Turkish Online Journal of Qualitative Inquiry (TOJQI)
Volume 12, Issue 7, July, 2021:1368 – 1383

Mars Self- Learning Habitat - Generating the Optimum Form for Future UAE's Space Exploration Missions

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Abstract

Having life on Mars is a long-lasting dream that scientists have been working on for years. Extensive research and experiments have been conducted ever since the 1960s; this research is a summary of the findings of these experiments until this very day. The purpose of this research is to bridge various fields to design an ultimate habitat for astronauts and scientists on Mars in order to study the surface of Mars and the potential of habitability. Excessive research has been done on Mars' harsh environmental conditions, materials availability, and site selection. As a result, the derived knowledge led to design a self-learning adaptive system using reconfigurable robots and different technologies suggested to solve problems concerning the environmental conditions on Mars, adding to that the potential of utilizing in-situ resources in fabricating the structure of the units. This study also includes several design guidelines taking into consideration multiple elements affecting the project program, and a concept that studied possible options adaptable to the environment in terms of form-finding using artificial intelligence and mimicking the nature on Mars while focusing on automated approaches in construction.

Keywords: Martian Habitat, Mars Society, Self-Learning Habitat, Space Architecture.

1. Introduction

Humans have always looked up into the night sky and dreamed about space, the hunger we have for curiosity and exploration has driven many countries, such as The United Arab Emirates, The United States of America, Japan and a few more, to establish space agencies and satisfy the eagerness towards expanding and exploring new technologies and better futures.

Space has caught people's imaginations quite long ago, designers, scientists, researchers, and writers have constantly visualized a future on far planets and Mars was on the top list as the best habitable candidate in our solar system after Earth which makes it at the center of this discourse. Proposals for Mars investigate how we can make new realms of mankind in outer space and depend on the creation of safe, durable, and protective habitable units [1].

One of the main objectives in this project is to gather significant data to establish guidelines and references for the Martian base design that would serve the need for living on Mars in the upcoming years.

2. What is space architecture? and why mars?

Space Architecture

It is impossible to narrativize outer space without referencing the bright impact that Architecture archived on expanding the knowledge about space [2]. So, what is Space Architecture and how important it is? Space Architecture is a set of theories, practices, and development of systems for designing and building inhabitable environments in outer space [3], It studies and highlights the key areas of research in space, such as design methods, possible building materials, structure and construction techniques, comfort conditions for living in the outer space, and the most cost-effective equipment, also it studies the possible robotics systems, and it addresses the psychological effects on living there [4].

Space architecture work has been in designing concepts for orbital space stations, space elevators, solar satellites, and lunar and Martian exploration ships and surface bases for the world's space agencies, chiefly NASA. According to Roger 2001, Stephen Hawking once said "I don't think the human race will survive the next thousand years unless we spread into space" [5], in our case, Mars will be the first step of exploring the life vast beyond our planet with the help of Architecture, Robots, and Artificial intelligence.

Why Mars

Mars is the fourth planet in the solar system, and it is as close as Earth to the sun, it may be a cold desert with not much to survive with, however it has the most similarities with earth. It takes nine to six months to reach and that depends on the orbit length of Mars and Earth, on top of that, no planet beyond Earth has been studied as intensely as Mars, in fact, it has many rovers, probes and landers sent to it [6]. Space agencies have been collecting information about it since 1996, it has been reachable by probes, landers, and rovers to collect data about the weather, soil, and atmosphere [7].

According to National Aeronautics and Space Administration (NASA), Mars is 229 million kilometers away from the sun, and the average temperature might be as cold as -63^0 C, however if we take a closer look at other planets near earth, we will find that it has unlivable conditions due to its extremely high temperatures, taking planet Venus for example, it has a thick atmosphere which causes heat to be trapped in, thus, making it one of the hottest planets in the solar system [8].

On the Red Planet, a human being will experience 62.5% less gravity than they are used to on earth, this is not entirely a bad number to work with, in fact we might even use it to our advantage in terms of building and construction the habitat. In terms of pressure and oxygen availability, this project aims to provide the right measurements inside the settlement using the most advanced technologies to ensure the possibility of living on the Red Planet. Regarding the temperature on Mars, the average temperature on Mars is -63^0 C, this is not a number that we have not experienced on earth, it has been recorded before that Russia has reached temperatures that dropped down to -67.8^0 C in the Sakha, Republic of Russia back in 1933 [9]. All four seasons on Mars exist, however each season lasts a bit longer than what we are used to on earth, also, day length is one of the similarities between mars and earth, however the year is almost twice as long and the solar day on Mars is called "Sol" in order to distinguish between a solar day on earth which is only 3% shorter [10].

3. Site selection criteria

A few questions come in mind when selecting a site, what is the context of the surrounding? How did this project affect the neighboring area? Is the project tailor made for this site, or can we place it elsewhere? And many more questions and criteria required, inputs and data studied to select the perfect site. However, this is what we are used to on planet earth. So, what if the site is on a terrestrial planet?

This process may not follow the same questions or criteria, however it is as crucial to determine the most suitable location, for it sets many things at stake. It is very important to analyze all data available about the Red Planet's surface and locations, to make the habitation process a little bit easier and a bit more achievable.

