Mars Colony 1.0

Welcome to Mars! Enjoy the red sky and be careful not to float! This project examines what would a post-earth human civilization would look like on the Red Planet. The framework used in designing is solving current problems by using technologies that already exist today or at least are in development.

The "why" of multi-planetary living is quite universal. From the scientific perspective, its necessary to solve the puzzle of genesis that has yet to be fully understood. From the technological perspective, its necessary to push novel inventions. From the philosophical perspective, its necessary to fulfill our deep instinct to explore new and unknown territories. Lastly from the most pragmatic perspective, its necessary to spread our civilization in case our beloved Earth could no longer sustain human life.

But what about the "why" of this challenge? Why Mars? Why Mawrth Vallis? Why one million people? Why urbanization and not suburbanization or rural-ization of Mars? Questioning the questions, these are some of the things I asked myself continuously throughout this project.

Making the Same Mistake from Masdar City

We've dreamt and built utopian cities in the past. The most recent and my personal favorite would be the Masdar City in Abu Dhabi. Zero carbon, zero waste, humanely scaled, integrated public transportation system, attractive buildings, controlled environment in the middle of a desert, all sounded like a fairytale. As of 2016, fewer than 2,000 people employed in Masdar and only 300 students of the Masdar Institute live on site; way below its design goal which was to host 45,000 to 50,000 people once completed in 2030. There is a possibility that it would increase exponentially, but people are re-questioning whether the goals are too lofty.

The architects and urban planners are so far very successful in reaching their technical goals, and technological development have been pushed in building a greener and more sustainable built environment. The problem isn't with their expertise; its because the "why" had been predetermined, and the role of architects and urban planners are cut to just answering the "how".

The problem is because there is no "why" behind the "why". For example, regarding the 50,000 people, why is that necessary? Who would those people be? Are they going to be Abu Dhabi citizens who would work there, or are the clients hoping there would be futurists that would be enticed with how sophisticated the city is and would be willing to leave their current homes? The entire proposal might not be necessary if the client had asked themselves that.

Tabula Rasa: An Exercise of Ideas in An Alternate Universe

Beside solving the issues regarding the harsh environment, I personally feel this project challenges and at the same time allows me to dream another way of living; almost like having an alternate universe. This project however will not discuss so much on politics and regulations but **rather on the built environment aspects.**

- What could happen if our civilization did everything differently (not necessarily right), in terms of designing our built environment? Do we even want large houses, lawns, wide highways, and cars? Can we produce food in ways that the environment wouldn't be hurt?
- What does it mean to live in a low gravity environment? Do we get to build three times taller than we do on Earth? Do we let our bodies adapt to it, or do we maintain our Earth bodies?
- What does it mean to live in an environment that is harsh unlike our friendly Earth? Do we have to hide from the sun and wear pressurized suit all the time? What kind of relationship should we have with the Red Planet?

- Seeing the urgency, would Martians worship plants as they produce oxygen? How would this newfound affection look like in the built environment?
- What does it mean to explore new territories? Assuming there was no microbial life on Mars, how much footprint do we get to leave? Can we then treat Mars however we want?
- What relationship do future Martians have with their Earth counterparts?
- What would social life look like in a tightly packed environment? What other source of entertainment would exist?
- What would the one million people do on Mars? Are they working? Assuming most works would be done automatically, what would their roles be? Will "jobs" in its current state and definition still apply in the Martians life, commuting everyday working 9-to-5 jobs?
- Would we have Mars government? What would it look like and what relationship does it have with the other Martians?

There are other questions that I don't have the capacity to answer from fields far outside of my expertise, such as whether kids would be allowed to live on Mars and whether school should exist, or even whether there should be the first Mars-born baby.

Big Problem 1: Low Gravity

One of the problem with Mars is the low gravity; only 3.711 m/s2, or 38% of Earth's gravity. Unlike other problems, this cannot be easily solved by artificially creating Earth's gravity. Although this could be achieved by rotating module to simulate that, the studies have been very little; some even suggest that living in a rotating habitat on a long term might be as bad as living in a microgravity environment.

In this proposal, by the time we actually decide to populate Mars with one million humans, we are assuming that the problem of microgravity have been solved, likely with the help of genetic engineering. In this case, every future settler from earth must mutate their genes on purpose to live in the thin-atmosphere and small gravity environment of Mars.

