix B – Interview with Michael Morris, Space Architect
Appendix C – Interview with Brent Sherwood, Space Architect
Appendix D – Paper Participation in IAC 70 – Galina Balashova: The First Space Architect
Appendix E – Participation in SAS, Space Architecture Symposium. September, 2018 Bremen.

Q&A with Mike Massimino
In Web Summit Lisbon 2018
Former NASA AUSTRONAUT.

Mike Massimino, is a former NASA astronaut and current Professor of Mechanical Engineering at Columbia University and the Senior Adviser for Space Programs at the Intrepid Sea, Air & Space Museum.

He has a Bachelor of Science from Columbia and Masters of Science in both Mechanical Engineering and in Technology and Policy, as well as his PhD in Mechanical Engineering from the Massachusetts Institute of Technology.

He did two missions to the Hubble Telescope and four space walks to make critical repairs to the telescope.

Fig. 117 - **Mike Massimino**

Can you comment about the difference between sci-fi and reality regarding space travel?

We haven't been to the Moon since 1972. I was a young boy and if someone would've told me that we wouldn't go back for over fifty year, I would have said "Come on!".

Sometimes we forget that because there is a lot of movies. The Martian movie wasn't a real true story. Anyway, there is a bit of disappointment: In 1968 with 2001 with Space Odyssey people thought that they were going to be going to Jupiter by 2001. We don't know when we will be able to do that. That's just the reality of it, somethings are sometimes more difficult than we expect.

Should we go to the Moon or Mars?

It's not unusual to go somewhere, look around, learn something, like we did with the Apollo Missions and in the end, we are able to come back and set up shop.

So, I think the moon is closer, not only to get there (time related, it takes six months to Mars versus three days to get to the Moon) but also regarding communication with the ground. There is a team of people looking after you, and being able to get help from Mission Control Center is vital for space missions. In the future, with A.I things will be more independent. But we are not quite there yet, although I believe eventually, we will be. I think going to the Moon is the quickest way to get to Mars.

I'm an architecture student, working on my thesis right now, and I decided to work on possible designs for Mars and moon colonies. I wanted to ask you what you think is the biggest challenge to build this colony.

Well, I'm not an architect, but I think some of the things to think about are that it can't be totally utilitarian it has to be enjoyable, have windows. Sometimes windows are a problem in space because it's harder to pressurize and that becomes a danger, but I think they are essential. You want people to be able to enjoy their experience. Give people the chance to look out the window.

Also, being there safely, and one of the biggest challenges that we don't always think about it it's radiation. And the higher we get, the further, where the atmosphere becomes thinner, the more we get ourselves into a higher radiation.

Being a space walker, you are not as well protected, and when you get outside our magnetic field you are going to be in harm's way. That is another thing to think about that too, maybe on your design, how are you going to protect people. And then you have the obvious ones, being outside our atmosphere, like food and water supplies. I think it would be a cool place to go, make it a nice place, a nice home.

Earlier, you also said that you wanted to go as a tourist, would you think of becoming a permanent resident of Mars?

Oh, I like the Earth too much. I don't want to go on one way trips, and I DON'T want to go with anyone that wants to go in a one-way trip. I would be like "Why don't you want to come back?'' and I would be very suspicious. I want a roundtrip ticket.

When I went to Space, I was working for U.S.A – NASA, and the way government does things, they are very precise in everything they do. So, when we travel places thru the government, you always get a travel itinerary. And when I went to space for the first time, no kidding, I got a travel order and it said on it, from Kennedy Space Florida to Low Orbit AND RETURN. I was happy to see that "and return", I'm attached to Earth.

Interview with Michael Morris
Lisbon, May 2019
Astroctect

Michael Morris is an architect that founded the award- winning Morris Sato Studio Architecture in 1996 in New York City with his late wife – Yoshiko Sato.

Morris took lead of Yoshiko's Space Architecture studio program at Lab Columbia University, after her death in 2012. He participated as a Subject Matter Expert in NASA's Net Habitable Volume Consensus Session to define the volume of a future Mars Transit Habitat.

In 2015 he formed a team with five graduates from his and Sato's studio and founded independent research group - Space Exploration Architecture (SEArch), they proceeded in the same year to do a collaboration with Clouds Architecture Office to win first prize in NASA's Mars Habitat Challenge with Mars Ice House where Morris led as the project team leader.

https://cooper.edu/architecture/people/michael-morris

Fig. 118 -**Michael Morris**

How did you come with the term "Astrotect"? Normally architects that work in the space industry call themselves space architects. There is a document that was made in 2002 and that defines what is space architects.

I thought it was original, but of course, I was not. I came up with the term for a paper title "The first astrotect in Mars" – since the editor wanted something 'buzzy', but later on I became across the work of Dr. Marc M. Cohen– he was the one who used it first.

He is an architect, who's been one of the leading voices of architecture in NASA. He came up with the term (Trademarked in 2014). I used the term as a combination of how we can make it simpler, cause when we say space and architecture – well ll everything with architecture is dealing with space.

I was also interested in the idea of becoming a space architect, because it requires many people, I love the idea of collaboration. My interest is to create a society that collaborates, and in this case you need a huge team of different expertise.

Astrotecture - research, planning and design for all gravity regimes earth-moon lagrange points ners phobos deimos main belt europa icy moons enceladus exoplanets

You teach a space studio at Columbia: How do you approach the subject, and what skills are essential for a space architect?

To teach you should also have speculative, crazy, scifi aproaches. Almost should be the first introduction on working in a space project.

15 years ago, it all started very speculative, very sci-fi, with my late wife. When I took over it was still very speculative and we had a relationship with NASA but the doors weren't very open to architects. NASA weren't really interested on what we could bring. They were polite and entertained by these sci-fi, speculative idea's, but we always had to bring them down to some physics possibility for them to be engaging. The more they could be engaged the more we received valuable information from them. So, then I decided to take a more realistic turn with the program, after I inherited it from Yoshiko.

On the studio I was building the network of colleagues, I treat them now as equals – as they are. (ex-student were Part of the team to design the Ice mars HOUSE)

So, the Ice House Project, it's interesting how it was completely redesigned for NASA. Did you have input on restructuration?

We had a lot of input, from reading different papers. For instance, we thought that a wall of 5cm of ice would be enough to protect people from radiation.

We found out after, that 5 cm of ice is not a reality, and to be able to use Ice and to properly secure the Habitat from radiation it would be needed 3 meters of thickness. Also, I must say that the shape was not ideal for physics.

How long was the process? From first idea to the final?

The Ice Mars House took about 3 months. I was the leader of 8 people, some full-time, some not. When Ice was proposed, my immediate reaction is that was a unique idea, let's go with it. It took a lot of arguments, but as a former teacher I was able to mediate the ideas and direct the path.

The second version of it is still ongoing, and now it's more of a NASA project and we are just collaborating with them. We still do some consulting – Kristina and Melody were just there to be a jury on a student competition for Mars Ice House.

I noticed some change in the industry in the past year– they are looking back to the Moon now. How do you think that your projects would adapt to the Moon or better: what things would you think differently with a site on Moon versus on Mars?

Well, they are very different conditions, different soils. In the Moon you have a lot more possibility of a meteorites. Norman Foster has very beautiful projects for the Moon, that was this skeletal 3D-printing structure, done alongside with ESA, where they dealt with the issue of impacts.

On Mars this is not such a big problem. We have many information about dust storms, but it's not like the movies, I can't understand the violence.

In conclusion, the Moon has 1/6 of the gravity, has meteorites, not as much resources, and it doesn't behave. Mars in another hand is very similar to Earth in behavior.

Would you personally like to go to Mars?

I would, I didn't before. But after we've done so many convincing models. I would go to supervise the construction, even though its mostly robotic.

When Elon Musk wanted to go to Mars, a lot of people turned they attention to Mars –but now after NASA announcement of going back to the Moon they have been shifting they attention back to the Moon.

NASA definitely wants to go back to the Moon. Before Bush and Obama, 8 years ago they were because Bush was from Texas, and he was getting lots of support to basically going back to the Moon. They were very excited, because they know. If you really want to go to Mars, building a Moon base is the best way to go to Mars.

Would you say you have been influenced by Pop culture, science fiction movies to end up researching about this topic?

I like science fiction movies, just don't like them when they are completely unrealistic. For instance, I don't like Star Wars, it just doesn't appeal to me. I like the psychological movies better such as 2001: Space Odyssey, Interstellar, Solaris. Movies that are more about humans and relationship, abstract, dealing with existential ideas of who are we, and why are we here.

Regarding design, what would be the most import aspect to consider when designing a Mars habitat?

For me it's different of what it would probably be for students. After having this experience and knowledge, I feel compelled to push the boundaries of knowledge and remain even more creative. How do we take the technical knowledge and make a more creative project? That for me is my next challenge. Also how do we create a community environment in it.

For a student, the Space problem, the question is to be hyper aware of your body, biology in relationship to the Habitat.

Do you have lots of students from Space Architecture?

We used to, but maybe in the future we'll have more. Your generation is becoming more interested, a reason for it is also marketing, and people are thinking more about it. As you said, it was dead subject in the 90's.

I see that you are very environmental-aware in your projects.

How do we live and how well do we live?

The idea of Mars Ice House as my concept was that every time you switch compartment thru the center you walk thru the garden.

I believe it is a very beautiful and poetic concept that is vital to the success of the project. Projects as technical as they can be, still need to be spoken about in very poetic terms. How nice would it be on Earth if I to walk to this room to the other I had to walk through a Garden to go to the next function?

How do you organize the space inside the habitat? What should be together, or what should be avoided?

You are going to have your lab space, the living room and the bedroom.

Sleeping compartment needs to be the most protected. So, in many projects is mostly situated in the middle zone, not the top one. A third of our lives are in bed. So, there is lot of time of being passive. If there was a radiation storm, or something that happened, you would have the inability to run and for somewhere safer. So, that is the important point to be the most protected from radiation.

It's not just physical aspects that you need to deal with when designing a Mars Habitat but also psychological. Did you think about it in your work? (eg. isolation, space for interaction, etc).

Yes, of course. They are competition entries. We have the basic suggestion, of how to develop these spaces. But it could honestly be worked on for five years, each part of the habitat. I was very disappointed in the last project, since I had all this design ideas for the last part and had no time. Drawing it, rendering it, it all happened in a rush.

We spoke about the sense of space earlier – in terms of dimensions do you have any guidelines from NASA?

Yes, the competition is very strict. It must be exactly the efficacy, because of the size of the EVA system – that supports limited space. Limited people, limited space, it need to be calibrated. All the precedent systems are measures based on ISS. So how that adapts from 0 gravity for 1/3 gravity.

You talked about how in your next project you want to scale it up, more in a community sense. Do you have any ideas of how a community should work in Mars? Eg. SpaceX project

I think that a cooperative society would be the answer, and for that we may need to look back in history and see pre-historic societies.

The community was like a horseshoe, somehow everyone was part of the shape and part of the function, so it's an interesting expression of belonging and functional in a harsh severe environment.

Could you tell me more about the shape that you've chose for the last contest?

It's a shape that is more resistant to pressure. This shape is equal to a spherical shape and then you have a tower. With a sphere, you lose a lot of area- that's an equal pressure vessel. But with a tower you have a more efficient structure. So here the question is the relationship between efficiency – material.

The windows are very different on this last project too.

It had to do with the reinforcement – the hexagonal window seamed a better choice.

How will we get there? NASA? Private companies?

Private companies appeared after the Challenger explosion, people weren't interested in space. That affected NASA to give away all the technology to outside companies that were privatized. They just didn't want to be blamed if any other disaster happened. NASA became truly sad; they've become so conservative and risk adverse.

Interview Brent Sherwood
Space Architect
Bremen, Germany
October 2018

Brent is a Space Architect with both a degree from architecture and aerospace engineering, with 27 years of experience in the space industry.


Fig. 119 - Brent Sherwood, Space Architect.

For 17 years, he led a human-exploration concept engineering and program-development teams at Boeing. And from 2005 onwards on JPL, creating and proposing mission concepts for NASA for scientific exploration throughout the solar system.

He has published over 50 papers on exploration, development and settlement of space.

http://www.iafastro.org/biographie/brent-sherwood/

How did you become interested in Space /Space Architecture?

I was born the same year as NASA, I was 8 years old when start trek came on TV, 10 years old when 2001 (Odyssey) was in the theaters, so I grew up in the Apollo era, and we all know that the future was on the Moon, on Mars and in Space. And I always wanted to build cities on the moon.

I read every book on space in the Philadelphia public library when I was a little kid, and that's what I always wanted to do. And then life got in the way and as I was graduating from high school

and it was obvious that Space wasn't the good thing to happen to because nothing was happening (except in Russia).

And that was when I realized, before I was ready to retire that there were people doing what I wanted to do. After that I just dedicated my life to be able to do that.

When I graduated, I had to take a year off because no Aerospace company would hire an architect. It was obvious I needed an engineering degree. So, in 1984 is when I went back to Grad school to get an aerospace engineering degree, graduating in 88 and I had the once in a lifetime opportunity to work for a guy who had been my hero when I was 8 years old, Boeing. And he hired me to work on what they called a configurator, which closest thing they had to Architects that existed.

So, you didn't need to get the second degree?

I did have to do a second degree in Engineering because it was very hard for the Boeing HR System to hire non-engineers, same with JPL or NASA.