Site Selection Criteria

Choosing a suitable site needs certain requirements to be checked. While taking these requirements into consideration, we must simultaneously consider some limitations. We have some constrains such as engineering and planetary protection requirements. We studied and compared multiple sites that are mentioned later in details, the key factor that decided which site was the most suitable was how many boxes it ticks amongst the suggested criteria [11].

The list of criteria studied is:

1) Site landing must be at a low elevation.

The lower the elevation is, the thicker the atmosphere. Landers rely on the atmosphere for some de-acceleration, which helps them reduce the speed by 18,500 km/h. On top of that, lower elevations have higher pressure, and since pressure is extremely low, we can use every bit of help we can get. This is basically the concept of choosing any site for any project, which is taking advantage of the area in any way possible [12].

2) Site should be flat, free of rocks and boulders.

In order to ensure the safety of landing, the area should be relatively flat and doesn't have any boulders to crash on. We also want to consider the subsurface of the underground area, for if we want to do any kind of excavations, we are not equipped with big machinery instruments that allows us to

dig through the rocks. The maximum a rover has dug before was about 3-5 meters maximum [12].

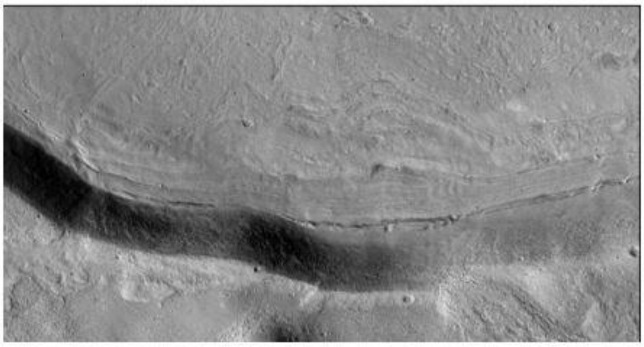

Fig 1. Example of relatively flat surface, in Arcadia Planitia.

3) Site should be relatively close to the equator.

This ensures that the settlement will be a bit warmer, have sufficient sunlight and adequate energy for solar panels all year long. Location can be between 5 degrees north latitude and 3 degrees north latitude [13].

4) Site should have access to frozen carbon dioxide.

We might as well benefit from what already exists extensively on Mars. Frozen CO_2 can be used in different fields, so the closer the site is to it the easier will be the process of extracting it. Sending vehicles to supply us with what we need is not very efficient, for it takes a lot of time to reach and a lot of energy resources. Having direct access to frozen CO_2 minimizes the need to use these vehicles [13].

4. Proposed Sites

To demonstrate the process of selecting a suitable site for our project, three possible sites are studied, analyzed, and compared based on a set of criteria mentioned above, the first proposed site is Valles Marineris located close to the equator [14], the second one is Arcadia Planitia near the northern lowlands [15], and lastly Vastitas Borealis at the northern hemisphere [16]. After choosing the suitable site we studied the existing environment of the proposed sites, and how the Martian atmosphere will influence the design of the site.

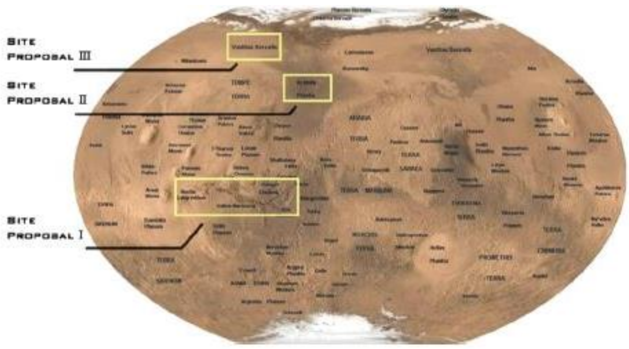

Fig 2. Site Proposals Marked on Mars Map.

5. Comparison Between The Proposed Sites

Many sites have been suggested, studied, and analyzed by multiple space agencies, such as NASA, Spacex and European Space Agency (ESA). Choosing a site for a future settlement is one of the most critical steps in the entire process, for it will determine the path the future city will take. A list of criteria was made to settle on the most suitable site that serves all requirements best [17].

Site Criteria	Mariner Valley	Arcadia Planitia	Vastitas Borealis
Low Elevation	✔	✔	✔
Flat Land	✔	✔	✔
Free of rocks and boulders	✗	✔	✔
Relatively close to the equator	✔	✗	✗
Direct Access to Frozen CO2	✗	✗	✔

Fig 3. Table showing sites check according to criteria.

After analyzing the criteria and every site's characteristic, we concluded that Vastitas Borealis ticks most of the boxes, which makes it the best candidate. The fact that it is not relatively close to the equator is in our disadvantage, but it is not enough to disregard the fact that it is the best candidate amongst other sites. All three sites are very good suggestions in general, and the differences are not day and night, which is what made it a tough decision to make.

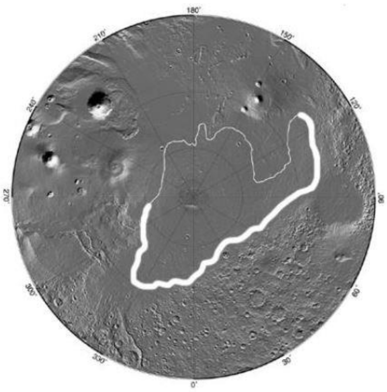

Fig 4. Mapped boundary of the Vastitas Borealis Formation.

