

Aula 

NOVA SPKA

Tomorrow 's future, today's solution





Tomorrow 's future, today's solution

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01. INTRODUCTION

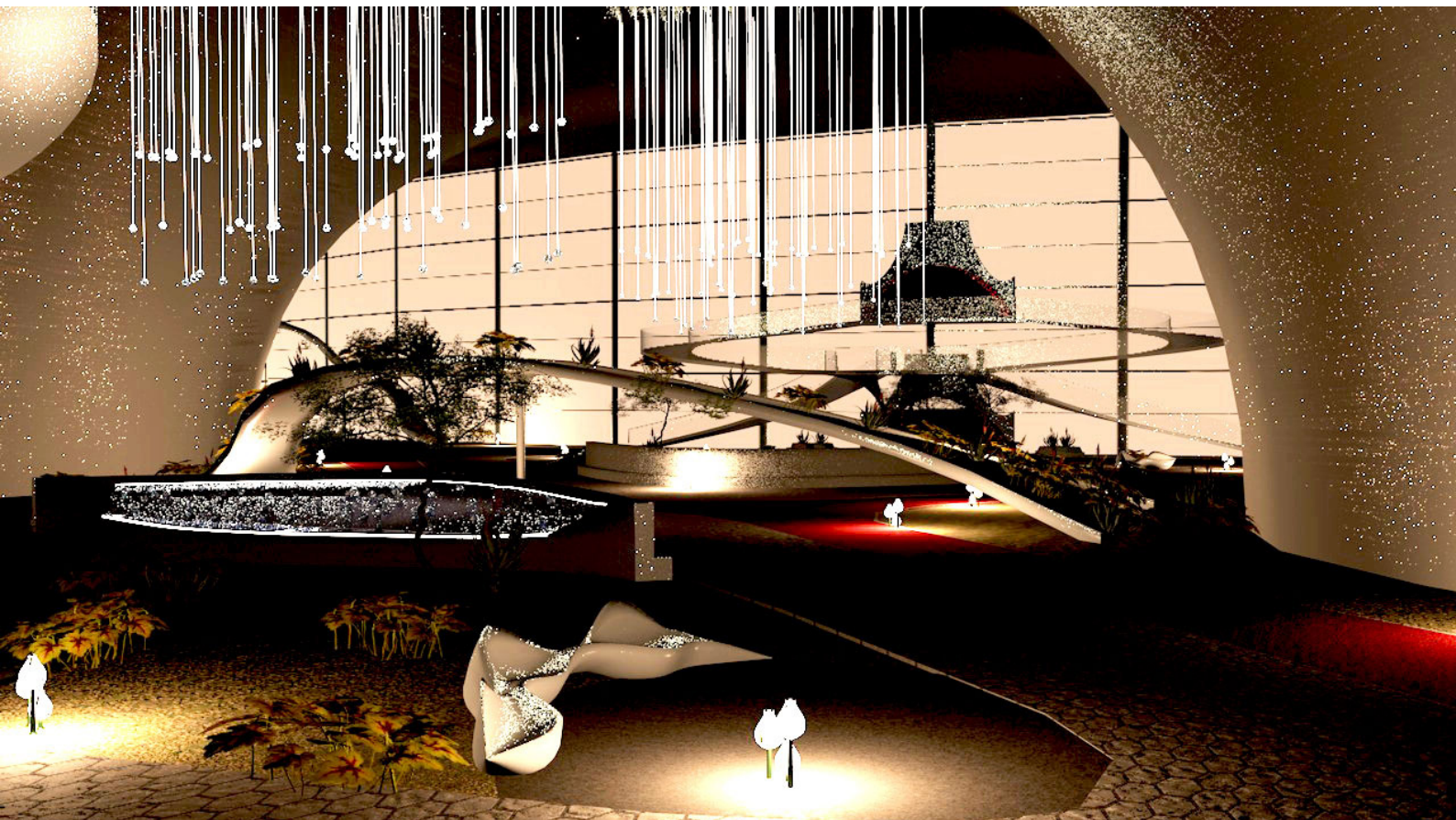
Space: the final frontier.

Since the first orbital flight was successfully achieved during the Space Race, humankind has been dreaming about travelling through the stars beyond Earth surroundings, to "where no man has gone before". This inspirational motto, among others, has carried us to a historical moment, where the "science fiction" is nearer and nearer to turn into "science reality", where the first step is exploring and settling in the not-so-far unvisited planets. And concretely, on Mars.

The HP Mars Home Planet initiative has become the best opportunity for us, students who are fulfilling their careers at Rey Juan Carlos University, to show our own vision about the future of space colonisation. Thanks to the workstations in "Aula HP", we are developing a whole design of how the first great martian colony will be, with a team of 3 people compound by Aerospace Engineers collaborating with Architects and Designers for planning and modelling the home of tomorrow; and working along with Software Engineers and Videogames Programmers to bring the concept to life in a fully interactive and unique experience of virtual reality.

With this report we will build up all the information about Mars we have found, and display the analysis we have made of its characteristics, revealing all the main issues and troubles of living in a hostile environment out of Earth. Once we have these results, the following step is taking the design choices to solve all the problems that fit in our constraints of space, resources and technology available; and, last but not least, modelling the different pieces that will compound the home of the future.

Thanks for giving us the opportunity of forming part of this little big step for humankind.



02. IN DEPTH MARS ANALYSIS

02.1. Martian atmosphere

Characteristics

If we compare the Mars and Earth atmosphere, we can appreciate substantial differences in the composition, pressure, density or temperature.

In the next table we can see the percent amount of the most abundant gases that compose Earth and Mars respective atmospheres:

	Earth	Mars
Pressure (kPa)	101.3	0.6
Density (Kg/m ³)	1.225	0.02
Mean Temperature (°C)	14	-60
Atmosphere components (%)		
CO ₂	0.33	95.32
N ₂	78.08	2.7
Ar	0.93	1.6
O ₂	20.95	0.13
CO	$0.19 \cdot 10^{-4}$	$700 \cdot 10^{-4}$
O ₃	$0 - 12 \cdot 10^{-4}$	$0 - 0.0008 \cdot 10^{-4}$
H ₂ O	$0-0.04 \cdot 10^{-4}$	$0 - 0.00086 \cdot 10^{-4}$

02. IN DEPTH MARS ANALYSIS

02.1. Martian atmosphere

We can immediately realize the lack of an appropriate oxygen level, the essential gas for us to live.

The Mars atmosphere is lighter than Earth's: while in Earth there is a pressure of approximately 101.3 kPa in the surface, in Mars the pressure has a mean 0.6kPa (less than a 0.06% of Earth's one). Mars has an atmosphere density of 0.02 Kg/m³. The average temperature is about -60°C and it varies drastically between day and night, having almost a difference of 70 degrees. Due to this great difference of temperature, there are atmospheric currents.

Wind storms

Because of the variation of temperature, pressure along the surface and wind direction varies. Thanks to the Viking and Pathfinder observations, we know that the mean velocity of a weak wind is about 15km/h, but in case of global storms it can reach far more than 110km/h. A quick comparison: A wind of 360 Km/h would perform a force of 50 N/m² in a flat spherical surface in Mars, while in Earth, the same force, is given with only 50 Km/h. This is because of the low density. The most destructive storm in Mars, is less than a moderate wind in Earth.

So, the problem in these storms is not the wind strength, but the dust it transports: some of the particles can be electrostatically charged and stick to the different surfaces and, in case of a global storm, the dust covers most of the planet, keeping the sun light out of reaching the surface.

Usually, the spring and summer of southern hemisphere are dustier than the northern ones, and is where the global wind storms happen. The wind storms seem to be cyclical generally, and concretely global storms seem to happen when Mars angular momentum rises (because of the effect of surrounding planets) at the same time that the first storm season happens.

Mawrth Vallis, the location where the first human colony is planned to be set, is in the North hemisphere near the equator, so we expect that wind storm effects will always be less destructive than Earth's average hurricanes.

<http://cab.inta-csic.es/remes/es/atmosfera-de-marte/>
<http://cab.inta-csic.es/remes/es/atmosfera-de-marte/>
<https://actualidad.rt.com/ciencias/186463-nasa-revela-verdad-tormentas-polvo-marte>
<https://universitam.com/academicos/noticias/descubre-la-nasa-tres-grandes-tormentas-de-polvo-que-cubren-a-marte-cada-ano/>
<https://observatori.uv.es/en/un-estudio-predice-la-proxima-tormenta-de-polvo-en-marte/>

02. IN DEPTH MARS ANALYSIS

02.2. Mars' gravity

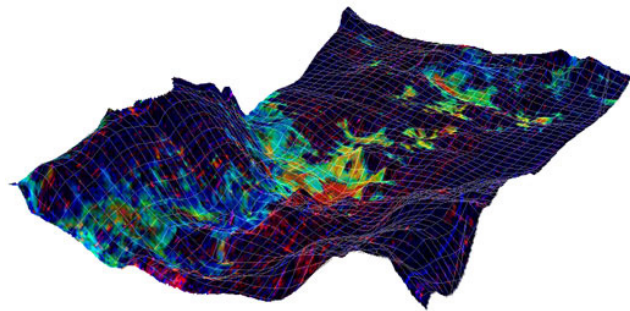
There is a gravity of 3.71 m/s^2 , a 38% of Earth's. This lower gravity affects us, not only at construction decisions (such as reducing the number of piles compared to Earth), but at our own body: first we will have more strength, be faster, but when time pass by, our muscles and bones will start to deteriorate, forcing us to take a sporty lifestyle in order to keep our body tuned up until we get used to this condition.

02.3. Martian soil and terraint

Mars has a density of 3.93 g/cm^3 .

As we have said, the location of the colony is in Mawrth Vallis, where one of the biggest occurrences clay minerals is. The following map shows the location of some clay minerals in a portion of 10 km wide of Mawrth Vallis :

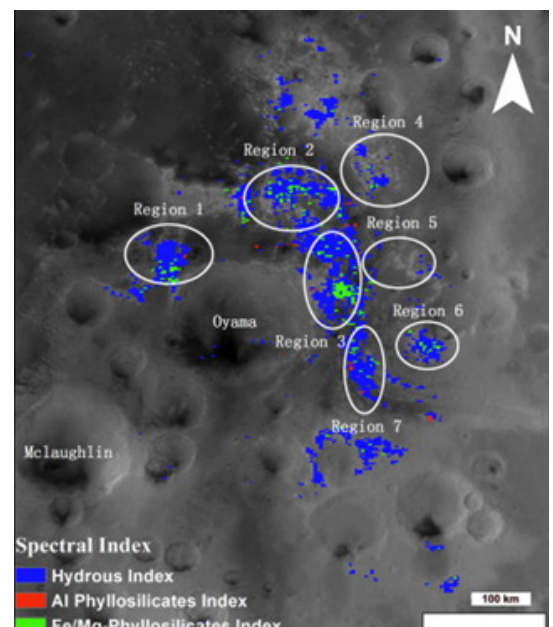
- Iron-magnesium phyllosilicate is shown in red.
- Aluminium phyllosilicate is shown in blue.
- Hydrates silica is shown in yellow.
- Ferrous iron is shown in green.



In the paper 'Mineral abundances and different levels of alteration around Mawrth Vallis' from Science Direct it is evidenced that there is two main phyllosilicates exposed in and around Mawrth Vallis: Al-phyllosilicates and Fe/Mg phyllosilicates. Using the MESMA (multiple endmember spectral mixture analysis) they suppose that primary rock-forming minerals are plagioclases, pyroxenes, olivines, ferric oxides and phyllosilicates. They selected 6 regions of study as shown in the map, where we can find:

- Al-phyllosilicates in Region 1 mainly
- Montmorillonite and hydrated silica in Region 1 and 3
- Fe / Mg Phyllosilicates in region 2, 3 and 6.

