NASA Space Settlement Contest 2007

[1]

Small Group 9-12 Grade

Can Becerik
Ahmet Okan Özaydın

[1] "The Return To Abalakin", Alexender Preuss, http://vampeta.cgsociety.org/gallery/378795/

Acknowledgements

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Finally, we heartily thank NASA for organizing this contest, which made us gain a broader perspective concerning the space technology.

Foreword

"I should not proceed by land to the East, as is customary, but by a Westerly route, in which direction we have hitherto no certain evidence that any one has gone."

Christopher Colombus

For the past two years, we have been participating in the NASA Space Settlement Contest with projects ATA-1 and ATA-2, with different teams each year. This year, we didn't begin from scratch; we aimed to further improve our first prize winner project ATA-2. We chose a new name simply for the sake of a more universal approach to the concept of space settlements. We also tried to involve more mathematics and calculations this time (thanks to our increased level of knowledge by the help of the previous projects), making our project more concrete rather than an abstract one, and we integrated the concept of nuclear fusion power into space settlements, mostly inspired by a formal agreement by the international consortium to build the reactor ITER, signed on November 21, 2006.

This challenging work has been completed after many months of toil and work. In the process of preparation, we sometimes worried about not being able to finish all the topics, but we never lost our belief in succeeding. Our success may not be winning the first place, but we certainly succeeded in learning many things about Aerospace engineering, Environmental Sciences, and even political and social issues. We are glad for what we achieved by working on such a project.

One of the greatest inspirers of PINTA is the famous Italian explorer Christopher Colombus, who, with his belief and determination, have changed the horizons of whole humanity. Just as Colombus, who was brave enough to proceed to "a direction nobody has gone", we aim to proceed for the direction of space settlements, also "a direction nobody has gone".

The name of the settlement, "PINTA", is the name of the fastest of the three ships used by Christopher Colombus on his first voyage across the Atlantic Ocean in 1492. The new world was first sighted by Rodrigo de Triana on the Pinta on October 12, 1492 [157]

Replica of the Pinta[157]

We chose the name "PINTA" since it is a landmark in the history of humanity, expanding our horizons and beginning the age of discoveries. We hope our settlement to do the same for the world, beginning the age of space colonization.

The impact of PINTA on the Education in Turkey

PINTA not only represents the passion and enthusiasm of a group of high school students, but also a promising attempt of our country in the fields of space industry, which is unfortunately one of the fields it has fallen behind. In this project, one of our aims is to take a step to attract the interest in this field, and encourage other schools to participate in such contests. We hope that in the future, with more people interested in space sciences and developing projects like ours (in which we pushed to the limits of our imagination, and supported our ideas with scientific facts, and designed a settlement where we would like to live), we could help space sciences and astronomy to be of more importance in our country's education system, as well as the general governmental science policies.

The political and economical aspects of PINTA

As a group, we thought not only about sustaining daily life in the station, but we indicated the importance of such a station in terms of the maintenance of the international peace. With a multinational environment, PINTA will be a symbol of peace and tolerance among the nations of the world. That is why; we especially worked to prepare a suitable constitution which would provide an equal and peaceful environment for all the people from different nations to be able to live together, along with the physical and biological aspects of the station. Our aim is to create a fair environment of comfort, friendship, peace and equality, as we wish to see in the world.

Chapter I - Construction of the Station

Chapter II – Atmosphere

Chapter III - Nutrition, Water and Waste Management

Chapter IV - Power

Chapter V – Radiation Shielding

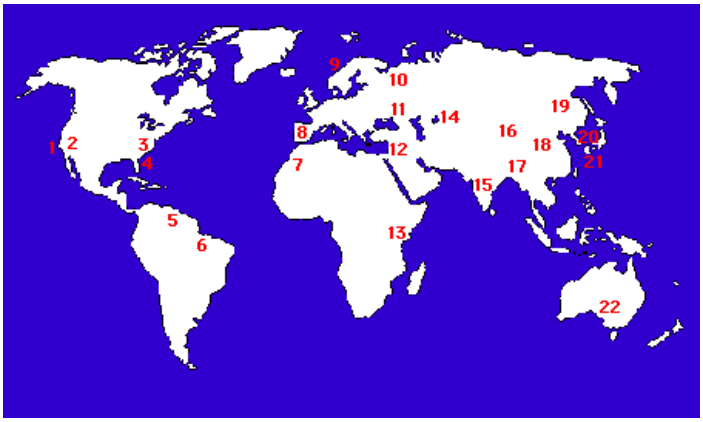
Chapter VI - External Transportation

Chapter VII – Social Life

Chapter I - Construction of the Station

I.A. Launch Site

The transportation between the Earth and the station is essential for the construction of the station. The construction materials will be carried from the Earth to the Lagrangian points, and there, they will be processed for the building of the station. In order to minimize the expenses of transportation, the launch site should be located near the geomagnetic equator; because the gravitational pull is less on this area, due to the shape of the Earth, and fuel consumption is diminished as the rotational speed of the Earth is increased. Below on the diagram, numbers indicate the launch sites on our planet.



Italy's San Marco platform can be suitable for the launches. On the diagram, number 13 indicates the location of this launch site. Its coordinates are; Latitude 2.9° S Longitude 40.3° E. Italy's San Marco Range is in Formosa Bay, three miles off the coast of Kenya. Santa Rita platform holds the firing control blockhouse [(1)]. The range started firing rockets in 1966. The San Marco station is not used since 1988, although the platforms were certified until 2014[(2)]. The San Marco platform is one of the closest platforms to the equator. This is preferable for spaceports for a few reasons: It allows maximum use of the Earth's rotational speed, provides a good orientation for arriving at a geostationary orbit and the rotational boost increases the amount of mass that can be lifted to a given orbit with a given amount of fuel. The launches therefore can be carried through this launch platform.

I.B. Location of the Station

I.B.a. Orbits around the Earth

As it is known, orbits, are the paths followed around the Earth by spacecrafts. According to the function of an artificial satellite launched from the ground there are several orbits around the Earth, which differ in height. For simplicity, eliminating the effect of other celestial bodies near the Earth, we can state that, on an object revolving around the Earth within an orbit, there are two forces acting to keep it revolving. The gravitational pull of the Earth and the centripetal acceleration the object experiences, which causes the object to feel a 'centrifugal force'. When these forces balance each other, the object stays in the orbit.
If the centripetal acceleration is;

$$a = \frac{v^2}{r} \quad (3)$$

Then the centrifugal force caused by this acceleration is;

$$\mathbf{Fc} = ma$$

$$\mathbf{Fc} = (mv^2)/r$$

According to Newton's law of universal gravitation, every object in the universe attracts each other, with a gravitational pull given in the equation below;

$$F = G\frac{m_1 m_2}{r^2} \quad (3)$$

If the two forces balance each other then;

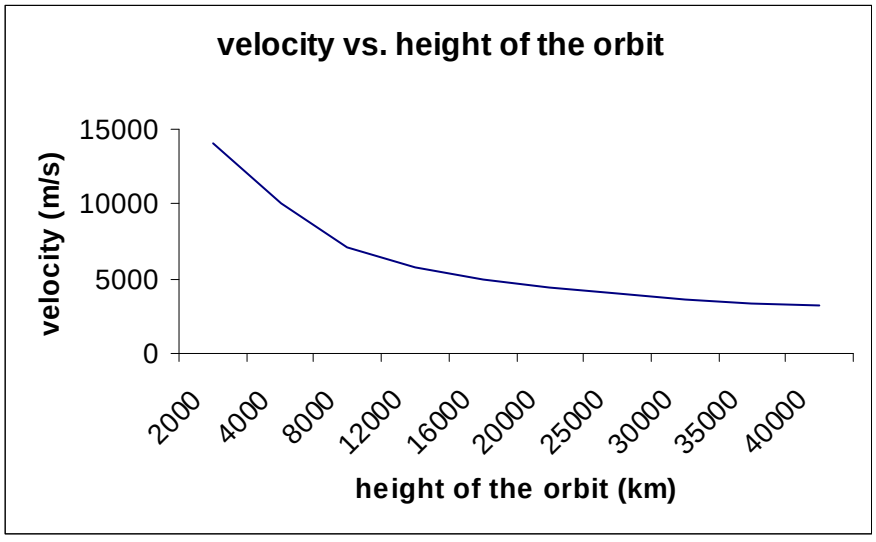
$$\mathbf{G\,(m.m_E) / r^2 = m\,.\,v^2 / r}$$

Where;
m; the mass of the object in the orbit
$\mathbf{m_E}$; the mass of the Earth
r; the distance of the object from Earth's center
v; the speed of the object.
G; a universal constant (6.67×10^{-11} N.m^2/kg^2)

In terms of the velocity and radius of the orbit, the equation can be written as;

$$V = \sqrt{(6.67 * 10^{-11} * 5.98 * 1024/(6380 + r))}$$

In the equation above;
5.98×10^{24} is the mass of Earth, and 6380 km is the radius of the Earth.
If we plot the v values on the y-axis and the r values on the x-axis, we would obtain a graph like the one below;



Graph - 1

By looking at the graph, we can easily determine what the velocity of a spacecraft will be revolving in an orbit, if we know the height of the orbit from the ground.

For the PINTA space station, we are interested only in the Geosynchronous orbit . , whose height allows the satellites moving in it to have the same angular speed with the Earth, and thus they seem fixed on a point on the Earth. From the equation of the graph above, we can determine the height of the geosynchronous orbit;

$$V = \sqrt{(6.67 * 10^{-11} * 5.98 * 1024/(6380 + r))}$$

We know that in this orbit v must be such that the satellite revolves around the Earth with the same period that the Earth rotates on its axis, which is once in 24 hours.
If; $v = (2\pi r) / T$
then the radius of the orbit must be;

$$r^3 = 6.67 \times 10^{13} \times 5.98 \times 10^{24} \times 24^2 \times 3600^2 / 4\pi^2$$
$$\underline{r \sim 35{,}870 \text{ km}}$$

The height of the orbit from the ground is found to be approximately 35,870 km. If we put this value to the graph on a graphing calculator, the graph yields the velocity of the satellite to be approximately 3072 m/s, which corresponds to 853 km/h.

The reason why we are interested in the geosynchronous orbit is that we want to locate the Solar Power Satellites (SPS) in this orbit (See Chapter IV – Power). Although the station will be located on a Lagrangian point, as explained later, the SPS should always be above a fixed point on the ground in order to be able to transmit the energy in the form of microwaves to the receivers on the Earth.

I.B.b. Lagrange Points

There are points between the Earth and the Moon where the gravitational pull of these two bodies are balanced. When a spacecraft comes to one of these points, for a moment, the spacecraft will move with constant speed, because the net force on the spacecraft becomes zero. When the spacecraft passes these points and moves toward the Moon, it will start to accelerate again because now it is monitored by the gravitational pull of the Moon.
Joseph-Louis Lagrange (1736-1813), a French mathematician, while dealing with some calculations on Earth-Moon relationship, determined five points in which the gravitational forces and the centripetal force on an object are balanced[(4)].

L1, L2 and L3

The first Lagrangian point (L1) is between the Earth and the Moon. Although the net force on this point is zero, this point is very unstable. If the object at this point moves in the Moon-Earth direction, the three forces acting on the object will make the object move back to the L1 point. However, if the object moves in another way other than the Earth-Moon direction, the object will fall to either the Earth or the Moon. The second and the third Lagrange points (L2 and L3), are also located on the Earth-Moon direction. L2 is on the other side of the Moon, L3 is behind the Earth relative to the Moon. L1 and L2 are not as unstable as L1; with a small amount of fuel, the object falling to the Earth or Moon can recover its position at the point[(4)].

L4 and L5

The remaining two points, L4 and L5 are the most stable points. These points are symmetrical to each other, and they are found on the third corner of an equilateral triangle whose other two corners occur on the Earth and the Moon. The difference of these points from the others, is that when the mass proportion of the two bodies, in this case the Earth and the Moon, is bigger than 25, these points become extremely stable. Since the proportion of the Earth's and the Moon's mass exceeds 25, this stableness is present in the Earth-Moon system too. The objects or spacecrafts located on these points, no matter which way they move, will

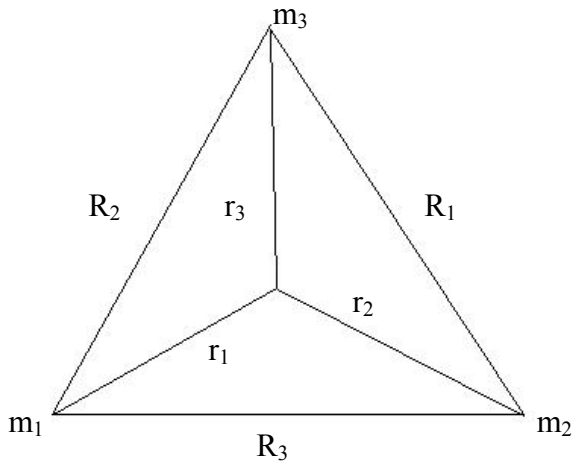
always turn to their original locations. The objects placed at these points will either stay at the point or they will revolve in a small orbit around the point. Therefore, these are optimal places to locate big spacecrafts like space stations. However when discussing the stability we did not include the effect of the other bodies beside the Earth and the Moon. If the gravitational attraction of the Sun is considered none of these Lagrange points are perfectly stable. To maintain the stability, the PINTA space station will be placed in a small elliptical orbit around the points[(4)].

The PINTA space station will be located at the L5 point.

The Derivation of the L4 and L5 Points [(133)]

In the following, the proof for the locations of the L4 and L5 points is discussed. This carries a crucial role, since it will determine the location of the PINTA space station.

We are going to show that if we have three bodies in space, in order to cancel out the effect of gravity, we have to arrange them in the form of an equilateral triangle. Clearly, these bodies will orbit around a stationary center of mass. In order to ignore the coriolis forces, and make our job considerably easier, we are going to do all our calculations in a frame of reference that is rotating with the bodies.



