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Design of a space habitat in Mars for 10000 people – A conceptual report

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Abstract—Space had a radical shift in heading by turning space as a haven for unanswered scientific questions and the black box holding answers for the future of sustaining humanity. Space has always been a lurking void withholding key answers and solutions for understanding the very existence of life. The intangible desire to explore and challenge the boundaries of what we know and where we have been having provided benefits to our society for centuries. Contrary to the stereotypical comment, the extensive efforts we make today in space exploration is a costly yet significant investment for finding solutions at the earliest to sustain humanity exploration, and that we should undertake it for the most basic of reasons -- our self-preservation finding potential spin-offs for application of those technologies for solving problems on earth. Ever since we discovered our dusty neighbour, Mars has been an object of fascination and awe. Mars, the speculation of several science fiction movies for ages, the hotspot for varied scientific researches and the basis for active volunteer researches, is not an extensive hostile planet as it seems. The starking resemblance between Earth and Mars in several aspects, the proximity to Earth and the extensive availability of in-situ resources, in comparison to other potential candidate planets in the solar system, makes it the suitable planet to terraform and eventually convert into a pitstop for future deep space explorations.

Index Terms— Mars, Martian habitat, Space exploration

1 INTRODUCTION

FROM the first stirrings of life to man soaring high above the skies, humanity and its magnanimous progress in technology have been exponential. From what just started as a winning point of the existential cold war during the late 20th century between US and Russia, to conquer the space had a radical shift in heading by turning space as a haven for unanswered scientific questions and the black box holding answers for future of sustaining humanity

The moment we speak about space exploration, the striking and pragmatic question of "Why we should explore space and fund heavily when we have our problems on earth to deal with?". The intangible desire to explore and challenge the boundaries of what we know and where we have been having provided benefits to our society for centuries. Contrary to the stereotypical comment, the extensive efforts we make today in space exploration is a costly yet significant investment for finding solutions at the earliest to sustain humanity exploration, and that we should undertake it for the most basic of reasons -- our self-preservation finding potential spin-offs for application of those technologies for solving problems on earth. This helps in expand technology, create new industries, and help to foster a peaceful connection with other nations. Curiosity and exploration are vital to the human spirit and accepting the challenge of going deeper into space will invite the citizens of the world today. According to a popular technology projection graph – "Gartner Hype Cycle", the advancement employing space exploration and technology is expected to shoot up to new heights in the coming decades.

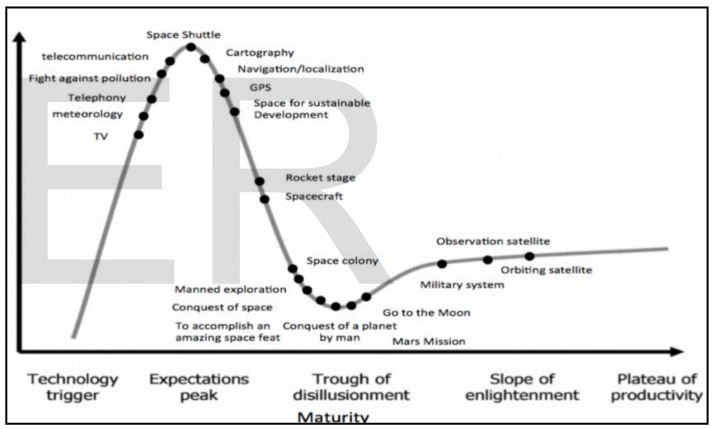

Fig 1. Gartner Hype Cycle - Space Technology projection

In addition to a mere justification of scientific advancement by space exploration, wider socio-economic benefits that might derive from their activities, including both the direct and indirect (or less obvious) benefits of space exploration are also inclusive. According to press reports by NASA on socio-economic benefits, it is calculated that 444,000 lives have been saved, 14,000 jobs have been created, 5 billion dollars in revenue has been generated, and there has been $6.2 billion in cost reductions due to spin-off programs from NASA research.

Our solar system, formed from a maelstrom of protoplanets from a centrifuging cloud of rock and dust is about 3.8 bn years old. Being a heliocentric solar system, our sun remains the primary source of energy for all activities. Due to the gravitational influence and the region of energy transversal, the solar system is split into the Rocky world (Mercury, Venus, Earth, Mars) and the outer worlds (Jupiter, Saturn, Uranus, Neptune, Kuiper belt). The wild collisions between protoplanets at the early ages of formation sculpted the current arrangement we see.

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In our solar system, the sun is the prime mover. Its energy remains the primary source of sustaining all-natural phenomena that occur. It is a fireball of about 1393684 Km and surface temperature of 5500 C. Sun is not going to last for eternity, however, its life is ephemeral. For ages, it has been in its main sequence and is already half a way through its lifetime, ageing about 4 bn years. A representation in comparative means is depicted in the HR diagram. It is expected that in another 5 bn years, the raging surface of the sun will vaporize the incumbent positions and possibly the planets of Mercury and Venus. Among all the planets, Earth is the only known planet, that sustains life as complex beings. This planet revolves around the sun in an almost circular orbit, with distance from sun varying from 0.98 AU to 1.1 AU. Currently, the Earth is in a habitat able zone. A habitat able zone is the region, where liquid water can exist and extremities of temperature don't occur. The amount of sunlight each planet receives and the amount it reflects determines its habitat ability. Just as a comparative means, calculating the habitat able zone,

Earth reflects about 37% of incident energy from the sun,

The temperature influence by the sun over the earth is estimated by Stefan Boltzmann Law,

$$L = \sigma A e T^4 \quad (1)$$

Where A is the area taken till the surface of the earth

By this estimation, we get the surface temperature received on earth about T = 285K(for simplicity, calculations are neglected)

Now, for liquid water to sustain, it should lie within the limits of its melting and boiling point (Tm = 273 K and Tb = 373 K). Hence, the habitat able zone is

Upper limit:

$$(T_m / T)^{(-2)} \times 1AU = (273/285)^{(-2)} * 1AU = 1.089AU \quad (2)$$

Lower Limit:

$$(T_b / T)^{(-2)} \times 1AU = (373/285)^{(-2)} * 1AU = 0.583AU \quad (3)$$

Any planet that lies within this region is expected to have water in liquid form. But besides, there are varied other influencing factors like the Greenhouse effect, Viscosity and atmospheric influence, gravity etc…These factors are very evident in our solar system. Despite the fact that Venus lies in the habitat able zone, due to its highly CO2 rich atmosphere, inducing greenhouse effect, the planet is sweltering with heat and thus doesn't support water in a viable form. Returning to the sun, over a period of time, the star's transition from the main sequence to Red Giant results in the star moving up in the HR diagram. Its radius becomes about $100R_0$ (100 times solar radii). However, due to the expansion and reduction in the influence of pressure energy and gravitational influence, the star's surface temperature drops to about 5000 K(approx.).