Big Problem 2: Thin Atmosphere

High level of solar radiation, unbreathable air, low atmospheric pressure, are caused by the thin atmosphere on Mars. Average surface radiation is around 30 µSv to 60 µSv per hour. The average atmospheric pressure is only 0.6% of Earth's 101.3 kPa, containing almost 96% of carbon dioxide, almost 2% of argon and nitrogen, and only 0.15% of oxygen and 0.05% of carbon monoxide.

Big Problem 3: Energy Harvesting

The thin atmosphere might not be ideal for wind-based energy, and there aren't a lot of studies yet regarding the potential of geothermal energy on Mars. Solar energy would be ideal to sustain one million future settlers and all of their necessities. Although assuming that solar panel efficiency would have increased by that time, there is still a problem regarding the sandstorm that occasionally happens on Mars, lasting up to months.

Big Problem 4: External Transportation System

The thin atmosphere means that a rocket would have to use a lot of energy to directly land on Mars. To travel regularly to and from earth, another means of transportation system would have to be implemented. Ships from earth could simply "land on" a platform, before descending into Mars' surface without the use of rocket.

Big Problem 5: Rocky and Dusty Terrain

An ATV rover might be able to get across the rocky and dusty terrain, but when thinking of transporting the logistic of an entire city with one million people continuously to and from the Outer Station, it might not be efficient and quick enough. A rail based system might have a hard time with maintenance, keeping the small rocks out of the track. A flying vehicle might not be effective since there would be very little wind to propel against. A gondola might be used, utilizing Mars' low gravity and would be more efficient, but it might have the same issue with Mars' dusty air that could disturb the rotating wheel and cable.

Mars Outer Station

Mars Outer Station (MOS) combines a transitioning laboratory with rotating modules, a large scale solar farm, a ship station, and a space elevator system to transport people and logistics connecting Mars to Earth or other future space colonies. MOS would be the very first place every ship must go before reaching Mars' surface, acting as the gate to Mars. First settlers must take part in the transitioning process, gradually moving from the first rotating module that mimics Earth's gravity to the second module with Mars' gravity, aided by genetically engineering their basic system.

MOS would orbit Mars on the areostationary orbit which is about 17,031 kilometers above its equator, located quite close to the future colony on Mawrth Vallis. Ships would dock onto the station, whether its for human or other deliveries, to be transported further into the Mars' surface by space elevator. Assuming our technology would have advanced, the space elevator can be constructed by using cables made from a super strong material in the future, even though current super material such as M5 or Zylon might be sufficient since Mars have lower gravity and thinner atmosphere.

The MOS solar farm is a space based solar power (SBSP) system that would be the main energy supplier to the Valley Colony and other future colonies in Mars. There are multiple advantages of having an SBSP system, mainly the freedom from Mars' sandstorm that could block the sunlight to the surface for months, and the more effective sun energy collection. The collected energy will be beamed to a receiver below to support the one million colony, resulting in a cleaner and more sustainable way of living.

A magnetic levitation (maglev) train would serve as the connector between the Surface Station and the Valley Colony. The levitation means that there would be almost no friction, resulting in a faster and more efficient way of traveling. Suspending the train would need two separated magnetic guiding track on each side, meaning less possibility for small rocks and dust accumulation, resulting in the less need for maintenance. The train could be used to transport both humans and logistics, albeit the seemingly small and fragile look, considering Mars' smaller gravity.

Mawrth Vallis City

The city of Mars Colony on Mawrth Vallis, in short, would be "snuggled" in between the valley that is predicted to be an ancient river channel. This form of intervention would only be specific to the area of Mawrth Vallis, or at least any area with the same morphology, where a low valley is sandwiched between two hills.

Different way of building is necessary to not make the same mistake as we've already done in the past on Earth. The concept of growth for the city would utilize the small gravity of Mars, where building vertically would be the first priority way of construction. Another important thing is to put the buildings on "stilts", to make as minimum impact as possible to Mawrth Vallis' mineral-rich and possibly-life-supporting surface.

The first Mawrth Vallis city that would contain one million people is a thin a tall configuration of inflated buildings with exoskeleton support, protected by a massive regolith skin on each of its long side, as a protective measure against Mars' sandstorms, and against the Sun's radiation. On top of the megacity, a large water storage in the form of ice pumped from below the soil of Mawrth Vallis would stretch from each side of the hill, allowing a little sunlight to enter the city while diminishing its radiative properties.

