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Humanizing Being on Mars: A Martian Colony

Manal A. Alamoudi, Rahma Doheim, Mohammed F.M. Mohammed*

Department of Architecture, College of Architecture and Design, Effat University, Qasr Khuzam St., Kilo. 2, Old Mecca Road. P.O.BOX 34689, Jeddah 21478, Saudi Arabia

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Abstract Even though planet Mars is considered the most similar to earth, it still differs in some aspects. The gravity is lesser. Its atmosphere, climate and geology are a bit different from Earth. Thus, several robotic missions were conducted on the Mars surface to find the way to make the planet habitable and safe for human. This project aims to design the first human colony on the planet Mars. This would be a new home for humans to live, work and explore. This colony will establish the first humanized research center out of Earth. It will also provide a sustainable habitat for future explorers, by providing living dwellings along with all the other needed facilities for humans to live. The considered space program in this project includes the living quarters, common social zone, health zone working zone, and utilities zone. Several key elements were considered during the project design such as water and oxygen, planting (soil), temperature, radiation, pressure, wind, power (energy source), surface (construction), materials, and psychological aspect. This project will provide a comprehensive study to design a suitable settlement that can support a safe daily human life in an extreme environment location.

Keywords Planet Mars, Planet Habitable, Martian Colony, Sustainable Habitat

1. Introduction

"That's one small step for man, one giant leap for mankind." That was what Neil Armstrong said in the 20th of July 1969, when he set foot on the Moon for the first time [1]. Hoping in the near future human will reach even further to another giant leap for mankind. It is the norm of human nature to seek more, to know more and to learn more. Thus, that has led mankind to many astonishing explorations and discoveries. Space missions and exploration programs have already started long time ago, because knowing more about the surrounding space will help people to understand more, as it is the duty as humans to seek more. It is only logical that with all these new discoveries in technology, aeronautics and space exploration, to aim even further. To aim for setting foot on planets other than the Earth. For instance is planet Mars, to colonize it and make it as human new home, new destination.

Colonizing Mars is not a new idea. Missions to Mars by NASA have been already going ever since the twentieth century. It started by sending robotic machines to study the different aspects of the planet, and to prepare for human arrival and exploration of the planet, with the help of the current undergoing studies [2]. Also, NASA revealed the new mission called "Artemis" whose plan is to explore Moon to Mars. This mission intends to make the Moon a base for humans to stay by 2024. After that, the plan is to use the Moon as a station to reach Mars around the 2030s [3]. On the other hand, the timeline of the Mars journey according to the Space Exploration Technologies Corp (SpaceX) includes sending humans to Earth's neighboring planet during the 2024 [4]. Furthermore, there were several competitions held for the purpose of designing a habitat for colonizing Mars. As well as organizations are devoted for teaching design for space such as The Space Architecture Technical Committee (SATC)

Mars is the fourth planet from the Sun and the closest planet to Earth that shares some similarities with it. It is the closest choice for human colonization. It has atmosphere, climate and geology that have been changing throughout time just like Earth [5]. Mars is described as a cold, dry planet with a thin atmosphere consists mostly of carbon-dioxide. It has no liquid water. But, extensive space exploration of Mars has discovered geologic features that proved there was liquid water once on Mars. Mars was very different in the past. Though currently scientists are not certain on the existence of liquid water on the Martian surface, they are aware that water exists in the form of ice. Both the north and south polar caps are made of frozen water [6]. Therefore, the project is dedicated to researching and designing human settlements on Mars, making it the first human colony in the universe besides the Earth.

2. Case Studies

Each one of the discussed case studies has a feature that can be useful in the design process. The first case study is Mars Ice House, a winner in NASA’s 3D printed habitat challenge, the second case study is the Mars-Base 10 a simulation in the Antarctic, and the third case study is a Self-Deployable Habitat for Extreme Environments (SHEE).

2.1. Mars Ice House

Mars Ice House (Figure 1) is an extra-planetary habitat located at Northern Slopes, Alba Mons, Mars, designed by Clouds AO (Clouds Architecture Office) and SEArch (Space Exploration Architecture) [7]. This project is the winner of the 3D Printed Habitat Challenge for Mars that was held by NASA and America Makes. The team was asked to provide a habitat for four astronauts on Mars and use native materials and 3D printing techniques. The project depended on using ice as the native material. SEArch and Clouds AO's proposal won the first prize from other 30 teams [7].