I graduated with the perfect combination of degrees, in the correct the time when they were creating a new group under Gordon to do Advanced planning for Moon and Mars (that was in 1988).

It wasn't the best thing to start all over again when you are already 25 and with a degree and a lot of people told me I wouldn't be able to do it, but ultimately doing that degree (even if it took me 4 years to do a 2 year degree) was what got me the opportunities that I wanted.

Eventually it didn't work out in that company, but even so it was a great opportunity.

So, you've got so sick of waiting that you choose another path.

Right, and now with Obama I watched us not going to Mars for the third time, so I've watched us not go to Mars three times already in my career. Sometimes when I'm talking about it, I can get a little revolted about the difference between a vision and a reality and it's because of that. I've devoted my adult life to making it happen and then I watched it not happening three times in a row. I'd be lying if I said I wasn't a bit bitter about that, and so, when I see what SpaceX is doing it amazes me because it's a game changer. And it's possible that with our new administrator we are also able to change the game remarkably.

There was a time the NASA was a baby. – they took a bunch of existing laboratories and said: "You are NASA" – and then 3 years later (that was in 1958), in 1961 they give this new agency this impossible job, and 10 years to figure this out. The average age there was 26.6. These were people that didn't know how to solve a problem. There was nobody telling them "you have to do it this way, or that's not the way we do it" – nobody knew. And they figured out and did it in 9 years. That was history, now my interpretation of it. After that a very weird thing happened which is the whole community did it – the agency, contactors and stakeholders all misinterpreted what they had just done. Because what

they did, what they were tasked to do – which was to embarrass the soviets on the world stage. And as soon as that happen they said "Oh, our purpose is to put boots on Planets – that was never the purpose – the purpose was to embarrass the Russians.

But as soon as you feed your purpose is to put boots on Planets you start to look out for other planets to put your boots on – which becomes Mars. Which by the way, is what Von Braun always wanted to do. The methodology that the organization has is from Von Braun – you know, space station in Mars/Moon (…) and we have been struggling ever since to make that happen.

Do you think that the "Hype" about the Moon is over and that's why we don't look at the Moon anymore hence all the interest that Mars?

No, I think people misperceived how many times Mars is harder to get to than the Moon. And so, to take people the Moon is not worth doing because we've been there, we've done that.

That is what Buzz Aldrin would say, because by the way, he has been there. And I've said, that works for you that you have been there – the rest of us hasn't, we were watching on Tv, you know…

So, this to people feels boring, but in fact it is still incredibly hard to do it today. And Mars is a lot further and way more expensive. More problems to solve. The heaviest thing we have landed on Mars was 1 ton and it took a sky crane to do it.

So how is anybody going to land humans on Mars? With a 30-ton payload? I have no idea! We have ideas, but we have no proof –

well no demonstrations. We know from the history of spaceflight there will be errors, there will be mistakes, accidents, and we are just not taking them in account now!

Humans to Mars? Yes! Some day. But we are not the civilization that can do that. We are the civilization that can put people on the Moon, settle in the Moon, harvest solar energy, develop nuclear power, extract resources from mineral– we can do all of that- on the moon, just three days away.

Thirty years ago, there was no event like this, there was Constance, Marc Cohen, (and others) but we didn't know each other. Some of us will be focus in Mars, and I think that's great. They just need to be realistic, they are talking about decades in the future. That's fine. But you need to have a career and put food on the table, so you need to That's why some of us are focused in tourism, which is the opening for the mass market.

You said that you didn't know Constance Adams and the others, so how did you meet each other and organized the first panel?

I was doing my own thing, a couple of the other got together and in AWA and a technical committee for space structures (not sure) but Marc (Cohen) was trying to do a subcommittee of Space Architecture. That was before my engagement with DATC of Space Architecture. That was before my engagement with DATC– Design Engineering. For a couple of years, I wasn't a member.

The real big the event was in 2002, we did a meeting in Houston, The first space architecture symposium. And miraculously, we 47, wrote this thing – the Millennium Charter. We worked hard in the definition. Various people tried to modify it, but it can only be done when another symposium happens. I do believe it is time for another one. So it's a bit scary, since another definition could come out. Because it matters, "this is who we are, and what we are".

I went to see movies since 1903, and it's interesting to see the evolution of the idea of living in space, the different modules. 2001: Space Odyssey, for instance, was a revolution movie. You see one type of architecture in the other movies and after that one, you see it more technical.

It was the pilot. And it was fiction but it was a realistic, and it's still realistic.

All those details are very real, which is amazing to think about, how it still applies 40-50 years later. That's an amazing achievement. In our field to do anything that lasts for 50 years and is still accurate, that's phenomenal.

Appendix B - Paper 70th IAC 2019 Galina Balashova - The first Space Architect

Abstract

Galina Balashova (1931-), was a Russian architect who worked in of the Soviet Space Program with the Experimental Design Bureau OKB-1, under the guidance of the rocket engineer, space Pioneer Sergei Korolev (1907-1966). She participated in the interior design of the Soyuz spacecraft and the Salyut Space Station and Mir Space Station and later as a consultant for the Buran Program. Her responsibilities went from designing the interior space, where she worried about ergonomics design of living and sleeping areas, to designing a zero-gravity bathroom facility. She thought of innovations that are still used today (use of color to avoid disorientation). She retired in 1991.

Although other names of Soviet space program went down in history, hers was kept unknown and a secret, being her work highly classified. She was a Woman (an architect nonetheless) in a world dominated by aerospace engineers. Some also appoint Galina Balashova as the first Space Architect.

Acronyms/Abbreviations

OKB-1 –Exprimental Design Bureu
LOK – Lunnyi Orbital'nyi Korabl'
ISS- International Space Station

1. Beginning

Galina Andreevna Balashova was born in December 4 of 1931, near the city of Kolomna, situated 100km south-east of Moscow, USSR.

Both her parented graduated from the Muron Forester Technical college. Her father, Andrei Fedorovich Bryukhov was a descendent from an old-established aristocratic family from Murom, because of that he was given the *white ticket*, which meant he could only work as a physical labourer, in the provinces. As such he traveled around for employment often. He was a person proficient in musical arts and painting [1].

In 1941, when Galina was 10 years old, she witnessed the ongoing war. Her own mother was a victim of a bombarded building while working in a textile factory, surviving with only a head injury.

In 1943, her father was placed for work in the city of Dimitrov, and only the she could return to school there.

Also joining her normal classes, her father arranged for her to have watercolor lessons from the painter Nikolay Alexandrovich Polyaninov, who had taught on Institute in Moscow, this in exchange of firewood. She learned the basics of watercolor and feel in love with it, this was the start of her unique style and love for watercolors.

2. Education

Fig. 1: Moscow Architectural Institute MArchI (1954)

She finished her secondary school in Dimitrov, in 1949 (Fig.1) with a silver medal. Then with her father advise, her uncle being an architect, and because of her

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experience in drawing and painting she decided to pursue Architecture in the Moscow Architectural Institute.

She studied the first years under Vladimir Fedorovich Krinsky, and later, in the third year under the well-known architect Mikhail Fedorovich Olenev and Yuri Nikolaevich Sheverdyaev. On her very first lesson she was told "Our task is to cultivate your taste". Her studies took a more practical approach over theoretical, where she painted and drew constantly. She learned and developed her grasp of proportion in architecture, between the space (building) and the human body, and how they can exist in harmony [1].

3. Work

After graduation (1955), she started her first work experience with in the Design Institute GriProAviaProm ridding buildings of any embellishments in their facades, this following Nikita Khrushchev address in December of 1954 at All-Union Convention of Construction Workers, demanding to apply Moscow's new construction standards to the rest of the Soviet Union, blaming architects for the housing crisis because they only designed "buildings of an individual characters – monuments to themselves" [3].

In 1956 she married a former high school colleague, Yuri Paulovich Balashov, he had gone to study at the Moscow Institute of Physics and Technology and subsequently went to work for the Experimental Design Bureau OKB-1 under Sergei Pavlovick Karolev, considered the father of the Soviet Space program, in Kalingrad (town later names as Karolev as a tribute to him).

During this time, she was working in the Institute for Standardization of Design in Kuibysha for six months – with no prospects of a job, her husband talked to a colleague at OKB-1, proceeding her being contracted as Senior Architect. She was the only certified architect in the company, having huge responsibilities. Her jobs spectrum went from designing memorials to the City's Palace of Culture (Fig. 2).

Fig. 2: Design of the Palace of Culture in Korolev (1956).

OKB-1 was responsible for the launch of Sputnik (1957), and placing the first human being on space Yuri Gargarin (1961) and with the preparation for longer space mission, Sergei Karolev understood that the spacecraft needed to be redesigned to have comfortable accommodations. As such, in 1963, the Design Bureau finalized development work on the Soyuz spacecraft, which had for the first time a habitation module.

After Karolev rejected a first model, which only had two red cases for the cosmonauts' instruments [1]. Konstatin Petrovich Feoktistov decided to involve Galina Balahova – who was still employed as a senior architect at the company – meeting her at the staircase in secrecy, to challenge her to design a habitation module. In a weekend, she produced a series of sketches and watercolor paintings which impressed Karolev, and was approved to further studies, doing a 1:1 model. Reviewing it, Karolev asked to make it in a modern style, as such doing variants with different color schemes.

In this design, she turned one of the red cases into a cabinet which served the purpose to be a wardrobe and to store cans of food and water, personal hygiene items and books and could also be used as a work space. The other cabinet turned into a couch which the intention was to fill it with equipment, and finally she added a device named ASU – Sanitary disposal unit [2].

In the following Soyuz-type spacecraft she painted watercolor landscape murals that were taken to space and most were burned down when reinterring Earth. Her paintings were of landscapes familiar to her, and had the purpose to remind the cosmonauts of home.

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After that she was pushed back to her old job at the company for a year, until the opportunity arose to work on planning habitation modules of the Lunar Orbital Craft – LOK, in the position of an engineer since the architect position didn't exist.

She noted the difference to approach design from engineers to her own as an architect. Engineers designed individual components, to create the whole while her methodology was to focus on volumes and the overall result in appearance instead of the small, individual details. What followed was some friction with certain engineers, that were not that inclined to produce and adjust their element to her follow her designs [1].

> *"To them, I was just some woman playing around with colors. And I was racking my brain trying to figure out how to ergonomically fit various sized devices into spherical shapes (…), I had to explain these basic things to those supposedly super smart men: that architects not only build houses, but they can also design the internal spaces of planes, ships, and other objects. For the engineers, the relationship between man and machine did not matter much (…).* [2]"

Left mostly alone to design the modules, determining the dimension of individual areas specifying position of fittings and appliances, controlling scales, balancing proportions and trying to achieve harmony between the machine and the human body. Something that wasn't so obvious for the engineers, since they considered the relationship between man and machine irrelevant. The engineers always had the final say, and it was complicated to make her voice heard not only because she was just an artist is an engineer-world but also because she was a woman in a man's world.

Another one of her proposals was to define the floor and ceiling for better orientation to cosmonauts have a notion of below and above. She achieved this by using color schemes.

She thought deeply on the layout thinking of question such as where would the cosmonauts sleep, eat, and go to the toilet?

She incorporated a divan as a sleeping accommodation and a toilet (adapted to zero gravity) situated in separate area. She adapted everything to the people's needs, such as the position of the fittings and control system, bookshelves, storage – things foreign to the engineers since they didn't understand certain necessities some as simple as a sleeping.

Fig. 3 Diagram of housing units in the Soyuz-M spacecraft (1970-74, never executed). Galina Balashova Archive.

Another responsibility on this project was cladding, which in itself had various responsibilities associated. She had to allocate functions in it, and also, since cladding also served as an informative tool since it could help differentiate the below from above. She also decided to use bright colors, since the lightning was scarce, and it helped compensate the lack of illumination.

An experiment was made when she suggested the use of velcro fastening to attach objects, it was even used in the cosmonaut's seats and pants for them to be able to sit and not float around – this was later dismissed since it was too strong of a material. They started using seatbelts to sit on the divans.

She was careful to try everything herself and test out the different designs, from sitting to handles.

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<u>Soyuz M</u>

LOK was finished in 1969, following the American's landing on the Moon. Since the American got the Moon first, it was too late to use LOK, and so the project was putted aside. Galina Balashova returned to her position as Senior Architect, and stayed for a year and half, until she was called to plan the construction of the new Soyuz M spacecraft, specific to design the servant and the landing capsule.

A problem arose with the weight of the spacecraft of Soyuz M, due to the tape that secured the cladding. She was able to cut 9 kilos of tape, by envisioning a simpler method of attachment – fastened with non-flammable tape that was able to be loosened and clamped in simple steps.

This suggestion had a prize of 540 roubles (50 roubles for kilo saved) which she was cheated out of by her colleagues – she got 28 roubles after complaining.

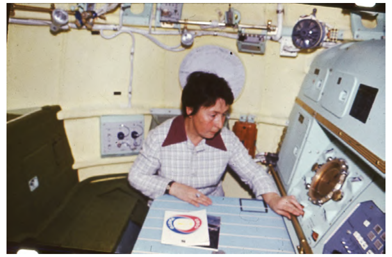
<u>Soyuz 19 (Apollo-Soyuz)</u>

In 1973, after the creation of the new department to work on Apollo-Soyuz program, Galina Balashova was once more called to design the habitation module, supervised by Oleg Konstatinovich Fedorov. She worked alongside the engineer Alesha Petrov who was responsible to design the components while she did the interior design.