Besides the abundances of clay in Mawrth Vallis, landers Viking I, Viking II Pathfinder, Opportunity Rover and Spirit Rover identified aluminium, iron, magnesium and titanium in the martian soil. The basalt dunes are believed to contain minerals as chromite, magnetite and ilmenite.



https://www.nasa.gov/mission_pages/MRO/multimedia/bishop-20080807.html
<http://www.sciencedirect.com/science/article/pii/S1674987114001315#fig7>

02. IN DEPTH MARS ANALYSIS

02.3. Martian soil and terraint

Water

The water that exists in Mars is either evaporated or frozen. There are underground deposits of frozen water at the poles and at Utopia Planitia region . These facts lead to think that probably there are other deposits at mid north latitude which can be used. Right now, every surface water on Mars sublimates into water vapor, although the presence of silicates indicates that long time ago, there was liquid water in Mars. There are two main theories respect the dark feature of Mars summer: the first one considers that they probe subsurface flowing of salt water in summer when there is enough temperature, while the second one considers them as a consequence of granular flows (this seems the most logical option).

Recent studies from NASA (published on National Geographic web on 11/1/2018) shows frozen water near the surface .

Mars farming

The high differences of temperature, high saline and dry soils, and the atmosphere composition, it is not possible grow anything in the martian surface.

Some experiments carried in similar conditions of growth as it would be in Mars has led to crops growing successfully using worms and fertilizer . Thanks to worms, the soil is aerated, and its structure is improved, allowing a more effective watering. Also, it is important to say that the worms could reproduce under the experiment conditions. A great preoccupation was that, due to the presence of heavy metals in Martian soils, the crop might be poisonous. Fortunately, an experiment (farming tomatoes, peas, radishes and rye) demonstrated that the levels of these heavy metals are safe for the crops to be consumed. Further details of viable crops to grow and technics followed will be discussed in section 04.7.

<https://www.jpl.nasa.gov/news/news.php?feature=6680>
<https://www.nasa.gov/press-release/nasa-confirms-evidence-that-liquid-water-flows-on-today-s-mars>
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02. IN DEPTH MARS ANALYSIS

02.4. Dangers from outer space

In this section we will focus in the different kinds of radiations (cosmic and solar) and the consequences of the lack of a magnetic field.

Solar radiation

As its name says, it is the radiation whose source is the Sun. The dangerous radiations for humans are those with a wavelength lower than 320nm, which represent mainly UV-C and a part of UV-B. In Mars, dioxide absorbs radiation with a wave length lower than a 200nm (in the Earth this function is done by the oxygen) but, unlike on Earth, there is no ozone layer to absorb radiation with a wavelength between 200 and 300 nm, so this wavelength reaches the mars surface. The South hemisphere receives more UV radiation than North hemisphere, and the amount of radiation is influenced by the 11-year cycle of activity of the Sun .

Cosmic radiation

Its source is unclear, but it is believed that the main sources are explosion of supernovas (at least they are responsible of the initial acceleration), accretion disk of a black holes (most of the radiation that arrives to our solar system comes from an active black hole in Centaurus) and big explosions of the Sun (which has a very low energy, and occurs unfrequently).

The particle energy can reach almost 10 GeV, which means between 10 and 20 times higher energy than protons erupted by the Sun. It consists of protons (90%), alpha particles (8%), and heavy nuclei (2%), which is the most problematic kind of this radiation. Luckily, cosmic radiation has a very low flow, so its dangerousness decreases.

The Sun's electromagnetic field protects the solar system just like Earth's one protects the planet. The level of protection depends of the Sun's 11-years activity cycle: when the sun is at its maximum activity, the electromagnetic field is stronger, so the solar system receives more solar radiation and less cosmic radiation than in main conditions. When the sun is at its minimum, its happens the other way around.

<https://es.gizmodo.com/las-plantas-cultivadas-en-suelo-marciano-son-perfectame-1782574207>
<http://www.semae.es/wp-content/uploads/2011/04/MARte-y-UV-Rad.pdf>
<http://danielmarin.naukas.com/2011/03/23/la-radiacion-en-el-espacio/> https://es.wikipedia.org/wiki/Radiaci%C3%B3n_c%C3%B3smica
<http://danielmarin.naukas.com/2011/03/23/la-radiacion-en-el-espacio/>

02. IN DEPTH MARS ANALYSIS

02.4. Dangers from outer space

Radiation effects

The dose of radiation, taking into account the effects on living tissue, is measured in Sievert(Sv). 1Sv can be seen as a rise of the probability of having cancer in 5% (for humans). In some countries, like Spain, a worker must have less than 50 mSv in a year. In mars there is 1'8-106 Sv/day approximately spread around all the surface.

Age	Man	Woman
25	0.7 Sv	0.4 Sv
35	0.9 Sv	0.6 Sv
45	1.5 Sv	0.9 Sv
50	2.9 Sv	1.6 Sv

The table shows the maximum radiation recommended for an astronaut in 10 years in services (in 2000). Unfortunately, this dose has been established with data from gamma ray and X-ray expositions, and we do not exactly know much about heavy nucleus effects .

An important consequence of cosmic radiation is a significant damage to the central nervous system: performance decreases, memory deficit, loss of consciousness and attention .

Radiation and materials

Though we know that materials with a low atomic number are the best option to protect us against protons radiation, the problem lies again in the heavy nuclei, because when they crash on a metallic structure it generates one or various secondary radiation sources.

Some materials that protect against protons radiation are polyethylene layers, water, electromagnetic fields or electrostatic fields.

<http://danielmarin.naukas.com/2011/03/23/la-radiacion-en-el-espacio/>
<https://es.gizmodo.com/la-radiacion-haria-hoy-en-dia-imposible-una-mision-trip-510629533>
<http://www.laopiniondezamora.es/sociedad/2015/05/02/radiacion-espacial-provocar-danos-cerebrales/840252.html>
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02. IN DEPTH MARS ANALYSIS

02.5. Lack of resources

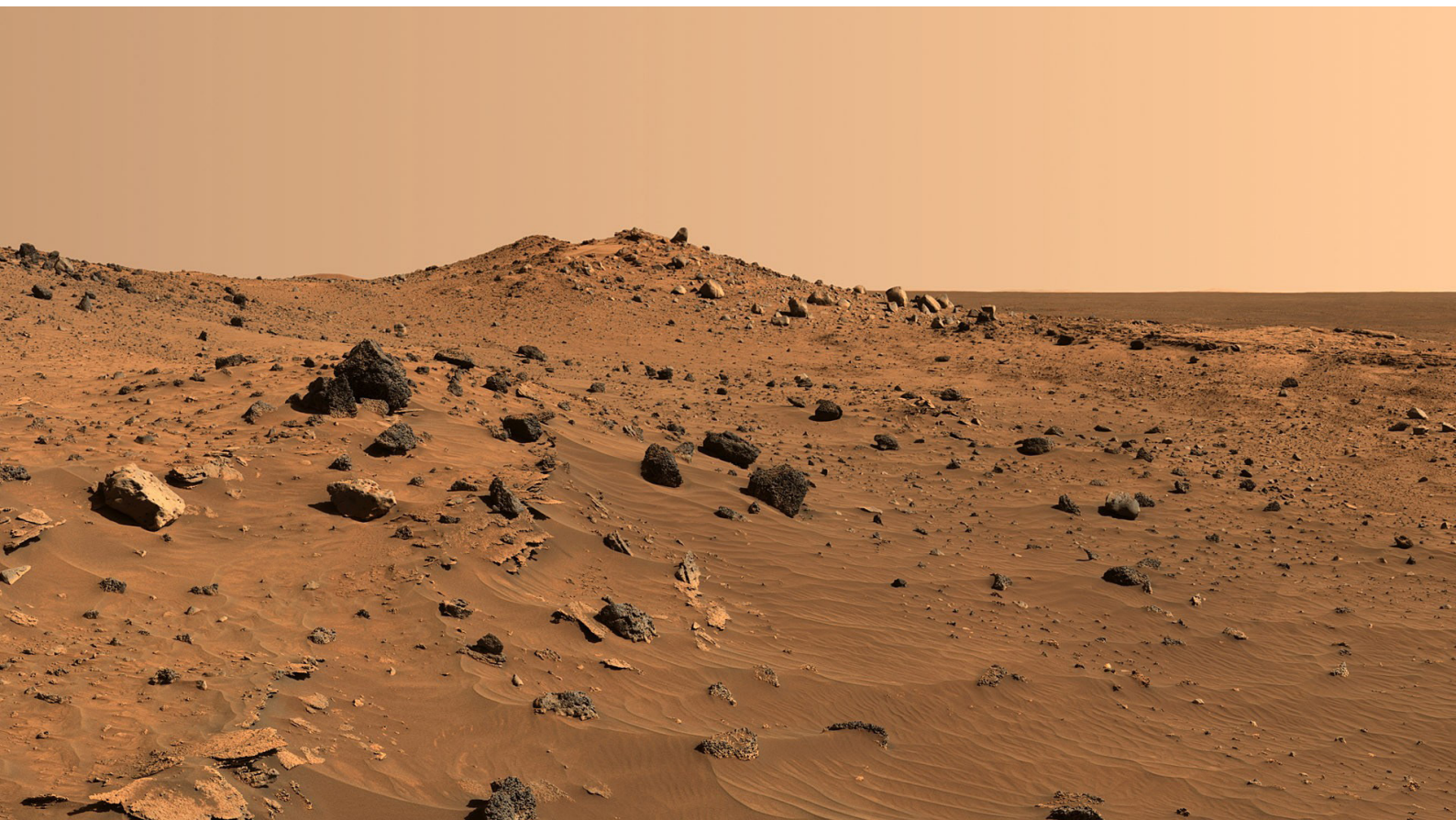
Life on Mars would suppose a **change of paradigm**, a totally different way of living from the one which we are used to. We won't only have to sacrifice some commodities, but also, we won't have water, oxygen, food or fossil fuels, so we will need to find alternatives solutions.

Firstly, the most important: **water, oxygen and food are basic to survive**. As we have seen before, there is no oxygen to breathe, we need to find an efficient way to get it or produce it, and generate a breathable air. The liquid water can't exist on Mars surface due to the temperature and pressure conditions. It is known that there is iced water underground, but we don't know exactly how much, neither if we can reach it easily enough nor if iced water we can find is abundant enough. The way of recycling will be crucial for both oxygen and water. Also, our diet should change to what we can rise in Mars or what can be sent from Earth.

Now, let's focus about what **fossil fuels** are needed for. As a combustible, we will have to find alternatives to move vehicles and producing power; in order to manufacturing plastics, we could substitute all the oil-derived materials for those that can be obtained from microalgae biofuels or directly from plants. We can absolutely not be an oil-dependent colony.

On the other hand, won't have access to Earth resources such as **wood** (there won't be huge trees to use) and other vegetal or animal sources materials.

In conclusion, we need to adapt to new circumstances to be able to survive. We need a way to reach the point where we can be independent enough from Earth sources, just like a child that has grown up and is prepared to live by his own.



03. COLONY PLANNING OUR MAIN VIEW

As we have seen, living in Mars propose a challenge not only architectonically, but also socially, as it will change paradigm of lifestyle, both in Mars and Earth.