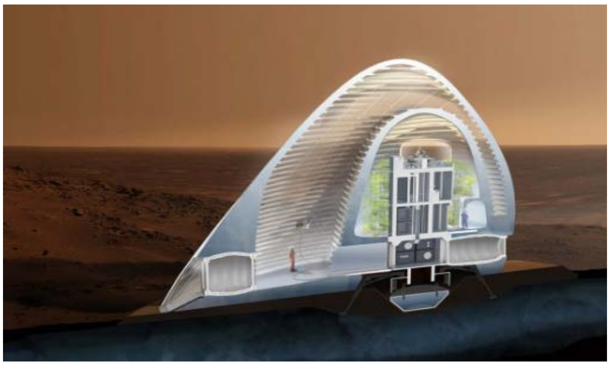

Figure 1. Mars Ice House [7]

The project needed to have access to ice and a zone where temperature remains below freezing all year long to sustain the habitat ice skin. Another thing needed in the project is to have an area with gentle slopes and soft topography for construction, also a site where it can maximize solar exposure. Thus, this site was chosen, on the northern flanks of Alba Mons between 45N-50N latitude and 230E-270E longitude. According to SEArch and Clouds AO, “Ice House is born from the imperative to bring light and a connection to the outdoors into the vocabulary of Martian architecture – to create protected space, in which the mind and body will not just survive, but thrive." [7].

2.2. Mars Base 10

Mars Base 10 (Figure 2) is a proposal for simulation as an analogue system in terrestrial desert environment [8]. The project located at the Olympus Mons Western Scarp. The project is designed by Ondrej Doule, and Tomas Rousek. This project is a design of a permanent settlement on Mars, Housing 10 astronauts. The habitat is equipped with all needed systems including a greenhouse with bio-regenerative Environmental Control and Life Support Systems (ECLSS) and a laboratory. And it is divided to 3 levels.

Site criteria on Mars, according to Thomas Sinn and Dr. Ondrej Doule’s research, the recommended location is Western Olympus Mons Scarp (19.6°N, 139.7°W) [8]. It contains the late Amazonian piedmont glacial deposits and it might be an area of an extinct life. The project concept of this case study is “The main purpose of the Mars-Base 10 is to enable scientific research on the surface of Mars while withstanding the harsh environmental conditions.”

Figure 2. Mars Base 10 [8]

2.3. Self-Deployable Habitat for Extreme Environments (SHEE)

Self-Deployable Habitat for Extreme Environments (SHEE) (Figure 3) is a transportable space analogue habitat, developed in Europe [9]. The designer of this project are International Space University, France; LIQUIFER Systems Group GmbH, Austria; Space Applications Services N.V., Belgium; Institute of Technology, University of Tartu, Estonia; Compagnie Maritime D’Expertises S.A., France; Sobriety s.r.o., Czech Republic; Space Innovations, v.o.s., Czech Republic [9]. This project is a hybrid transportable structure made of inflatable, rigid and robotic components. It works as a prototype of a ready functional habitat. The SHEE project is created to withstand extreme environments. It is applicable for both Earth and space. Each unit supports two people only.

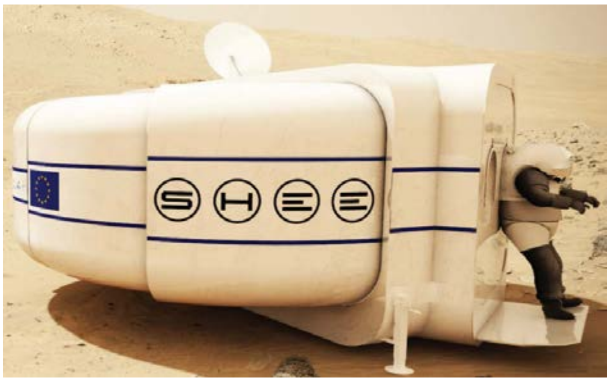

Figure 3. Self-Deployable Habitat for Extreme Environments (SHEE) [9]

Site criteria for this project are the extreme environments that are hostile to sustain human life. The site could be on Earth or space, wherever humans cannot operate for extended periods without support, and where it is risky for humans to build the habitat themselves. The project concept of this case study is to create a locale for terrestrial analogue simulations for extreme environments such as on the Moon, Martian surface or disaster zones on Earth.

