A POETIC MARTIAN HABITAT

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By

MEHDI SHIRVANI

Miami University

Oxford, Ohio

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Advisor______________________________
(Sergio Sanabria)

Reader_______________________________
(Patrizio M.Martinelli)

Reader_______________________________
(Gulen Cevik)

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A POETIC MARTIAN HABITAT

"Let your imagination soar. It might be reality tomorrow" (Firouz Naderi)

"Human beings have to explore. We have always done it. We always will do it. The only thing that changes is the target" (Jeffery Kluger)

Introduction

In August 2013, I learned that anyone from all around the world could register and volunteer to be a member of first Red Planet Colonist project. I wanted to register the same night, but when I checked the website the deadline for registration had passed!

Most probably, I am not the only one who wants to explore new planets, who wants to break the limits, who wants to experience an unexperienced world.

Mars is the second livable planet. This is the notion that has been discussed for several years now, and gradually it is being taken more seriously. While many people believe that housing on Mars will not happen and it is just a futuristic dream, there are some people who are more optimistic that this dream will come true. National Aeronautics and Space Agency (NASA) is conducting much research and every year they have a competition of housing on Mars Designs. Many housing designs for Mars are being conducted by architecture students or architectural firms, as university design courses, architectural competitions or individual projects. They might seem great projects, but they lack in a very important factor for the residents and their experiences no matter where people reside identity, personal and cultural identity is key to how people perceive their experiences. The identity of people and their relationships, identity of place and its connection with people, identity of experiences and habits are shaped through time and space.

The question is, do the residents on Mars need only a building that works as a shelter or do they need more? How will the housing respond to both physical and mental needs? How will Mars housing help inhabitants not feel alienated or isolated far away from earth, where they have born, lived, and grown? This essay suggests that if human beings are going to live on Mars, they need a place that not only responds to the climate and conditions on Mars, but is also a poetic and livable space as they will be spending most of their time indoors.

To better understand the environment of Mars, a brief analytical study of the science on Mars and its conditions is discussed. However, the focus of the essay concerns the habitat of Mars.

Methodology

My responsibility as an architect is to focus more on the Architectural and livability aspects of housing on Mars idea, as I do not have neither the specialty, nor the resources to focus on the technological aspect of housing on Mars idea. I will approach this goal by a comparative analysis on the case studies of Mars Science City by BIG (Bjarke Ingels Group), the MARS HAbitat (MARSHA) project by AI Space factory, the RedHouse Red Planet project by Redhouse Architects, and Redwood Forest design by Valentina Sumini and MIT team, and also by analyzing the International Space Station design. Interviews with Valentina Sumini (MIT professor working on Mars and Moon structures), Christopher Maurer (founder of Redhouse architects and working on the materials for Martian construction), Angelo Vermulen (an artist, biologist and space systems researcher at Tu Delft University) and Chris McKay (NASA Astrobiologist), introduced later, to conduct information based on their experiences, works and studies.

Background research includes "*The Plan of Saint Gall*", a plan introduced in middle ages that has considered all the needs of the society; "*Exile Identity*" in which the feelings, needs and experiences of people in exile are discussed; "*The Architecture of Closed Worlds*" a book in which the self-reliant environments are discussed; and "Endurance", memories and stories of Scott Kelly in his one year stay in International Space Station. Also, reviews on "*How We Will Live on Mars*", by Stephen Petranek a narrative about the companies working seriously on the notion of living on Mars and interviews with key participants to see how human beings are going to live on Mars, "*Should We Colonize other Planets*", by Adam Morton, "*The architecture of Closed Worlds*" by Lydia Kallipoliti, "*What Do We Give Up and Leave Behind*", by Marc M. Cohen & Sandra Haeuplic-Meusburg, "*Human Migration To Space*", by Elizabeth Song Lockard, and "*Life On Mars: What To Know Before We Go*", by David A.Weintrub.

The result of the research is a design that uses cultural elements, colors, patterns, geometry and dimensions, and will have the potentiality of creating a space for the residents to feel connected to their identity as who they are with roots on the earth in the new context of Mars.

Although housing on Mars seems a very futuristic idea, there are some companies that have invested a lot of money and studies to make the dream of living on Mars come true. These companies are working on Space Tourism, and many people have already registered to participate. SpaceX, Blue Origin, and Boeing may be of the first three companies working on it more seriously. Even though traveling to Mars has been postponed several times because of working on the safety factors found by NASA in SpaceX's and Boeing spaceships, many volunteers who have paid billion dollars, are waiting for this journey to take place.

While some might maintain we, on Earth, are far away from Mars, and that we are separated from it and have nothing to do with it, others have a broader view that the planets, the Earth and the Mars, are in the same solar system, in the same galaxy, so we are connected even though we are far from each other. We are all a part of the cosmos.

When we talk about life or housing on Mars, it does not mean we will leave earth and go to Mars at once. Of course, Earth will always remain the best planet for human beings, but the nature of human beings is to explore.

What is Mars?

Mars is the fourth planet from the Sun and the second-smallest planet in the Solar System. Though Mars is much smaller than Earth, its surface area is about the same as the land surface area of Earth.[1]

The planet Mars, early in its history, 3.5 billion year ago, was much more like Earth. As with Earth almost all of its carbon dioxide was used up to form carbonate rocks. Unlike Earth, Mars does not have the plate tectonics, so it cannot reuse the carbon dioxide which would have helped Mars create the greenhouse effect on its atmosphere. Therefore, the surface of Mars is drastically colder than the Earth.

We now know that, though Mars may currently be very cold, very dry, and very inhospitable, this wasn't always the case. What's more, we have come to see that even in its current form, Mars and Earth actually have a lot in common. Between the two planets, there are similarities in size, inclination, structure, composition, and even the presence of water on their surfaces. And they differ mostly in pressure, temperature, radiation, gravity and atmosphere.[2]

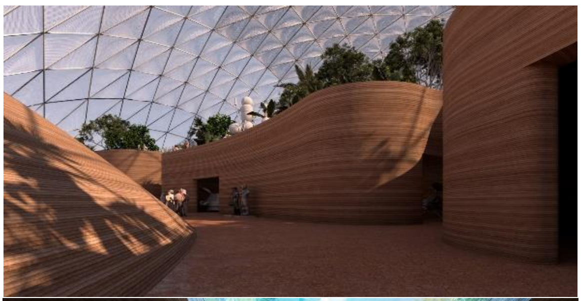
Case Studies

Human beings have not stepped on Mars yet and there is not any habitats made on Mars to be considered as A case study, but there are a number of projects and design proposals for housing and habitats on Mars, as well as some habitats in some parts of the earth in extreme conditions, like Hawaii, or other parts of the world creating the artificial Mars environment in order to simulate and study the life on Mars.

Case study 1: Mars Science City

This project is the largest simulation project which is under construction now, with the area of 1.9 million sf. Mars Science City is planned to house different programs for different groups of people such as researchers and visitors. It will include food study lab, energy lab and water lab, landscapes, agricultural areas and workshops to study the security of food and test the food.

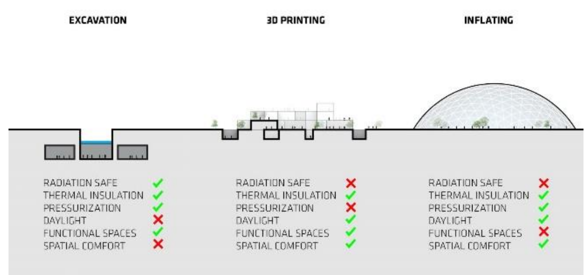
There also will be a museum to celebrate the most important space achievements and also to provide more details of the project's research for the visitors. 3D printed walls, in the museum, is one the techniques used in the project, and the sand for the walls has been gathered from the deserts of Dubai. Advanced technologies in laboratories will allow researchers to study and test living strategies and construction methods under the specific temperature and radiation of Mars. Experimental living scenario is included in the plans for Mars Science City where a team is planned to live for a full year in the Mars-like created environment.

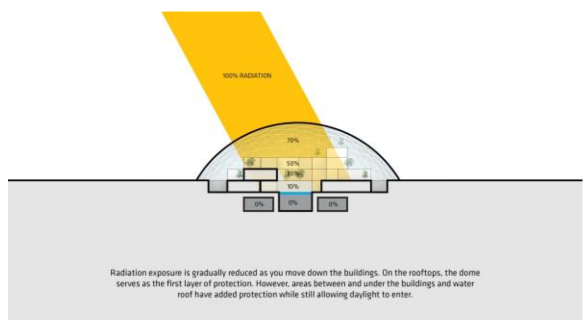


The design team has also provided some basic information about the science of Mars, compared to earth and why Mars is a better option for the second planet compared to other planets. They have also mentioned that in the suggested design, a Martian vernacular has been considered and how it will look like. As a vernacular architecture, a Martian vernacular is to design specifically for an environment like Mars where there is low gravity, low pressure, extreme colds and high levels of radiation that radically changes the architect's tool kit and the resulting architectural form and space.[3]

BIG has suggested excavated underground spaces that will have the maximum protection from harmful radiations such as solar flares. They have also designed a dome structure that covers the whole project site and protects it.

The designers believe that this module could be repeated in torus shape for urban scale design.





Even though this project seems to have considered many factors that might affect the design, I believe there are some other important factors that would have been studied as well. For the simulation site, they have considered the deserts of UEA, where the dunes move easily with winds, and the sand is soft, while based on the studies by NASA and other researchers, Mars has a hard and rigid surface.

The fact that the design team have considered other needs and activities such as education, rather than just the need for housing is also very good and seeing the project in an urban scale that could connect the complexes. Even though there are not many designs that have considered this factor, it does not seem BIG architects have studied that thoroughly and there is not a reason behind putting buildings with different functions close to each other and there is no order or hierarchy.

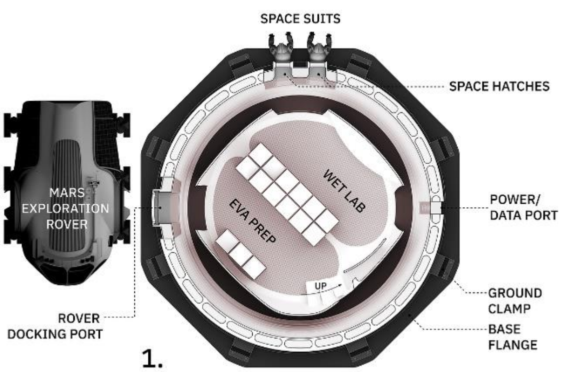
Case study 2: MARSHA Project

This project was designed by Al Space Factory for the NASA 3D Printed Habitat Challenge. The challenge was designing an effective and functional habitat, by the use of 3D printing construction techniques, for a team of four astronauts to be located on Mars. The proposed designs in the challenge were judged by the architectural layout, innovation, and the BIM modeling details considered in the proposed design.

According to AI SpaceFactory, MARSHA represents a "radical departure from previous habitat schemes typified by low-lying domes or buried structures."[4] As the result of spatial and efficiency studies MARSHA adopts a cylinder that is orientated vertically. This cylindrical shape, according to the designers' claim, allows the habitats being very effective vessels, responding well in the environment of Mars with atmospheric pressure and structural stresses. This cylindrical habitat is also claimed to be providing a high ratio of usable floor area to the volume.

According to the project information on AI SpaceFactory website, "MARSHA relies solely on materials harvested from the surface of Mars during construction. Formulating an innovate mixture of basalt fiber (derived from the planet's surface) and renewable bioplastic (derived from plants grown on Mars) the scheme eliminates the need for material transportation from Planet Earth. The construction process is also aided by the cylindrical form of the habitat, presenting the most printable pressure vessel with a reduced need for mobility" [5]. There is a large water-filled skylight on top of the structure that provides natural light for the residents. This is achieved by the intermittent windows and the light is diffused by the inner and outer shell's, which, in the designers' opinion, reflects conditions on Earth.

MARSHA habitat has four levels: there is a garage in the ground level, a kitchen and dry lab in the second level, there are some cabins and a hydroponic pond in the third level, and the Skyroom (recreational room) is located on the fourth level. Each one the four levels has one window at least, that combines to create a 360-degree panorama view. This habitat is designed to accommodate the challenging tasks during a day on, as well as creating an evocative space to maintain both mental and social health.



Even though this habitat was studied and designed for a group of four people as a challenge, there are some points of interest that could be considered in future studies:

1. Using materials harvested from Mars itself
2. The cylindrical shape that is claimed to function better in Mars climate and its pressure
3. Designing double shell separating the pressure vessel and the habitable area

Despite these details in the suggested design, There is much to be considered for any kind of housing on Mars design, and the most important question would be: Will this design be respondent for its resident's psychiatric needs in a long term such as the shape of the building, dimensions, colors, materials? In addition, if this shape is well respondent to the circumstances on Mars for the scale of a habitat for four astronauts, will the shape be an appropriate design for a larger habitat that would house more people?

Case study 3: International Space Station (ISS)

The International Space Station (ISS) is a multi-nation construction project that is the largest single structure put into space by human beings. The main construction of the station was completed between 1998 and 2011, but it is continuously evolving. Since the beginning of the 21st century, astronauts have occupied the ISS.

The International Space Station includes contributions of 15 countries.[6] United States (NASA), Russia (Roscosmos) and the European Space Agency (ESA) are the major partners of the station who also contribute the most part of the funding.

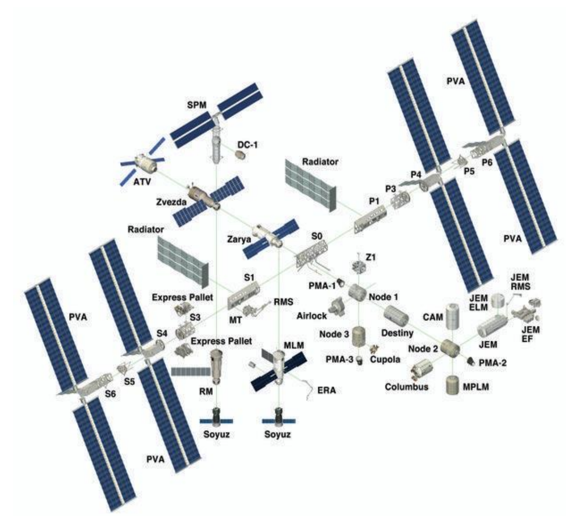
The ISS generally accommodates groups of three to six astronauts, but in different situations this number might vary. Once there were only two people in the ISS, whereas there has been a time a group of 12 astronauts have stayed there for a few days, when there was a changeover in the crews.

One of the important facts to consider is that astronauts spend most of their time on the station in order to do experiments or the maintenance duties. They spend minimum of 2 hours per day on themselves: working out, doing exercises or other personal healthcare activities. Sometimes they have to do spacewalks while they are harnessed to the ISS.

The ISS is a platform for long-term research for human health, which NASA bills as a highly important stepping stone to letting human beings explore other destinations in the solar system like the planet Mars or the moon. Human bodies change in microgravity, including alterations to muscles, bones, the cardiovascular system and the eyes; many scientific studies and investigations are trying to characterize how severe the changes are, and whether they can be reversed. (Eye problems in particular are vexing for the agency, as their cause is unclear and astronauts are reporting permanent changes to vision after returning to Earth.) [7]

Structure of the International Space Station

The space station, including its large solar arrays, spans the area of a U.S. football field, including the end zones, and weighs 861,804 lbs. (391,000 kilograms). This space structure now has more livable room than a conventional five-bedroom house. Some of the facilities and spaces include: two bathrooms, gym, and a 360-degree bay window. The living space of the ISS has also been compared to a Boeing 747 jet, by the astronauts.[8]



ISS was taken into space piece by piece and it was gradually constructed in orbit by the help of astronauts doing spacewalks and the robotic facilities. Most missions used NASA's space shuttle to carry up the pieces that weighed most, even though some individual modules were launched on single-use rockets. The International Space Station includes modules and connecting nodes that contain labs and living quarters. There are also trusses in the exterior parts, functioning as structural supports, and some of the power for the station is provided by the solar panels.

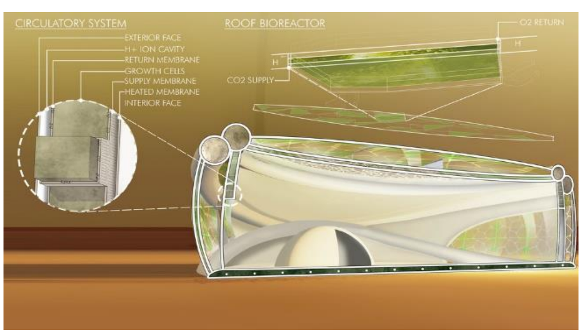
The Russia Zarya, was the first module launched on Nov. 20, 1998, on a Proton rocket. After two weeks, space shuttle flight STS-88 launched the NASA Unity/Node 1 module. Astronauts performed spacewalks during STS-88 to connect the two parts of the station together; and then other pieces of the station were taken to space and launched on rockets or in the space shuttle cargo bay.[9]

Case study 4: RedHouse Red Planet

This project is a Martian habitat design proposal by Redhouse Architects. In their design they claim that after an unmanned mission is landed on Mars, their hermetically sealed bag that contains spores and microbes is delivered with a rover. The rover also carries Carbon Dioxide (CO_2), Nitrogen and water from earth to Mars. Once the form is filled with air and water, the algae embedded in the sealed bag, starts growing. This chemical reaction creates oxygen and biomass which has enough power to fill the form (hermetically sealed bag).[10]

A strong composite is produces when fungi are released, as it binds with the dried algae biomass.

This new biomaterial uses the binding properties of Mycelium (an organism that creates mushrooms). It is then put into a brick-shaped form, or any other forms, then, they are bound together into biomaterial and the result is a material that is rigid, a good insulation, strong and flexible.



Redhouse studio's goal is to continue researching on this type of material in cooperation with NASA and MIT Media Lab, so that when constructing on Mars, we will only need a small amount of mycelium to add to the embedded biomaterial, and then it will grow fast and make the structure of the habitats.

Case study 5: Redwood Forest

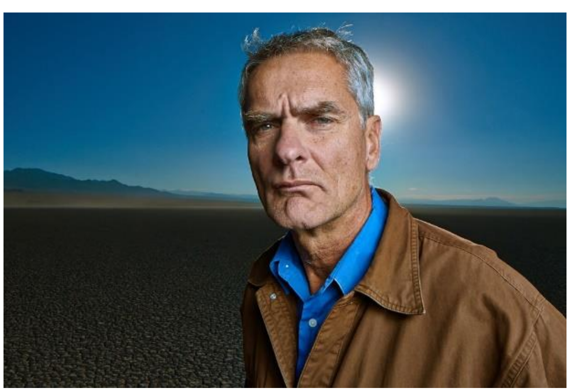
This project was designed by Valentina Sumini and MIT team, and is the first winner for the Mars City Design Competition 2017 in Architecture category. The project they have worked on they have seen buildings as trees. As Dr. Sumini says: "Even when a tree dies in a forest, the roots are still alive and the reason is that the root of this tree is connected to the root of a system of trees". In her design she has used algorithmic design to design bubble-like habitats and each bubble is a symbol of a tree and can host 20-50 people and is connected to the root system of other buildings, and they are underground in order to be protected against radiation. There are some water shafts (the water comes from the ice on the surface) that provide water for drinking and you can feel the difference between the outside and the inside. The architecture is not anymore having a building here and a building there [solo buildings with distance from each other] but we will need to create a system like a network, like how trees create a forest.

George Lordos, the system architect of this project, mentions that every tree in this design will collect solar energy and distribute water through the tree. He adds that "Water fills the soft cells inside the dome providing protection from radiation, helps manage heat loads, and supplies hydroponic farms for growing fish and greens. Solar panels produce energy to split the stored water for the production of rocket fuel, oxygen, and for charging hydrogen fuel cells, which are necessary to power long-range vehicles as well as provide backup energy storage in case of dust storms."[11]

Interviews

Interview 1: Chris McKay

I came to know about Chris McKay after watching the documentary *Mars Making the New Earth*. He is an astrobiologist and his research focus is on the evolution of the solar system and the origin of life. Chris McKay is also one of the members of the team who are planning for future Mars missions that also includes human exploration. While his colleague David Grinspoon believes there is no life on Mars, McKay believes that there is life on Mars and we can restore inhabitability on Mars after 3.5 billion years.



Chris McKay (Image from google)

Included in McKay's research is his study of plants and trees and their life in extreme environments here on earth, to learn more about the possible plant's life on Mars in the future. His specialty and studies is the reason I want to have an interview with him, as in my design I need to consider the agriculture need of the inhabitants and also how trees and plants will help in producing Oxygen.

I contacted Sr.McKay and unfortunately his schedule was really busy. Although I missed the opportunity of having an interview with him, he was nice enough to read my abstract and later on sent me two papers, hoping they are going to help me in my research process:
1. "What Do We Give Up and Leave Behind", a paper by Marc M. Cohen & Sandra Haeuplik-Meusburger.
2. "Human Migration To Space", a dissertation by Elizabeth Song Lockard

Interview 2: Christopher Maurer

Christopher Maurer is an architect, researcher and an educator. He is the founder of Redhouse Architects Studio in Cleveland Ohio. In his Redhouse studio they have worked on a proposal design for a habitat on Mars [discussed in case studies]. Maurer is also working Dr. Lynn Rothschild, an astrobiologist from NASA on a type of material that is basically made with fungi and is also strong, rigid and flexible.

Chris Maurer (Image from Google)

I had the chance to meet Christopher in his office on June 19th, 2019. After he heard about my thesis focus, he was really interested to know more in the future, and to help more. In addition to his explanation on his own design proposal for a Martian Habitat, he gave me a brief of what they are focusing and why. He also shared his opinion on the other projects designed for Mars and added that he believes that most the projects have good renders with glass domes and little houses, but he doesn't really believe they are serious scientific proposals, and they seem more like real estate sales pitches for astronauts to come to Mars.

He voluntarily agreed to contact MIT Media Lab, as he is doing some research with them, and find someone who I can meet or interview. He also mentioned he can contact his colleagues in NASA Glenn and ask them to schedule an appointment with me [even though it seems not easily possible since only US citizens are allowed in there].

Interview 3: Valentina Sumini

She is a postdoctoral associate at MIT, at Tangible Media Group, investigating human-material and inter-material interaction for sustaining astronaut life in space. Her research is focused on finding forms and structural strategies for habitats on moon and Mars. She has also won the first prize for Mars City Design 2017 Competition of urban design.

Valentina Sumini (Image from Google)

I had the hance to meet Dr. Sumini on Auguest 5th 2019, at MIT Media Lab. After I told her about my thesis and what I'm trying to work on she shared her experiences and related projects she has worked on. She started with general facts that need to be considered:
1. connection with nature (grass, water, etc.)
2. Distance and delay in communication with earth
3. Separation (from earth and our friends and families)

She continued that how we will connect to the life there and the new experience takes time and what "we call home here will be different than what we will call home there. What we call home here is not only where we live, but also who we live with. On earth we live with our families…". From this she highlighted the importance of human component and our relationships.

She added that the trip will take up to 6 month and you will be part of the crew. These are the people we will spend most of the time with and it could be big deal how we will get along with them during the spaceflight.

Based on the experiences of astronomers, Dr. Sumini added, there are 3 important factors to be able to call a place home:
1.being connected to the nature (the green element inside the habitat) as it will bring us a. little bit of earth
2. Having a responsive architecture. Architecture that will help you do daily activities.
3. Most important one, is being connected to earth and our people on it.

Dr. Sumini mentioned that creating a private space is not easy so that you will have a private environment for yourself, like people living on International Space Station. You can go into your cocoon, into your private bubble, and you can teleport yourself elsewhere. This teleportance/teleportation can bring us back to earth and connect to real life on earth. We can do the same thing on Mars, to feel the things we miss.

Another fact is the political fact on Mars. When make a large city there, how is this city going to be governed and also how do we connect different buildings to each other?

In one of her other projects, she has designed a habitat in which there is a ramp that you can walk or run to go to the upper levels of the habitat, while there is green area with trees in the center of the habitat. "When you run on this ramp, seeing the trees could give you the feeling that you are running in nature back on earth", she says.

"How we are going to feel the presence of water on Mars, where there will be no rain? We can come up with an idea that flows water in a way that could give us the feeling of the rain", she brought this up to mention the importance of water not as something we will need for or body, but also for our mental health.

“A successful design is a design that could bring the natural elements inside”.

“There has been some missions left unfinished because the crew members couldn’t have stand the situation anymore and they were psychologically under pressure. Even if we have a small a flower that we can take care of and see it grows it will have a great positive effect up there on Mars”.

She also mentioned the role of robots: “If robots are going to take care of everything then after a while we might have the feeling that there is no meaning in our presence there anymore. Also, we are the people who empower machines and robots to be in our service and help us, but if they are promoted a lot they might get scary, if our life will rely on their performance”.

Dr. Sumini also shared her project for moon with SOM Company. They have designed responsive surfaces that change according to the environmental conditions and the airflow, and some interactive surfaces, like a wall that can hug you!

Later, she mentioned a different project they are working on with astronauts in order to solve the issue of microgravity. The tail-like component is worn by the crew and it changes as they change their position. It is going to help human body to save its normal shape. The concept of this design was the seahorse.

“WHAT WE CAN LEARN FROM THE NATURE IS HUGE! We can learn a lot from nature, especially the sea world because the situation under the water might help in microgravity.”

“The perfect shape would be a spherical shape as there is too much pressure there.”

The Identity discussion was picked up by her asking me: “who are you?”, “how do you identify yourself? Normally people will answer, this who I am, this is where I come from, and this what I do.”

When we ask astronauts what they missed the most, most of them say flowers, and that we they come back on earth, they lie on the grass and look at the flower and cry.

She mentioned the study on the effect of VR. When you eat a tomato on earth its fine, but when you are on Mars or space, we could use virtual reality so when you are eating the tomato there, you could feel that you are somewhere on Earth. You can choose your desired place to be on the google map.

Here are some of the suggestions by Dr. Sumini:

- Origami structures and learning how to connect them to each other.
- Starting to write a story and imagining that I’m going to live on Mars. “Describe it for yourself. Imagine you will be away from earth for years and write about your moments. This is who I am, this is how I’m living, going to mars, what identity is, how my home look like, what a like about it, what’s the best part, what is it missing, etc. feel yourself there. If this thing is important to me it might be important to other people on Mars. What I want to see on Mars, how am I going to behave with other crew.”
- Asking my school to help me contact Analogue Missions in different location and living in one them for 5 days, so I can experience the habitat and talk to the people living there: “What you are doing is about experience, so you should go and experience this kind of life.”

Interview 4: Angelo Vermeulen

He is an artist, biologist and space systems researcher from Belgium. He is the crew of the Hi-Seas project (a simulation habitat in Hawaii). He has lived in in the Hi-Seas habitat for 4 months, and since then he has been doing researches about space, as well as working on art installations.

Angelo Vermeulen (Image from Google)

He also holds a PhD degree in Space Habitat Design and Participatory Systems Engineering from Delft University of Technology.

I had the chance to interview him in the September of 2019. He started our conversation with his experience living for four months as the crew in the Hi-Seas, Mars Simulation Project. There were many important points mentioned in our conversation. He mentioned the importance of virtual reality (VR) and even video games, helping them to stay sane. [Virtual reality could be used in many different ways. For example it could bring the nature in and helping the crew feel attached to the nature, or it could bring the street-life inside the habitat with all the lights and noises]. Angelo, also shared that not all the people like or enjoy the same things or artifacts; there are some crew who love to have a small plant in their room, looking at it, taking care of it and watching it grow; there are some who do not care to plants an collects rocks instead. He even mentioned that they had the 20-minute delay in contacting with their friends and family, which is the same amount of time that takes a message to reach Mars from earth.

He also recommended me to make my own isolated room with inexpensive materials and live there with a crew of two, and have other members outside for technical support and simulate the mission my own version.

Interview 5: Guillermo Trotti

Gui Trotti and Dava Newman (Image from Google)

He is an architect and an industrial designer. He has designed many architectural projects (Healthcare, Educational, etc.). He also has a lot experience in designing buildings for extreme environments such as remote islands.

He has worked with NASA, the Institute of Advanced concepts on revolutionary mission architecture concepts to explore the Moon with habitable rovers. He is also working with The Extreme Expeditionary Architecture: Mobile, Adaptable Systems for Space and Earth Exploration (EXP-Arch) project proposes a revolutionary way for humans and machines to explore the Moon. TAI is also working with MIT on the Biosuit project, an advanced mechanical counter pressure space suit for Lunar and Mars surface exploration. Mr. Trotti's spouse, Dr. Newman, is the designer of the Biosuit at MIT and they have given several talks together sharing their experiences.[12]

I talked to him in September 2019. He mentioned his experience working with different students working on designing a habitat on Mars or Moon. He suggested me to make some framework and rules and design in that framework. He wanted me to make decisions on what I want to do, whom I want to design and how I want to approach this project, and also to make sure I do not drawn in doing the researches only and being scared of starting the design process. Honestly, his feedback helped me a lot and took my project more seriously after talking to Gui.

Background Research and Bibliography

The Plan of Saint Gall (*Walter Horn & Ernest Born)*

The Plan of Saint Gall is building complex design in the Middle Ages. In one of the plans it is stated by the architect(s) [still unknown] that the building complex was designed for the abbot of Saint Gall, Gozbert (816-837 A.D.) according to the Stgallplan website, that studies this plan with details, the design does not fit the actual terrain of the river valley in which St. Gall is located, nor does the Carolingian church of St. Gall reflect the design of the church on the Plan. These facts have caused scholars to see the Plan as a generic solution for the ideal monastery. When, why and how this ideal was developed has been the focus of Plan research during the last fifty years.[13] I believe the strongest point of the plan is how different functions that are needed in a society have been considered. There is a specific building for every specific function, including lodgings for visiting monk, a church, a dormitory, kitchen, bake and brew house, refectory, abbot's residence, novitiate and infirmary, health services and many other functions, and the buildings for these functions have been designed well-thought and the relationship between these buildings and their location is also well-thought.

Even though this is an old plan, it helps me learn and keep in mind that for designing houses on Mars I should consider all different needs and functions for the residents.

The importance of considering different needs of the community and placing them inside the complex, in a way that the complex is self-sufficient, is not something old fashioned that could be seen in the Middle Ages. In some of the futuristic designs, like the Redwood Forest design by Dr. Sumini from MIT, this solution seems to be one the most logical and applicable solutions.

Endurance: A Year in Space, A Lifetime of Discovery (*Scott Kelly)*

This book, written by American astronaut Scott Kelly, is the story of Scott Kelly's long stay in ISS (International Space Station) for almost a year, 340 days. He shares the details and memories of his journey, from some days before the flight, during the stay and after coming back on earth. Scott took this journey with another Russian astronaut, Mikhail Kornienko, who has also shared some of his feelings and experiences in "A Year in Space". In one of the episodes of this documentary he starts with these sentences: "The technology on the station definitely tires you. Most of all psychologically. You miss literally everything. You miss water that flows from the faucet and doesn't fly around you. You want to be surrounded by nature. You miss Earth even though it is always in front of you. All the normal everyday things that we often don't value here [on Earth], up there [in space] they become the most important".[14]

How We Will Live on Mars (*Stephen Petranek)*

The book is based on a TED talk by Stephen Petrenak who is currently an editor in *Breakthrough Technology Alert.* He has begun his talk with this sentence: *"Strap yourselves in, we're going to Mars!"*

First he mentions the reasons he had on his first TED talk that there are 10 ways the world could end and that's why we have to find other planets to live on, and also that exploration is in our DNA's and it is what human beings have done for thousands of years.

He continues with bringing some facts about Mars;

- Mars is far less than the size of Earth but the surface area of Mars that we can stand on is the same surface area of the Earth.
- The atmosphere of Mars is 100 times thinner than the atmosphere of Earth, and the vast majority of it, 96%, is Carbon Dioxide which is not breathable
- The temperature of Mars is extremely cold (-81 average)
- While the day length of both planets is almost the same, seasons and years are longer on Mars (almost as twice long as of Earth)

Petranek predicts that we will be on Mars in 2027 and he also mentions that Elon Musk, CEO of SpaceX, believes that human beings will land on Mars by 2025, and it is in a way that NASA believes we will be on Mars by 2040.