The entire city would be terraformed, completely sealed off from Mars' environment and constantly pressurized, before future technology allows humans to fully terraform Mars. Each module of building, however, would have their own Environmental Control and Life Support System (ECLSS), in case the city's ECLSS fails. One human would breathe 50 liters of Oxygen in an hour, and the main source for the entire city would be the Solid Fuel Oxygen Generator in the ECLSS. There is a secondary source and probably would be preferred more in the future, which utilizes the Oxygen created by various plants in the greenhouse and where Carbon Dioxide could also be fed to, which will be discussed further in the "Food Production" sub-chapter. If the main ECLSS fails, emergency oxygen from lithium perchlorate containers and reserved nitrogen would provide the city temporary breathing air.

Ten clusters of neighborhood are grouped based on functions and are arranged vertically using adjacency matrix. Human habitats, civil functions, laboratories for science and technology, industry and manufacturing, are all contained within the thin megastructure. Some would be separated farther away than the other, based on the possibility of disruption and the hazard level.

Every module of building except the Habitat provides jobs for the Martians. There would be two categories to divide these fields: based on whether they are managerial (M) (main job performed automatically) or active jobs (A); and based on whether they are for civil service (C) or private entities (P)

- Science and Technology (A+P) would be the main focus for research and development purposes, whether they are for Mars, Earth, and future space exploration. The labs would be located in the middle to avoid radiation even further.
- Arts and Entertainment (A+P) would involve producing entertainment materials to be broadcasted to Earth, while at the same time importing materials from Earth for Martians consumption in the form of digital media. The entirely different condition between the two would create a diverse range of shows: there could be a new form of ballet dancing where the dancers jump three times higher than on Earth; there could be a new reality show about living on Mars to be watched by people on Earth, etc.
- Industry, Mining, and Manufacturing (M+P) would involve producing materials and goods for construction and consumption. It could also export raw or processed materials to Earth in case

there is a demand for it. In this case, it would be the most intense user of maglev train since there would be a lot of cargo transferred regularly back and forth the city and the Surface Station. The cluster would be located close to one of the hill, for ease of material transport to the train and closer to the possible source of mineral according to the data from HiRISE imaging.

- Farming (M+P) would be located higher above, as the greenhouse would need a lot of sunlight.
- Energy Harvesting (M+P) would be located higher above, as it would receive energy beam from the main harvester orbiting above.
- Freshwater Processing Plant (M+P) would be located at the bottom, for easy drilling and processing the ice. Once the liquid H20 obtained, it would be pumped to the storage above the city as a protective measure against sun's radiation. They would then be redistributed to everyone using gravity and aided by extra pumps.
- Liquid and Solid Waste Plant (M+P) would be located at the bottom and completely separated from any cluster. The liquid waste would be treated and repurposed for secondary usage, such as watering plants and flushing the toilet; while the solid waste such as domestic trash would be recycled as much as possible. Organic trash, for example from a leftover, could easily be processed and turned into fertilizer for the greenhouse; but it wouldn't be as easy with inorganic waste. The problem of recycling and waste processing might even be more complex than, say, the problem of low gravity. There haven't really been many studies about dealing with the waste one million population would produce on another planet. But hypothetically if these one million people consume the same way the Earth people have been doing, it would be catastrophic. The one thing that could be done towards a better way of living regarding waste is to prevent it as much as possible. There would not be a lot of packaging, and food would be prepared and eaten as fresh as possible.
- Business (A+P) cluster would be reserved for working offices and headquarters of private companies on Mars. These would not be large rental buildings like traditional offices where there would be a lot of cubicles. Employees of these companies might mostly work at their own habitat; the business clusters would be needed only for live meeting, database handling, and as a representative.
- Health and Medicine (A+C) would cater the needs of the Martians. One important thing is that a quarantine facility might be necessary in case there's someone has an airborne disease, so that it would not spread very easily. It might be necessary also for the hospital cluster to have some areas reserved, for in the future there might be new diseases specifically happened caused by Mars' environment, so that new facilities can be built while still close to the existing hospital.
- Educational Institutions (A+C) would house educational activities for all of the civilians. It would be located close to the Science and Technology cluster so that students will spend more time experimenting rather than listening to lectures like traditionally done on Earth.
- Mars Government (A+C) would house the elected government whom regulates all activities and ensures the well-being of all Martians. Continuous communication to Earth would be done ensuring a good relationship and supply of everything produced for and in Mars could flow smoothly.
- Security (M+C) cluster would house the main headquarter for law enforcement. Most of the work would be done through surveillance and only few personals would patrol the city daily, ensuring security and safety of all Martians.