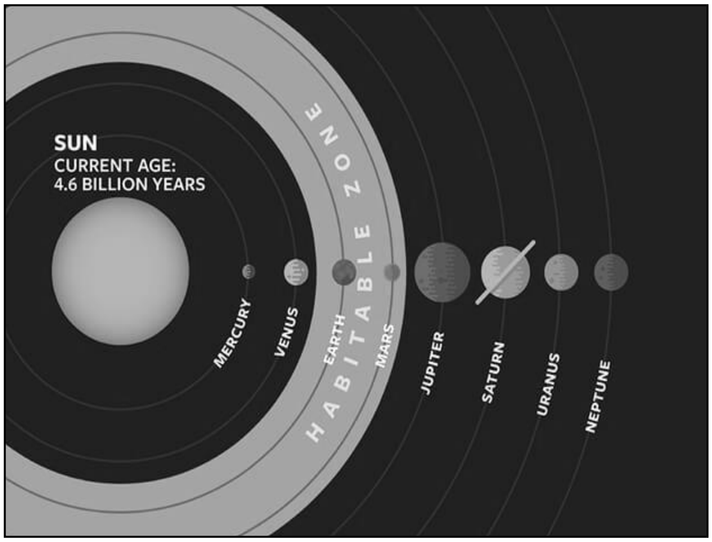

Fig 2. Habitatable zone in Solar System[1]

With a basic understanding of habitable zone within the solar system, we can infer that, Earth is the only planet with potential liquid water sources, within which there tends to be vapour state of existence and beyond which, there exists water in the frozen form alongside other liquified/frozen gases. This leaves us at the verge of a selection of the next nearest planet for sustaining

2 Mars – An Overview

Mars, the speculation of several science fiction movies for ages, the hotspot for varied scientific researches and the basis for active volunteer researches, is not an extensive hostile planet as it seems. Mars is now a bitterly cold planet with a bit of hostility and radiation hazards. It has no potential sources of "liquid" water and is a barren rock world with mineral deposits scattered around the platform. This planet had its molten core hardened few million years ago, due to which it doesn't have potential blockade from radiation hazards unlike that of our earth, where molten core rotation aids in magnetic field retention. In addition, it lacks the ability to hold a dense atmosphere due to its weak gravity. The hostile lands have frequent dust storms, at times, rising to about 3000ft and lasting for several weeks. But despite several shortcomings in even "entering" such planet, why do we still accelerate our end goal to reach Mars?

2.1 Mars – Why is it a suitable candidate?

After the Earth, Mars is the most habitable planet in our solar system due to several reasons:

- Its soil contains water to extract
- It isn't too cold or too hot
- There is enough sunlight to use solar panels
- Gravity on Mars is 38% that of our Earth's, which is believed by many to be sufficient for the human body to adapt to
- It has an atmosphere (albeit a thin one) that offers

protection from cosmic and the Sun's radiation

- The day/night rhythm is very similar to ours here on Earth: a Mars day is 24 hours, 39 minutes and 35 seconds

The only other two celestial bodies in orbits near the Earth are our Moon and Venus. There are far fewer vital resources on the Moon, and a Moon day takes a month. It also does not have an atmosphere to form a barrier against radiation. Venus is a veritable purgatory. The average temperature is over 400 degrees, the barometric pressure is that of 900 meters underwater on Earth, and the cherry on top comes in the form of occasional bouts of acid rain. It also has nights that last for 120 days. Beyond Mars, there due to the extensive gravitational influence, there exists a lot of implications in sustaining with technology and besides, no land to stay on! Humans cannot live on Mars without the help of technology, but compared to Venus it's paradise!

Mars has once been a flourishing land with immense water resource, carving out almost entire façade of the planet. It is a very well-known fact that one of the major stepping stone for “sustaining” life is the availability of water. Due to its safe distance from the radiative effects of sun, water, remains in a frozen state at the poles. The starking resemblance between Earth and Mars in several aspects, the proximity to Earth and the extensive availability of in-situ resources, in comparison to other potential candidate planets in the solar system, makes it the suitable planet to terraform and eventually convert into a pitstop for future deep space explorations.

2.2 Existing Hurdles

Maturation of technology to meet the audacious demands of reaching Mars amidst balancing the real-world necessities remains one of the most challenging hurdles to date. The road to the launch pad is nearly as daunting as the journey to Mars. Even before the trip to Mars can begin, a craft must be built that not only can make the arduous trip but can complete its science mission once it arrives. Nothing less than exceptional technology and planning is required. If getting to Mars is hard, landing there is even harder. "During the first four minutes into descent, we use friction with the atmosphere to slow us down considerably," says Dr Naderi, chief scientist from NASA. "However, at the end of this phase, we're still travelling at 1,600 kilometres per hour (1,000 miles per hour), but now we have only 100 seconds left and are at the altitude that a commercial airliner typically flies. Things need to happen in a hurry. A parachute opens to slow the spacecraft down to 'only' 321 kilometres per hour (200 miles per hour), but now we have only 6 seconds left and are only 91 meters (100 yards) off the ground. In addition, radiation and resource availability remains one among few other main hurdles to be addressed. The first hurdle is the radiation that we might be exposed to when we are in deep space. Long term, radiation exposure will increase astronauts' risk of developing cancer and can also lead to the damaged cardiovascular system, eyes, and central nervous system. To colonize Mars, we first need to get there safely and in good health. That's why it's so important that scientists find a way to protect astronauts before they travel anywhere far from Earth. The second hurdle to colonization is the technology that will help humans survive on Mars.

Most of the biggest hurdles to reach mars, to be honest, are not technical but rather, political and socio-economic related issues. There are unquestionably passionate differences of opinion regarding the future of space exploration, including whether we can send humans to both the moon and Mars (and when), how large a role commercial partners should play, and whether we can achieve our stated goals in space within likely budget scenarios, but these differences have tended not to be based on partisan politics. Speaking in the context of the US, despite varying opinions from the political establishments in the states, the funding for NASA has never been compromised reasoning public development. However, it is a well-known truth that countries always have priorities, and not all countries have their priority as space exploration. With the rapid advancement in science and existential collaborative research efforts, it is to be understood that technology has never been much of an issue.