Since, the frame of reference is rotating with the bodies; we know that the triangle formed by the bodies is stationary. In order for these bodies not to move, the net force on each one should be equal to zero. Each body is attracted by the other two and by the centrifugal force. The centrifugal force is $\frac{mv^2}{R} = m\omega^2 R$. This lets us write the following equations, where F_{AB} stands for the gravitational pull exerted on body B by body A:

$$F_{21} + F_{31} + m_1\omega^2 r_1 = 0$$
$$F_{12} + F_{32} + m_2\omega^2 r_2 = 0$$
$$F_{13} + F_{23} + m_3\omega^2 r_3 = 0$$

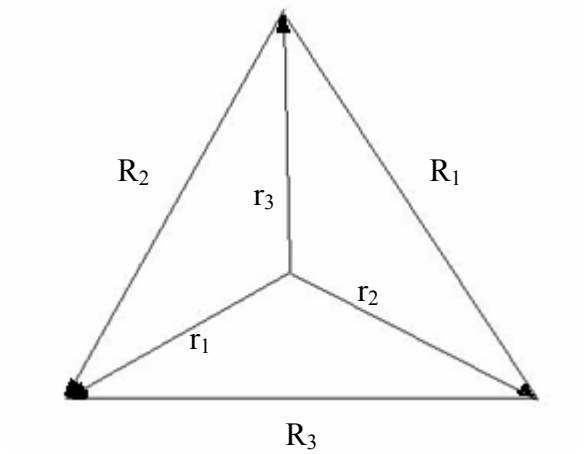
The sum of all these equations is:

$$(F_{21} + F_{12}) + (F_{31} + F_{13}) + (F_{32} + F_{23}) + \omega^2 (m_1 r_1 + m_2 r_2 + m_3 r_3) = 0$$

Since the forces are vectors, the pull on A by B is in the opposite direction of the pull on B by A. This means that we actually have the following, much simpler equations:

$$\omega^2 (m_1 r_1 + m_2 r_2 + m_3 r_3) = 0$$
$$(m_1 r_1 + m_2 r_2 + m_3 r_3) = 0$$

Having derived this identity, we now go back to our original diagram. However, this time, we interpret the line segments as vectors. Only, some of the vectors are shown in the new diagram, and we are going to use this diagram to prove that $R_2 = R_3$.



Interpreting the vectors graphically and using end-to-tail vector addition, we get the following identities:

$$r_1 = R_2 + r_3$$
$$r_1 = R_3 + r_2$$
$$r_1 = r_1$$

We multiply these equations by m_3, m_1 and m_2 respectively, and add them up:

$$r_1 (m_1 + m_2 + m_3) = R_2 m_3 + r_3 m_3 + R_3 m_2 + r_2 m_2 + r_1 m_1$$
$$r_1 (m_1 + m_2 + m_3) = R_2 m_3 + R_3 m_2 + (r_1 m_1 + r_2 m_2 + r_3 m_3)$$
$$r_1 (m_1 + m_2 + m_3) = R_2 m_3 + R_3 m_2$$

We now introduce another constant, M, which is the sum of the masses of all three bodies. Then our equation becomes:

$$r_1 M = R_2 m_3 + R_3 m_2$$
$$r_1 = R_2 \frac{m_3}{M} + R_3 \frac{m_2}{M}$$

We let $\rho_2 = R_2 \frac{m_3}{M}$ and $\rho_3 = R_3 \frac{m_2}{M}$, and get $r_1 = \rho_2 + \rho_3$. Since masses are scalar quantities, we know that ρ_2 and ρ_3 are parallel to R_2 and R_3 respectively.

We also know that if three vectors sum to zero, then they must form a closed triangle. Since the net force on m_1 is 0, the vectors F_{12}, F_{13} and $(2\pi T)^2 r_1$ form a closed triangle. These vectors are parallel to R_2, R_3 and r_1 respectively. This makes them also parallel to ρ_3, ρ_2 and r_1, respectively. Using the parallel relationship between these vectors, we know that all these triangles are similar. Thus:

$$\frac{F_{12}}{F_{13}} = \frac{\rho_3}{\rho_2}$$

$$\rho_2 F_{12} = \rho_3 F_{13}$$

$$\left(R_2 \frac{m_3}{M}\right)\left(G\frac{m_1 m_2}{{R_3}^2}\right) = \left(R_3 \frac{m_2}{M}\right)\left(G\frac{m_1 m_3}{{R_2}^2}\right)$$

$$\frac{R_2}{{R_3}^2} = \frac{R_3}{{R_2}^2}$$

$${R_2}^3 = {R_3}^3$$

$$R_2 = R_3$$

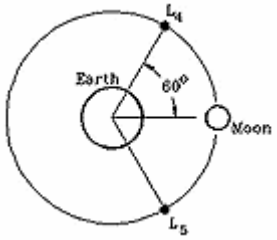
This shows that two sides of the triangle are equal in length. However, by doing the exact same calculations for the other two masses we would have found that any two sides of the triangle are in fact equal: This means that in order to have 3 bodies in gravitational equilibrium, we must place them on the vertices of an equilateral triangle.

In our case, the vertices of the equilateral triangle are the Earth, the Moon and the PINTA Space Station.

Now we need to calculate the speed of the station around the Earth. We already decided that the settlement would be placed in the L_5 orbit. Now we need to find the speed required to stay in the orbit. Newton's First Law of Universal Gravitation will help us.

In order for the settlement to stay in orbit, its kinetic energy must be equal to its gravitational potential energy. That is:

$$\frac{1}{2}mv^2 = \frac{GmM}{r}$$



The masses will cancel. The L_5 point is on the orbit of the moon. (129)

The distance between earth and moon is 384403 kilometers. (130) The radius of earth is 6,378.135 km. (130) We already decided the grater radius of the settlement to be 4000 m. Therefore, (r) will be equal to 390,781,410 meters.

$$G = (6.6742 \pm 0.001) \times 10^{-11}\ \mathrm{N\ m^2\ kg^{-2}}$$ (131)

Mass of earth (M) is equal to 5.9736×10^{24} kg. [132]

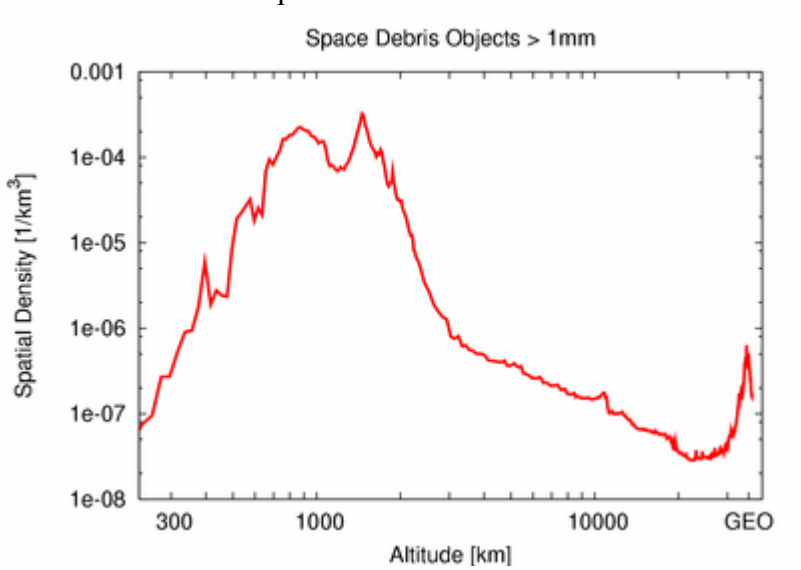
When we do the math, we find that v = 1428.45 m/s.

Therefore, the PINTA space station will travel around the Earth, within the L5 point with a speed of 1428.45 m/s.

Earth's Orbits vs. Lagrange Points

For several reasons we decided to place the station on the L5 point instead of on one of the orbits around the Earth. These reasons are listed below.

- ✓ **Material Supply.** L4 and L5 are much closer to the Moon than any orbit would be. As explained in the Material Resources section, the Moon will play a crucial role during the construction of the station and in life support systems, by being an excellent resource of materials. In addition, if the materials sent from the Moon are sent to an orbit, there will be another challenge for controlling the packages to stay in the orbit.
- ✓ **Stability.** Although we declared that because of the solar influence L4 and L5 are not exactly stable, they are better from the orbits. In an orbit, because of the atmospheric friction, which is present at very high altitudes too, the velocity of the station will eventually decrease and the station will start to lower its altitude not to fall to the Earth. Extra energy will be consumed to stay the velocity of the station constant, whereas on L4 or L5 we will not have to deal with such troubles.
- ✓ **Energy.** Because L4 and L5 are in a different plane of the Earth-Moon direction, at these places maximum benefit from the solar power can be enjoyed.
- ✓ **Space debris.** The Lagrange points unfortunately attract also small asteroids and other small bodies wandering in space. This is a disadvantage as long as the station is concerned, but with maneuvering or using weapon technologies, any crush with these bodies can be prevented. [146]



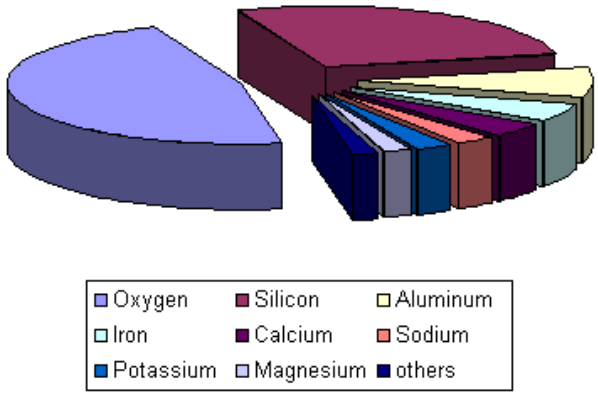
I.C. Material Sources

One of the advantages of building a space station is the abundant source of materials that is available near the location of the station. Primarily the Moon, the asteroids and comets will provide material supply. The extraction facilities to benefit from these sources are financially

convenient due to the low-g areas and diminished request of fuel for energy. The maximized use of solar energy and minimized expenses on transportation and extraction make the orbits around the Earth attractive places to build a colony. However, some elements cannot be found in neither of these, therefore some of the materials need to be shipped from the Earth.

I.C.a. Terrestrial Resources

As indicated in the diagram, Earth's crust mainly consists of Oxygen and silicates. Since transportation between the Earth and the station is very expensive in comparison with the transportation between the Moon and the station, only few materials like oxygen and nitrogen, which cannot be found elsewhere, will be transported from the Earth, along with construction materials of the station. The Moon, on the other hand, due to its low gravitational pull, will be preferred over the Earth for the materials available. Another alternative is Mars, however; due to Mars being a lot further away from our settlement, it would be impractical to attempt to provide the required resources from Mars.



I.C.b. Lunar Resources

An Overview on the Lunar Minerals Necessary for the Station

Most of the materials required for the construction of the colony and for the life support will be transported from the Moon. The crust of the Moon is abundant in water and the elements such as Si, O, Fe, Al, Ti. According to the analyses for lunar elements, at least 60% of the required silicon, aluminum and oxygen could be obtained from the Moon[5].

Mineral	Avg. Abundance from Eight Samples
SiO_2	44.60%
Al_2O_3	16.49%
TiO_2	0.036%
Cr_2O_3	0.30%
FeO	13.47%
MnO	0.18%
MgO	9.04%
CaO	11.97%
Na_2O	0.43%
K_2O	0.18%
P_2O_5	0.11%
S	10.63%

(7)

Crust composition	
Oxygen	43%
Silicon	21%
Aluminum	10%
Calcium	9%
Iron	9%
Magnesium	5%
Titanium	2%
Nickel	0.6%
Sodium	0.3%
Chromium	0.2%
Potassium	0.1%
Manganese	0.1%
Sulfur	0.1%
Phosphorus	500ppm
Carbon	100ppm
Nitrogen	100ppm

(6)

These two tables indicating the percentages of the lunar minerals give an idea of the Moon as a potential material resource. From solar panels to rocket fuels, the Moon is a perfect source of material providing the required elements to produce them. In the following sections of this chapter the areas to benefit from the lunar elements is discussed.

Important Minerals

Silicon; is another element that can be found on the lunar crust. Silicon is used in semiconductors. This makes silicon the building block of the solar panels (See Power section). Silicon as well as being the second most abundant element on Earth's crust, is the most common element found on lunar crust too. It occurs widely as the compound silica (SO_2). Silica is a hard, rigid network solid that is insoluble in water. Silica gets its strength from its covalently bonded network structure. Being strong makes silica useful in aerobraking tiles on rockets (See Transportation section). Pure Silicon is obtained by reduction with high-purity carbon;

$$SO_2(s) + 2\ C(s) \longrightarrow Si(s) + 2CO(g)$$

The crude product is exposed to chlorine to form silicon tetrachloride, which is then distilled and reduced with hydrogen to a purer form of element:

$$SiCl_4(s) + 2\ H_2(g) \longrightarrow Si(s) + 4\ HCl(g)$$

For this reduction Carbon is necessary, but the products CO can be used further processed to obtain Carbon and Oxygen[8].

Aluminum; being a good conductor and reflector, is one of the important elements needed in the station. First of all, aluminum will be used in benefiting from the thermal energy of Sunlight. Mirrors used in the 'solar ovens' will be made of aluminum. With these structures, sunlight will be focused on a point, and high temperatures are going to be obtained. The reflectivity of aluminum will be used in melting metals, electricity generating turbines (see Power section) etc. Also, the conductivity of this element makes it useful in communication and other structures inside the station. aluminum is furthermore needed for the thermite reactions during the construction of the colony (See Thermite Reaction). Fortunately, aluminum mines in the Moon exist in an attractive mineral form, anorthite ($CaAl_2Si_2O_8$). On the Earth, aluminum is extracted from bauxite mineral; however, research for extracting aluminum from anorthite are made due to the bauxite sources becoming depleted.[147] Therefore it is possible to extract aluminum from the Moon.

Titanium; is a light, strong metal that is resistant to corrosion. It is widely used as the external shield of the aero vehicles. Therefore in transportation and in construction of the station it will be widely used. Titanium can be choused as the material to cover the station. The principal sources of titanium are the ores *ilmenite*, $FeTiO_3$, *rutile,* TiO_2. TiO_2, which is known also as titanium dioxide, acts as a semiconductor in the presence of light, so it can be used in *photoelectrochemical cells*. These cells use light to produce chemicals, e.g. hydrogen from water[9] . Titanium requires strong reducing agents for extraction from the ores. (See Ilmenite Reduction).