After observing the previous case studies, each case study is different in a way and focusing on different aspects. Even though at the end, they are all serving the same purpose which is establishing a colony on Martian surface. These case studies have provided different ideas and techniques that can help in later stages. In the first case study, Mars Ice House, the team has focused on the use of ice and 3D printing technologies. While in the second case study, Mars-Base 10, the project focused on inflatable structures. And the third case study, SHEE, the focus was on foldable structures. These are three different techniques for the same main idea of the project. Each technique has its pros and cons.

3. Space Program

Based on the idea of the project and according to the information from the case studies, the main zones of this project are classified as living quarters, common social zone, health zone, working zone, and utilities zone. The living quarters will include sleeping area, hygiene area, work area, kitchen, and living room. The common social zone will include a multi-purpose activities area, and cafeteria. The health zone will include fitness unit, and medical unit. The working zone will include greenhouse, laboratories, command room, and meeting room. The utilities zone will include life support systems areas, storages, power plant, vehicles parking, and rocket landing site. The space program of each zone is tabulated in Table 1. The program assumption based on the number of crew people for each trip. The first tripe will host 12 -24 members according to SpaceX company. The estimated gross floor area for 48 members is about 11300 m^2.

Table 1. Space program

Zone	Function	Min. Area / person	No. Users	No. Units	Area (m^2)	Total net area (m^2)	Circulation (20%)	Gross Area(m^2)	Volume (m^3)
Living unit	Sleeping	2.5	1	48	480	1440 (on 3 levels)	288	330	2475
	Work	1.3			26.4				
	Hygiene	1.1			144				
	Storage	1.1			144				
	Kitchen	2.1			672				
	Living	3.2			76.8				
Social unit	MPU	1.7	48	1	216		54	270	675
	Dining	2.5		1	216		54	270	675
Health unit	Fitness	1.4	48	1	216		54	270	675
	Medical	1.4	12	1	216		54	270	675
Work unit	Green house	133	48	1	2000	2830	500	2500	37500
	Labs	41.7	12	2	112		28	140	350
	Command room	1.4	24	1	152		38	190	475
Utilities	Airlocks	5.2		6	210				
	Life support system		48	8	251				
	Storage	8	48	1	112		28	140	1400
	Power plant								
	Vehicles garage	25		4			70	350	3500
	Landing site								
Total shell								11300	75000

4. Site Selection and Analysis

In October 2015, NASA held a conference that was for collecting proposals on possible areas on Mars for human landing. These conferences had great scientific research value and provide natural resources to enable human beings to live and work safely. According to NASA, the first human explorer might be restricted to approximately 100 km of travel from their touchdown site due to life support and exploration technology requirements [10].

Altogether 47 proposals have been gathered by the agency for exploration zones (EZ) locations on the Red Planet that would offer natural resources to assist human explorers to land, live and work safely on Mars as well as to provide a rich destination for scientific discovery [11]. NASA has already generated a criterion for selecting the best exploration zone for humans to land. Thus, the most important highlights for the chosen spot would be:

- Potential for past or present habitability
- Potential for organic matter
- The site needs to have enough surface exposure to provide solar energy for solar panels
- Protected against radiation
- Site must have access/near to water source
- Located within 5 km from landing site
- The habitat should be located on 50 square kilometers of flat and stable terrain or on gentle slopes and soft terrain for construction

Choosing a location requires in-depth and advanced research to determine the best place to settle on Mars. Thus, this project will depend on one of the sites selected by NASA. The site chosen is named Mawrth Vallis at northernmost latitude 26.12°, southernmost latitude 18.78°, easternmost longitude 346.63°, and westernmost longitude 340.21°. The site has diameter 634.63 km, center latitude 22.43°, and center longitude 343.03°.

This location has been chosen because it has several advantages such: it is an area that has gentle slopes and soft topography that helps in construction; it is considered to be hazard-free landing zone next to an ancient channel valley created by ancient floods; the cliffs are rich with clay that can be used for ISRU (In-Situ Resource Utilization) purposes, considered to be northern site (receives more solar energy) minimizes required mass of the energy storage subsystem, also the presence of regolith for building, and the site provides the prospect to understand the potential for early habitability on Mars [12].