He continues by naming four important elements we need to survive on earth, including: water, food, shelter and clothing, and adds that in order to survive on Mars we will need Oxygen as well as the four mentioned elements.

All these elements are discussed further and separately by the author;

Water: is the most fundamental need of all life and it will be very heavy if carried from Earth to Mars. That being said, we will need to find a source of water on Mars itself rather than carrying it from Earth. Even though the images of Mars might show it like a dry desert, there is water on it! The Martian soil has 60% of water and also it seems that there is ice on the surface of Mars. There is also, based on the data orbiters give us, underground water and some glaciers.

Oxygen: it is the next crucial element we need to worry about and find a way to overcome the issue. This problem seems to be solved already by NASA with Moxie, a machine developed by Michael Hecht, MIT scientist. This machine sucks the Martian air and produces Oxygen. [This machine is still being developed and will be sent to Mars in 2020].

Food: what we will eat on Mars is the third crucial need we have to consider in order to survive on Mars. We will not be able to produce more than 1/5 of our food before we will have access to sufficient source of water, so, the food sent from Earth and some limited hydroponic foods, will be the food on Mars.

Shelter: where we need to live on Mars is the next important factor to be considered. Stephen Petranek suggests that in the early stages we can use inflatable and pressurized buildings, or maybe the landers themselves, but of course this is a short-time solution, and in order to keep safe from the radiation, we will need to dig deeper and move undergrounds. He also adds that NASA has already found a solution for this problem by throwing polymer plastic into the brick-which could be made from the Martian soil- and after they are pressurized in a microwave oven, they will be ready to be used for making walls. Petranek also adds that we might end up living in tubes or caves in the underground.

Clothing: this is the last most important fact that needs to be considered in Martian life. As there is not much atmospheric pressure on Mars we will need well-designed suits to wear. Dava Newman [who I am also trying to interview, and also her husband Guillermo Trotti, who is a space architect] is an MIT scientist who has been working on this idea and has developed a space suit responsive in Martian environment and will protect us against the radiation as well as keeping us warm.

Petranek continues by claiming that the next step would be to make the atmosphere and the environment of Mars look like earth. This process is called Terraforming.

Stephen Petranek, reminds us of the Neil Armstrong stepping on the moon in 1969 and that people started saying, "If we can get to the moon, we can do anything". He adds that if we get to Mars, we can go anywhere!

He also claims that we [human beings] have had the power and technology to land on Mars for the past 50 years, after landing successfully on the Moon with Apollo 11 mission.

Petranek brings the example of *homo sapiens* [our human species began to evolve with homo sapiens about 200, 000 years ago] who ventured out of Africa about 60,000 years ago, and they pushed the boundaries and horizons until today they have populated the whole globe [all human beings are classified as homo sapiens]. He also adds that: "Exploration maybe connected to human survival".

In the beginning parts of the book Von Braun's ideas and designs to how to land on Mars is widely discussed.

Petranek has also raised some questions about landing and living on Mars, and has added some kind of support and answer to the questions. The most important questions are about the gravity, human relationships with each other for a long time, what will happen if someone gets ill, and radiation on Mars.

In the final chapter of the book, a brief history of the *Age of Discovery* that happened about five hundred years a go by Europeans to explore new places and the result was people being residents of the Earth, entirely. He uses this history to support the idea of exploration of Mars, and landing and living on it will be a changing point in the history and people will be multi-planet residents, but we should definitely do our best to save our home planet as we will never find a planet like Earth anywhere.

He adds that: "voyaging to Mars may give us the insight to see our planet in true perspective".[15]

Should We Colonize Other Planets? (*Adam Morton)*

Adam Morton is a Canadian philosopher and in his *Should We Colonize Other Planets* he discusses the colonization plans in a critical way.

In the early parts of the book, Morton studies the *Escape from Earth.* He mentions issues on Earth such as global warming or the combination of different hazards: war, hatred, and environmental damages. He admits that the threats are serious and that these facts raise questions that will be discussed in the book.

Morton, brings an example to highlight the philosophical issue of *frame problem* in Artificial Intelligence (AI): "if you tell an AI program "take everything out of the fridge and put it on the table", you may find that all the dirt in the fridge and the light bulb and the drawers are also on the table. It takes you at you literal word, but it is hard for humans to see what their literal words, especially taken in large quantities, actually entail. The result is unexpected consequences that paradoxically comply with what we asked for." This discussion is brought by Morton, to add to different dangers human beings might have in moving to Mars; the idea or fear that machines might be beyond the control of human beings.

Morton discusses if we consider the extinction of human beings threat as a possible threat on our home planet, the Earth, we will need a different planet to help the human beings survive, and Mars seems to be the best place to colonize.

In the first chapter of the book Morton gives some general information about the Planet Mars:

The distance of Mars from Earth is between 54.6 to 401 million km, depending on its position orbiting the elliptical axis, and predicting that a one-way trip to Mars will take about nine months when the Mars is in its closest distance. Solar energy is weaker than the earth, but still it will possibly be the largest energy source on Mars. It is also highlighted again why Mars would be the best option in the solar system to colonize: planets closer to the sun will be extremely hot, and planets further away are extremely cold, and moon also is not a good choice as it has huge variation in the temperature and it does not have any atmosphere.

Morton also claims that the structure that will be built on Mars has to be solid enough, otherwise it will be exploded due to the extreme pressure on Mars and he suggests using heavy materials so solve this problem. As carrying materials from earth will be very expensive, he suggests using the local Martian materials to do so.

Adam Morton, in the last part of highlighting problems with colonies on Mars, brings an agricultural fact and problem. He mentions that the Martian soil is very rich in Perchlorates that reacts to the violet light. As the atmosphere of Mars is transparent, it will make the atmosphere almost completely fatal for the cells and crops. Even if there is hope that indoor farming is the solution, it should be kept in mind that Perchlorates could be exploded if heated. This fact makes it harder to produce Oxygen from the soil on Mars by heating it.

Morton, later on in his book discusses the *three kinds of catastrophe* including: Physical, Medical and Social.[most of which discussed earlier].

In the last chapter of the book, Morton talks about why he believes that *Human Colonization is Bad Idea.* He mentions that the questions he raises here are not the issues to put in the foreground of the colonizing Mars plans. The first question is about the continuation of the human species and the biological life, and the second question is "how long we should think about colonization proposals before doing anything".[16]

The Architecture of Closed Worlds (*Lydia Kallipoliti)*

This book explores the development of closed systems including: space capsules, submarines and office buildings in the 20th and 21st centuries. Kallipoliti has begun the book with the oldest closed system, and then the book is continued to the newest one. Each project is described by some written description and history, and there are some diagrams explaining how the whole systems works and is being heated or cooled, or how they go to the deep oceans or how they fly. There are 37 case studies or living prototypes in total, and the oldest one is a project in 1928.

Each project come with a color-coded graph that shows the systems and their resources life-cycle, and making it easier for the reader to understand the functionality of the prototype.

As mentioned before, the book contains many different closed systems including, Bucky Fuller geodesic dome, House of the Future, Disneyland project (EPCOT), the FNRS Balloon, Rocky Mountain Institute, Biosphere 2, and many more. Some of these projects are directly related to my project, like Biosphere, which was a simulation project to study the human life in outer space, and there are lessons to learn from other projects; from their form and geometry, their failures, the systems and functionality.[17]

What Do We Give Up and Leave Behind
(Marc M. Cohen & Sandra Haeuplik-Meusburger)

This paper studies the following question:

What will happen when a crew must give up so many of the familiar things, comforts, and personal associations that they [the crew] take for granted?

The authors begin their discussion by bringing the cover image of "the golden age of science fiction" showing Noah's ship in a more modern science fiction form, and they highlight the question of what and whom to leave behind. It is also mentioned in the introduction of the paper that the psychological aspect of living in space is the focus of the paper.

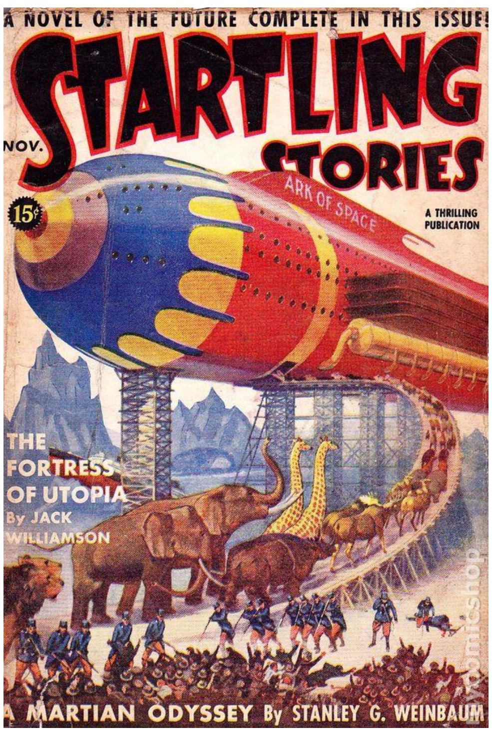


Figure 1: Nov 1, 1939 Startling Stories Martian Odyssey by Stanley G. Weinbaum

The paper is continued by a short history of the minimalist mission proposals, most importantly by Robert Zubrin, who in his design suggested that the key to have the playload delivered on Mars is to use the available resources on the surface of Mars in order to make fuel, oxygen and water. More minimalist design proposals for crews with different number of members, designed by different companies, designers or engineers are discussed with their diagrams, dimensions and capacity. Mars One, for instance is discussed in the paper and its diagrams, dimensions, number of crews it ca carry, how the crew will bath, etc. are discussed briefly with some percentages of the needed gas for agriculture purposes and oxygen need. In Addition, some of Mars One's vague features, such as not mentioning the place where crew can rest, eat or exercise, are discussed.

In chapter three, the critical habitability is discussed; "in 1985, Rockwell International completed the space station crew safety". The alternatives studied for NASA included five volumes with hazards and threats the crew will potentially face and have to overcome.

The Crew Safety-Human Factors Interaction Model.

1. Protocols, such as stressors exacerbated by varying degrees of autonomy from ground,
2. Critical Habitability, such as living in a closed atmosphere with severe volume limitations, noise, and sanitation
3. Task-Related Issues, such as responsibility for task assignment, role definition, monotony, and boredom,
4. Crew Incapacitation, in terms of illness, injury, or and emotional or mental health problem, and
5. Personal Choice, such as restrictions on cooking or eating habits, restrictions on personal property, and limits to personal hygiene.

Among which, the Critical Habitability seems to be the most related to the issue of the crew surviving in long and extreme missions. From the critical habitability, the authors highlight the question of what is lacking from the living and working environment.
It is continued that even though there are very important psychological dimensions to the performance and experience of the crew in long-duration flights to space, a more philosophical perspective is taken in this paper.

TABLE 1. CRITICAL HABITABILITY I[7]

STRESSORS ON THE CREW	COUNTER-MEASURES AGAINST STRESS	DEGRADED CREW PERFORMANCE	COUNTER-MEASURES AGAINST ERROR	CREATION OF POTENTIAL SAFETY HAZARD
Volume Limitations: Insufficient Pressurized Volume, Inadequate Free Volume.	Architecture, Design, Privacy, Windows, Stowage, Sufficient Work Envelopes.	Feelings of Claustrophobia, Lack of Privacy, Irritability.	Increased Privacy or personal space, More Volume, Evacuation.	Irritability, Conflict, Paranoia.
Noise.	Vibration Isolation, Control.	Sleep Disturbances, Sleep Deprivation, Circadian Desynchronization, Poor Communication.	Earmuffs, Headsets, Drugs, Communication Devices.	Failure to Respond, Failure to Communicate, Failure to Coordinate.
Inadequate Housekeeping (or Lack thereof)	Routines and Training, Assignment of Responsibilities, Teamwork.	Environment Quality Deterioration, Unhealthy or Unsanitary Environment.	Assignment of Responsibilities, Teamwork.	Breakdown in Life Support.
Lack of Hygiene, Lack of Cleanliness.	Improve Personal Practices, Repair Hygiene Facilities, Training.	Discomfort to Others, Illness, Disease.	Group Standards, Teamwork.	Individual or group Illness, Inability to Perform Tasks, Death.

Fig. 1. Table 1 this table is brought directly from the original paper by the authors where they discuss 5 concerns of habitability in a space-flight

In the above table, the 5 concerns of habitability in a space-flight and a space mission with more aspects and details are discussed by the authors. The architectural design of the spaceship or the space habitat is mentioned as the first countermeasure against the stressor. [Privacy, windows, environmental quality, etc. are some very important aspects that could have a direct or an indirect effect on the performance of the crew or inhabitants].

Table 2 also shows some other aspects that could affect the physical and mental health of the crew.

TABLE 2. CRITICAL HABITABILITY II

STRESSORS ON THE CREW	COUNTER-MEASURES AGAINST STRESS	DEGRADED CREW PERFORMANCE	COUNTER-MEASURES AGAINST ERROR	CREATION OF POTENTIAL SAFETY HAZARD
Thermal/ Humidity, Closed Atmosphere – odors, bad air.	Environmental Controls	Discomfort; Irritability, Illness	Air Movement; Gas Composition and Control; Temperature and Humidity Control; Mitigation Against Inadequate Environmental Controls	Increased Anxiety, Toxicity Concerns, Threat of Heat Prostration, Cold Injury, Illness, Suffocation.
Confinement, Isolation, Separation from society, Separation from nature.	Reliable Comm with Family and Friends, Social Events, Recreation, Counseling, Architecture, Stowage.	Loneliness, Morale Deterioration, Impaired Judgment, Skewed Perception Under Stress, Claustrophobia.	Group Activities, Hobbies; Personal Interests, Judgment Checks, Color Coding, Lighting; Multiple Access to Modules, Mobility Aids.	Breakdown in Group Process, Faulty Teamwork, Mistakes in Judgment, Perception, or Action, Paranoia, Depression.
Artificial Lighting.	Lighting Design, "Natural Light."	Fatigue, Irritability, Blurred Vision	Indirect, soft lighting, Special Task Lighting.	Mistaken Perception,

Table 1 this table is brought directly from the original paper by the authors where they discuss 5 concerns of habitability in a space-flight

The paper is continued by the crucial questions and concerns the authors ask considering the sacrifices the crew members will make, in a long-time mission in space. These questions are discussed in 6 categories by the authors:

A. Restricted Diet: the authors raise the question of what will happen if the crew or inhabitants do not have fresh vegetables or food for a long time? Will this fact affect the crews' performance? Will the crew need to drink beer and alcohol to help them relax and if yes, should/could they brew their own drinks, like Monks did in the Middle Ages? Will the fact that they will never eat fresh foods or vegetables affect their mental and physical health? These questions are asked by the authors because they believe food is of great importance helping the crew perform well. They also continue by pointing in what astronauts and polar stations feel about growing plants in the space or Antarctic stations? They [space or Antarctic crew] refer to the plants as their love or pets, showing the mental effect of growing plants in extreme environments.

B. Constant Confinement: The issue of not being able to go outside without wearing a spacesuit and never feeling the fresh air, is highlighted in this part of the paper. The authors point to the issue of constant isolation, living and performing in limited volumes, and breathing recycled air in a mechanically controlled environment.

C. Disconnection from the Natural World: losing the contact from the natural world, where humans evolved and how it may feel for the crew not to be able to swim, see different seasons, walk in the woods, etc. is the third issue focused by the authors. The importance of water and the fact that people live, play and work on the water, and how water shapes human experiences, is also discussed in this part of the paper. There are also some questions about Martian life at the end of this part: "how will a Mars crew "blow off steam", celebrate, relax in a merry company?" "what will it feel like to never go on a picnic and enjoy the pleasures of a fresh breeze on the naked skin while chanting with friends?"

D. No Family Life: How will the crew members be affected by living without their family members or pets, is the fourth question of the authors.
Cohen and Haueplik, also bring in the discussion of first and second generation of humans moving to Mars and the children born on Mars, and raise the question that if the environment

of Mars habitats will be healthy or not, or what will happen if these children want to come back to Earth?

E. No Separation of Work and Social Life: "How it will look like to socialize with the limited number of people for a long time?", is the next question asked by the authors.

F. Repetitive and often Meaningless Tasks: How will feel for the crew to follow the same routines and tasks every day, for a long time, is the other question asked in this part. in this part, like other parts of the essay, the authors have referred to the study done by Dudley-Rowely et al, who have considered the task related issued.

At the end of the paper, the authors claim that they believe the Mars mission could be done successfully and the questions they are asking is not to tell that it is impossible to be done. They remind that they have tried to highlight some neglected areas and aspects in order to help Mars missions consider, like the size of the habitat and psychological effects on the crews performance.[18]

SITE Information

For my project site I did a lot of research and I checked NASA's studies on different location on Mars. NASA has chosen Jezero Crater for the 2020 Mission Landing Site. They have chosen this site after five years of studies and intense researches on 60 candidate sites.

Scientists rated each of the criteria for the potential landing sites of the Mars 2020 rover. NASA considered these results from the Mars science community as a key input in narrowing down Mars 2020 landing sites from eight to three.

Criterion1:
The site is an astrobiologically-relevant ancient environment and has geologic diversity that has the potential to yield fundamental scientific discoveries when it is a) characterized for the processes that formed and modified the geologic record; and b) subjected to astrobiologically-relevant investigations (e.g., assessment of habitability and biosignature preservation potential).

Criterion2:
A rigorously documented and returnable cache of rock and regolith samples assembled at this site has the potential to yield fundamental scientific discoveries if returned to Earth in the future.

Criterion3:
There is high confidence in the assumptions, evidence, and any interpretive models that support the assessments for Criteria 1 and 2 for this site.

Criterion4:
There is high confidence that the highest-science-value regions of interest at the site can be adequately investigated in pursuit of Criteria 1 and 2 within the prime mission.

Criterion5:
The site has high potential for significant water resources that may be of use for future exploration-whether in the form of water-rich hydrated minerals, ice/ice regolith or subsurface ice.[19]

There were 3 finalist sites including:

1. Columbia Hills, Gusev

2. Jezero Crater

3. NE Syrtis

JEZRO CRATER REGIONAL TOPOGRAPHY

Isidis basin, about 1500 kilometers (932 miles) in diameter, was the last of Mars' large impact basins to form. The landing site of Mars 2020 will be in Jezero crater, on the northwest edge of the basin. Nili Fossae is a region of fractured terrain. Geologists think that the fractures in Nili Fossae formed as a result of the Isidis impact. Syrtis Major, to the southwest, is a volcanic region. This map shows topography derived from the Mars Global Surveyor Mars Orbiter Laser Altimeter (MOLA). According to the scientists' researches and rovers' samples and satellite maps and high quality images, Western Isidis offers one the most interesting landscapes on the red planet. Jezero crater is 49 kilometers (30 miles) wide and it has a large diversity of different minerals, and offers many important sampling targets of different rock types (at least five types) Jezero Crater's ancient lake-delta system offers many promising sampling targets of at least five different kinds of rock, including clays and carbonates that have high potential to preserve signatures of past life. In addition, the material carried into the delta from a large watershed may contain a wide variety of minerals from inside and outside the crater.[20]

Jezero Crater, Wet and Dry and Wet Again

Jezero Crater tells a story of the on-again, off-again nature of the wet past of Mars. About 3.5 billion years ago, or perhaps more, water filled and drained away from the crater on two occasions; the river channels spilled over the wall of the crater and formed a lake. There are evidences seen by scientists that after the lake dried up, water carried minerals from the surrounding areas into the crater. They believe the microbial life could have existed in Jezero Crater during at least one of these wet periods. And if that is the case, the signs and clues of their remains could be discovered there (in the lakebed sediments).[21]

DESIGN PROCESS

Diagrams; Fractal Diagrams

I started my design process by studying 2d and 3d fractal diagrams. The fractal diagrams helped me understand how spaces in different sized-modules could be connected and grow in different directions. Fractals are highly ordered geometry that could be repeated and grow infinitely. They suggest different modules in different sizes that could give the opportunity to be used for different functions, as large as city, or building, or as small as a black box that could be used as a black box that could be used for plumping or duct works in architecture.

Diagrams; Chaos Diagrams

I also studies and worked on chaotic diagrams to free my mind from the geometry and restrictions. So having my program in my mind I let chaos show me the way. I have to say that it took me some time to trust chaos and it was not easy at the beginning! You can see some of my earlier diagrams here and the latest ones in the bigger scale.

Master plan

I tried to apply my program to fractal, which is very ordered, and to chaos, which is very random, and then merge these two at some point. I learned many things from each of them. Fractals gave me the opportunity to use different sized modules for different functions in all directions, and if it was not for chaos, I wouldn't have tweaked some of my design ideas such as having the green space as the heart of the complex.

PROGRAM

After doing some research and interviewing experts, I decided to design my Poetic Martian Habitat for the first 72 people colonizing Mars. These crew should have different skills in different fields to help everything work. They include:

- ENGINEERS: 18 *(Gas 1 / Mechanical 3 / Electrical 1 / Water 2 / Waste-Recycle 1 / Economist 2 / Material 1 / Structure 1 / IT 1 / AI 1 / Air 1 / Robotics 2 / ICE 1)*
- GEOLOGISTS: 3
- BIOLOGISTS: 3
- CHEMISTS: 3
- MATHEMATICIANS: 2
- PHYSICISTS: 3
- ASTRONOMERS: 3
- DOCTORS: 3 *(Dentist, women specialist, etc)*

- NURSES: 2 *(Taking care of patients + assisting doctors)*
- PHYSICAL THERAPISTS/BODY: 2 *(Training for muscles & bones + exercises)*
- PSYCHOLOGISTS: 3
- SOCIOLOGISTS: 3
- PHILOSOPHERS: 3
- NUTRITIONISTS: 3 *(what to cook/eat-how /what to grow and farm)*
- AGRICULTURE/GARDENER: 4 (Food 2 - Beauty/landscape and flowers 2)
- ARCHITECTS: 4 (Interior, Landscape, Material, Structure)
- LITERATURE: 3
- MUSICIANS: 3
- VISUAL ARTISTS: 2
- DOCUMENTARIANS: 2

Spaces needed in the habitat

I divided my habitat in 5 general categories and each of them have their own spaces and requirements:

1. Engineering, Mechanical and Technology

All the engineering, technology and mechanical activities of the complex happen in this zone.

Some of the activities are listed but not limited to the following items.

- WATER (Production, distribution and recycle)
- GASES (OXYGEN)
- RECYCLE
- IT + AI
- ROBOTICS
- MECHANICS + MAINTAINANCE
- ROBOTICS
- LIGHTING
- ENERGY
- FOOD STORAGE

*There is a loading dock for the engineering section where all the machines and robot and rover could be brought inside for maintenance. This loading dock will also be used for bringing ice inside [there is ice in poles on Mars]

This water production part is intentionally designed close to the green area and the gas production part, as I believe these three activities are related to each other and will make a triangle for oxygen and water and vegetation.

2. Science

There are different scientific activities needed in this complex. Some of the activities and skills are mentioned below. Geologists, for instance, can study the rock samples, biologists the germination and many other crucial studies.

- GEOLOGY
- CHEMISTRY
- BIOLOGY
- PHYSICS
- ASTRONOMY
- MATHEMATICS
- ASTRONOMY

*There is a separate loading dock for the science and health section. The rock samples could be brought inside for further studies in here. Also, n accident happens to someone on Mars, they could be brought inside from this loading dock in immediately get to the health and medical building for emergency.

3. Health

The Healthcare Center of the complex is also very important. Doctors and nurses will help the crew with emergency services, surgeries, and medical needs and also in doing exercises to keep the bone density

- TESTS
- X-RAY + MRI
- BEDS
- MEDICINE STORAGE
- PHYSICAL THERAPY
- SURGERY
- ISOLATION ROOM

4. Social, Art and Leisure

This part is the most important part of the complex. Besides all the technical and engineering activities that need to be done in an absolutely precise way, these activities are the ones that will help the colonists to stay sane. The crew need to party, listen to music, do performances, theater, read poetry, and do many other leisure activities to stay mentally healthy.

- GROUP MEETINGS
- LITERATURE
- CRAFTS
- ARCHITECTURE
- MUSIC
- THEARTRE
- VISUAL ARTS
- SPORTS
- VIRTUAL REALITY
- KITCHEN

5. Dwelling

There are 72 dwelling units for the 72 colonists who will live, work, study, experiment and do more in this habitat. Every individual has their own private space equipped by 3 printed, built-in furniture including a bed, a chair and shelves. They have some adjustable spaces in their cocoon, and they can adjust them based on how they will use it. They can of course make their cocoon, their *home* perhaps by collection beautiful stones, or having pictures of their loved ones back on earth or in any other way they want or they can.

There are to dwelling clusters, and each has 6 groups of 6 bedrooms. In each bedroom, there is also a bathroom and a light scoop that brings in the light from outside.

*There are four Extravehicular Activity (EVA) spaces in the complex. Two of them are close to the engineering are science sections, and two of them are close to the two dwelling clusters. The inhabitants can climb the stairs and get to the Spacesuits room and after wearing their spacesuits, they can enter the EVA room, and when the airlock happens, they can step outside, to the surface of Mars. And when they are with their activities or tasks on the surface of Mars and they want to go back inside, the same process will be repeated and they can climb down the stairs to enter the dwelling or community or work areas.

Water Features

There are some water features in the complex. These water features are used to distribute water in the complex and water the vegetation, and more importantly keep the connection between people and nature and water, which has been proven to have a positive impact on people's mind to keep them calm, and also they won't feel too limited from what they had on earth.

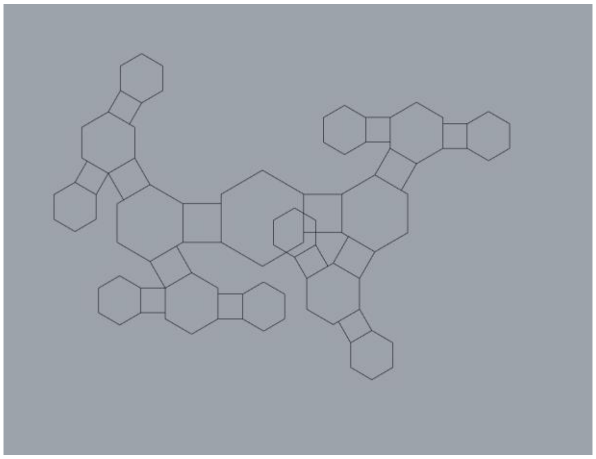
Vegetation and Farms

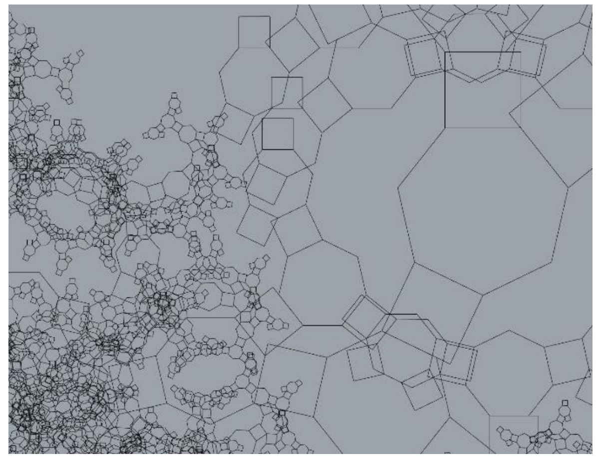
Vegetation and farms play an important role in the complex. The farms and vertical gardens are used for food purposes, and they cooperate with the Oxygen and water sections in the complex for creating a livable atmosphere inside. The vegetation also helps the crew feel still connected to the nature and stay mentally healthy.

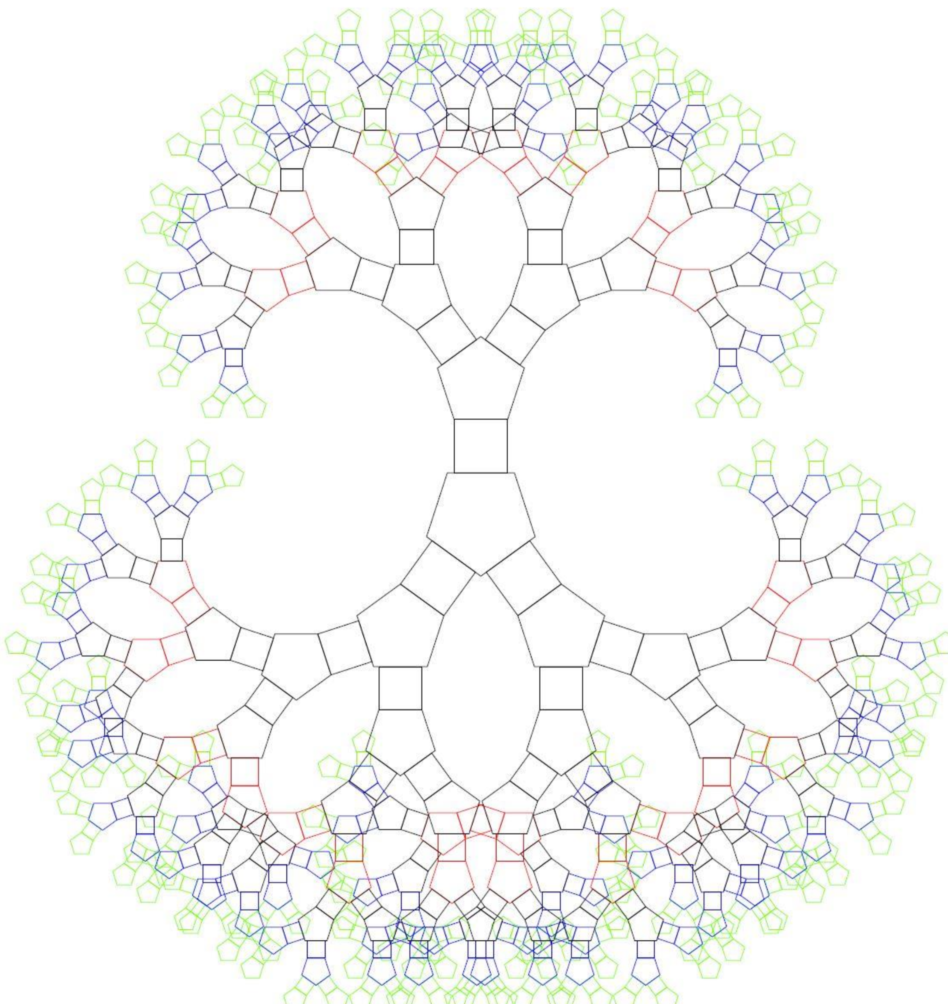
Construction

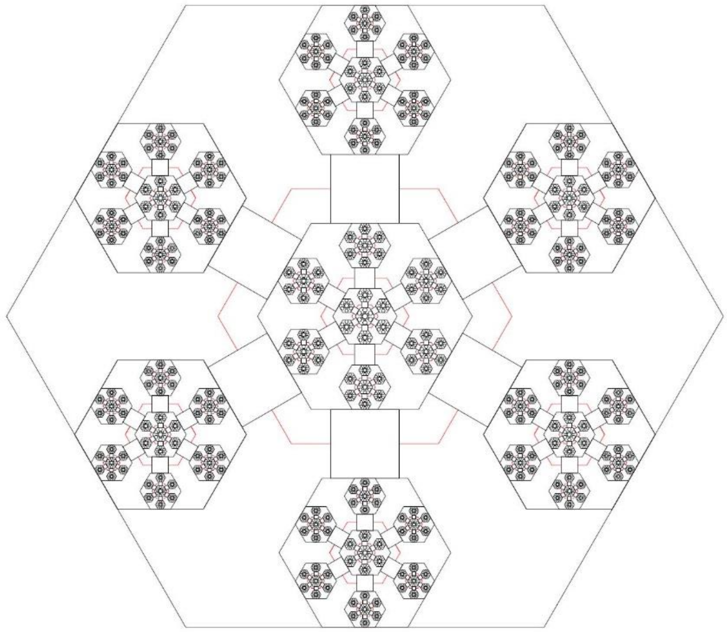
I also did a lot of research on the construction we can have on Mars. The most popular which is 3d printing on the surface of mars may seem appealing, but I'm not sure how they are going to survive in the extreme condition on Mars. So after doing some research and experiment I combined the existing methods and added my suggestion. I think we can use excavated spaces underground (step 1). It provides more protection against radiation and extreme winds. Then, we can use the same local material, maybe the carved materials from step one, and use 3d printers to make thick walls, creating the interior spaces (step 2). We also need to make 3d printed domes and vaults to cover the inside (step 3). And finally we will need to seal the whole complex by spraying insulating Martials (step 4). I believe this is the best way as we will not be able to send materials, such as steel or glass to Mars and we should use local materials, or when something is broken, we won't be able to fix it unless we have the material on Mars. We cannot rely on Earth.