The decision taken was not only according to how many checks, but also which of these boxes are not ticked. For instance, the fact that Vastitas Borealis is the only site that has direct access to on surface CO_2 makes it best to save energy from using robots to excavate. In other words, small differences are what tipped the scale.

6. Site Analysis

Mars is the fourth planet in the solar system, it is 227.9 million km away from the Sun, and 99.853 million km far from The Earth. The longest trip can reach up to 9-11 months depending on the positions of Mars from Earth, while the shortest trip to the Red Planet can take at least 6 months and this only happens every 26 months when Earth and Mars are properly lined up [18].

Since the first Viking Lander touched down on The Red Planet on the 20th of July 1976, NASA scientists use the convention that each Mars solar day, called a Sol is 24 hours and 40 minutes long [19].

One of the differences is that on Mars the gravity is just a fraction of what it is like on our planet Earth. Also, the Martian atmosphere is less dense than the Earth's atmosphere, and gravity is what holds the atmosphere to the Martian surface [20].

Studying the Martian atmosphere is for more than scientific purposes. It is also a fundamental prerequisite for any missions or project designed to be on the surface of Mars. Martian meteorologists are responsible for informing mission designers what conditions to expect (temperatures, dust levels, winds etc.) at a landing site. On our planet Earth heat from the Sun is the force that drives winds. On Mars it is similar, but the two planets have different aspects to their atmospheres [21].

Air rises when it is warmed by a hot surface, and the movement pulls in cooler air at ground level. Additionally, this sometimes creates a dust devil when fine particles of dust are cleared up by the cooler air moving over the ground. Moreover, temperature differences between one territory and another causes air to flow between them, creating winds [21].

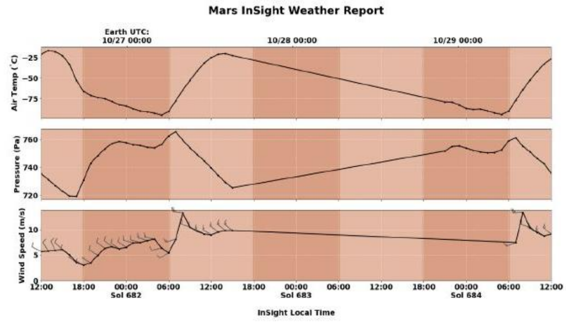

Fig 5. Graph of the Weather Report at Elysium Planitia in October 2020.

This plot gets updated daily depending on the InSight mission. It shows the most recent three Martian days weather information studied by InSight rover near the equator of Mars. Time is provided at the bottom of the chart with the latest data at the right. Lighter and darker vertical bands indicate daytime and nighttime at the lander, in order. All information points are one-hour averages of the calibrated data from the spacecraft [22].

Outside our protective thick atmosphere, there is a universe full of cosmic radiation, Mars' radiation is a different kind of radiation that we usually experience here on our planet, due to its thin negligible atmosphere and the absence of the magnetosphere that protects Earth, Mars receives much higher solar radiation compared with Earth [23].

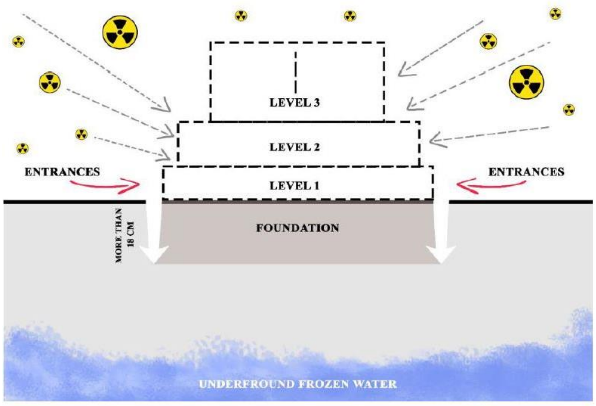

Fig 6. A Diagram explaining the environmental conditions affecting the design.

Curiosity rover was able to measure the high energy radiation coming from the cosmic rays and the sun using The Radiation Assessment Detector (RAD), NASA detect and analyze radiation on the surface of Mars, and it was around 18-30 rad per year, about 40-50 times the average on Earth [24]. Martian radiation has very different effects on humans, it can damage human's cells, it is quite to predict the long-term effects of space radiation on the human body, especially on our astronauts, who may spend many months in the Red Planet, and here comes our role to design a protective and super shielded habitat to a level equal to our planet Earth.

7. design guidelines and project program

This project includes the design of a constant Martian settlement to accommodate a specific number of settlers in the upcoming years. Astronauts will be operating new experiments continuously on the surface, living in the first permanent unit, conducting scientific research, experimenting new technologies, and most importantly prove the long-term successful living on Mars in a permanent self-sustaining settlement.

The spatial planning of each unit is based on including the human factors element of design in extreme environments, according to the programmable and reconfigurable nature of the design, these numbers are flexible and adaptable to change based on the settler’s requirements. Scientists are expected to spend mostly half of their time in these areas, so space efficiency, comfort, and access to natural light are all critical to reduce the negative impacts of living in a harsh environment [25].