The habitation had to provide space for gatherings between the soviet cosmonauts and the American astronauts. As such the *servant* in a larger scale was placed on the portside to store tools and equipment.

She also incorporated a folding table that was used to store objects using Velcro fastening and elastic bands. A divan of bigger proportions was positioned on the right, being able to sit two people. It was taken to attention that the space should be very well lit since it was going to be used for film and television recordings. Filming also influenced the color used – since the red (one of the country's official color) appeared to be black in the film it was decided to go with green (Fig.4). For the Soyuz 19 model light yellow for the walls and green was used for the floor and light blue for the folding table.

Always attentive, she would often ask for reviews and feedback of the furniture an layout to the cosmonaut after



each flight, to better improve her designs with their suggestions [2].

Fig. 4 – Galina Balashova in the prototype of the Soyuz 19 space capsule which she designed 1975

In 1976 she was transferred to the department responsible for the orbital stations, she got involved in the Salyut in the interior cladding for a time.

Another project she was responsible for, was the design of the interior of Soviet Buran reusable shuttle, that never flew.

<u>Mir</u>

One of the lasts projects she was tasked was to design a new orbital station called 17 KS, later named Mir. It was composed by two cylinders, one with 4.5m of diameter and a smaller with 2.8m. It had the innovation of a window being permitted and it was requested that the station had nice cabins and cozy interiors (Fig.5).

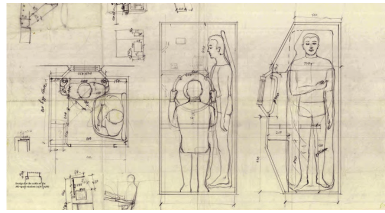


Fig. 5 - Drafts and studies of sleeping compartments in Mir Space station, by Galaina Balashova (1976).

Although the design didn't go in her preferred way – in a vertical plane, but rather horizontal structure (due to radiation protection), it was able to fit a workspace, a communal area and two private cabins for the cosmonauts. The design principles on Mir were later used in the ISS.

Again, the colors used were from Galina's scheme: Green for floor, yellow for walls and white for ceiling (Fig.6).

Fig. 6 - Design for the cabinet of the space station Mir, final version interior design (1980). Galina Balashova Archive

Emblems

She also designed emblems such as the famous Apollo-Soyuz emblem, which she was certified of her authorship by the factory in Mytishchi, but when her supervisors found out she was threatened to 8 years of jail for betrayal of state secrets. She waived all legal claims to the design, afraid that she and her husband and would lose their job [1].

4. Recognition

Galina's American counterpart would be the industrial designer who NASA contracted: Raymond Loewy (from 1967-1973). He starts working in the space industry a few years later than Galina Balashova, and stayed for a fraction of the time. His work is very well known today, which overshadows completely Galina, eventhough she appeared first. This is probably because her collaboration and drawings stayed top secret until her retirement in 1991, with the dissolution of the USSR, this due to the secrecy of the Cold War. But even after, not much recognition came from it.

The first exhibition of her works was held in 2000 at the Moscow Central House of Architects, but she remained mostly unknown until recently. Credit should be given to the German architect Philipp Meuser who curated an exhibition of Galina Balashova work, at DAM, Frankfurt, Germany in 2015: "Design for the Soviet Space Program – Galina Balashova, Architect.". Which followed by publishment of her autobiography "Galina Balashova: Architect of the Soviet Space Programme" [4].

A small documentary was also made in April 2016 in the TV channel "Russia- Kultura".

Even after these small recognitions, Galina Balashova's name is nowhere to be found in the Museum of Cosmonauts in Moscow, even though you can find the interiors of modules with green upholstering and with one of them holding one watercolor painting of an autumn landscape in Moscow Oblast [2].

Today, with 88 years old, she lives in a small two-room "Khrushchev" in the city of Korolev, near Moscow with a pension of $297 a month, mostly forgotten by her compatriots and the World [5].

5. Acknowledgements

A thanks to my tutor Alexandra Paio and the architect Philipp Meuser, who brought Galina Balashova to light after so many years.

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Participation IAC - Space Architecture Symposium, September 2018, Bremen, Germany

Participation in IAC69, Bremen. September 2018. Space Architecture Symposium, in Bremen. Author of reference books present: Brent Sherwood, Olga Bonnova,

SAS BREMEN

SPACE ARCHITECTURE SYMPOSIUM

29.9.2018

A CONVERSATION ON SPACE ARCHITECTURE:
WHERE WE ARE
AND WHERE WE ARE GOING

THE SPACE ARCHITECTURE TECHNICAL COMMITTEE, HOSTED BY THE DLR IN BREMEN, INVITE YOU TO JOIN A DAY LONG SYMPOSIUM DISCUSSING THE RECENT MILESTONES AND STATE OF SPACE ARCHITECTURE, AS WELL AS CURRENT AND FUTURE OPPORTUNITIES FOR THE FIELD. JOIN THE SPACE ARCHITECTURE COMMUNITY IN PRODUCING A STATEMENT ON RECENT SPACE ARCHITECTURE ACTIVITIES AND IDENTIFYING GOALS AND ACTIONABLE ITEMS TO TAKE SPACE ARCHITECTURE THE NEXT STEP.

29.9.2018

9:00 INTRODUCTION & KICKOFF
WITH A SPECIAL LOOK AT SPACE ARCHITECTURE BY REGION

10:00 MORNING SESSION: WHERE WE ARE
A REPORT ON RECENT SPACE ARCHITECTURE ACTIVITIES: THE OPPORTUNITIES, SUCCESSES AND FAILURES, TARGET AUDIENCES, INTENDED OUTCOMES, AND PARTICIPATION AND ENGAGEMENT WITH THE SPACE ARCHITECTURE COMMUNITY.

10:00 PROJECTS
10:45 COMPANIES
11:30 COMPETITIONS
12:15 EDUCATION / THEORY

GOALS: PRODUCE A STATEMENT ON THE RECENT ACTIVITIES OF SPACE ARCHITECTS TO REFLECT ON THE CURRENT STATE OF SPACE ARCHITECTURE

13:00 LUNCH

14:00 TOUR OF THE DLR BREMEN

15:00 AFTERNOON SESSION: WHERE WE ARE GOING
A LOOK FORWARD TO WHERE SPACE ARCHITECTURE WOULD LIKE TO BE WORKING IN THE NEAR FUTURE: IDENTIFYING AMBITIONS, NEXT STEPS, AND ACTIONABLE ITEMS TO TAKE US THERE AS A COMMUNITY.

13:00 LUNCH

14:00 TOUR OF THE DLR BREMEN

15:00 AFTERNOON SESSION: WHERE WE ARE GOING
A LOOK FORWARD TO WHERE SPACE ARCHITECTURE WOULD LIKE TO BE WORKING IN THE NEAR FUTURE: IDENTIFYING AMBITIONS, NEXT STEPS, AND ACTIONABLE ITEMS TO TAKE US THERE AS A COMMUNITY.

15:15 NEW SPACE
16:00 BRANDING THE PROFESSION
16:45 WORKING ON EARTH
17:30 OUTLETS FOR IDEAS/STARTUPS/PROJECTS

GOALS: PRODUCE A SERIES OF ACTIONABLE ITEMS TO HELP PROVIDE SPACE ARCHITECTS WITH FUTURE OPPORTUNITIES

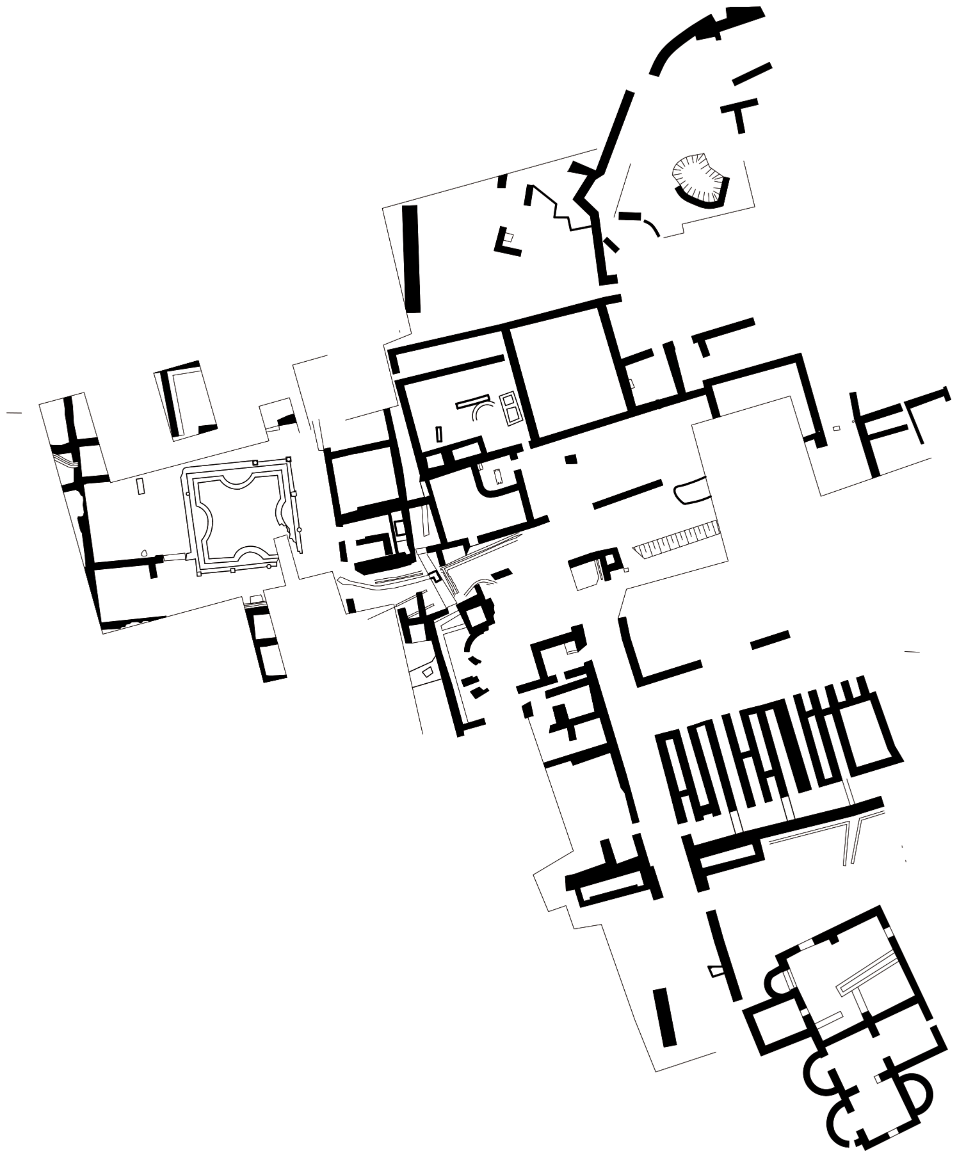
18:15 CLOSING SUMMARY

19:00 DINNER

CHEILA CORDEIRO ARRUDA

ISCTE-IUL, 2019

Roman villa of Freiria: Interpreting the Past



ISCTE-Lisbon University Institute
Department of Architecture

Final Project of Architecture - Pratical Aspect

Roman Villa of Freiria: Interpreting the Past

A Dissertation presented in partial fulfillment of the
Requirements for the Degree of Master

Cheila Cordeiro Arruda - 72635

Tutor
Professor Dr. Architect Pedro Mendes, Assistant Professor, ISCTE-IUL

October, 2019

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Cascais location in relation to Lisbon.