- Service (A+P) would house other enterprises that might exist to aid the Martians daily life. From fixing a broken ECLSS to providing dating advices between two Martians, new demands and markets would be created and an endless possibility exists.

The last five clusters would be grouped together and located in the center of the city, forming a large civic center, where every other cluster could reach rather easily.

A. Construction

Understandably, windows are not common and widely used when discussing the design of a life shelter outside of earth, since there's a larger possibility of hazard, such as high radiation from the sun or rupture caused by micrometeoroids, or in the case of Mars' environment, sandstorm and regolith debris accumulation. But the design of this megastructure involves quite a lot of them, since I personally think one of the most important thing about space exploration is for the people to be able to see and fully experience the alien environment. In that case, the design of the windows and everything around it would have to be thought out more elaborately.

First of all, the windows would be deeply recessed into the regolith wall to minimize the sun exposure and risk of direct impact with microparticles. Tempered glass, a material with at least five times stronger than a regular glass, of 30 mm thickness would be used for each pane, with an extra layer of acrylic glass for UV filtering. The tempered glass would be double layered as an added protection against the risk of material damage caused by an impact. The windows will be mounted on a steel frame to transfer the pressure strain onto the ends of the overall structure. Instead of using multiple array of glasses in a single pane supported by another angle bars, only a single surface of glass measuring about 1000 mm x 500 mm would be used, resulting in a configuration of small and narrow slits. The windows would be evenly distributed along the large regolith skin, just enough in order for people could observe the outer environment every now and then.

The risk of debris accumulation would occur in these windows due to the recessed configuration. Therefore, along the steel frame of the windows, there would be a robotic window cleaner that could remove the accumulated dust. These robots could move along the line of the frame from end to end, minimizing the need for manual intervention.

B. Base Module and The Supporting Structure

The entire megastructure would be divided based on grid system, allowing ease of modification and grouping based on needs. The dimension was chosen based on the volume of the Habitat since it would be the smallest module, but of course further studies and calculation regarding volume would be needed. Although highly-specialized function such as laboratories or manufacturing might need modification, the majority of the building would use this prefabricated module as the base. The main door would be able to dock with the LMT cars using magnet.

The Base Module would be constructed using aluminum composite shell, anodized for thermal efficiency. Aluminum would also be used for the interior, but coated or painted white. The use of flammable material would be minimized, such as choosing silicon insulation for wiring instead of PVC, or choosing Teflon for hoses, and acrylic glass for the windows. The entire city is already paraterraformed and shielded from Mars' harsh environment, but each building would have their own pressurization system and emergency ECLSS as a redundancy measure in case the main system of the city fails.

The supporting structure is a vertical and lateral load distribution columns and beams, likely would be made of steel by utilizing in-situ resource such as hematite. Other than as a support structure and guiding track for the Personal Mover, this structure would also be the track for the distribution of energy and waste. The supply would consist of electricity, oxygen, and communication lines; whereas the waste would consist of trash, carbondioxide, and wastewater. All this would be hidden in the supporting structure, ensuring safety and yet pertaining ease of management and maintenance.

C. Transportation

Personal Mover with linear motor technology (LMT) will be used for all movement both for people and logistics within each cluster. This technology isn't new; MULTI by Thyssenkrup are currently in development, although a slight change in design might be needed to be appropriately applied to this megastructure. The cars would move vertically guided by tracks on the side of the buildings that would also act as the main structural support for every module; and horizontally by tracks that bridges one vertical line of buildings to the other.

On the other hand, transportation from one cluster of function to the other will be using the same maglev train, which would be the extension from the Surface Station. The train would be located close to the surface of the valley, below the water ice storage on each of the long side of the megastructure. This configuration allows every cluster to be reached from everywhere. The transit station would be located on top of each cluster of function on the same level as the train track, so that commuters would be able to descend straight to the destination by using the Personal Mover. These transit stations would also be the main storage of the Personal Movers to the cluster below, assuring there would be short waiting time for commuters and continuously providing sufficient number of cars.