Iron; is another element that can be readily extracted from the lunar ores (See Ilmenite Reduction). Iron ores are primarily used to make steel. Steels depending on the carbon content, have various strengths, hardnesses, ductilities. The higher the carbon content is, the more brittle yet harder the steel is. By alloying the steel, its resistance to corrosion can be improved. For example, stainless steel that contains 15% chromium by mass is highly corrosion resistant [8].

Iron oxide (FeO) which is commonly present on the lunar crust can be reduced with Carbon;

$$2FeO + C \longrightarrow 2Fe + CO_2$$

Oxygen; is abundantly present on the lunar crust. It can be extracted from the lunar ores, with hydrogen reduction as explained in the 'ilmenite reduction'. Oxygen constitutes a crucial role in life support, since it is necessary for the management of the atmosphere within the station. (See Atmosphere section) Moreover, some of the oxides, such as silica (SiO_2) are required during the construction of the station. The vehicles to provide transportation between the Earth and the station will be covered with tiles made of silica, due to their resistance to high temperature [10]. Other fields like chemical rocket fuels are the areas in which oxygen usage becomes one more time very important. In order for the combustion to take place, oxygen is needed. Therefore, in space the vehicles have to contain oxidizing elements within their combustion chambers. As understood from these examples, oxygen has many more areas where used. The Moon is a great opportunity to meet the oxygen requirement.

Water; is also found on the lunar crust in the form of ice. The lunar ice is more abundantly found on the north pole than the south pole. However, on the North Pole lunar ice is preserved at very low temperatures (around -220 8C) [11]. Therefore, the extraction of the ice would be a big challenge. Very strong machines resistant to extreme cold must be used. One way to deal with this is to benefit from the microwaves. With Aluminum mirrors, microwaves can be focused and heat can be obtained, thus protecting the machines. Despite these difficulties, water undoubtedly is crucial for life support.

I.C.c. Asteroid and Comet Resources

Comets:

Comets are mostly composed of ice and dust. Comets have a nucleus, which is hard rock or ice. As a comet gets near the sun, the icy part vaporizes. The gases vaporized from the nucleus cover the nucleus like a cloud, and this part is known as the coma. In addition to the coma, the gases and the dust particles form tails. [12]

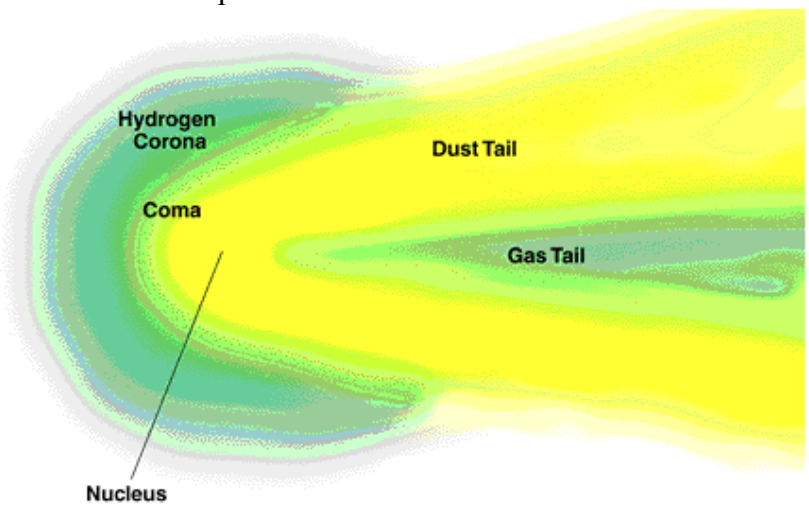


fig. 1: a comet [13]

A comet's composition may differ according to its origin. However, many of them are composed of ice. Ice is necessary for the station since ice the solid form of water. Another possibility is that the icy part may have some gas samples. Comets may also consist of metals like iron, iridium etc. [13]

There are four types of comets and the table below indicates the composition of these comets. The Superscript ^{A} indicates the elements' antimatter.

	[A]Mineral	[A]Carbonaceous metal-rich Type C2 (meteorite Renazzo)	[A]Carbonaceous matrix-rich Type C1 or C2 (meteorite Murchison)	[A]Chondrite Low-High Type C3 - C4, (typical meteorite)	[A]Iron meteorite
Free metals	[A]Fe ([A]iron)	10.7%	0.1%	6-19%	~88%
	[A]Ni	1.4%	---	1-2%	~10%
	[A]Co	0.11%	---	~0.1%	~0.5%
Volatiles	[A]C	1.4%	1.9-3.0%	~3%	--
	[A]H_2O	5.7%	~12%	~0.15%	--
	[A]S	1.3%	~2%	~1.5%	--
[A]Mineral oxides	FeO	15.4%	22%	~10%	--
	[A]SiO_2	33.8%	28%	38%	--
	[A]MgO	23.8%	20%	24%	--
	[A]Al_2O_3	2.4%	2.1%	2.1%	--
	[A]Na_2O	0.55%	~0.3%	0.9%	--
	[A]K_2O	0.04%	0.04%	0.1%	--
	[A]P_2O_5	0.28%	0.23%	0.28%	--

Composition of comets (14)

Asteroids:

Asteroids orbit the sun and they are mostly composed of rock and metal. There are three types of asteroids. C-Carbonaceous asteroids contain ancient carbon silicates. S-Silicates are another type of asteroids that are made of rocky silicates and iron. M-Type asteroids are rich in terms of metals. They mostly contain nickel and iron.

fig. 3: an asteroid [(15)]

Asteroids are mainly found in the asteroid belt which is between Mars and Jupiter. In addition to this, also asteroids can be found within the orbits of Mars, Earth, Venus, and Mercury. [(15)]

Meteorites:

Meteorites are grouped into three different types; irons, stony-irons, and stones. Meteorites consist of nickel-iron alloys, silicates, sulfides etc. iron meteorites consists two different kinds of nickel-iron alloy metals; kamacite and taenite. Stony-iron meteorites consist of approximately same amounts of nickel-iron alloy and silicate minerals. The third type, stone meteorites are the most abundant meteorites. These meteorites mainly consist of silicate minerals. In addition to these, also Metallic nickel-iron and iron-sulfide mineral is found in meteorites. (16)

Important minerals:

Comets, asteroids and meteorites consist of many different minerals that can be used in our station in different fields. First of all, they contain iron and silicon in large amounts. These minerals' areas of use are explained in the previous module about lunar sources.

Nickel is abundant in meteorites. Alloys of nickel are very useful, i.e. Nickel silver is used as a good conductor in its oxide form. Also they can be used in industries about food processing. Nickel is a very beneficial material which is put in stainless steel, to make food-handling equipments. Stainless steel does not taint the food and it can be easily cleaned. (17) In addition to this, electronic and aerospace equipments consist nickel. (18)

These materials are easily found in comets, meteorites and asteroids may be used in the station according to its needs.

I.D. Material Mining and Processing

I.D.a. Lunar Extraction Facilities

In order to extract the minerals from the lunar crust lunar extraction facilities should be established on the Moon. The construction of these facilities will not cost very much because of the low gravitational area and lack of atmosphere. However, after the extraction, further processing is decided to be handled in the L5 point (See Location of the Station) depending on the location of the station. Space offers several advantages than the Moon. These are listed below;

- ✓ First of all the lack of gravity is a big advantage. For some mining techniques to work zero-g areas are required (See Mining Techniques). The maneuvers of the spacecrafts used for the activities made in space could be done with the help of reaction wheels and magnetic fields. (See External Transportation). Moreover, if a gravitational field is needed for any purpose, it can be created with centrifuge wheels. The centrifuge wheels consisting of a spinning wheel use the centripetal acceleration to create a gravitational effect. Among the mining techniques, 'vibration' is for example a technique that requires a certain gravitational field.
- ✓ The benefit from the sun power to generate electricity for the machines to work would be maximized in space. The solar panels can be monitored to follow the sun at all times with the solar tracker systems (See Power). However, on the Moon Sun is not always available. The use of batteries or power storage systems becomes compulsory if we choose to work on the Moon.

- ✓ Instead of constructing residential areas on the Moon for the workers to live in for a short time period, the workers can benefit from the station as it is constructed.

Mining Techniques

I.D.b. Electrophoresis

Electrophoresis uses the different molecular natures of minerals, based on their affinities to different electric charges. In this technique, a tank filled with liquid is used and an electric field is created inside this tank. Two opposite walls facing each other are charges, one positive and the other negative. Here zero gravity environments are required. The mineral grains therefore will be suspended in the tank. From one wall to the other, electric charges will pass through the fluid, and the minerals will collect different electric charges due to their different natures. According to the different "isoelectric" values formed among the minerals, the minerals will accumulate in the form of parallel planes between the two walls of the tank [11].

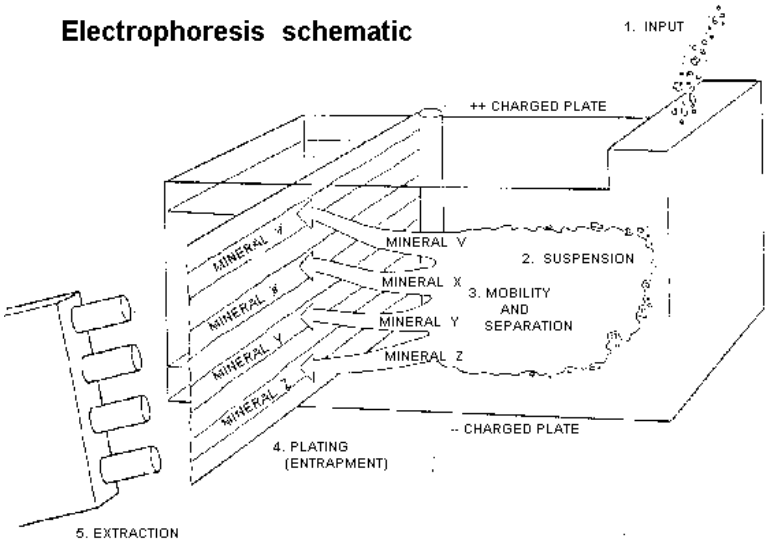


Fig. Electrophoresis [11]

I.D.c. Thermite Reaction

The thermite reaction is a highly exothermic reaction, one that can melt the metal it produces. The thermite reaction is the reduction of a metal oxide by aluminum. One example is the reaction with the reactants iron (III) oxide and aluminum;

$$2Al(s) + Fe_2O_3(s) \rightarrow Al_2O_3(s) + 2Fe(s) + \text{energy}$$

The reaction gives off so much heat that it is used to weld iron rails together. During the reaction the iron (III) oxides transforms into molten iron, which is then poured to the space between the two rails and holds them together. This process can be applied to the construction of the station, since the particle will be joined to construct the big structure. This technique is different from the others because of the fact that we will not use it obtain minerals but we will use it obtain energy to weld [19].

I.D.d. Ilmenite Reduction

Ilmenite is a compound consisting of Fe, Ti and O ($FeTiO_3$). These elements can be extracted from the ore with hydrogen reduction.

$$FeTiO_3 + H_2 \longrightarrow Fe + TiO_2 + H_2O$$

For the reaction to take place, high temperatures are needed. To create a suitable environment 'solar ovens' can be used. As it is seen from the equation above, water is one of the products of the reaction. With electrolysis, Hydrogen can be recycled for further reactions and Oxygen used in the atmosphere management. Later, iron and titanium dioxide can be separated with magnetic separation [8].

I.D.e. Magnetic Separation

Magnetic separation will be very useful since we will deal with metals. The work principle of this technique is to use the different magnetic permeability of the minerals. Since it will be hard to transport huge magnets to space, we could make use of electromagnets. Also only few elements such as iron, cobalt, nickel and gadolinium show strong magnetic effects, and they are said to be ferromagnetic [3]. On the other hand if we place a piece of iron inside a long coil of wire with many loops, which is called a solenoid, and pass current from the wire we can create a magnetic field. The electricity can be generated from the solar panels as usual.

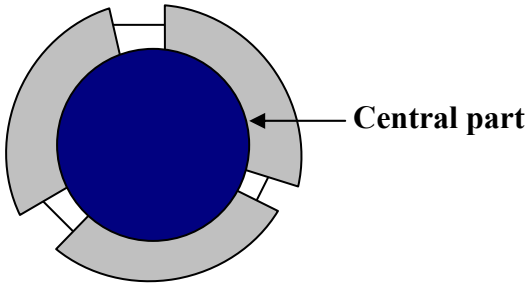
I.D.f. Centrifugal Separation

In this technique, the materials will be separated simply according to their different 'weights'. A centrifuge wheel supplied with electricity from sunlight will turn in varying speeds according to the gravitational pull desired to be created. The kinds of materials placed in a centrifuge wheel are those that do not separate quickly under the action of gravity. The purpose of a centrifuge is to provide an 'effective gravity' much larger than the normal gravity because of the high rotational speeds, so that the particles move down, or towards the outer edge of the wheel more quickly.

I.E. Assembly and Temporary Life Sustaining

During the construction processes, habitable areas must be offered to the workers. First of all, a large number of robots should be present in the area, to avoid many workers, who may be affected by the challenging conditions of space. The parts of the station will be launched from the Earth to the L5 point. We did not consider using any other Lagrangian point, because the points except L4 are not very stable, and L4 is too far from L5 to be preferred as the construction site. Instead, on L5 the construction processes will be completed.

The workers will not be kept for long periods on the construction area; there will be a continuous exchange of workers. They will shelter in the spherical case which later will become the central area of the torus. As shown below, at first three parts of the torus will be arranged around the central section, which will communicate the parts with the tunnels emerging and passing between two parts.



Later on, as more particles are sent, a larger circle will be formed around the central part, and so on. The center will rotate creating a low-g area, but it will provide the workers with radiation shielding.