03.1. Hypotheses taken

Before detailing the main characteristics of the colony, we have assumed some hypotheses moreover the ones proposed by Concept and Modelling challenges:

- We have all the technology for building the colony and crafting the materials used.
- As we have previously said, there are evidences of the past presence of liquid water on Mars surface and a recent notice has shown that it has been found layers of water ice buried mere feet beneath the red planet's surface, so we assume there is enough water that can be extracted to be used in the colony.
- All the facilities and devices located outside the residential area are autonomous enough to minimize the time a human is exposed to exterior harms.
- The energy supplied is always the theoretical value, assuming that we produce enough energy, so we will not have energy shortages. Although, our energy production tends to low consumption economies.
- The living spaces (homes) will be inhabited in groups of 4 people, families or roommates, and there will not be houses with less than 3 people.
- Utopic future: by the time the colony is settled, people will assume that living together and helping each other is the only way for colonial prosperity, so coexistence is a priority for colonists before some individual needs.
- We efficiently produce and consume all the materials needed, and recycle them effectively, so the colony is self-sufficient. As well, all the oxygen and water are efficiently recycled.

These hypotheses are crucial for the correct functioning of the colony.

03. COLONY PLANNING OUR MAIN VIEW

03.2. Our vision: An underground future

It is very difficult to foresee the whole set of harms that habitats will be submitted to: the constant radiation striking the surface, meteorites, and dust storms. When we firstly thought in a colony, we imagined a complex structure of domes connected each to another, but immediately asked ourselves “**how we will protect our homes from outer harms?**”. Shielding against meteorites, cosmic radiation and the cold at the same time is a hard task, as we needed to cover the domes with a resistant and thick material capable of absorbing the impact of space rocks, another layer that absorbs the heavy nuclei of cosmic radiation without converting itself in a secondary-radiated coating of death, and additionally, having a layer of heat-isolating material in order to keep the -60°C temperature away from our homes. And a material with an acceptable gas impermeability for pressurizing, also. Considering all these issues, we would need near 3 meters of wall between the interior and exterior of a colony in the surface, quite hard to try a modular structure.

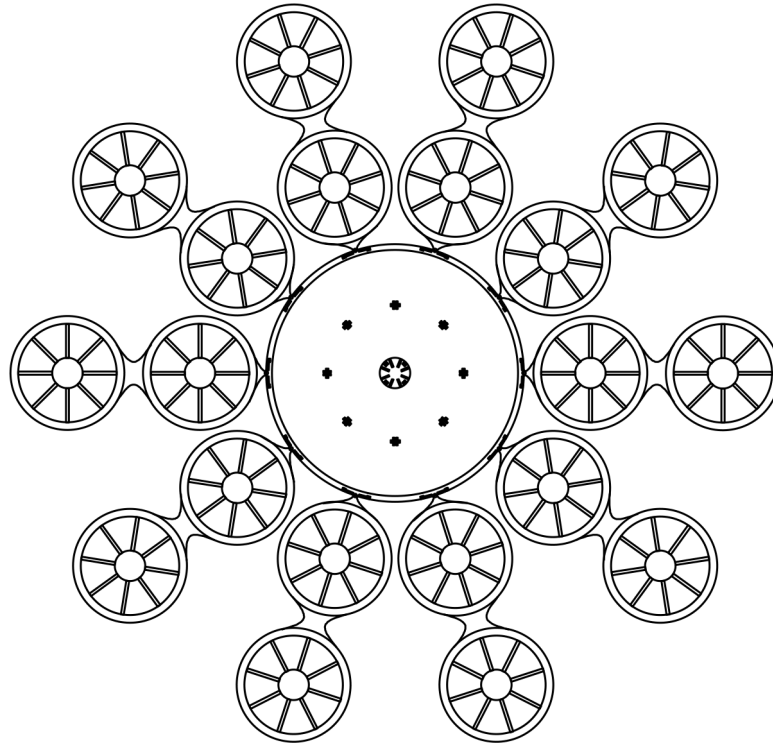
So, our vision focused on the ground, or more accurately, underground. Since gravity in Mars is almost 1/3 of Earth's, **underground cities are a more plausible choice**, and would bring multiple advantages respect building outside. We need only 5 meters of martian regolith above the least deep floor in order to nullify the effect of the most energetic nuclei from cosmic radiation²⁰, and can shield us from the small meteorites that could impact near it. Though we need a thicker layer of thermic isolator due to the relatively higher thermal conductivity, we can gas-proof the inner layer easier, and we can excavate up to 150-200 meters deep underground, having plenty of space and scalability, being able to expanding the main colony and building more and more facilities as the colony needs. Besides, it helps to wiring and piping, and controlling the environment inside. Although, the power plant, hangars for exploration and transport modules, and the natural light dome will be at surface level.

After deciding how to protect ourselves, another question came: 1 million people will have to survive and live in 40 km², so **how can we organise everything to make it happened?** Our concept includes a city split in 10 main cores that will be self-sufficient and will provide life support to up to 1024000 inhabitants, interconnected with subway-like transport, and boulevards connecting residential areas. We will discuss it below.

03. COLONY PLANNING OUR MAN VIEW

03.3 Structure and planning

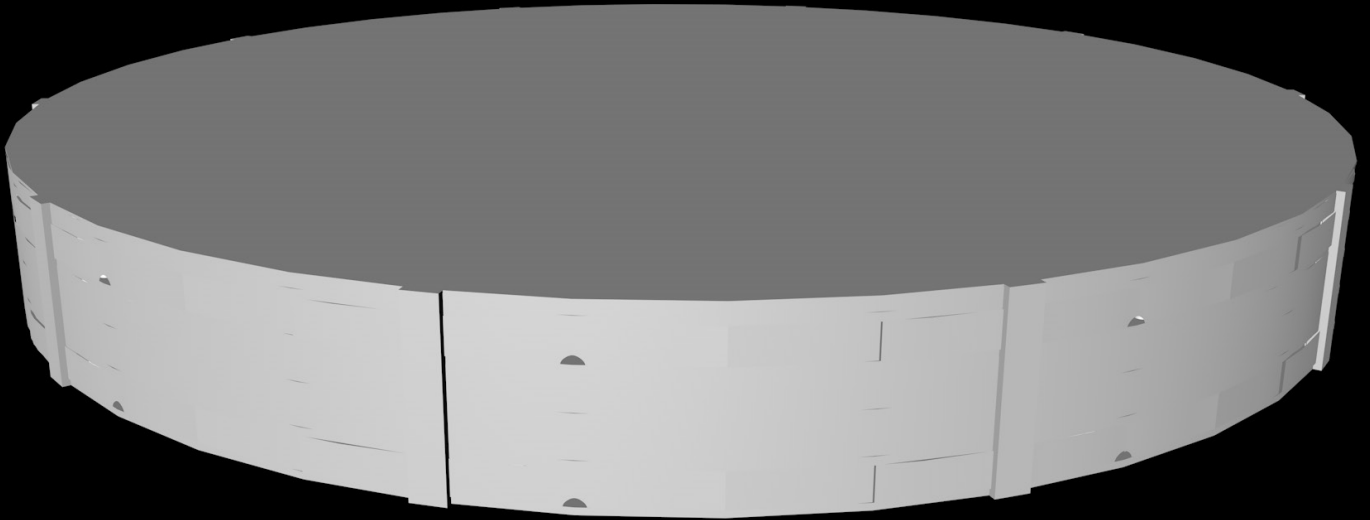
Colony plans, scale 1:20000



Nova Spika, the first city of tomorrow's space colonial era. An underground complex that consists of 10 central facilities, the Tochos, the neuralgic centres of the city, around which are located the Districts, smaller neighbourhoods where are the residential areas. There are 20 Districts for every 1 Tocho, and can hold up to 102400 people inside, and every Tocho is independent from the others. Although we considerate the numbers above, this plan is designed for scalability: we can excavate deeper, adding new floors, or connect new Tochos surrounding the city. But we are only scratching the surface, let's take a deeper look.

03. COLONY PLANNING OUR MAIN VIEW

03.3 Structure and planning

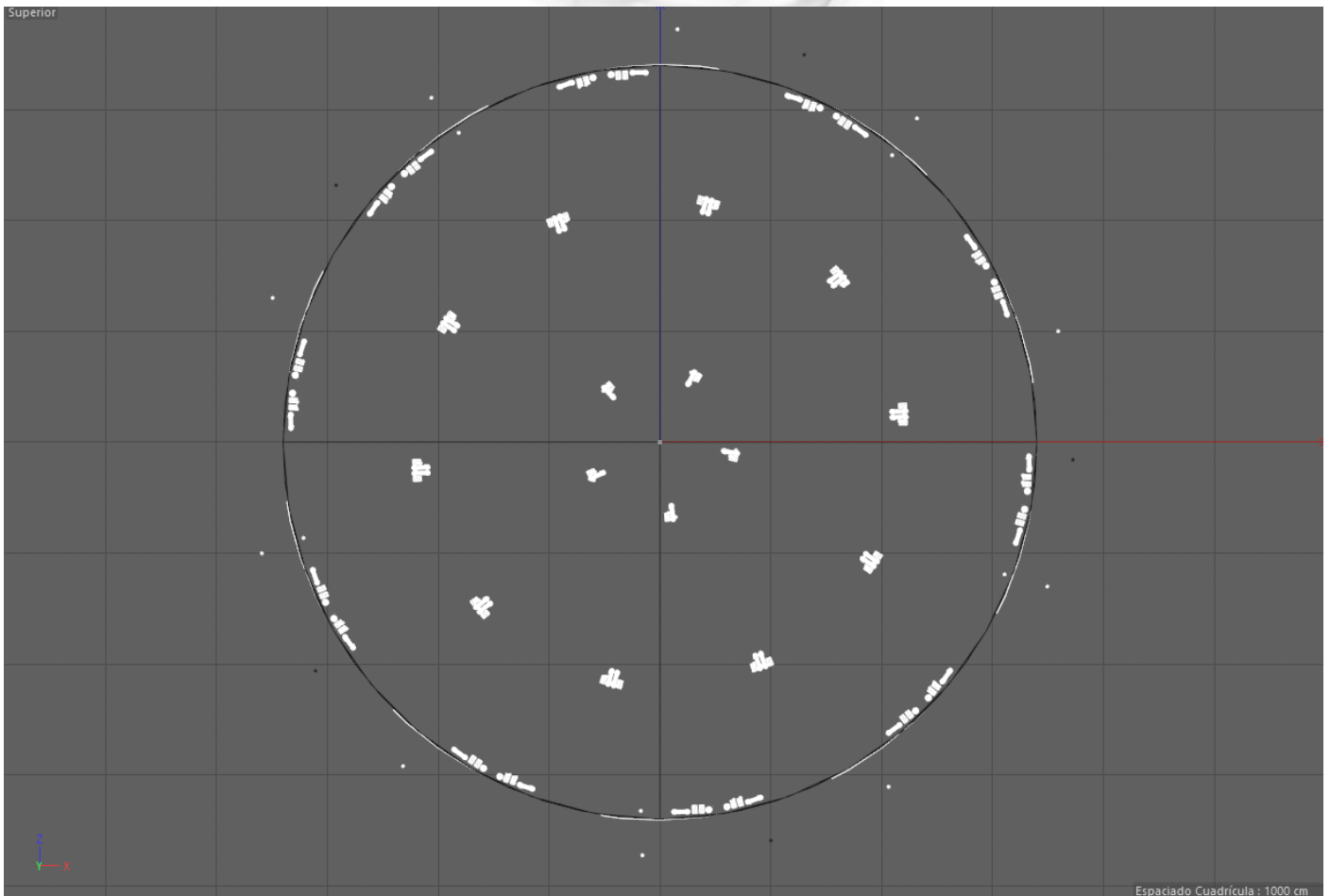


Tocho morphology

This is the **main building**, the brain and the heart of a set of Districts. Here is where the big building necessary for living are located. Divided into 4 floors with 15m height and one additional floor with only 8m height (where the 1st is the small one, located near the surface, and the 5th one is the deepest), each of them has a diameter of 680m, and the 2nd and 5th has 10 entrances to the boulevards connected to the Districts. There would be an additional floor where the subway would connect the Tochos between them, and each Tocho with its 20 District (see section 4.4).

