

SELF SUSTAINING BIOSPHERE IN MARS

A THESIS

Submitted in partial fulfillment of the requirements for the award of
Bachelor of Architecture degree

By

SAPTARSHI GHOSH

(37210031)



**DEPARTMENT OF ARCHITECTURE
SCHOOL OF BUILDING AND ENVIRONMENT**

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY) Accredited**

With Grade "A" by NAAC

**JEPPIAAR NAGAR, RAJIV GANDHI SALAI,
CHENNAI - 600 119**

NOVEMBER 2021



DEPARTMENT OF ARCHITECTURE

BONAFIDE CERTIFICATE

This is to certify that this Thesis Report is the bonafide work of Saptarshi Ghosh (37210031) who carried out the Thesis entitled “Self sustaining biosphere colony on Mars” under our supervision from July 2021 to November 2021.

Internal Guide

Ar. Arun S.K Sripaadha

Internal Review Member

Ar. Surya Rajkumar

External Guide

Ar. Kishore Pannikar

A handwritten signature in blue ink, reading 'Devyani'.

Dean and Head of the Department

Dr. DEVYANI GANGOPADHYAY

Submitted for Viva voce Examination held on 08/12/2021

Internal Examiner

Ar. Shankar Venkatraman

External Examiner

Ar. Sathish Mosses

DECLARATION

I, **Saptarshi Ghosh** hereby declare that the Thesis Report entitled “**Self sustaining biosphere colony on Mars**” done by me under the guidance of **Ar. Arun S.K Sripaatha** Internal Guide), **Ar. Surya Rajkumar** Internal Review Member) and (External Guide) Sathyabama Institute of Science and Technology is submitted in partial fulfilment of the requirements for the award of Bachelor of Architecture Degree.

DATE: 06/12/2021

Saptarshi

PLACE: Chennai

SIGNATURE OF THE CANDIDATE

ACKNOWLEDGEMENT

I am pleased to acknowledge my sincere thanks to Board of Management of **Sathyabama Institute of Science and Technology** for their kind encouragement in doing this Thesis and for completing it successfully. I am grateful to them.

I convey my thanks to **Dr. Devyani Gangopadhyay**, Dean and Head of the Department, School of Building and Environment, Our Design Chair **Dr. Suresh Kuppuswamy**, Thesis Coordinator **Ar.Surya Rajkumar** for providing me necessary support and details at the right time during the progressive reviews.

I would like to express my sincere and deep sense of gratitude to my Thesis Internal guide **Ar. Arun S.K Sripada**, Internal Review member **Ar.Surya Rajkumar**, and External Guide their guidance, suggestions and constant encouragement which paved the way for the successful completion of my Thesis work.

I wish to express my thanks to all Teaching and Non-teaching staff members of the **Department of Architecture** who were helpful in many ways for the completion of the Thesis.

Saptarshi Ghosh

THESIS SYNOPSIS

Mars colonization has been in the talks due to various reasons such as over population lack of resources on Earth, a backup due to a catastrophic disaster and so on. This design aims to develop a completely self sustaining colony on the planet of Mars with the means of an artificially created biosphere in the vastly different planetary conditions of the planet which will be designed optimally for human civilization.

One of the most important reason for colonizing Mars is that it offers a backup plan for humanity. Every few million years, the Earth tends to be wiped clear of almost all life in a globally catastrophic event. It also serves as an answer for overpopulation and rapid resource depletion on earth and for humanity to survive in the future leaving the planet to settle on a new one might be the only way moving forward.

TABLE OF CONTENTS

CHAPTER No.	TITLE	PAGE No.
	THESIS SYNOPSIS	V
	LIST OF FIGURES	viii
	LIST OF TABLES	ix
	LIST OF PLATES	x
1	INTRODUCTION	1
1.1	INTRODUCTION	1
1.2	NEED OF THE PROJECT	1
1.3	AIM	3
1.4	OBJECTIVE	3
1.5	METHODOLOGY	4
2	LITERATURE CASE STUDIES	5
2.1	Biosphere 2	5
2.2	Mars X house V1	7
2.3	Mars X house V2	9
3	DATA COLLECTION	11
4	SITE STUDY AND ANALYSIS	14
5	ARCHITECTURAL DESIGN	17
6	STRUCTURES AND SERVICES	24
7	Future Expansion	27
8	References	28

LIST OF FIGURES

FIGURE No.	TITLE	PAGE No.
4.1	Model of Arcadia Planitia	14
4.2	Archeon Fossae	14
4.3	Erebus Montes	14
5.1	Site Plan	17
5.2	Construction Process	18
6.1	Construction Process of dome	24
6.2	Dome Details	25
6.3	Materials	25
7.1	Future Expansion	27

LIST OF TABLES

TABLE No.	TITLE	PAGE No.
4.1	Comparative Analysis	15

LIST OF PLATES

TABLE No.	TITLE	PAGE No.
2.1	Case study biosphere 2	5
2.2	Case study biosphere 2	6
2.3	Case study Mars X house v1	7
2.4	Case study Mars X house v1	8
2.5	Case study Mars X house v2	9
2.6	Case study Mars X house v2	10
5.1	Design Of Laboratory	15
5.2	Design Of Residence	16
5.3	Design Of Bunker	17
5.6	Design Of Farm-station	18
5.5	Entrance Pocket spaces and universal temple	19
6.1	Services	26

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

What is a biosphere?

Biospheres are the regions of the surface and atmosphere of the earth or another planet occupied by living organisms. In this project, the goal is to create an artificial biosphere that's going to be enclosing self contained ecosystems. This design aims to develop a completely self sustaining colony on the planet of Mars with the means of an artificially created biosphere in the vastly different planetary conditions of the planet which will be designed optimally for human civilization.

1.2 NEED FOR THE PROJECT

Its similarity to Earth.

- Mars has water, frozen underground and at the polar caps. There is evidence that this water has, in the past and present, flooded the surface in liquid form. Signs of erosion can be found on the slopes of craters and volcanoes. Geological features resembling those on Earth suggest that Mars was once a wet and hospitable planet.
- A day on Mars is 24.5 hours long. Mars is a third the size of Earth, but it has as much land area as the seven continents combined. Its gravity is 2.7 times less than that of Earth: enough to remain flat-footed on the surface, but a low enough escape velocity to make launching from Mars relatively simple.
- Construction materials would be lighter as well, facilitating labour in the early colony.
- The health benefits of such an environment are unknown, but it is theorized that Mars might prevent and relieve forms of arthritis and back pain. Also, Martian-born children might be taller than their Terran cousins.
- Both planets have seasons and similar rotational patterns.
- Mars is roughly in the same heat-range as Earth, being the next planet in the solar system. Today, Mars's temperature varies from 20°C to -90°C, with an average global temperature of -60°C. That's as cold as the average temperature on Antarctica, but still the solar system's most hospitable for humans.
- Observations by NASA's Mars Reconnaissance Orbiter, ESA's Mars Express and NASA's Phoenix Lander confirm the presence of water ice on Mars.
- Mars exploration missions such as MARIE has shown that plants and some algae that are known to survive in extreme conditions can survive the nature of Mars, which is helpful in dealing with the environment there.