5. Zoning and Project Design

The concept and philosophy of the project is to be a new horizon, a settlement and a new safe home for humans to live, work and explore. It is for humankind to act as one hand helping each other for reaching beyond the sky. It aims to be a lighthouse of the galaxy. It is a place for guiding the weary traveler to their new home. The project also guides and illuminates a new path for humankind. Figure 4 illustrates the main preliminary zones of the project. Whereas the abbreviations in the diagram are: LS is Landing Site, U is Utilities and storage, P is Power Plant, W is Work zone (greenhouses and laboratories), MPU is Multipurpose Unit, and H is Habitat Unites.

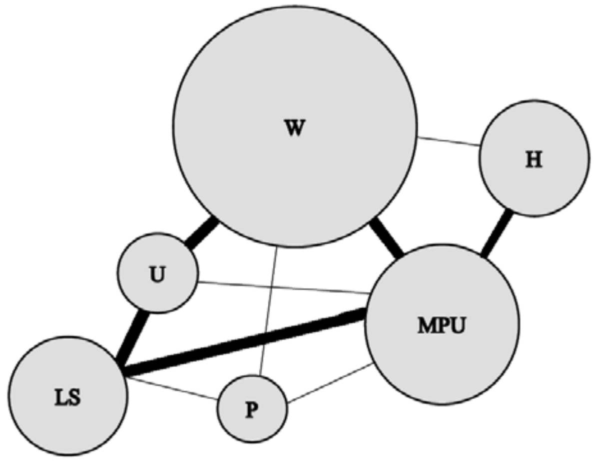

Figure 4. Initial zoning: The thick lines are main link and thin lines are secondary link.

5.1. Design Considerations

In order to be able to survive the Martian life, there must be some key elements to be considered. These main elements and design considerations include: how to provide water and oxygen, how to utilize the Martian soil to plant for self-sufficient food, how to deal with temperature - pressure - wind, how to provide protection from radiation, how to provide energy and power source, also how to deal with the surface of the planet in the means of which construction type and material to choose. Not to forget that the psychological aspect plays a major role too.

5.1.1. Water and Oxygen

Because of Mars's thin atmosphere, water is formed in ice.

Based on the assessment done using radar aboard a NASA spacecraft, it was found that this water ice actually made up 50% or more of an underground layer in a large region of Mars. This is equivalent to about midway from the equator to the North Pole. Furthermore, water sources can include bringing stored water from Earth, making it by means of fuel cells utilization, or recycling water (hygiene water and urine).

According to NASA, hydrogen can be combined with excess carbon dioxide in the air via chemical reaction done using the ECLSS (Environmental Control and Life Support System) machine to produce water and methane. The water produced from this reaction would be able to substitute the water used to make oxygen while the methane would be vented to space or reused in the thrusts. Most of the oxygen can be provided through a process called "electrolysis" also by using the ECLSS machine. By applying electricity harnessed from the solar panels, water molecules can be split into hydrogen molecules and oxygen molecules. This is what is used on the ISS (International Space Station) or it can be provided from Mars atmosphere by using the Mars Oxygen ISRU Experiment (MOXIE), a technology that is tested in the 2020 according to NASA's missions.

5.1.2. Planting (soil)

Scientists expect that humans would be able to use the Martian soil as a base for plant growth with adding a little fertilizer, and with a controlled environment that could keep the plants warm and give the plants enough atmosphere, light, and water to live [13]. Also, planting could be achievable by using an inflatable and deployable greenhouse, to be used for the production of plants. According to NASA, the prototypes that are being developed are cylindrical and with the dimensions of 5.486 m long and more than 2.438 m in diameter [14].

5.1.3. Temperature

The temperature could be handled by providing double skin and thick walls structure that will help in maintaining the interior temperatures, such as in igloos. Also, transform the solar radiation into heat for space heating.

5.1.4. Radiation

According to NASA, the colors in the global map of Mars refer to the average number of times each human nucleus is hit by high-energy cosmic ray particles each year. The range is categorized from low risk level - two hits (color-coded green), a moderate risk level- eight hits (coded red), and a high-risk level [15]. To handle and limit the radiation, the design of the habitat could be by building it above ground using inflatable modules encased in ceramics created using Martian soil, which will depend on robots using 3D printing technique known as "sintering", where sand is turned into a molten material using x-rays [16].