1.1. Introduction

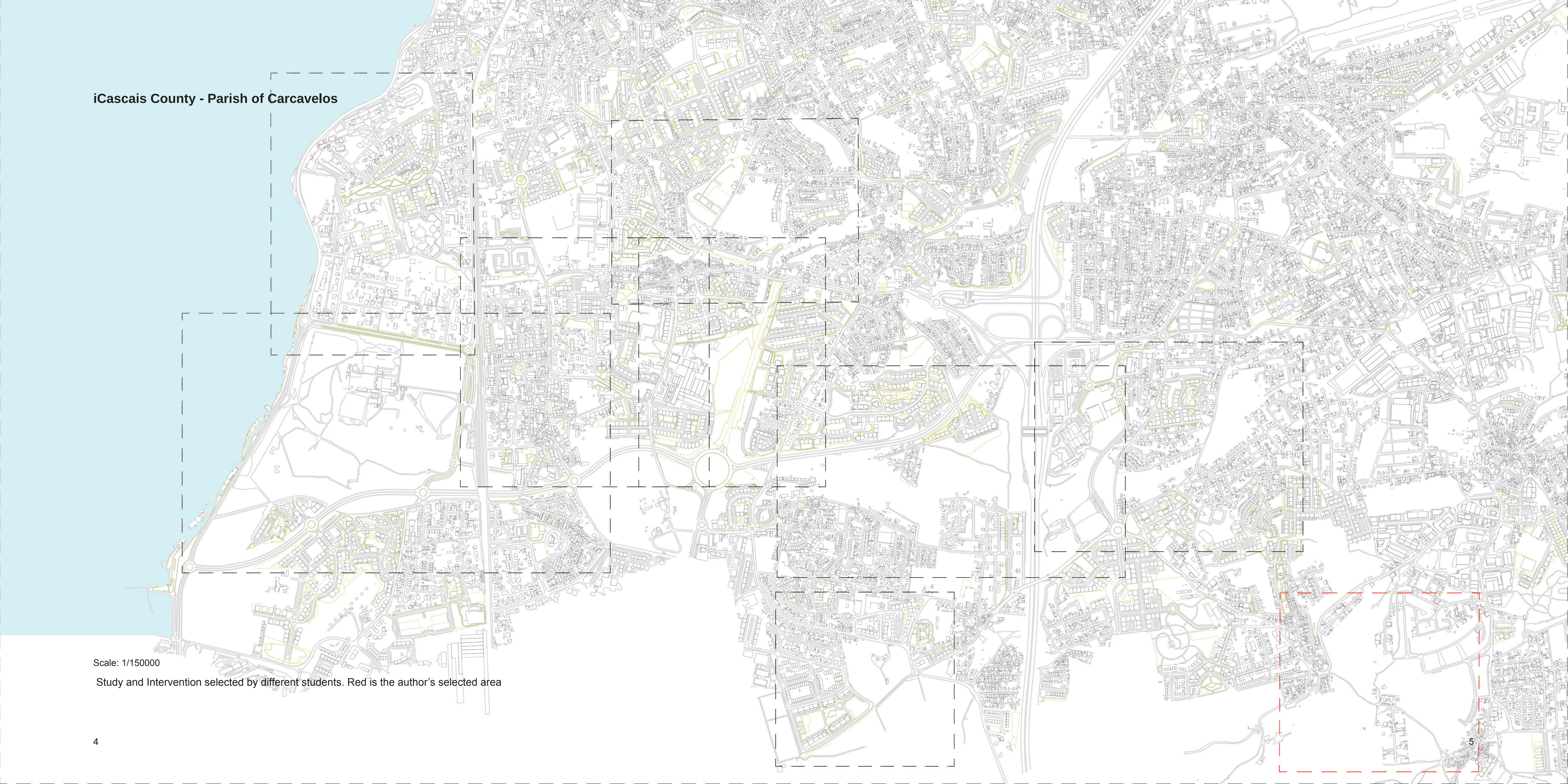
The program for the academic year 2018/2019 of the Final Project of Architecture, led by Architect Pedro Mendes, looked over the territory of municipality of Cascais, located in west of Lisbon. The proposed limits of possible interventions were inside the boundaries made between stream of Sassoeiros, stream of Marianas, extending up to Stream of Caparide.

Inside these limits, different realities are found in terms of occupation: up north we find a more 'natural' territory with a lower construction density than the south. There is also a contrast between mobility infrastructure network between north-south. It's important to note that this territory is under construction pressure due to housing demands and the opening of the Nova SBE – School of Business & Economics.

In a first phase, the class did an analysis of the territory in general, to which the author was responsible to provide a review of demographics and the economy at the county - focusing on Carcavelos.

Students could choose to work in developing public space,
on requalification of existing buildings, proposing of new construction, and even rehabilitation of the previous stream boundaries. The author chose to study further about the archeological patrimony in Cascais due to a recent intervention on the ruins of the roman villa of Freiria, through a participatory budget. In the basis that it that intervention should be completed with a Intrepertetive center.

iCascais County - Parish of Carcavelos



Scale: 1/150000

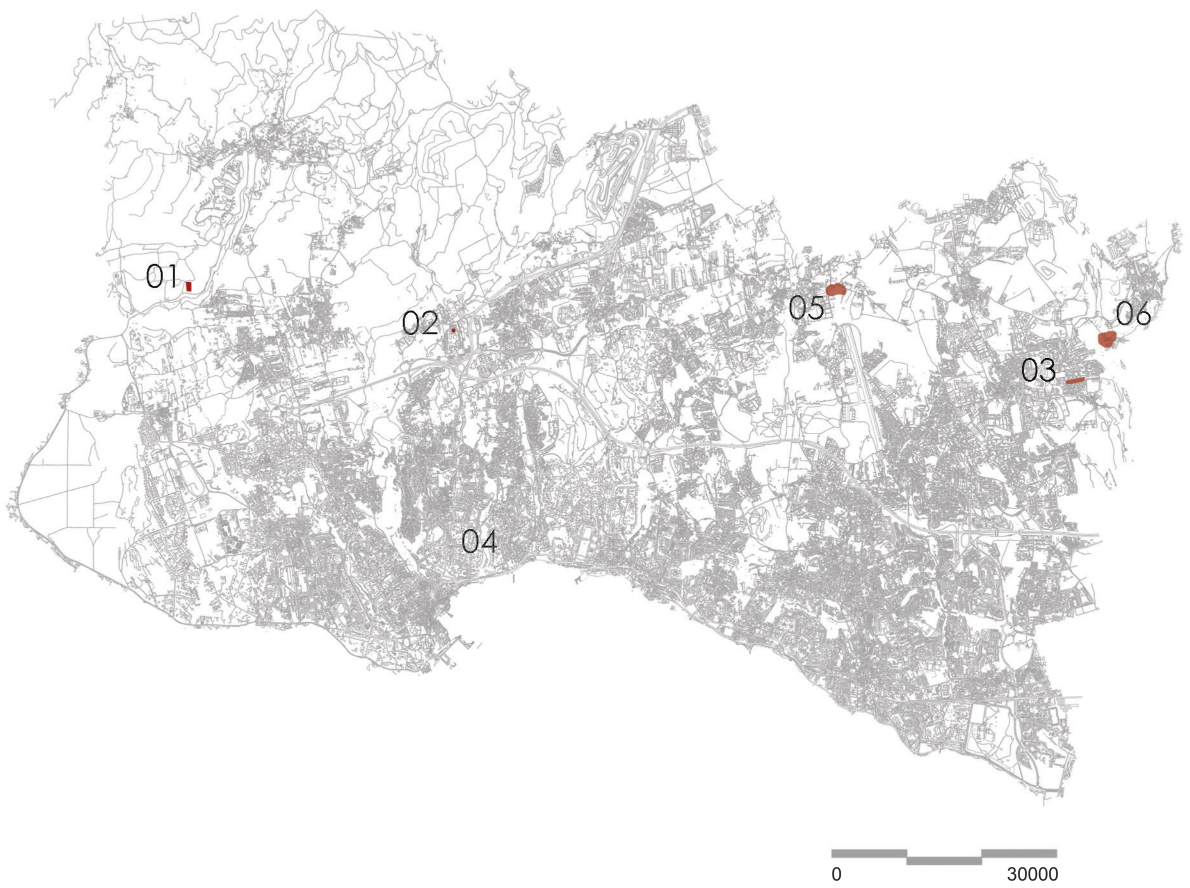
Study and Intervention selected by different students. Red is the author's selected area

Chapter 1 - Past

“As an architect you design for the present, with an awareness of the past, for a future which is essentially unknown.”

– Norman Foster

1.1 Roman presence in Cascais



Cascais was a pioneer municipality by publishing an archaeological chart, dated in 1991, where identifies deposits and finds of archaeological interest.

The Council of Cascais did not simply use the charter as an identification, but also used its information as an instrument in territorial management. Emphasis to the 1997 PDM, where there was a concern in the norms of protection of archaeological heritage and it was implemented conditioning on the land where the archaeological assets where identified in the Cascais Archaeological Chart.[1].

The map on the right side shows five places that archeological romana ruins where found - on page 8 and 9 we take a closer look to thei location in the present urban structure.

1- Roman villa of Casais Velhos

2-Roman Villa romana of Alto da Cidreira

3-Roman villa of Outeiro

4-Roman Cetariae

5- Roman Villa of Miroiço

6- Roman Villa of Freira

1 Cascais.pt. (2019). Carta Arqueológica do Concelho de Cascais | Câmara Municipal de Cascais. [online] Available at: https://www.cascais.pt/carta-arqueologica-do-concelho-de-cascais [Accessed 8 May 2019].

01. Roman villa of Casais Velhos
St. São Rafael, Cascais
Classified as Property of Public interest in 1984;

02. Roman Villa romana of Alto da Cidreira
St. of Alto da Cidreira
Identified as Property of Public Interest, in 1984;

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03. Roman Villa of Miroiço
St. Manique, , Cascais
Classified as Property of Public interest in 2002;

04. Roman villa of Outeiro
St. Boa Esperança, São Domingos de Rana
Classified as Property of Public interest in 2002;

Aerial photo (n.d.), taken from DGPC.

1.2. Roman villa of Freiria

The roman villa of Freiria is a place of high historical and cultural value, located in the valley between Outeiro and Polima, in the parish of S.Domingos de Rana, county of Cascais.

It is situated in a rural area, isolated from the urban mesh and surrounded by agricultural terrains. Its borders are defined by the water line from Lage's stream in the oriental side. In its immediate surroundings, there are some habitations and an illegal genesis complex.

The Villa is an important reference of the national and peninsular archaeological patrimony, since it was declared as a public interest property in 1990 (Decree nº 29/90, DR 1st Series, nº 163, 17/07) in which was developed a detailed plan in progress since 2006.

1.2.1. Toponymy

Elders insinuate to the existence of an old nunnery, however there is no knowledge of any ruins at the site or in its surroundings. The existence of a nunnery would explain the toponym of "Freiria" since according to Fr. Joaquim de Santa Rosa Viterbo "(…)

Se chamam freirias os lugares, sítios, ruas ou bairros em que estes freires, por algum tempo, residiam" (Cabral, 1998, p.51) or yet in places that had dependencies from a monastery (of monks or nuns), which was the case at certain point, since this location was, a long time ago, dependent from the S.Vicente de Fora's Monastery (from Lisbon) and it would receive annual rents [1] .

1.2.2. Historical Context

Vergílio Correio is the first one to mention about Roman ruins after he identified a Roman grave that was located alongside the quarries, close to Casal da Freiria (Cabral, 1998). He published his findings in *"Archeologo Portuguez"* (1913), where he stated his suspition about the existence of a Roman villa in the surrounding area, due to all the shards, pieces of clay tile (surely roman) and pieces of roman mosaic found around there.

In 1985, clandestine construction of habitations threatened the site, which had suffered a previous embankment, where it was suspected to exist the said Roman Villa, (which was confirmed after the first excavations3). Various excavation campaigns were organized every year from 1986 to 1994 and then from 1997 to 2002 with Guilherme de Jesus Pereira Cardoso and José Manuel dos Santos Encarnação as the archaeologists in charge.

Due to the success of the excavations, they were able to put together various exhibits, the first one being "Cascais no Tempo dos Romano" (Cascais in the Roman Times) in 1986. Followed in 1997 by "Cascais Romana" (Roman Cascais) and in 2004 by another exhibit named "Cascais há 5000 anos" (Cascais 5000 years ago) and in 2005 "A Presença Romana

Cardoso, G. Encarnação, J. (2010) Roteiros do Património de Cascais: Património Arqueológico. Câmara de Cascais. Lisboa.

em Cascais – Um Território da Lusitânia Ocidental" (Cardoso, Encarnação, 2010).

The romans settled down in a location previously occupied by populations that preceded them, this was proven by findings of ceramic fragments that dated to pre-historic times (Cardoso & Encarnação, 2013). With this, it's possible to point as an estimate that Freiria's occupation goes back up to 4 thousand year ago (Cabral,1998), but that the roman occupation happens sometime after the I century B.C. and lasts until the beginning of the V century .

Shepherd with his lambs in the archeological site of Freiria.

The choice of location for the villa could have a number of reasons, the first of them being the existence of fertile soil which is excellent for cultivation. The proximity to Olispo, city of sea and a centre of commerce, also had a key role in the development of this location (Cardoso & Encarnação, 1994). Still regarding its location, there is a contrast between the location of this particular villa and others from the county of Cascais. While in others its noticeable a preference for strategic locations with good visibility, Freiria, being located in a valley, lacks in this department, however, it had available an abundant spring (Cardoso & Encarnação 2013).

The villa was the country residence of a gentleman of great possessions, with cultivating fields of great dimensions, presenting important structures such as the celery, the olive press, tanks and the spa. One of the first owners supposedly called it I Cuniatinus Rufinus, because he was a worshiper of an indigenous divinity of its name Tribaniunis, "o *génio protetor do sitio e das boas e permanentes águas correntes do Ribeiro*" (Cardoso,2018).

General view of the excavations DGPC

1.2.3. Villa Structure

The villa can be divided in various sections: The urban zone, the rustic or productive zone, the thermal complex (which would include the bathhouse) and the necropolis, found in 1998, located on the other side of the stream. “Era preciso passer o rio para ir para o Além” (Cardoso & Encarnação, 2010).

The thermae were highly privileged, since they were destined for warm baths, or with more seasoned water, even cold one.

The celery, located southeast, was meant for the gathering and storage of the cereal. This particular one is identified as the second best in the Iberic Peninsula, regarding its ventilation conditions and protection against humidity .

The domus (manorial residence) was organized around an open court, which was surrounded by a peripheral hall, the peristylum.

In Outeiro de Polima, there is record of another roman villa or “the house of Vilicus de Freiria”, who had been a person in charge of taking care of the villa.

This villa was classified as a propriety of public interest in 1997 (Cardoso & Encarnação, 2010).