Despite the above-specified issues, few ethical and health-related concerns are also brought up by several astrobiologists and space enthusiasts. Imagine there was once life on Mars, but in our haste to set up shop there, we obliterate any trace of its existence. Or imagine that harmful organisms exist on Mars and spacecraft inadvertently bring them back to Earth. These are scenarios that keep astrobiologists and planetary protection specialists awake at night. They’ve led to unbelievably stringent international policies around what can and cannot be done on government-sponsored space missions. Ecoterrorism, Climate change and Space Politics are few other important parameters to be scrutinized before we set our foot on Mars and set up a building block for “second Earth”

2.3 Site Selection

Deciding where to land the rovers was critical to the success of the mission. The sites chosen had to ensure the rovers' safety while placing the rovers in geologically promising locations. Trent Hare of the United States Geological Survey's Astrogeology Team has provided a tutorial that lets readers map both rover landing sites in ArcMap using digital elevation models (DEMs) created with the recently released Mars Orbiter Laser Altimeter (MOLA) data and other data sources. Selecting the perfect landing site will be essential for the successful establishment of the first Mars colony. Growing food crops will be one of the key tasks for the astronauts. Scientists of Wageningen University & Research have identified places on Mars that are favourable for plant species to grow. Even though plants will be grown indoors, resources as regolith and ice will be used. To estimate the optimal landing places on Mars the researchers used several of the Martian maps showing essential information that are made freely available by JPL, the Arizona State University and NASA. "Without them, this endeavour would not have been possible," explains Wieger Wamelink. The maps contain information about mineral content, which can for example be related to calcium and heavy metal content. But also, element maps for potassium, chloride, iron and silicon and maps for radiation level, climate, terrain including altitude and cosmic radiation were used.

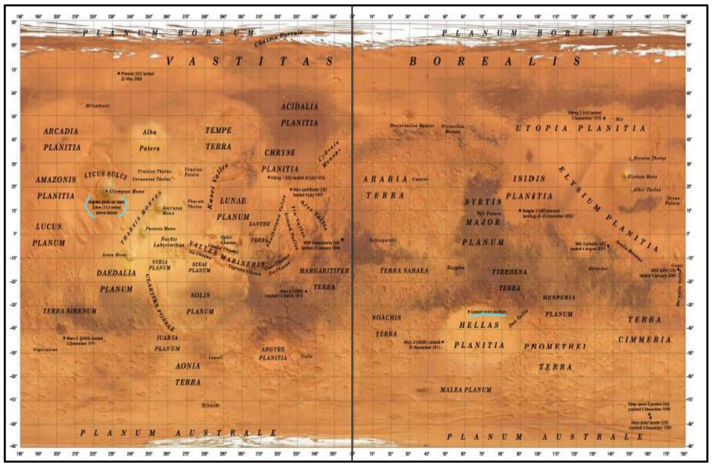

Fig 3. Mars Map[2]

High levels of heavy metals in the soil and strong radiation make a location unsuitable for the establishment[3]. High contents of heavy metals and high doses of radiation make a location unsuitable for colonisation, "explains Line Schug. "While we see high temperatures or calcium levels and a relatively flat terrain as positive". The maps were merged and the average score was calculated, with high scores marking the best landing sites from a plant's perspective. In the past the Mars Pathfinder and Viking 1 landed at hotspots to establish a colony, however, MSL Curiosity and Viking 2 landed on less favourable spots.

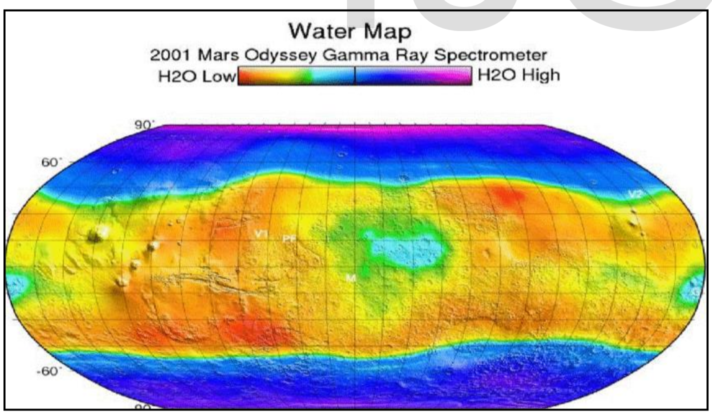

Fig 4. Water resource distribution in Mars[4]

A video by ESA, compiling all the potential mineral deposit on planet mars by the name Mars Mineral Globe provides a complete review of Water, ferrous oxide and various other deposits. (ESA)

2.4 Material Selection

Space endeavour relies heavily on materials with outstanding properties – they must survive in an environment that combines ionizing radiation, extreme temperatures, and micrometeorites. Certain missions add extra threats: low earth and geostationary orbits inflict ferocious ozone-induced degradation, while deep-space missions involve high levels of ionizing radiation and, eventually, extremely low temperatures.

The main requirements for space materials are lightweight (to reduce mission costs); resistance to ionizing radiation (accelerated electrons, protons, and ions); multifunctional capabilities; smart features; self-healing capabilities; and outstanding thermal stability[5]. It is also very vital that the materials are available insitu with the aim of immensely reducing the demand and the egregious import cost from Earth to Mars. reducing manufacturing energy in the later stages is vital for reducing power consumption, and restrictions on material manufacturing on Mars severely limit potential building materials and techniques. Space materials research is concentrated on composites obtained by dispersing nanofillers with designed functionalities within different polymeric matrices. The polymeric matrix gives low weight. An appropriate choice may also add structural and thermal stability. Polymers also act as a radiation shield because of their high hydrogen content, reduced radioactive activation, and lightweight.