03. COLONY PLANNING OUR MAIN VIEW

03.3 Structure and planning



We have distributed the building that we considered a priority along the floors(transport floor not include). A schematic of the planning is shown below:

- 5th floor: energy converters (the power plant is outside) and distributors, entrance from surface, metal industry and mineral processing.
- 4th floor: Colony bureaucracy management offices, central post and delivery office, Mars University campuses, commercial centers and big commerce, entertainment industry and general Research and Development department.
- 3rd floor: Farming lands, hydroponic culture, and alimentation industry (meat labs, animal farms, food processing and packaging).
- 2nd floor: Waste treatment and recycling, sewage water recycling, and atmospheric control.
- 1st floor: Hospitals, medical research and development and pharmaceutical laboratories, and communication node (telephonic wiring and the Colony Wide Web networking and servers) and funeral services.

In order to move among floors, there are 3 rings of lifts, heavy elevators and mechanic stairs displayed according to the volume of use: the more peripheral, the more abundant.

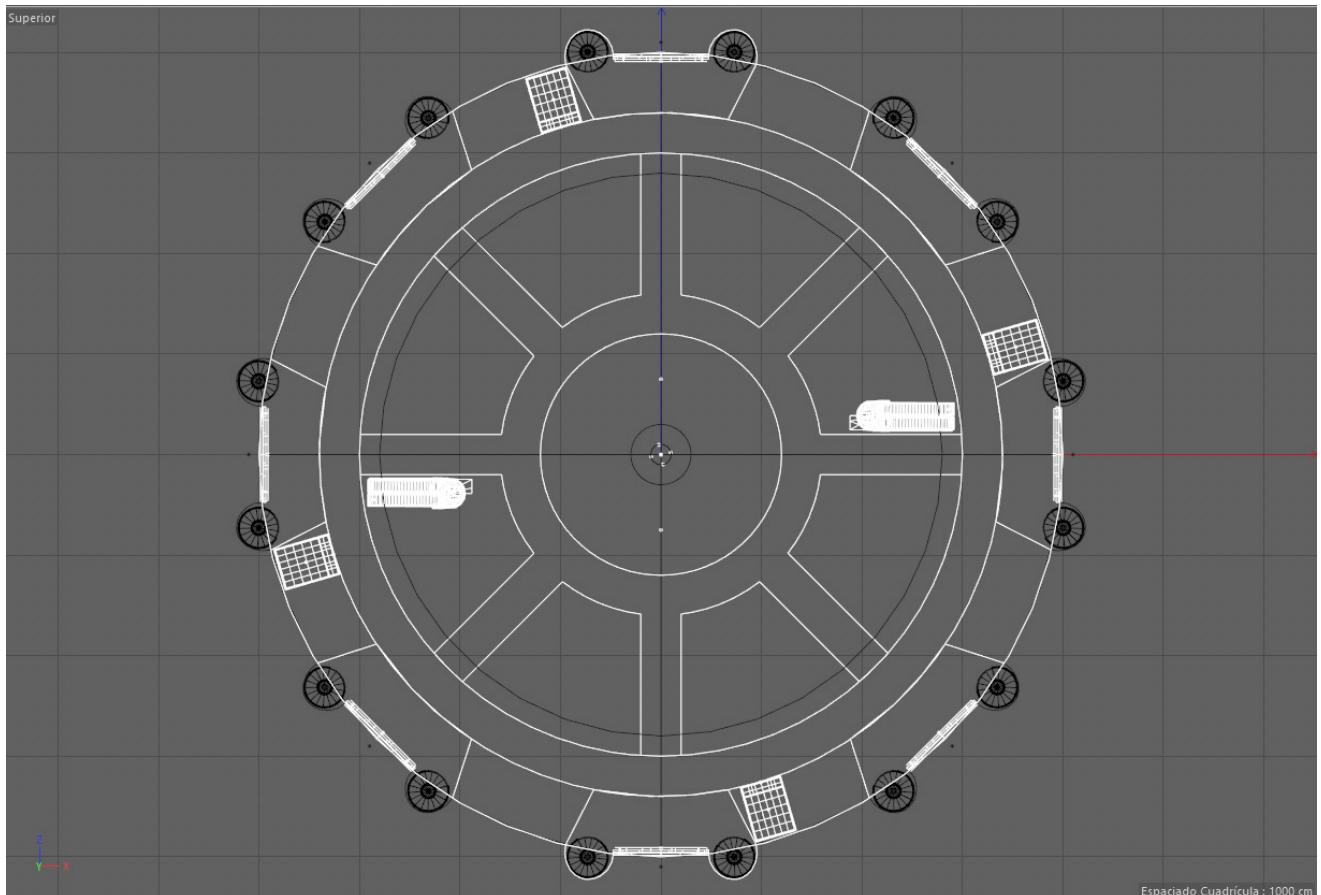
However, this appointment is **flexible enough to adapt to circumstances**. According to the new necessities, we may add sports stadiums, cinematographic studies, great auditoriums, or even a parliament palace. We have no boundaries yet. Further details of planning will be discussed in the point 04

03. COLONY PLANNING OUR MAN VIEW

03.3 Structure and planning

District morphology

As we have said, each Tocho has 20 districts, which are the residential areas whose last floor is 15m deep underground. We can separate each district in two parts:



→ A central cylinder of 40m of radius and an initial height (or depth, maybe?) of 72m. There, it is where people can satisfy their daily needs. Here we can find the light dome, an important part of the district, because it's how we will deliver natural sun light inside the district. Due to its importance it will be explained at point 03.4.

→ 8 Residential Branches per floor, corridors with 10 houses for each side (20 by branch) connected to the central cylinder and to a boulevard.

The districts and the Tocho are connected by a subway and a boulevard just like in image.

For subway's connection, there would be another floor (see section 4.4).

Districts and Tochos have their outer breast walls excavated in the martian rock, like vertical caves, and a set of stylized columns to bear the whole weight.

03. COLONY PLANNING OUR MAIN VIEW

03.3 Structure and planning

Possible distribution

In this section we propose a possible internal distribution of the central cylinder of a district. Remember: this is just a proposal; the people will be able to build according to their needs and reorganize the distribution after; also, we don't include the transport floor because it would be explained on section 4.4.

Our approach supposes that districts are complementary 2 by 2, that is: you will not find every primary service inside one district, but are spread between two districts. This way, two districts must be directly connected, by a boulevard and a subway in this case; allowing people to easily satisfying their needs and encouraging the movement between districts.

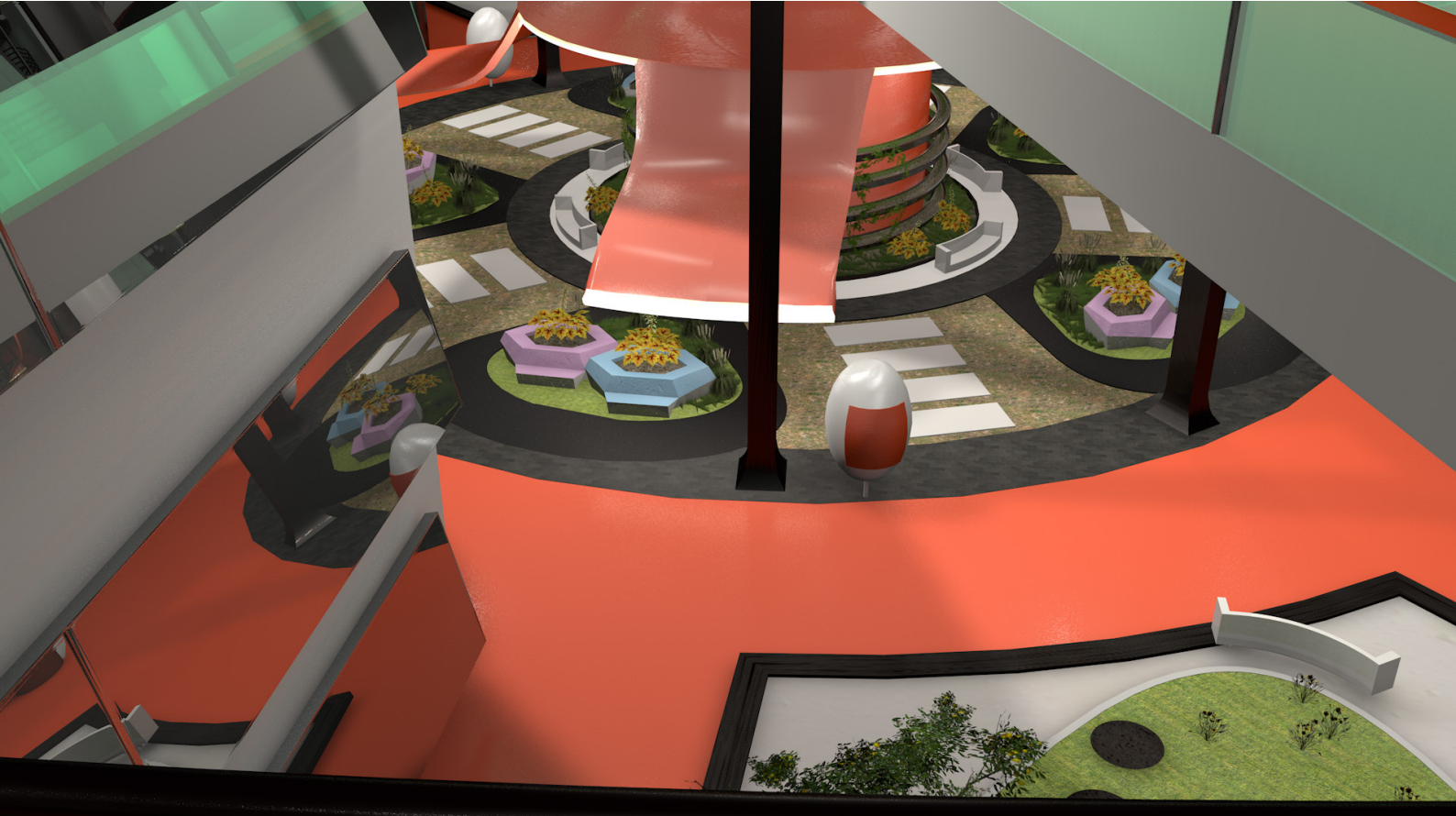
In the next table we show the possible distribution of the two complementary districts:

	District 1	District 2
<i>7th and 8th floors</i>	School and educational institutions. A Theatre.	Sport area. Gymnasiums and sport shops.
<i>5th and 6th floors</i>	Commercial area: shops, recreative areas, pubs, restaurants.	Cinema, amusement arcade, VR rooms, hobbies lobbies.
<i>4th floor</i>	A small court, banks, a "town hall" and other bureaucracy offices.	A small court, banks, a "town hall" and other bureaucracy offices.
<i>3rd floor</i>	Police quarters and instruction yard.	Bomber headquarters.
<i>2nd floor</i>	Veterinaries and pet amusement zones. Forums and open sites.	Nursing home, with commodities for disabled people and elderly
<i>1st floor</i>	Clinics and medical facilities. Pharmacies.	Clinics and medical facilities. Pharmacies.

In addition, every floor may include a little kind of grocery store for daily shopping, and local bistros or coffee shops for amusement.