Thus, the habitat could be covered by several meters of soil, which provides reliable shielding even against galactic cosmic rays. In comparison to the Earth's atmosphere, five meters of soil is equivalent to 1,000 g/cm^2 of shielding [17]. Also, a water wall or ice wall could be used as a radiation shield. And by the use of double skin structures, it can provide protection against radiation. Another thing the design could consider is building on lower elevations to provide protection as well.

5.1.5. Pressure

The main structural challenge on Mars is to hold down the interior pressure of all habitats. This could be achieved by the selection of the structure form such as domes that are good for stability, and a material type that can resist tension forces such as ETFE.

5.1.6. Wind

Curvy surfaces like domes could be the most suitable forms to resist the Martian dust storms and winds.

5.1.7. Power (energy source)

Energy saving is a key requirement to support the concept of sustainable development, so electricity can be collected through solar panels [18]. Given Mars environment, there might be some days that the solar energy will not be accessible due to dust storms. Thus, according to NASA, there is another source for power still in testing and it can be ready by the time for the mission. This new source is called "The Kilopower project". It is a system that uses reasonable fission of nuclear energy to support extended stays on planetary surfaces [19, 20].

5.1.8. Surface (construction)

Construction on the Martian surface could be achieved via 3D-printing, inflatable and deployable structures. Mars regolith is mostly silicon dioxide and ferric oxide, with a fair amount of aluminium oxide, calcium oxide, and sulphur oxide. The composition varies from place to place on the planet's surface. The regolith could be turned into bricks by simply compressing the material rapidly. The soil is full of iron oxide and oxyhydroxide particles about 25–45 μm across. "If you compress the soil grains at high enough pressure, you are going to cleave those iron oxide nanoparticles," says Qiao [21].

5.1.9. Materials

The envelope structure of the project plays an important role in controlling building energy consumption [22]. The main two materials chosen for this project are ETFE (Ethylene tetra fluoroethylene) and Martian made concrete. According to the work of Lin Wan and pals at Northwestern University, they have found out a way to make Martian concrete using materials found on Mars. And, luckily this concrete can be formed without using water. Instead, it will be using sulphur [23].

Scientists at the University of California, San Diego, found an easy technique that could be used to make Martian bricks that are stronger than steel-reinforced concrete. Lead researcher Yu Qiao and his team worked with a NASA-formulated simulation of Martian soil and found that it contained minuscule iron oxide compounds that could bind the soil together when put under pressure to form a strong yet simple brick [21].

On the other hand, there is a material in development at NASA, which is "Hydrogenated boron nitride nanotubes - known as hydrogenated BNNTs". They are a tiny nanotube made of carbon, boron, and nitrogen, with hydrogen interspersed throughout the empty spaces left in between the tubes. Boron is an excellent absorber secondary neutron, making hydrogenated BNNTs an ideal shielding material [24].

5.1.10. Psychological Aspect

A big part of the design comes from considering the psychological aspects for the members. Some of these aspects and considerations are such as: decreasing the effects of isolation and confinement. The interior design should consider privacy and social spaces, with certain flexibility to adjust to crew needs. Also, provide windows or wide screens to display nature scenes. Some of the problems can be addressed by optimizing lighting to accurately mimic the 24-hour cycle and UV spectrum of sunlight on Earth. Cultural issues can be overcome by the capability of people to communicate with one another and creating different activities and leisure time aside from work. Also, crewmembers should be fluent in a common language to ease the level of understanding. Maintain the depression and anxiety that could appear due to work or homesickness by the support from crewmates, a brief course of tranquilizers or counselling. As well as providing communication between the crewmembers and their family and friends on Earth. The longer the mission, thus the greater need for crew privacy and recreation.

5.2. Zoning

The colony shell contains five main zones, which are living zone (habitat units), social zone (multipurpose activities unit, dining unit), health zone (medical unit, fitness unit), work zone (command unit, greenhouse unit, laboratories unit), and finally utilities zone (airlocks, storages, ECLSS, garage). Both the shell and layout zoning are as shown in Figure 5 and Figure 6 respectively.