Pars Urbana
Pars fracturia
Pars rustica
Balnearium

1.2.4. Archeological findings

In the excavations, it was found several artifacts: several decorative components, such as dog-like gargoyle, a solar quadrant. Besides this, it was found multiple ceramic tools, needles, bone pins, iron alloys, and a ceramic mold with the decoration of a lion (Noé,1994).

It was also found a sacred Ara to the indigenous divinity Triborunnis used by one of the first owners of the Villa, T*itus Curiatius Rufinus.*

None of this finds are located on site but rather in the Museum of Vila, located in the center of Cascais. 12 Km away.

Roman funerary vases

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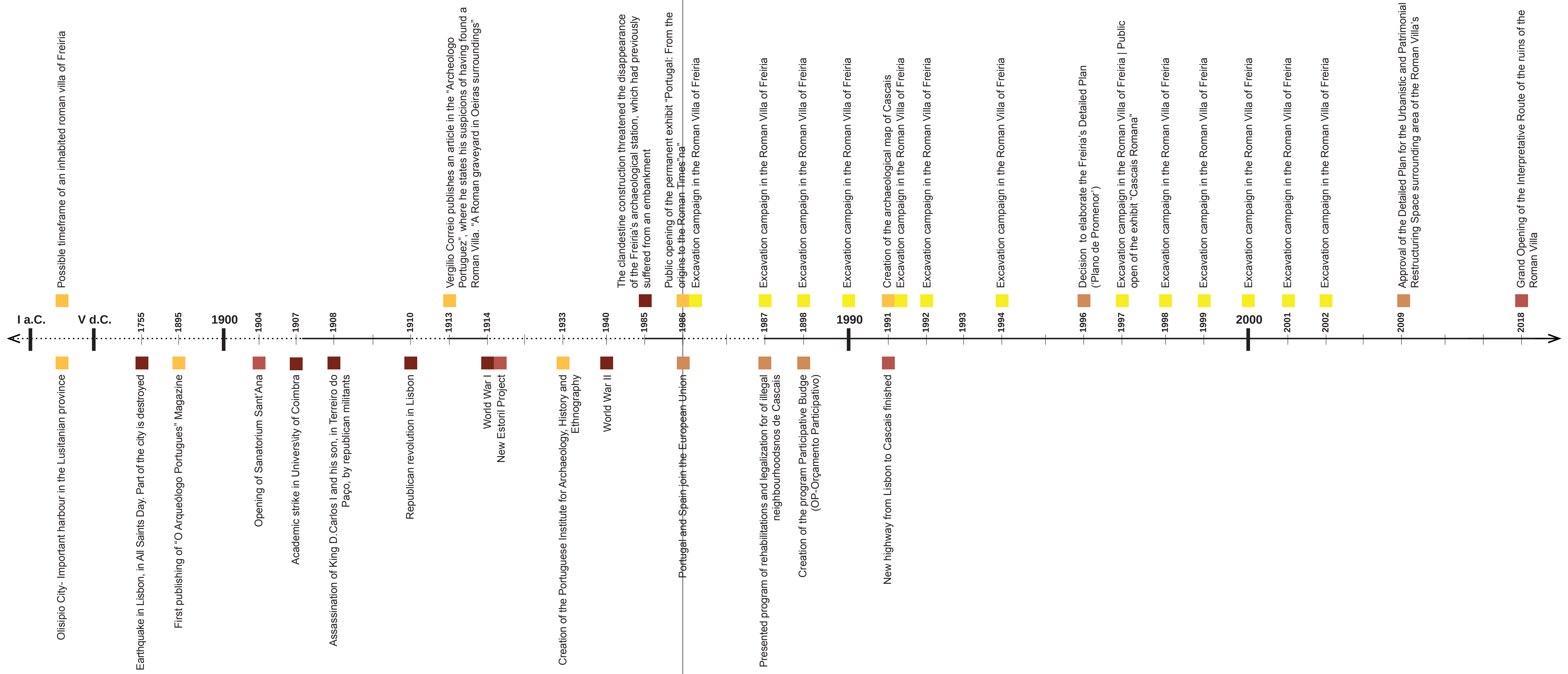
Altar dedicated to Triborunnis found in Freiria's Roman villa, S. Domingos de Rana (DGP)

Dog-like gargoyle with barred teeth.

Parcial view of the site previously (SIPA) (no date)

Peasant with ox cart, c. 1900, Caparide (Cascais.com)



2.3. Timeline:
Ruins of villa of Freiria in context with Cascais and Portugal.

- Archaeological Campaigns
- Archeology in Cascais / Portugal
- Politics
- Projects
- Other

Chapter 2 - Present

“Architecture should speak of its time and place,
but yearn for timelessness.”

-Frank Gehry

2.1. Orthophotomap

Orthophotomap: Surrownding area of roman villa of freiria, as of 2019.

Scale: 1/5000

Houston we've got a problem. How to Design for Mars?

2.2. Detailed Plan

This plan covers a territorial area of 58,523ha, situated in the parish of S.Domingos de Rana, and its limits are:

- At North/Northeast by the municipal road 1338 that articulates Abóboda to Polima and the village of Polima;

- At West by the industrial area of Abóboda and the municipal road 584;

- South by the village of Outeiro de Polima and the municipal road 584;

-At East by the Lage's stream, which separates the county of Cascais and the county of Oeiras.

The elaboration of the plan was delegated to the team of the architect José Alves Bicho and it has been in progress since 2006.

The area is characterized by the coexistence of big urban extensions of illegal genesis and areas that have important patrimonial, environmental, cultural and landscaped interest, that must be preserved.

The main goals of the plan are (but not restrained to):

-Qualify the territory, electing the environment and the patrimony as competitive factors, and act in conformity with the strategic options of social, territorial, urban, patrimonial and environmental qualification.

-Give response to the needs regarding the collective use equipments and infrastructures and promote the re-qualification of the urban areas of illegal genesis;

-Consolidate the water lines that go through the intervention area;

-Promote the landscaped framework of the Archaeological Nucleus for the Roman Villa of Freiria, implementing actions to value this part of the territory;

Scale: 1/1000

2.3. Interpretative route of roman villa of Freira

The Requalification of the roman villa of Freiria was done through a Participative Budget program (OP39) , the project was approved in early 2017 and its inauguration was in September, 2018. The total cost was of 323.269,20 euros. The intention of this intervention was to preserve, protect and publicize the ruins of the villa and to create a new centrality.

Thru this program it was possible to not only fence around the archeological site, but also develop an interpretative route (that takes around 40 minutes), done mostly in a walkway (Passadiço em português) to preserve the patrimony. The chosen material used on the walkway was wood, which fits in the landscape as a natural element. It was also integrated a wood structure that would serve as a viewpoint, and a small annex for the guard.

Pedagogical material was created both in Portuguese and English and placed along the route, which helps visitors understand each ruins history.

"*É diferente poder estar pessoalmente dentro de um local que foi habitado na era romana. (...). É quase possível sentir quais os usos e costumes*", says João Miguel Henriques, head of the Division of Archives, Libraries and Cultural Patrimony for the Municipal Hall of Cascais.

It was a necessary measure to assure the future of this important archeological site, its shows a change in the mentality

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people on how important these archeological finds are, but it was a long process to get here since the site was classified as a Public Interest Propriety in 1997, and only 20 years did the government take measures to ensure its conservation.

- Aereal Photo os the intrepertetive route, 2018. (Câmara Cascais)

2.4. Photographic Survey

Fig. XX - Panorama of site of intervention

Entrance

Wooden Paths

Walkways of the intrepertative route of the Ruins of Villa de Freiria. 2019.
From the author.

Ruin of a *'Casal Saloio'*

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Dead ead road - dangerous since the is no barrier between the road and a 1.5 meter dro adjacent to the wall.

2.5. Museum of Agrarian Explorations

As a note to the near future, in the proximities of (south of the villa) there is the existence of a typical *'casal saloio'*, where they are developing plans to turning it to a museum about the agrarian farming across time. It would be of interest to associate this museum with the future proposed project, due to being located in the middle of two roman villae (Freiria and Outeiro), (see Appendix B).

'Casal Saloio' of Outeiro de Polima (jf-sdrana)

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Chapter 3 - Project

“Architecture should speak of its time and place,
but yearn for timelessness.”

-Frank Gehry

The Smile

Location: London, United Kingdom
Architect : Alison Brooks Architects
Year: 2016
Area: 136.0 m2

Na installation made for the London Design Festival, in 2016 designed by Alison Brooks Architects in collaboration with The American Hardwood Export Council (AHEC).
It's a curved, tubular, timber structure that measures 3.5m high, 4.5m wide and 34m long. It has the peculiarity of curving up at both ends.

One of its objectives was to show the potential of CLT.

The Walk Above

Kobylí, Czech Republic
Architect: Keeo4design
Year: 2018

Area : 113.5 m2

The Walk Above is located in Kobylí, (Czech Republic) in a hill covered by vineyards designed by Keeo4design in 2018.

It's an observation deck made to overlook the vineyards. Its shaped like a 334º circle ramp segment, and iIt goes up to 7.6 m from the ground, and its fully accessible to everyone.

The use of the circle also represents a connection with the natural circle of life, and it's a symbolic reference to the growth.

Center for High Yield - Rowing Pocinho

Vila Nova de Foz Côa, Portugal
Arq. Álvaro Fernandes Andrade
Year 2008

Area 8000.0 m2

The program was exigent since it was a complex for training and preparing high performance, Olympic level athletes, it had to be designed for 130 users with a possible expansion of 2225.

The architects describe that the project itself can be divided in three areas: social zone, housing zone, and training zone.

They were very sensible to the peculiarities and identity of the pre-existing site, situated the landscape od Douro River Valley, a World Heritage Site. As such, they (re-)interprets of the two elements of secular construction of the Douro landscape: the large white bulks of the building and the ever-present terracing of the valley to use it in the project.

Fig XX - Part of the center for High Yield- Rowing Pocinho View (Fernando Guerra | FG+SG)

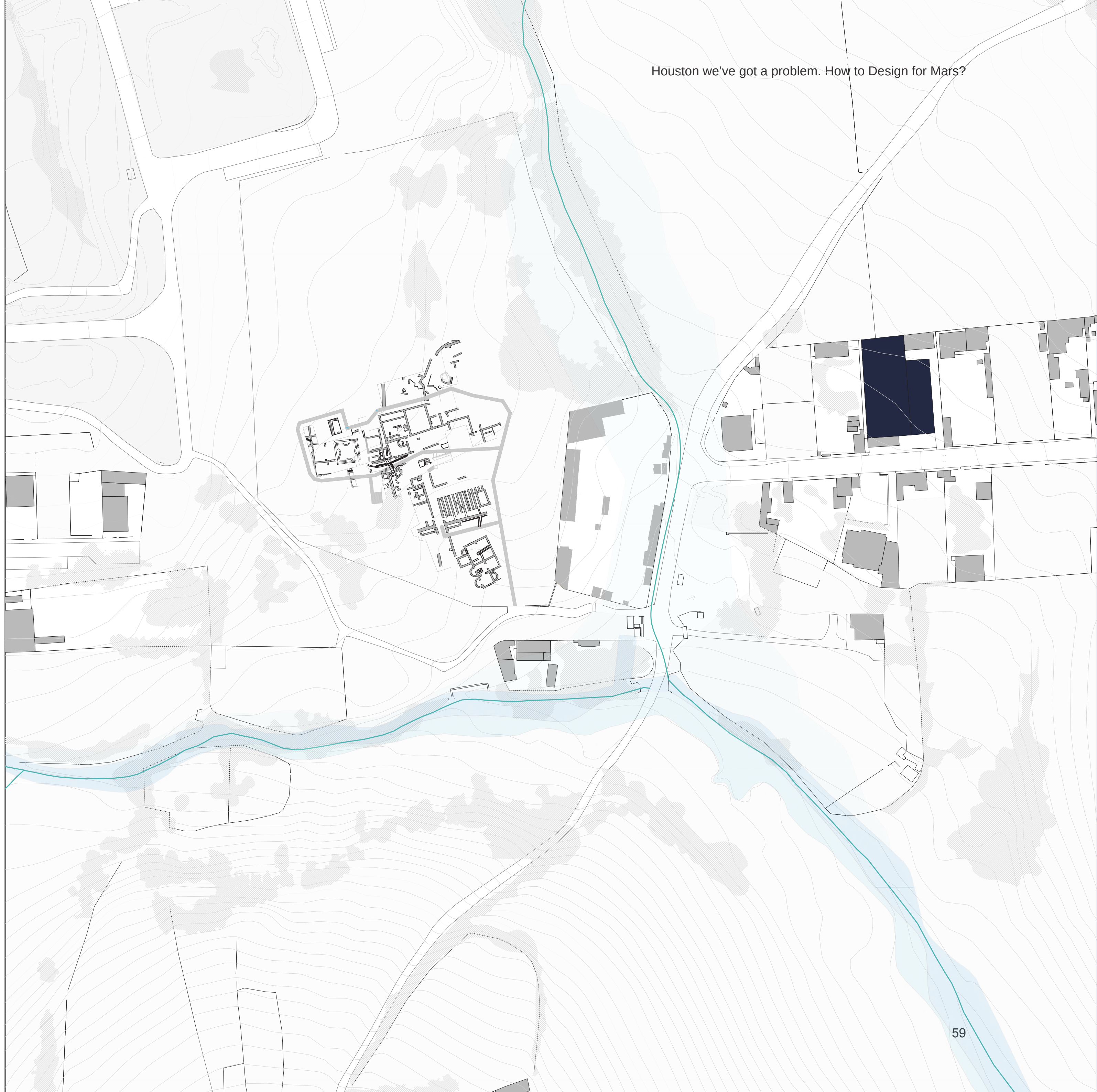
Chapter 4 - Project

“You cannot simply put something new into a place. You have to absorb what you see around you, what exists on the land, and then use that knowledge along with contemporary thinking to interpret what you see.”