I.F. Artificial Gravity

Calculating the spin velocity for the required gravity

I.F.a. Kinematics of Uniform Circular Motion

An object moving in a circle at constant speed is said to undergo uniform circular motion. In this case, the magnitude of the velocity remains constant, but the direction of the velocity changes as the object follows a circular path. Acceleration is defined as the change in velocity in a period. Since velocity is a vector, changes in its direction will constitute acceleration, just as do a change in magnitude of velocity. Therefore, the object moving in a circle at constant speed would continuously accelerate.

As shown on the diagram, at each point the instantaneous velocity is in a direction tangent to the circular path. The change in the velocity vector is shown in Fig. 2

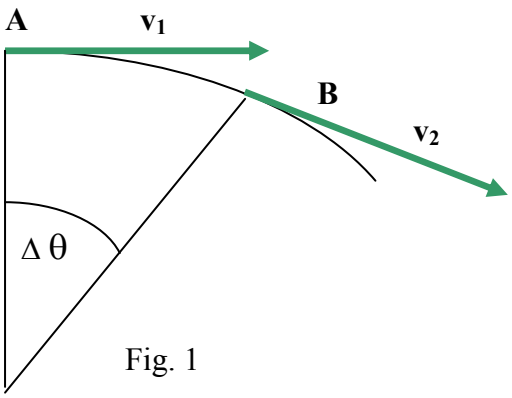


Fig. 1

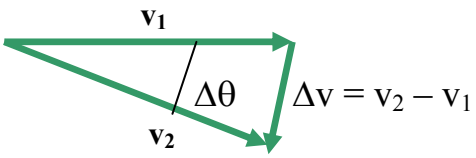


Fig. 2

Assuming Δt to be very small, $\Delta\theta$ will also be very small and v_2 will almost be parallel to v_1. In this case, Δv will essentially be perpendicular to them, and will point toward the center of the circle. Since the acceleration is in the same direction as Δv, it too should point toward the center of the circle. Therefore, it is called the centripetal acceleration [(1)].

Likewise, if the torus shaped station is rotated around its axis, it will experience a centripetal acceleration. According to Newton's second law ($\Sigma F = m\mathbf{a}$), an object that is accelerating must have a net force acting on it. If the centripetal acceleration is directed towards the center of the circle, the net force too must be directed towards the center of the

circle. In the station, with use of such acceleration, pseudo-gravity is going to be created. Although the net force due to acceleration is directed inward, the people will stand against the inner wall of the station. This is caused by Newton's third law, which states that for every action there is a reaction. The inward force exerted on the object following a circular path, causes the object to exert an equal but opposite force. This can be explained also with inertia. When a car rounds a curve, the passengers would feel that they are thrust outward. This results from the tendency of the passengers to move straight, whereas the car has begun to follow a curved path. Similarly, a constant rotation of the station will create pseudo-gravity on the colonists.

I.F.b. The Gravitational Effect Created by the Centripetal Acceleration

For uniform circular motion;

$$\mathbf{a_R = v^2 / r} \quad (3)$$

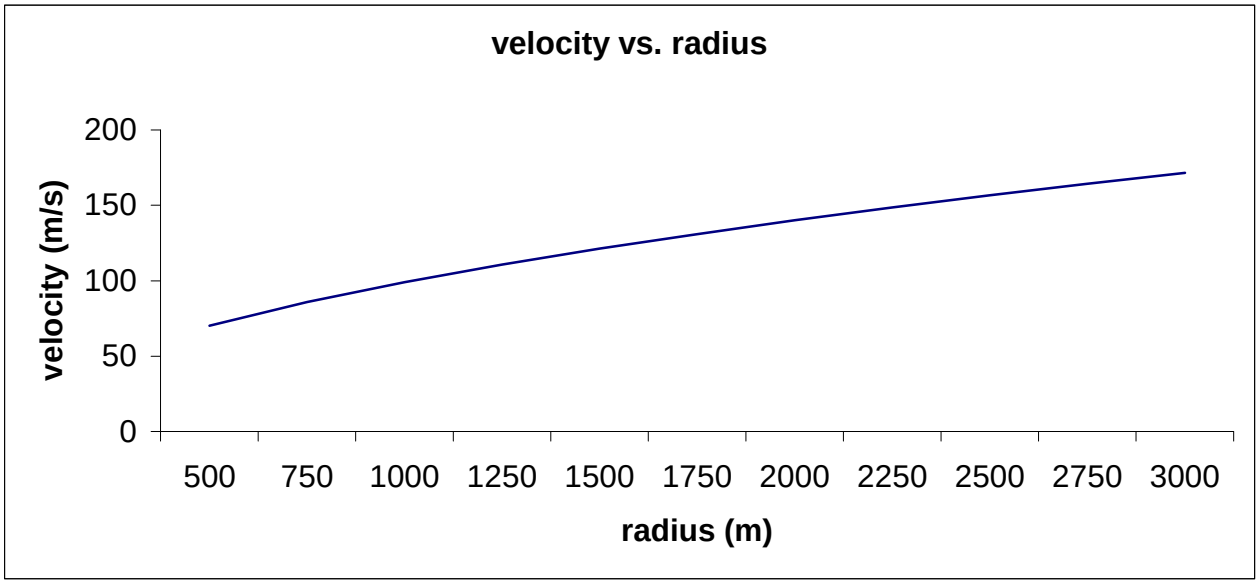
where;
a_R is, the centripetal acceleration (since it is directed along the radius it can be referred as the radial acceleration)

v is, the linear speed of the station
r is, the radius of the station.

The formula above indicates that acceleration is directly proportional with velocity, and indirectly proportional with the square of the radius, in this case the radius of the space station.
From this formula, we can derive the equation for the velocity of the station, in order to achieve the required pseudo-gravity.

If $a_R = v^2/r$,
Then $v = \sqrt{(a_R\, r)}$

Since the desired pseudo-gravity on the station is 9.81 m/s^2, the equation for the linear speed in terms of radius is, $v = \sqrt{(9.81r)}$. Below is given the graph for this function:



The graph shows the relationship between the velocity and the radius of the torus shaped station revolving in its axis, in which pseudo-gravity is established.

If approximately 150 m^2 of area per person is required in the station of a population of 10,000 people, the area of the torus shaped station will be $1.5x10^6$ m^2 . To meet the required residential area and the uninhabitable area, the larger radius of the torus should be about 4,000 m, and the smaller radius 500 m. By using these values, we could determine the angular speed of the station to create 1 g.

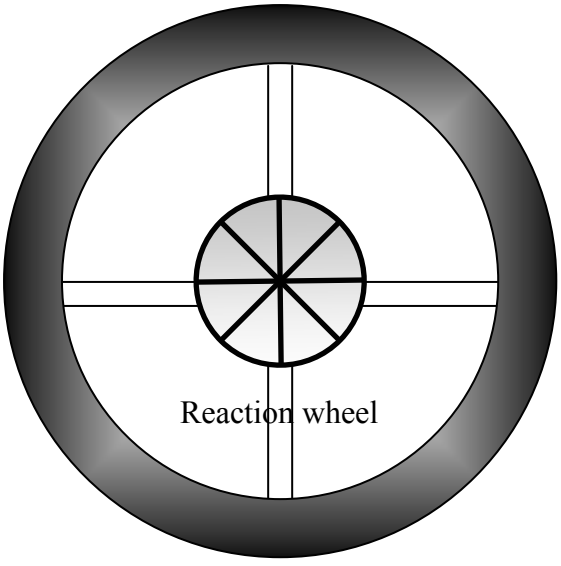
v = 198 m/s or 0,473 rpm

I.F.c. Creating and Maintaining the Spin of the Station

Different Methods to Initiate the Rotation

As used in rocket propulsions, Newton's third law will be used in creating the rotational motion of the station. The rotation of the station could be achieved with the traditional technique of using the thrusters at the outmost edges of the station. However, for the station to reach the required speed a lot of chemical fuel must be consumed, therefore we would have to spend a considerable amount of money to initiate and adjust the speed of the spin. An alternative solution for the chemical thrusters is the ion thrusters. As explained in detail in Chapter VI - External Transportation, the ion thrusters use the Xenon gas as fuel and consume the fuel very efficiently. However, they generate low thrusts; they would push the station 'gently'. Because these thrusters are very reliable, and because during the construction phase we will not need the torus to sustain high gravitational field, it is very convenient to use the ion thrusters.

A different approach to this issue is the usage of the "reaction wheel" technology commonly used in the satellites today. Based on Newton's third law, the principle of this technique is very simple. In the satellites, small reaction wheels are used to manipulate the orientation of the satellite. As these reaction wheels turn in one direction, the satellite turns in the opposite direction as the reaction force. The angular position of the satellite could then be adjusted by directing the reaction wheels to turn for a specific angle, which in turn rotates the satellite proportional to its mass. Likewise, a wheel placed at the center of the torus would provide such motion



Reaction wheel

The wheel shown on the diagram, could be a permanent solution for the manipulation of the spin velocity. The energy to turn the motors will be supplied from the photovoltaic cells generating electricity from sunlight. Solar panels mounted on the wheel would supply the energy. In emergency situations or when the station needs to decrease its speed the reaction will be turned in the same direction of the rotation of the torus, so that the torus would respond to it by trying to turn in the opposite direction, eventually decreasing its speed.

I.F.d. Coriolis Force

In a torus, there are two different radii experiencing centripetal acceleration. Therefore, there exists another pseudo-force called the Coriolis force. Two people standing on the inner and the outer edge of the torus would have the same angular speeds but different linear velocities since they are at different distances from the axis of rotation. The person standing on the outer edge would turn with a greater speed because he is farther from the axis of rotation. Therefore, if say a ball is thrown from the person standing on the inner edge to the person standing on the outer edge, the path of the ball would be deflected, and appear to be bent, and it would land behind the person on the outer edge. This effect is the Coriolis acceleration [3]. The Coriolis pseudo-forces can cause nausea, disorientation and inner ear problems, which would lower the quality of life on the station [20]. The Coriolis acceleration is given by the equation:

$$\mathbf{a_C} = -2\boldsymbol{\omega} \times \mathbf{v} = \frac{-2v}{r} \times \mathbf{v}$$

Therefore it is directly proportional to the spin velocity, and inversely proportional to the radius of the torus.

In order to minimize the undesirable effects of the Coriolis acceleration, the spin velocity of the station should not exceed 1 rpm, which is the rotation rate that humans generally can tolerate. In the PINTA space station the spin speed is 0.473 rpm, therefore, the Coriolis Effect would not be a big concern for the habitants of the station.

I.F.e. Effects of Microgravity

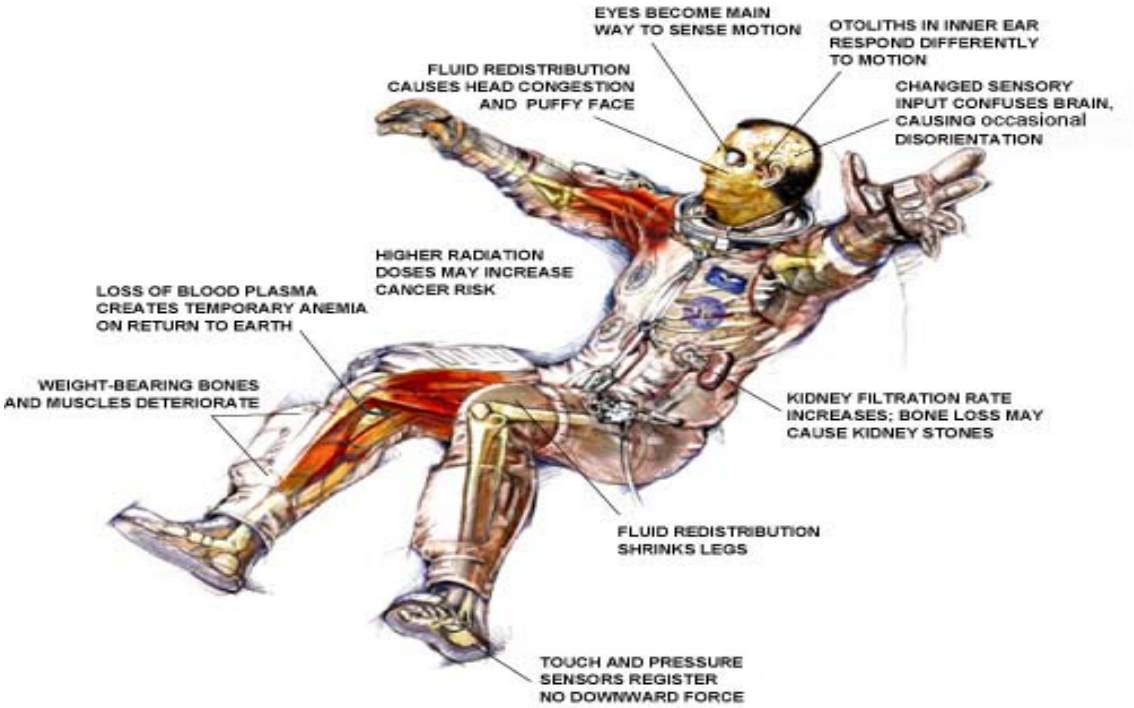
A-Introduction:

Although the inhabitants will be exposed to artificial gravity, that is equal to the one on the Earth, due to the rotational motion of the settlement, we should consider the effects of microgravity on humans. The necessity of discussing this issue arises from the following causes:

* Astronauts who are involved with the construction of the settlement will be exposed to microgravity.
* During the transportation of necessary materials, such as water and soil, from the Earth or other planets, astronauts will be influenced by microgravity.
* A certain number of people will be responsible for the outer-space oxygen-carbon dioxide balancing system (mentioned in the atmosphere part) and taking care of some other parts which are directly in contact with outer space. These inhabitants will be exposed do microgravity

* In case of emergencies, such as energy block-outs or times when the rotational pseudo-gravity system has a problem, every inhabitant will be affected by microgravity.