Economic Value

- Mars is worth a lot of money. There are 144 trillion square meters of surface area, roughly the land area of the Earth, available for development.
- An important part of the fusion reaction process is deuterium, a stable isotope of hydrogen. Once we can contain a fusion reaction, the deuterium-tritium reaction has a high yield of energy for the small amount of fuel put in. Deuterium, or heavy hydrogen, is hard to obtain on Earth, but on Mars it is five times more abundant in the form of Hydrogen-Deuterium-Oxygen. A millilitre of liquid heavy-hydrogen fuel would produce as much energy as 20 tons of coal.
- There is an abundance of rare metals on Mars such as platinum, gold, silver, and others.
- Shipping from Mars to Earth, as mentioned above, is much easier than the other way around. Even more promising is the proximity of the asteroid belt to Mars. These asteroids could be mined near Mars and shipped from the planet for little cost. The economic potential is great.

Its scientific Secrets

With its similarity to Earth, there is a strong possibility that bacterial life exists on the planet. The ease with which a human being can cover a stretch of ground and examine specimens along the way, gathering and processing data, cannot be emulated with a machine. If we ever find life, we can begin to answer some of the biggest questions we've ever asked: "Are we alone in the universe?" From a geological standpoint alone, Mars is exciting because it offers scientists a view of how planets develop. Mars is billions of years older than the Earth, and its features are much more exaggerated. The largest canyons, volcanoes, and craters in the solar system are available for our study. Conditions can survive the nature of Mars, which is helpful in dealing with the environment there.

Its Location

Mars is relatively close to the Earth. Mars sits between the asteroid belt and us, acting as a kind of stepping stone to what lies beyond. It remains close enough to the sun to benefit from its heat (and light) but remains far enough away to be protected from any significant change in the sun's heat output.

It can be a Second Home for Mankind

One of the most important reason for colonizing Mars is that it offers a backup plan for humanity. Every few million years, the Earth tends to be wiped clear of almost all life in a globally catastrophic event. It also serves as an answer for overpopulation and rapid resource depletion on earth, and for humanity to survive in the future, leaving the planet to settle on a new one might be the only way moving forward.

1.3 AIM

The aim of this thesis is to design a completely self sustaining colony on the red planet using various studies on materials, construction techniques and drawing inspiration from and using systems that have been proven to be able to provide the necessary life and well being support on the conditions of Mars.

1.4 Objectives

The design of this colony will face a number of challenges because of the difference in the terrain and environment of Mars while in comparison with the environment on Earth, the main challenges or questions that should be asked while designing this should be-

- ☐ How many people can it hold?
- ☐ How can we deal with the radiation?
- ☐ How are we going to produce energy?
- ☐ Will gravity be a problem?
- ☐ How are we going to transport construction materials?
- ☐ How will we produce water and oxygen?
- ☐ What about the temperature?
- ☐ How will we produce food?
- ☐ What about the psychological effects on the residents?

1.5 Methodology

The methodology behind this thesis will involve studying and referring to various studies and research done on the above identified problems and gather solutions for the same which will form the base of the design and its systems, then the design will proceed with identifying spatial requirements for the various needs of its residents and the systems required to sustain them and will finally proceed onto combining the functional and design aspects of the project in order to create a second home for the residents far away from their home planet while still trying to

emulate most of what makes Earth special, this project will also focus on trying to make it completely self sustaining with multiple security measures in case of breaches including bunkers and other things to safely allow the residents to live in the conditions of the Red planet.

CHAPTER 2

LITERATURE CASE STUDY

2.1 Biosphere 2

CASE STUDY | BIOSPHERE 2



Biosphere 2 is a 315-acre (12,700 sqm) structure originally built to be an artificial, materially-closed ecological system in Oracle, Arizona (USA) by Space Biosphere Ventures

Constructed between 1987 and 1991, it was used to explore the complex web of interactions within life systems in a structure that included five areas based on natural biomes and an agricultural area and human living/working space to study the interactions between humans, farming and technology with the rest of nature. It also explored the possible use of closed biospheres in space colonization, and allowed the study and manipulation of a biosphere without harming Earth's.

This structure was taken as a case study as it has different systems that allows it to completely be sealed off from the outside world and self sustain, which is similar to our conditions on Mars where we aim to create an entire biosphere in the sealed region of our colony; hence would be drawing inspiration from some of the systems used to keep this Biosphere 2 running.

SPACES



THE AGRICULTURE MESOCOSM

Also known as the intensive agriculture biome (IAS), it provided food for the inhabitants of the facility. It had systems such as CELSS (controlled ecological life support system) to enrich their yield to feed the crew of the Biosphere 2.



THE LUNG

The reason as to why the whole sealed structure didn't explode due to the change in air pressure and density, the 'lungs' of the biosphere were two aboveground geodesic domes that contained huge variable expansion chambers that dealt with the expansion of air in the structure and kept it stable.



HUMAN HABITAT

The dwelling area for the residents of Biosphere 2, this space includes the sleeping cabins, kitchens, medical area, storage for laboratory equipments, Research labs, Exercise area and the library. It was designed in an elevated area to give the residents a view of the entire site while looking out of their windows.



THE RAINFOREST

This is an artificially created rainforest inside the Biosphere 2, serving as one of its 5 major biomes. This also was one of the main source of oxygen production inside the structure.



THE SAVANNA

The second major biome of the Biosphere 2, it features mixed woodland-grassland ecosystem with widely spaced trees and primarily consists of different variants of grasses.



THE MARSH

The third major biome of the Biosphere 2, it is characterized by poorly drained mineral soils and by plant life dominated with grasses and trees.



THE OCEAN

The fourth biome of Biosphere 2, it is a large tank of 35 x 20 meters with almost 7 meter deep grading to a shallow lagoon partially separated by a reef. A lot of research and tests happen here to find solutions to the coral reef crisis.