Table 1 Space Materials and their properties

Material		Material Properties			Property Ratios	
	Sy (GPa)	E (GPa)	p (g/cm³)	S,((Ep)*1000	S,JE 1000	S,pp 1000
Vitreloy 1 (metallic glass)	1.8	95	-5.8	3.27	18.95	310.3
Al alloy 7050	-0.44	70.3	2.82	2.22	6.26	156
Al alloy 7075	~0.45	71	2.8	2.26	6.34	160.7
Ti-6AI-4V	0.825	110	4.43	1.70	7.52	186.7
Elgiloy (85% HT)	2.12	189.6	8.30	1.35	11.2	255
Inconel 718 (Nickel alloy)	1.034	202.7	4.43	1.15	5.10	233
MP35N (65%)	1.62	234.8	8.43	0.82	6.90	192
Stainless 17-7TH 1050	1.034	200	7.64	0.68	5.17	135
Stainless 15-5PH H1025	0.986	196.5	7.83	0.64	5.02	126
Invar 36 (cold rolled)	0.679	148	8.05	0.57	4.59	84.3
Tantalum (UNS R05400)	0.22	185	16.6	0.07	1.19	13.2
Copper alloy (C10200-060)	0.0758	117.2	8.94	0.072	0.65	8.5
Teflon PTFE film	0.018	0.5	2.2	16.4	36	8.2
Mylar A film	0.103	3.8	1.4	19.4	27	73.5
Kapton HN film	0.07	2.8	1.42	17.6	25	49
Teflon FEP film	0.012	0.48	2.15	11.6	25	5.6
Tefzel film	0.006	1.2	1.7	3	5	3.5
Butyl rubber	0.014	3.4	0.92	4.5	4.1	15

Nanotubes can enhance the mechanical strength of polymers and add high electrical and thermal conductivity. Minute amounts give polymers antistatic features, while concentrations are as low as 1 wt.% trigger electrical conductivity. The intimate relationship between the electrical and mechanical properties of these composites adds smart capabilities. The search for space materials includes other nanomaterials for extreme temperatures, conversion of light into electricity, and optical and magnetic applications. Nanomaterials are extreme-

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ly appealing, as they promise reduced volume, weight, and energy consumption. However, their survival in the space environment has yet to be assessed. The details of the interaction between ionizing radiation and nanometer-sized features are not yet fully understood and a new theoretical description – nanodosimetry – is under development.

Self-healing capabilities will protect polymers and composites from the effect of ionizing radiation, temperature, and micrometeorites. Further advances are required to extend the temperature range over which the polymeric matrix is protected and to decrease the size of the microbubbles containing the healing agent[6].

Constructing buildings in-situ makes use of an abundant material at our landing site - basalt in the form of drawn fibre, a material with incredible tensile strength, which can be made into an airtight composite with a thin layer of imported plastic. Basalt fibre reinforced plastic composite5 (BFRP) is an incredibly well-suited material for our purposes - strong enough to make pressure vessels tens or even hundreds of metres in diameter, very low import weight, and production energy a fraction that of traditional materials like sintered bricks and steel. Weaving basalt fibres into a net-like structure to reinforce clear polymers (at a fraction of the cost of glassmaking) allows for vast greenhouses. The technology of production of basalt continuous fibre (BCF) is a one-stage process: melting, homogenization of basalt and extraction of fibres. Basalt is heated only once. Further processing of BCF into materials is carried out using "cold technologies" with low energy costs.
Basalt fibre is made from a single material, crushed basalt, from a carefully chosen quarry source. Basalt of high acidity (over 46% silica content) and low iron content is considered desirable for fibre production. Unlike with other composites, such as glass fibre, essentially no materials are added during its production. The basalt is simply washed and then melted.

Table 2 ETFE Mechanical Properties[7]

Property	Value[10]
Tensile strength	2.8–3.1 GPa
Elastic modulus	85–87 GPa
Elongation at break	3.15%
Density	2.67 g/cm³

Another proposed material is ETFE – Ethylene Tetraflourethene. Ethylene tetrafluoroethylene (ETFE) is a fluorine-based plastic. It was designed to have high corrosion resistance and strength over a wide temperature range. ETFE is a polymer and its source-based name is poly(ethene-co-tetrafluoroethylene). It is also known under its brand name: Tefzel. ETFE has a relatively high melting temperature, excellent chemical, electrical and high-energy radiation resistance properties. ETFE film is self-cleaning (due to its nonstick surface) and recyclable. It is prone to punctures by sharp edges and therefore mostly used for roofs.[2] As a film for roofing it could be stretched (up to 3x) and still be taut if some variation in size occurs (due to thermal expansion, for example.) Employing heat welding, tears can be repaired with a patch or multiple sheets assembled into larger panels. ETFE has an approximate tensile strength of 42 MPa (6100 psi), with a working temperature range of 89 K to 423 K (−185 °C to +150 °C or −300 °F to +300 °F). ETFE resins are resistant to ultraviolet light. An accelerated weathering test (comparable to 30 years' exposure) produced almost no signs of film deterioration. ETFE exhibits a high-energy radiation resistance and can withstand moderately high temperatures for a long period. Commercially deployed brand names of ETFE include Tefzel by DuPont, Fluon by Asahi Glass Company, Neoflon ETFE by Daikin, and Texlon by Vector Foiltec.

3 Marsopolis – The 21st Century Advanced Martian Settlement

Marsopolis is the 21st Century, modernized and highly advanced Martian Settlement for the first-generation Martians. Its impeccable design with safety and security as its highest priority is built to sustain difficulties and hazards that includes radiation exposure on its surface, toxic soil, low gravity, the isolation that accompanies Mars' distance from Earth, a lack of water, and cold temperatures.

Organization and proper urban planning coupled with a well-connected transportation system ensure seamless functioning of sol-to-sol life in Mars[8][9]. Extensive research and urban planning were done to satisfy the above-specified requirements. The entire city-state is divided into 6 major districts and 2 minor districts each with its unique protocols and functionalities. Architecture is used here and finds its importance. Humans need an environment reminiscent of their home planet to give them a sense of belonging to survive and live.

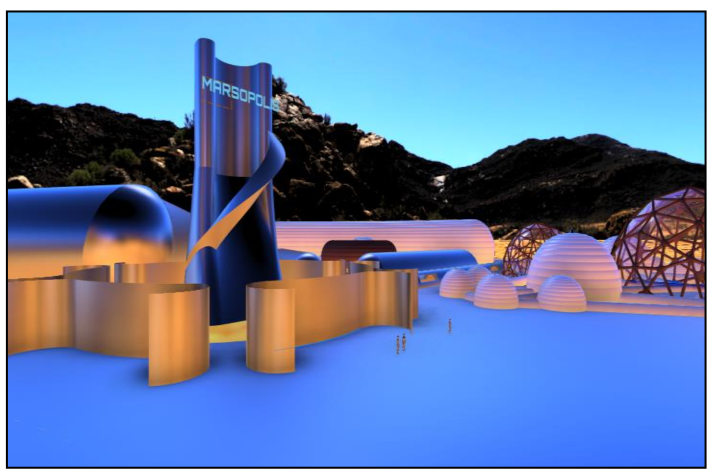

Fig 5. Marsopolis - City View

The city-state establishment is made in hexagonal fractal shape. Because expansion is one of the most critical design parameters of the Martian habitat, the concept was inspired by fractals geometry. In the first stage, the inhabitants are divided so that fractal units or modules based on them can be defined sequentially[10].