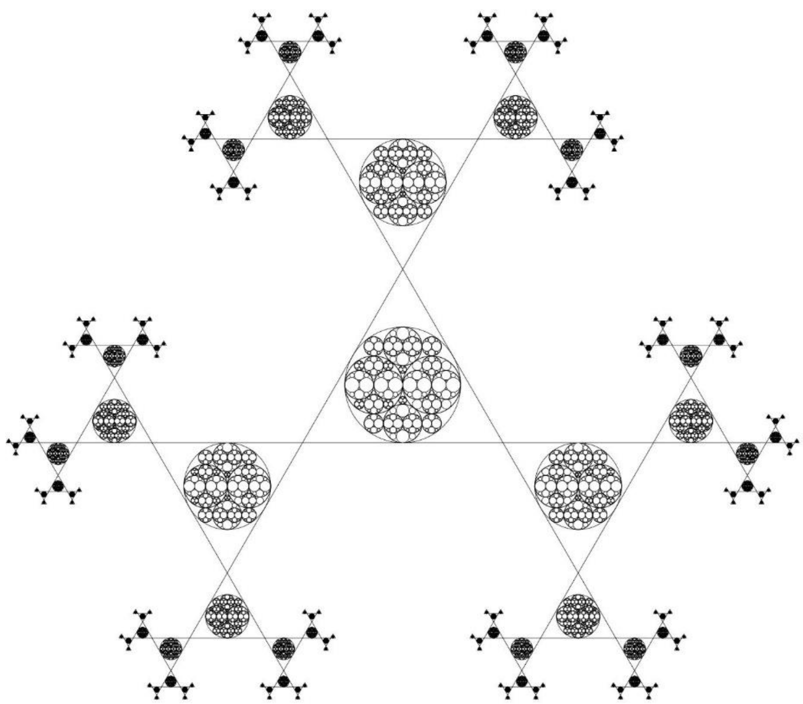
Fractal Studies and Diagrams

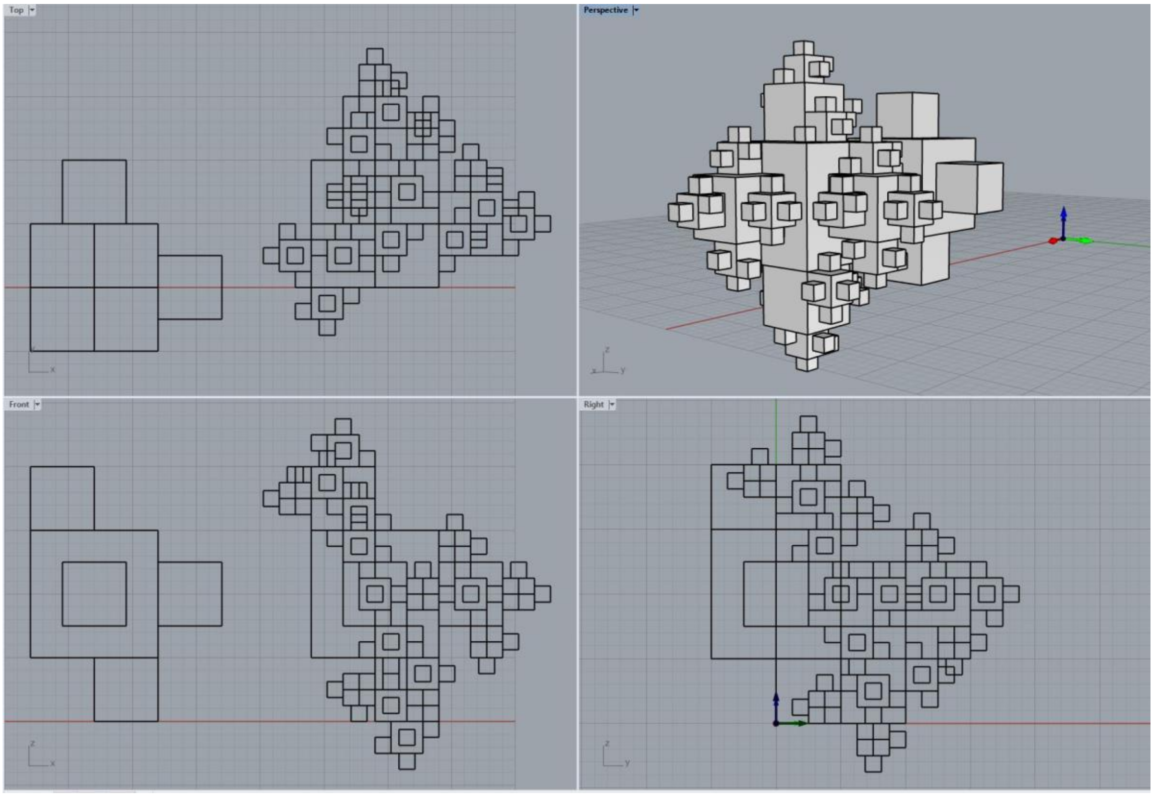








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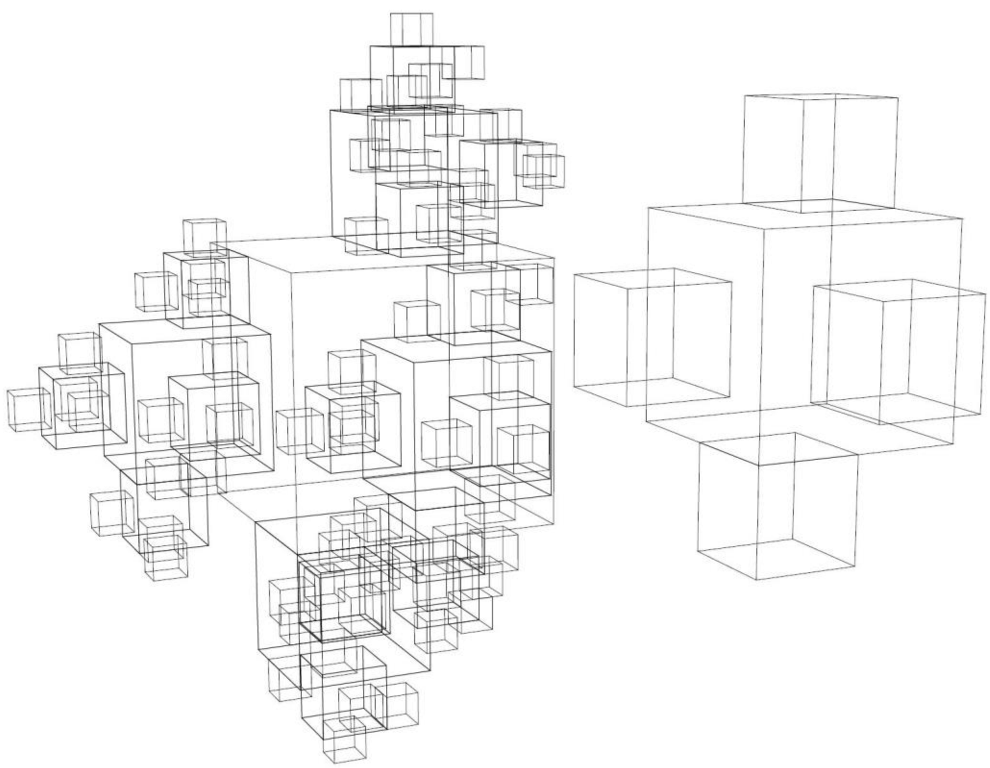
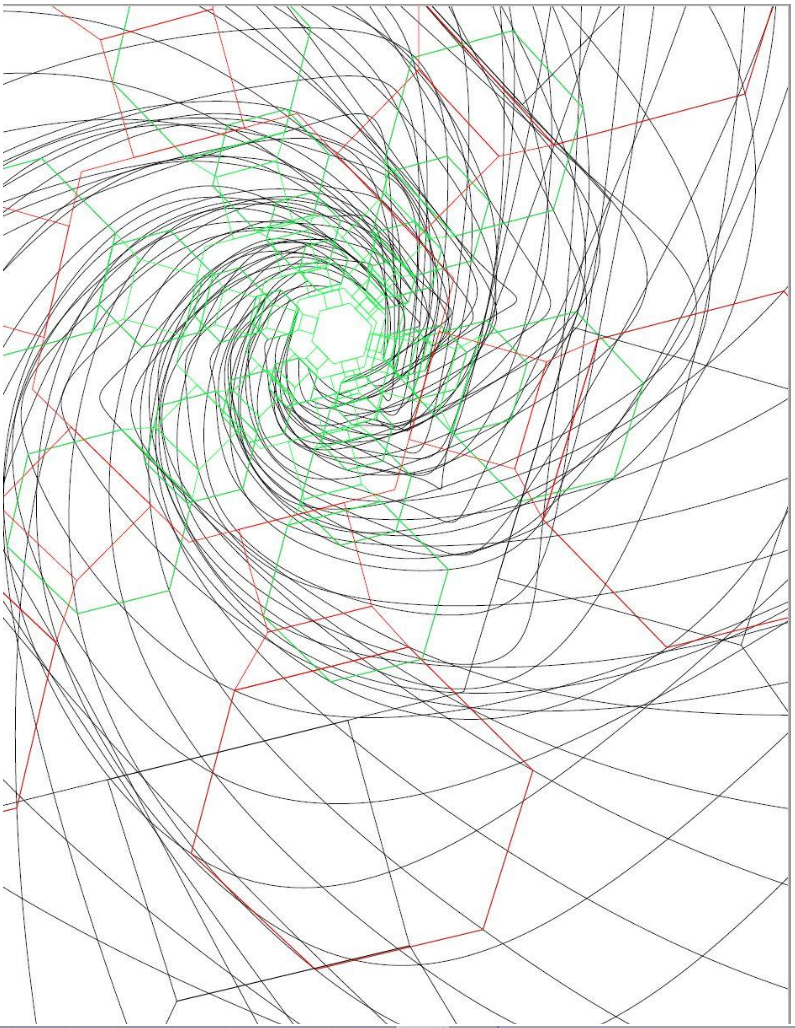
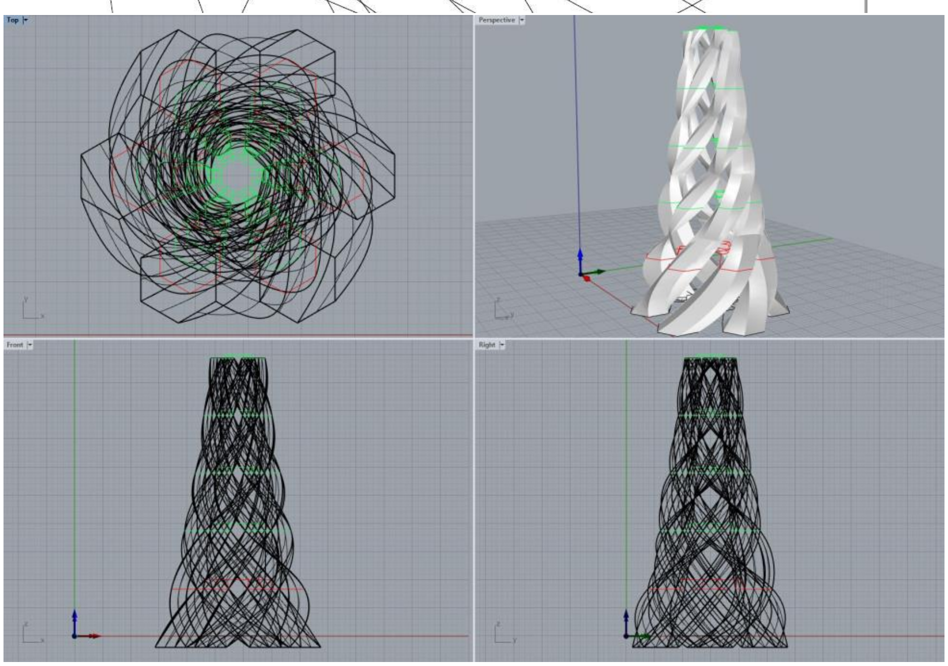
Perspective
Front
Right






Top
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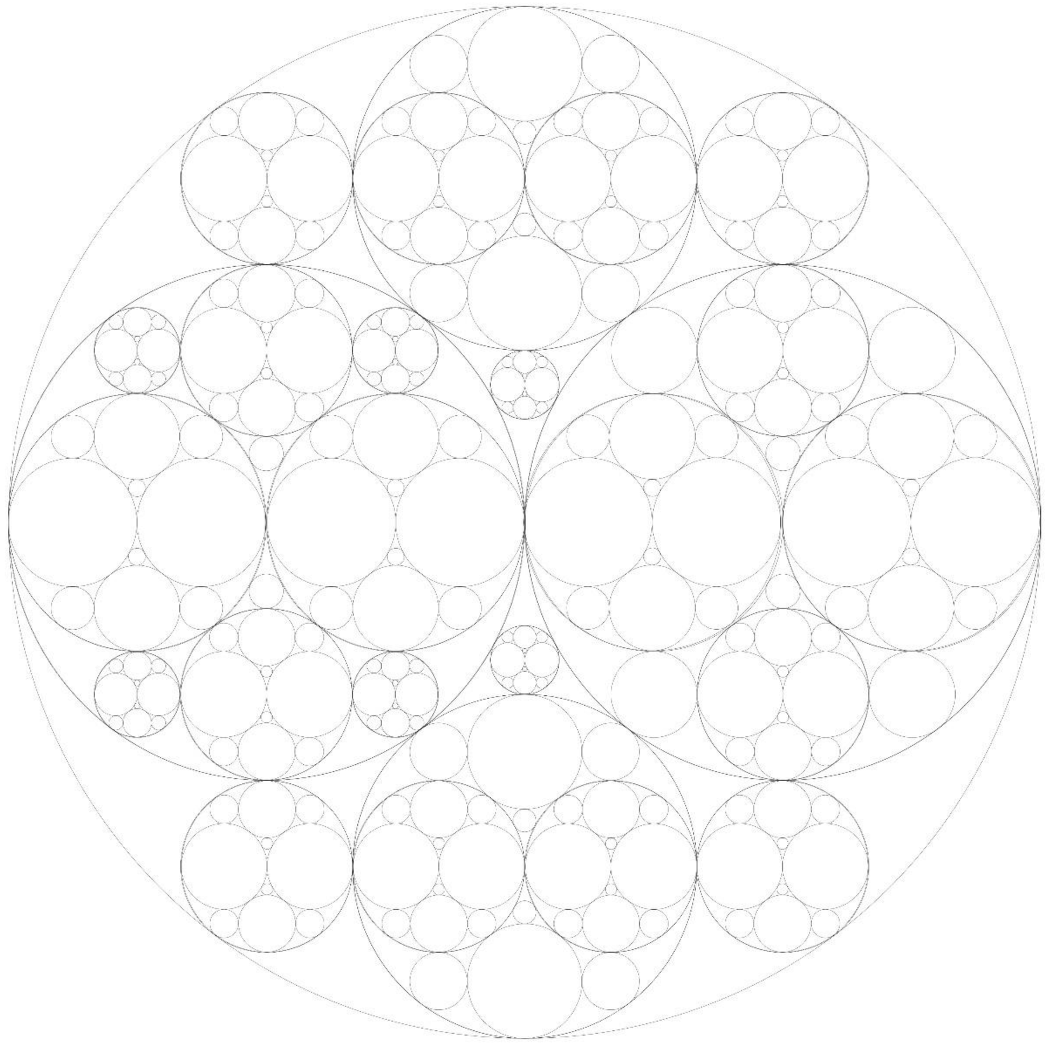
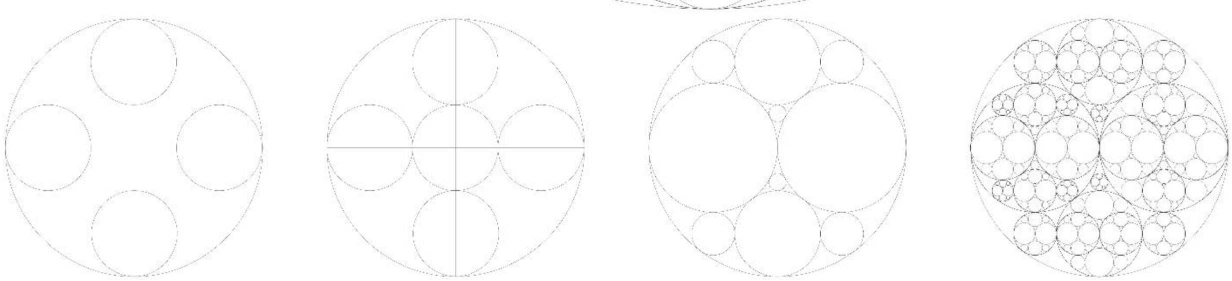
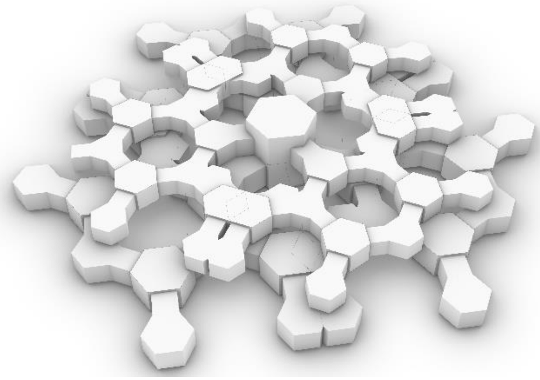
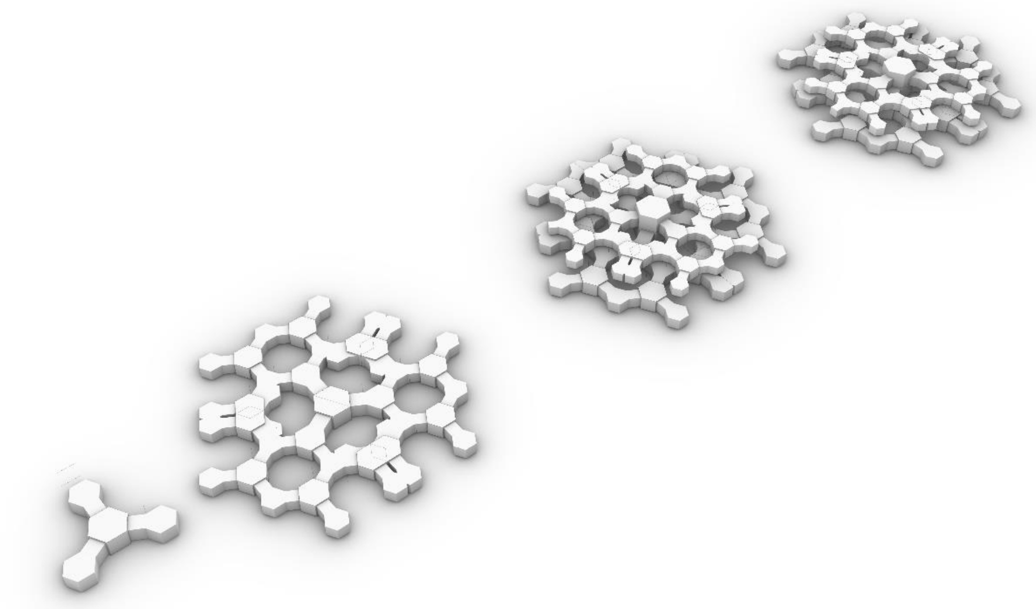
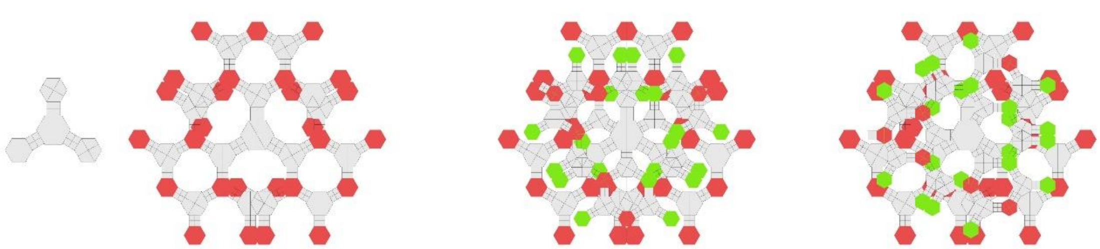
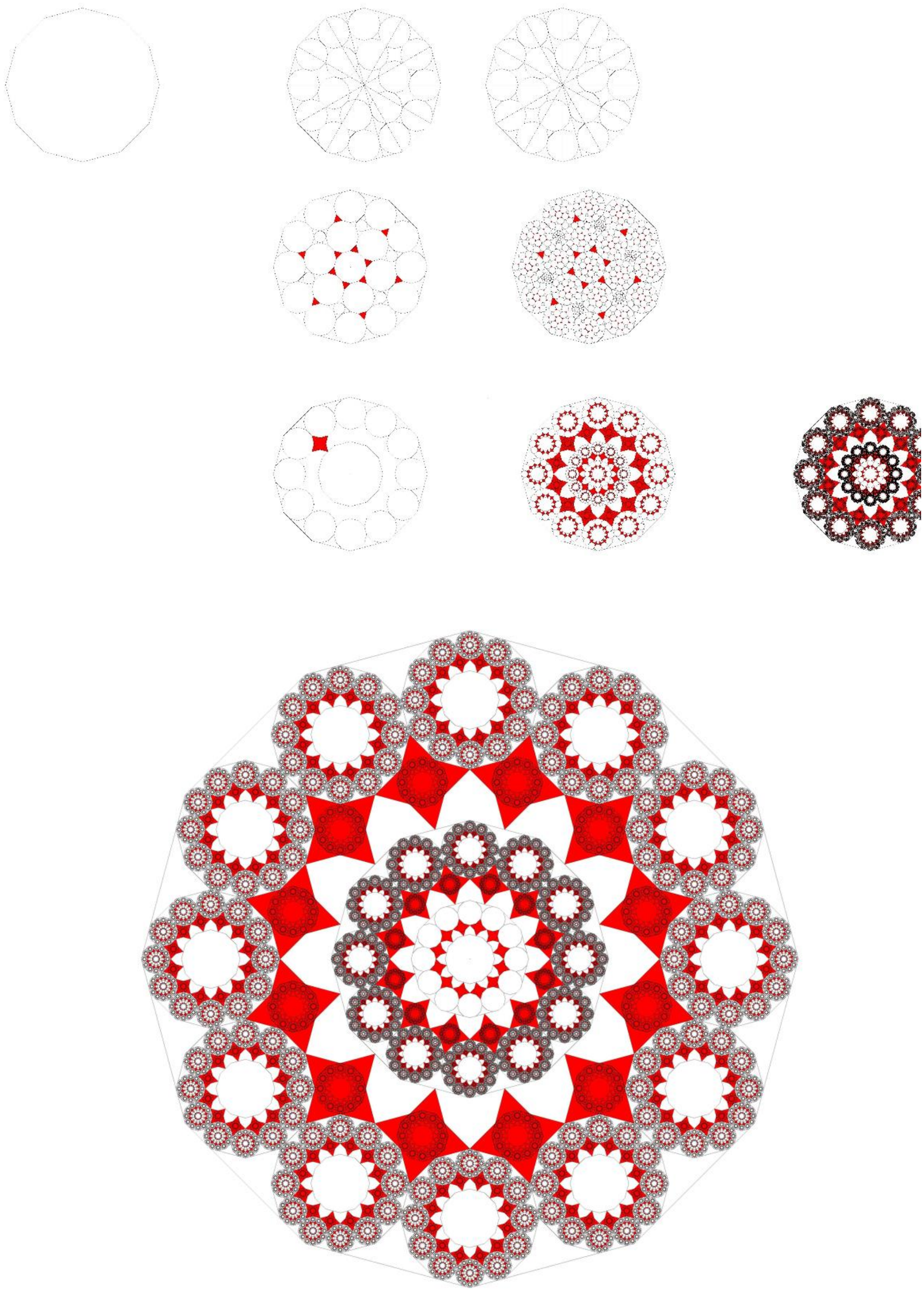