03. COLONY PLANNING OUR MAIN VIEW

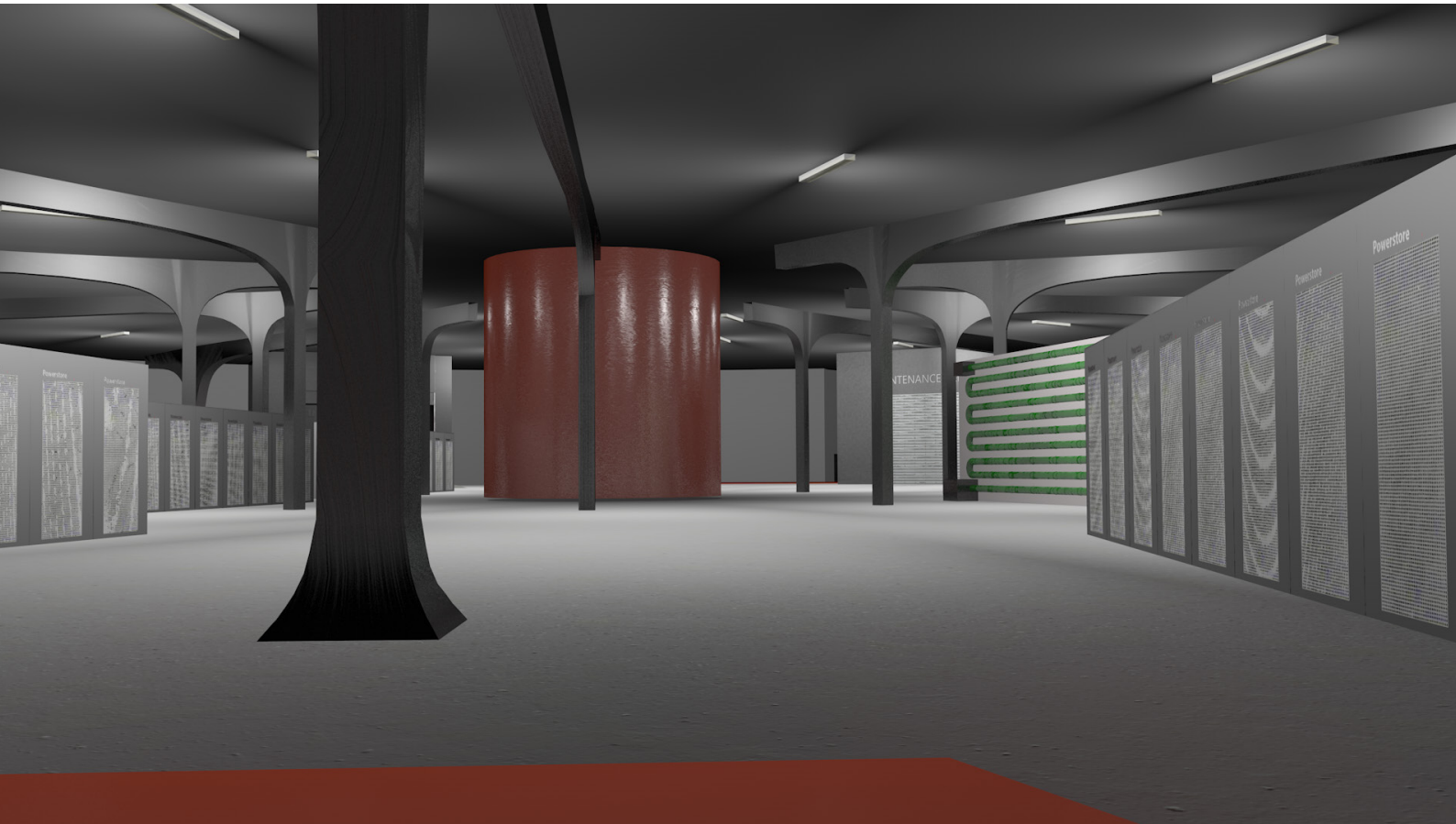
03.3 Structure and planning



03. COLONY PLANNING OUR MAIN VIEW

03.3 Structure and planning

Maintenance floor



Every district has its own Maintenance floor. Here are located several workshops where repairing tasks can be carried out. There is a pressurizable elevator to the surface, for Dome's in situ maintenance, and workers can also bring parts from the surface for exhaustive repairing.

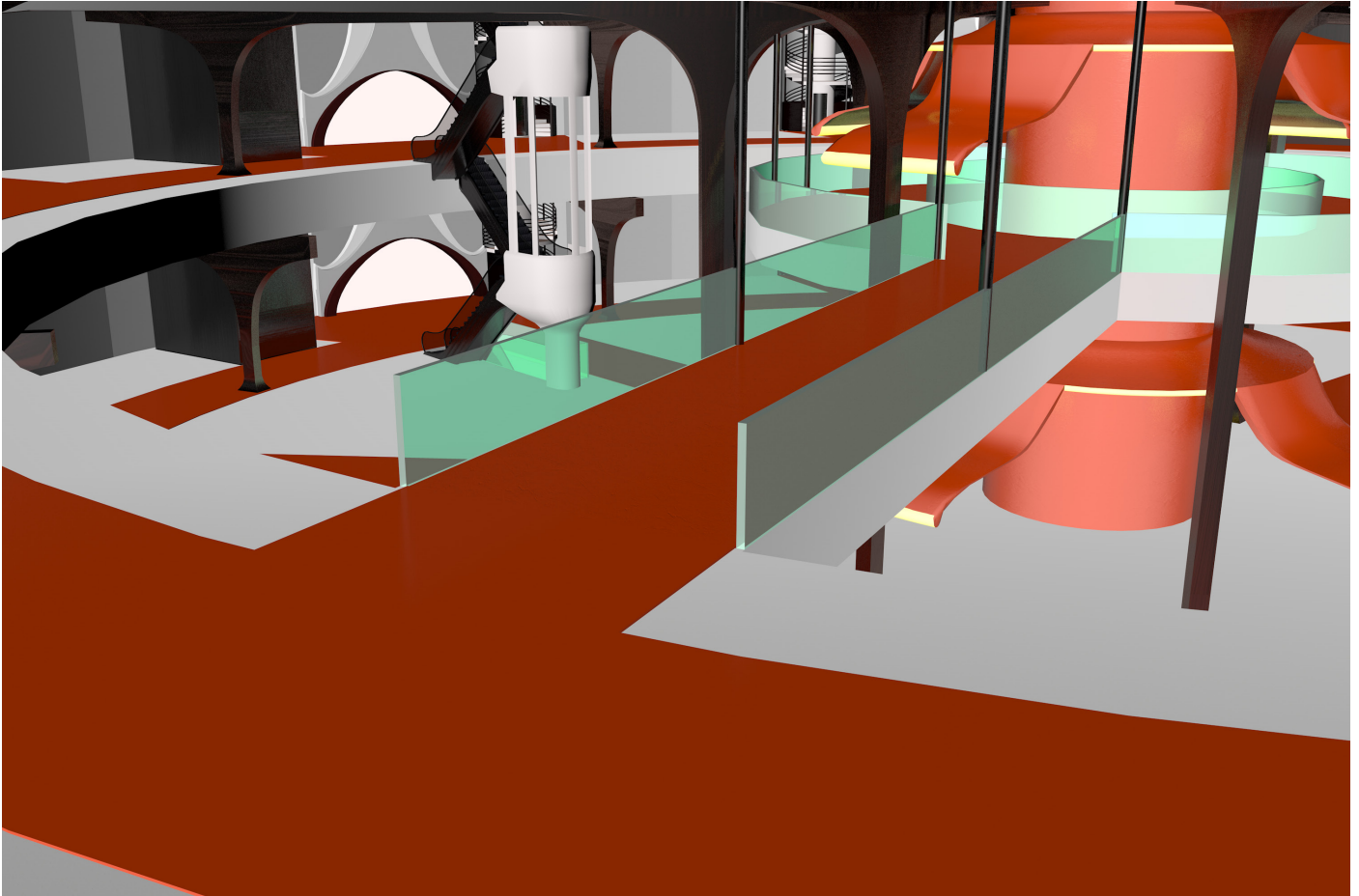
Besides, there are resources buffers for emergency store: Water tanks can supply 700 m³ if water piping is cut down; a set of 550 power stores can provide energy for one day in case of power shortage; and a dedicated microalgae plantation which generate the volume of oxygen for breathing along one day without filtering. These emergency sources give colonists the enough time for fixing the network troubles or evacuating people to another district.

You can find the consumption data of water and energy supposed in sections 4.2 and 4.1 respectively.

03. COLONY PLANNING OUR MAIN VIEW

03.3 Structure and planning

Transport between floors



Verticality is an important issue for our colony. As we have our “buildings” been constructed with various floors, we shall make up efficient ways for vertical movement.

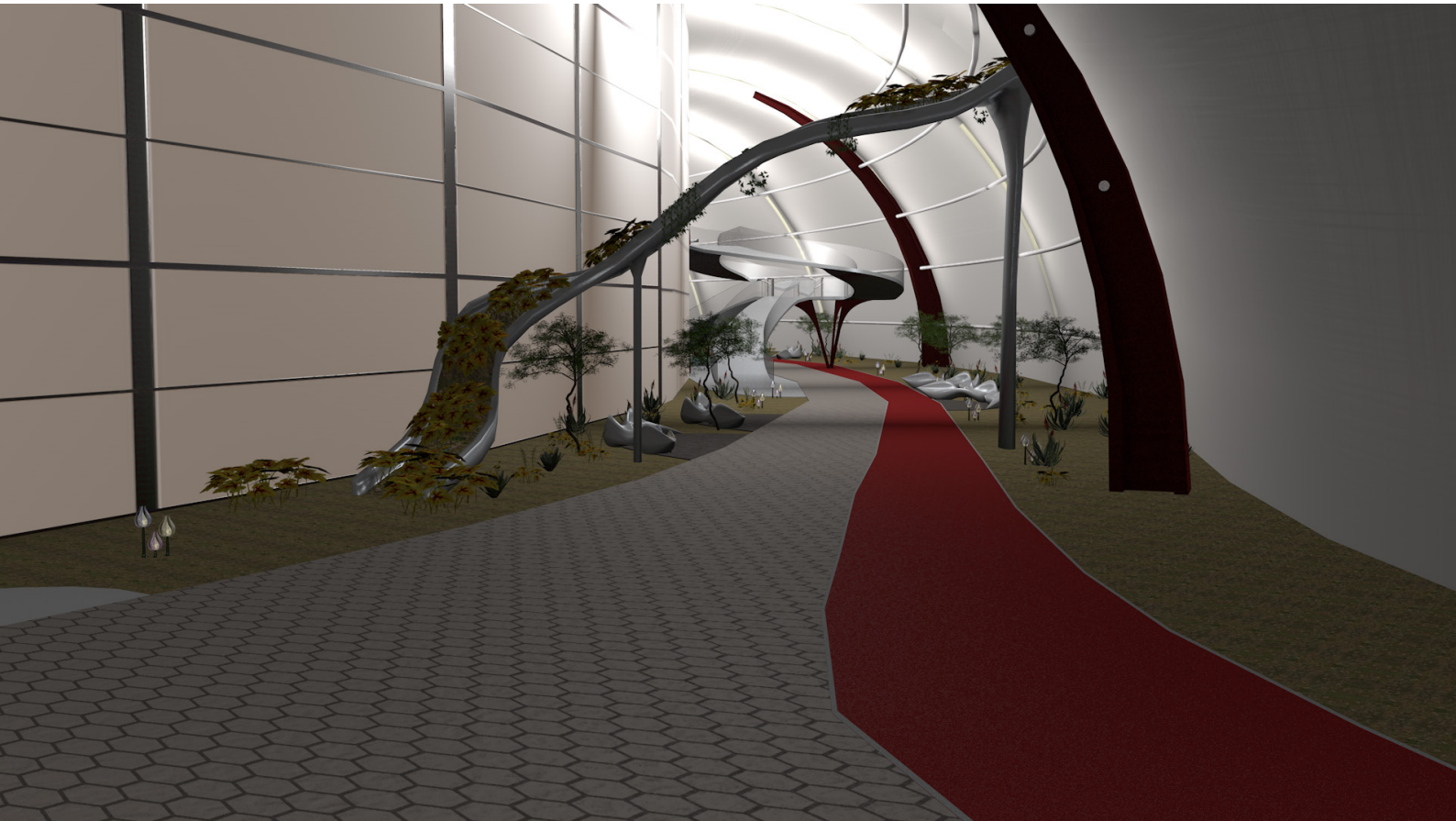
Regarding to people movement, near the residential corridors we have lifts to comfortably move between floors in groups of four, or carry low weights; and spiral staircases around it for climbing on foot. Despite of Mars’ low gravity, steps of stairs are thought as we were on Earth because, though we will be more agile, next generations would adapt to Mars environment, and our muscles and bones will also atrophy, so after acclimated we need Earth-like movement conditions. Moreover, there are mechanic stairs near the centre of the district for easy vertical shifts.