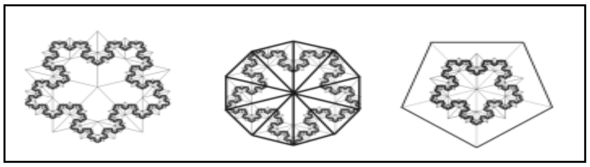

Fig 6. Fractal Designs

Districts:

- Gaia Bio Residential District
- Kratos Educational District
- Plutus Agricultural District
- Themis Pentagon Administrative District
- Sigourney Commercial Neon District
- Oneroi Marsopolis Central Station
- Herodotus Mars United Research Establishment for Higher Sciences
- Hephaestus Industry District

4 MARSOPOLIS – URBAN PLAN

For the sake of ease of the design, a scaled-down city-state model of the ratio 1: 49,55,75,221.2389 is designed and rendered. The fractal design ensures future expansion possibility of the city-states.

Sustainability, expansion and feasibility are the key criteria in Marsopolis design. Proper urban planning and organizational structure ensure better management and resource distribution across the City-state[11]. As specified earlier, the entire city-state is divided into 6 major fragments, each having its functionality and vibe

4.1 Gaia Bio Residential District

Gaia Residential district is the prime region of habitat for all the Marsopolis dwellers. Its impeccable design and array of well-connected hubs ensure the life on mars just not as a means of survival but as a means of thriving. This residential district comprises of 22 mini-Hubs and 4 luxury Hubs. Several assumptions were made in the initial design of the mars mini-hub. With its 3 storey dome structure and relatively large base area, each hub can house a maximum of 45 families, comfortably living in the Martian Space of about 1200 sqft (for the sake of comparison this area is equivalent to a 2 BHK living space).

A living space should not be a mere shelter but should provide the ambience and enjoyment to keep the civilian's mood balanced and pumping. Concerning this, each hub houses an entertainment complex with supported AR/VR technologies to keep the residents entertained. Besides entertainment, necessities within the hub are one of the critical aspects of residing in Mars. Well planned trade and transportation structure within the habitat and across the city-state ensures shortage free availability of food and water resources. The methods of food production and water extraction are briefly reviewed in the coming sections. The luxury hubs are elevated luxurious and spacious residential spaces in Gaia Residential habitat. Its larger base area can accommodate a relatively larger population of about 2200 families per base. This facility houses several basic, entertainment and recreational facilities. Even though most of the habitat houses basic facilities like groceries availability, Neighborhood store for stationeries and other basic necessities, Marsopolis wide manufactured and other imported products are predominantly sold in the Sigourney Commercial District, located right next to the Gaia residential district.

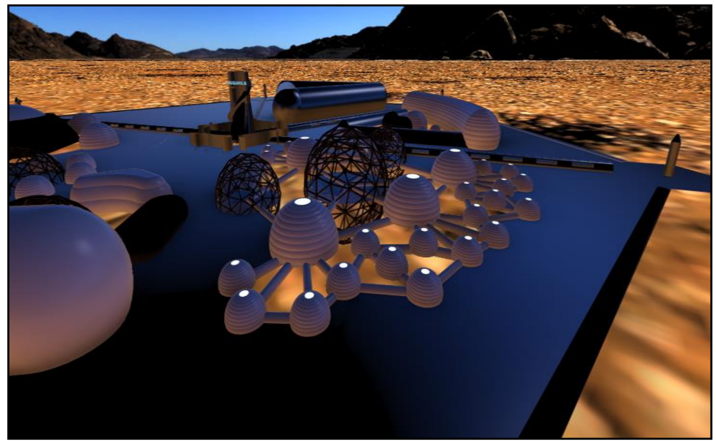

Fig 7. Gaia Bio Residential District - Night view

The central ETFE Hemisphere is truly a magnificent establishment in the Gaia district. This hub is a natural paradise with artificial waterfalls and several storeys of natural habitat. This area is the ultimatum for social gatherings and recreation. Its controlled temperature chamber atmosphere and nature mimicking setup is a semblance of the small segment of terraformed Mars, to put it in optimistic terms. Moderate-temperature heat rejection becomes a problem during the Martian day when the effective sink temperature exceeds that of the heat-rejection system. The Martian atmosphere poses unique problems for rejecting moderate-temperature waste heat because of the presence of carbon dioxide and dust. The key design drivers of an active thermal control system (ATCS) are the total heat rejection required and the thermal environment. The primary factors affecting the thermal environment of Mars are fairly large changes in surface temperatures, a 24.7-hour light-dark cycle, a moderate solar flux, a thin CO, atmosphere, and dust storms. Winds and 0.38 Earth gravity are factors which also affect ATCS design. Analysis indicated that on Mars, the effective heat sink temperature is low enough, even at noon, that an exposed vertical or horizontal radiator can reject moderate-temperature habitat waste heat. A vertical radiator orientation is much preferred on Mars since it takes advantage of two-sided radiation. Despite the sole purpose of Earth mimicking setup, these 3 EFRP hubs also house a small count of housing, commercial spaces and other vital communication and automation spaces for facilitating the stay of astronauts/civilians

4.2 Transportation

Transportation in Marsopolis primarily relies on the vacuum-based interconnected railway system spanning across the city-state. The interconnected network of railways bridges the vast gaps between several sectors. Apart from the primary means of railway-based travel, by means of land-based SEV transportation, the civilians could travel in restricted spaces within the same district[12]. As per the initial considerations, individual nature powered SEVs are utilized on commute basis, scattered around each district. Considering a Utopian future, a review of the existing technologies in the primary Hyperloop vacuum-based train is presented and the prospective projections of this groundbreaking technology are considered.