A small group (4-6 people) of Scientists, researchers, and engineers mostly will occupy the first permanent unit in phase I, while the modular and reconfigurable concept of this design will permit flexibility of accommodations to be convenient for various ranges of people. However, this project is not limited to the initial base camp unit, later one it will expand in phase II to occupy more astronauts from different fields, and in this stage, the possibility of conducting advanced researches and experiments is getting higher because of the optimum facilities provided at this level. In phase III, the final design stage, assumes that people sent to Mars will be only adults, working to conduct research and encourage extensive settlement efforts on the planet.

Phase I: The Base Camp Unit

In the initial stages, a set of robots will be shipped to mars to begin the process of building, long before any human sets foot on the surface. Once they land, they will begin the process of finding a suitable region in the chosen landing site. Next, they will scan and study the area to send data to the station back on earth in order to make further scientific analyzation. After that, robots will split into groups to start performing different tasks such as: excavating the surface, collecting the dug up soft regolith, and lastly, transporting these materials to the last group responsible of melting the Martian soil and 3D printing it.

This unit is a compact unit, and it will include the following functions: main airlock, neutral zone, core, dry labs, wet labs, recreational area, exercise area, kitchen, compact bedrooms, hygiene area, medical bay, and storage. However, later in phase II and III, the functions will be distributed each in a separate specific unit. The base camp unit is designed to fit 4-6 scientists (a botanist, pilot, IT specialist, medical specialist, engineers) where measurements and areas have been studied and distributed in this unit according to the number of habitants, and the space required to perform their everyday activities.

Phase II: Replica

After the success of phase I, three more units will be introduced with new functions and they will be as the following: plantation unit, engineering unit, and lastly the AI unit, all provided with the most advanced technology in order to complete the scientific journey of phase I. In addition to that, this phase includes the heart of the project, which is the control station, where it will have basic functions that are crucial for future expansions such as: space center, communication center, and meteorology center, it will also be the tallest building amongst all units and most essential.

Phase III: The Futuristic City

After the success of building the basecamp unit, all the way to the replicated units and the Control Station, further future expansion is indeed possible. Our vision began beyond earth, and so it will expand up until beyond Mars itself if it takes. The idea of a future city sounds far-fetched, but we are proposing this after both phases I and II are completely successful. In this phase, new units and functions are proposed as clusters. However, the process of trial and error will never stop, this is to ensure a continuous progress and secure the best strategies provided, this stage will include the following clusters: medical, research, and habitation which means more people will be sent to the red planet and the foundation of establishing communities will start from here.

8. Concept Design Proposal

The concept behind our project lies in the folds of technology, engineering and architecture combined altogether. In order to achieve a conceptual design that isn't only aesthetically pleasing, but also provides safety from all outside factors, is sufficient and easily 3D printed, we needed the help of artificial intelligence and mathematics. After doing some research we found out about "Minimal Surfaces". A minimal surface is a surface that locally minimizes its area, this means it has zero mean curvature. The term "minimal surface" is used because these surfaces originally arose as surfaces that minimized total surface area subject to some constraint [26]. After studying the mathematical aspect of minimal surfaces, we decided to apply it in terms of design and structural methods, for it serves the benefit of using as little material as possible. Conclusively, minimal surfaces achieve all requirements in terms of structural stability, ability of being 3D printed, and the complexity in the façade which provides shading and safety from the radiation.

A. process

The building process is inspired by Swarm Robotics technology which is the study of designing a huge number of simple physically embodied operators such that a desired collective behavior arises from the local connections among the operators and between the operators and the surrounding environment. Swarm Intelligence (SI) prime inspiration came from the observation of order living animals and social insects [27].

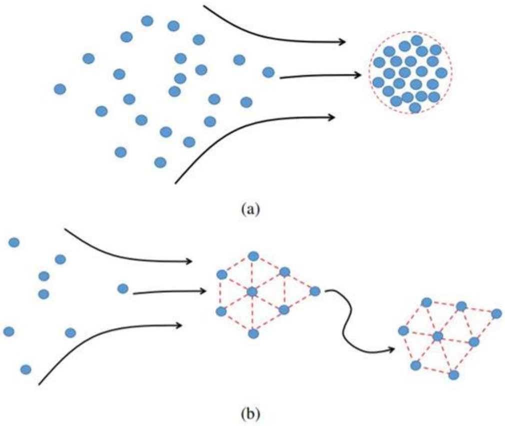

Fig 7. Illustration of a usual robot swarm coordination and controlling difficulties: (a) Aggregation. (b) Formation acquisition and maintenance.

Trip from earth to mars 6-9 months

A human mission to Mars and colonization of the planet will necessitate multidisciplinary expertise in a variety of fields, including engineering, technology, education, human health, and medicine, as well as human psychology and behavior [28].

Landing and Site Analyzing

The landing location for our mission will be on the largest lowland region of Mars Vastitas Borealis as mentioned before in site selection. On the surface of Mars, a fleet of about 20 robots will be released. These robots will begin 3D printing the over ground cave system where the inflatable Command Center will be housed, using Martian Regolith.