THE DESERT

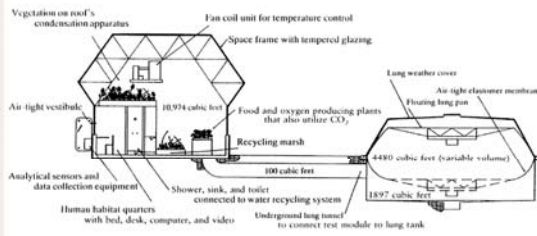
The fifth biome of Biosphere 2, the desert biome was designed to simulate an arid desert ecosystem in a coastal climate with aridic winter rainfall and summer drought. Soils were constructed to simulate those found in arid places.

The above-ground physical structure of Biosphere 2 was made of steel tubing and high-performance glass and steel frames. The frame and glazing materials were designed and made to specification by a firm run by a one-time associate of Buckminster Fuller, Peter Pearce (Pearce Structures, Inc.). The window seals and structures had to be designed to be almost perfectly airtight, such that the air exchange would be extremely slow, to avoid damage to the experimental results.

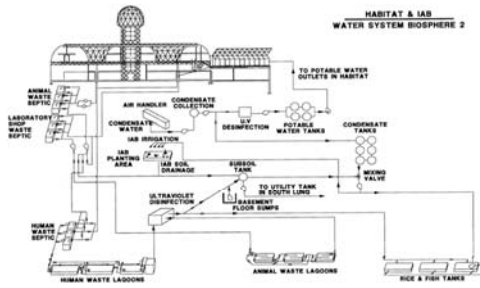
ODYSSEY

Thresh

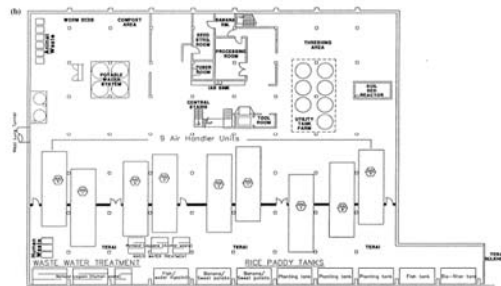
CASE STUDY | BIOSPHERE 2



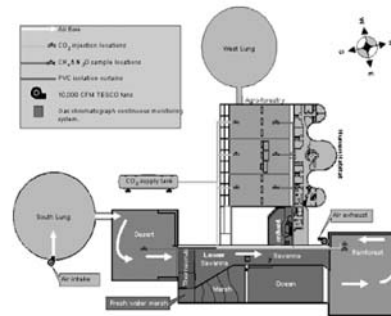
Air Circulation system in the biosphere 2



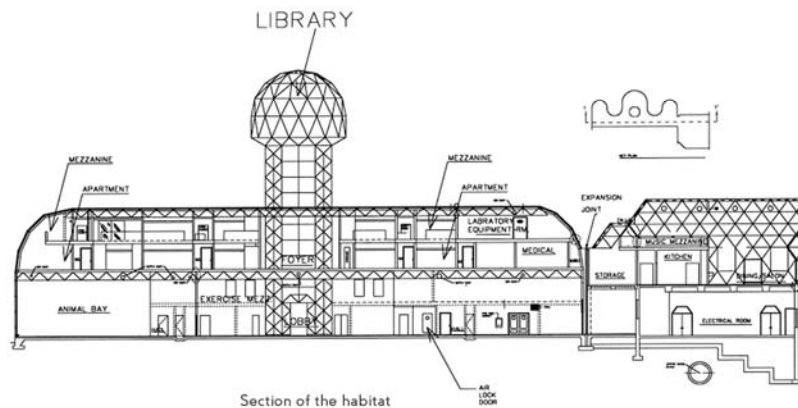
Water Supply system in the biosphere 2



Agriculture biome's supply and irrigation system



How the air flows in the structure



Section of the habitat

The structure was notable for how it dealt with atmospheric expansion. During the day, the heat from the sun caused the air inside to expand and during the night it cooled and contracted. To avoid having to deal with the huge forces that maintaining a constant volume would create, the structure had large diaphragms kept in domes called lungs:

Since opening a window was impossible, the structure also required huge air conditioners to control the temperature and avoid killing the plants within. For every unit of solar energy that entered the structure, the air conditioners would expend approximately three times as much energy to cool the habitat back down.

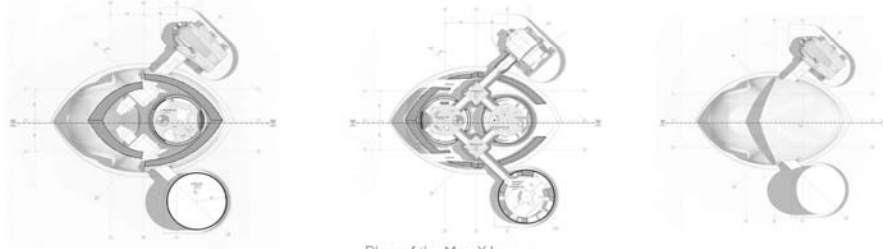
2.2 Mars X house V1

CASE STUDY | MARS X HOUSE V1



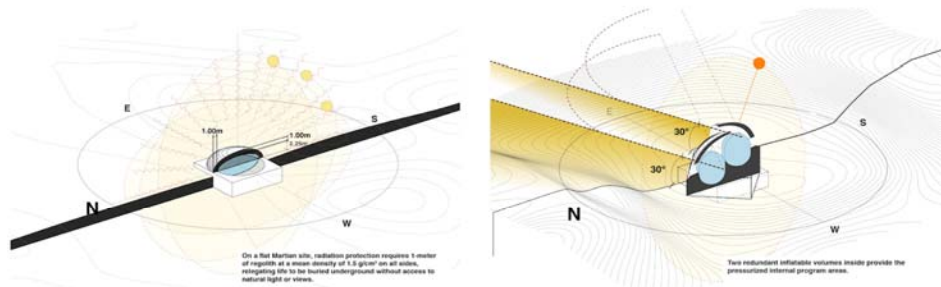
X-House is the First prize winner of Virtual Design within NASA's Phase 3 Habitat Challenge. Prioritizing safety, redundancy, and the wellbeing of the crew above the Martian surface. Mars X-House seeks to exceed current radiation standards while safely connecting the crew to natural light and views to the Martian landscape.

X-House presents a habitat scaled to fit within the 4.5m x 4.5m footprint of the Level 3 Head-to-Head event of the Phase 3 competition at 1/3 scale. By vitally connecting the human residents with views to the Martian landscape, the habitat synthesizes key design factors fundamental to future Martian habitation: program and construction efficiency, light, and radiation protection-creating a highly functional and protective habitat for its occupants.



Plans of the Mars X house

FEATURES AND INFERENCES

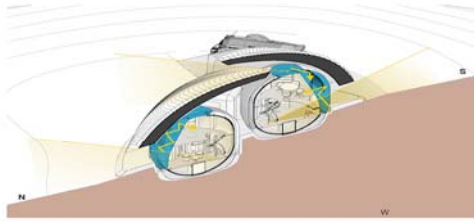


the angle of incidence of sunrays coming through any openings must below 30° to prevent most of the radiation from entering.