Regarding vehicles (mostly service-related ones) lift trucks were deployed in the outer ring of the district, holding up to 45000 Kg (3 times the maximum weight as Earth).

03. COLONY PLANNING OUR MAN VIEW

03.3 Structure and planning

Boulevard and green areas



But not only bread live human. Being confined underground could become one of the hardest challenges to beat for colonists, as they can feel imprisoned and get depressed without being able to "going out". That is why we planned to add "green" open zones for amusement and relaxing. The central area of the district is dedicated for a small park where hang out, sit to sunbathe and give the feeling of "oasis beneath the desert" thanks to the light dome system(see 03.4). Around the districts there are 2 Boulevards. People can access to the first boulevard through residential branches on 7-8 floors and to the second , through residential branches on 1-2 floor . A boulevard is a wide promenade filled with grass areas, not-so-tall trees, and flower beds for walking, sporting, gathering and other ludic activities. It also connects two districts to the Tocho, and it is planned to connect adjacent districts from adjacent Tochos as well.

03. COLONY PLANNING OUR MAN VEV

03.4 The Light Dome

As we have previously said, living on the surface of Mars is complicated, but the life in the underground also has a big problem: the darkness. We can illuminate the entire colony with LED lamps, bulbs or even fluorescent materials, but the sun gives us life. We want to take advantage of sunlight. People need sunlight for health reasons, but as there are dangerous radiations outside going to the surface to sunbathe is not recommended. Our solution is “bringing” the sun to the underground, and this is possible thanks to the **Light Dome**.

The Light Dome uses mirrors to collect and redirect the sunlight to the district, and then, diffract light in the interior. The mirrors only reflect light and UV radiation (which can be filtered or attenuated), but not dangerous cosmic radiations, so people can sunbathe in the underground without unnecessary risks.

It is not only a dome, it consists in 3 parts:

- 1-The exterior mirrors, orientable, which reflects sunlight to
- 2-The Dome, that blocks radiation, and concentrates the sunlight, and sends it down to
- 3-The central axis, what distributes the same light to every floor.

Utilities:

1st Health.

It is demonstrated that the absence of sunlight is related with insomnia, depression, stress, lack of vitamin D and calcium; and increase the amount of our white blood cells.

2nd Day-Night cycle.

In the underground we do not have a time reference, so the sun will be our reference for day and night.

3rd Light and heat.

The principal purpose is having light underground, and the concentration of sunlight heats the mirrors and the central axis. This heat could be used to save energy for calefaction, though it involves a problem for the material selection.

<http://www.eltiempo.com/archivo/documento/CMS-11568443>

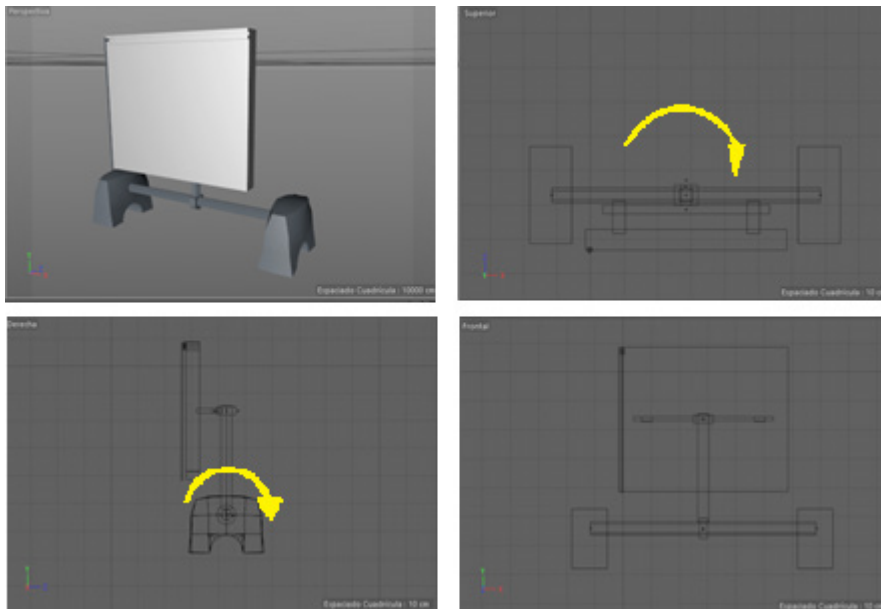
03. COLONY PLANNING OUR MAN VIEW

03.4 The Light Dome

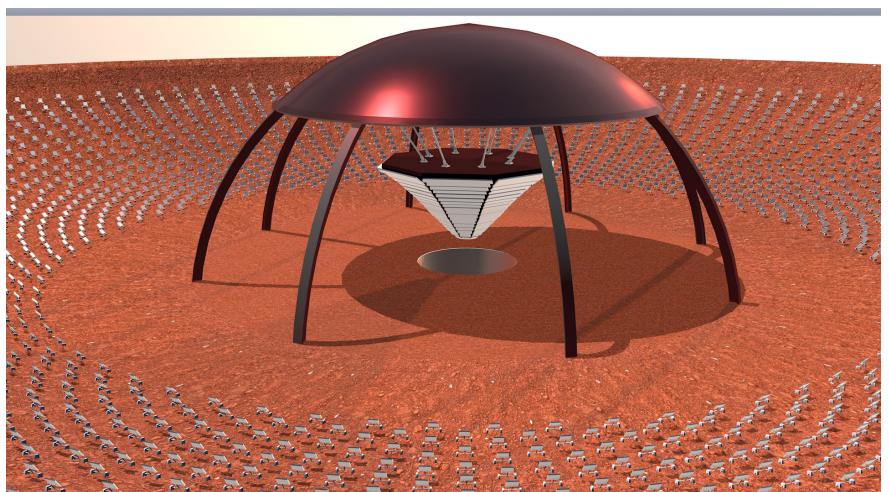
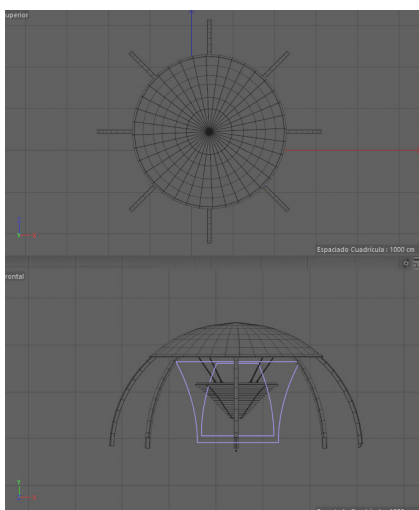
The exterior mirrors

The exterior mirrors orientate themselves to reflect the sun to the center of the dome. It has two turning axes, pitch (bottom left picture) and yaw (top right picture). Orientating the mirrors let us having the same angle between the sun and the dome along the day, to reflect the most quantity of sunlight we can. Besides, mirrors are autonomously solar powered, they are flat (easy to manufacture), and can be put down during night or sandstorms to prevent damage. It has also a brush to clean the dust automatically.

They are around the dome, and some elevation is better to take more sun and a better angle. There are 2500 mirrors approximately for each district. The dimensions of the mirror are 50x60x7cm and 77x90x30cm with the support.



The dome



03. COLONY PLANNING OUR MAIN VIEW

03.4 The Light Dome

The dome consists in the holding structure and the pyramid.

The structure is compounded by 4 beams that support a radiation insulating cover, which avoids direct radiation enters in the hole that goes to the district.

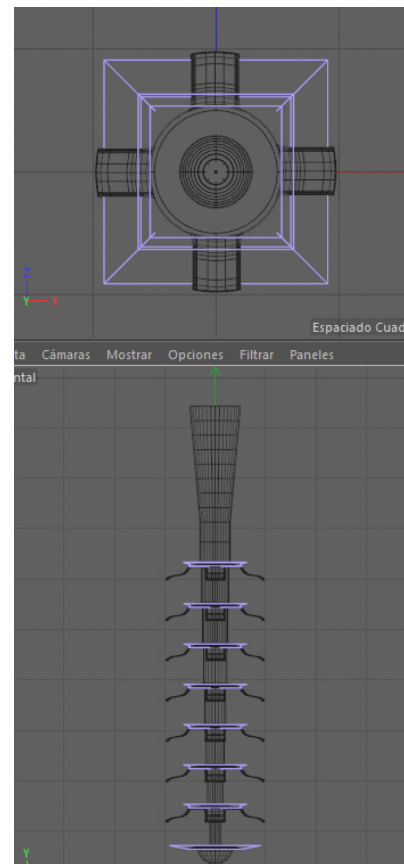
The pyramid is a deformed octagonal pyramid, attached to the structure with 8 steel wires. The core of the pyramid, that can be solid or hollow, is covered by 144 mirrors in 18 levels, that can rotate small angles to reflect the sun to the hole. Due to the number of mirrors that spot the dome, the temperature around the pyramid would be high, meaning a remarkable difference of temperatures between day and night, leading to material dilatation problems.

The central axis

The central axis is a big hollowed column located in the center of districts. The axis works similar to a channel of light, distributing light in all floors.

The top is a truncated conus, 5m radius in the top and 3m radius in the base. Following the cone, there is a 2-pieces structure:

The exterior cylinder that has 3m radius; and the interior structure, a succession of cylinders which reduce its radius every floor. The ring area is the same in each floor, this is, we have the same sunlight area for every lamp. In the different sections, the light is reflected by mirrors to a circular lamp, which has two parts: the cone, that captures the light from the axis; and the Moser' lamps. These lamps are a transparent container with water and chlorine inside, that diffracts the light, illuminating the center of the district.



04. COLONY PLANNING THOUGHT BUT NOT MODELLED

04.1. Energy supply

Like it or not, we are nowadays energy-dependants. We are used to turn on a switch and, voilà, let there be light. On Mars, energy will play an even more important role, because all our chances of survival will rely in air filtration, pressurization, water recycling devices, and other machinery that needs power to work. We can neither forget the commodities we are accustomed to, and all the illumination needed in the underground. To sum up, not a trivial affair. In this section we will discuss the results of a quick energetic analysis we have done.

First, we searched for an approximate estimation of how much energy would we need per human and day, or power (counting on street lighting, industrial manufacturing for daily products, and life support). NASA estimates that is needed 5kW per crew member²³. Being optimistic and having a strict policy of energy saving (this is the reason why we didn't consider an active field for colony protection), we calculated an energy quota of 7kW per human, which means we have to produce 7GW power for all the colony, or 700MW for every Tocho. The way we obtain that huge amount of energy was widely discussed, and we have collected our thoughts of using the energy sources known for humankind.