The robots will be given new tasks after the cave is finished, such as scouting new places, digging Martian regolith, and other tasks to establish a self-sustaining environment [29].

Construction begins (3 main stages)

1) Collecting Materials
2) Melting Materials
3) 3D Printing

B. Geometry

Choosing the geometry of both the interior and exterior shell needed to serve the form and function requirements. The main feature of the Gyroid was the symmetrical shapes it always gave out, so we used that into our advantage and produces organized plans and façades. Using the gyroid on its own was not always enough, so we embedded it into either spherical or capsule shapes when creating the shells.

C. Internal shell

In order to reach this concept, there was a certain level of complexity embedded using artificial intelligence and advanced software like Rhino, Grasshopper and multiple plug-ins worked in simulating the environment, these programs helped in transforming data into objects.

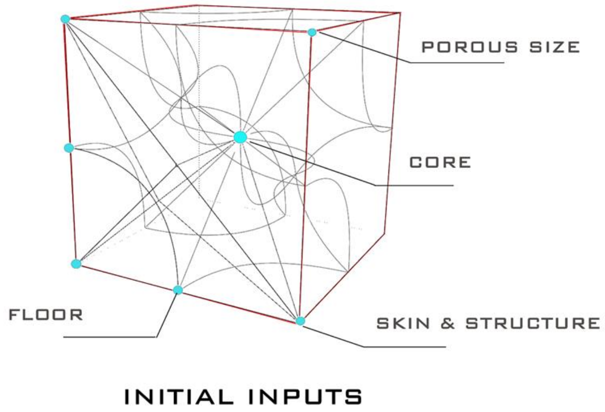

Fig 8. Diagram explaining the form finding process according to certain inputs.

A form of minimal surfaces is the gyroid, a base of the lightweight component produced by additive advanced technology, it is triply periodic, what means that a small piece of the surface may be used to assemble the entire surface by taking a fundamental piece and translating copies in three independent directions in space.

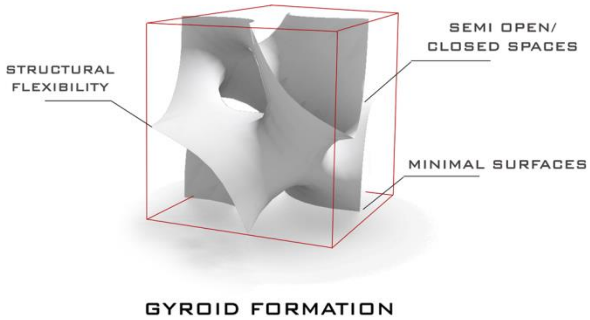

Fig 9. Diagram explaining the formation of the gyroid.

D. External Shell

The chosen form should handle the pressure difference within the unit and outside it, and in this manner, we had to stay clear of edges, so we directly avoided using cubic and sharp edges geometries because it undergoes high stresses in extreme pressure conditions. After additional inputs required in terms of floor heights, space division, and the number of users, we ended up with this capsule and spherical shapes.

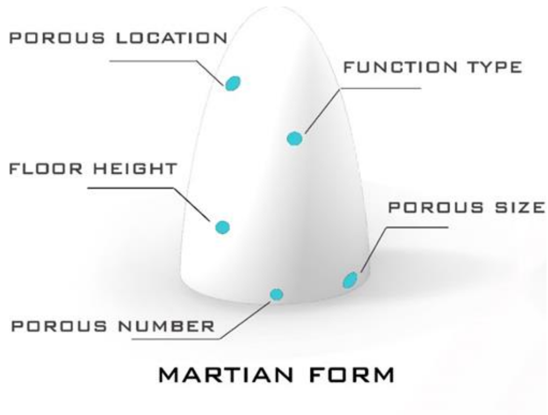

Fig 10. The initial Martian form that is qualified for the Martian environment.

The next step was to apply all of these inputs using AI and the most advanced software to understand the form, and this is where the generation experiments began. A single gyroid was able to form multiple shapes with different spaces and functions whenever we change the inputs.

Fig. 11. Experimental studies.

Afterward, when we analyzed the sectional plans furthermore, we took advantage of the gyroid's main feature which is symmetry. This feature was naturally created in the following three defined zones: The Core, Internal Spaces, and The Exterior Skin. **The Core** where the hydroponic garden and main stairs are located, **Internal Spaces** where the main functions are located such as the dry labs, wet labs, recreational areas, bedrooms, and hygiene areas, and **The Exterior Skin** that works as a protective barrier from the radiation.

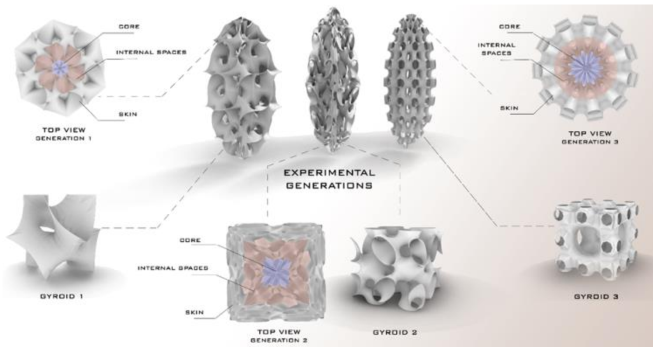

Fig 12. Concept development.