Although scientific studies and experiments show that animals and humans can withstand microgravity for a short period of time, long-term exposures can cause harmful physiological effects:

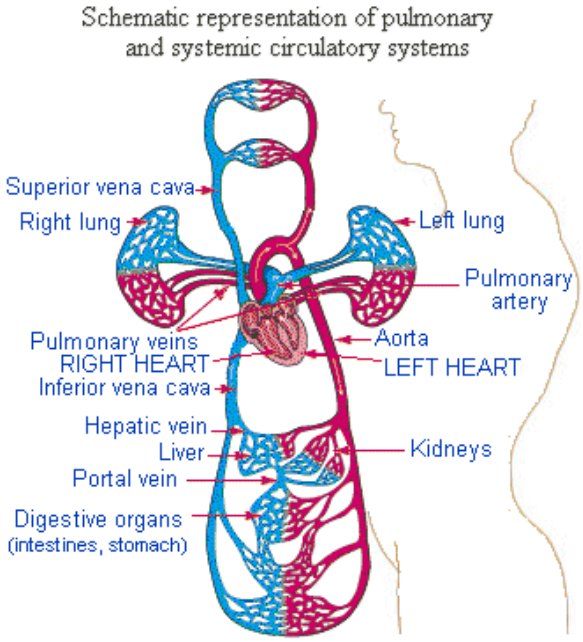


Effects of weightlessness on human body [106]

B-Fluid Redistribution:

Normally, blood pumped by the left ventricle in the heart is distributed to the lower parts of the body with the help of gravity. Since the gravitational force is downwards, blood can be efficiently distributed through vessels and capillaries to organs like limbs. Unlike the distribution of blood to the lower parts, blood is distributed to the upper parts of the body mainly with the effect of cardiovascular contractions. [103, p.469]

While deoxygenated blood is returning to the right atrium, gravity helps its downward motion through superior vena cava. However, blood coming from the lower parts of the body has to overcome the gravitational force to enter



Pulmonary and systemic circulatory sytem [5]

the right atrium via inferior vena cava. Considering the fact that the speed of blood flow decreases in veins due to frictional effects, we can realize the role of valves in veins and skeletal muscles in the distribution of blood. These valves let blood flow only towards the heart, preventing backflow. When we move our limbs, skeletal muscles situated around veins give acceleration to blood towards the right atrium. Moreover, breathing helps veins that are close to the heart with expanding and filling.[103, p.473]

When a human or an animal is exposed to microgravity, this system of blood distribution does not work properly. As a result of fluid redistribution, body fluids, especially blood, accumulate in the head and upper parts of the body, since the balance between the gravitational force and skeletal muscles/valves/valves is not maintained anymore. Dehydration is among the side effects of this occurrence, since brain senses the increased amount of fluid in the upper body and interprets this as an excess in total amount of fluid in the body. As a result, excessive execration of fluids is triggered. [104]

C-Cardiovascular effects:

In the presence of gravitational force, the heart regulates its pace and the strength of pumping commensurate with the external conditions and the demands of the body. When there is no sufficient gravity, the heart decreases its pace, sine less force is needed to overcome the effects of gravity. [104]

In addition to that, the accumulation of blood in the upper part of the body leads to a reduced re-filling of the heart with deoxygenated blood, resulting in a decrease in blood pressure and fainting. During the course of space flight and exposure to microgravity, the ability of regulating the blood pressure in upright position decreases. This is called *"orthostatic intolerance"* [105]

D-Effects on skeletal system:

Bone degeneration and calcium loss are among the results of microgravity. The cause leading to these problems is mainly the decrease in physical stress on bones. Since the stress caused by gravitational force increases bone growth and contributes to bone intensity, a decrease in the amount of minerals or bone mass can cause severe physiological problems. 2 Some experiments made on long-term space travelers show that demineralization can cause *"up to 20% loss"* in the mineral content of a bone.[108] In addition to the loss of bone mass and some minerals, muscle atrophy due to the decrease in physical stress.[104]

Microgravity can also lead to a decrease in bone marrow mass, resulting in a decreased production of red blood cells and anemia. Although this is not life threatening, it can lead to a decrease in the performance of the crewmen in the settlement.[104] An increase in the risk of osteoporosis and fractures are also among the dangers.[109]

E-Space Sickness:

Under the presence of normal gravity, the vestibular organs situated in the inner ear sense the effects of direction and gravity. During the absence of sufficient gravity, these structures cannot get the same cues, thus causing difficulties of sensing directions, interfering with balance disorders, hand-eye disorders and dizziness, headaches, and vomiting. (*space sickness* in general) [104]

Nevertheless, the symptoms of space sickness cease after 72 hours. Therefore, with the help of training and medical precautions, the effects of this problem can be overcome. [110] An environment emulating the conditions of the settlement would help.

The problem of "Puffy Face and Birdy Legs" also occurs, since fluids begin to accumulate in the upper part of the body.[111]

"Astronaut Story Musgrave on Earth (left) and in orbit (right). You can see the puffiness around his eyes and cheeks caused by microgravity." [113]

F-Effects on the Immune System:

Susceptibility to illnesses increases in microgravity, since body's immune response loses efficiency with the lessening of lymphocytes. Among the symptoms are nausea, lethargy, headache and sweating. Nevertheless, they only last for a short amount of time (usually a few days.) [104]

G-"Effects of microgravity on Cell Cytoskeleton and Embryo Genesis"[115]

Microgravity can influence cellular metabolism and reproduction. Among the risks are death of the cell/embryo and problems with the morphology of the embryo/cell.[115]

H- How to tackle these problems:

1- **Regular Exercising:** Especially during the construction period where artificial gravity might not be maintained, regular exercising is crucial in avoiding skeletal and muscular problems, especially bone loss and muscle atrophy. (We should also consider the time consuming effects of this exercising.) However, after the construction period is over, sports and other activities that require physical effort should be encouraged without putting obligations and restraining the free-will of the committee.

2- **Transportable Medical Systems:** In a case of emergency where any of the aforementioned risks turn into a danger, light and transportable medical devices should be available for professional use. These Systems can also be used for experimentation. [114]

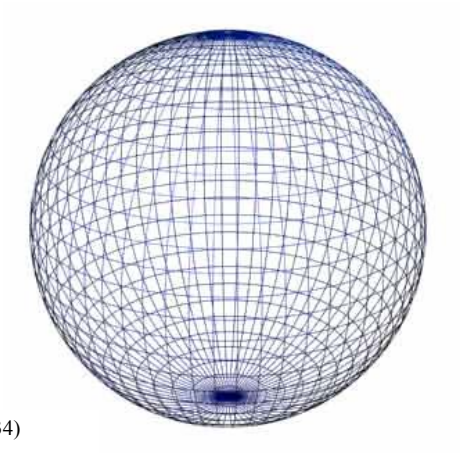
3- **Further Research on the Similarities between Aging and Effects of Microgravity**: Aging and microgravity have a lot of common side effects, such as insomnia, bone loss, decreased immune response and other skeletal problems. [104]

I.G. Structure of the Station

I.G.a. Shape of the Station – Choosing Among Alternatives

Do we have to use a torus? In this section, we will try to answer that question. Let's take a look at our alternatives. First of all, our shape must be circular, because in order to provide gravity, we will make use of centripetal force. One may claim that gravitation on earth occur even though earth is not a circular object. The answer is that earth has a relatively huge mass and radius in comparison to our settlement, and therefore the difference in the gravitational acceleration between the poles and the equator is not significant. However, if such a shape is used in our settlement, such differences will be quite significant.

After finding the basic requirements, let's take a look at our two alternatives which offer a constant radius; sphere and torus.



(134)

1. **Sphere**

When one thinks about a space settlement, it is not uncommon for him to imagine a huge sphere floating in deep space. Let's take a look at the concept of a sphere.

In three-dimensional Euclidean geometry, a **sphere** is the set of points in $\mathbf{R}^3$ which are at distance r from a fixed point of that space, where r is a positive real number called the **radius** of the sphere. The fixed point is called the **center** or **centre**, and is not part of the sphere itself. The special case of $r = 1$ is called a **unit sphere**. (135)

The surface area of a sphere of radius r is:

$$A = 4\pi r^2$$

R=4000m, therefore;

$A = 4\pi 4000^2 = 201{,}061{,}929.8\ m^2$

and its enclosed volume is:

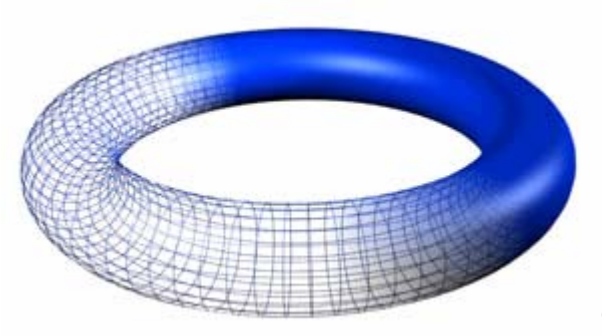
$$V = \frac{4\pi r^3}{3}$$

R=4000m, therefore;

$V = 4\pi 4000^3 / 3 = 268{,}082{,}573{,}100\ m^3$

We will get these values if we were to use a sphere.

2. **Torus**



(136)

In geometry, a torus is a doughnut-shaped surface of revolution generated by revolving a circle about an axis coplanar with the circle. The sphere is a special case of the torus obtained when the axis of rotation is a diameter of the circle. If the axis of rotation does not intersect the circle, the torus has a hole in the middle and resembles a ring doughnut, a hula-hoop or an inflated tire. The other case, when the axis of rotation is a chord of the circle, produces a sort of squashed sphere resembling a round cushion. (137)

The surface area of a torus is;

$$A = 4\pi^2 Rr = (2\pi r)(2\pi R)$$

The interior volume of a torus is;

$$V = 2\pi^2 Rr^2 = \left(\pi r^2\right)(2\pi R).$$

R = 4000 m

At this point, a critical decision has to be made. The two dimensional horizontal radius of the torus must be constant, according to our calculations. However, what we need to decide is that how much volume and are we want. When we increase r, we will have to decrease R in order to satisfy the volume. These changes will affect the volume and the area significantly. We decided that 3500 meters of height will make the colonists feel comfortable; that means r=500.

Therefore:

A = $4\pi^2$ x 4000 x 500 = 78,956,835 m^2

V = $2\pi^2$ x 4000 x 500^2 = 19,739,208,800 m^3

3. **Comparing torus and sphere – The final verdict**

Our calculations show two things: A sphere will have a much bigger area and volume than a torus of the same total horizontal radius. Now we have to consider the advantages and the disadvantages of the two designs.

Since a sphere will provide much a higher volume and area, it will provide a greater space for living. Or will it? We should consider the properties of a sphere. If we take the rotational axis vertically; or in other words, if the sphere rotates horizontally, the angular speed of the sphere will increase as we go towards the top, causing the force towards the surface of the sphere to increase. At the top or at the bottom pole, there won't be any net force towards the surface, due to the increase in the centripetal force:

$$\boldsymbol{F}_c = m\boldsymbol{\omega} \times (\boldsymbol{\omega} \times \boldsymbol{r})$$

That means, everything that is placed at one of the poles will fall down towards the center. Despite the earth is very similar to a sphere, such a situation does not occur. The reason is that people live on the outer surface of the earth. However, in our settlement, it is impossible to survive on the outer surface of the settlement, since the colonists will be exposed to free space in such a situation.

In other words, we can have the real gravitational acceleration value only at the equator in the sphere. Therefore, a lot of the extra space of the sphere will be useless.

In addition, since there will be a much higher area, the power required for the electromagnetic radiation shield will increase dramatically, resulting in a higher power demand. Furthermore, the chance of being hit by flying objects such as meteoroids will increase due to the big volume. In other words, we will have to protect the volume and area which we cannot use. This really makes the sphere a terrible choice. Considering the bigger energy requirement, not to mention the great cost and lack of space for a nuclear reactor, as well as the construction difficulties, it is not applicable to use a sphere.

On the other hand, torus seems like the perfect solution. Even though it offers less space, since there is no way we could use this extra space efficiently, it saves us from unnecessary energy consumption as well as unnecessary building and maintenance costs. The smaller volume will decrease the possibilities of a meteor crash. Furthermore, the space in the middle of the torus allows us to build a nuclear reactor or two. Considering all these, torus seems like the best choice. Torus wins!

Chapter II - Atmosphere

Introduction:

One of the most crucial properties of our space settlement is the presence of an atmosphere with a chemical composition that is appropriate for human respiration and photosynthesis.

To provide this, we should first shield the settlement against radioactivity; so that rays coming from the sun will not have deleterious effects for the inhabitants. (See the section on shielding as well.)