Solar power

The Sun is the most promising source of clean and efficient energy to use in Mars, but without the proper calculations, we were not sure the viability of its efficiency. Let's take a closer look into mathematics around it.

The energy radiated by the Sun is of $4 \cdot 10^{23}$ kW, that attenuates in with the distance by the equation $1/r^2$, where r is the distance between the Sun and a point in space.

To Earth, we receive a mean power of 1kW/m² of our star²⁵, and it is at 1 AU distance form Sun. Mars is located 1.5 AU away from Sun, which quickly makes us thought in a reduction of 2.25 times the total power per square meter that reaches the surface, approximately 0.444 kW/m² (the most accurate calculus is

$$: \frac{4 \cdot 10^{23} \text{ kW}}{(227.9 \cdot 10^9 \text{ m})^2} = 0.51 \text{ kW/m}^2).$$

Additionally, if we suppose we have high-efficiency solar panels²⁶(hybrid perovskite panels, with an efficiency of 44.5%), we estimate a production of 0.2kW/m² power. To sum up, we consider we can power a Tocho with 3.5·10⁶ m².

What a huge surface covered in solar panels, isn't it? Our plan is produce around 40% of total energy needed with photovoltaic power, covering approximately 700 ha for every Tocho.

Nuclear power

Unfortunately, Cold Nuclear Fusion is not yet discovered (neither seems plausible), and Hot Nuclear Fusion is still being investigated with discouraging results, but we still have the quite-reliable nuclear fission. Despite of the fact that is very contaminating, its use could be crucial for space colonization, and NASA is currently investigating its use in small reactors²⁷. Though very expensive, we could maintain colony's energy levels pumped up with periodical not-enriched Uranium shipments from Earth, or searching for Uranium veins in Mars. We plan to produce near a 60% of total energy this way, keeping power plants 5km away from the city.

04. COLONY PLANNING THOUGHT BUT NOT MODELLED

04.1. Energy supply

Coal and fossil combustibles.

In previous sections, we have seen the minerals present on the surface of Mars, and coal is not found between them. While it is rather unlikely that coal could not be found in Mars undergrounds we cannot rely on finding a coal vein that could not be enough for us, so we rejected coal as a viable energy source. Transportation such a massive material would not be a viable choice either: the costs are exorbitant for only little weights, and we would need tons; and the time needed is too long, for emergency supplies in shortage situations. On the other hand, fossil fuels are not present in Mars, and its processing facilities consumes lots of energy. We have also rejected its use.

Biofuel

Bio-oil and bio-alcohol extracted from microalgae could be used to power certain industries and devices. In relation to vehicles, we discourage its use in the colony because of carbon oxides produced by combustion; and for outdoors use, we would have to think in a new combustion engine able to inject both fuel and oxidant to produce energy. Despite of these facts, biofuel is taken into consideration and not rejected yet.

Aeolian energy

Harnessing the strong winds and storms that occurs in Mars surface was the first idea we had. Using the following equation²⁴ for power (with its respective data):

$$P = \frac{1}{2} \rho A V^3 C_p$$

Where:

ρ is density in Kg/m³ (0.02)

A is the area swept by rotor in m² (considering $r = 3m$, $A = 9\pi$)

V is mean velocity of air in m/s (10)

C_p is the maximum power coefficient, which estimates the power harnessing, and bounded superiorly to 0.59 (we consider an optimistic 0.5)

P is power obtained in watts.

With these values, we obtain a power of $4.5\pi \approx 13.9W$ for every aerogenerator. We cannot use big aerogenerators for risk of breakage due to tensions in storms, and we will not always have such strong winds, so using the wind power is proven inefficient.

Other sources

You might have realized at this point we did not talk about some interesting sources as geothermal or hydroelectric energies. We are not taking these into consideration because the little evidences of the presence of it.

In conclusion, combining a thick energy policy, solar and nuclear power, and an optimised plan, we can light up our future in Mars.

04. COLONY PLANNING THOUGHT BUT NOT MODELLED

04.2. Water and mineral extraction

In the beginning, we will need to ship a “boost pack” for colony building tasks with some materials and machinery, but once the core of the colony is established, we are going to extract the prime materials for manufacturing and building. The presence of iron, aluminium, clays, etc, gives us the chance to obtain nearly 90% the metals and materials we will need in Mars. Mineral prospecting expeditions around colony emplacement will scan for ore veins before we settle mines and ore loading facilities. Once loaded in cargo vehicles, will be carried to ore processing industries in Tochos, and readied for several purposes.

As well, we will do the same with water: although we will have closed water cycles, the volume of water needed should be taken from underground reservoirs in Mars. We hope to find these reservoirs of liquid water under great pressure, or even ice mines. Closed in special pressurized tanker trucks, water will be transported to water treatment plants before using them for consumption. We consider a person would roughly have a consumption of 900 litres of water considering industrial, maintenance and farming uses, which means 90000 m³ for people of one Tocho.

04.3. Waste management. Water and air recycling and processing

We do not conceive life on Mars without efficiently managing wastes. It is not a choice, it is a duty. Today, Global Warming is one of our first concerns, and we shall not miss it when colonizing other planets in order to not fall in the same errors we committed in Earth. Instructing colonist to effectively separating wastes and using handy waste transportation system embedded in house's walls and ground, we can change the paradigm in trash processing.

Firstly first: separating. Plastics derived from biomass can easily be manufactured to be biodegradable, and put together other organic wastes for compost and nitrogen recycling. Not-biodegradable plastics could be recycled for extended lifespan, as well metal from scrap can be reused. Glass from martian silica-rich sand can be easily reutilised. Specific recyclable materials (batteries, oils, paints, etc) would have a point where being deposited for further transportation to specific plants. All those wastes that cannot be recycled would be accumulated in dumps outside the colony, but only those whose recycling is impossible.

You may now be thinking “No paper separation?”. Well, although it is possible to farm trees for paper industry, our vision does not involve its use. All the situations where paper would be needed can rely in electronic devices with personal credentials, electronic newspapers, official documents, and even books. Trees are very valuable for cutting them off and converting them in paper.

Following the separation, a transportation system of conveyor belts will carry wastes to Tocho's recycling sites, where being processed for other uses or reutilization.

Water will also be treated. Sewage water would be conducted to water treatment plants through sewers-like pipelines, and perfectly deputed for human consumption (that is why people shall not litter water with any pollutant harmful or which could make impossible water recycling).

Air will be constantly controlled as well. Humidity will be regulated to human comfortable levels, toxic gases will be measured and filtered, and CO₂ used to feed photosynthesis of all the plants across the colony. In emergence case, expulsion of gases to Mars' atmosphere is taken in consideration, we can breathe easy.

04. COLONY PLANNING THOUGHT BUT NOT MODELLED

04.4. Vehicles and transport

It is not possible planning a colony without thinking the way people and freight will move around, and vice versa. Transport is another mainstay in our project. Though we are not modelling any kind of vehicle or transport specifically, we had into consideration which features vehicles shall have, and how transport inside and outside the colony shall be organized.

Firstly, let's talk about energy. Transport as we know in Earth, with heavy combustion engines, will be remembered as an obsolete technology. Air (specifically, oxygen) is a scarce source on Mars. Outdoors we simply cannot find the oxygen needed, and having vehicles working with air-polluting engines indoors is not the greatest idea we can have. That is why all the vehicles will be powered by electrical engines and long-range batteries. Charging stations will be in garages, and near critical colony sites. The only exception is outdoors vehicles, which will have a hybrid design: will have an electrical engine powered by batteries and solar panels; and a hydrogen combustion engine, powered by oxygen/hydrogen power cells in case the batteries are depleted, and no sunlight can reach the panel. Once the way our vehicles are powered is decided, we decided to sort out the transport by different scope, so we can choose the suitable vehicles for each purpose.

Private vehicles

As you may have already realized, distance inside a district are really short. Even going from one point to the farthest of a Tocho would only take half an hour on foot. Considering this, and the fact that we have little space, the use of big, personal cars is quite a waste of space and power. So, we imagined people will move by bicycle, fostering healthy habits, or using self-balancing vehicle (this is, Segway-like) transports for covering long distances and moving light to medium weights.

These transports would be a modified version of Earth's, because we would need far less effort to move in Mars, and providing surplus power could carry disastrous consequences and unwanted accidents.

Some signposting would be also added for safety reasons.

Public transport

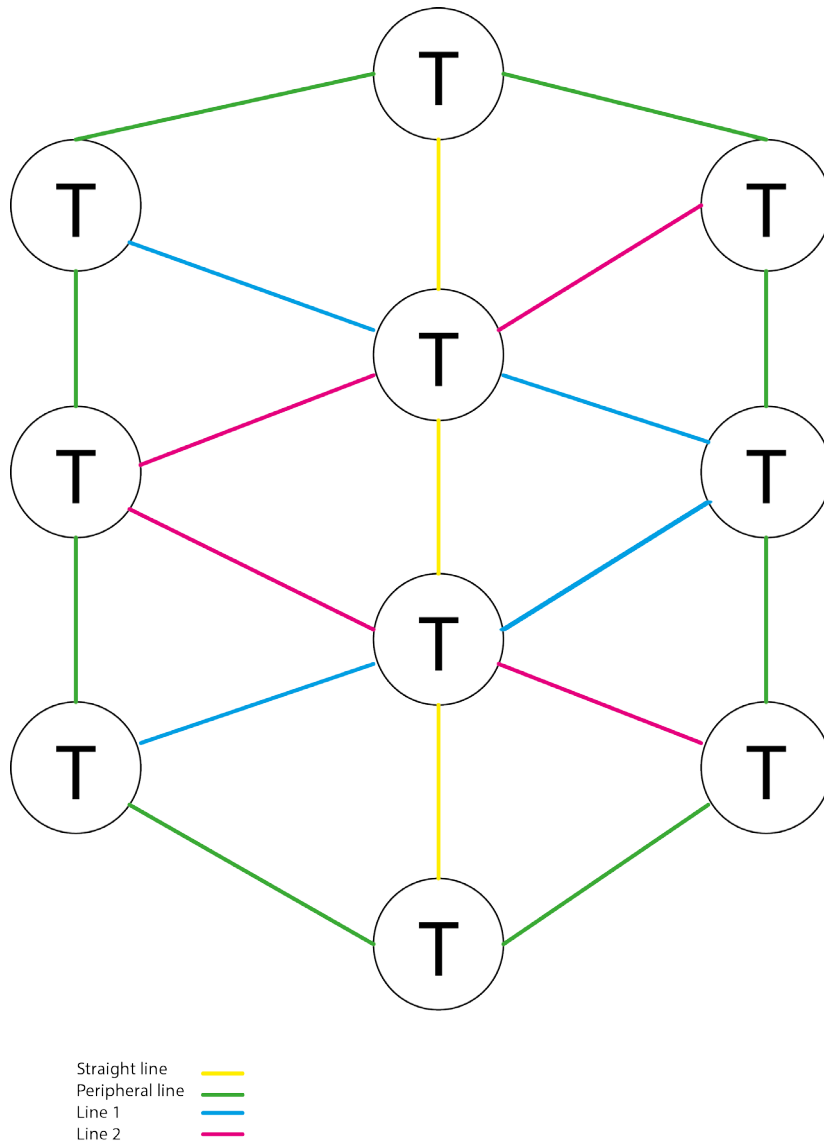
As well as distances inside a district or even a Tocho are short, time factor is determinant in transport, so it is tiredness. A public transport system was planned for these reasons, a sort of magnetic-levitating trains (for reducing friction) traveling through an intricate tunnel network, pressurized for emergency cases.