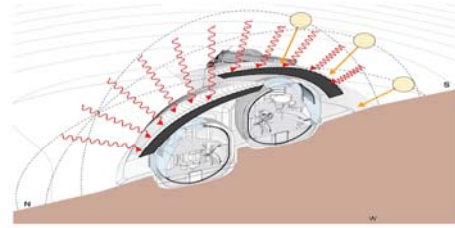
ODYSSEY

Ghosh

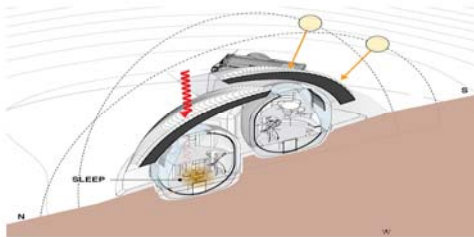
CASE STUDY | MARS X HOUSE V1



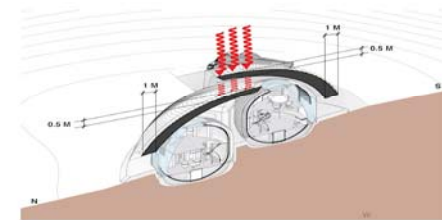
Light is transmitted through transparent CO₂-inflated window pockets and greenhouses. Light is bounced into internal skylights and horizontal apertures.



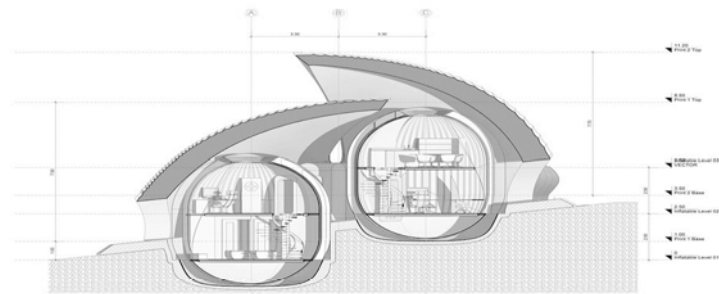
The structural shell protects the interior spaces from Galactic cosmic radiation and solar radiation.



The spaces where the crew spend most of their time is most protected from radiation through multiple layers of protection and insulation.



The designers have achieved 1-meter of overhead radiation shielding by overlapping two 50cm thick structural load reducing shells.



Sectional illustration of different spaces in the structure and how the shells overlap to shield from radiation and how they also allow some light to go through while reducing most of the radiation from entering the inflatable pressurised tube-like spaces inside the structure.

ODYSSEY

Ghosh

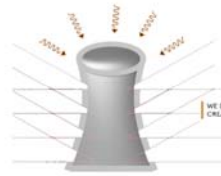
CASE STUDY | MARS X HOUSE V2

FEATURES

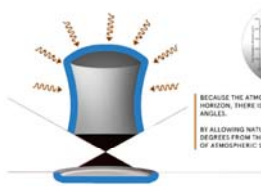


MECHANICAL CORE

A PRE-INTEGRATED ECLES SYSTEM IS LOCATED IN THE CENTER OF THE HABITAT FOR OPTIMAL AIR CIRCULATION AND FLOW.



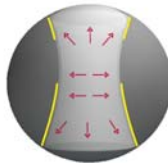
WE SHADE EACH OPENING WITH A 3D DEGREE "OVERHANG" CREATED BY THE THICKNESS OF THE WALL.



BECAUSE THE ATMOSPHERE IS THICKER AS WE APPROACH THE HORIZON, THERE IS LESS REQUIREMENT FOR SHIELDING AT LOWER ANGLES.
BY ALLOWING NATURAL LIGHT TO ENTER THE HABITAT AT 30 DEGREES FROM THE HORIZON, WE ARE STILL ENDURING -40 IS/CW2 OF ATMOSPHERIC SHIELDING.



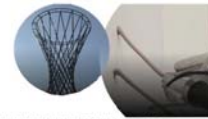
WHILE THE CONCRETE + BASALT FIBER CONSTRUCTION ADDRESSES INTERNAL PRESSURE FORCES, THEY ARE STILL MATERIALLY POROUS. AN INNER LINING OF PRINTED HDPE CREATES AN AIR BLADDER - THE INNER TUBE TO THE REGOLITH STRUCTURAL TIE.



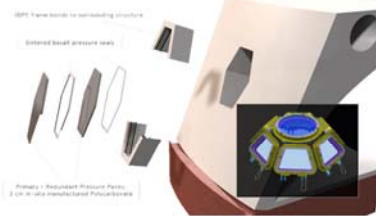
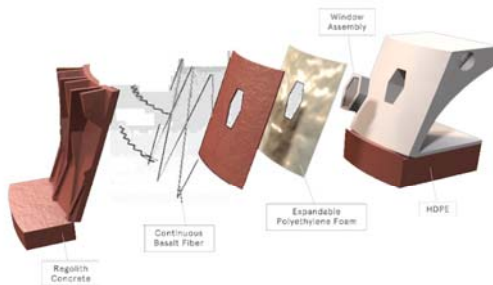
AN INWARD FACING ARCH IS A MORE EFFICIENT COMPRESSION STRUCTURE - IT HOLDS BACK THE FORCES OF AIR PRESSURE LIKE A DAM HOLDS BACK THE FORCE OF WATER.



THE UNIQUE SHAPE OF THE HYPERBOLOID ALLOWS FOR CONTINUOUS REINFORCEMENT FROM BOTTOM TO TOP OF THE STRUCTURE.



MATERIAL USAGE



ODYSSEY

Ghosh

Plate
2.5

2.3
Mars X
house
V2

CHAPTER 3

DATA COLLECTION

3.1 Population

According to a study by French researcher Jean Marc Salotti, who used a mathematical model to determine the minimum number of people required to make a sustaining colony on mars based on comparison of time requirements and implementation of activities along with the inclusion of a model known as the sharing factor, he deduced the minimum number of settlers and calculated it to be 110 people.

3.2 Radiation

Due to the much thinner atmosphere on earth, there is a lot more solar radiation on mars compared to earth but there were studies done by NASA that were concluded with structures inside Martian Lava tubes that are cavities formed by volcanic activities on mars were ideal to counter this, there are also researches done on anti radiation materials such as Regolith Concrete from the surface of the planet itself with a higher concentration of sulfur and the angle of incidence of light in openings to be kept under 30 degrees to minimize radiation.