Hyperloop is a completely new mode of fastest transportation that seeks to change this pattern by being both fast and inexpensive for people and goods. The idea of Hyperloop is to travel at high speed in the low-pressure tube along with levitation. Due to the presence of low pressure, the aerodynamic drag is very low thereby reducing the energy consumption. Hyperloop is firstly proposed by Elon Musk and a team of an engineer from Tesla Motors and the Space Exploration Technologies Corporation in August 2013. Basically, hyperloop is magnetically levitated train which runs inside a long tube or pipe. It consists of a low-pressure tube with a capsule that is transported at both low and high speeds. It is driven by a linear induction motor and compressor. The tubes would house a low-pressure environment, surrounding the pod with a cushion of air that permits the pod to move safely. Musk's design recommends an air compressor on the front of the pod that will move air from the front to the tail, keeping it aloft and preventing pressure building up due to air displacement. In MAY 2016 Ahmed Hodaib, Samar F. Abdel Fattah discussed the design of a hyperloop capsule with linear induction propulsion system which is used to accelerate and decelerate the capsule. In 2016 Mark Sakowski Discussed the current maglev technology along with the theoretical evacuated tube technology and they concluded that the hyperloop is feasible and if properly designed, has the potential to be much more efficient in terms of energy usage of pods traversing down the tube. since Mars has only 1% the air pressure of Earth, air resistance would not be a factor. Whereas his high-speed train concept requires tubes with very low air pressure to reach the speed of sound here on Earth, on Mars they could reach those speeds out in the open. Normal high-speed trains already exist that can travel at about 300-400 mph. The Hyperloop train concept would travel faster than this because it runs within a low-pressure vacuum tube that's had 99.9% of the air inside removed; with most of the air gone, most of the drag is gone too. The Hyperloop is predicted to have top speeds of about 760 mph.

Other alternative means of transportation includes SEVs and LER concepts. Despite the sole purpose of exploration, NASA has actively been working on Space Exploration Vehicles (SEVs), which is a suitable candidate for rough terrain movement. LPI Texas proposed a novel parabolic shaped transit vehicle called Mars Surface Transportation System. The proposed design will support multi-range and multi-purpose scientific/exploratory activities for extended periods. However, it is to be noted that several assumptions were made before developing this design. The Space Exploration Vehicle (SEV) is a modular vehicle concept developed by NASA. It would consist of a pressurized cabin that can be mated either with a wheeled chassis to form a rover for planetary surface exploration (on the Moon and elsewhere) or to a flying platform for open space missions such as servicing satellites and missions to near-Earth asteroids.[1] The concept evolved from the Lunar Electric Rover (LER) concept, which in turn was a development of the Small Pressurized Rover (SPR) concept

4.3 Agriculture and Nutrition in Marsopolis

When the astronauts land on Mars, there will be storable food from Earth waiting for them to use. The storable food from Earth will only serve as emergency rations, which means the astronauts will try to eat as much fresh food that they produce on Mars as possible. Likely, algae and insects will also be part of the diet on Mars. Trade-off study has been conducted to decide the basic principle of life support between the closure of materials recycle loop and one-time usage of consumables. If an open loop is chosen for the life support system, a cumulative number of consumables is summed up with the rate of consumption, duration of the mission, and the number of people. On the other hand, the closure system requires shipping mass and volume for hardware and apparatus for recycling. This mass and volume are constant regardless of the duration of its operation, as long as the hardware lifetime is longer than the mission duration. The trade-off study with taking the system mass and volume into account, thus, becomes the comparison between the sum of the consumables in the case of open-loop and the hardware mass in the case of the closure system. As the mission duration and number of the crew become longer and larger, the balancing point for water is reached and then, gas (oxygen and carbon dioxide), and food, in this order. If a slice of this environment and terrestrial ecology is cut out and reconfigured in extraterrestrial space to live in, then we might be able to exploit supreme functions of natural ecology. Those elements and functions have been selected and sustained through the long history of the terrestrial biosphere. It is already known to us in part, not all, what type of mechanism or event let the living organisms extinguished or survived through their evolutionary history. At configuring natural elements and ecology, we may count an advantage of their durability taking in the space system. Homeostasis, implemented in organisms and the other levels of the hierarchy of the living system, keeps their internal state and function adjusted within optimum range against outside environmental changes. Space agriculture is meant to utilize such homeostatic ability through its system components, thus can make the system stable and reliable.

Pressurized greenhouse dome will be built for cultivating plants. The human living compartment is included inside the dome but separated and isolated from the planting part. The total inside pressure of the greenhouse dome can be maintained at 20 kPa. The partial pressure of oxygen, water vapour and carbon dioxide are regulated to 10 kPa, about 2 kPa and less than 500Pa, respectively. Nitrogen is separated from the

Martian atmosphere and balanced to adjust the total pressure of 20 kPa by filling the rest. The total pressure in the human living compartment is maintained higher than 50 kPa, with oxygen at 20 kPa. Space agriculture on Mars takes advantage of the similarity of a day length on Mars to that on Earth. Solar light is a major and almost only natural energy source for space agriculture on Mars. However, the additional artificial light system is also required to regulate long day/short-day for plant flowering and substituting sunlight during Martian sandstorm period. Space agriculture should utilize hyper thermophilic aerobic composting bacterial ecology to process human and animal waste and inedible biomass. Fertilizer and humus can be acquired through the process to result in the creation of soil. While ordinary composting has a typical reaction temperature around 50-60 ºC, optimum reacting temperature for hyper thermophilic aerobic composting bacteria is as high as 80-100 ºC. After the metabolic substrate is given, the reaction temperature is auto-regulated to the optimum range after being heated by heat release due to metabolic reaction, in case volume of reaction bed is relatively large compared to its surface area. Since most of the bacteria are proliferated under aerobic condition, pathogenic bacteria are rarely a member of this microbial ecology.

For long-term residence on another planet or in a space vehicle, it is essential to operate an agricultural system to generate food as well as decompose and recycle waste products. Historically, humans have consumed a variety of animals, and this will also be necessary and desirable when they live in space. Thus, interesting, varied, and high-quality food may very well be a crucial factor in creating a livable environment. Among the many candidate groups of animals that might be chosen as components of a space-based agro-ecosystem, insects have several advantages. The idea of eating insects came up from the consideration of nutrition for human. The ideal recipe for the human crew in space cannot be realized with the only vegetable source if a sufficient amount of both nutrient and energy is supposed to be supplied. Even vegetarians on Earth take some kind of animal source food such as milk as a supplement. The problem to be solved here is the selection of the right and ideal animal as a food source in space to supplement vegetable recipe. The ideal animals should provide proper nutrients, be easily raised, requires a relatively smaller area to be raised, and have an acceptable taste.