Tadao Ando

The area is poor in offers in services and commerce, this is due to being moreof a residential area.

Site on present time
Scale 1/2000



Objectives and Strategy

First, as a strategy at the territorial level, the objective would be to apply the principles applied in the Roman ruins of villa Freiria to other archeological sites, to fence the sites in order to preserve them, and develop an interpretative route in each.

After this first step, the idea overall would be to develop an archeological route map that passes through the different archeological sites in the county of Cascais, and that could later even be connected to already existing archeological routes/museums throughout Lisbon.

Regarding the Cascais archeological route: the objective would for the last stop would be where Freiria's. To close this route, an equipment is necessary, both to archive the artifacts found in this various villas ruins and to consolidate this idea of the route, as such, an interpretive center was designed to complement the previous project of the county.

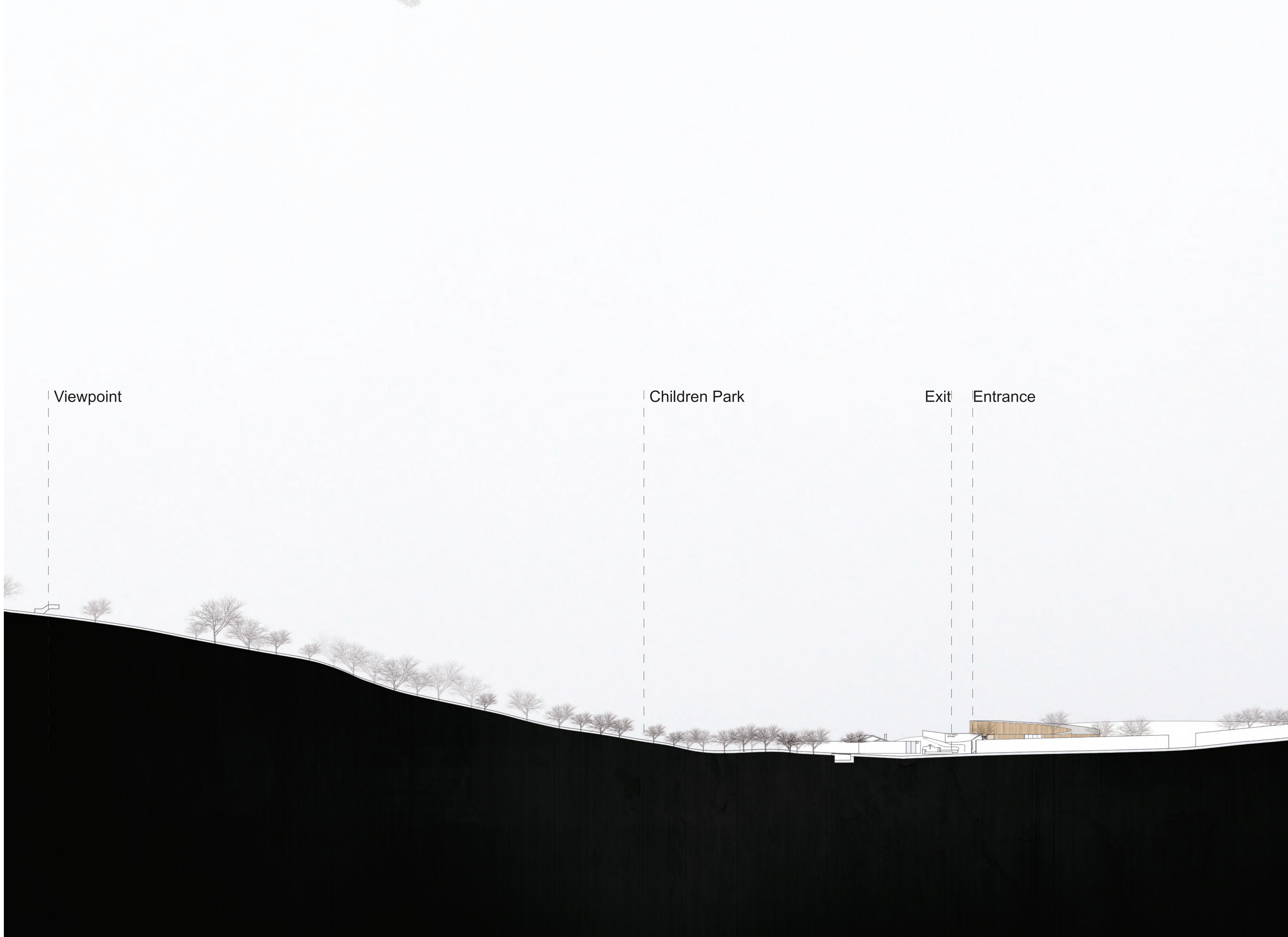
It's important to point out how difficult is to go visit the ruins of Freiria, it's very isolated, and also doesn't have a good (or better - none) transportation system, for example, taking a bus from the Carcavelos train station in direction of the ruins gets you as close as a 23 minutes' walk, in which the last 5 minutes would be a peak descent on an unbeaten path. Proper connections need to be rethought and implement a bus stop in the street of Freiria, which is suggested in the intervention plan.

This unbeaten path was also seen as an opportunity since it opened the prospect to connect the future Museum of Agrarian Explorations with the proposed interpretative center of

the Roman ruins, on foot. The path would be completely redone to be longer with less of a slope, and thus smother to go down. The path would be equipped along its route with a viewpoint plat-form, an exercise area, and a playground area. The plantation of trees and vegetation is also desired in the plan.

Another opportunity appeared in the form of an empty lot across the street. It was proposed the construction of a car and bus parking, to support the interpretative center and for the current and future residents of the area (which per the Detailed Plan, will be densely populated in the future).

A problem that also had to be dealt with was a peculiar , dangerous situation involving an open-air water line structure that had no barrier whatsoever from the street, adjacent to the walls. This particular water line is a subsidiary from Stream of La-ges that passes alongside the streets of the area of intervention. It is extremely dangerous for both cars and people that can fall easily in it. It is proposed that it's piped since there is almost no water most of the time and that a sidewalk is constructed.



Section
Scale: 1/10000

Intervention Area

The selected area of study had 897999 m2, it is a place of low density construction and with a lot oof green spaces. It was calculated that about 70% of it was permeable area, witha total of 624226 m2. Nature is still very present.

<u>In resume:</u>

Total Area: 897999 m 2
Permeable Area: 624226 m2 (69,5 %)
Estimative of intervention area: 29032 m2

01- Intrepertative center
02 - Interior 'Patio'
03 - Parking area :
 - 34 cars
- 2 bus
-Bus Stop
04- Park /Exercise aREA
05 - Viewpoint
06 - Park

The developement of the project focused in the bullding of the intrepertative center, and its surrowndings.

General Plan
Scale:1/1000

General Plan

Scale:1/500

Interpretative Center

East of the archeological site there is the existence of an illegal occupation with some constructions, an apparent junkyard. Its area is quite considerable since it occupies 2750 m2. The illegal occupants have excavated, and built a retaining wall that at its maximum point reaches the 3 m of height. The first step of the intervention would be to naturalize this terrain to its previous natural state, working the landscape and scenery that fits the natural elements of the villa.

After this property is devoid of all illegal construction and worked to be naturalized, the interpretative center would be constructed it.

The project keeps the preexisting walls (east and south wall) that limited this illegal-occupied land and the existing entrance points were also kept (two in total) and used. One would be the main entrance, that is right beside the previous path that accesses the entrance to the interpretative route and the other would be for cars, employees, and loading/unloading's.

With the naturalized terrain to walk from the main entrance to the lowest point of the interpretative route it will still need a 3 m ascent. To solve this, the building develops in two parts — the first is where the reception, small auditorium /storage, washrooms are all the same height. The second part is where the permanent exhibitions are, that due to the need to be covered must rise the 3 m, the building needed to act as a ramp with a 6% slope, having obligatory 50 meters of length.

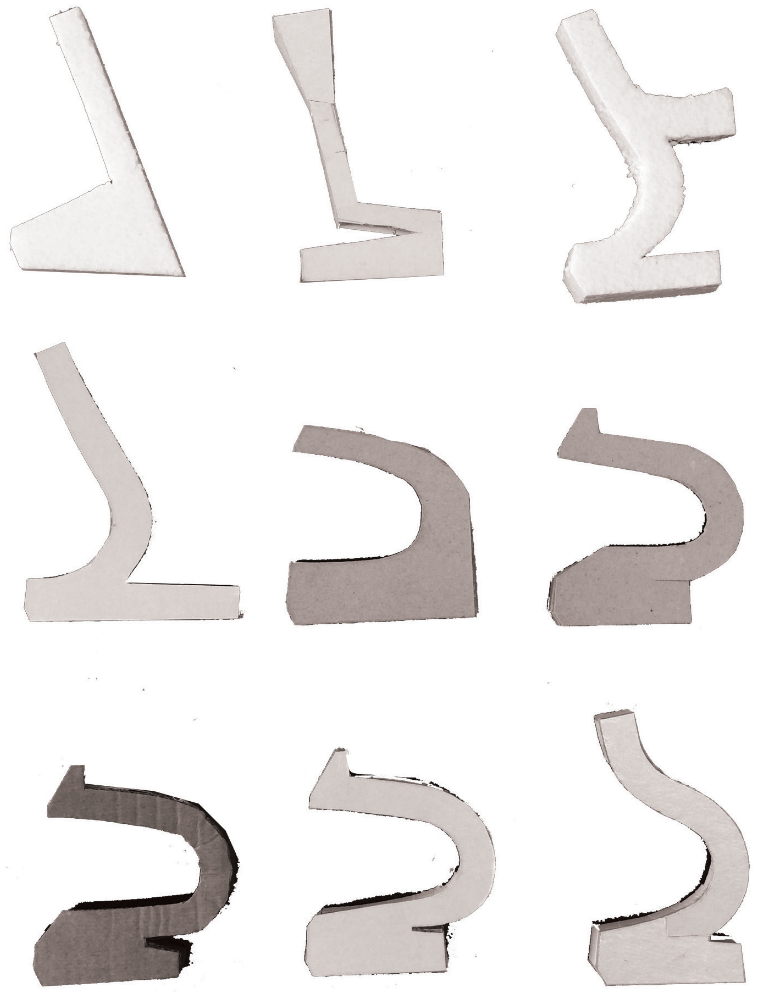
Form

In this case, the form was brought by function — this due to the 3 m difference between the entrance of the center till the exit (that gives access to the interpretative route. A way to counter that difference was by the use of a ramp — but even with 6% if needed 50 meters to rise the 3 m, hence the curvature.

This shape also allowed dividing space — the (re)naturalized terrain is kept without direct access to visitors, as such it also has the advantage of providing a area for private parking for all the employees, for and for loading and unloading, avoiding the main entrance.

The 'inside' of the curve was designed to be a public spaces, where public events could occur: gatherings, outdoor expositions, small concerts, and even theater — which could be something linked to the roman culture.