3.3 Energy

Mars has abundant Solar energy throughout the year which coupled with Nuclear fission reactors can produce ample energy for the sustainability of a colony there..It also has abundance of Deuterium which is an isotope of hydrogen that can produce a large amount of

energy which will be used to fuel the energy needs of the colony.

3.4 Gravity

The gravity on Mars is 2.7 times less than that of Earth enough to remain flat-footed on the surface but a low enough escape velocity to make launching from Mars relatively simple, It also makes the materials for construction lighter which means easier construction and less amount of loads to be carried by the structural features. It is theorized that the Martian environment's gravity might prevent and relieve forms of arthritis and back pain for its residents.

3.5 Transport of construction materials.

Although some processed supplies would have to be shipped from Earth to successfully build a colony on Mars, There were multiple ISRU studies done on mars exploration missions that have led to the conclusion of Excavation of Majority of construction materials on Mars to lower the cost of construction and shipping.

3.6 Water and Oxygen

Several studies have shown the presence of water and hydrated minerals on mars which can be and also can be produced by making an artificial ecology similar to that of BIOSPHERE 2 that can generate its own water and oxygen and using systems such as ISS water recovery system can help to recycle water there are also processes such as WAVAR that can extract water and oxygen from the air in mars.

3.7 Temperature

With an average temperature of -60 degrees , along with artificial heating, the living quarters and colony would have to be artificially heated and the usage of greenhouse gases such as CFC or PFC could help to trap the heat in case of a biosphere dome also the usage of

aluminized PET film could be used to increase the insulation of the environment.

3.8 Food

In 2012 there were studies done on martial simulation labs that showed the survivability of certain algae and Cyano bacteria that could photosynthesis in the mars environment and also other organism cross cultured with these could survive in their environment. There are also studies on terraforming of the mars soil to perform agriculture using wastes as fertilizers.

3.9 Psychology of residents

Apart from the first few batches of inhabitants going under training, these are to be countered using the various means of architectural studies on psychological effects of spaces and architecture that can aid in psychological recovery of an inhabitant.

CHAPTER 4

SITE DETAILS

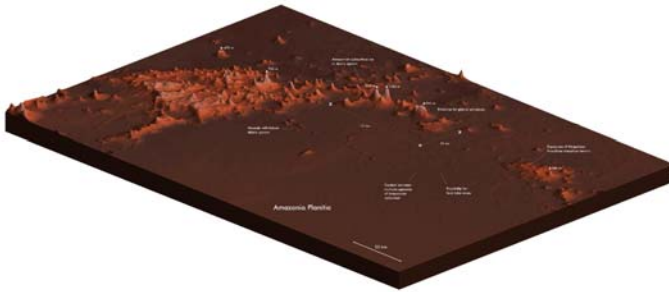


Fig 4.1- model of Arcadia Planitia

The selected site is located in Erebus Monte in the Arcadia Planitia region, This is a region in mars that has an abundance of shallow ice at a relatively low altitude and closer to the equator of the planet where temperatures are warmer compared to the poles. Under this

regions, two sites Erebus Montes and Archeron Fossae have been deemed to be the most habitable sites in the entire region.

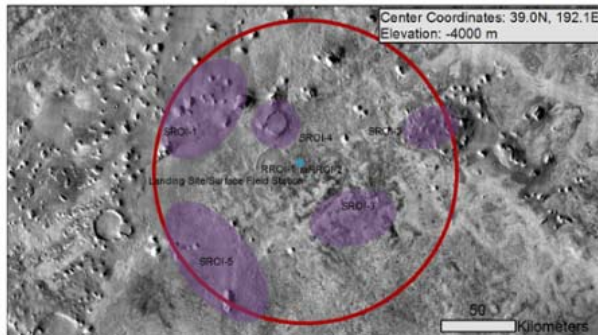


Fig 4.2 -Acheron Fossae

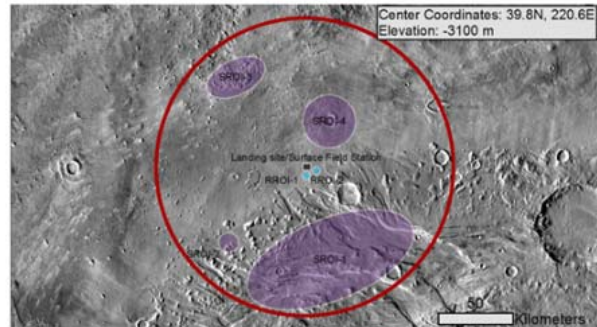


Fig 4.3 -Erebus Montes

comparative study and study of research done on the two sites based on several expedition data, Erebus Montes is determined to be the better site for the building of this colony at the shores of Arcadia Planitia at the coordinates of 35.66°N 185.02°W, due to its closer proximity to

the landing site and less terrain features that block the sunlight.

Additionally, the presence of potential glacial ice, resources like silicon, basaltic sands, and loose clay to produce Regolith make for an ideal site to start a colony on the 50km of flat and stable terrain.

Upon future expansion of the colony its possible to expand to the Archeon Fossae site as well since there will be more food, oxygen and other necessary resource production facilities at that point of time.

SITE FACTORS		SITES	
	Criteria	Acheron Fossae	Erebus Montes
Water Resources	Potential for ice	✓	✓
	Potential for hydrated minerals	✓	✓
	Quantity for substantial production	✓	✓
	Located no more than 3m below the surface	✓	✓
	Accessible by automated systems	✓	✓
Engineering and construction	~50 SQ KM region of flat and stable terrain with sparse rock distribution	✓	✓
	Slope of <10°	✓	✓
	Located within 5km of landing site location	□	✓
	Abundance of cobble sized or smaller rocks and bunlk , loose regolith	✓	✓
	Utilitarian terrain features.	✓	✓
Food Production	Low altitude	✓	✓
	No local terrain features that would shadow light collecting facilities	□	✓
	Access to water	✓	✓
	Access to dark , minimally altered basaltic sands	✓	✓
Availability of mineable resources	Potential for metal/silicon	✓	✓
	Potential to be minable by highly automated systems	✓	✓
	Located no more than 3meters below the surface	✓	✓
	Traversable route to location	✓	✓

Table 4.1

TEMPERATURE- It can get as high as 20°C and as low as -125°C with an average of -60°C globally, around the equator (Arcadia Planitia) the variation is lower where it shifts between 20°C and can get as low as -80°C.

SEASONS- It has 4 seasons similar to earth due to its almost equal tilt and similar Elliptical orbit.

STORMS- While mars has hurricanes and storms, due to the density of the atmosphere being

about 1% of Earth's atmosphere, it only feels like a gentle breeze.