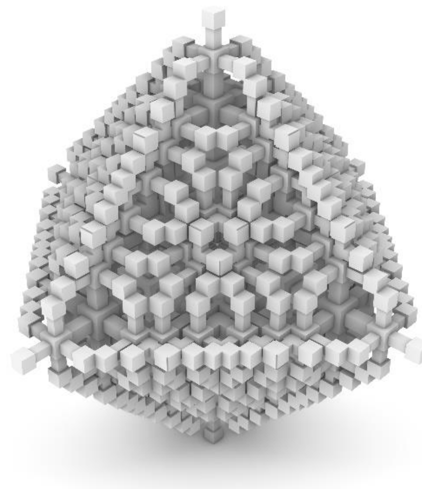


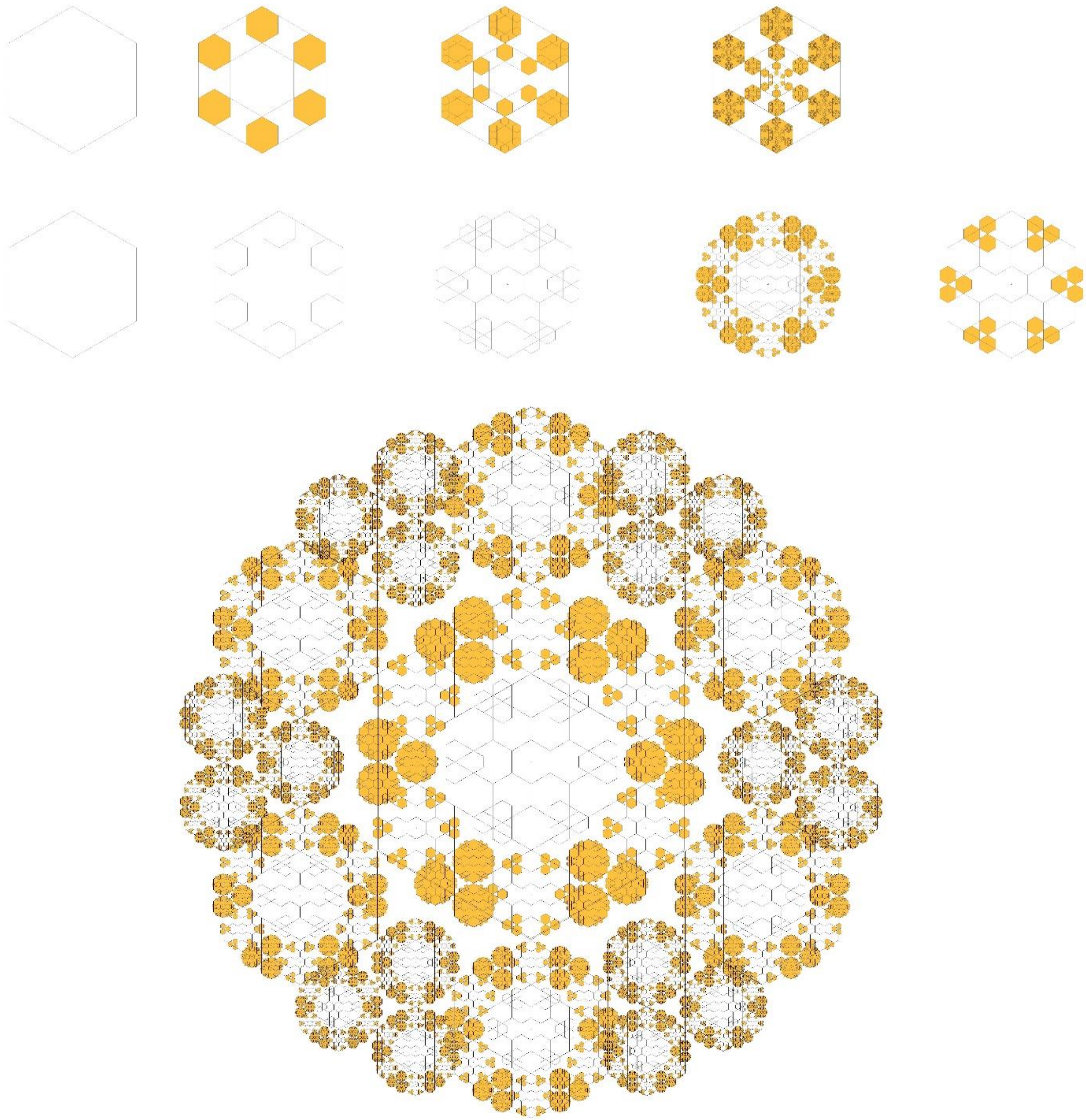




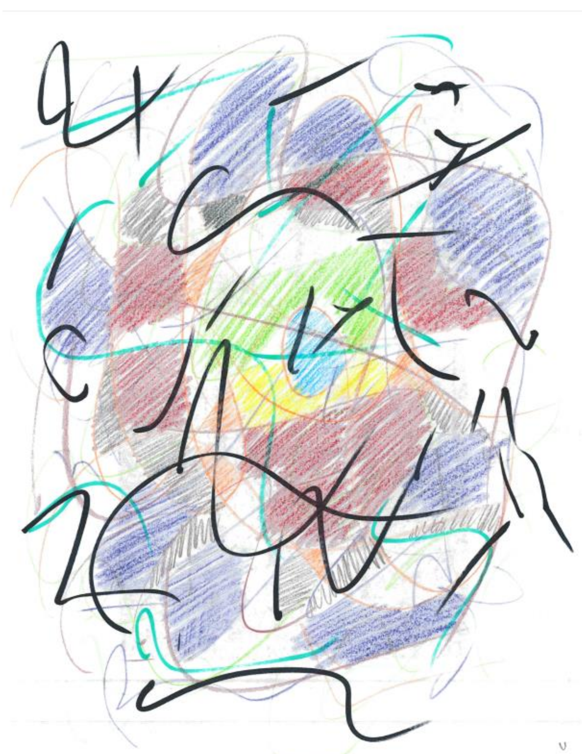




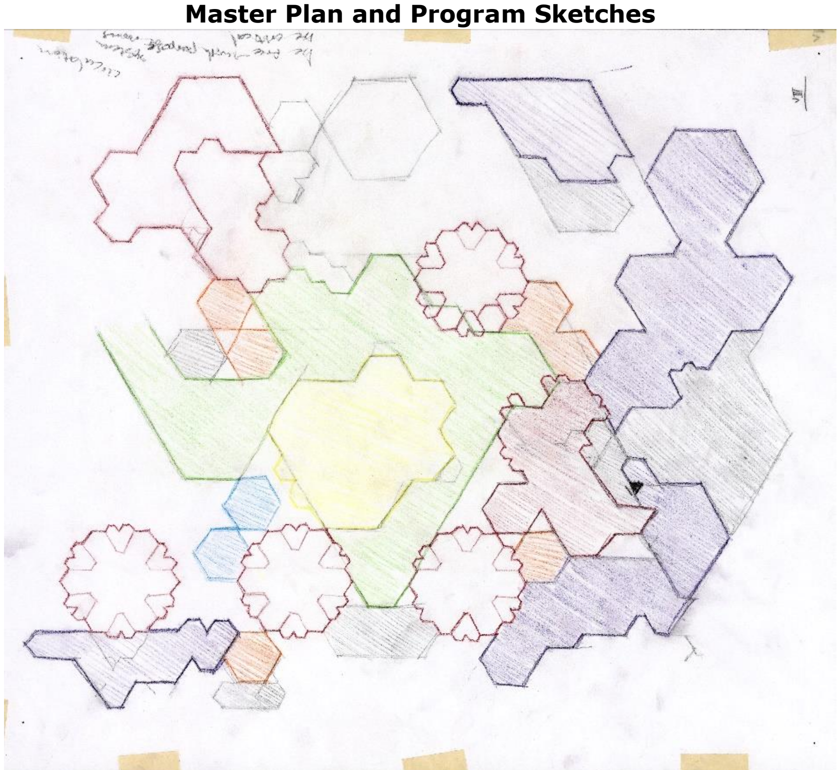


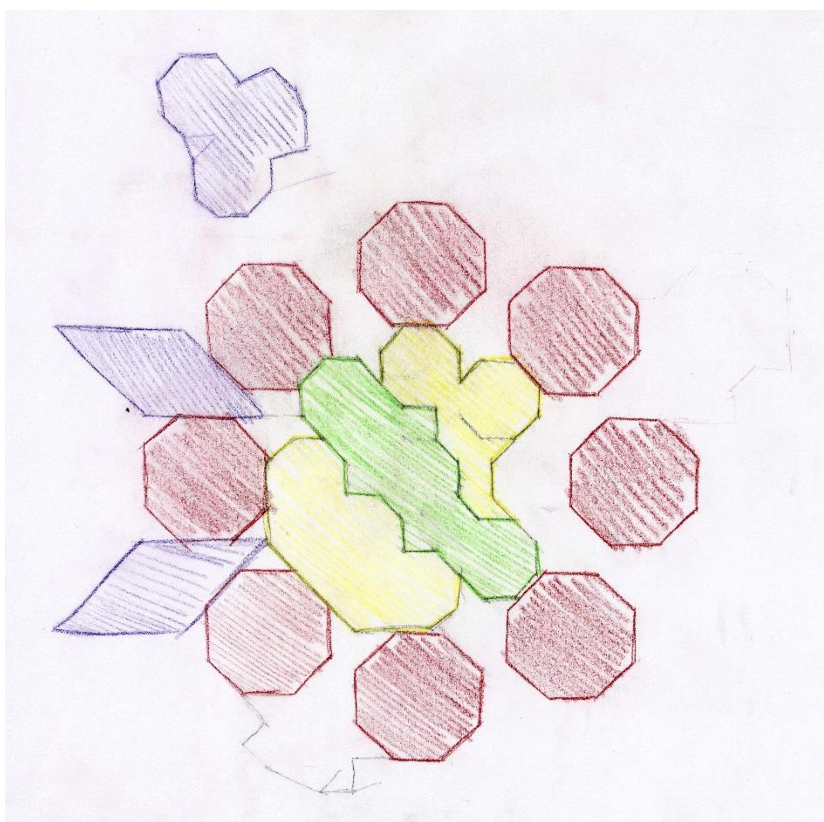


Chaos Studies and Diagrams

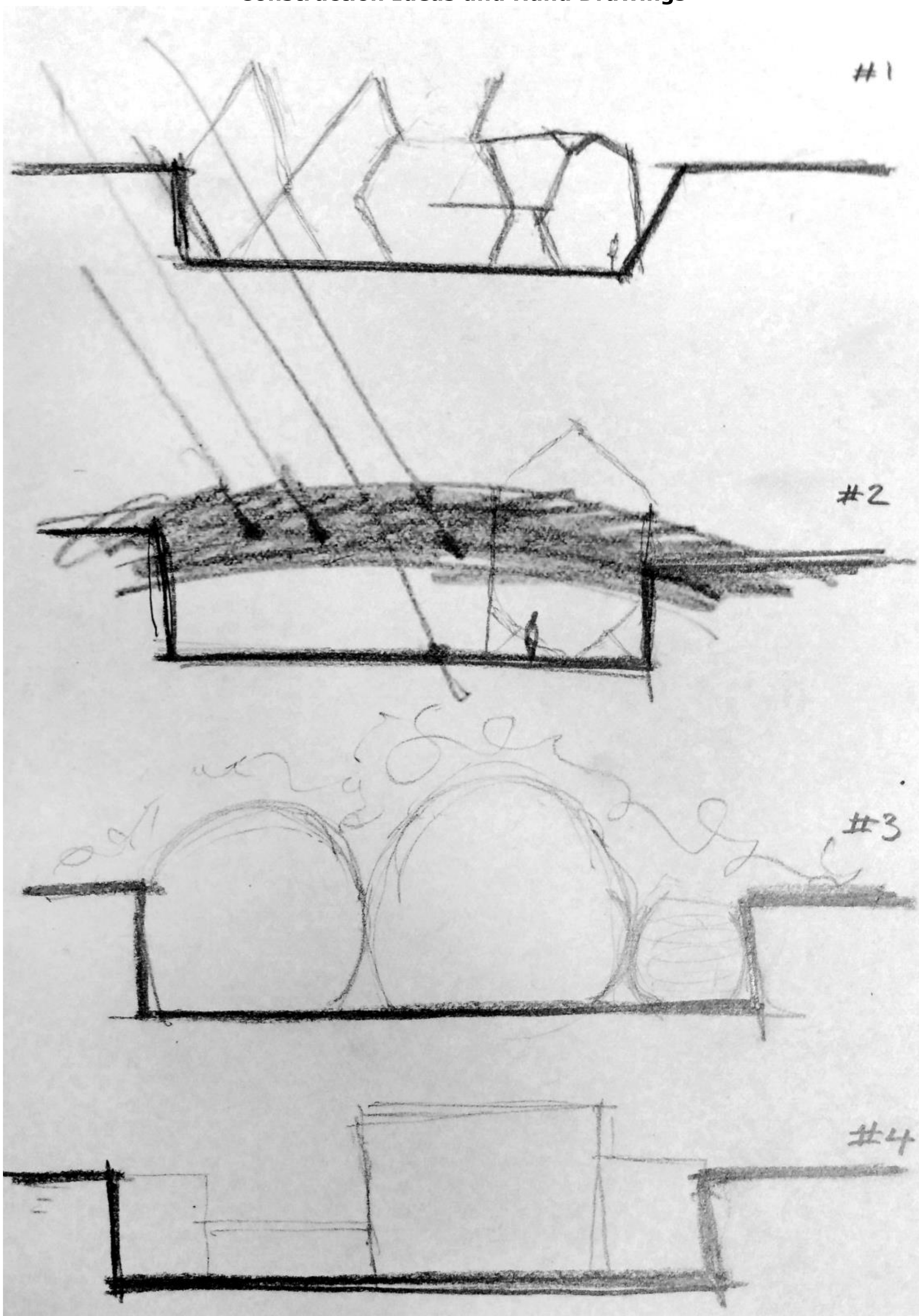


Master Plan and Program Sketches



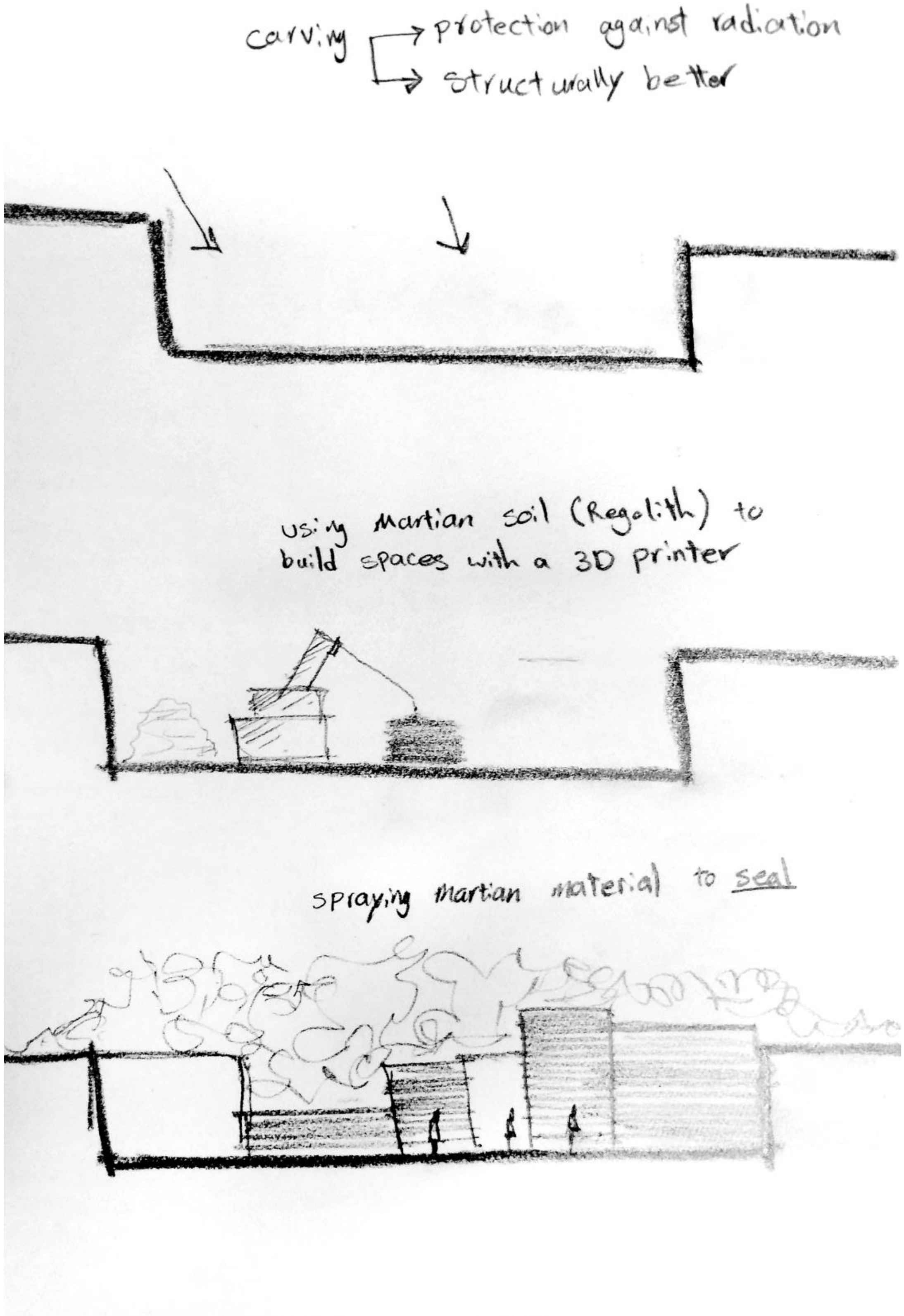


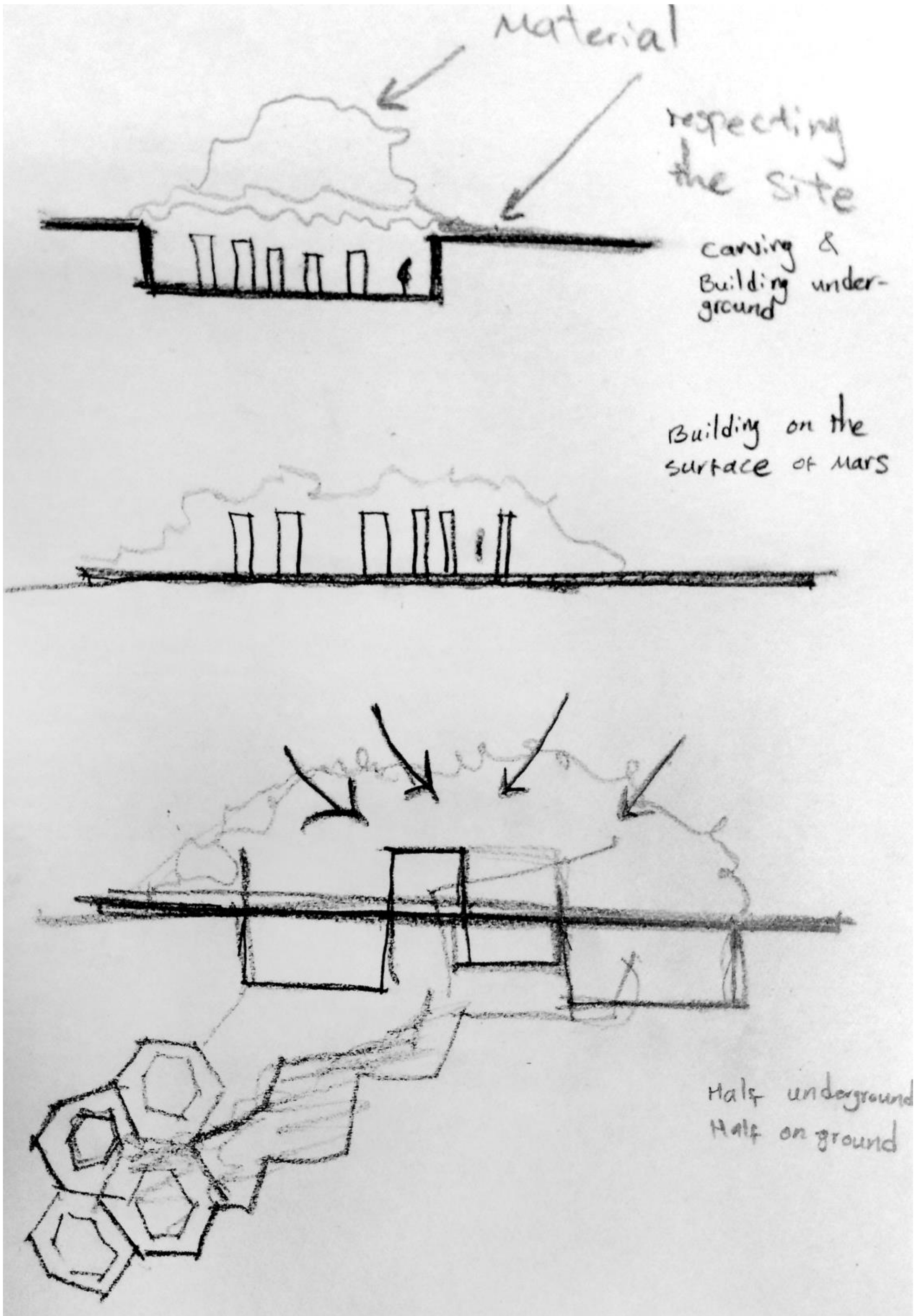
Construction Ideas and Hand Drawings



Stydying different ways of building carved spaces

combination of 3 ideas=Carving+3d print+sealing

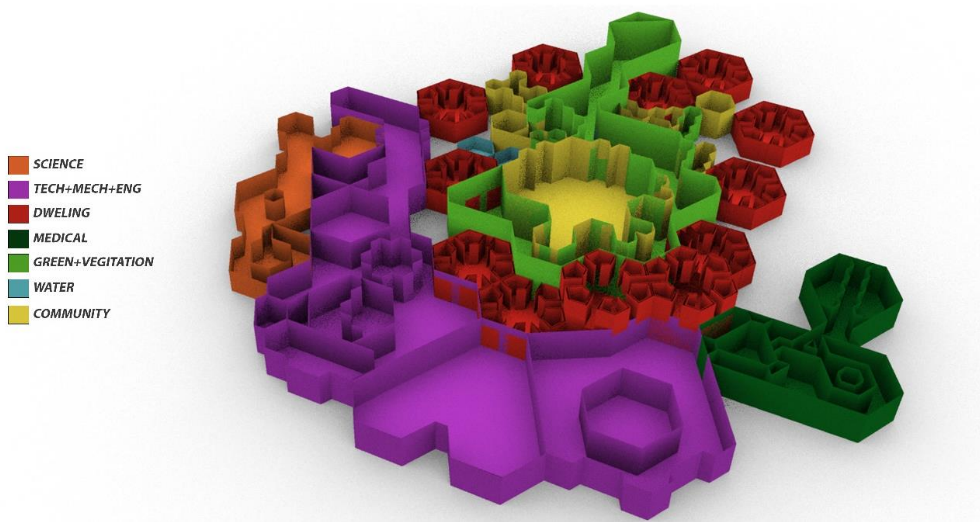


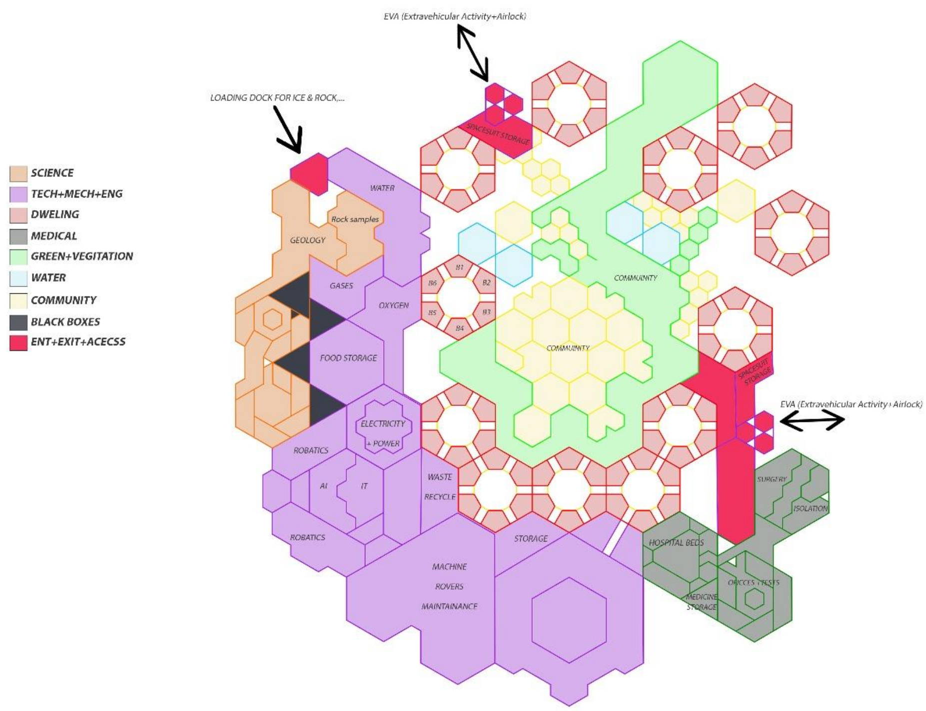


Considering different ways of building on Mars

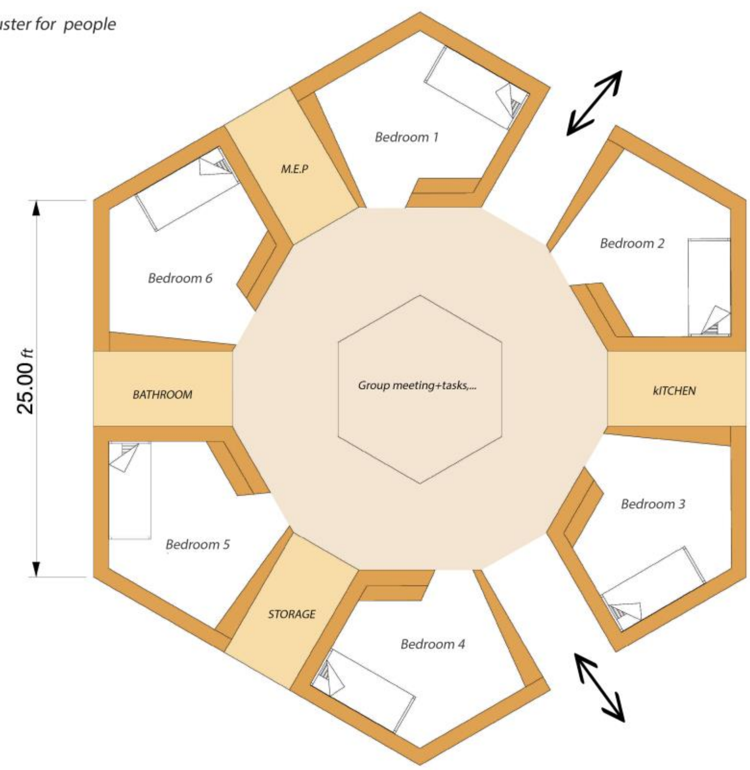
First Master Plan Proposal for 2nd Internal Review (plans + 3d printed & digital model)

3d model

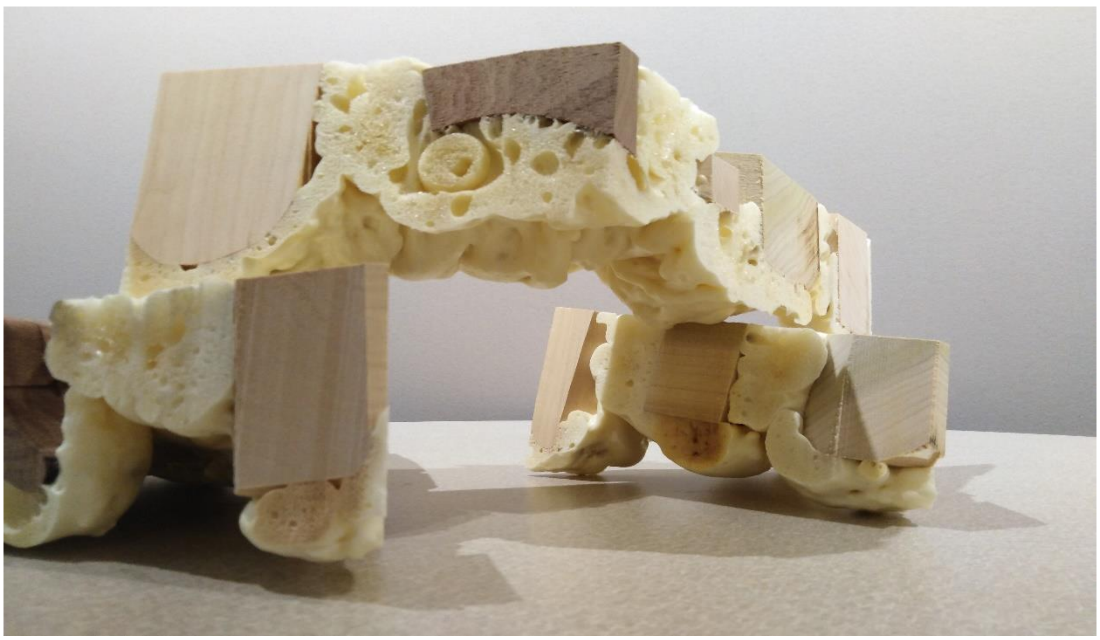




modular dwelling cluster for people

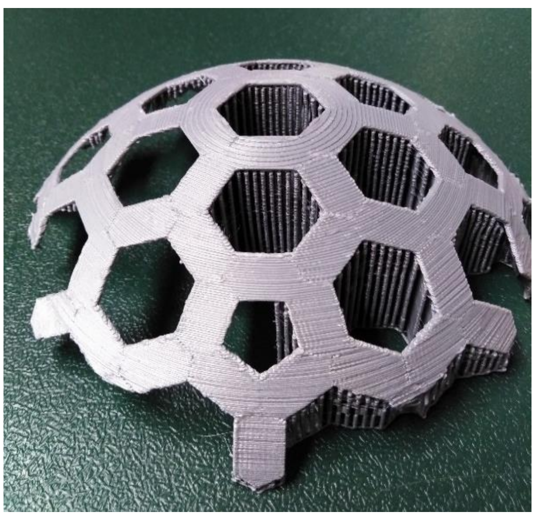
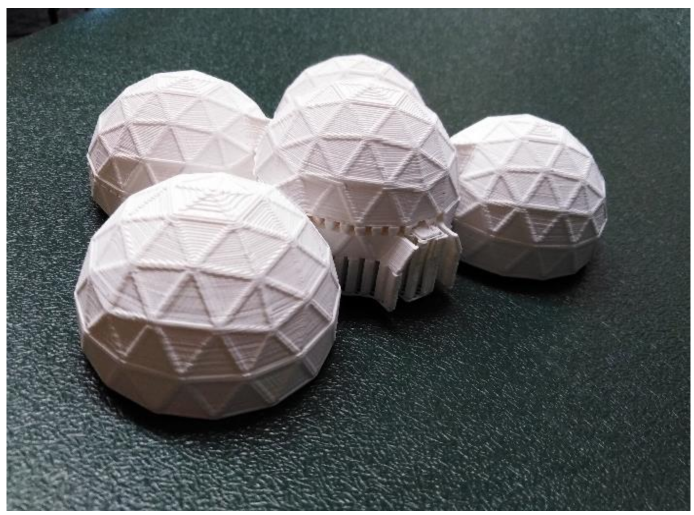


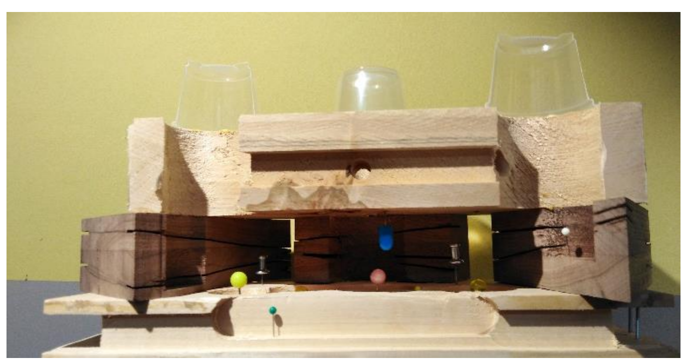
Physical Model Studies and Experiments



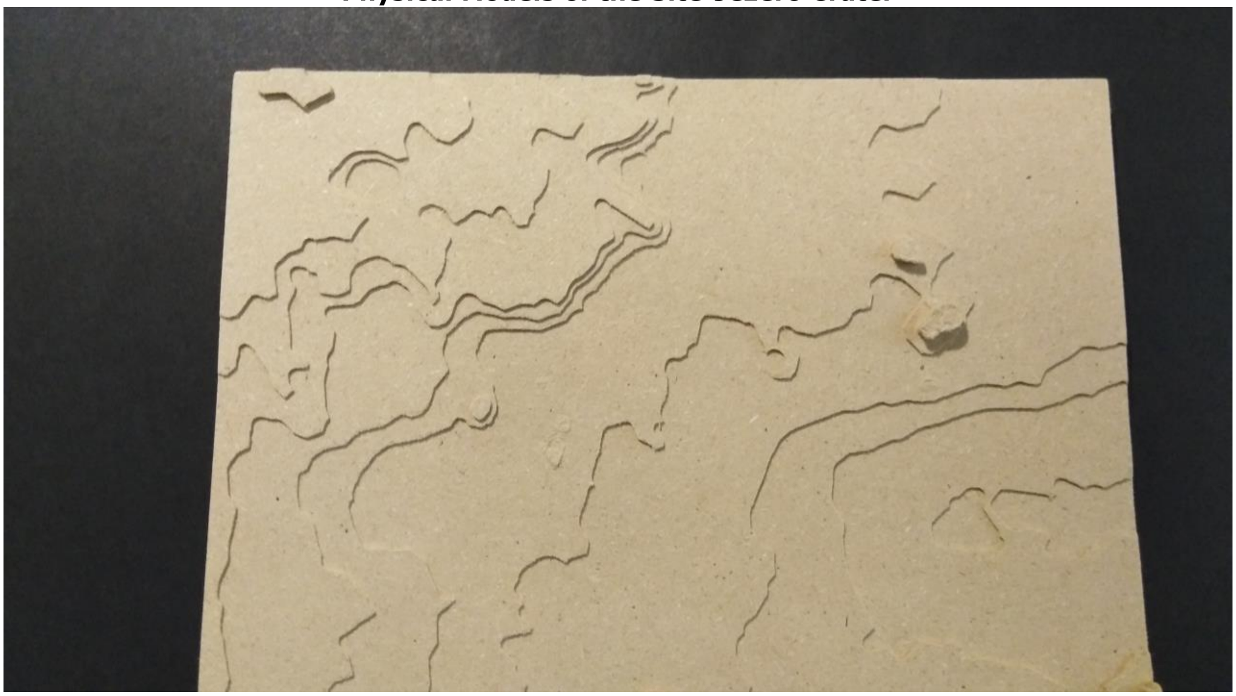
Study Models and Studies Using 3d Printers

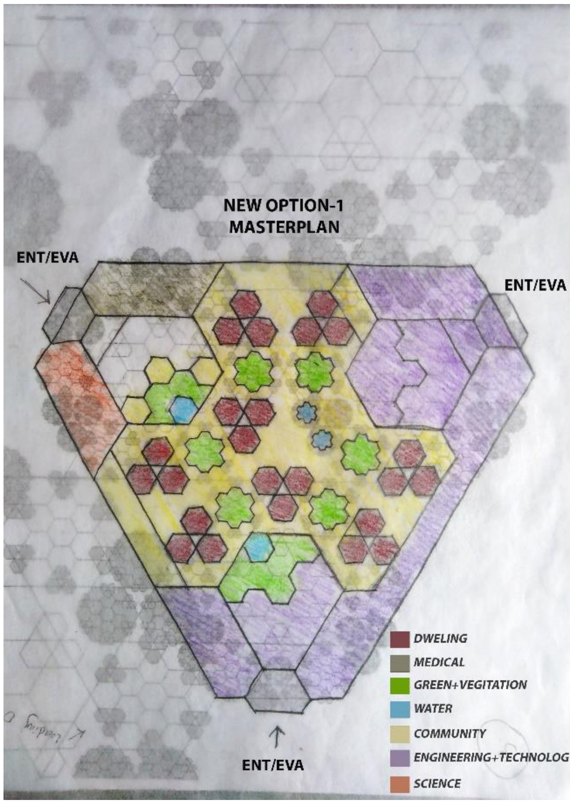


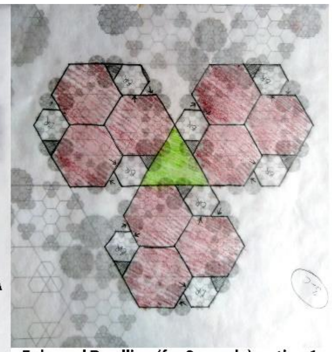



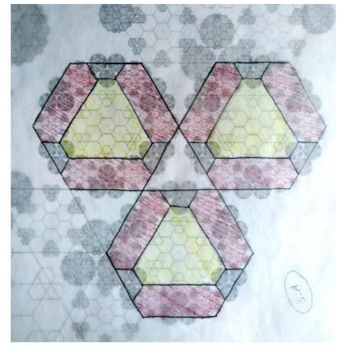


Physical Models of the Site-Jezero Crater

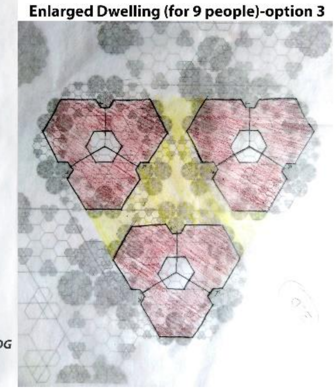




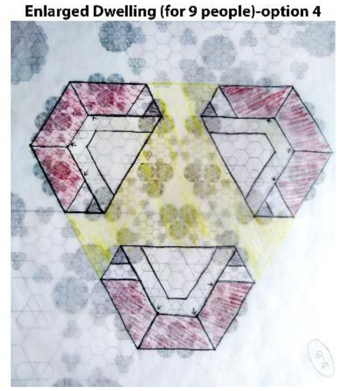

Enlarged Dwelling (for 9 people)-option 1

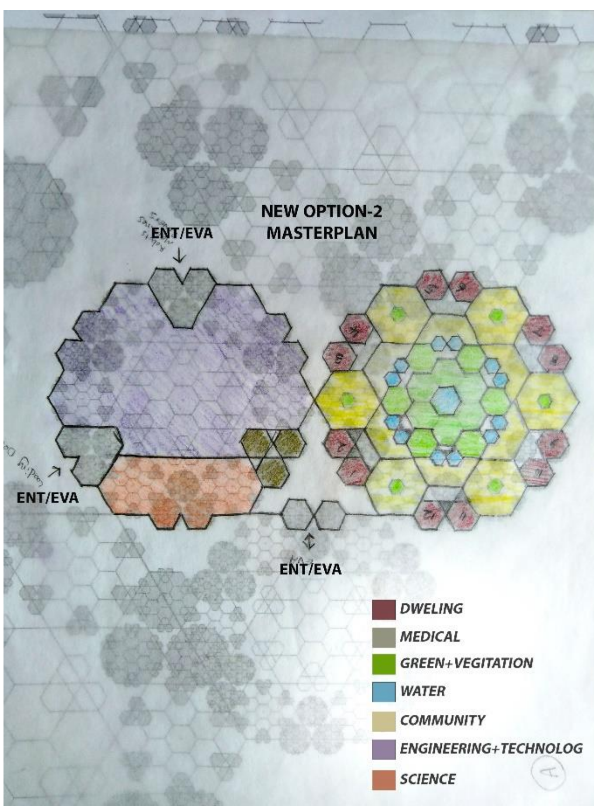

Enlarged Dwelling (for 9 people)-option 2

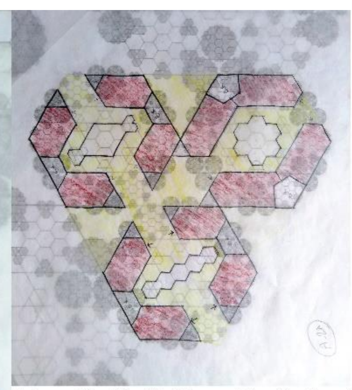
Enlarged Dwelling (for 9 people)-option 3