Food production will occur indoors under artificial lighting. In total, there will be approximately 80 m2 available for plant growth in the original habitat. The first crew will also be able to use the habitat of the second crew to grow food because the hardware for the second crew lands only a few weeks after the first crew lands. A thick layer of Martian soil on top of the inflatable habitat will protect the plants (and the astronauts) from radiation. CO2 for the plants is available from the Mars atmosphere and water is available through recycling and the soil on Mars. Nutrients for the plants could come from recycling human waste or could be imported from Earth. Marsopolis Agriculture district contains an array of inflatable and BFRP constructed hemispheres where crops and other vital plants are grown under a combination of artificial lighting and natural lighting. Each inflatable hemisphere is of the base area about 6227.4 m^2 and there are totally 14 inflatable hemispheres of that kind. The central light allowing BFRP hemisphere is of an estimated area of about 38922 m^2, large enough to meet the food production requirements of the entire city-state without any shortage. Thanks to the mechanical shield sectors incorporated within these BFRP hemispheres, the sectors could be temporarily be converted into artificial lighting chambers as well, pertaining to the needs of the ever-growing population.

4.4 Power production in Marsopolis

Power generation in the completed Marsopolis colony is not significantly different from that in the early stages of colonization. The notable difference is the diversification of the power generation and storage infrastructure to safeguard against failure. We have also varied the number of technologies considered as a precautionary measure against anyone energy production method becoming significantly more or less viable in the 80 years from today to the completion of the project. In practice, Marsopolis will use some blend of these generation techniques with exact numbers determined by the colonists. The total power demand of the base is estimated to peak at 10 GW, with the vast majority of that needed for the production of construction materials.

Nuclear power is our primary plan for power generation in the later years of the colony, as it removes the need for storage. The most suitable architecture for our purposes is CANDU, as it operates with low-purity uranium, has many passive safety features and does not require large pressure vessels to be manufactured. Providing 10 GW using purely CANDU reactors would require approximately 1400 tonnes of unenriched uranium per year, which can be imported or mined in-situ. The primary concern of a nuclear power system on this scale is cooling - radiator arrays would have to span around 20 km2, including buildings radiating heat.

Ground-based solar energy remains highly effective, scalable, and resilient against failure. Manufacturing lightweight, high-efficiency photovoltaic cells on Mars is not practical due to the complex production process, so heavier and less efficient arrays will have to be deployed in greater numbers. One-axis tracking is also very promising for increasing output. To fully power the city in this way, roughly 300 km2 of solar farms would be required.

“Noticeably, as moon nights last about 14 days, growing plants might require full artificial lighting, which in turn would have a tremendous impact on energy requirements, suggesting that more human resources would be needed for that domain.”

4.5 Water production in Marsopolis

Our astronauts will be settling on Mars indefinitely. It's not feasible to send water, oxygen and food from Earth to the astronauts: they will produce those on Mars. On Mars, water can be extracted from the soil. The rover will select the location for the settlement primarily based on the water content in the soil.

In the past decade, orbital measurements revealed that a third of the Martian surface contains shallow ground ice. MRO's SHARAD sounder has revealed the presence of ice-rich materials in several non-polar terrains, including debris-covered glaciers and ground ices extending down to latitudes of 37°. These deposits are up to several 100 m thick and many appear to consist of nearly pure water ice. The ability of the radar to resolve shallow layering is limited to ~20 m. Thus, to reach ice and extract water, a system would need to penetrate through at most 20 m of regolith. Few notable methods of water extraction are:

- Coiled Tubing (CT) & Rodwell method
- Planetary Articulating Water Extraction System (PAWES)
- Solid Extraction
- Volatile Extraction method

The discoveries of nearly pure ice deposits in mid-latitudes on Mars enable implementing two proven terrestrial technologies: Coiled Tubing (CT) for drilling and Rodriquez Well (Rodwell) for water extraction. CT rigs use a continuous length of tubing (metal or composite) that is flexible enough to be wound on a reel and rigid enough to withstand drilling forces and torques. The tube is pushed downhole using so-called injectors (for example, a set of actuated rollers that pinch the tube and advance it downward). The end of the tube has a Bottom Hole Assembly (BHA) – a motor and a drill bit for drilling into the subsurface. To remove drill cuttings, compressed air (or other drilling fluid) is pumped down the tube. A hole is drilled by advancing coiled tubing deeper into the subsurface while blowing cuttings out of the way. Several subsurface frozen water extraction methods were researched and implemented.

PAWES is a remote-controlled robotic system. It is comprised of three subsystems: an auger, a 360◦ articulating heated water extractor, and an electro flocculation filtration system. The process begins with the drilling phase. It targets the desired extraction site and drills a borehole to the ice layer. A heater in the auger tip is engaged for the duration of drilling. The extractor is lowered into the hole until the heated articulating nozzle contacts the ice. The articulation of the nozzle allows it to maintain contact with the ice during the melting phase. The filtration phase separates particles in the water through electro flocculation (EF) assisted gravity separation. Filtration is engaged when the chamber is filled and can process water in parallel with other phases.

Solid extraction is advantageous in terms of atmospheric conditions. Solid ice can temporarily exist on the Martian surface while liquid water would require pressurization. Furthermore, solid extraction ice cleaning could use mechanical methods such as shaking or sweeping debris from the surface of the ice. This would result in cleaner water, mitigating the complications caused by handling high turbidity fluid. Solid extraction allows for more efficient melting of the removed ice, as it can be brought into a controlled environment post-extraction. Additionally, solid core extraction has been validated in Martian analogue on Earth

A volatile extraction well and method to utilize heat, which could be from the Sun or Some other energy source, to directly vaporize subsurface water-ice, or other frozen volatile substance, in-situ. The pressure of the vaporized water (or other volatile gas) released in the heated soil causes the vapour to flow into a sealed drill-hole, or well, and on through an extraction tube to a surface collection vessel where it is condensed and stored

Considering the feasibility and large-scale implementation of our project, utilization of CT and Rodwell method seems more appealing in contrast to other above-proposed methods. Hellas Planitia is expected to have huge deposits of pure frozen subsurface water. The geographic location of Marsopolis and the insitu availability of water resources makes CT and Rodwell a better candidate for water extraction within the habitat city-state.