II.A. Gas Concentrations, Atmospheric Layers and Pressure

Undoubtedly, we must keep the atmospheric pressure at a level which will enable the inhabitants to inhale and exhale without damaging their respiratory system. When lungs expand due to the contraction of diaphragm and rib muscles, the air pressure in alveoli decreases. Since the atmospheric pressure is higher than the one in the lungs during inhalation, air molecules move towards the lungs. In exhalation, the volume of the lungs decreases, increasing the internal pressure and causing the air molecules to move towards the atmosphere. This process is called *negative pressure breathing*. When the atmospheric pressure is too low, the lungs cannot work efficiently since air cannot get into the lungs sufficiently. When the pressure is too high, excessive amount of air molecules may get into the lungs, causing *hyperventilation*(See the note below)*. It is also possible that the inhaled air cannot go back to the atmosphere, since the pressure in the lungs might not overcome the atmospheric pressure. [11, p.458] Maintaining a balance between the components of air is the first step in providing a suitable atmospheric pressure. The table below shows the pressure of Nitrogen, Oxygen, Carbon dioxide and Argon exert on the Earth at sea level: (Table1 [21])

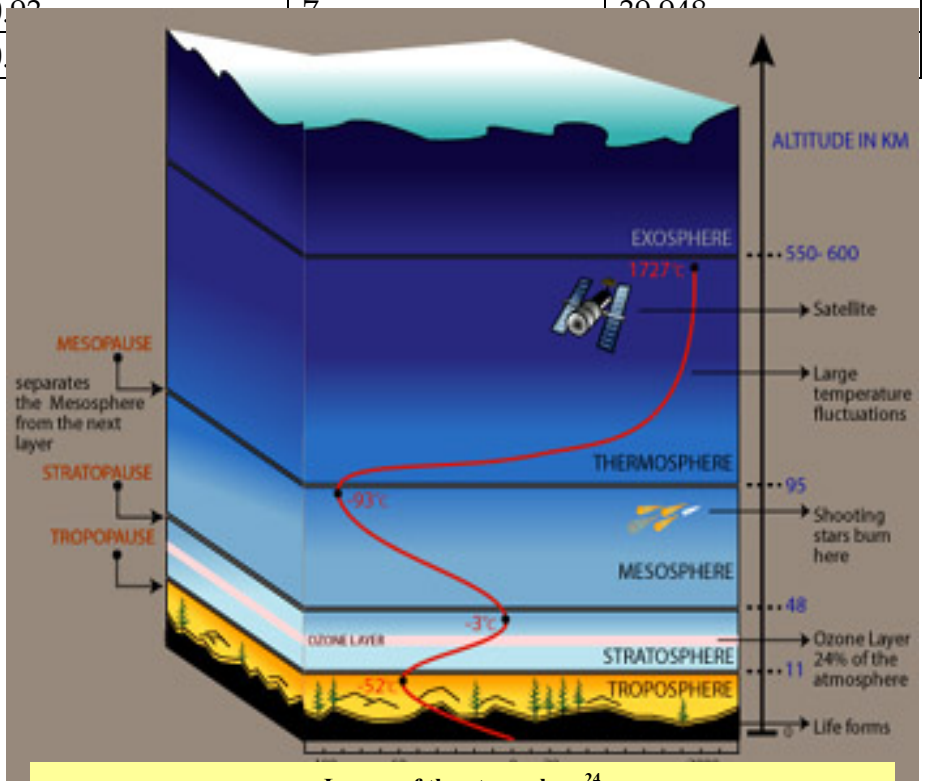
Note: *759.9 mmHg = 101.3 kPa* [22]
Note: *Since under the same conditions, all gases with the same amount of moles occupy the same volume, the column for "volume percentage also applies to mole percentage.*

NOTE*: *CO2 is carried in three different ways in human circulation system:*
- In the form of dissolved CO_2
- In the form of carbonic acid ($H_2O+CO_2 \rightarrow H_2CO_3$)
-In the form of bicarbonate (HCO_3) ions dissolved in blood

There are special ***breathing controlling centers*** *in the brain, called* ***pons*** *and* ***medulla oblongata****. In addition to these, the O_2 sensors in the arteries help to maintain an O_2-CO_2 balance. These structures are able to "monitor" the amount of dissolved CO_2 and the pH levels (related to the presence of carbonic acid) of the blood. In this way, when the CO_2 levels are below the expected values, these structures inhibit the activity of the rib muscles until the gas level comes up to the optimal value. Until this level is reached, respiration ceases, causing* ***hyperventilation****.*

Component	Volume Percentage	Partial Pressure (mmHg)	Molecular Mass (g/mol)
Nitrogen (N2)	78.08	593.4	28.013
Oxygen (O2)	20.95	159.2	31.998
Argon(O2)	0.93	7	39.948
Carbon dioxide (CO2)	0.[illegible]		

In addition to that, we have to consider the fact that air pressure decreases as the altitude increases, since the mass of the gases above decreases. *(This is related to the formula PV= nRT, where P, V, n, R, T stand for pressure,*



Layers of the atmosphere[24]

volume, mole number, gas constant and temperature respectively. As the mass of the gases above a certain level decreases, the mole number decreases, so does the pressure.) Since atmospheric pressure changes more than 9kPa is not healthy, [22] it will not be necessary to have an atmosphere with layers like mesosphere, thermosphere and exosphere, where the pressure is very low. (Normal air pressure is 101.325kPa.). In addition to having no appropriate air pressures to sustain human life, these layers do not possess a stable temperature (It's extremely high in some layers in the day, about 1,982^{O}C, and extremely low in some layers in the night, about -93 ^{0}C. It is because as the mass decreases, the gases heat up more. Remember the formula $q=mc\Delta T$, where the temperature change is inversely proportional to the mass.

The reason for the big temperature differences is that these layers are far up in the ozone layer, which is found in the stratosphere, filtering the sunlight and avoids excessive heating. By this way, the temperature can easily go up and down in the absence of ozone, evoking great and quick temperature changes. Because the ozone layer of our space settlement will be near the top of the atmosphere, we will not be having layers like mesosphere, troposphere, ionosphere and exosphere. Instead, we will keep the levels of Nitrogen, Oxygen and Carbon dioxide at the percentages of 78.08, 20.95 and 0.03 respectively. Because every gas has the same volume under a certain temperature, we will not be having an atmospheric pressure other than 101.3 kPa, with partial pressures same as the ones on Earth. [23]

II.B. Recycle of the atmospheric gases

II.B.a Photosynthesis

Since the inhabitants, including all the plants, bacteria, protozoa, animals and etc. will be consuming oxygen and releasing CO_2 to the atmosphere, recycling and maintaining a balance between these molecules will be essential to sustain life. Plants, bacteria and algae convert carbon dioxide, water and minerals into oxygen and glucose with the heat energy supplied by sunlight (photosynthesis), having a crucial role in keeping the CO_2 level at the normal level of 0.03%. Thus, before bringing animals like dog, cat, horse or bird to the settlement, we will first put plants, photosynthetic bacteria and algae into our settlement. We will also supply them with sufficient water, CO_2, sunlight (from artificial sources), minerals (like nitrogen) and O_2 (for cellular respiration before a suitable level of O_2 is sustained). In this way, before the non-photosynthetic living things are put into the settlement, the level of atmospheric gases will be regulated. The production of O_2 will also be essential in the formation of the ozone layer, as we will discuss later.

In order to increase the efficiency of this process, we will grow plants, algae and bacteria cultures in laboratories (The surface area of the leaves will be as large as possible, unless the big size of these leaves do not inhibit other leaves' usage of light by eclipsing them.). Since photosynthesis increases as the light density increases, we will maximize the intensity of light until it reaches the "plateau". (After this level of light intensity,

photosynthesis starts slowing down).[32] These plants, algae and bacteria will be exposed to light 18-20 hours per day. The color of light will be purple or white to provide efficiency. (Photosynthesis is at the maximum rate under these colors of light. At green light, almost no photosynthesis occurs since all the light is reflected back.)

The plants, algae and bacteria will be divided into at least 6 sections. Light sources will be put in each section. However, the plants, algae and bacteria in a particular section will be "resting" for 4 hours a day. During this time, they will continue their other metabolic activities and their photosynthetic cells will not be damaged by overworking. In addition to that, these plants/algae/bacteria will be supplied with additional O_2 from the other sections, while the CO_2 produced by the "resting" section will be transported to the working sections to be used. A computer will monitor all the chemical compositions in the sections, enabling us to make regulations. Because plants and algae produce more oxygen than their carbon dioxide consumption during photosynthesis, this method will be a way to maintain the CO_2 and O_2 levels in the settlement.[37] Similar to this system, CO_2 in the atmosphere will also be carried into the labs for photosynthesis. The O_2 produced in the labs will be released outside after being separated from carbon dioxide and other gases.[25]

However, we should also consider the fact that not all bacteria produce oxygen during photosynthesis. Photosynthetic bacteria containing bacteriochlorophylls, such as *Rhodospirillaceae,*[35] *purple bacteria, green sulphur bacteria, chloroflexi and helico bacteria*, (generally called anoxygenic *photosynthetic bacteria*) do not produce oxygen, due to their different pigments and using *"different wavelengths of light not absorbed by plants"*.[16] Therefore, we will mostly use cyanobacteria, which can produce oxygen. [37]

We should also make sure that the oxygen/carbon dioxide balancing system continues working even though some plants/bacteria/algae die. Therefore, we should enable the plants, algae and bacteria to reproduce, in order to keep a certain amount of these alive. Putting the same type of species in the same rooms under optimal conditions could solve the problem. However, for the first couple of weeks/months of the settlement, this reproducing system might not work efficiently, since reproduction of plants take longer than it takes for bacteria. Therefore, by transporting an additional number of plants that have not yet germinated and are not able to make photosynthesis can enable us to continue with this system as these non-germinated plants mature and are substituted for the damaged/dead plants. For algae and bacteria, this problem is less dangerous since their reproduction take much less time.

II.B.b Usage of ores in producing oxygen

In addition to the photosynthesis technique, ores (especially the ones on the earth, asteroids and the moon) can also be used in producing oxygen. Because these are basically metal oxides, the oxygen can be separated from the metal in the production of O_2. For instance, ores like;

* Hematite (Fe_2O_3)---(Found on Earth. In 2004, "Opportunity" had found some rocks that probably contain hematite. Later on, when we start sending more rovers to Mars, we can collect these rocks and use them in the production of oxygen) [33]

* Barite ($BaSO_4$) (Found on Earth), Cassiterite (SnO_2), Beryl ($Be_3Al_2(SiO_3)_6$), Ilmenite ($FeTiO_3$), and Magnetite (Fe_3O_4) can be used in this process since they all contain oxygen. [33]

Ore Name	Oxygen Percentage	Ore Name	Oxygen Percentage
Hematite (Fe_2O_3)	30.1	Beryl ($Be_3Al_2(SiO_3)_6$)	53.6
Barite ($BaSO_4$)	27.4	Cassiterite (SnO_2)	21.2
Ilmenite ($FeTiO_3$)	31.6	Magnetite (Fe_3O_4)	27.6 [34]

The percentage of Oxygen can be found by the relation (16.00*x g/mol)/(Molar Mass of the Ore), where x stands for the number of oxygen atoms in each molecule.

As we can conclude form the table above, Beryl has the highest oxygen level among the ores mentioned. Thus, in our space settlement, beryl will be mostly used in producing oxygen by the decomposition of ores. (**Note:** Purifying these ores is also needed to derive oxygen in an efficient way.

Here is a list of places where we can get these ores:

- Hematite: England, Mexico, Brazil, Australia and the Lake Superior region,[45] Mars [33]

- Barite: Oklahoma, Connecticut and Colorado, USA; England and Germany.[46]

- Ilmenite: Ilmen Lake in the Ilmen Mountains, Miask in the Southern portions of the Ural Mountain Chain, Russia as well as Sweden; Germany; Froland, Arendal and Kragero, Norway; Gilgit, Pakistan; Allard Lake and Mont Saint-Hilaire, Quebec and Bancroft, Ontario, Canada; Finland; the Eastern Shores of Australia and Brazil, Sri Lanka, China, Thailand, South Africa, India, Malaysia, Sierra Leone and in Orange County and Essex County, New York; Iron Mountain, Wyoming; Chester, Massachusetts; several sites in California and along the eastern seaboard of the United States.[47] Moon also has great ilmentie sources, as detected in 2005 by Hubble Space Telescope.[48]

- Beryl: Colombia, some African localities, Brazil, Russia, Pakistan, California, Brazil, Africa[49], Austria, Germany, Ireland, Madagascar and Ural Mountains[50]

- **Cassiterite:** La Paz and Colquiri areas of Bolivia; Cornwall, England; Durango, Mexico; Malaya; Indonesia; Russia and China[51]

- Magnetite: South Africa, Germany, Russia and many localities in the USA[52]

II.B.c An alternative way of recycling CO_2 and O_2: Using the extremely low temperatures in outer space:

To separate oxygen from carbon dioxide without using extra energy (except transportation of Carbon dioxide), we will use the outside of the asteroid. . "*Because space is so cold, the air from the inside of the asteroid would liquefy once outside on the surface. The*

carbon dioxide would then be separated from the oxygen and put into storage, while the oxygen returns to the colony's air supply." [28] Therefore, since carbon dioxide liquefies at -57°C and solidifies at -78°C, we will only need energy to keep the temperature about -57°C.[53] Meanwhile, we will be able to control the input and output of oxygen and carbon dioxide. The oxygen derived from this process can also be used forming the ozone layer of the settlement

Note: *While integrating this idea into our project, we were inspired by "The Babylon Project: On the Edge of a New Frontier", 1998, prepared by Thomas Beatty and David Peter.*

II.B.d Recycling of nitrogen:

Substantial amount of nitrogen is also needed for photosynthesis, the formation of proteins, nucleic acids and cellular structures. However, the presence of strong triple bonds between two nitrogen atoms prevents these atoms to react with other atoms/molecules. That is why nitrogen must be *"fixed"* (combined to form ammonium (NH_4) or nitrate (NO_3) ions. Therefore, we have to have some nitrogen-fixing bacteria in our settlement. Let's first look at how the amount of nitrogen is balanced on earth: [26]

Biologic Fixation:

- *In the process called nitrogen fixation, some bacteria convert nitrogen to ammonia (NH_3). Some of these bacteria are free-living whereas some of them form symbiotic associations with plants or other organisms (e.g. termites, protozoa)* [6]
- *Some other fixing bacteria convert ammonia to nitrate, and then convert nitrate to N_2 or other nitrogen gases* [26]
- *Many bacteria and fungi decompose organic matter, releasing fixed nitrogen for other organisms.* [26]

Thus, the presence of nitrogen fixing bacteria is essential for the settlement. By bringing these bacteria from the earth, we can supply the plants and animals with nitrogen for metabolic activities, such as photsynthesis.[27]

Here are some of these bacteria: [26]

Examples of nitrogen-fixing bacteria (* denotes a photosynthetic bacterium)			
Free living		Symbiotic with plants	
Aerobic	**Anaerobic**	**Legumes**	**Other plants**
Azotobacter *Beijerinckia* *Klebsiella* (some) Cyanobacteria (some)*	*Clostridium* (some) *Desulfovibrio* Purple sulphur bacteria* Purple non-sulphur bacteria* Green sulphur bacteria*	*Rhizobium*	*Frankia* *Azospirillum*

In addition to biological fixation, atmospheric fixation and industrial (artificial) fixation of nitrogen can be used to keep the nitrogen level at 78%.