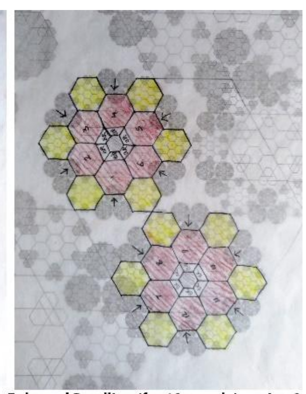


Enlarged Dwelling (for 9 people)-option 4

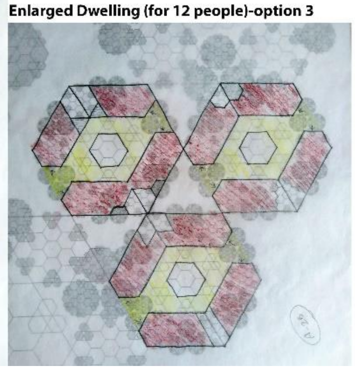


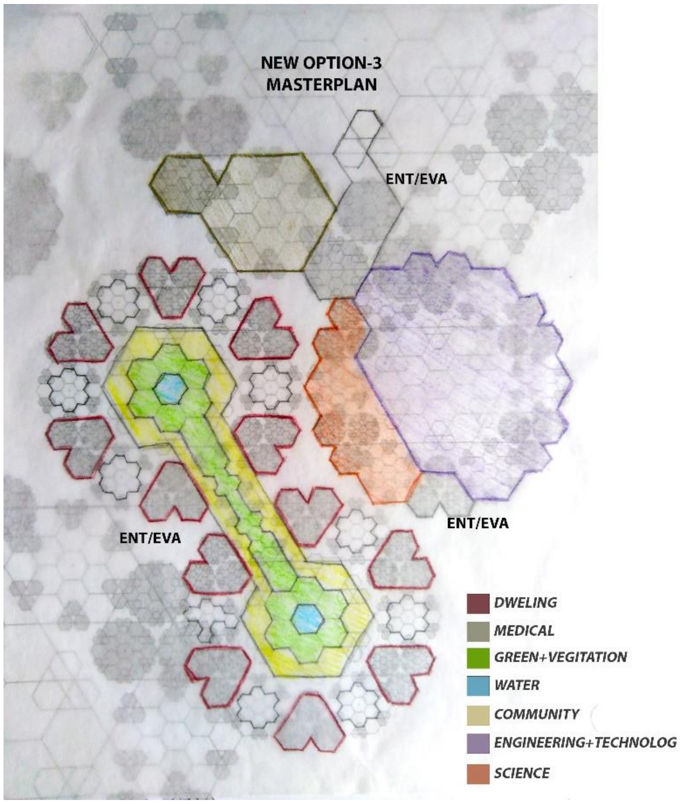


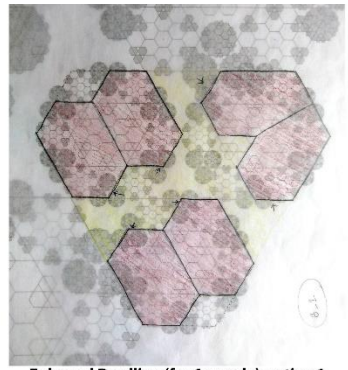

Enlarged Dwelling (for 12 people)-option 1


Enlarged Dwelling (for 12 people)-option 2

Enlarged Dwelling (for 12 people)-option 3

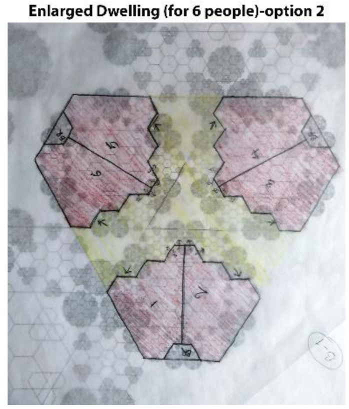




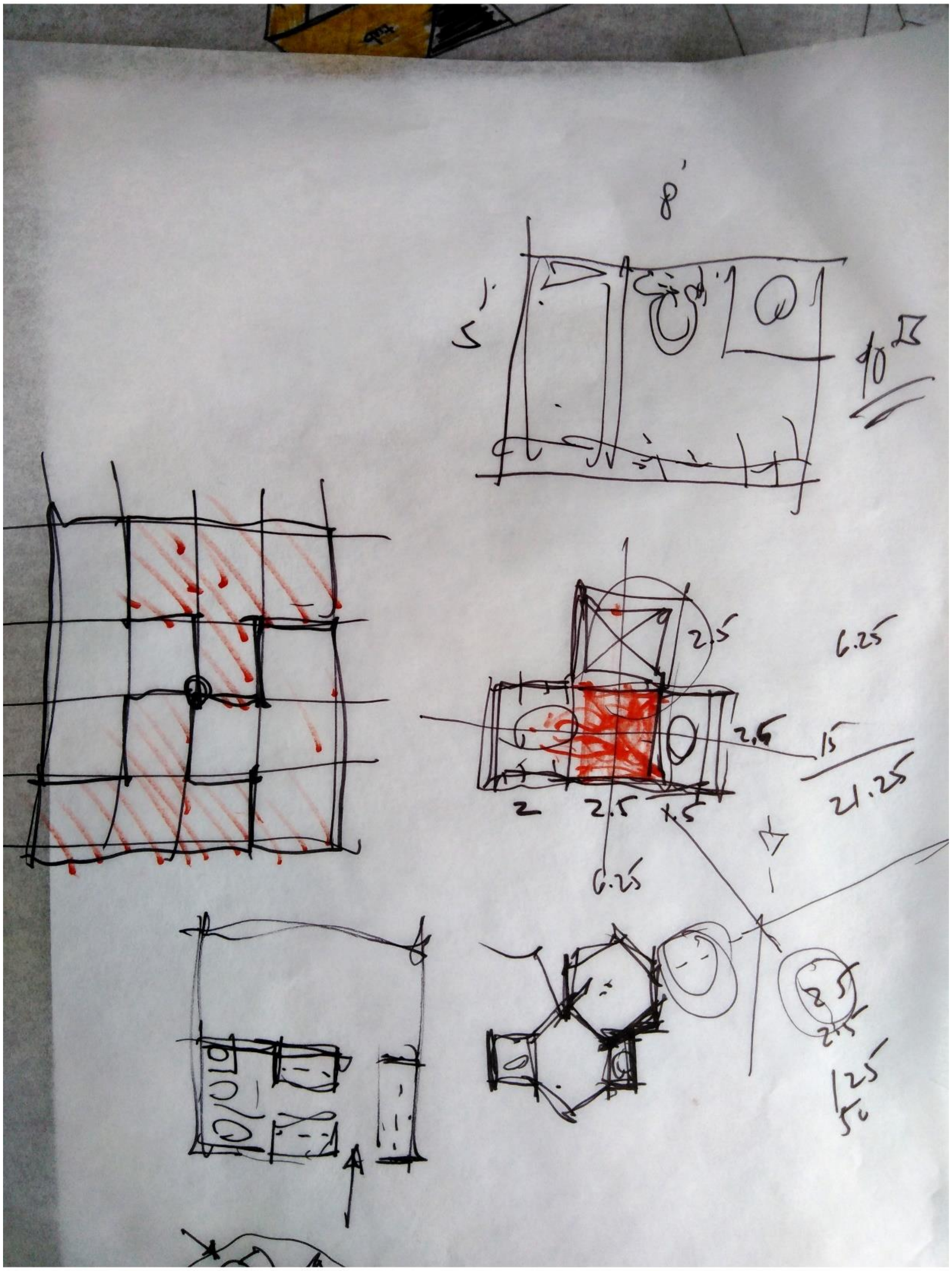


Enlarged Dwelling (for 6 people)-option 1

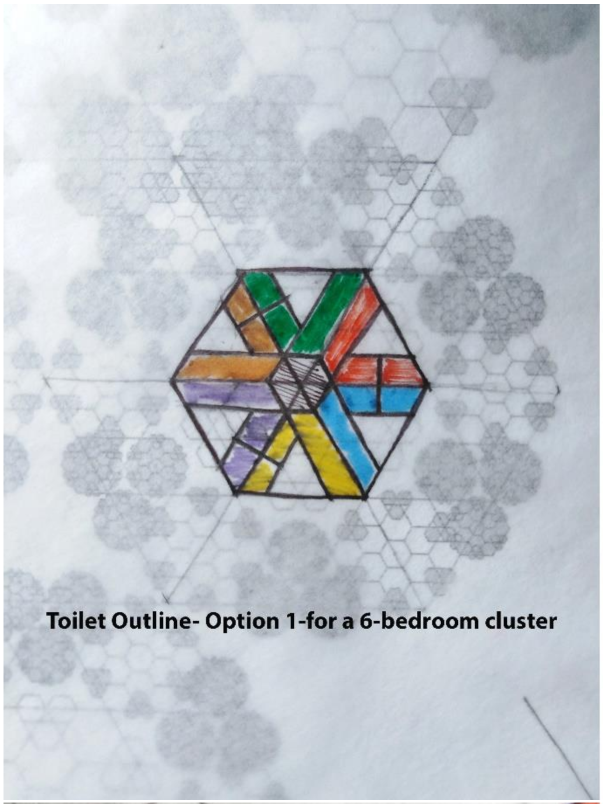
Enlarged Dwelling (for 6 people)-option 2



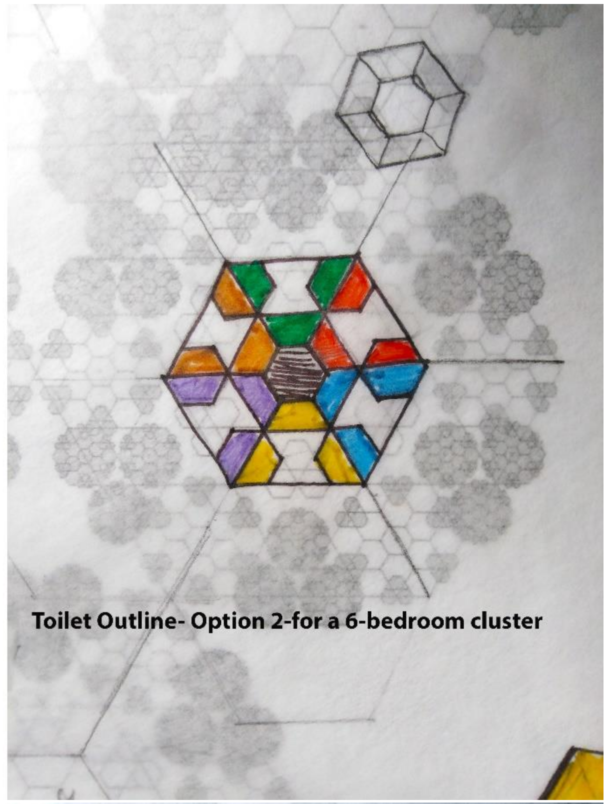
TOILET OUTLINE



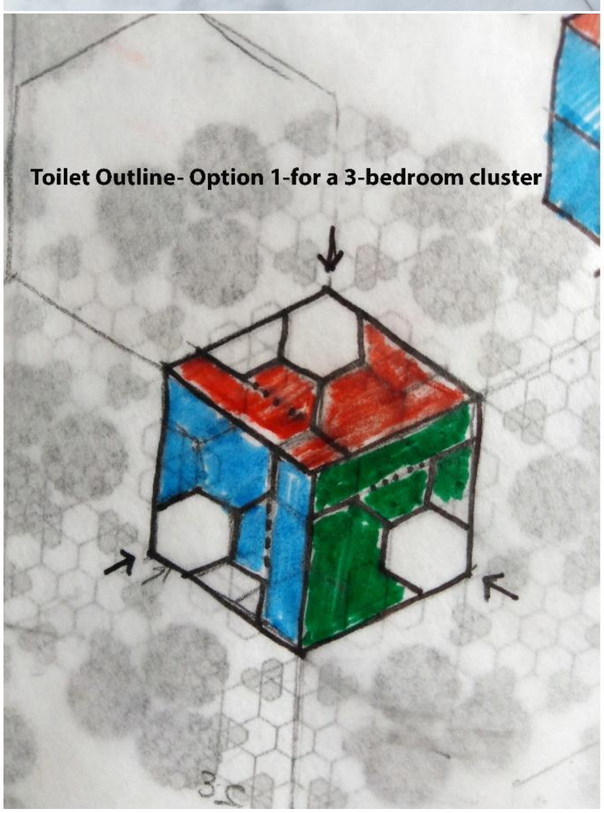
Hand drawings by Sergio Sanabria



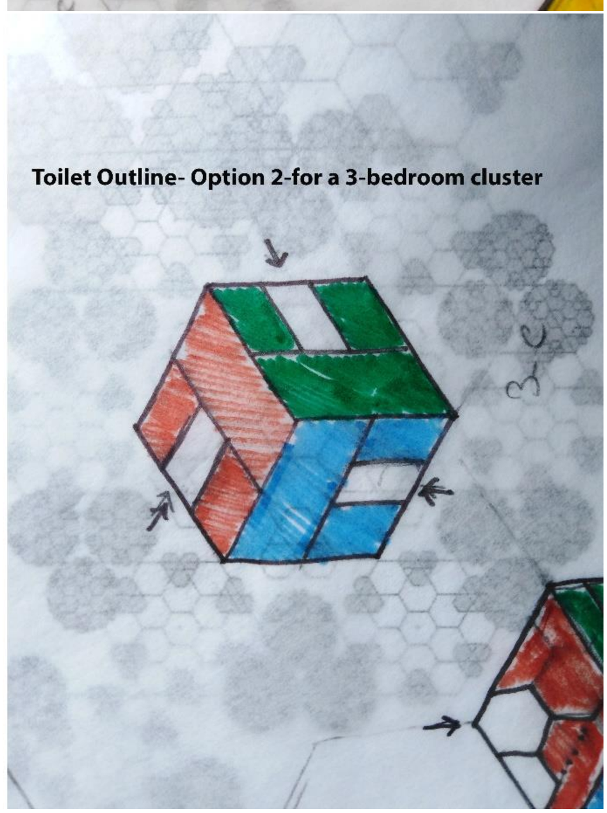
Toilet Outline- Option 1-for a 6-bedroom cluster



Toilet Outline- Option 2-for a 6-bedroom cluster

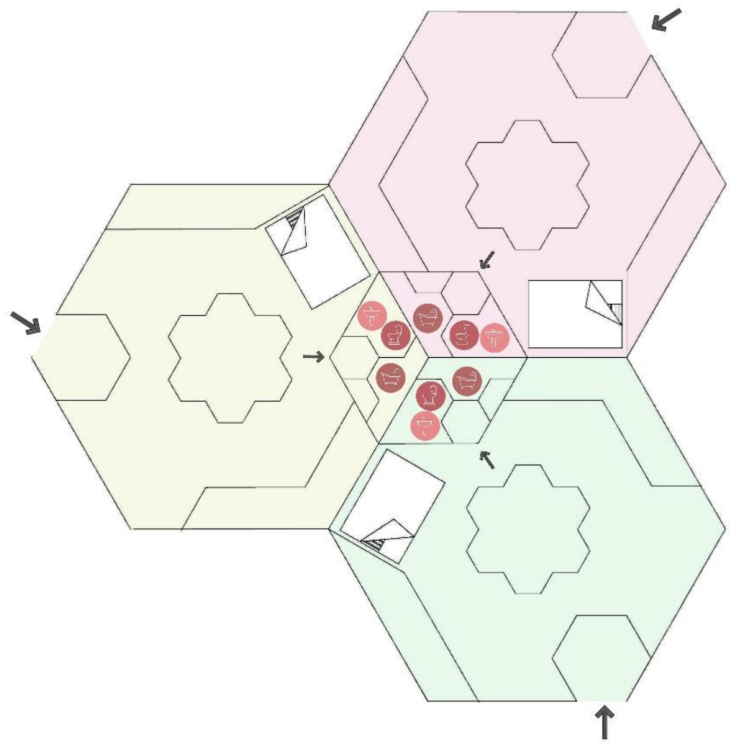


Toilet Outline- Option 1-for a 3-bedroom cluster

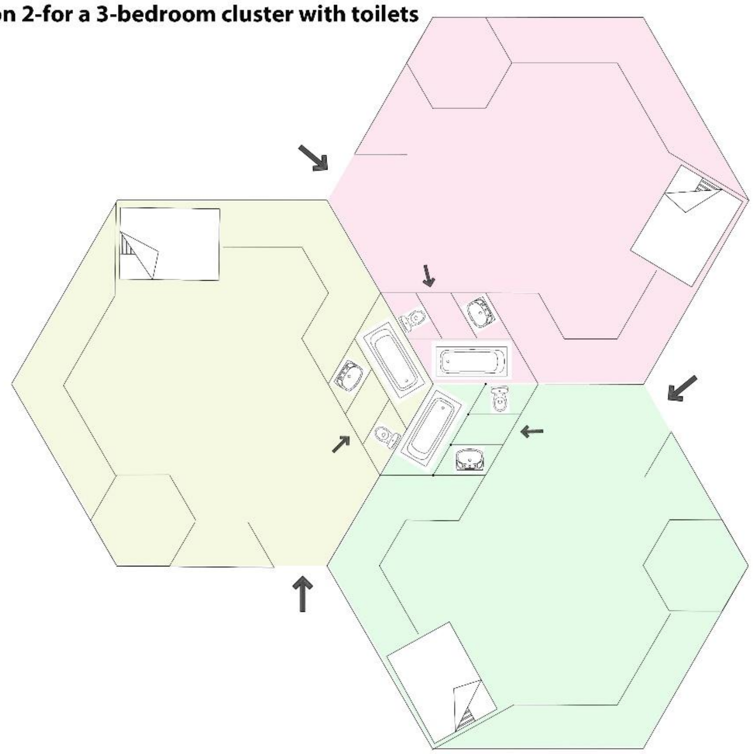


Toilet Outline- Option 2-for a 3-bedroom cluster

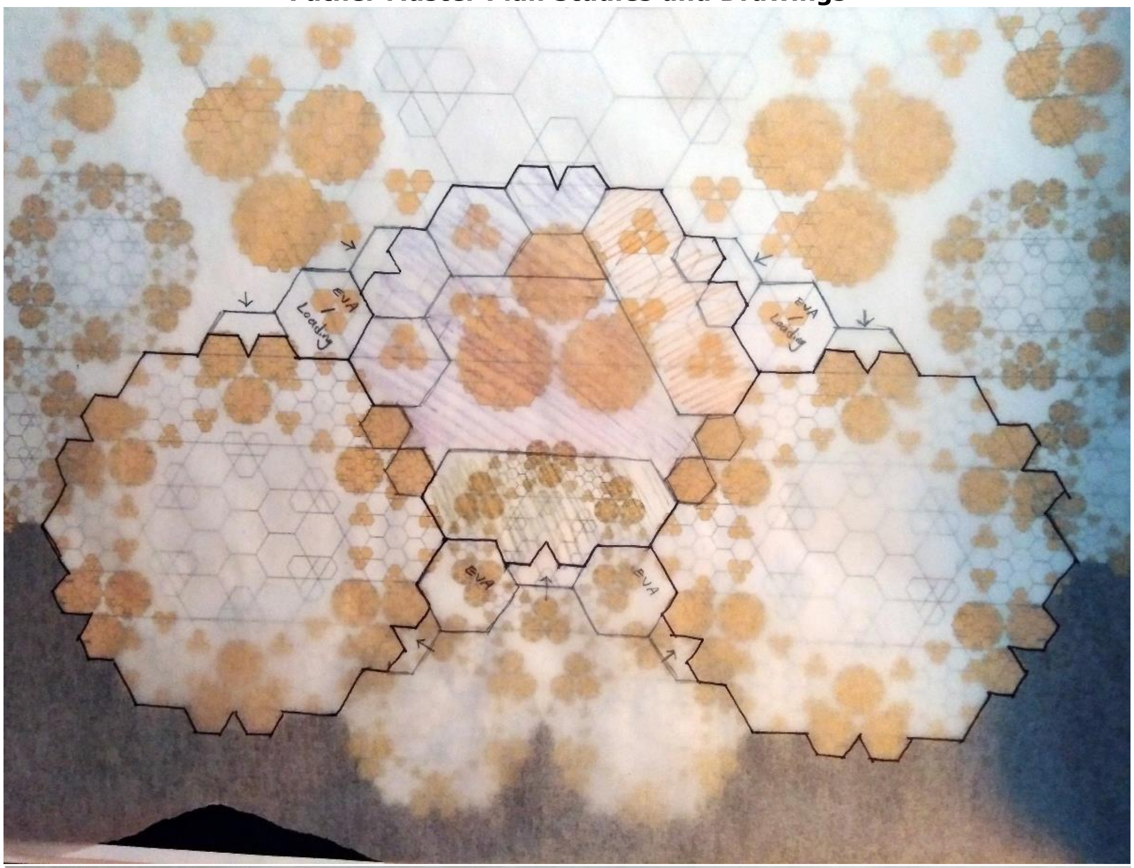
Dwelling Outline- Option 1-for a 3-bedroom cluster with toilets

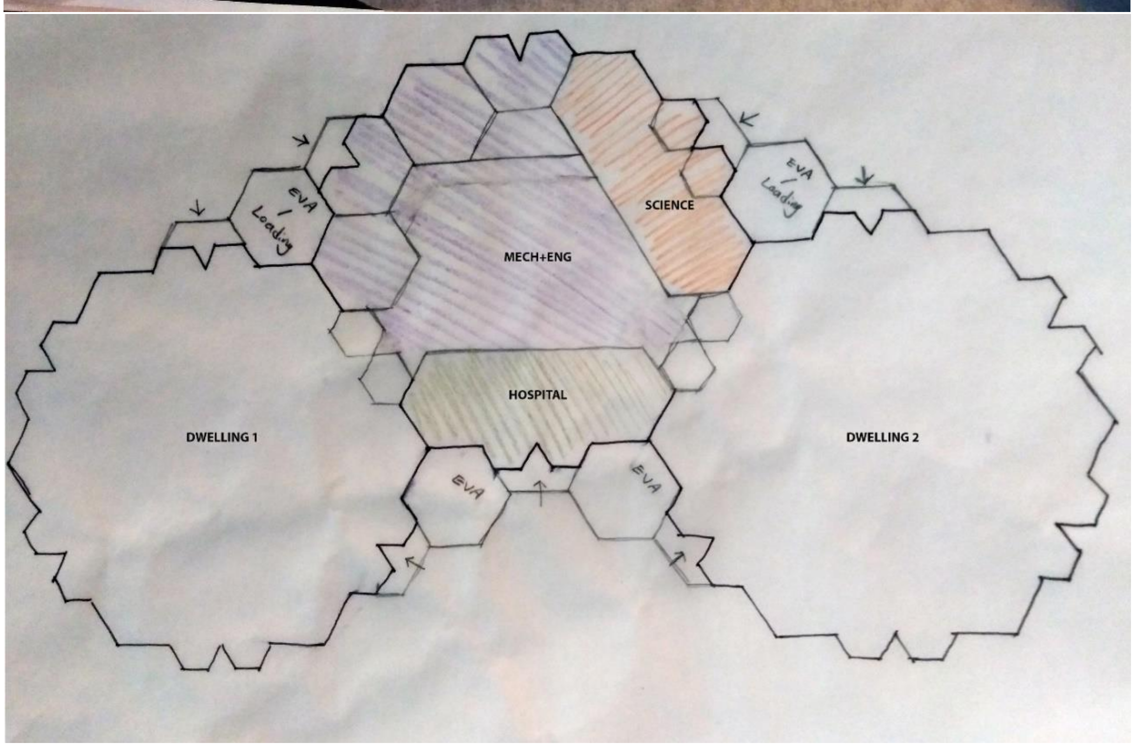


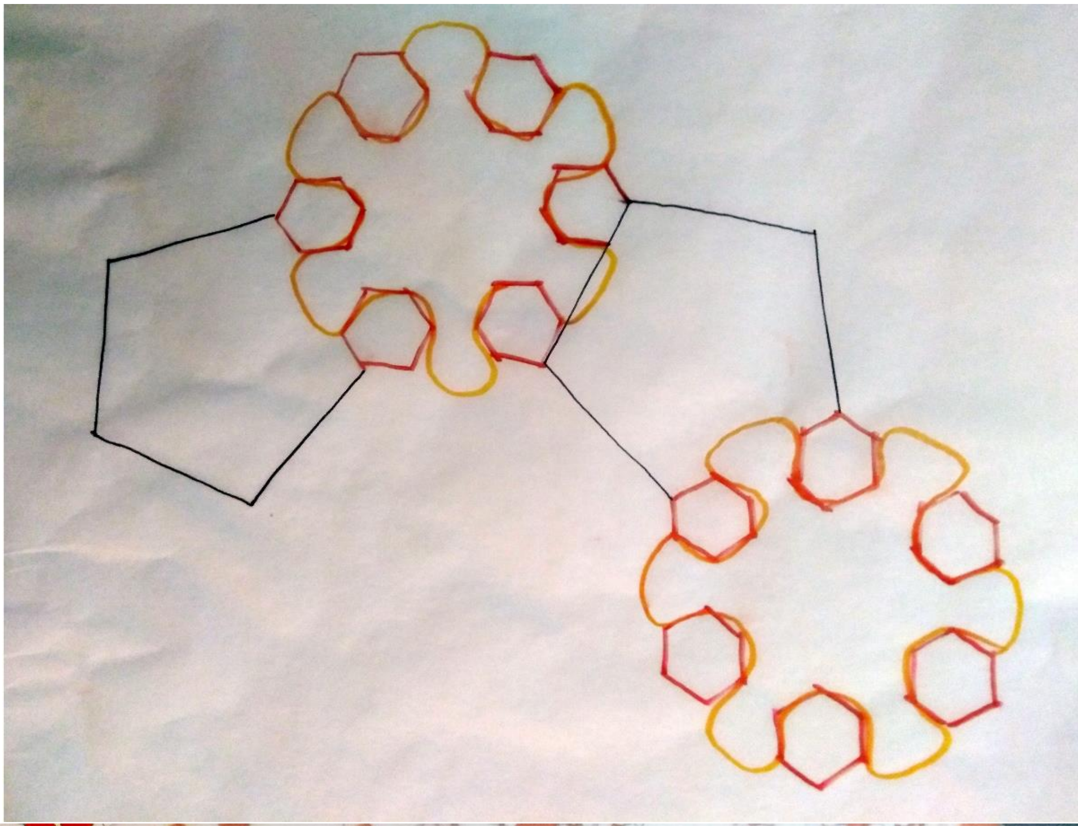
Dwelling Outline- Option 2-for a 3-bedroom cluster with toilets