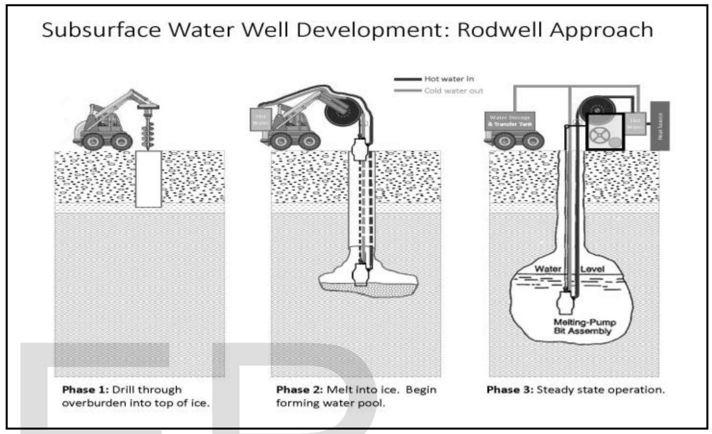

Fig 8. Rodwell Water Extraction Method[13]

5 Demographics - Marsopolis

A new study says the minimum number of colonists to make a tenable settlement on another planet is 110. That number is based on an extensive calculation about resources, distribution of skillsets the colonists will need in order to survive and thrive, and more. Salotti, a computer scientist, makes this specific mathematical analysis using two major parameters: available local resources and production capacity of the colonists. Resources and technology carried in on spacecraft are too variable and unpredictable to make a good model, for now, he says. He divides the workload the colonists will have into five domains: ecosystem management, energy production, industry (metallurgy and chemistry), construction and maintenance, and finally, human care and socializing.

Our population distribution over the Martian Habitat is expected to be 10000. According to the initial societal and economic plan for sustaining the city-state, the prime industries in the city-state remains agriculture, Production, Management, Education and Research Sector. Amongst the specified sectors, primary scrutinization is to be laid on Management, Research and Production sector, with assistive support for Agriculture. The more people are on the planet, the more they can cross-train on each other's tasks and make shorter work of the most urgent tasks. As a result, the curve for the required work-time falls as the population increases. The very minimum to complete all the tasks for a group of any size is a static value calculated with the same Mars Society numbers. Once enough people are involved in a settlement, they just barely squeak below that line, and that intersection point is where the settlement could begin to survive and thrive with the resources they have. first astronauts will be aware that after the almost one-year journey they will have to live on Mars for at least several years or probably their entire lives due to the fact that their return will most likely be technologically impossible. Perhaps these first colonizers will know that their mission is a "one-way ticket"

To assess their suitability, there are three tests administered to all potential residents:

- Adaptation test: settlers are put in a special section of the adaptation centre, where they remain without access to the outside world for three or four weeks in a windowless building. Before and during the evaluation, physical and psychological tests take place to assess the impact on the settlers and examine their capacity to survive in a cramped area for an extended period.
- Medical and criminal examination: every settler is checked by a physician who assures that they are stable and that no harmful pathogens (such as tuberculosis) are present. The settler then undergoes a forensic review, where their identity is reviewed for the police records of the world government to see if they have any criminal background.
- An interview: Each family of settlers meet a psychologist who assesses their social behaviour and may detect any alarming behavioural patterns that could influence other settlers (e.g. hostile and abusive behaviour, alcoholism, etc.).

Consequently, 50 per cent male and 50 per cent female are the aims for sex distribution, with a tolerance of 15 per cent (up to 65 per cent male and 35 per cent female, or vice versa).

6 Economy in Marsopolis

Building a strong economy for Marsopolis carries many broad-stroke similarities to projects in contemporary international politics and macroeconomics. It is important to distribute the economic benefits of growth among both societal and corporational interests while minimizing the chance and effects of economic depression. The overarching goal of the fiscal plan of Marsopolis is to achieve self-sufficiency from terrestrial economics, which is to minimize investment tying Martian policy to the interests of groups on Earth, and a neutral or even positive trade balance.

There are no precedents for building an economic system for Mars that can be simply adapted for Marsopolis. Rigid shipping times, a hostile environment requiring high welfare, long payback time on investments and deep political involvement in the economy means that a historic economic model cannot be simply adapted[14].

The early stages of Marsopolis will be in deficit - a colony of tens of thousands can produce almost nothing to offset the large cost of shipping production equipment to Mars[15]. Small income streams may exist, such as high-value tourism or scientific research, but the colony will run at an enormous loss for decades.

To fill this gap, investment from private and public groups on Earth will be needed. This will primarily include national governments, large firms and private individuals. In this early stage, all investment will be quantified and unified into a national bond system. This minimizes the undesirable political entanglement from non-monetary investment, a strategy commonly employed in neo-colonialist enterprises. The incentive for national governments providing this investment is the fact that almost all of the initial funds will be spent on manufacturing and engineering on Earth, essentially turning investment in Marsopolis into a national jobs programme. Trade with other locations on Mars does not carry the prohibitively expensive launch costs of Mars-Earth trade, and the same launch costs mean that materials can be sold with a significant markup. Secondary physical exports will include products that Marsopolis can produce in greater quantities and at lower prices than other colonies: pharmaceuticals and biochemical products. The internal economics of Marsopolis will also shift as it grows from an industrial and research outpost to a full-fledged city. To facilitate innovation and attract immigration and investment to the colony, I intend to encourage partnerships with both Earth-based and Martian companies to create a free market for goods and services for the citizens of Nexus Aurora. However, this market will require new regulatory structures to adapt to the peculiarities of the Martian economy.

Marsopolis features a standalone district, which acts as the premiere juncture for economic activities in the city-state. The Sigourney Commercial district is a vast expanse of inflatable establishment which provides the platform for all the civilians who wish to make a business or be a part of a business in the city-state. All the products, goods, businesses and other commercial aspects are entwined within this district. By means of well-connected transportation networks between the Hephaestus Industrial District, Agricultural District and the proximity to the launch centre and Gaia Residential District makes this the ideal place for commercial hosting.

7 Conclusion

Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions. Authors are strongly encouraged not to call out multiple figures or tables in the conclusion—these should be referenced in the body of the paper. This paper pitches in a plausible ideology for a prospective settlement for 10000 people in space habitat, with comprehensive review and addressal of several influencing factors that revolve around establishing a space habitat in Mars. The underlying design strategy involves several assumptions and factors to arrive at final design. The author owns the complete credibility for the exhaustive design study, modelling and analysis of the space habitat and it is to be highlighted that the supporting study for a sustainable design, are review of previous notable literatures.

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