Atmospheric Fixation

In the proceeding paragraphs, it was stated that the strong triple bonds between two nitrogen atoms prevent N_2 to combine with other molecules/atoms. The great energy of lightning is able to break these bonds, *enabling these atoms to combine with oxygen to form nitrogen oxides.*[27] Later on, these nitrogen oxides are dissolved in rain and carried to the soil. Since *"atmospheric nitrogen fixation probably contributes some 5– 8% of the total nitrogen fixed"* [27] on earth and requires an enormous amount of energy, so this technique is such an expensive one. Nevertheless, during the times when the ecosystem is in a desperate need, this high amount of energy can be produced by using electricity or magnetism.[27]

Industrial Fixation:

"Under great pressure, at a temperature of 600°C, and with the use of a catalyst, atmospheric nitrogen and hydrogen can be combined to form ammonia (NH_3). Ammonia can be used directly as fertilizer, but most of it is further processed to urea and ammonium nitrate (NH_4NO_3)." [27]

II.B.e. Other Gases Like Hydrogen, Argon, Neon, Helium, Krypton, and Xenon:

These gases are the most abundant trace gases in the atmosphere on earth. Since our space settlement's atmosphere will be identical to the one on the earth in terms gas composition, we will keep the abundances of these gases as follows: (Table 3 [38])

Argon (Ar)	Neon (Ne)	Kripton (Kr)	Xenon (Xe)	Helium(He)	Hyrogen (H)
0.93%	0.018%	0.0011%	0.00009%	0.0005%	0.00005%

In the transportation process, we will use the inert properties of these gases except for hydrogen, which is not a noble gas.[34] Therefore, gases like argon, neon, krypton, xenon and helium can be safely transported to the settlement in different containers. Since gases can be compressed into containers, it would be easy to carry them. However, the pressure inside the containers should not be so high, increasing the risk of any explosions.

For hydrogen, the hydrogen detected on Mars can be transported to the settlement.[39] Moreover, hydrogen can also be derived from the soil, since the soil is rich in hydrogen. While transporting some amount of soil from the earth to the settlement, we will be transporting an important amount of hydrogen. [40]

It is also important to stabilize the hydrogen levels. By prohibiting the usage of automobile engines with fossil fuels, this can be achieved, since *"automobiles are the major anthropogenic source of atmospheric hydrogen"* [41]

An alternative but utopic way of producing molecular hydrogen:

Molecular hydrogen can be prepared from atomic hydrogen, since atomic hydrogen is highly reactive. Atomic hydrogen (H) consists of only one proton and electron. *"Because of the spin structure of the particle, it is easily detectable using a high frequency radio signal at 21-cm wavelength. Atomic hydrogen in galaxies and in intergalactic space can be detected very easily, because the atomic hydrogen can change its spin (which changes its energy)."* [54]

"*However, when two atoms of atomic hydrogen combine, forming molecular hydrogen (H_2), their spins are coupled and completely cancel each other.*"[54] Therefore, we cannot detect the presence of molecular hydrogen by using radio waves. That is why we should first detect atomic hydrogen first, and then convert it into molecular hydrogen.

However, since extra spacecrafts that are able to travel great distances are needed for this mission, this method is such an expensive one.

II.C The Ozone Layer

II.C.a. How was the Ozone Layer Formed?

"*High in the atmosphere, some oxygen (O_2) molecules absorbed energy from the Sun's ultraviolet (UV) rays and split to form single oxygen atoms. These atoms combined with remaining oxygen (O_2) to form ozone (O_3) molecules, which are very effective at absorbing UV rays. The thin layer of ozone that surrounds Earth acts as a shield, protecting the planet from irradiation by UV light.*" [29]

II.C.b. Formation of the ozone layer in our space settlement

Since UV rays are needed to break down O_2 molecules to form O_3, the ozone layer we are going to form will be located at the top of the radiation shield, in order to use the unfiltered UV rays in sunlight. (The layer will of course be inside the settlement.) The source of oxygen will be the previously mentioned system which produces separated oxygen from carbon dioxide by liquifying CO_2 under the very low temperature of the space (around 2.7 Kelvin). [30]

II.C.c. An alternative method of producing ozone

We can also use high voltage electricity (about $22*10^6$V, like in a lightning) in order to split the oxygen molecules into atoms. However, since this requires an enormous amount of energy, we should use this technique in cases of desperate need.[42, p.277-279] In this method, we will electrolyze $HCLO_4$ at -50°C. We will use lead as cathode. Platin, which is previously exposed to high density anode current, will be the anode. As a result of this electrolysis, we will get a mixture of ozone and oxygen. At this point, the lower the temperature we have, the higher percentage ozone we get in the mixture. Later on, we can separate ozone from the mixture by liquefying it at -112°C. Since the temperature outside the settlement will be very low(around 2.7 Kelvin), maintaining the aforementioned temperatures will not be difficult.[43,p.30] In order to get the sufficient amount of energy to initiate the electrolysis reaction, we can use helyum-3, which is rich in energy as one million times as fuels like oil are. Since the Moon's atmosphere is very rich in He-3, we can transport some amount of He-3 to the settlement.

II.D. Dangerous Gases

"*Carbon dioxide, nitrous oxide, and methane (CH_4) are produced by the burning of fossil fuels, expelled from living and dead biomass, and released by the metabolic processes of microorganisms in the soil, wetlands, and oceans of our planet.*"[25] In order to avoid the excessive formation of these gases, we will prohibit the use of fossil fuels in transportation vehicles. Instead, we will use electric energy to preserve the chemical composition of the

atmosphere. Otherwise, these gases would easily poison people, since the atmosphere will be enclosed.

II.E. One of the biggest dangers: FIRE

Since our settlement will be an enclosed area, a fire case would be seriously dangerous for the inhabitants, intervening with the atmospheric gas balance in a drastic way. Therefore, an efficient fire extinguishing system is needed. Different from the normal fire departments on earth, the space settlement should have numerous smoke detectors and sprinklers [28]. Considering the fact that a huge amount of water might be needed to extinguish such a big fire, we have to make sure that we have big subordinate water supplies on the settlement, ready to be transported to the settlement. Therefore, the drastic effect on the water balance in the settlement would be minimized.

Conclusion:

We should not forget the fact that atmosphere is a fundamental part of life, having numerous connections with the other parts of this project, such as gravity, population, ecosystem and radiation shielding. Therefore, the solutions suggested in this part has many alternatives and should be reviewed from different points of view, by applying our knowledge of many other scientific branches, like physics, chemistry, engineering, math, biology, botanic and etc.

Chapter III - Nutrition, Water and Waste Management

III.A. Animals in the station

The station should be similar to Earth as much as possible to make humans feel much more comfortable. One of the main questions that come up was whether we should bring animals to the station or not. According to our principle stating that the station should be similar to Earth, we have to have animals there. However, there are some obstacles about having animals in the station.

First of all, if animals are brought to the station, a complete food chain should be composed. The population of animals must be calculated very carefully. However, even this careful calculation may cause some problems. There are interactions between two or more species in nature. There is predation, which can be explained by one species eating the other one. If we have animals there, one species will prey on another species. Therefore the population size of species will change according to the predators, environmental conditions

etc. Obviously, in a community the population sizes of different species should be balanced. In every community, there is a keystone species, which has a strong control on community structure due to its ecological role. The importance of a keystone species may be explained with an example. In the North Pacific, sea otters are key stone predators. Killer whales feed on sea otters; sea otters feed on sea urchins and sea urchins usually feed on kelp. If sea otters increase in the North Pacific, then the sea urchins' number decrease and kelp forests become abundant. When the sea otters are rare, sea urchins become abundant decreasing the abundance of kelp forests. During the last 20 years, sea otters decreased profoundly. Sea otters population is probably decreased because of over predation by killer whales. Killer whales' other prey species like sea lions have declined in density. Therefore, the killer whales prey only on sea otters decreasing their number. (54) As clearly seen, the population size of a species is significantly important in communities. Creating a community, which is balanced perfectly, is very hard.

Killer whales
↓
Sea otters
↓
Sea urchins
↓
Kelp

Furthermore, introducing a new species to a community is very dangerous, since the prey-predator relationship cannot be guessed exactly. For example, during 1940's, 12 pairs of European rabbits were brought to Australia. Since that species was not native to Australia, their population increased dramatically. There weren't enough predators, which would have kept the rabbit population under control. The overpopulation of European rabbits caused a big threat to sheep and cattle industries and destruction to Australia. (55)

fig.1: rabbits in Australia (56)

In our station, we have to create a new community but since none of the species will be native, it will be almost impossible to keep the populations balanced. Therefore, having animals in the station is extremely risky.

After all, of these discussions, we decided not to have animals in our station. It will be very hard for people to get used to live without animals. To prevent people from feeling uncomfortable in the station, we will have pets. Pets like birds, cats, dogs, fish etc. will relax people and make them feel at home. Since individuals will look after pets, there will not be a problem like creating a new community or a food chain.

III.B. Vegetarian Diet

Since there will not be animals around, people will not be able to feed on meat, dairy products etc. This will cause everybody who lives on the station to be vegetarian. The living creatures in our station will depend on plants for the food and energy because plants are the primary producers, which produce glucose and oxygen by photosynthesis. In communities, trophic structure can be explained as a pattern of feeding relationships among different trophic levels like primary producers, primary consumers, secondary consumers etc. Trophic levels are energy levels in a food chain or a food web. Primary producers are the bottom trophic level, which produces the energy needed for other trophic levels. The primary consumers, which are herbivores, get energy needed for them to survive from plants. If a primary consumer consumes plant matter containing 200 Joules of energy, it will give away half of this energy in its feces (fig.2). Approximately two-thirds of the remaining energy will be used to carry out cellular respiration, and when this primary consumer is eaten by a secondary consumer, only about 10 percent of the energy it gets from primary consumers will be available to the carnivore. In this way, only approximately 10% of energy, which a trophic level gets, is available for the next trophic level. (Fig. 5)

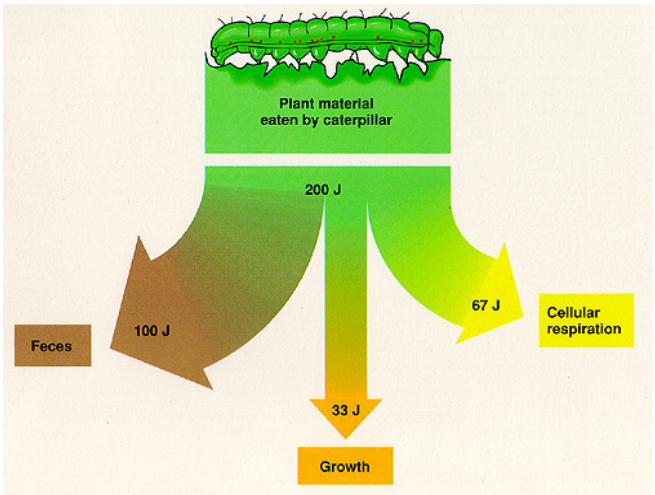


fig.2: energy partitioning [57]

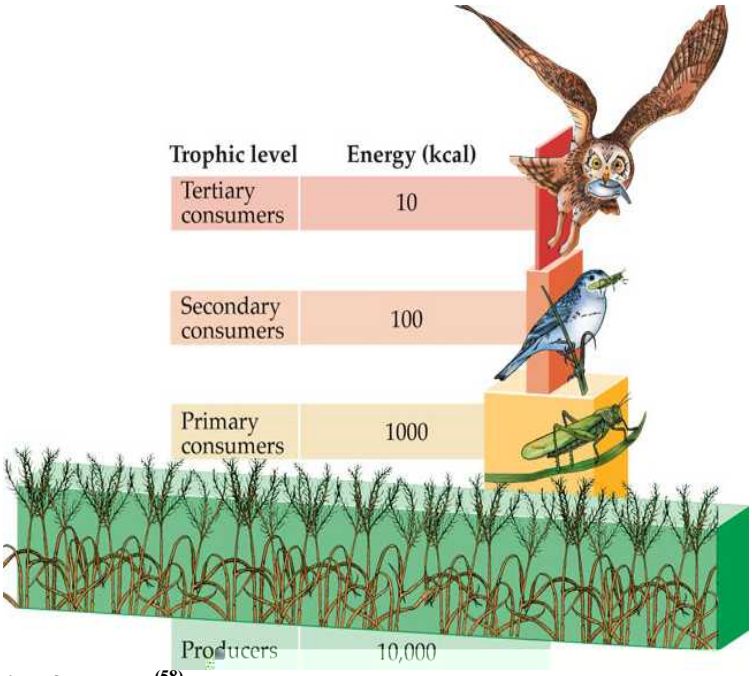


fig. 3: pyramid of energy (58)

According to this fact, it is better for humans to be vegetarians. When people are vegetarians, they are primary consumers therefore; they get the necessary energy for their survival from the primary producers. Humans may also eat herbivores, making them secondary consumers. These people get their energy form primary consumers. Since the energy decreases as we go up to the next trophic level, the meat eater humans only get 10% of the energy a vegetarian gets by eating the same amount of plant matter. The meat eater humans eat the same amount of plant matter with the vegetarian by eating an herbivore, which consumed it in this example. In another way, feeding meat eaters for their survival requires ten times more energy than feeding vegetarians. Therefore, eating meat is a luxury. Being a vegetarian is more environmentally friendly. (59)

In our station, we do not have animals therefore; we also do not have dairy products. Not consuming dairy products brings up the question that whether people will be able to live healthy. For example, cholesterol is important for people's survival. It's a component in the cell membranes of animals. Cholesterol is also used to as a starting material in the process of producing steroids like sex hormones. (60) As clearly seen, cholesterol is essential for a human's survival. Cholesterol is only found in animal products because it's produced in the livers of animals. However, this is not a problem because humans may make enough cholesterol via livers without getting any from animal products. (61) Milk is a source of vitamin D. However, without consuming milk; people may get sufficient vitamin D. Black light produces UVB. UVB stimulates reactions in human body to produce vitamin D. Therefore black lights may be used to prevent vitamin D deficiency in living creatures. (62) Researches are still not sure whether plants contain vitamin B12. So far, no significant amount of vitamin B12 is found in plant food sources. Therefore, in our station, we have to supply people with vitamin B12. Vitamin B12 may be taken from vitamin preparations, textured vegetable protein, vegetable and sunflower margarines, breakfast cereals etc.(63) calcium is found in dark green leafy vegetables, tofu etc. therefore calcium deficiency will not be a problem as long as people consume vegetables high in calcium regularly. (64)

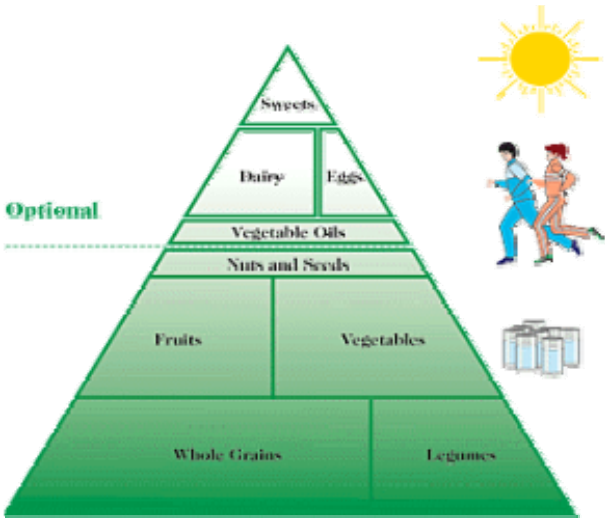


fig.4: food pyramid for vegetarians (63)

All in all, vegetarian diet is healthier for people and more suitable for our station. The only problem about the vegetarian diet is vitamin B12 but people can be provided with vitamin B12 via different sources. Therefore, it has decided not to have animals in the station except pets and people will have a vegetarian life style.