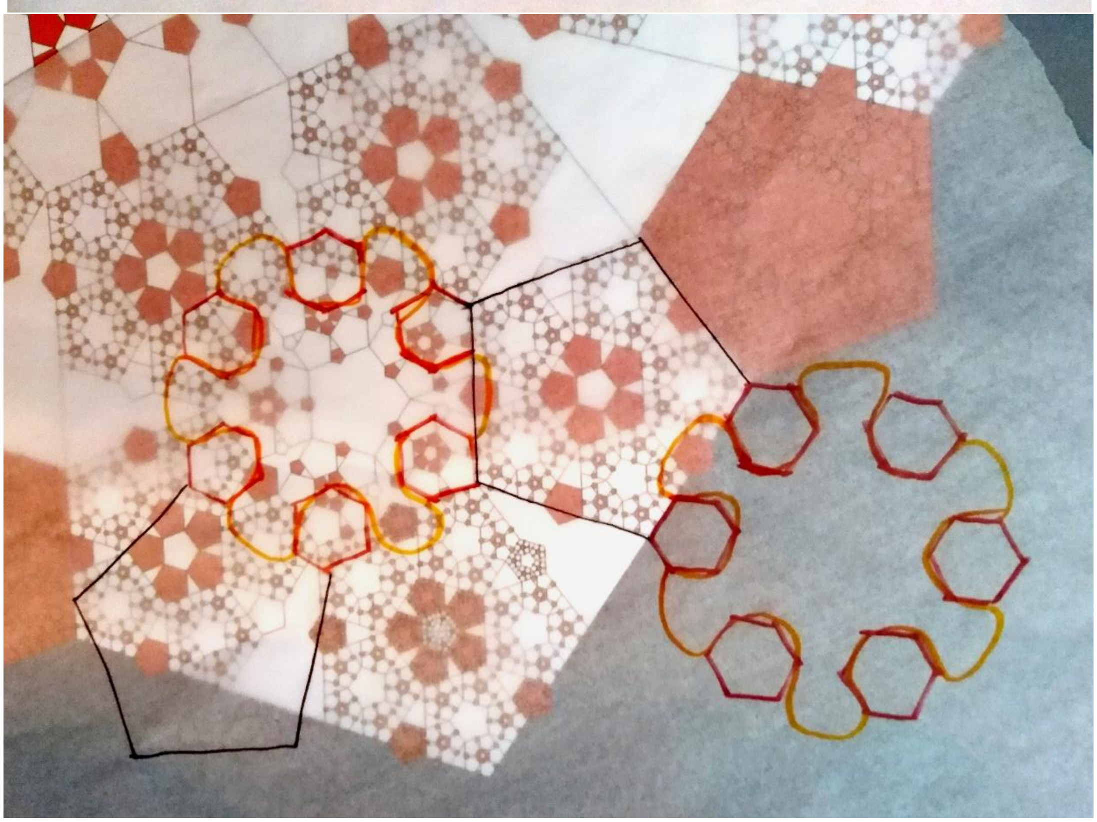


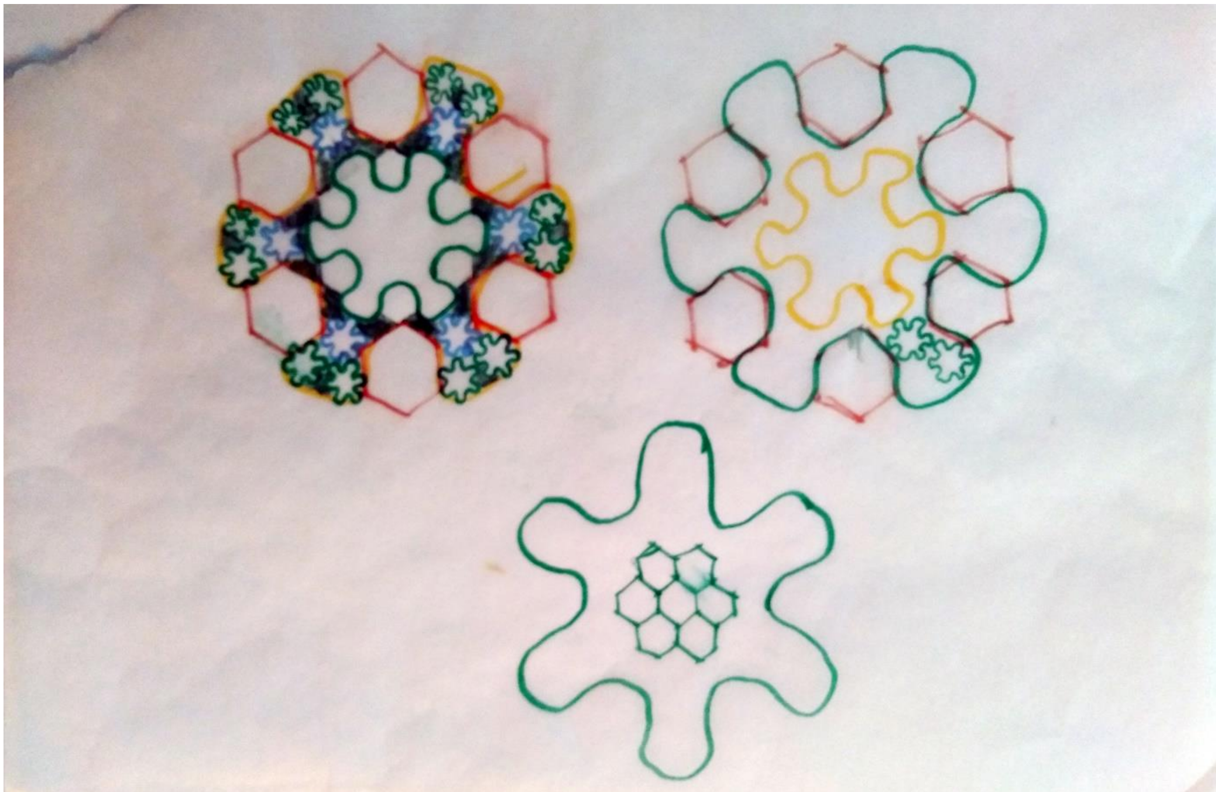
Futher Master Plan Studies and Drawings

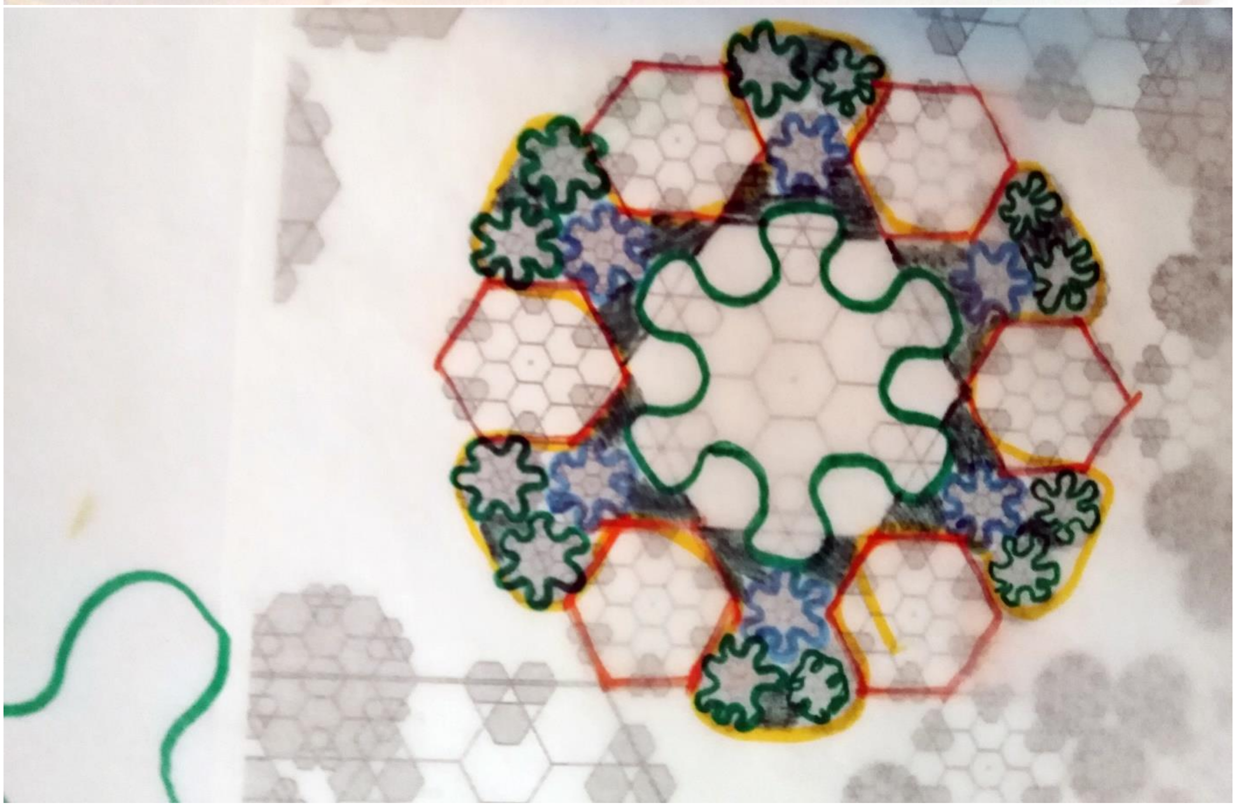






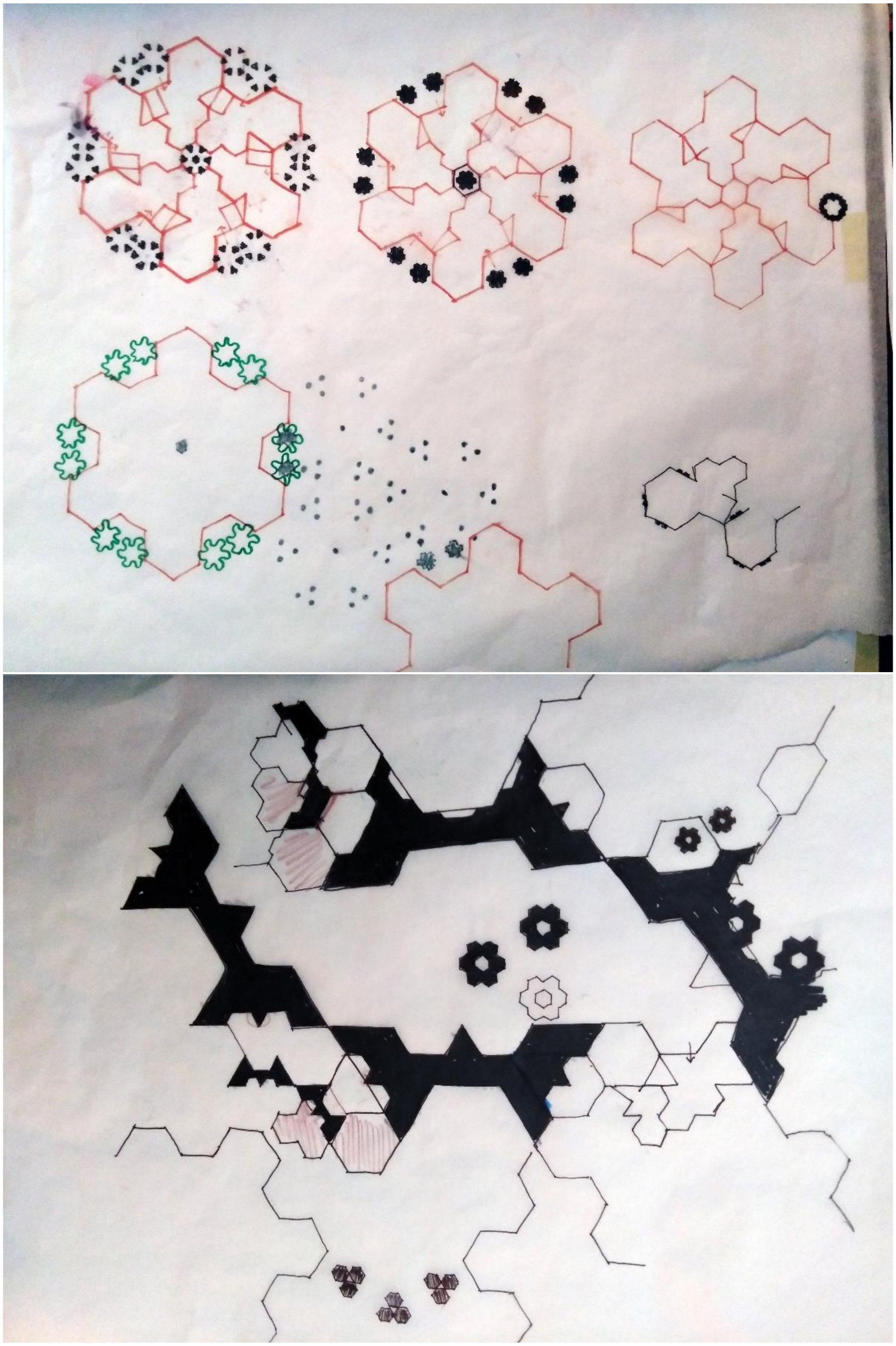


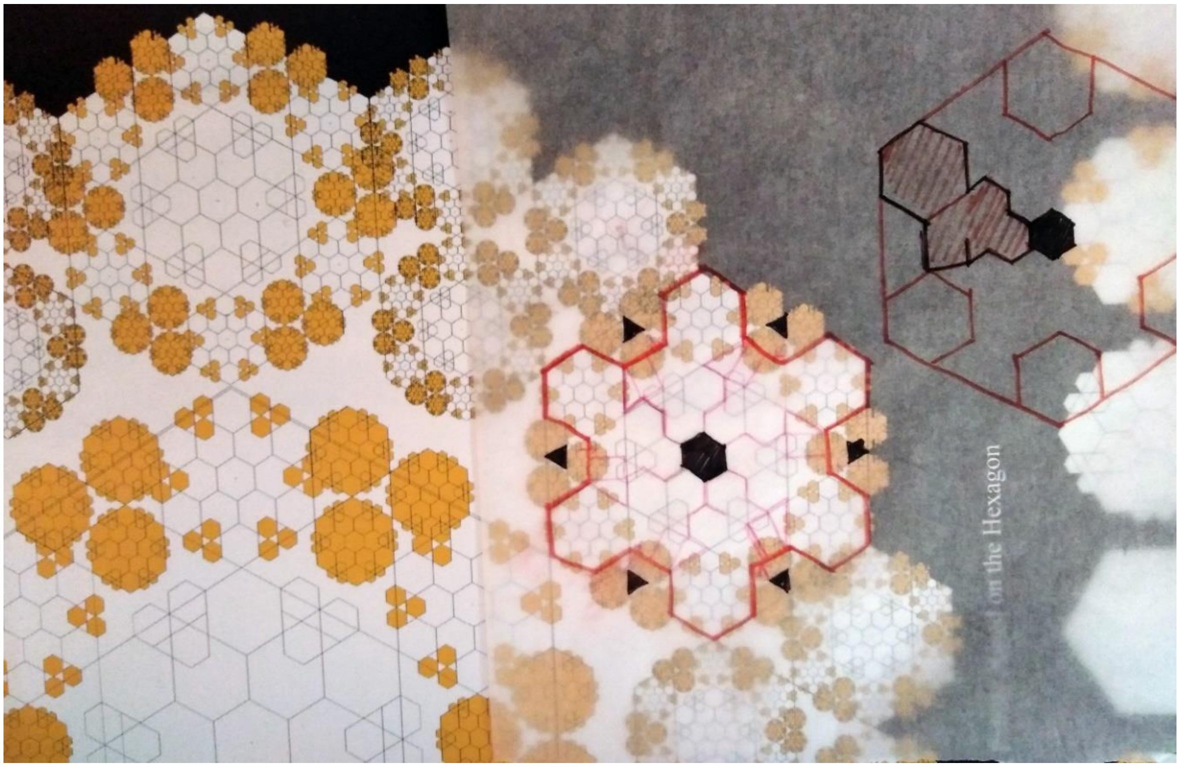


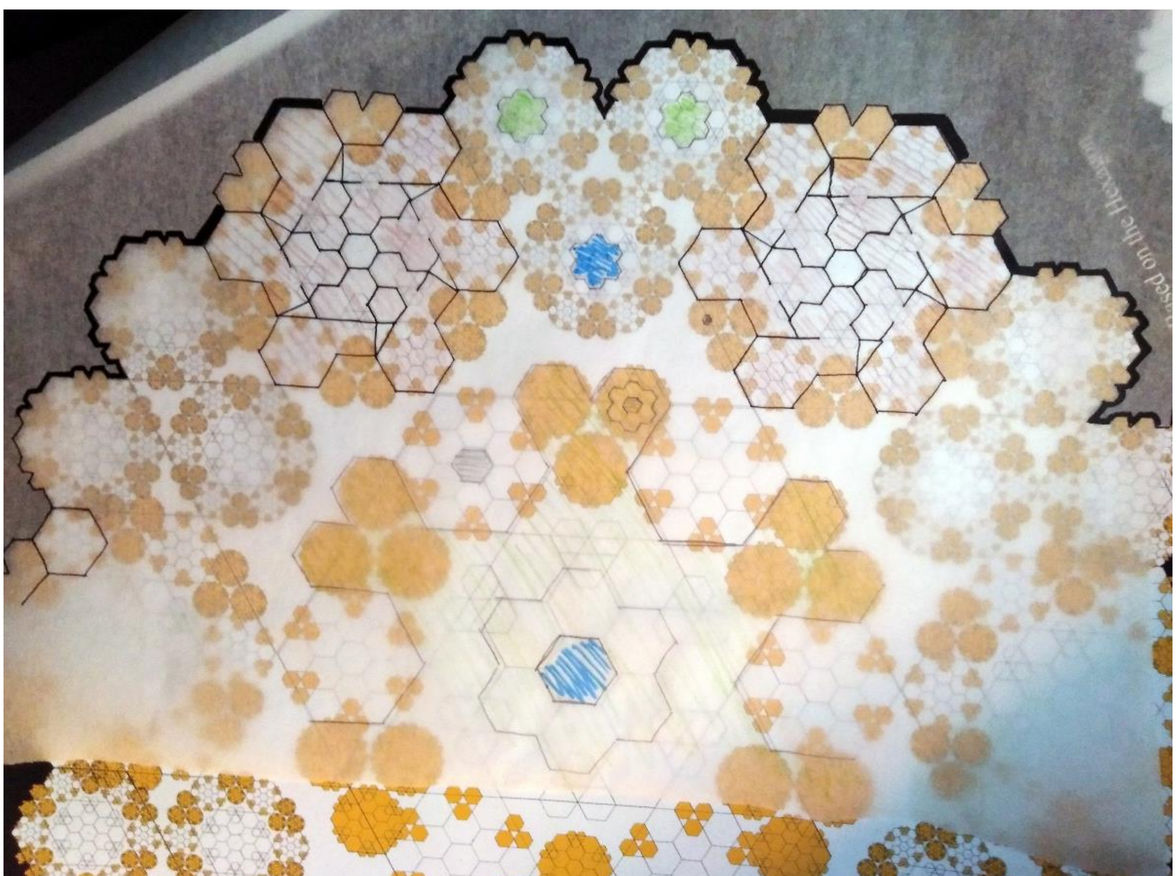


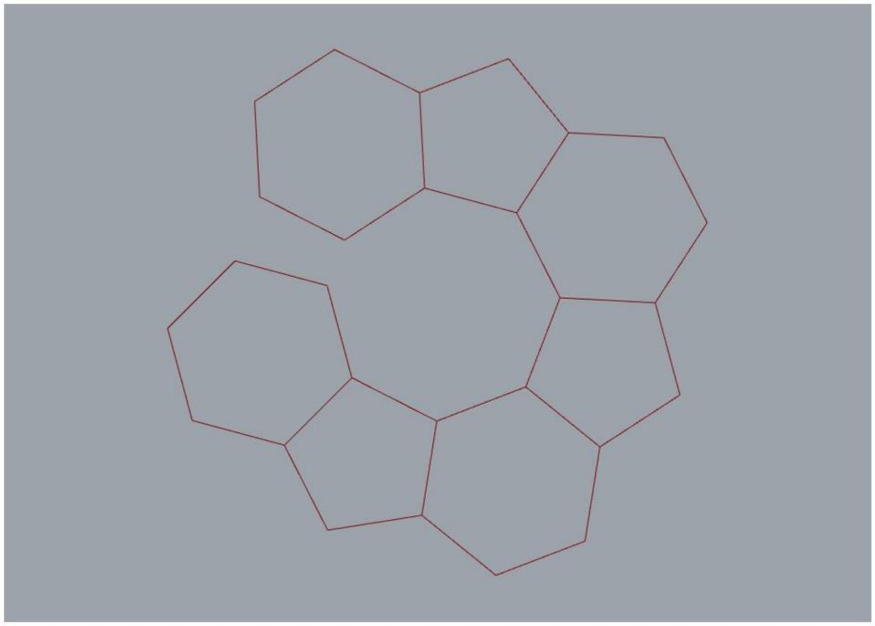
P

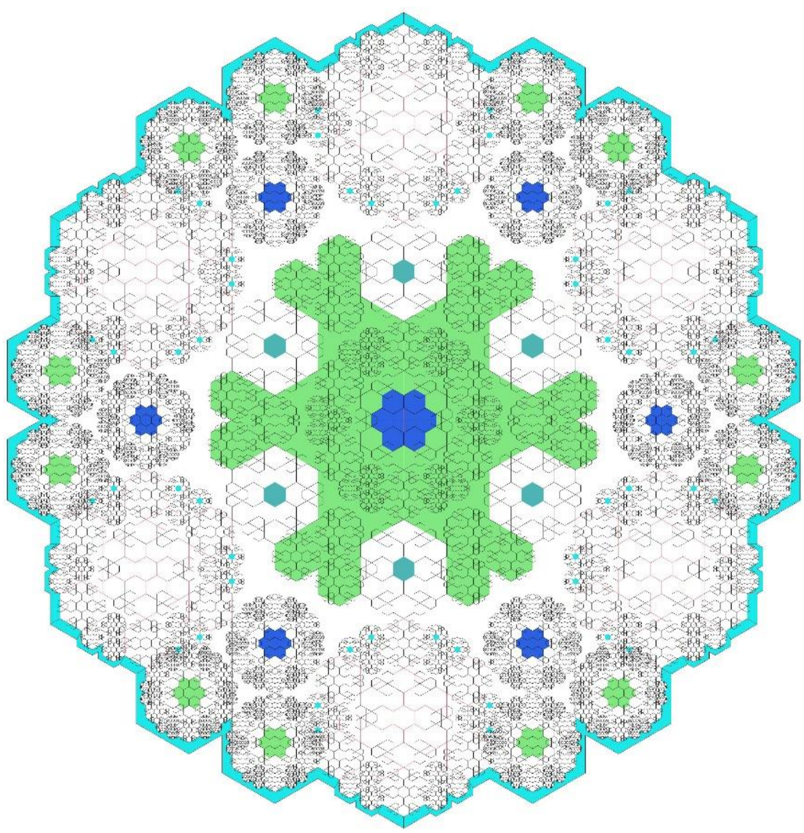
Poche Studies



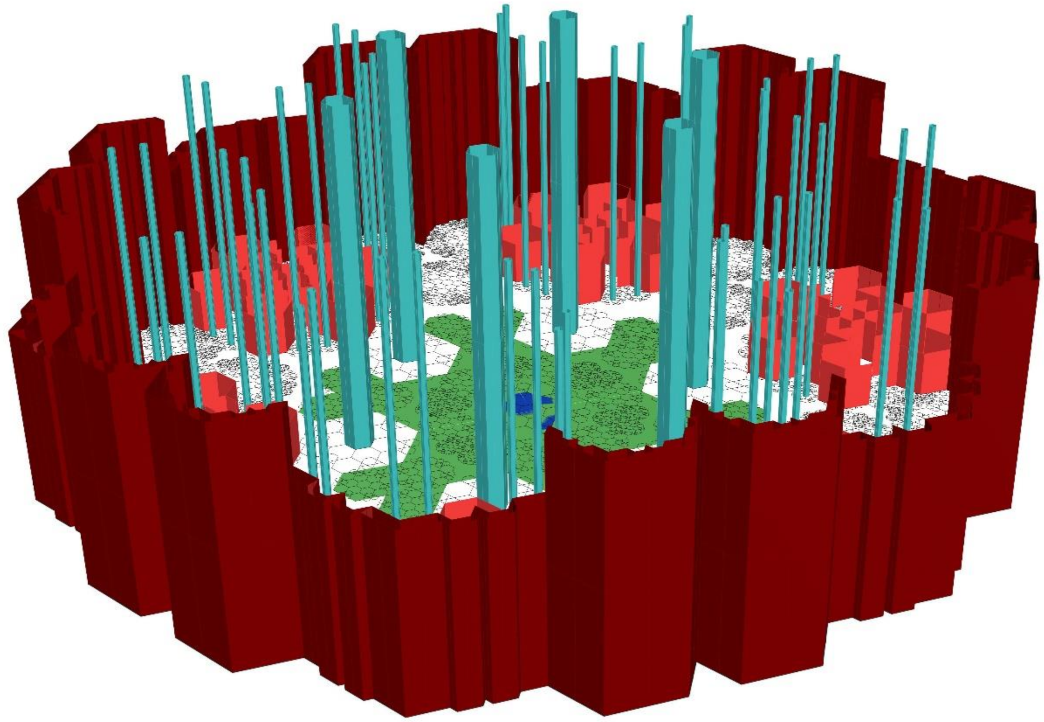

on the Hexagon



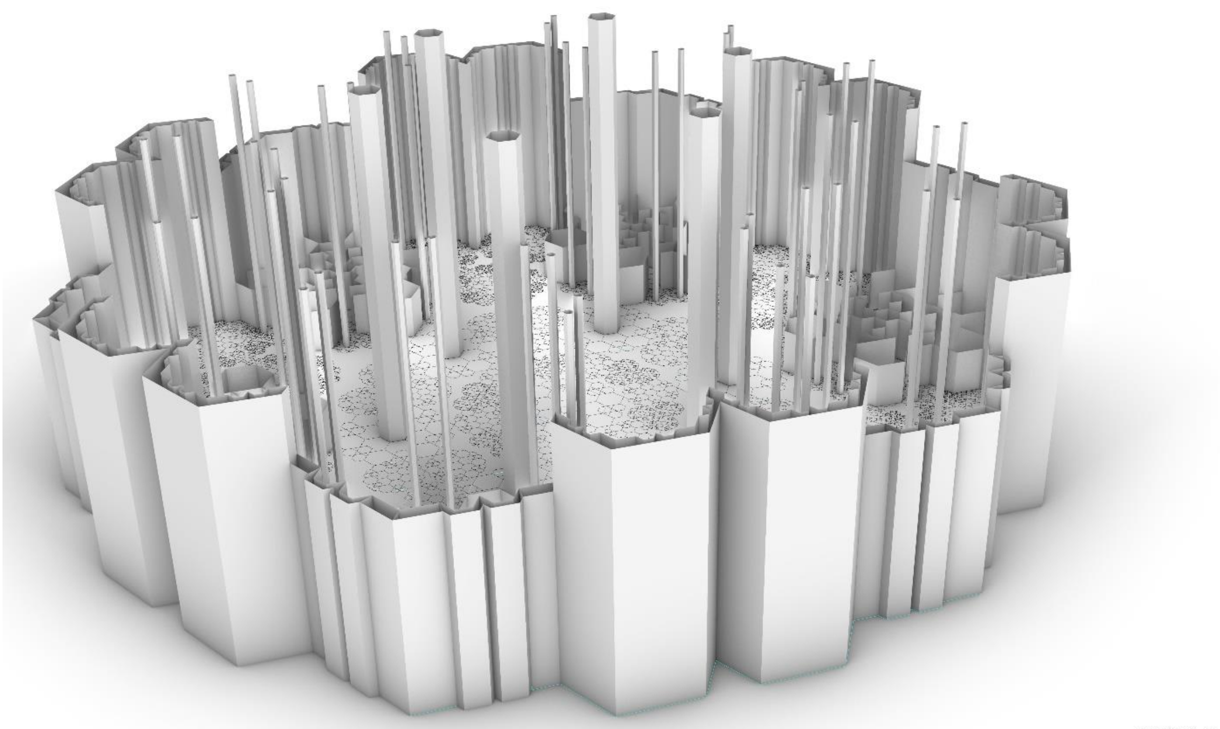




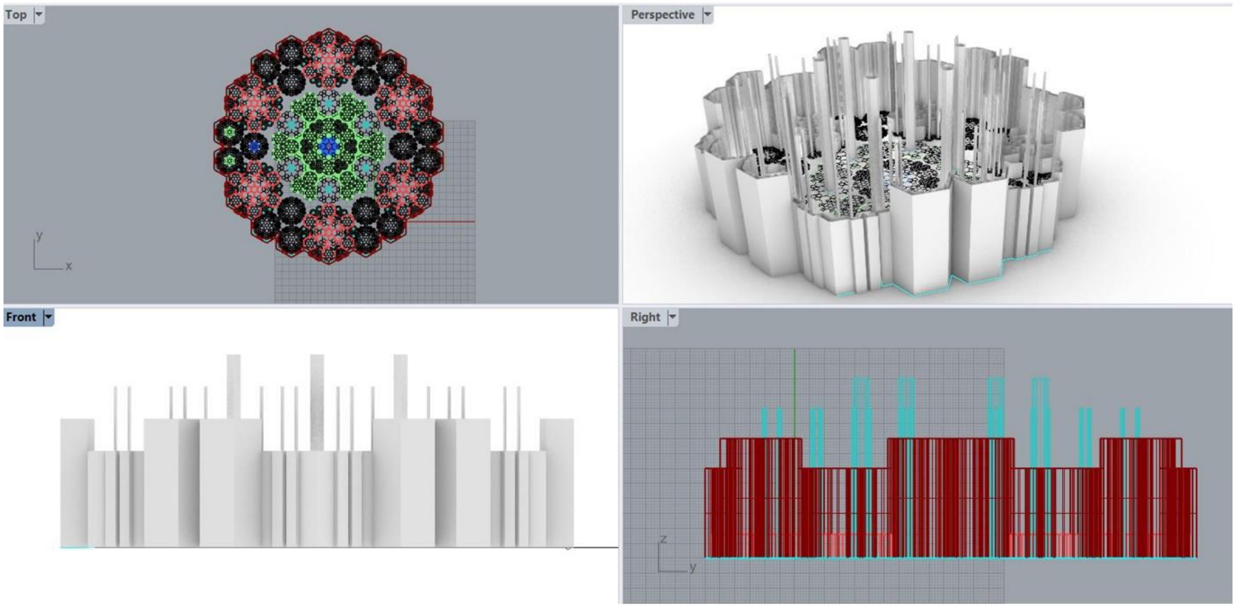
OPTION 1-A



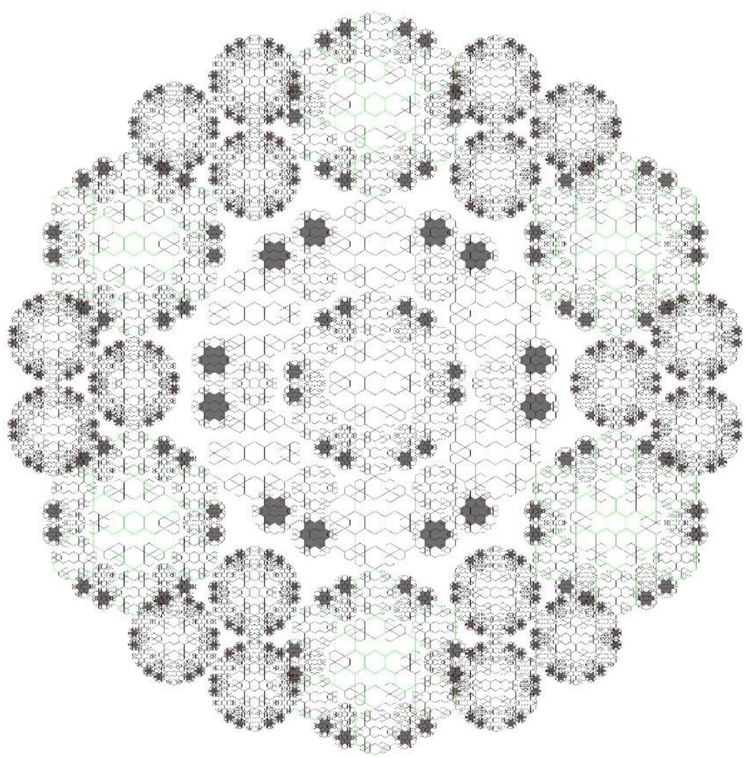
OPTION 1-B



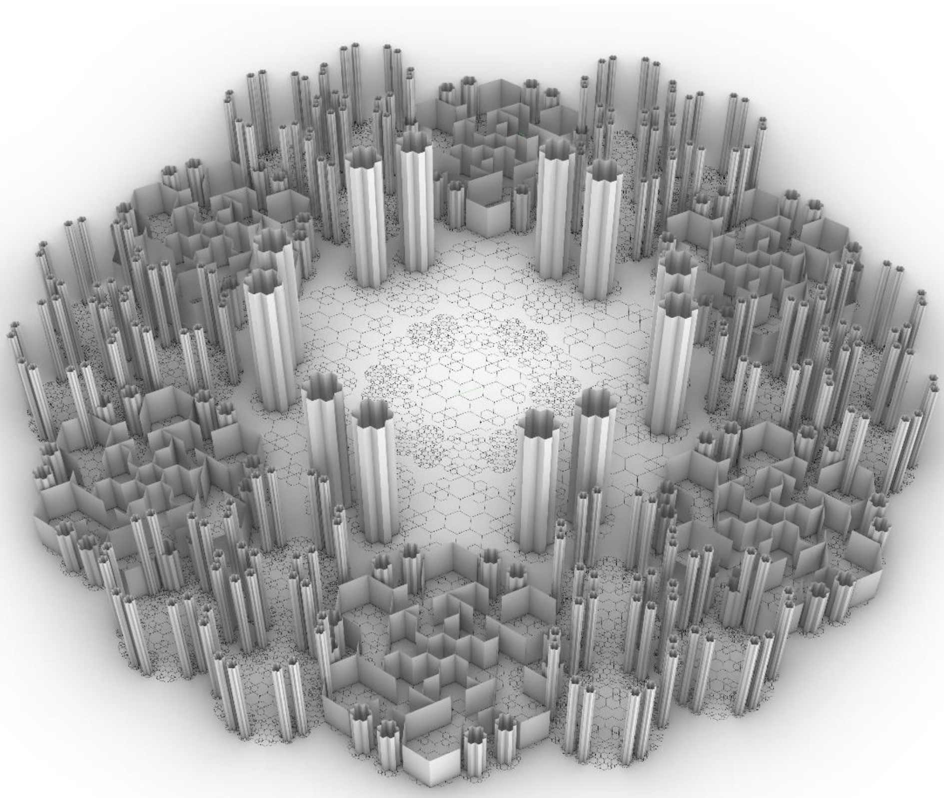
OPTION 1-C



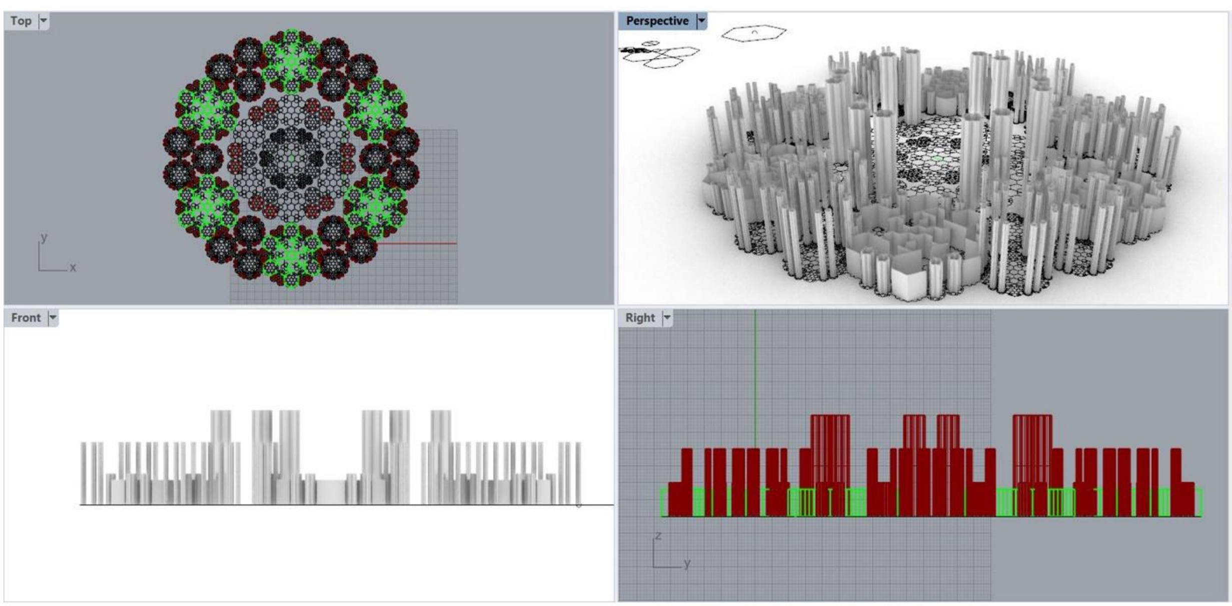
OPTION 1-C



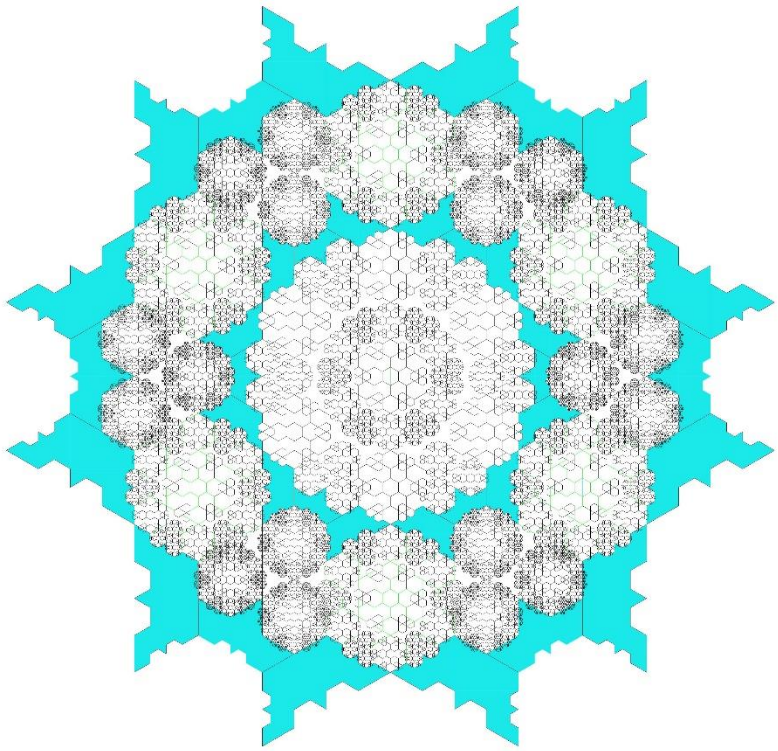
OPTION 2-A



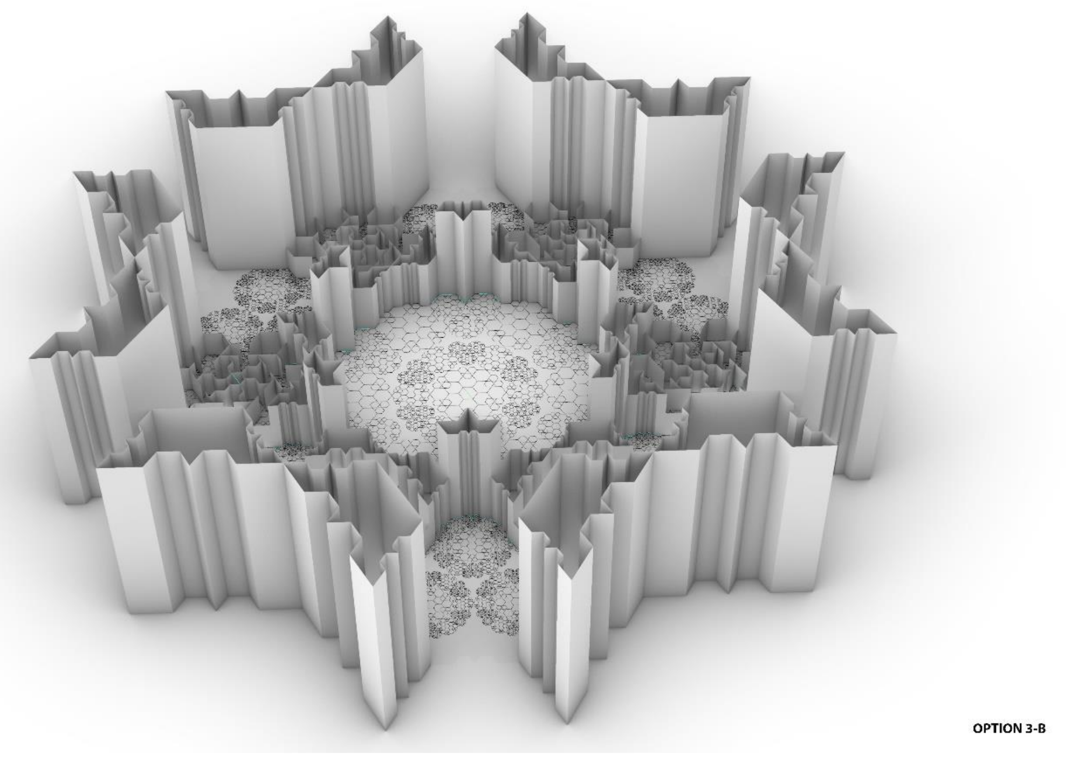
OPTION 2-B



OPTION 2-C



OPTION 3-A



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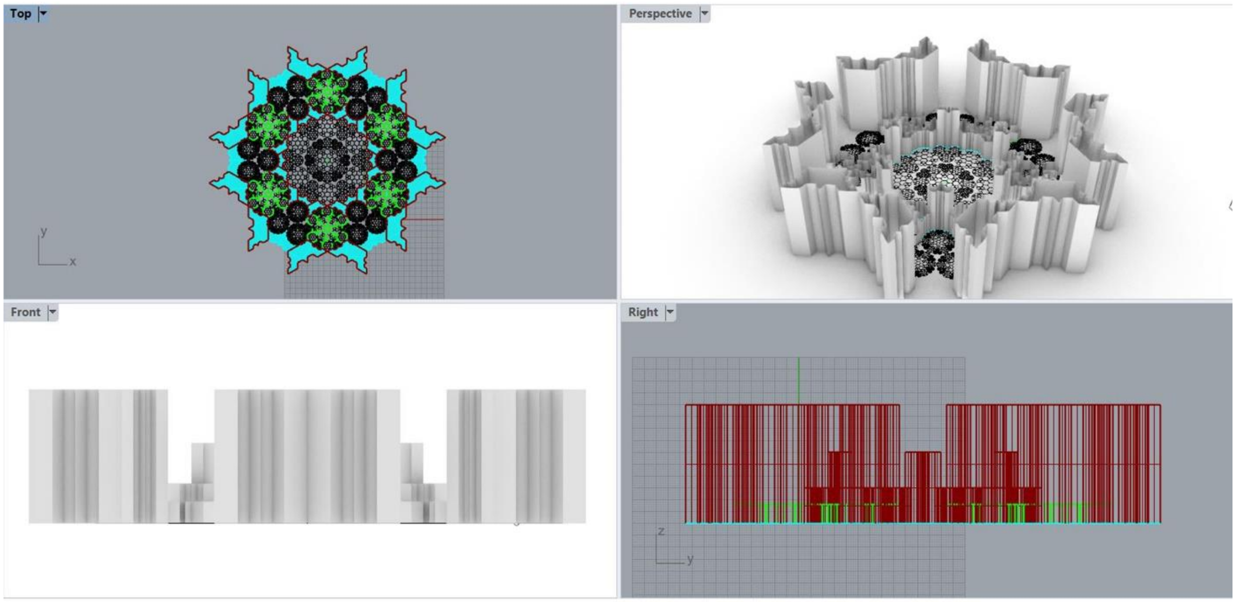
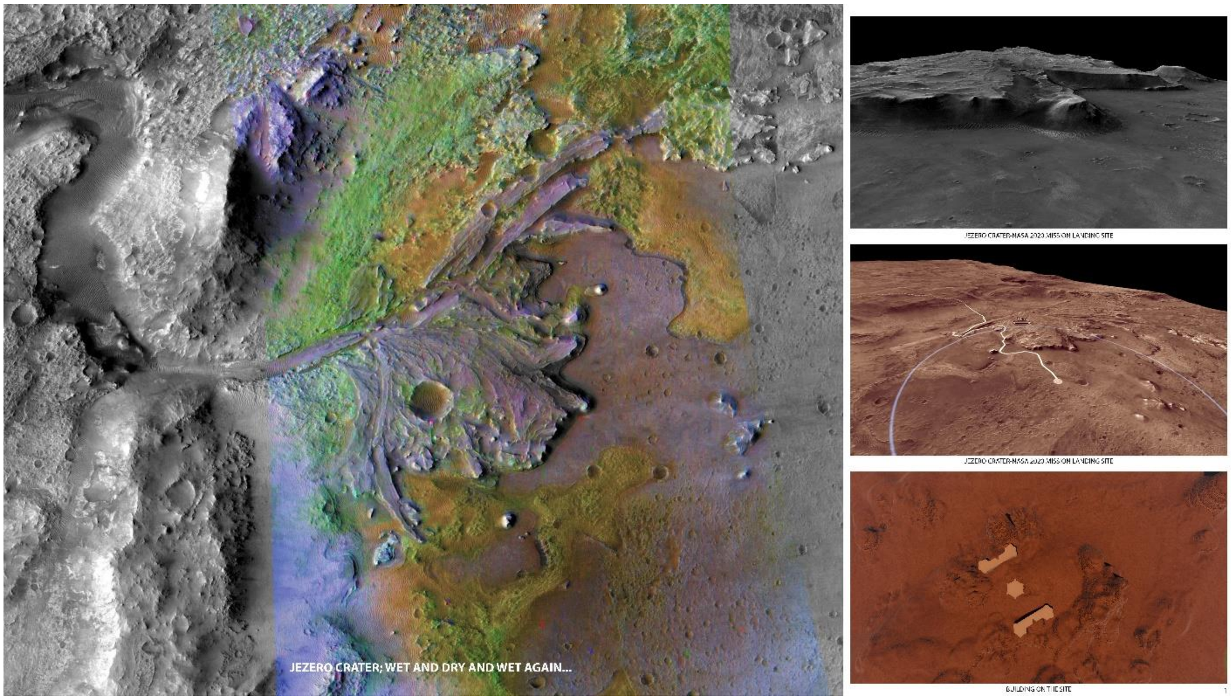
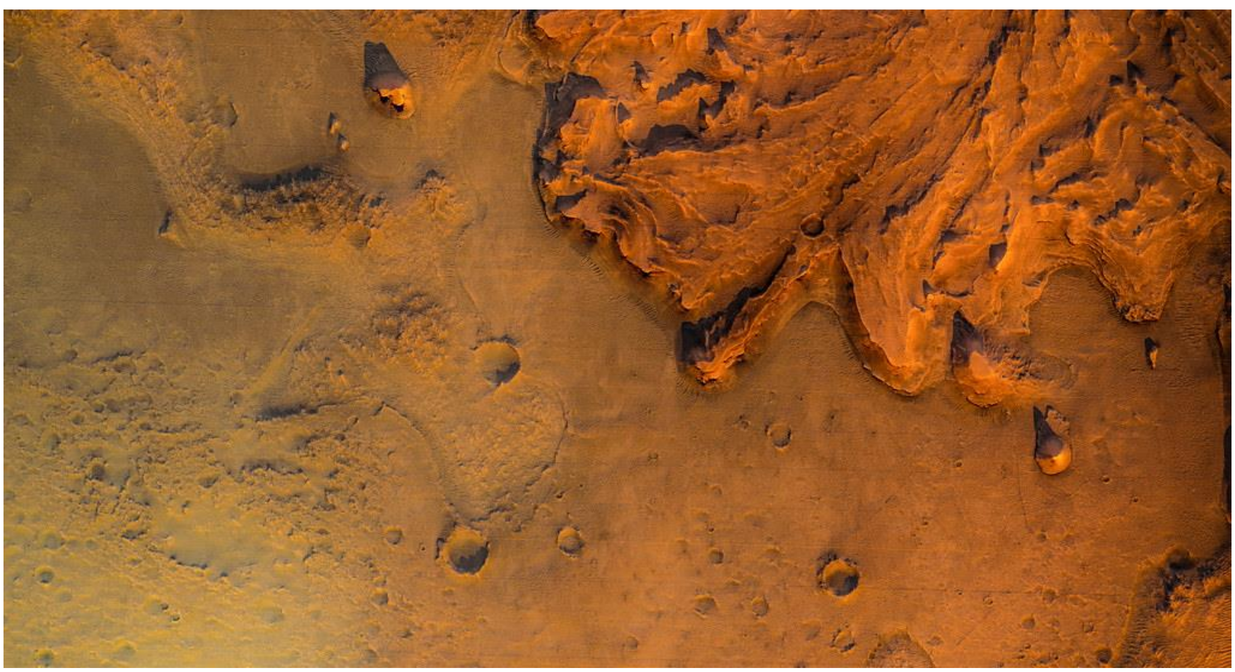
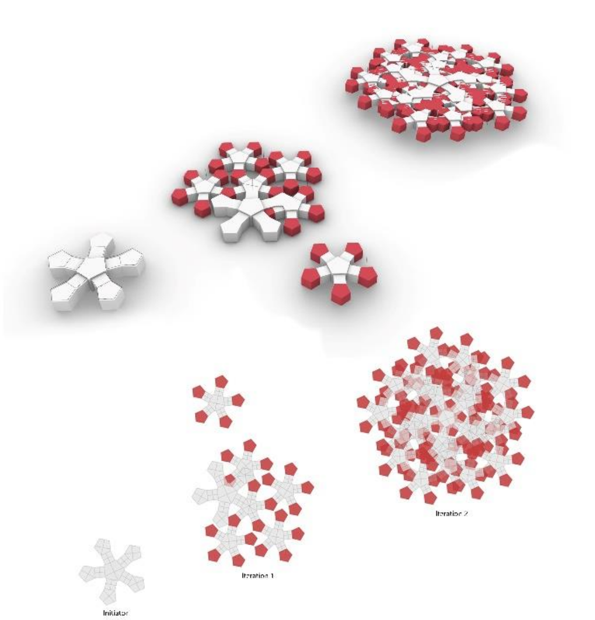


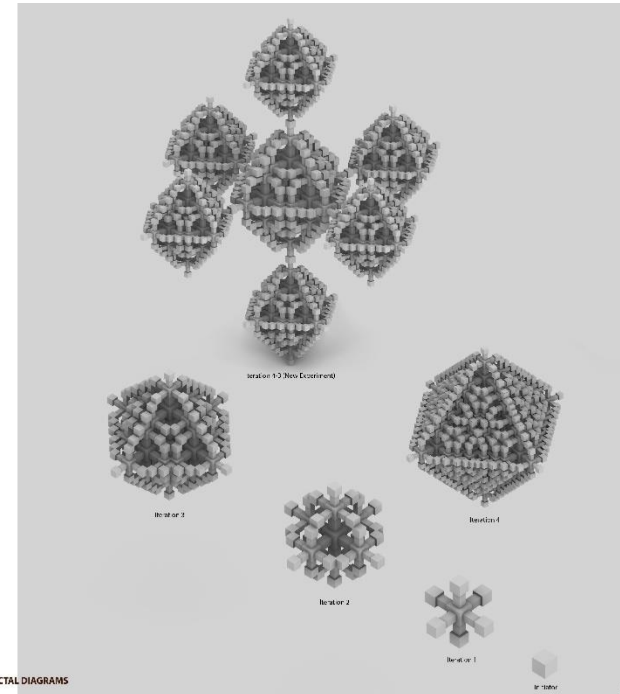
OPTION 3-C

FINAL PROPOSAL

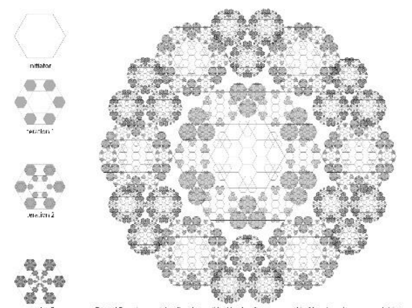




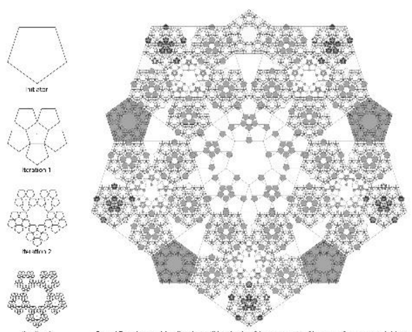




3D FRACTAL DIAGRAMS



Fractal Exercises and Studies that will be Used as Diagrams and in Planning - Hexagon as Initiator



Fractal Exercises and Studies that will be Used as Diagrams and in Planning - Pentagon as Initiator

FRACTAL GEOMETRY IS A HIGHLY ORDERED GEOMETRY. I USED FRACTALS AS A DIAGRAM TO MAKE MY PROGRAM WORK. THE RICHNESS OF FRACTAL AND OF COURSE THE DIFFERENT MODULES AND DIFFERENT SCALES IT GAVE ME, HELPED TO UNDERSTAND BETTER HOW TO PUT DIFFERENT FUNCTIONS AND SPACES OF MY PROGRAM OR HOW TO THINK OF SPACES LIKE "BLACK BOXES" WHERE ENGINEERING AND MECHANICAL FACILITIES WILL BE PUT.

THE FIRST FRACTAL, TOP LEFT, IS THE FRACTAL I USED AS MY DIAGRAM. IN THIS FRACTAL I STARTED WITH A HEXAGON THE INITIATOR AND THEN I TOOK IT TO THE 5TH ITERATION. AS IT WAS NOT RICH ENOUGH, I ADDED A SECOND INITIATOR AND TOOK THAT TO THE 5TH INITIATOR AND THEN I COMBINED THESE TWO TOGETHER. THE RESULT IS THIS RICH FRACTAL THAT COULD GROW IN DIFFERENT DIRECTIONS EVEN IF IT IS CUT.

THE SECOND FRACTAL, BOTTOM LEFT, IS THE SECOND OF FOURTH 2D FRACTALS I PRODUCED. IN THIS ONE I USED A PENTAGON AS THE INITIATOR AND THEN THE SAME PROCESS AS IN THE FIRST FRACTAL WAS REPEATED. THE RESULT IS A DIFFERENT FRACTAL WHICH IS ALSO RICH IN ALL SCALES AND DIRECTIONS.

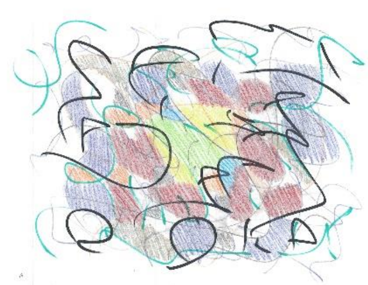