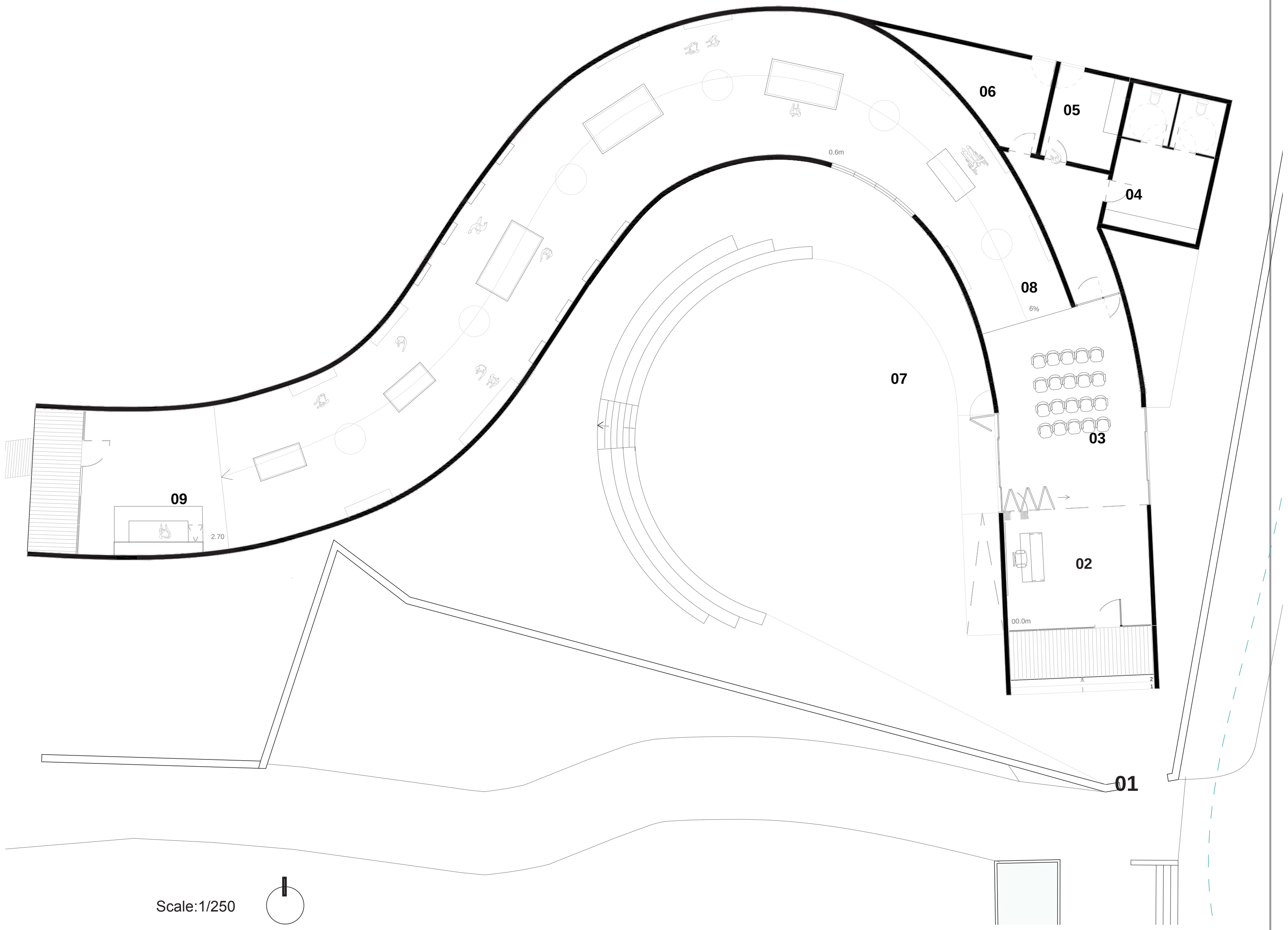
After you go through the exhibition ramp it will give direct access to the beginning of the interpretative route and after the visitor completes the route, they will exit through the existing entrance/ exit of the archeological site (exit only).



Previous explorations of form.

Plan Red and Yellow
Scale: 1/1000

Houston we've got a problem. How to Design for Mars?



Scale:1/250

Houston we've got a problem. How to Design for Mars?

Function

The aproach to the disturbution of function was to be simple - as the building is used as a ramp, a direct path to where the exhibition occurs was most of the area is dedicated to that function.

01 - Entrance
02 - Reception
03 - Multipurpose space - can be closed off.
04 - Wc's
05 - Service area (employees)
06- Storage
07- Patio
08-Exhibition Ramp
09-Souvenirs Shop

Route

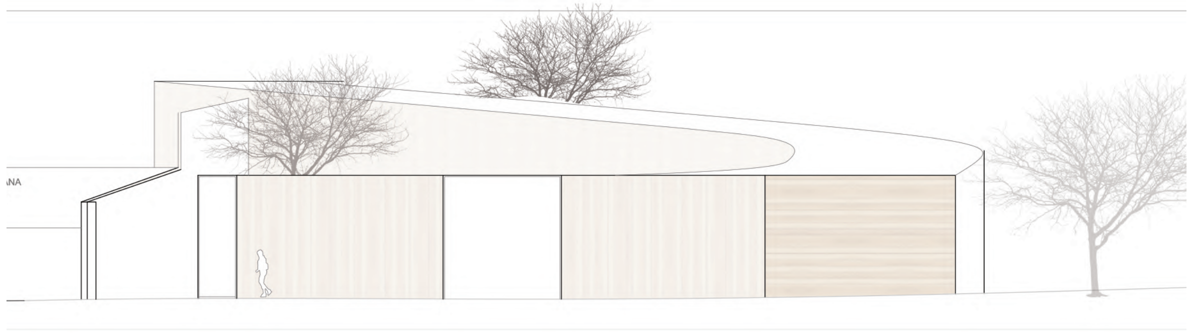
As said before, the entrance of the building is made in point B - where the person uses the building to go to point B - where the archeological spaces start and so you would be able to start walking on the intrepertative route.

To exit, visitor wouldn't go through the building again, but rather use the already existing entrance, now acting as exit only.

Construction

The building is built mostly of wood, a material heavily used in the intervention of the interpretative route. It was also chosen in

Elevations



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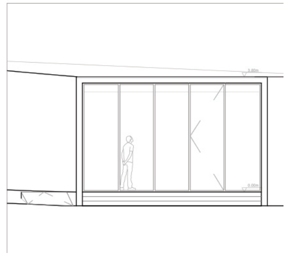
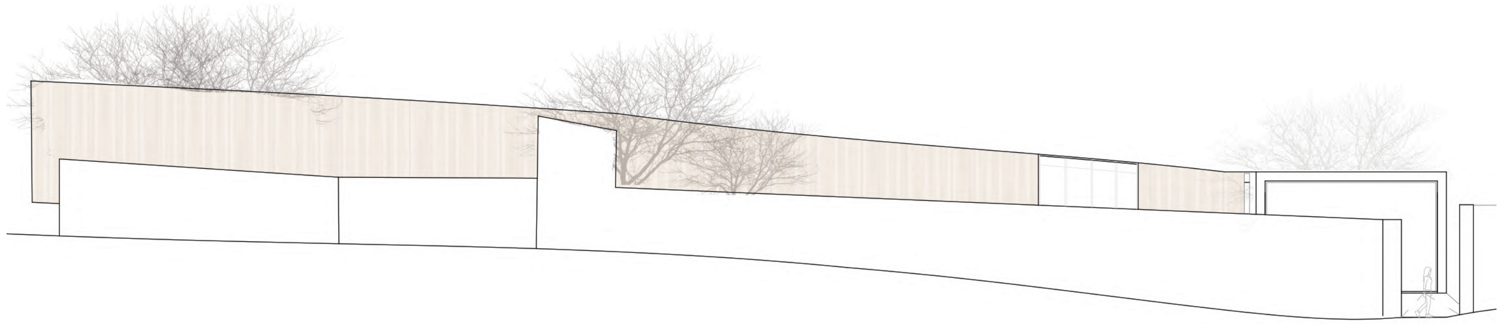
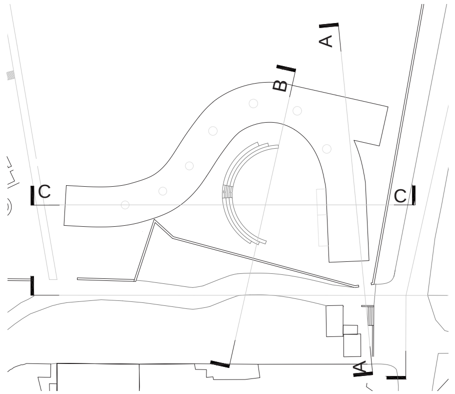
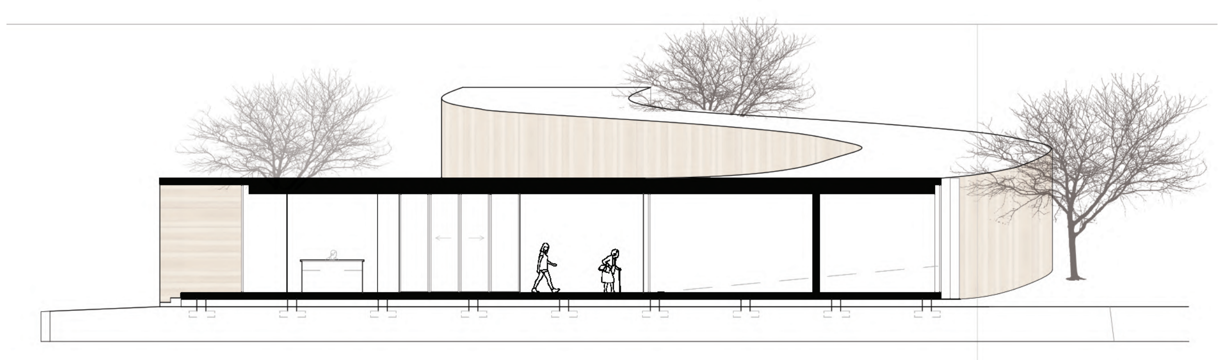
East Elevation





South Elevation





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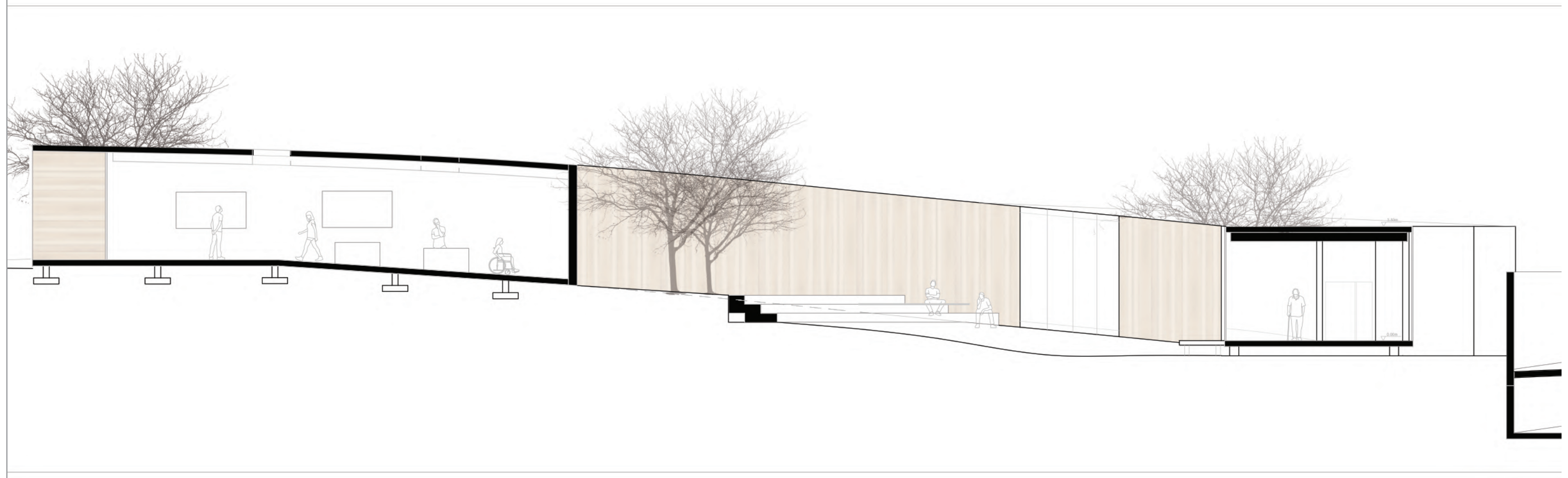
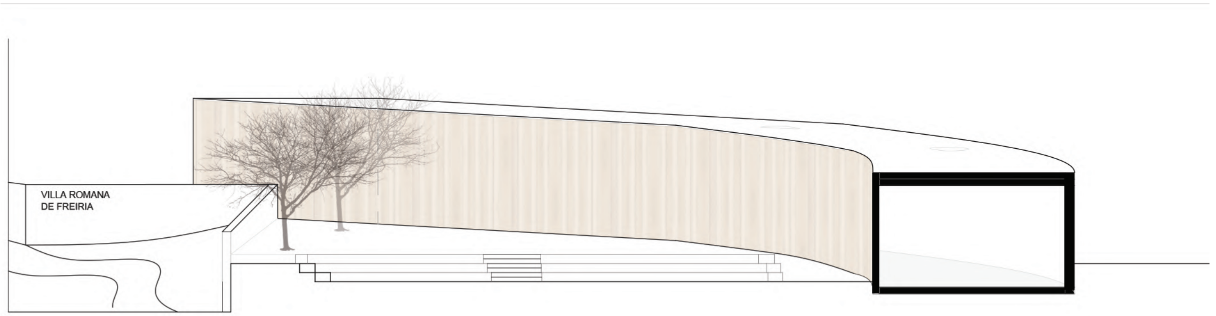
Section A



Section B



Section C

South Elevation
Sclale:

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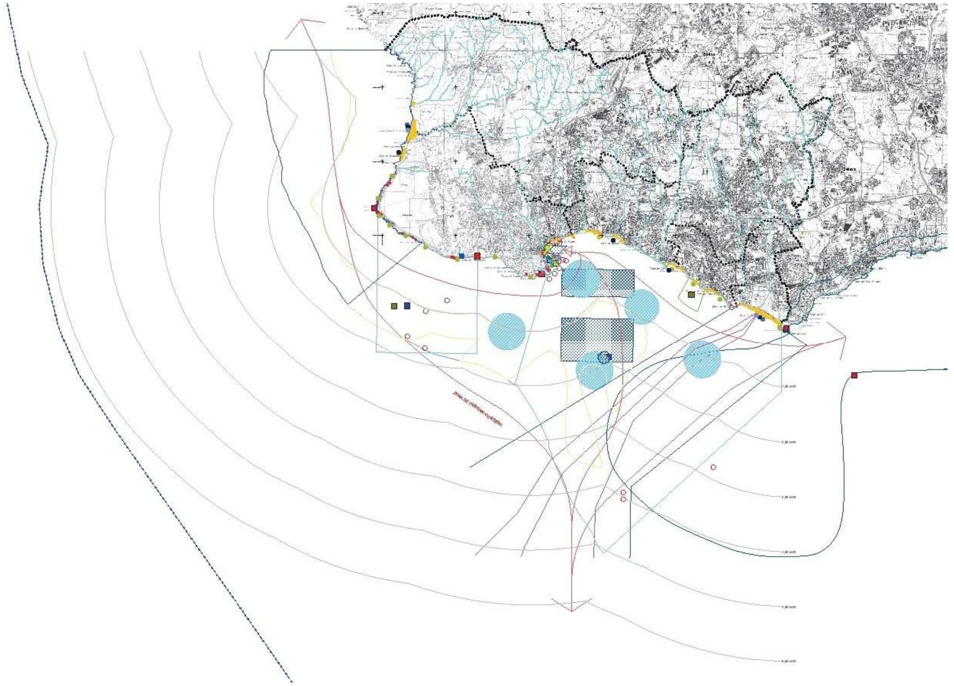
APPENDIX