D. Habitat

The living quarter would exist in modules suited to different needs, but can be divided into two groups: Communal or Family Living Unit and Single Living Unit. The first ones would have almost entirely the same design, only it will be used by different subjects and differs in bed configuration. The CLU would house a group of four people, while the FLU would house a family with the same quantity. The SLU, however, would house a single person for a short period of time and act more like a hotel. Privacy in a multi-planetary life would be treated as a luxury, and this is the sole purpose the SLU was made: to house rich travelers from Earth who would spend money to visit Mars for a vacation trip, rather than to permanently live there.

The list of rooms, general area and volume allocation can be seen on the table below:

Function	Zoning	Level	Dimensions (L x D x H)	Volume
Personal Quarter (CLU) / Bedroom (FLU)	Private	Top	4 rooms @ 2650 mm x 1550 mm x 2500 mm	4 x 10.27 m3
Communal Quarter (CLU) / Family Room (FLU)	Communal	Top	2770 mm x 2100 mm x 2500 mm	14.54 m3
Dining	Communal	Middle	2100 mm x 3500 mm x 2500 mm	18.37 m3
Kitchen	Communal	Middle	2520 mm x 1550 mm x 2500 mm	9.76 m3
Personal Hygiene + Toilet	Private	Middle	2900 mm x 1550 mm x 2500 mm	11.24 m3
Exercise	Private	Bottom	3510 mm x 1550 mm x 2500 mm	13.6 m3
Waste Management	Service	Bottom	1910 mm x 1550 mm x2500 mm	7.4 m3
Trash Management	Service	Bottom	1420 mm x 2100 mm x2500 mm	7.45 m3
Inventory Management	Service	Bottom	4000 mm x 2100 mm x 2500 mm	21 m3
			Arranged Dimension: 5420 mm x 4850 mm x7500 mm	Total Volume: 197.15 m3

E. Food Production

In one day, average 91 kg male humans who exercises regularly would need:

- 2500 calories
- 83 grams of fat
- 60 grams of protein
- 25 grams of fiber
- Various vitamins and minerals

This would result in the total of 547.95 grams of food per day, and women in average would need less than that.

There might be another way of doing agriculture in the future, but for the design of this city, existing mode of farming would be analyzed in order to provide enough food for one million people. Three modes of planting were being looked at:

- Primitive / traditional farming would produce 4,700,000 kcal/**km2**/day
  One million people would need 531.91 km2 of space.
- Hydroponics could produce 70,000 – 260,000 kcal/**ha**/day
  One million people would need 93.99 km2 of space.
- Aeroponics could produce 98.420.000 kcal/**km2**/day
  One million people would need 25.40 km2 of space.

Using basic math, the aeroponics system is the clear winner. Greens such as vegetables and fruits for regular consumption would be grown in a large greenhouse, using aeroponic system and stacked vertically. If the height of the aeroponic towers was taken to the extreme, for example 500 meters, there would be roughly 52 towers. Using the recommended spacing of 400 mm x 500 mm between each tower, the footprint of the planting area would only be 12.4 m x 10.0 m.

A single tower with the height of 150 mm could contain roughly 100 strawberry plants. One man breathes up to 50 liters of oxygen in an hour, while a single leaf in average produces 5 ml of oxygen in in an hour. Therefore, a single human needs 10.000 leaves for oxygen supply for himself, which is roughly 300 – 500 plants. If a single tower of aeroponic system with the height of 150 mm could contain roughly 100 strawberry-sized plants, one person needs about 800 mm of vertical aeroponic tower. Therefore, the vertical greenhouse with the configuration above would be able to provide roughly 1/30 of oxygen needed for one million people, making it the excellent secondary oxygen provider.

Other than greens, meat would also be provided for consumption through tissue culture. Although the method is not perfect, hopefully by the time one million people live on Mars it will. Current problem revolves mostly around extreme cost of production. But if we can bring this down, with current capability of producing 50,000 tons of meat using only 10 pork muscle cell, there would absolutely be no need for animal farming, both on Mars and on Earth, which will be a more sustainable and responsible way of eating.