Every District and Tocho has a subway station under the deepest floor, where light trains circulate between the two farthest districts in a Tocho, this is, as we have 10 symmetrically set branches, we have 5 bidirectional lines inside a Tocho. That is not all, every line has 3 lanes: A lane for personal transport; a lane for cargo transport; and the last, but not least, for medical evacuation and emergency movement of firefighters, police, etc. This way, we can get to any point of the Tocho in less than 5 minutes.

04. COLONY PLANNING THOUGHT BUT NOT MODELLED

04.4. Vehicles and transport

To move along the Tochos, a quicker, bigger subway would be used in a deeper subfloor of the station, in a similar way as short-distance transport, but larger in shape. The lines would consist in a circumvallation line around peripheral Tochos, a straight line for the farthest from each other Tochos, and two "V" shape lines covering the rest of opposite Tochos. This way, you can go from a Tocho to another passing through less than 4 stations wherever you go to, or come from.



Service transport

There will be situations where vehicles would need to be driven inside the district. Carrying packages and mail in a van, evacuating patients to a clinic in ambulances, or bringing a fire truck for extinguishing a burning, are examples where service vehicles are suitable. The dimensions inside the colony are prepared for let these vehicles passing between buildings, as the streets are 4 meters wide. Once again, power would be lesser than Earth analogous, and also lighter, as we would not need over-hardened heavy shells to protect the interior from other vehicles. They can use elevators for vertical movement, and can use emergency lanes for traveling fast to the Tocho or another district. Efficiency is always a priority for emergencies.

04. COLONY PLANNING THOUGHT BUT NOT MODELLED

04.4. Vehicles and transport

Outdoor vehicles

Extra-colonial activities should need a more specified vehicle. Harder than indoors counterparts, they shall not only have more autonomy, but redundant systems (power, life support), spare space for EVA-suits use inside, and guidance and positioning systems. Outdoors maintenance vehicles, exploration rovers and freight trucks for mining shall implement these features.

Space port and vessels

The surface above the colony is full of photovoltaic panels, the domes, monitoring stations and other delicate stuff. So, you know, I'd be cool if a space vessel doesn't break anything in a failed landing, don't you think? The Space port will be sited several kilometres away, in a flattened parcel of the martian surface, for landing safely. An outdoor bus will carry new colonists to inside, and shipments from Earth could be brought by trucks. A launching pad could be built for future "returning trips" (as we need far less fuel for the take-off), satellite launching, and far more.

04. COLONY PLANNING THOUGHT BUT NOT MODELLED

04.5. Communications

As communication is the fundamental of society, we want to devote this section to it. We will need a deep thought about the way we communicate both inside and outside the colony, and also between Earth and Mars.

An Earth-Mars communication may be carried out by UHF radio waves using directional, Line-Of-Sight antennas embarked in satellites. But we come across 2 problems: firstly, Mars can be concealed by Sun; secondly, the time the wave needs to travel from one planet to another ranges from 3 to 20 minutes, due to the long distance between them. We can solve easily the scenario where Sun hides the planets with a communication satellite orbiting the Sun and been used as a repeater, but we would never have instant communications, so we have to get use to high delay communications using previously recorded messages.

For colony comms, indoors and outdoors comms are treated separately.

Outdoors communications will consist in LF waves with tall antenna towers for long-range comms with outside facilities and vehicles, and enormous parabolic antennas will be used for satellite comms.

Meanwhile, indoor communication will be an evolution of telephonic wiring. Why using landlines when you can use personal devices to communicate wherever you are? Why using old copper wiring when you can benefit from glass fibre connections? Why only communicate inside the colony when you can even send messages to people in Earth? We introduce you to Mars Network, the WAN for Mars' colony. Using continuously connected devices like cell phones, you can communicate with anyone, anywhere, using VoIP technology, inside the colony or outdoors. This WAN will have Li-Fi repeaters for wireless connection, minimizing radio interferences. It also will be directly connected to the first ISAN (Interplanetary Satellite Access Network) in order to communicate with Earth, though not simultaneously.

04. COLONY PLANNING THOUGHT BUT NOT MODELLED

04.6. Manufacturing and industry

As we have a high-technology colony, we will need the means to give support and keep it working. Our lives are conditioned to using all kind of manufactured stuff, from forks to cell phones. Harnessing the prime materials from Mars is our main focus, as we should not depend on Earth shipments except for punctual, unobtainable resources. In this section we show the main industries we thought that might be used.

Metal industry

Metals will settle the base of manufacturing, along with ceramics industry. We differentiate in two main ores:

→ Iron and steel: our bread and butter. Structural frames, furniture, tools, all those whose resistance is a key feature shall be made of different types of steel. Iron is quite abundant in Mars surface, so obtaining would not be a problem. Treatment and refining will not differ from Earth methods.

→ Aluminium: as a light metal, is the best choice for vehicle chassis, casings and light, mobile structures. Al-rich phyllosilicates presents in martian ground can be a good extraction vein.

Jobs where other metals are needed should be reimagined. In example, unless we find copper veins, electrical wiring should be made of electrical-use steel wires (as we use in high-voltage lines). In those cases where material replacing is not an option, Earth shipments would be necessary.

Ceramic industry

Martian soil is compounded of clays and fine dust, the main source of ceramics, from plain clay to porcelain. These materials will not be only for decorative purposes, because we plan to use the revolutionary material, Marscrete, a concrete-like material that needs no binder to harden, and used to craft bricks and plates for building walls , floors and even structural parts like pillars. Construction industry is also included, due to importance of ceramics.

Fuel industries

Though no fossil fuel will be used, hydrogen/oxygen fuel cells will be used for outdoors vehicle auxiliary power units. Massive electrolytical pools will separate water in both hydrogen and oxygen, for filling 2-compartments fuel cells later. Rockets could use this fuel cells as well.

Fuel from biomass, or even biofuel, could also be refined for high temperatur

Plastic industry

Plastic industry

Plastic is hygienic and easy to manufacture, light and used in a wide variety of purposes. The very problem of them is their source, the oil, but we have not the means to transport it from Earth in enough amount and time for efficiency. Fortunately, we have alternative ways for obtaining plastics: Natural rubber can be extracted from rubber trees, and new kinds of biodegradable plastics may be obtained from vegetables and bio-oil. With these environment-friendly plastics we may cover near 90% plastic needs for the colony. It is also the best way to obtain synthetic fabrics for clothes.

04. COLONY PLANNING THOUGHT BUT NOT MODELLED

04.6. Manufacturing and industry

Mechanical industry

Here we consider all industries involving mechanical parts manufacture and repairing, vehicle industries, robotics, movable parts manufacturing and so on. The different type of tasks will be spread over several Tochos, and will be closely related to maintenance purposes, and R&D innovations.

Medical industry

We have already talk about this one. Despite of the fact that Mars is a hostile environment for life, we can encounter with foreign alien bacteria and microorganisms (sounds scary, huh?), whose effects inside our bodies are yet unknown. We need to make sure they are harmless, or in the worst case, knowing how to fight them to not getting sick. Although microorganisms were not found in Mars, we still have to deal with our own diseases, and the health problems we could suffer for living in Mars.

To sum up, we will need medical research facilities and pharmacy laboratories in order to investigate the sickness of tomorrow, and the drugs and health habits for keeping them away.

04.7. Feeding and food processing

Here comes the big one, the reason why Mars colonization is a colossal task: feeding one million inhabitants. In an optimistic initial guess, in 1970, it was estimated that one person could subsist with only 27 m² of cultivated land in its best conditions of growth rate and crop health . This estimation regards not only feeding issues, but use for production of fuel and fibre for clothes. With this data, we can consider we will need around 2700 ha of cultivated land this way for the entire colony, and 270 ha for every Tocho. But these calculations do not consider the actual, highly productive cultivation method: Hydroponics. Hydroponics consists on using nutrient-rich water solutions and substrates for cultivating vegetables, crops, and even fibre plants like cotton, in a limited space, highly controlled, but also with a high yield. We can consider that hydroponic farms take little more than a half of traditional farms to produce the same number of crops in best conditions, and also stack several horizontal layers of farm vertically, like "bunks", in order to use the least land possible. Hydroponics also allows to cultivate a high variety of crops , and also makes possible cultivation of non-feeding plants for industrial purposes .

But, as we have said previously, "not only bread". We need animal proteins as well, or a wide battery of vitamins and supplements, that cannot be synthesized in Mars. So, the solution seems to be easy, isn't it? Let's take animals to Mars.

Well, it is not that easy.

Let's first think about transport. The idea of a Noah's Arch full of chicken, cows, pigs and other tasty animals crossing the space in a long trip to its final destiny is more like a grimdark sci-fi plot than a real option. We would need an incredibly huge spaceship, or a huge fleet of currently available spaceships to transport all the animals to Mars, and carry all the food they will need during the trip. Moreover, 1-3 months of space trip will radiate animals to hazardous levels for human consumption, and all breeding after these could render unhealthy cubs for breeding.

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04. COLONY PLANNING THOUGHT BUT NOT MODELLED

04.7. Feeding and food processing

About breeding, we would need a great variety of healthy, strong animals for breeding, because breeding with a small set of breeding animals could result in genetic diseases. Furthermore, we cannot stack animals in low-space environments, they get stressed and anxious, lowering meat quality and finally causing sudden death to animals.

Next comes a picky question: what animals grow in Mars. Every mature cow consumes about 9 tons of food per year. Yes, 9 tons, while humans can subsist with around 1-2Kg per day (700Kg a year), and breeding them also needs 15 m³ water per year. Chicken needs around 36 Kg of food and 4m³ water per year, and pigs around 5 tons food and 10 m³ water. Considering the data of 2010 of this chart, approximately 30 Kgs of cow meat, 23 Kgs of pig meat and 81Kg of chicken meat are needed per capita a year. An average mature cow produces 450 Kg of meat, an average pig produces 300 Kg of meat, and an average chicken produces about 3Kg meat; adding all, for the colony, we need about 20000000 chickens, 60000 cows and 80000 pigs, increasing the food total consumption to 1660 Kilotons of food. Without counting on pasture feeding, space for animals to be located and gas produced that would be evacuated, maintaining such farms are such a great waste we cannot afford in Mars.

So, what to do? Can we already press the panic button? Of course not! Recently, researchers have achieved to elaborate synthetic meat from animal stem cells. The so-called (and bad-called in our opinion) "lab meat" is nowadays a reality, and affordable. The quality, though not the same as traditional meat, is good enough to satisfy the most whimsical tastes, and what is better, reduce energy consumption to 45%, water consumption to 99% and the land used to nearly the same amount. The nutrient serum is currently compounded by blood, sugar and amino acids, but we are nearer and nearer of obtaining a blood-free serum. The stem cells are easily obtained without harming the animals, and can be shipped efficiently and shielded from all kind of radiations. Scientist are also researching synthetic milk for daily products consumption, and we consider it plausible choice, but that is another story.

Last, but not least, besides contributing to ecologically maintaining a safe ecosphere inside the colony, we also go a step beyond in social terms, and create a completely cruelty-free environment, in where future animals will live only like companions of biosphere, not products of consumption. We can contribute to make future a better place to live for all of us.

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05. CONCLUSION

After all these sections, we hope you got an accurate idea of how we see the imminent future, our view of a colony in Mars, our view of the following step in human civilization progress. There is a lot left in our minds, as we cannot even imagine such a great project at such detail level, but we have settled the very basis of our new home, so the colonists can customize and adapt it to their necessities. They will be able to modify our mere thoughts into a real future. They will render our mere ideas in a reality beyond the stars.

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