Day Length(Sol) - 24 hours 37 minutes

Year Length- 687 days (22 months)

Duration of night- about 11h 20 minutes on an average, during winter the it can vary up to 3 hours longer and during the summer its about 3.

Mars has two moons, namely Phobos and Deimos, Phobos has a cycle of 30 hours and Deimos about 9 hours.

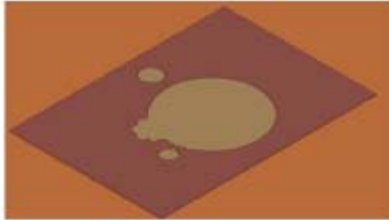
Dust storms although rare, can still happen on mars, during these times the dust particles may cover the entire sky for days which would pose a problem to the solar panels getting covered, it would be dealt with by storing enough power to offset the loss in solar power gain for the duration and by alternative electricity generation methods such as nuclear fission reactors.

CHAPTER 5

Architectural Design



Fig 5.1 site plan



The structure is constructed starting with excavation of the ground around the structure then moving on to the laying of the service requirements and necessary life sustaining systems around the site.



After which the structures are 3D printed by automated machines



which are sent in before the colonists arrive.

Upon arrival of the colonists, the life sustaining systems are put into function and the dome covering is laid out turning the inner space into a contained and air sealed space with the lungs acting as a regulating system.



After this the systems are up and running and the agriculture and energy producing systems are put into production, sustaining the residents and all the services they might require in the colony and the surplus are stored for emergency purposes and future expansion purposes.



Fig- 5.2 Construction Process



Plate 5.1 – Design of Laboratory Space

he laboratory are combined with entertainment spaces as a means to provide a break for the people working in them designed with a greenhouse courtyard in the center it has many elements of natural light playing a part in its design.



Plate 5.2 Residence design

The residence are designed using design factors and concepts identified in the case studies with a circular or curved shape to them in order to conserve materials on making the outer walls.

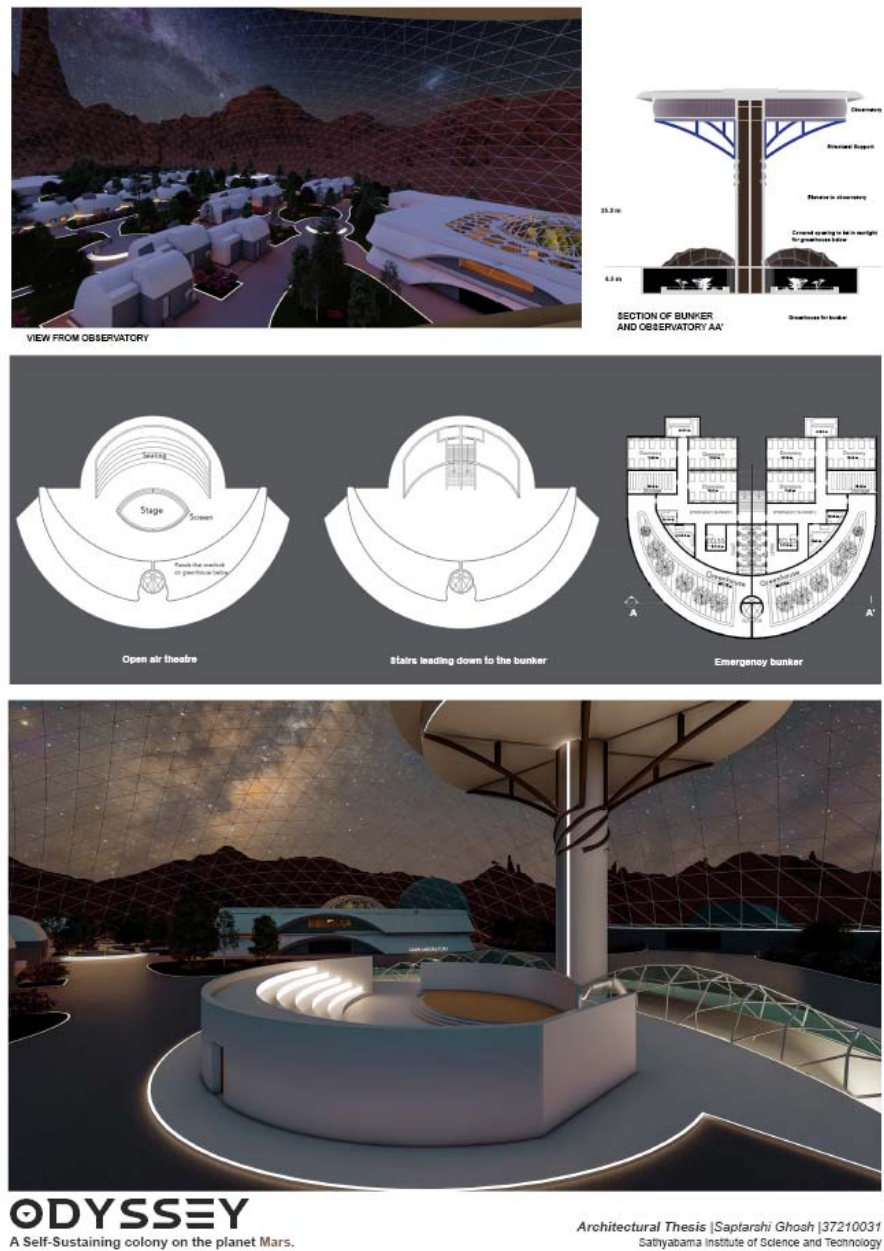


Plate 5.3 Bunker, OAT and observatory

The bunker is designed under the OAT and observatory with a stairway leading down to it from behind the OAT, it has access to an elevator leading to the observatory which can also be accessed from the ground floor near the openings overlooking the greenhouses in the bunker.