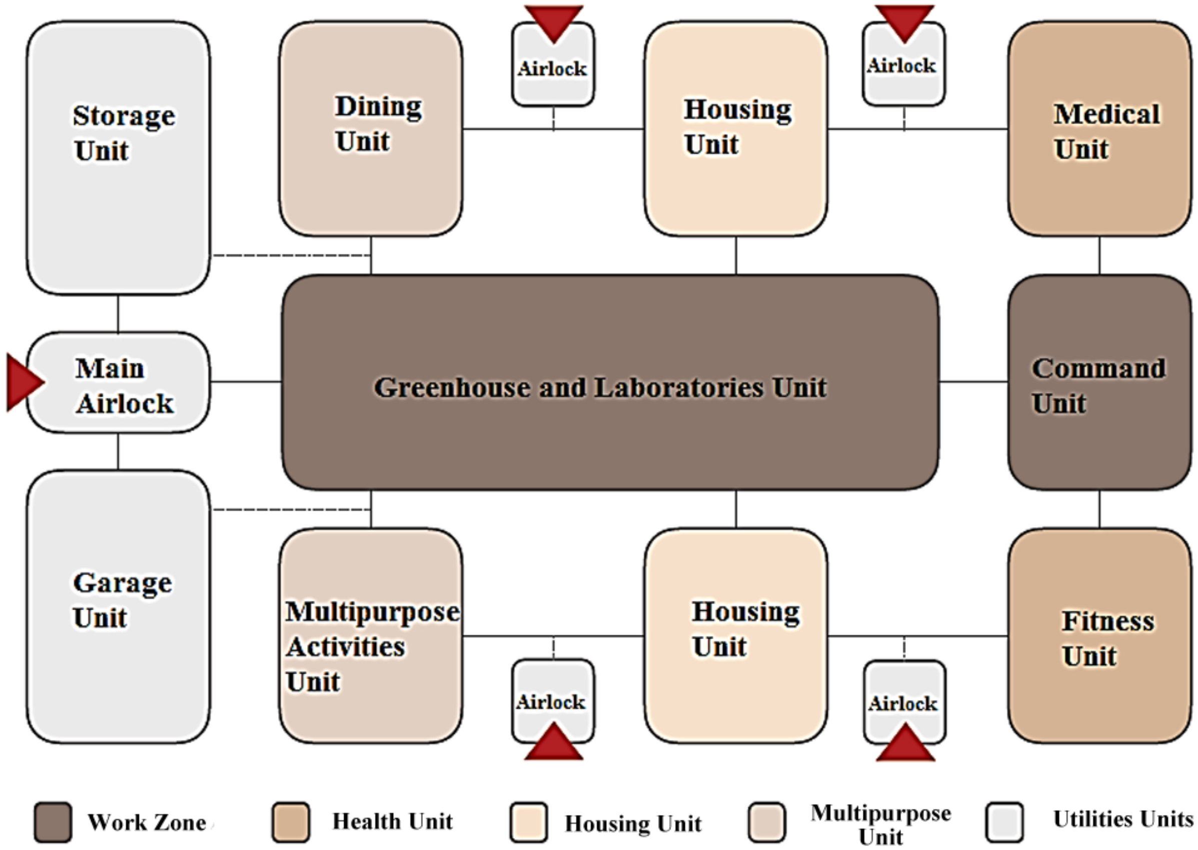

Figure 5. Shell Zoning

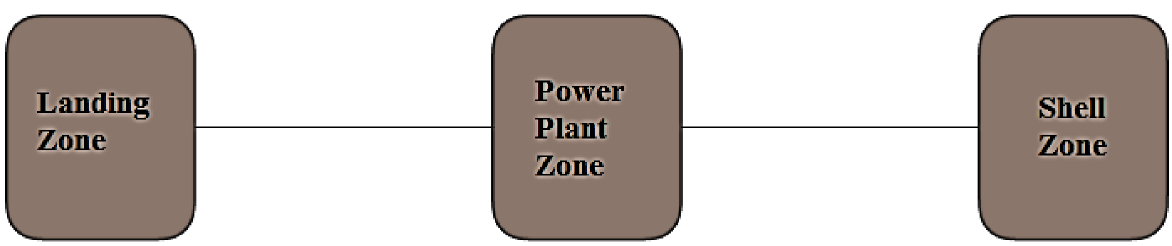

Figure 6. Layout Zoning

5.3. Architectural Drawings

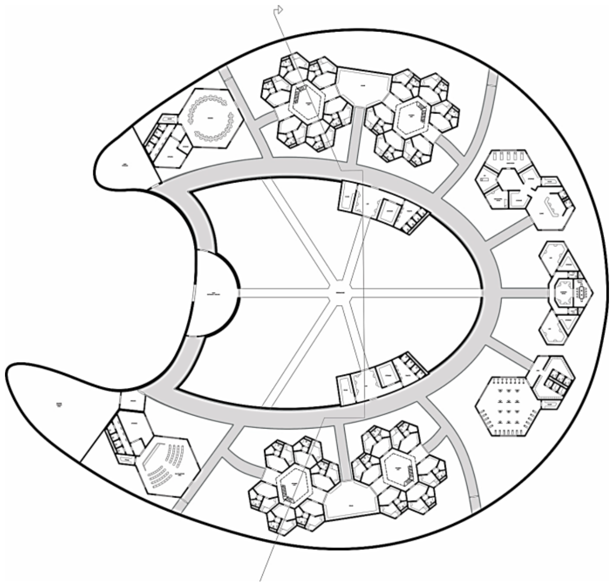

Figure 7. Site plan

Figure 7 demonstrates the site plan of the project and the shell contains all the units inside it. In the heart of the shell lays the greenhouse and the main two laboratories. Then all the other remaining units surround it. There is a direct passage from the main airlock (main gate) to the command unit that contains the communication room, meeting room, and two small laboratories with amenities. There are two housing units that provide living spaces for 48 members, divided on each side of the greenhouse and in between the social and health zones. The health zone consists of a medical unit and a fitness unit. The social zone is the dinning unit and the multipurpose unit. All units are provided with the needed amenities. Also, a main storage space and garage space are provided near the main entrance for easy access. Moreover, four secondary airlocks are added to provide future connection with other shells. The layout of the colony was allocated to enable easy and fast access from the landing zone to the power plant zone to the shell zone, and backward as well. The idea of putting the power plant in the middle between