ISCTE-IUL
Departamento de Arquitectura e Urbanismo
Mestrado Integrado em Arquitectura
PROJECTO FINAL DE ARQUITECTURA
5ªano, ano lectivo 2018|2019
Docente: Pedro Mendes



PDM Cascais
01.01.03 Carta do mar

bjectivos

ecto Final de Arquitectura (PFA) materializa o último ano do Mestrado Integrado Arquitectura e o início de uma carreira na área de arquitectura. Na conclusão de ., aos estudantes é requerida a demonstração da capacidade de explorar blemas complexos de uma forma aprofundada e que se desenvolvam enquadrados uma perspectiva crítica que articule as diversas áreas de conhecimento envolvidas. erá ainda ser considerado o domínio das ferramentas próprias do universo do ecto enquanto pedra de fundação do processo de investigação das propostas esentadas.
alunos é solicitado que elaborem um projecto de arquitectura que seja reflexo de rigoroso processo de investigação. Semelhante rigor é exigido na solução e unicação da solução desenvolvida. As opções assumidas, no universo do projecto, erão posicionar-se, numa perspectiva crítica, no contexto nacional e internacional área de investigação do projecto de arquitectura.

objectivos do último ano do 2º ciclo centram-se em capacitar o aluno a adquirir npetências para:

esenvolver e aprofundar os domínios da prática do projecto de arquitectura uanto processo que se materializa numa forma construída.
esenvolver a capacidade de elaborar uma leitura crítica e integrada de um território ano concreto em processo de transformação e requalificação.
ropor e desenvolver uma estratégia geral e os programas de regeneração urbana e uitectónica do território.

4. Trabalhar os objectivos, definidos em 1 e 2, num processo de simultaneidade e interacção.
5. Desenvolver e comunicar uma síntese de projecto que estabeleça o cruzamento de componentes formais, culturais, construtivas e estruturais.
6. Exploração das potencialidades da relação entre os processos de concepção de projecto e a sua representação e comunicação gráfica e oral.

2. Método

O processo de ensino/aprendizagem é desenvolvido em aulas de apoio tutorial e nos seminários/conferências sobre os temas e módulos do programa. No âmbito das aulas e seminários serão analisados, em grupo, casos de estudo relacionados com os temas do trabalho. Deste modo será possível estabelecer o cruzamento e interacção entre as componentes de carácter teórico com a prática desenvolvida nas propostas dos alunos.
Atendendo a que o desenvolvimento dos objectivos e a aplicação prática dos conteúdos programáticos se envolvem num processo não linear, pleno de avanços e recuos, caracterizado pela permanente interacção dos factores envolvidos na elaboração da síntese projectual, não é possível estabelecer uma relação unívoca e directa entre os objectivos de aprendizagem e o programa. As relações que se estabelecem, na definição da proposta final de projecto, são de carácter dinâmico e interactivo. Na síntese final da estratégia de projecto arquitectónico, a apresentar por cada aluno, não se trata de encontrar a solução ideal que responda a cada um dos factores individualmente; trata-se antes de investigar/descobrir a melhor relação entre os conteúdos e a forma arquitectónica, ou seja entre o quadro de temas e factores seleccionados para o desenvolvimento da proposta e sua concretização material e formal. Não sendo um processo arbitrário ou aleatório, a lógica da proposta constrói-se através de uma trama de relações que se definem e redefinem no universo alargado das várias vertentes da investigação do projecto de arquitectura.

3. Programa

O concelho de Cascais localiza-se a oeste de Lisboa. Trata-se de um concelho inserido na Área Metropolitana de Lisboa (AML).
A área de estudo do trabalho a desenvolver, localiza-se entre a Ribeira de Sassoeiros e a Ribeira das Marianas, estendendo-se para a Ribeira de Caparide. Esta última será tomada como referência de um território mais “naturalizado” caracterizado por uma menor densidade de construção. A área de estudo é caracterizada por um contraste entre uma rede de infra estruturas de mobilidade (rodoviária e comboio) e uma densa ocupação do território. Actualmente a área encontra-se sob uma forte pressão de ocupação, acelerada pela procura de habitação e pela abertura da School of Business and Economics.
O Exercício de projecto centra-se na abordagem da dinâmica de relações que se estabelecem entre o edificado existente e proposto, bem como do espaço público e do território. As áreas a abordar organizam-se em torno da Ribeira de Sassoeiros e da Ribeira das Marianas.
Cabe aos alunos desenvolver a leitura e interpretação do território existente e consequente selecção do tema e programa a desenvolver no trabalho. Deverá ser dada particular atenção às áreas em que as ribeiras ainda são visíveis. Deverão ser identificadas as questões chave do trabalho e apontar estratégias de intervenção. Ao longo das ribeiras, o território apresenta diversas oportunidades de intervenção. Desde Carcavelos até Tires e Abóboda, passando pelos bairros existentes até à estação de comboio de Carcavelos (requalificação de edificado e espaço público, construção de novos equipamentos, reabilitação das marcas “naturais” das ribeiras).

4 Exercício/Calendarização

Ao longo do ano será desenvolvido um exercício que se envolve numa permanente e progressiva articulação do todo com a parte e da parte com o todo.
O trabalho será desenvolvido de acordo com a seguinte calendarização. É de realçar

que as propostas deverão ser concluídas até ao final do período lectivo (Maio 2018), havendo a possibilidade de melhorar os trabalhos até Julho.

4.1 - Leitura crítica do território. Hipóteses de projecto
(Trabalho de grupo, máximo 4 elementos)
Entrega (29/10/2018): caderno síntese A2 e painel em A1, modelo 3D (facultativo), esquemas síntese, Memória Descritiva (máximo 5 000 caracteres), síntese do processo de evolução da proposta (todo o percurso de trabalho deverá ser registado em caderno A4. Poderão ser utilizados outros meios de registo complementares ou alternativos).
(Escalas 1/10 000, 1/2000) 6 semanas

Apresentações e críticas (31 Out. e 2 Nov.) 1 semana

4.2 - Proposta de projecto de Edifício/Espaços exteriores (individual)
Entrega (10/12/2018): caderno síntese A3, 3 painéis A1, desenhos em A1, maquetas, modelo 3D (facultativo), esquemas síntese, Memória Descritiva (máximo 5 000 caracteres), síntese do processo de evolução da proposta (todo o percurso de trabalho deverá ser registado em caderno A4. Poderão ser utilizados outros meios de registo complementares).
(Escalas 1/2000, 1/400) 4 semanas

Apresentações e críticas (13, 15 Dezembro) 1 semana

4.3 - Proposta de projecto de Edifício/Espaços exteriores (individual)
Entrega (25/2/2019): caderno síntese A3 e 3 painéis A1, desenhos em A1, maquetas, modelo 3D (facultativo), esquemas síntese, Memória Descritiva (máximo 5 000 caracteres), síntese do processo de evolução da proposta (todo o percurso de trabalho deverá ser registado em caderno A4. Poderão ser utilizados outros meios de registo complementares).
(Escalas 1/2000, 1/500, 1/200)

4.4 - Revisão das propostas de 1), 2) e 3) (individual)
Entrega (25/3/2019): caderno síntese A3 e 3 painéis A1, desenhos em A1, maquetas, modelo 3D (facultativo), esquemas síntese, Memória Descritiva (máximo 5 000 caracteres), síntese do processo de evolução da proposta (todo o percurso de trabalho deverá ser registado em caderno A4. Poderão ser utilizados outros meios de registo complementares).
Escalas 1/5000, 1/2000, 1/500, 1/200 3 semanas

Apresentações e críticas (25 – 30 Março) 1 semana

4.5.- Proposta de projecto de Edifício/Espaços exteriores (individual)
Entrega (27/05/2019): caderno síntese A3 e 3 painéis A1, desenhos em A1, maquetas, modelo 3D (facultativo), esquemas síntese, Memória Descritiva (máximo 5 000 caracteres), síntese do processo de evolução da proposta (todo o percurso de trabalho deverá ser registado em caderno A4. Poderão ser utilizados outros meios de registo complementares).
Desenvolvimento das soluções construtivas das propostas (1/50, 1/20, 1/10).

(Escalas 1/2000, 1/500, 1/200, 1/50, 1/20, 1/10) 6 semanas

Apresentações e críticas (27 – 31 Maio) 1 semana

5. Aferição da evolução dos trabalhos

A evolução dos trabalhos será aferida ao longo do semestre até à avaliação final. Incide sobre os trabalhos desenvolvidos pelos alunos e a sua participação efetiva tanto nos trabalhos de grupo como individuais. Será ainda dada especial atenção à regularidade das presenças dos alunos nas aulas.
No processo de aferição serão considerados os conteúdos dos enunciados do

exercício e da FUC. Será igualmente ponderado:

- O processo de pesquisa e reflexão sobre os temas do projecto.
- A clareza das propostas, nomeadamente na relação entre edifício e o contexto territorial.
- A utilização e controlo de princípios construtivos da forma.
- A incorporação de conhecimentos tecnológicos e de sustentabilidade.
- A qualidade das propostas.
- A clareza e rigor na apresentação (gráfica, escrita e oral) das propostas.
- A participação e assiduidade.

Houston we've got a problem. How to Design for Mars?

Appendix B

José d'Encarnação <jde@fl.uc.pt>
para mim
terça, 1/01, 19:43

Olá, Cheila!

É oportuna a ideia de preparar – como projecto final – uma proposta de Centro Interpretativo para Freiria. Não a pensar que as entidades competentes a venham a adoptar, mas exactamente com esse intuito: mostrar academicamente a sua capacidade de gizar um edifício com as valências necessárias ao Centro Interpretativo de uma *villa*.

Compreenderá que, na Câmara, assoberbados com tarefas como andam (a falta de pessoal sente-se por toda a parte), não lhe possam dedicar o tempo que a menina gostaria de ter e, acredite, o tempo que os técnicos também gostariam de poder dar-lhe.

1. Terá começado já por uma ponta, aproveitando o fim-de-semana: a visita à *villa* romana de Cardílio, em Torres Novas, e à de S. Cucufate, em Vila de Frades (Vidigueira). Duas outras lhe poderei sugerir, caso vá de abalada até ao Algarve: a *villa* de Milreu (Estoi, perto de Faro) e a de Vilamoura.

2. Está disponível *on line* - **Registo na Biblioteca Digital, com link para a obra:** https://biblioteca.cascais.pt/bibliotecadigital/DG103/ - a monografia do sítio, que deverá folhear com alguma atenção, nomeadamente nas sugestões dadas no capítulo referente à musealização.

3. Visita ao sítio, porventura acompanhada do seu orientador ou de alguém dos seus conhecimentos que saiba algo de Arqueologia Romana e de Museologia. A intenção é, de modo especial, aperceber-se do melhor local para a inserção do edifício que vai planear e das dimensões mais adequadas para ele. Dir-lhe-ei que, de caminho, ao passar por Outeiro de Polima, poderá dar uma vista de olhos ao casal junto à estrada e cuja foto anexo. É que para aí está pensado um pólo museológico sobre a exploração agrária ao longo dos tempos.

4. Isso me faz sugerir-lhe uma ideia meio louca, quiçá, que é a de pensar na arquitectura do centro integrando-a na paisagem arquitectónica da zona, assim como o Museu de Odrinhas se integrou na paisagem envolvente (veja imagem que junto). Louca mesmo seria a hipótese de aproveitar o que resta do casal saloio junto ao actual parque de estacionamento e 'transformá-lo' no Centro, propondo, naturalmente, o uso de materiais locais. Poderá, nesse aspecto, dar-lhe boas luzes a Arqª Amélia Cabrita, membro da Associação Cultural de Cascais, que defendeu tese de Mestrado sobre as características da arquitectura saloia. Recorde, a propósito, que o estaleiro de construções sito a nascente da *villa* vai ser demolido e atribuir-se-á a esse espaço, mui provavelmente, a função de parque de estacionamento, o que lhe dará maior liberdade para incorporar a estrutura a propor no espaço do actual parque.

5. Como interlocutores na Câmara (assoberbados de trabalho, mas elementos de primeira água para a sua proposta) são: o Doutor João Miguel Henriques e o Dr. Severino Rodrigues. Quando chegar a ocasião de os contactar, diga-me, para eu 'aplanar' o caminho. Dou-lhes desde já conhecimento desta sua intenção e acolherei as sugestões que, entretanto, me derem.

No voto de bom trabalho!

J. d'E.