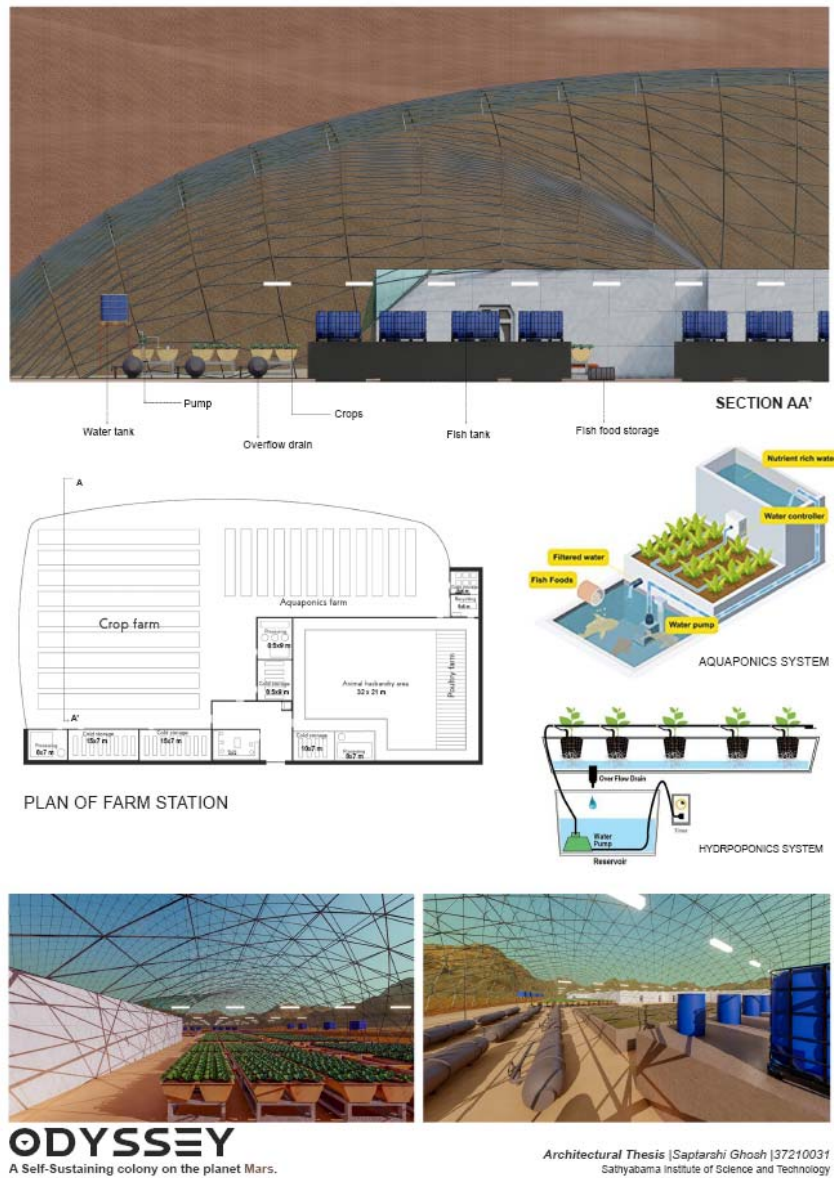


Plate 5.4 Farm-station

The farm-station has been designed with the help of the necessary equipment and spaces required for aquaponics and hydroponics.



Plate 5.5 Entrance, Pocket spaces and Universal temple

Pocket spaces have been provided in and around the site to break the monotony of the design and to provide interactive and social spaces for the residences living there, the universal temple acts as their meditation zone or a space for them to follow any religious activity

CHAPTER 6

STRUCTURES AND SERVICE

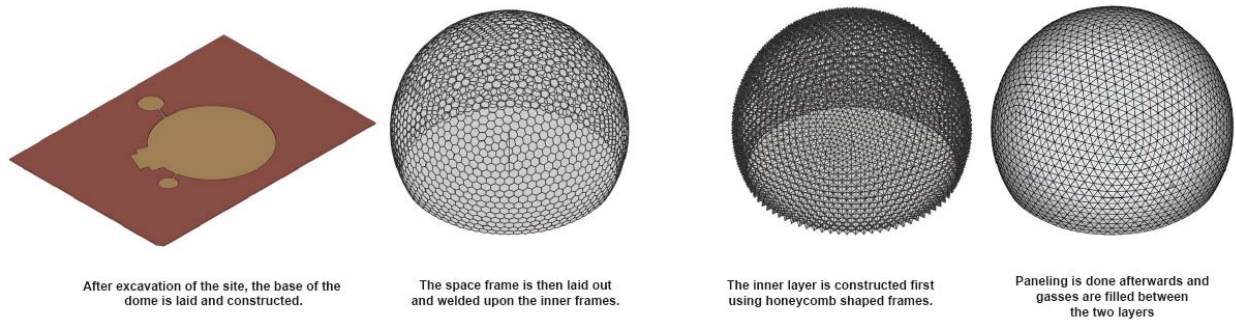


Fig 6.1 construction process of the dome

Using a geodesic dome as the outer shell of the biosphere , it will have two layers between which will first be vacuumed then filled with greenhouse gasses such as CO₂ taken directly from the atmosphere of mars. The inside of this dome will have multiple airlocks at the entry-docks and have an air handling unit “lungs” that will deal with the change in atmospheric air pressure, the goal of this is to create an artificial atmosphere inside the biosphere so that the residents can go outside without any need of oxygen equipment, this dome will also be cleaned **using automatic rover drones as seen in X-houses’s proposal in the Nasa space design contest.**



Fig 6.2 Dome Details

A geodesic sphere is an arrangement of polygons that approximates a true sphere. A geodesic

dome is a portion of a geodesic sphere. Geodesic domes are efficient structures in several ways. The triangle is a very stable shape; for example, a force applied to the corner of a rectangle can deform it into a parallelogram, but the same force will not deform a triangle. This makes geodesic dome buildings highly resistant to such forces as snow coverings, earthquakes, wind, and even tornadoes. A geometric dome supports itself without needing **internal columns or interior load-bearing walls**.