CHAOS DIAGRAMS AND SUPER RANDOM DIAGRAMS. I USED CHAOS DIAGRAM TO FREE MY MIND FROM THE RESTRICTIONS, FORMS AND LIMITS AND LET CHAOS TAKE ME TO MY GOAL. THIS WAS A TOTALLY NEW EXERCISE FOR ME AND TOOK ME A LONG TIME TO TRUST CHAOS.

IF IT WAS NOT FOR THE CHAOS DIAGRAM I WOULDN'T HAVE THOUGHT OF SOME IDEAS OR BEING ABLE TO REFINE SOME. THE TWO DIAGRAMS ON THE RIGHT ARE THE TWO OF MANY CHAOTIC DIAGRAMS I WORKED ON TO DECIDE AND FIT MY PROGRAM AND ZONING. EACH COLOR SHOWS A FUNCTION OR SPACES AND WHILE I WAS DRAWING THESE DIAGRAMS I HAD MY PROGRAM IN MIND AND LETTING CHAOS GUIDE ME THROUGH.

THE FIRST DIAGRAM, TOP RIGHT, HELPED TO THINK OF HAVING GREEN SPACES IN A WAY THAT GOES THROUGH OTHER SPACES AND BEING CLOSER TO THE DWELLING SPACES.

THE SECOND DIAGRAM, BOTTOM RIGHT, HELPED ME THINK OF HAVING THE GREEN SPACE AS THE HEART OF THE COMPLEX AND HAVING COMMUNITY SPACES AROUND IT.

Chaos Diagrams and applying the program into Chaotic Diagrams



Chaos Diagrams and applying the program into Chaotic Diagrams

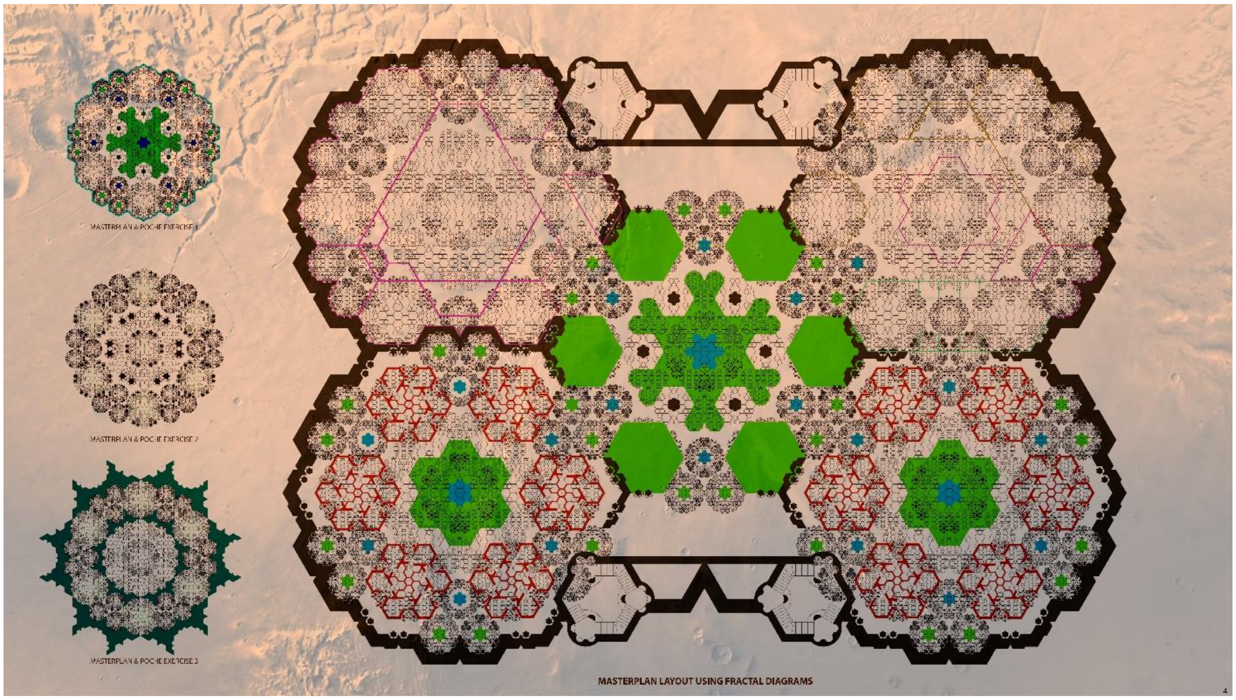
Primary Chaos Diagrams

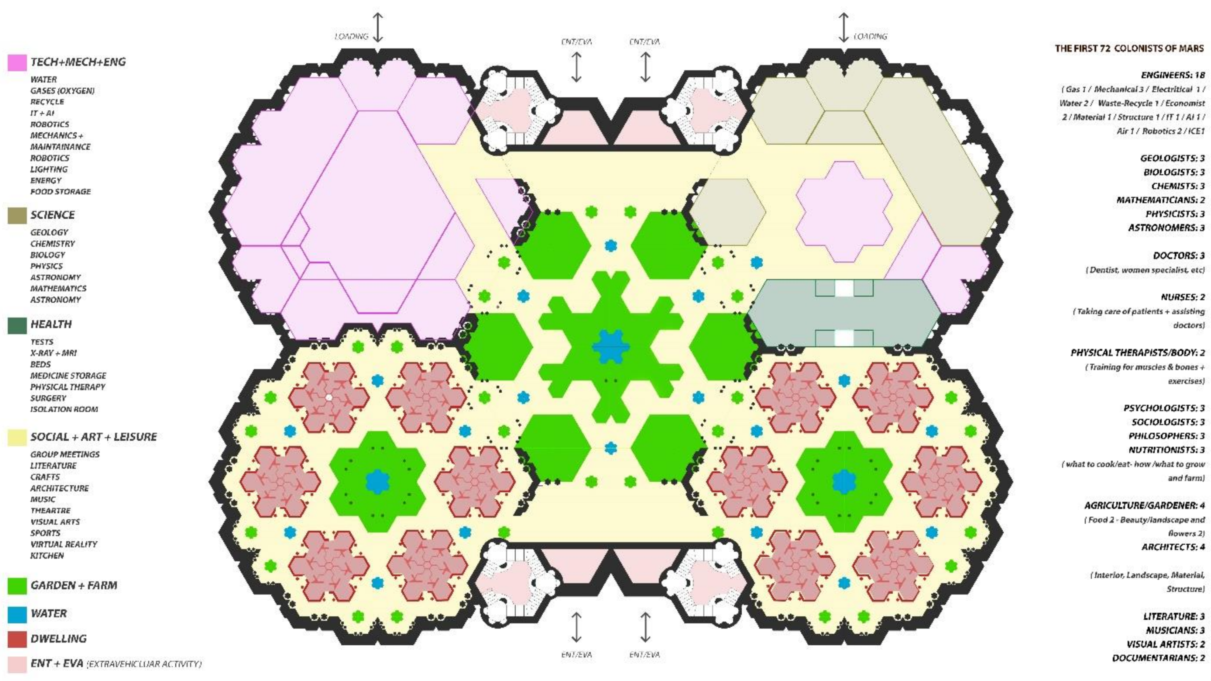
Primary Chaos Diagrams

Primary Chaos Diagrams

Primary Chaos Diagrams

3

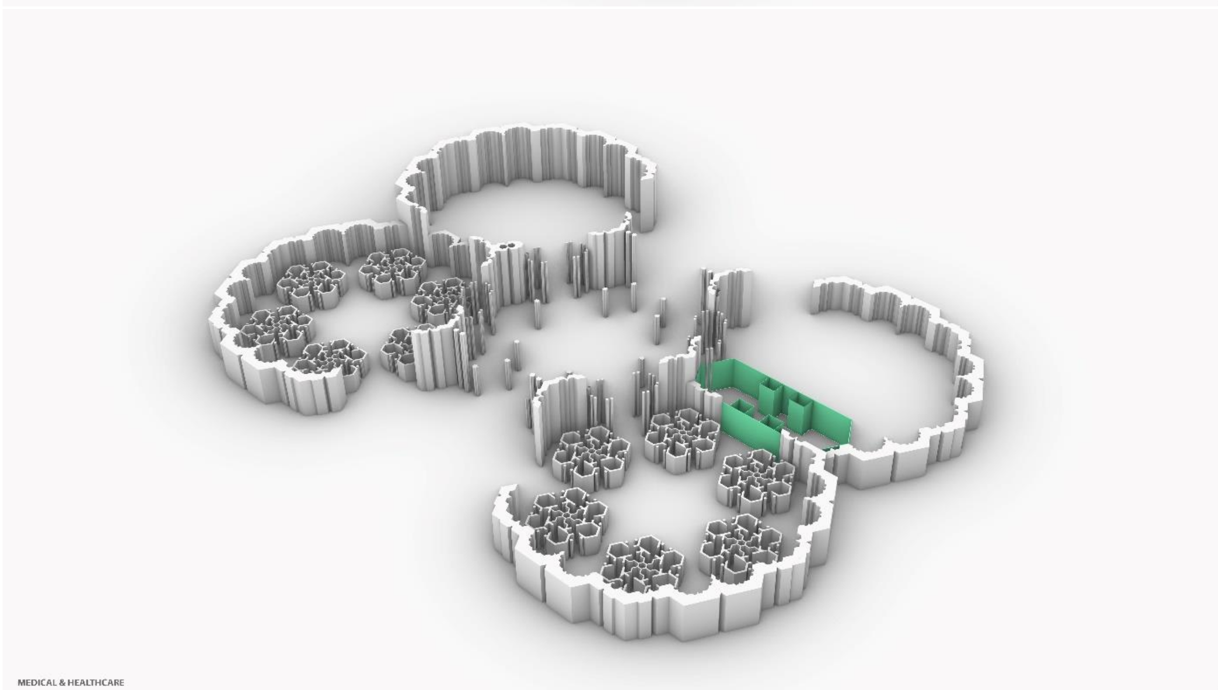

MASTERPLAN & POCHE EXERCISE 1
MASTERPLAN & POCHE EXERCISE 2
MASTERPLAN & POCHE EXERCISE 3
MASTERPLAN LAYOUT USING FRACTAL DIAGRAMS
4

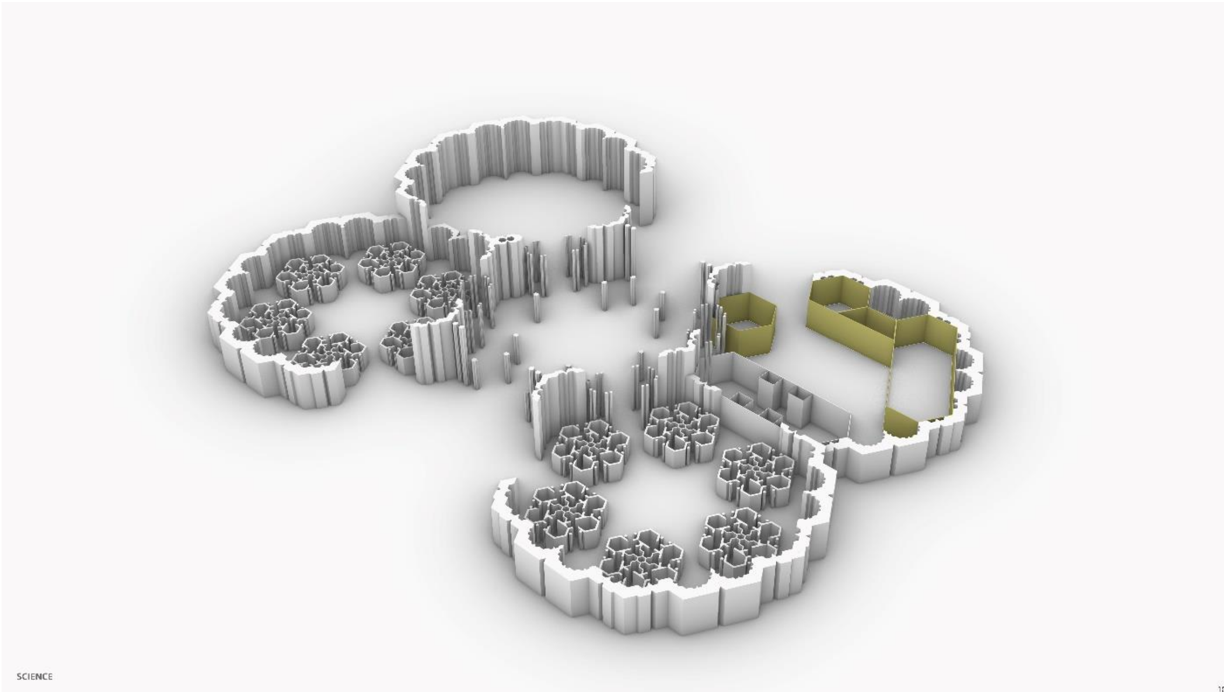

TECH+MECH+ENG
WATER
GASES (OXYGEN)
RECYCLE
IT + AI
ROBOTICS
MECHANICS +
MAINTAINANCE
ROBOTICS
LIGHTING
ENERGY
FOOD STORAGE
SCIENCE
GEOLOGY
CHEMISTRY
BIOLOGY
PHYSICS
ASTRONOMY
MATHEMATICS
ASTRONOMY
HEALTH
TESTS
X-RAY + MRI
BEDS
MEDICINE STORAGE
PHYSICAL THERAPY
SURGERY
ISOLATION ROOM
SOCIAL + ART + LEISURE
GROUP MEETINGS
LITERATURE
CRAFTS
ARCHITECTURE
MUSIC
THEARTRE
VISUAL ARTS
SPORTS
VIRTUAL REALITY
KITCHEN
GARDEN + FARM
WATER
DWELLING
ENT + EVA (EXTRAVEHICLUAR ACTIVITY)
LOADING
ENT/EVA
ENT/EVA
LOADING
ENT/EVA
ENT/EVA
THE FIRST 72 COLONISTS OF MARS
ENGINEERS: 18
(Gas 1 / Mechanical 3 / Electritical 1 / Water 2 / Waste-Recycle 1 / Economist 2 / Material 1 / Structure 1 / IT 1 / AI 1 / Air 1 / Robotics 2 / ICE1
GEOLOGISTS: 3
BIOLOGISTS: 3
CHEMISTS: 3
MATHEMATICIANS: 2
PHYSICISTS: 3
ASTRONOMERS: 3
DOCTORS: 3
(Dentist, women specialist, etc)
NURSES: 2
(Taking care of patients + assisting doctors)
PHYSICAL THERAPISTS/BODY: 2
(Training for muscles & bones + exercises)
PSYCHOLOGISTS: 3
SOCIOLOGISTS: 3
PHILOSOPHERS: 3
NUTRITIONISTS: 3
(what to cook/eat- how /what to grow and farm)
AGRICULTURE/GARDENER: 4
(Food 2 - Beauty/landscape and flowers 2)
ARCHITECTS: 4
(Interior, Landscape, Material, Structure)
LITERATURE: 3
MUSICIANS: 3
VISUAL ARTISTS: 2
DOCUMENTARIANS: 2
5