E. Experimental Studies and Final Outcomes

in order to study each form and analysis it in term of area efficiency, function distribution, vertical connections, and many other aspects, we decided to 3d printing them for better analysis purposes.

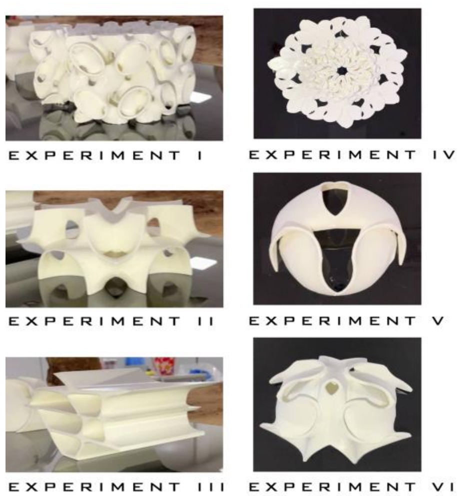

Fig 13. Experimental studies.

After studying all the aspects, we decided to go with the following forms.

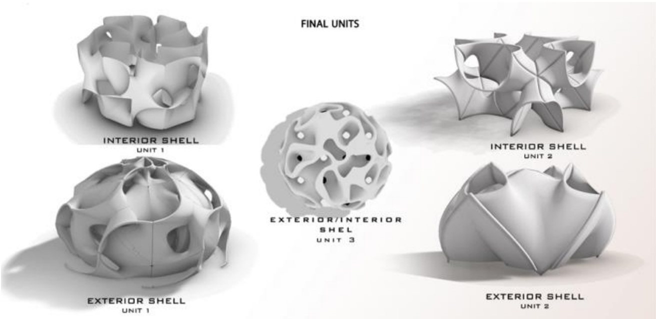

Fig 14. Final forms.

F. Unit plans

clusters include habitational, educational, and medical units. At this point, we developed a complex system on the façade where it provides shading and indirect lighting. this will help in preventing the direct radiation, and we would no longer require an additional shell for protection.

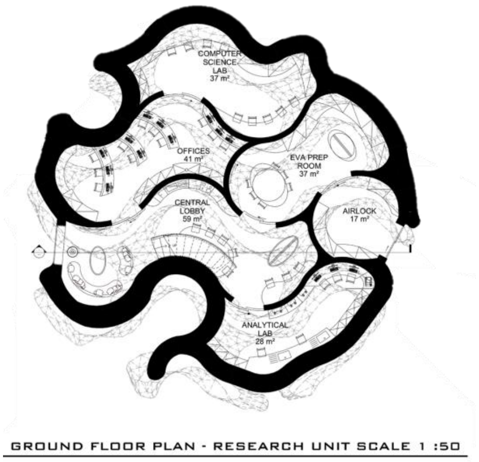

Fig 15. Ground floor plan.

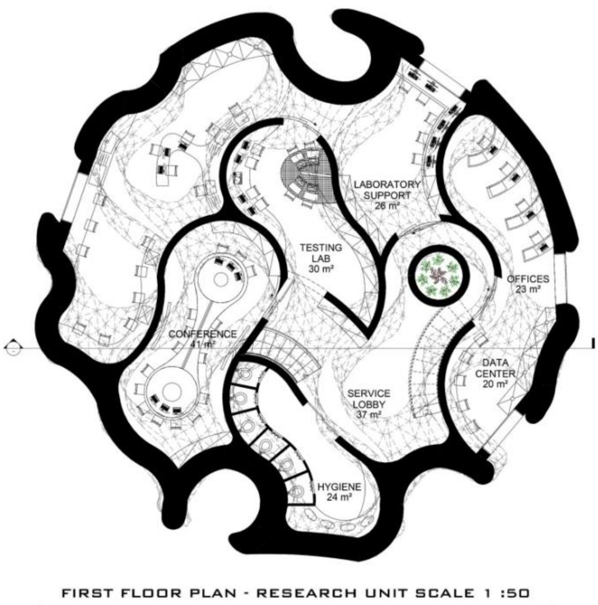

Fig 16. First floor plan.

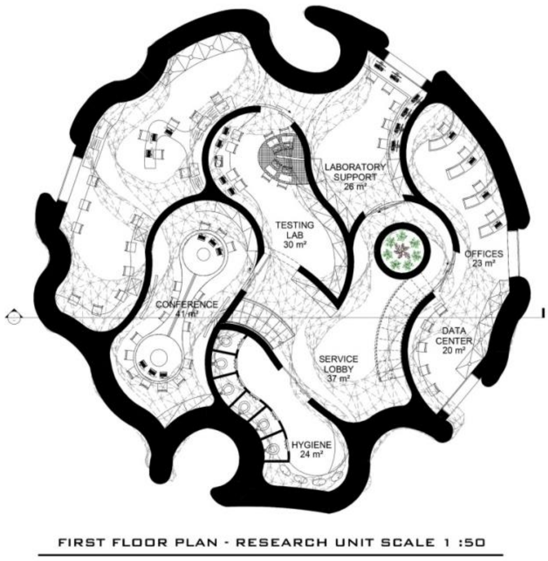

Fig 17. second floor plan.