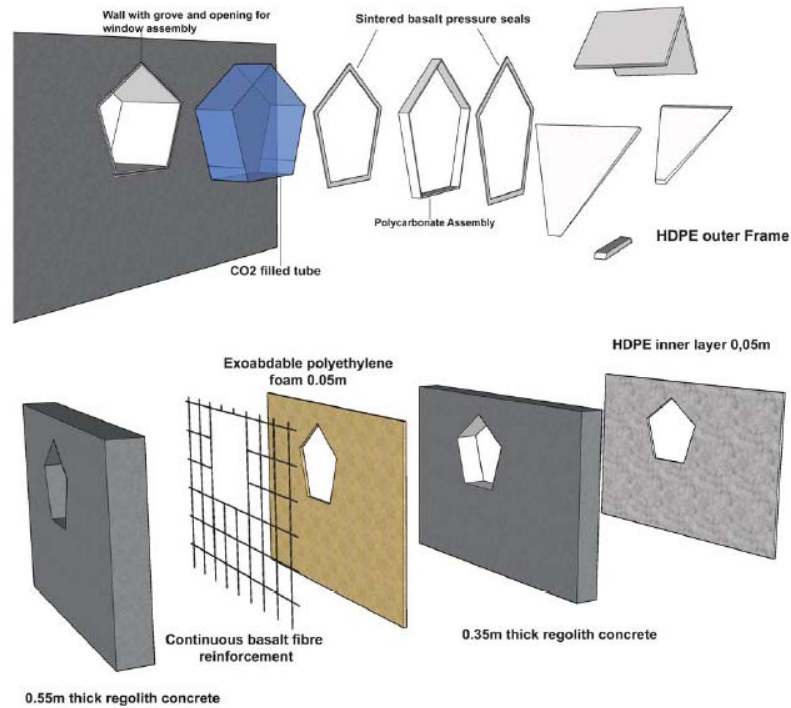


Fig 6.3

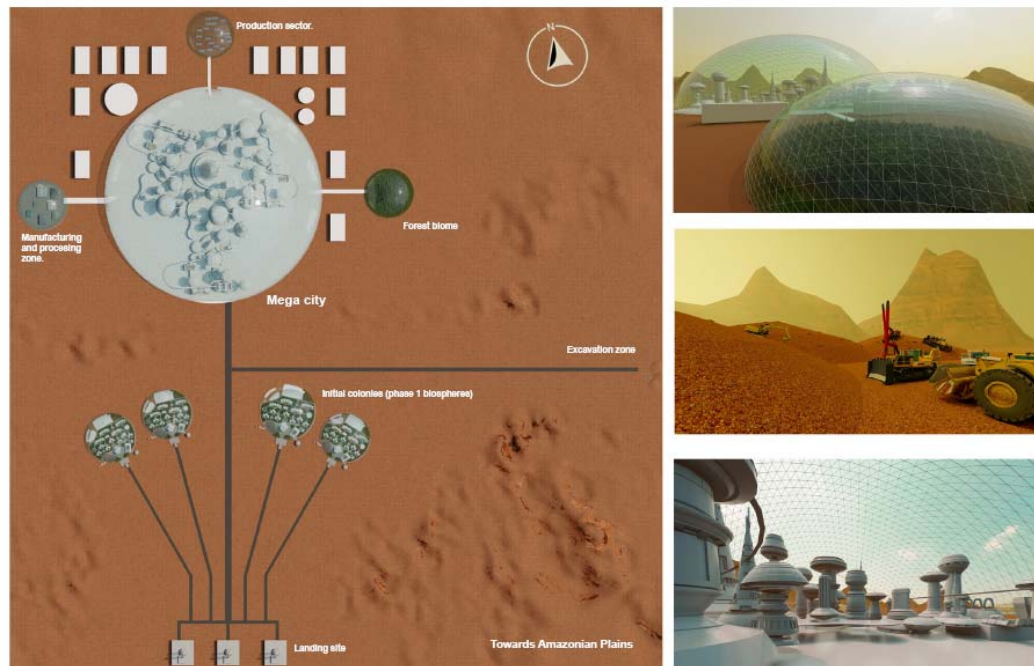
Materials

CHAPTER 7

Future Expansion

After the successful establishment of Biosphere 1 of the Odyssey project (the first colony) of 110 people, there will be further biospheres of similar size till the production and construction capabilities enable the production of a Mega city which will be several times larger than the current biosphere and will function similarly to a city, this will further be developed in other landing sites such as Archeon Fossae and other sites that have been deemed to be inhabitable and upon establishing a decent population on the red planet and establishing back and forth trade between Mars and Earth for the raw materials, a proper civilization will be built on Mars which may further be expanded in case of any scientific breakthroughs on Terraforming or upon finding new things during exploration that may enable us to do so.

Fig 7.1 Future Expansion



CHAPTER 8

References

- ❑ <https://www.hou.usra.edu/meetings/explorationzone2015/pdf/1011.pdf>
- ❑ https://www.nasa.gov/sites/default/files/atoms/files/viola_arcadiaplanitia_final_tagged.pdf
- ❑ Salotti, J. (2020, June 16). Minimum Number of Settlers for Survival on Another Planet. Scientific Reports. https://www.nature.com/articles/s41598-020-66740-0?error=cookies_not_supported&code=cd287d07-01bc-418e-8cc5-140f6c1f353a
- ❑ Pombo, D. V. (2021). A Hybrid Power System for a Permanent Colony on Mars. *Space: Science & Technology*, 2021, 1–16.
- ❑ <https://doi.org/10.34133/2021/9820546> - A research paper on designing a power system on Mars.
- ❑ Marino, B. D., Mahato, T. R., Druitt, J. W., Leigh, L., Lin, G., Russell, R. M., & Tubiello, F. N. (1999). The agricultural biome of Biosphere 2: Ecological Engineering, 13(1–4), 199–234. [https://doi.org/10.1016/s0925-8574\(98\)00100-1](https://doi.org/10.1016/s0925-8574(98)00100-1) - A journal on the structural systems of BIOSPHERE 2's artificial ecology.
- ❑ Levchenko, I., Xu, S., Mazouffre, S., Keidar, M., & Bazaka, K. (2018). Mars

Colonization: Beyond Getting There. Global

- **Challenges, 3(1), 1800062. <https://doi.org/10.1002/gch2.201800062> - Research paper on Challenges to be faced in a colonization of mars.**

- **Gibson, E. (2021, May 20). Scientists develop “greenhouse shields” to grow food on Mars. Dezeen.**

- **<https://www.dezeen.com/2019/07/16/harvard-university-scientists-develop-greenhouse-shields-growing-food-on-mars/> - Research article on greenhouse shields in mars.**

- **<https://wiki.nurserylive.com/t/how-many-trees-are-needed-to-produce-enough-oxygen-for-one-person/3430/>.**

- **Concrete on Mars: Options, challenges, and solutions for binder-based construction on the Red Planet. (2019, November 1). ScienceDirect. <https://www.sciencedirect.com/science/article/abs/pii/S0958946518312885>**

- **https://www.researchgate.net/publication/288169950_In_Situ_Production_of_High_Density_Polyethylene_and_Other_Useful_Materials_on_Mars**

- **Leucht, K. W. (2021, June 24). How NASA Will Use Robots to Create Rocket Fuel From Martian Soil. IEEE Spectrum. <https://spectrum.ieee.org/how-nasa-will-use->**

robots-to-create-rocket-fuel-from-martian-soil/particle-1

- ❓ https://www.researchgate.net/publication/234982912_In_Situ_Manufacturing_of_Plastics_and_Composites_to_Support_HR_Exploration**

- ❑ Choi, C. Q. (2019, September 18). How to Feed a Mars Colony of 1 Million People. Space.Com.**

- ❑ <https://www.space.com/how-feed-one-million-mars-colonists.html> - An article about producing food in mars.**

- ❓ Extensive glaciation in the Erebus Montes region of Mars. (2021, October 1). ScienceDirect.
<https://www.sciencedirect.com/science/article/abs/pii/S0019103521002293>**