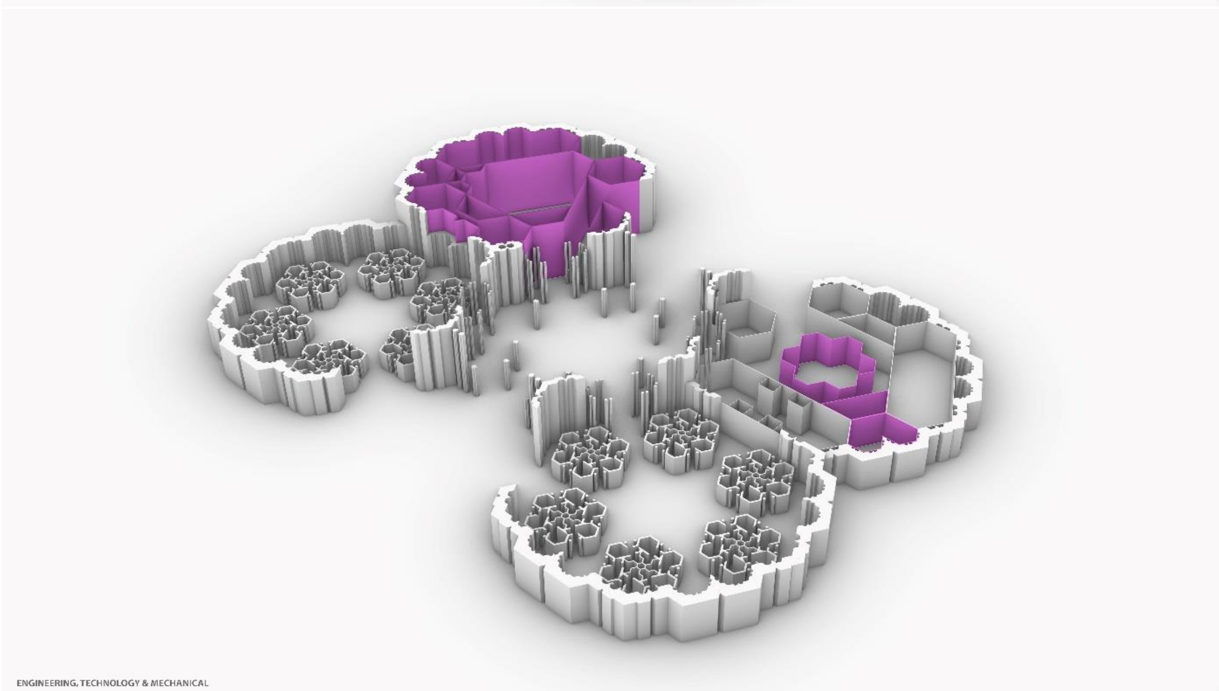

POCHE & WALLS
6

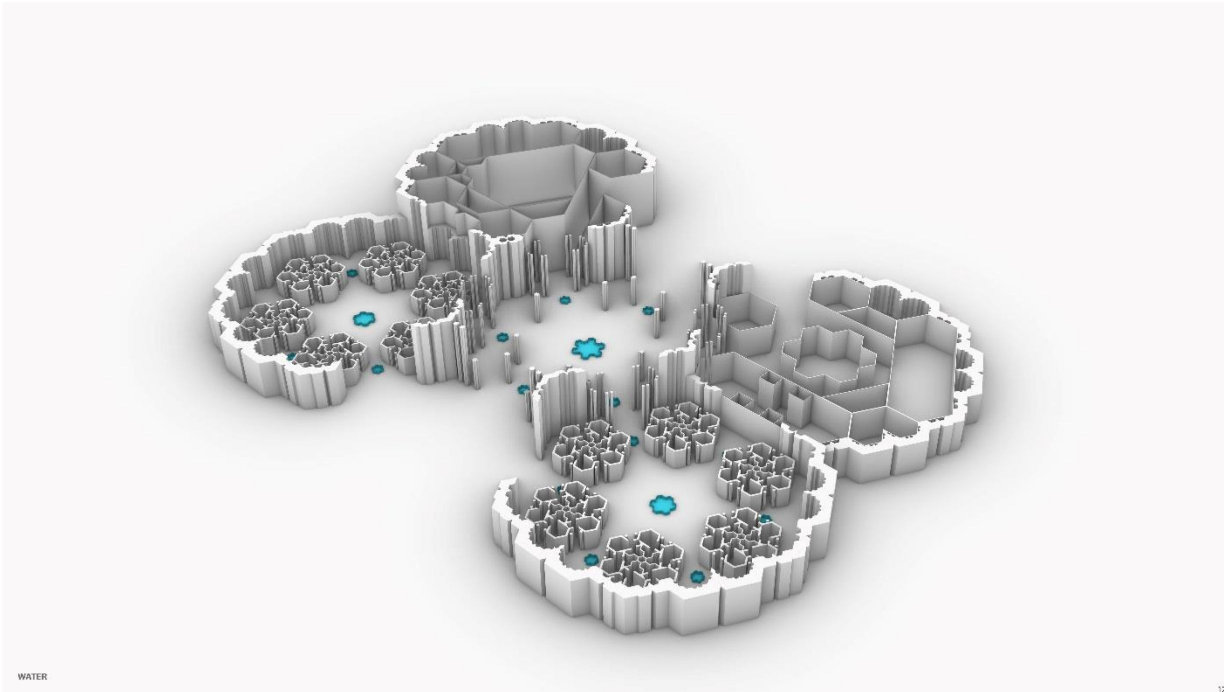

COLUMNS AND PIERS
7


DWELLING UNITS
8

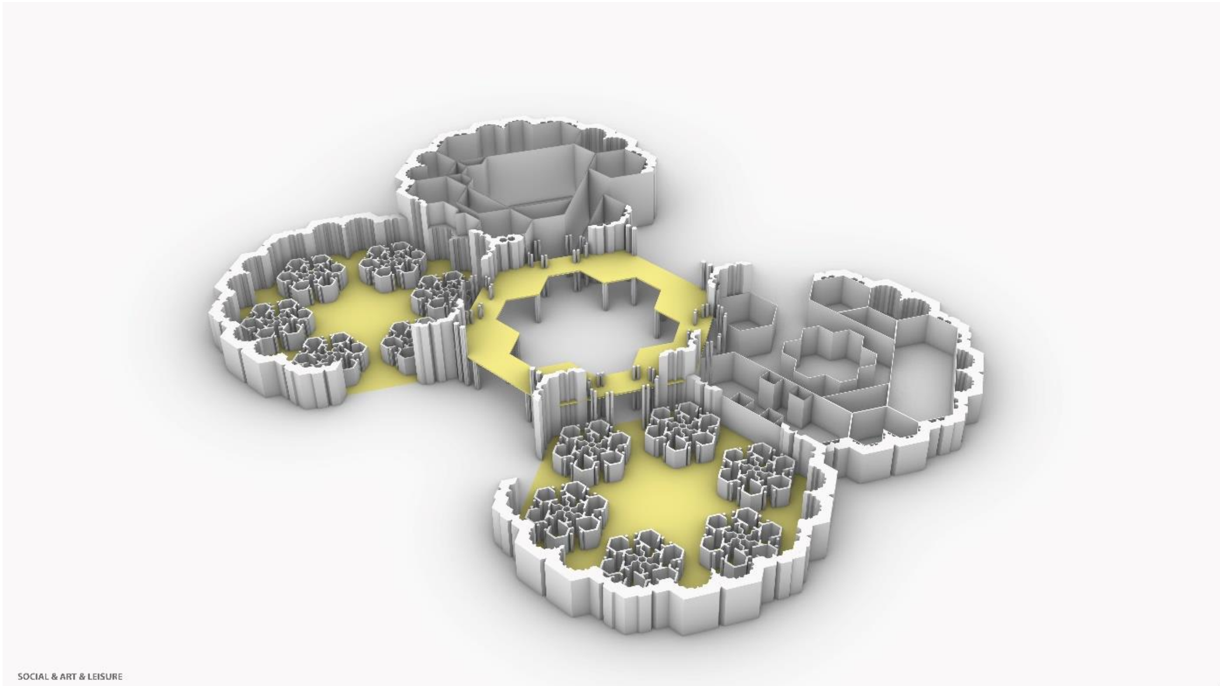

MEDICAL & HEALTHCARE
9

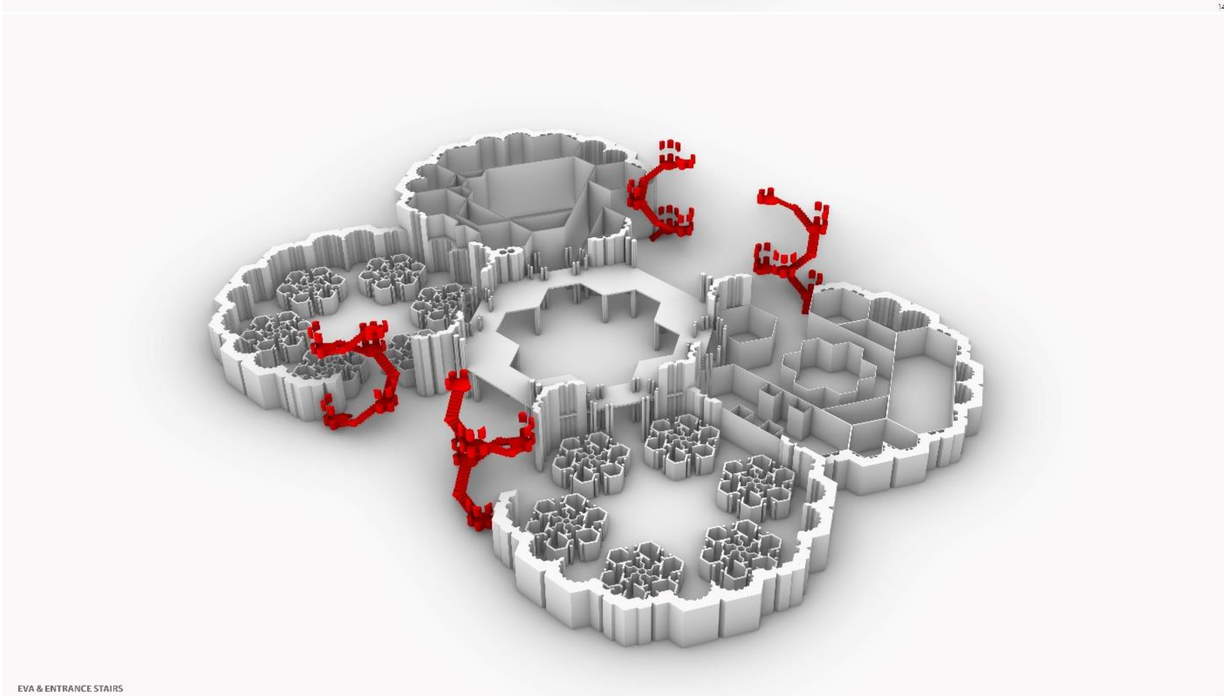

SCIENCE
10

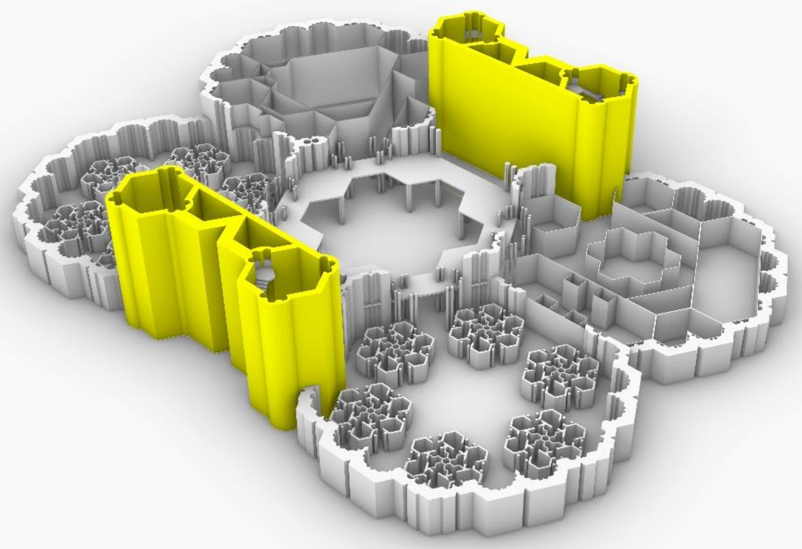

ENGINEERING, TECHNOLOGY & MECHANICAL
11


WATER
12


FARMS & VEGETATION
13

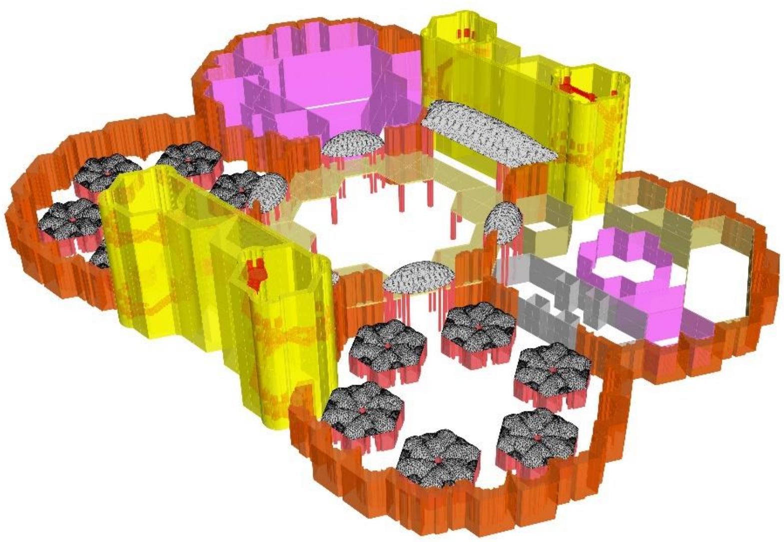

SOCIAL & ART & LEISURE
14


EVA & ENTRANCE STAIRS
15



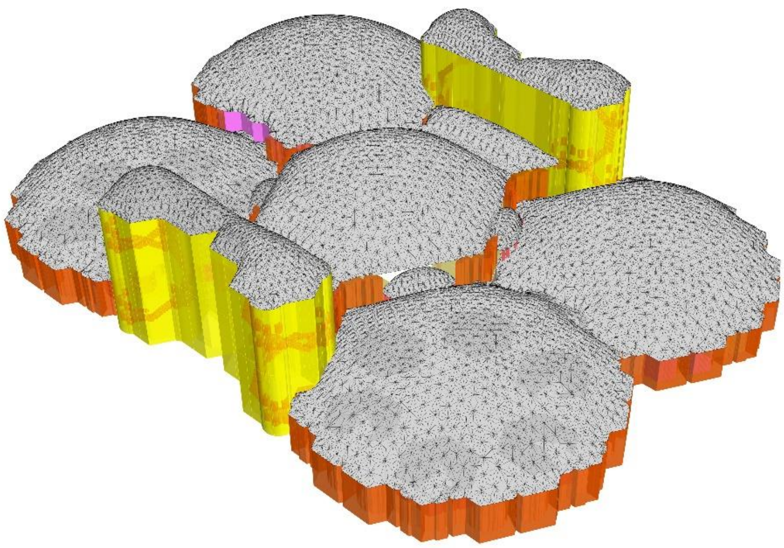
EVA & ENTRANCE WALLS

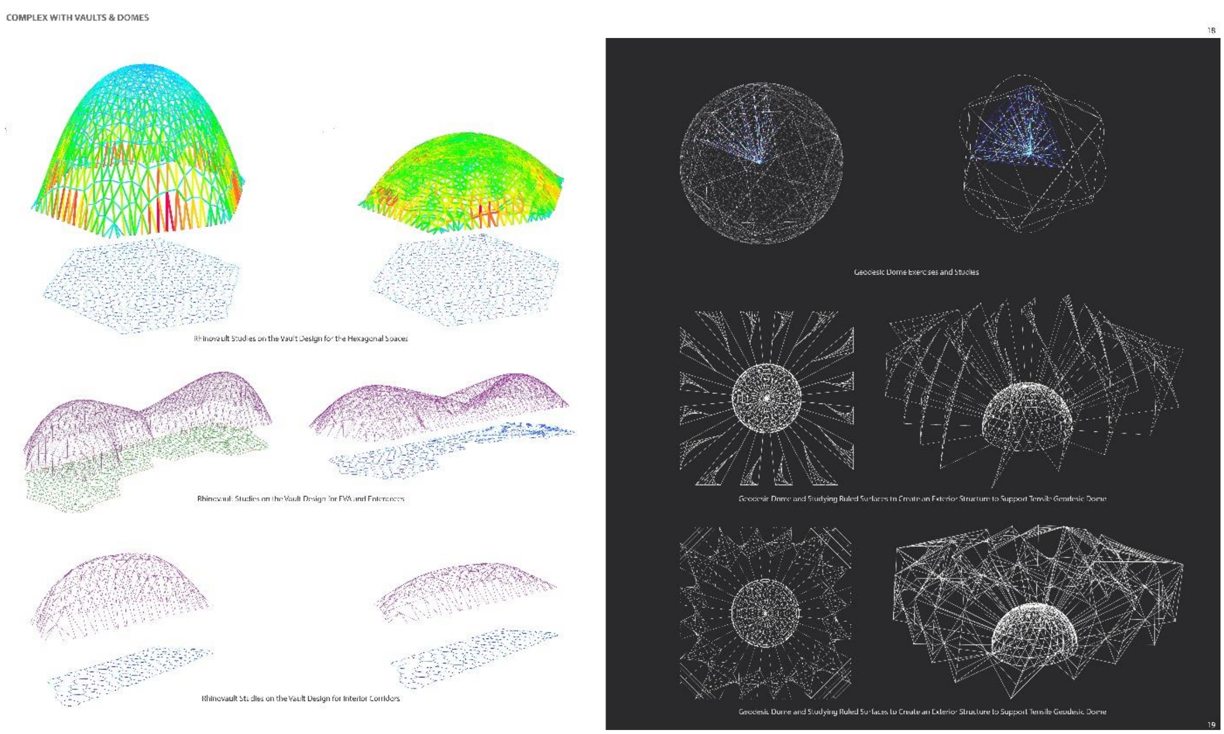
16



COMPLEX WITH INTERIOR VAULTS & DOMES

17

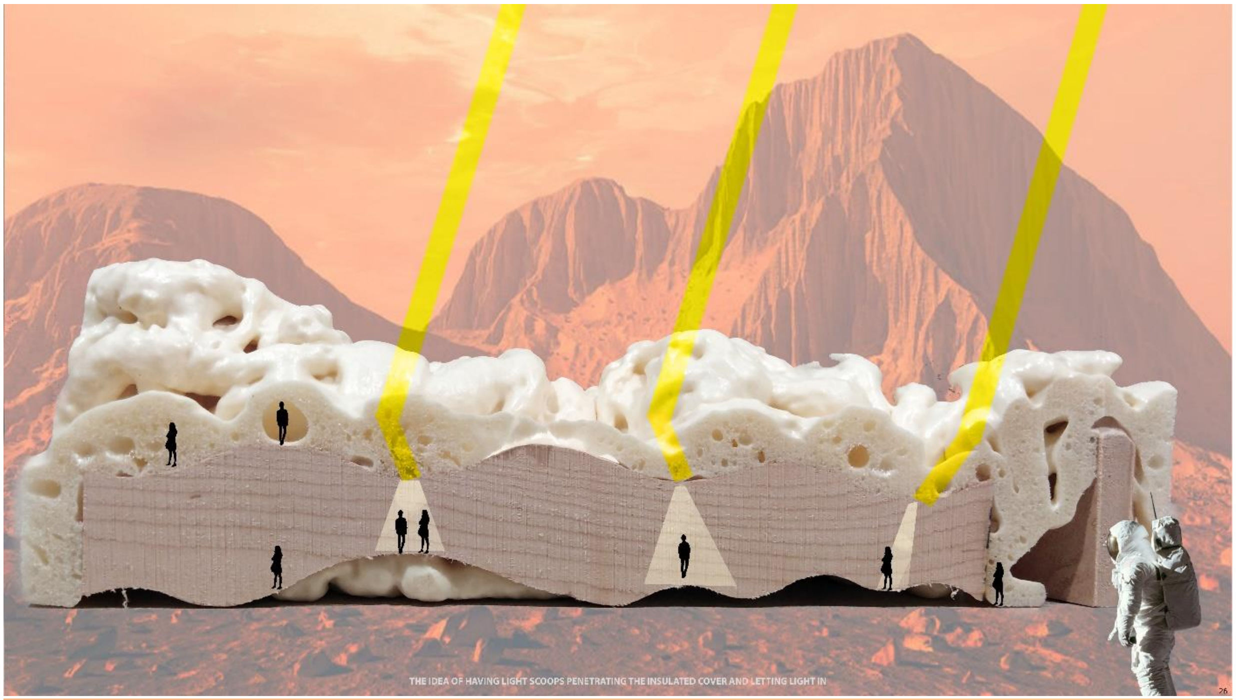



COMPLEX WITH VAULTS & DOMES
18
Rhinovault Studies on the Vault Design for the Hexagonal Spaces
Rhinovault Studies on the Vault Design for EVA and Entrances
Rhinovault Studies on the Vault Design for Interior Corridors
Geodesic Dome Exercises and Studies
Geodesic Dome and Studying Ruled Surfaces to Create an Exterior Structure to Support Tensile Geodesic Dome
Geodesic Dome and Studying Ruled Surfaces to Create an Exterior Structure to Support Tensile Geodesic Dome
19

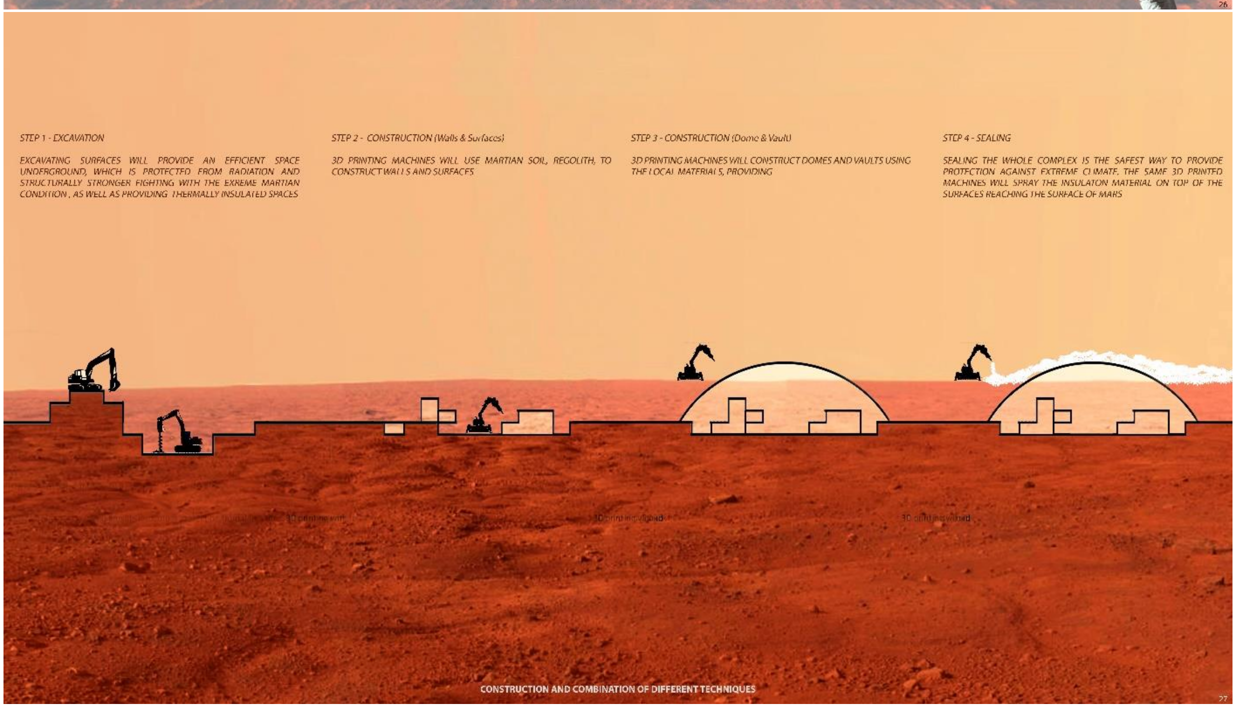

20


TERMINOLOGY
MEASUREMENT
BOOKCASE
TOP SH.
STEP SH.
84"
OVER HEAD S
71"—84"
HEAD SH.
49"—71"
TORSO SH.
27"—49"
KNEE SHELVES
1"—27"
25°
5'-6"
access by the eye
access by the hand
access by the torso
access by head-pivot
ideal access resultant
Fig. 12. Correlation-chart of book-storing. New measurements and terms.
21

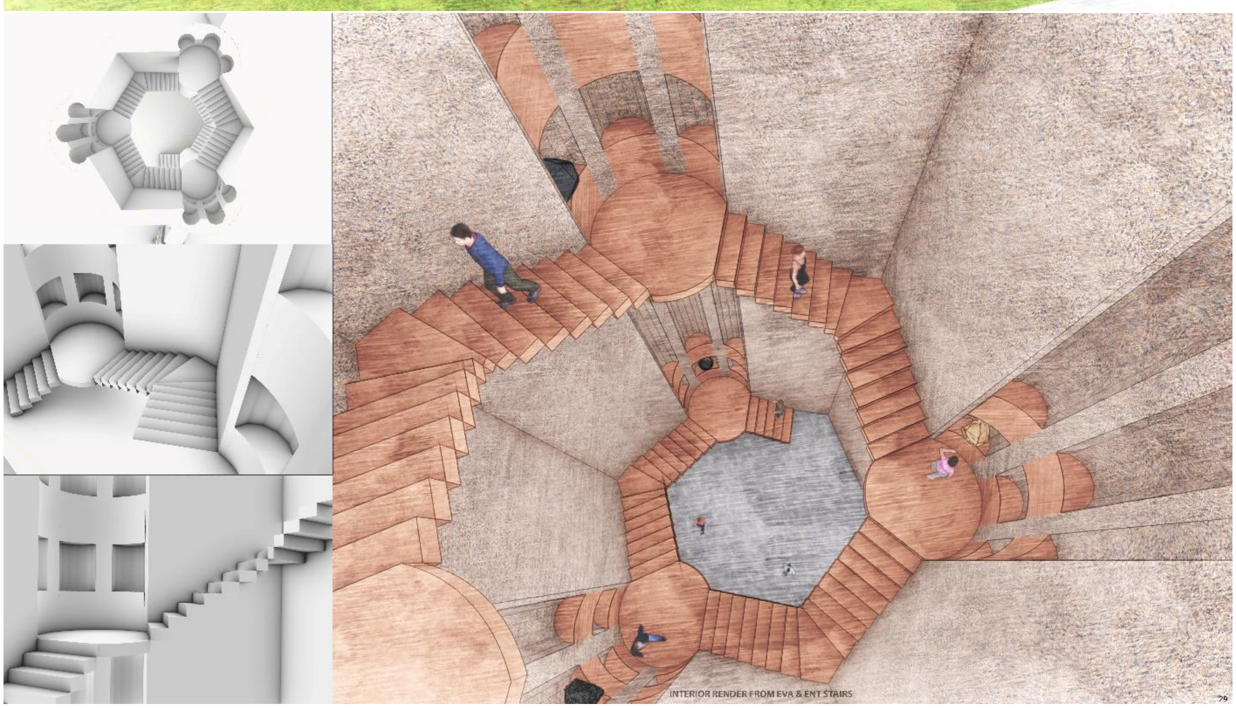

STUDY MODEL ON SEALING THE COMPLEX



THE IDEA OF HAVING LIGHT SCOOPS PENETRATING THE INSULATED COVER AND LETTING LIGHT IN

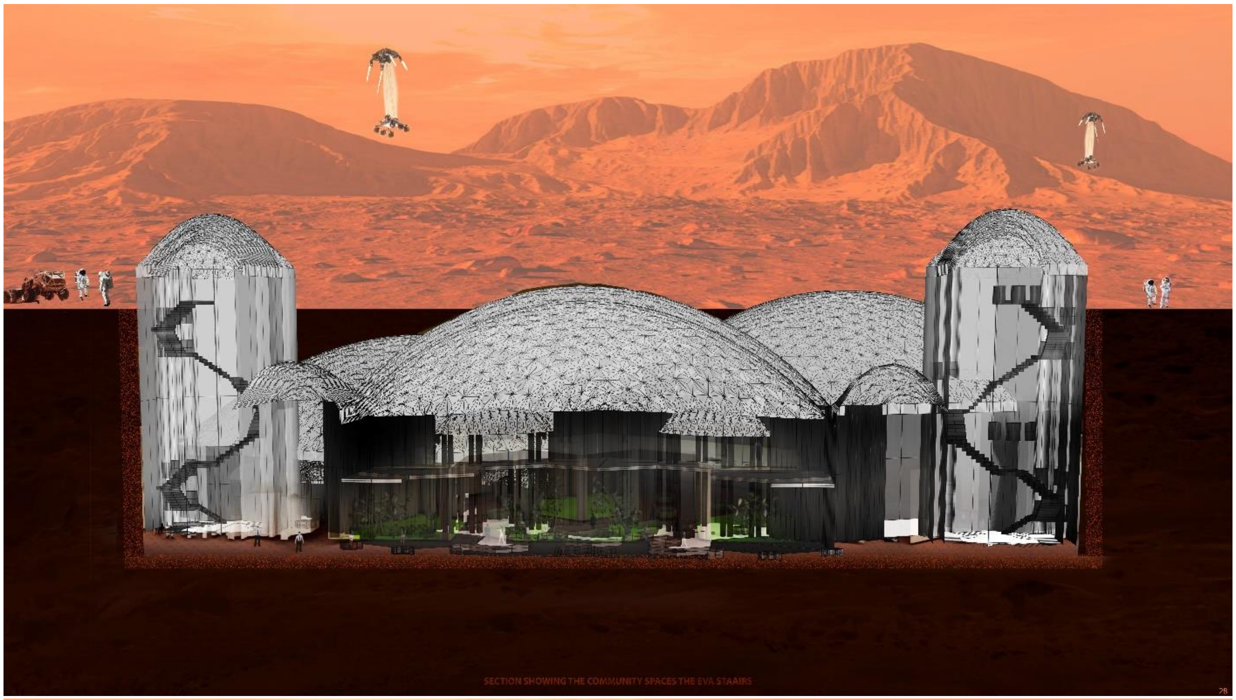


CONSTRUCTION AND COMBINATION OF DIFFERENT TECHNIQUES


INTERIOR RENDER FROM EVA & ENT STAIRS
29


30


31


SECTION SHOWING THE COMMUNITY SPACES THE EVA STAAIRS
28


SECTION SHOWING THE DWELLING, COMMUNITY SPACES AND ENGINEERING
32

Notes

[1] Charles Q. Choi, "Mars: What We know About the Red Planet", accessed May 17, 2019, https://www.space.com/47-mars-the-red-planet-fourth-planet-from-the-sun.html

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[5] Niall Patrick Walsh, "NASA Endorses AI SpaceFactory's Vision for 3D Printed Huts on Mars", accessed July 25, 2018, https://www.archdaily.com/898901/nasa-endorses-ai-spacefactorys-vision-for-3d-printed-huts-on-mars

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[10]"Redhouse Red Planet", http://www.redhousearchitecture.org/redplanet/2018/5/9/redhouseredplanet

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[16] Adam Morton, "Should We Colonize Other Planets", Polity, 2018

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