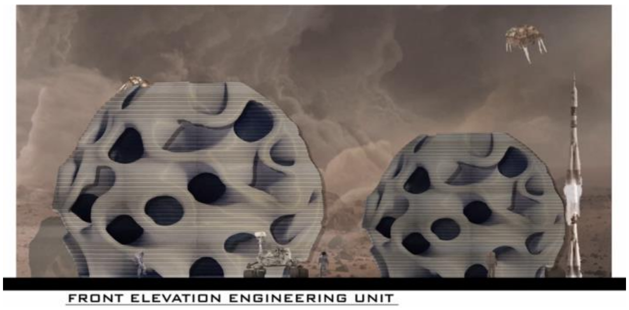

Fig18. Front elevation of unit 3 cluster.

The section provides a better view of the complex system of the unit, the depth of the windows as well as the main feature of minimal surfaces which is how the slabs and walls are connected together creating a structural system as well as a complex façade.

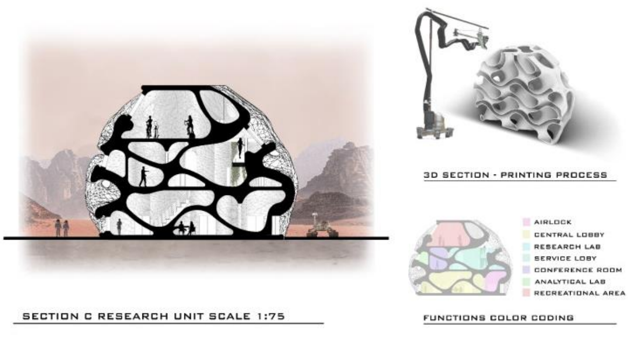

Fig 19. Architectural section of unit 3.

Fig 20. 3D Render of unit 3 cluster.

9. Construction techniques and details

The landing location for our mission will be on the largest lowland region of Mars *Vastitas Borealis* as mentioned before in site selection.

On the surface of Mars, a fleet of about 20 robots will be released. These robots will begin 3D printing the overground cave system where the inflatable Command Center will be housed, using Martian Regolith. The robots will be given new tasks after the cave is finished, such as scouting new places, digging Martian regolith, and other tasks to establish a self-sustaining environment [29].

In order to design a Martian settlement, we will need a large array of various mechanisms all with the aim of fulfilling as many tasks as possible. Construction is planned to be 3D printed by self-learning robots without any human involved to prepare the place for astronauts before they arrive. In other words, construction will begin years before any humans are sent [30].

The process starts with a lander which will settle on Mars and look for a suitable area according to the chosen site to start building the settlement. The lander deploys autonomous robots who will work on gathering the material for the process to start. They will be given simple instructions and complete their assigned tasks to the best of their ability as expected. Before any construction activities, an exact studied location must be selected according to multiple purposes [30].

Construction begins (3 main stages)

1) Collecting Materials

2) Melting Materials

3) 3D Printing

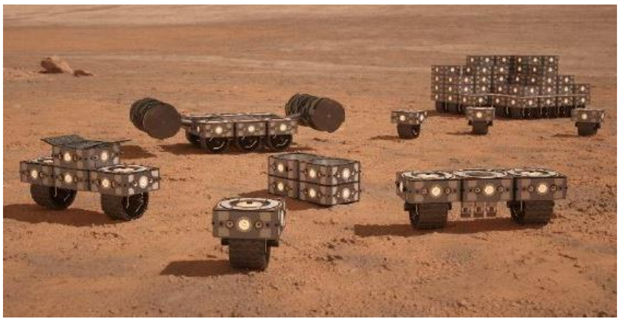

Fig 21. Hassel and Eckersley O'Callaghan robot designs for construction.

A swarm of wheeled robots excavates and collects regolith for processing into feedstock in Hassell + EOC's concept. Concurrent printing by the fleet of robots along the structure's x-y footprint allows for fast and efficient fabrication. The resulting Mars habitat has a contoured structure that is meant to blend in with the surroundings [31].

10. Design The Settlement Using In-Situ Resources

Mars is 63.365 million kilometers away from Earth and it is neither possible nor economically reasonable to provide an everlasting supply to Mars. In-situ resource utilization (ISRU) will be a must to keep the Earth launch burden and mission costs as low as possible and to provide a variety of construction materials and methods. Robotic Mars rovers confirmed that Mars topography has sufficient amount of raw materials needed to establish a human habitat on its surface [32].

Materials for feedstock are collected from the planetary surface by excavating robots. Polyethylene can be easily produced from the Martian soil on Mars, which has a 95 percent CO_2 atmosphere and availability of water. A gantry-style 3D printer extrudes ground basalt onto feedstock after adding it to polyethylene. The habitat design is a three-leveled printed shell structure. Inside the habitat, robotic assistance is used to position prefabricated components and penetrations [33].

According to the Northwestern team, sulphur would be the most important material in a Martian building boom. The basic concept is to melt sulphur at around 240°C, then mix it with Martian soil, which serves as an aggregate, and let it cool. The sulphur hardens, binds the aggregate, and forms Martian concrete. A mixture of 50 percent sulfur and 50 percent results in the ideal Martian Concrete blend.