the two other zones is to provide the needed power for both zones in the shortest and fastest way, also to maintain a safe distant from both zones too in case of an emergency. Figure 8 and Figure 9 illustrate the inside shell elevation and main shell section of the project respectively.

6. Conclusion

In this project the first human colony out of Earth is designed, on Planet Mars. The colony included all needed facilities for humans to live a healthy life, such as living quarters, common social zone, health zone, working zone, and utilities zone. According to NASA site selection criteria, the chosen site for this project is named Mawrth Vallis. The project aims to design a habitat for humans on the surface of Mars according to the new technology that today's science has reached. Considering all aspects of dedication, this can provide a safe and healthy environment for mankind. The driving force of this achievement will promote more development, just as the early explorers' agriculture, manufacturing and technology promoted the progress of global industry. This effort will take Mars out of the realm of science fiction and transform it to a world where humans can truly enjoy life.

Figure 8. Inside Shell Elevation

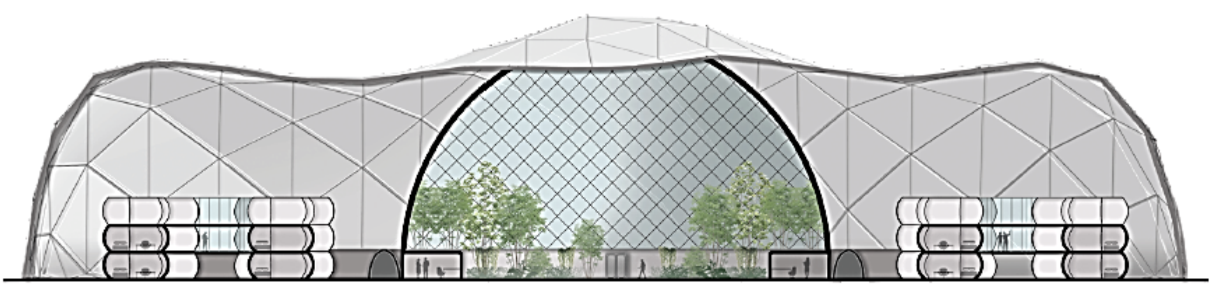

Figure 9. Main Shell Section

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