11. Structure Simulation

The structure of the unit must fit a whole set of new requirements such as air tightness, maintain pressure, provide protection from radiation, and be super insulated from the extreme weather conditions outside. On top of this, the structure of the unit must have a form and certain geometry that can endure the difference between inner and outer pressure levels. In this aspect, there is no room for error, for it might lead to extreme danger and any mistake can be fatal [34].

12. Structural Analysis

Studying the structure and the durability of the complex forms we had was rather more theoretical. Assuming that our main material 'Martian regolith' behaves in a similar way as concrete, we followed the same method when doing our analysis. Also, we needed to keep in mind of how the slabs and walls are connected in the interior units. We did our analysis using rhino plugins (karamba 3D, geomtrygym).

Few things we kept in mind when calculating some of these values are the dead loads, live loads, and the environmental ones. The dead loads include the slabs, walls and the 3D printed fixtures, the live load include the number of people in each unit, and the environmental one includes the sandstorms and wind. Lastly, All Z loads are multiplied by a factor to consider the gravity on mars, since it's only the third of gravity on earth.

13. Structural Analysis

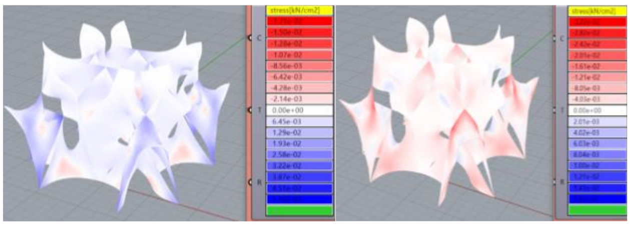

Fig 22. Images showing stress accumulation projected on structure.

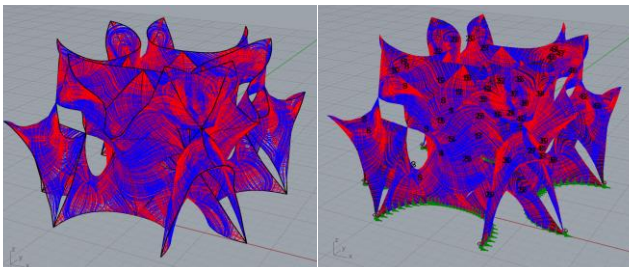

Fig 23. Images showing deformation of structure.

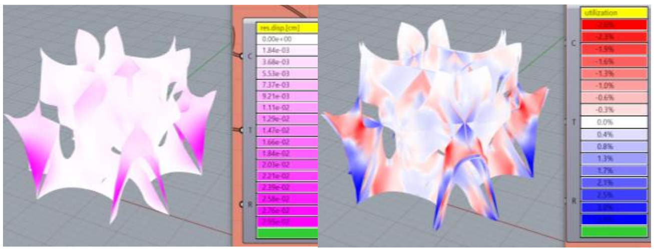

Fig 24. Images showing displacement of structure.

Item	Column 1	Column 2	Column 3
	Case	Load Combination$^{(1)}$	
		Principal Loads	Companion Loads
1.	1	$1.4D^{(2)}$	---
2.	2	$(1.25D^{(3)}$ or $0.9D^{(4)}) + 1.5L^{(5)}$	$1.0S^{(6)}$ or $0.4W$
3.	3	$(1.25D^{(3)}$ or $0.9D^{(4)}) + 1.5S$	$1.0L^{(6)(7)}$ or $0.4W$
4.	4	$(1.25D^{(3)}$ or $0.9D^{(4)}) + 1.4W$	$0.5L^{(7)}$ or $0.5S$
5.	5	$1.0D^{(4)} + 1.0E^{(8)}$	$0.5L^{(6)(7)} + 0.25S^{(6)}$

Fig 25. Showing dead and live loads calculations.

14. Conclusion

Humans are driven to explore the unknown, push the boundaries of our scientific and technical limits, wherefore this project aims to make Space Architecture a more common field in the Arab region and worldwide, as human space explorations answer fundamental questions about our place in the Universe, the past of our solar system, and the future of human living, noting that designing for this stage is the next step in this digital era that we are taking part of.

This project studied the history of the Red Planet and all the missions that helped explore what it feels like to live on it, it also compared between Mars and other possible planets; results showed that Mars is the most suitable option for habitation, and different technologies are suggested to solve the commonly known problems concerning the environmental conditions on Mars.

Different site locations were chosen according to several sites landing criteria, comparing with three distinct site proposals on Mars, each has different advantages to it. After analyzing the criteria and every site's characteristic, Results showed that Vastitas Borealis is the most appropriate site of all options. This paper also includes several design guidelines taking into consideration multiple different elements affecting the program and concept that are followed in the design stage.

Moreover, the project explains the three construction phases in order to build the optimum Martian base for future space exploration missions, where the first phase of the project is ending just after introducing the preliminary concept design, which is about the best formal base habitat geometry for our units and mimicking the nature from Mars to Mars to shield our settlement from the harsh environment, then the second and third phase starts to be built for larger community equipped with the latest technologies and more facilities to qualify the living environment on the Red Planet.

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