III.C. Food and Agriculture (128)

In the preceding section, the vegetarian diet was discussed to be perfectly okay for a healthy life, unless we do not choose what to eat carefully. The basic nutrition a human body needs is stated below, and the foods which will meet the requirements are indicated.

Protein

Women need about 45g of protein a day, men need about 55g. In a vegetarian diet protein can be obtained from:

- Nuts: hazels, brazils, almonds, cashews, walnuts, pine kernels etc.
- Seeds: sesame, pumpkin, sunflower, linseeds.
- Pulses: peas, beans, lentils, peanuts.
- Grains/cereals: wheat (in bread, flour, pasta etc), barley, rye, oats, millet, maize (sweet corn), rice.
- Soya products: tofu, tempeh, textured vegetable protein, veggie burgers, soy milk.

Carbohydrate

Carbohydrate is the most important source of energy, and most of it is provided by plant foods. There are three main types of carbohydrates: simple sugars, complex carbohydrates or starches and dietary fibre.

The sugars or simple carbohydrates can be found in fruit, ordinary table sugar. Complex carbohydrates are found in cereals/grains (bread, rice, pasta, oats, barley, millet, buckwheat, rye) and some root vegetables, such as potatoes and parsnips. A healthy diet should contain plenty of these starchy foods The unrefined carbohydrates, like brown rice are best of all because they contain essential dietary fibre and B vitamins.

Dietary fibre refers to the indigestible part of a carbohydrate food. Fibre can be found in unrefined or wholegrain cereals, fruit (fresh and dried) and vegetables. A good intake of dietary fibre can prevent many digestive problems and protect against diseases like colon cancer.

Fats & Oils

Although excess fat is dangerous, fats and oils are needed to keep our tissues in good repair, for the manufacture of hormones and to act as a carrier for some vitamins.

Fats can be either saturated or unsaturated (mono-unsaturated or poly-unsaturated). A high intake of saturated fat can lead to a raised blood cholesterol level and this has been linked to heart disease.

Vitamins:

Vitamin A (or beta carotene): Red, orange or yellow vegetables like carrots and tomatoes, leafy green vegetables and fruits like apricots and peaches.
B Vitamins: All the B vitamins except B12 occur in yeasts and whole cereals (especially wheat germ), nuts & seeds, pulses and green vegetables.
Vitamin C: Fresh fruit, salad vegetables, all leafy green vegetables and potatoes.
Vitamin E: Vegetable oil, wholegrain cereals, eggs.
Vitamin K: Fresh vegetables, cereals and bacterial synthesis in the intestine.

Minerals

Calcium: Important for healthy bones and teeth. Found in leafy green vegetables, bread, nuts and seeds (especially sesame seeds), dried fruits, cheese.
Iron: Needed for red blood cells. Found in leafy green vegetables, wholemeal bread, dried fruits (especially apricots and figs), and lentils.
Zinc: Plays a major role in many enzyme reactions and the immune system. Found in green vegetables, cheese, sesame and pumpkin seeds, lentils and wholegrain cereals.

Iodine: Present in vegetables.

III.D. Water Management

Water is essential for life. Every human being needs water to keep the vital chemical reactions going. F. Batmanghelidj, MD, author of 'Your Body's Many Cries for Water' states that 75 percent of a human body is made up of water. Brain's 85 percent, blood's 90 percent, muscles' 75 percent, and liver's 82 percent is water. These facts obviously emphasize that water is essential for a human life. All in all, water is a significant component of life in our space station.

III.E. Water Storage

Water will be stored into tanks, which are connected to the pipes that will reach houses, public buildings etc. Waste water will be collected and purified to maintain total amount of water in the station the same all the time. As the water is used from the storage tanks, purified water will replace it.

INPUTS - kg/person/day

Oxygen	0.83
Dry Food	0.62
Water in Food	1.15
Food Preparation Water	0.79
Drinking Water	1.61
Oral Hygiene Water	0.36
Hand and Face Wash Water	1.81
Shower Water	5.44
Clothes Wash Water	12.47 *
Dish Wash Water	5.44
Urinal/Commode Flush Water	0.49

Total: 31.0 kg/person/day

OUTPUTS - kg/person/day

Carbon Dioxide	1.00
Water from Respiration and Perspiration	2.28
Urine	1.50
Urine Solids	0.06
Hygiene Water	7.18
Latent (Evaporated) Hygiene Water	0.44
Clothes Wash Water	11.87 *
Latent (Evaporated) Clothes Wash Water	0.60*
Latent (Evaporated) Food	0.04

Preparation Water	
Dish Wash Water	5.41
Latent (Evaporated) Dish Wash Water	0.03
Feces Solids	0.03
Feces Liquid	0.09
Sweat Solids	0.02
Urinal and Commode Flush Water	0.49

Total: 31.0 kg/person/day

(From: Space Station *Freedom* Design Parameters - NASA SSP 30362 (1990).) [65]

III.F. Water Purification

Water purification consist different steps, which are respectively physical treatment, chemical treatment and biological treatment. These different treatment methods contain different applications.

III.F.a. Physical purification:

These treatment methods are used to remove solids from liquids. Some of the applications for this treatment are screens, cross flow filtration, sand filtration etc.

a) Screens: This method of filtration is usually done at the beginning of the water purification process. There are different types of screens, which can be chosen by the size of particles that ought to be removed.

b) Sand filtration: after this method, usually a secondary filtration is needed because these filters cannot prevent smaller suspended solids from passing through. This filtration method is done by multiple layers of sand, which differ in size and gravity. The filter keeps suspended solids while water flows through and the water with less suspended solids comes out of the filter.

c) Cross flow filtration: This method removes both salts and dissolved organic matter. There are several types of filters that can be used as a technique of cross flow filtration. These filters differ according to the particle size that will be removed. The basis of this technique is to use a permeable membrane.

- Microfiltration: This filter only removes the particles which are in the range of 0.1 to 1.5 microns that consists suspended solids, bacteria etc.
- Ultrafiltration: This filter only removes the particles which are in the range of 0.005 to 0.1 microns that consists salts, proteins etc.
- Nanofiltration: This filter only removes the particles, which are in the range of 0.0001 to 0.005 microns that consists viruses, pesticides, herbicides etc.
- Reversed Osmosis: This technique is the one that we will use in our water purification process. This filter removes particles with a particle size up to 0.001 microns that consists metal ions and all aqueous salts. Therefore that's the finest filter system that we can use.

Osmosis is the flow of water molecules from the high concentration of water to the low concentration of water across a selectively permeable membrane. Reversed osmosis is done by applying enough pressure on the contaminated solution to reverse the flow of water.

Consequently, the pure water molecules pass through the membrane, salts and other dissolved solids remain behind the membrane.
Reversed osmosis is quite different from other filtration methods. Since filters are porous, they just eliminate contaminants according to their size. In reversed osmosis, a semi permeable membrane is used and this eliminates contaminants according to their chemical structure.

Since the membrane will have to be able to withstand a certain amount of presure, a strong configuration of materials such as a **spiral-wound** and a hollow-fiber would be used. The complete system will include;

- a sediment filter to trap particles including rust and calcium carbonate
- a second sediment filter with smaller pores
- an activated carbon filter to trap organic chemicals and chlorination
- a reverse osmosis (RO) filter with a thin film composite membrane
- a second carbon filter to capture those chemicals not removed by the RO membrane.
- an ultra-violet lamp is used for disinfection of the remaining microbes. (149)

In order to save as much energy as possible, the pressure will be created by the effect of the spin of the torus which is used to generate gravitation. Therefore, the water purifier will work without a need of additional fuel or electricity.

III.F.b. Chemical purification:

In chemical purification, disinfection is the most important stage. There are several ways for disinfection. The advantages and disadvantages of these different ways are examined in the table below.

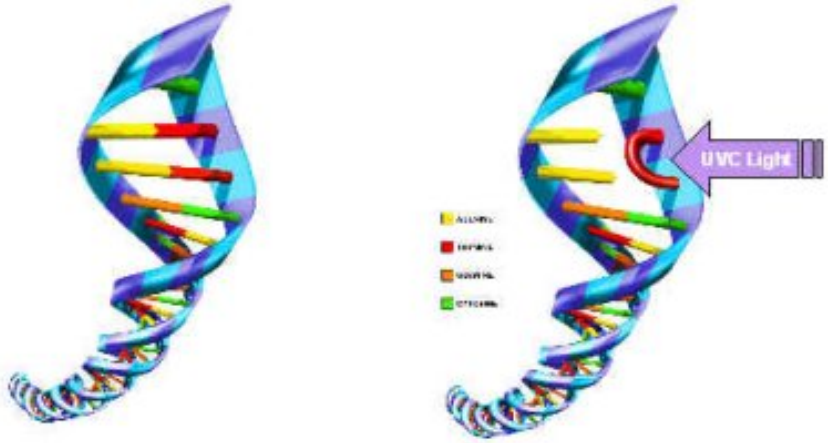
Technology	Environmental friendliness	Byproducts	Effectiveness	Investment	Operational costs	Fluids	Surfac
Ozone	+	+	++	-	+	++	++
UV	++	++	+	+/-	++	+	++
Chlorine dioxide	+/-	+/-	++	++	+	++	--
Chlorine gas	--	--	-	+	++	+/-	--
Hypochlorite	--	--	-	+	++	+/-	--

From: Lenntech *'Disinfection'*(66)

Usually, disinfection is done by chlorine however, it is not appropriate for the space station. Chlorine is toxic, heavy and corrosive. As shown in the table below, chlorine is definitely not environmentally friendly. There are other alternatives like chlorine dioxide, ozone or UV disinfection.

Ozone is formed by three oxygen molecules that bound together. Ozone uses the process called "cellular lyses" to kill microorganisms. Ozone ruptures the microorganisms' cellular membrane, spreads the bacterial cytoplasm and makes the reactivation impossible. When the bacteria are open to the external environment, it dies immediately. The water becomes fresh and free of harmful bacteria.

UV radiation is another way to disinfect water. UV disinfects water by changing the genetic material in viruses, bacteria etc. the alteration of genetic material prevents viruses, bacteria etc. from reproducing.



From: Hanovia – World Class UV '*How does ultraviolet work?'* [67]

There are four different nitrogenous bases, which are put in two different groups named purines, which consists adenine and guanine, and pyrimidines, which consist of thymine and cytosine. Pyrimidine bases absorb the UV light and therefore the hydrogen bonds between these bases are ruptured. This prevents DNA from replicating itself.

UV-C is the most effective one whose wavelengths are between 200nm and 300 nm.

Chlorine dioxide is an effective disinfectant and by-product of this process is chlorite. Even though this is an efficacious disinfectant, it has some disadvantages like requirement of technical expertise. It also produces odors and it is corrosive.

As a result, in our space station, we may use both ozone and UV to disinfect water.

III.F.c. Biological purification:

The main categories of this purification are anaerobic and aerobic treatment.

a) Aerobic treatment: In this kind of treatment, bacteria that work with oxygen convert the contaminants in the water. The bacteria consume organic matter and produces carbon dioxide. If the organic matter is totally consumed, then the bacteria die. Then dead bacteria are consumed by other bacteria. Aerobic digestion occurs faster than the anaerobic digestion, which does not require oxygen. This treatment needs plenty of oxygen to do any kind of conversion. As capital costs are considered, aerobic digestion is advantageous but it needs plenty of oxygen.

b) Anaerobic treatment: this treatment occurs in the absence of oxygen. This treatment has two types; one of them is thermophilic digestion, which takes place at approximately 38°C, and the other one is known as mesophilic digestion which takes place at colder temperatures. At the end pf the thermophillic digestion methane gas is produced and this gas may be used to heat the tanks and run engines. The production of methane gas is an advantage for anaerobic treatment. But its capital cost is considerably higher than the aerobic treatment. In addition, it's much slower. This method requires more work than aerobic treatment and it is less satisfactory. Another disadvantage of this method is that after anaerobic treatment, there is still need for aerobic treatment since the water is not clean enough.

In our station, both the aerobic and anaerobic treatments will be used according to the oxygen levels, which can be provided for biological treatment of water.

III.G. Waste Management

Waste storage is a quite unimportant issue at the settlement since recycling will have to play an important role in waste management. All organic wastes, including carcasses of plants, animals and humans as well as their excreted by-products can be fed back into the ecosystem. This can be achieved very simply by using decomposing fungi and bacteria and composting the organic waste. Similarly paper, plastic, metals and glass can be recycled. With an efficient recycling policy, only a little amount of storage space will ever be needed for waste. However, non-recyclable waste will certainly be produced and will build up and fill all available storage space at some point. If that happens, we will have two choices: either burning the waste, or releasing it to the outer space. Burning the waste will certainly help the storage aspect, since the ashes will certainly take up less space than the waste itself and the carbon dioxide produced can be used by the plants for photosynthesis. However, it is very dangerous to have fire in an isolated community and the short-term steep decrease in the oxygen level will definitely be too dangerous to risk. Thus, we compact and press the non-recyclable waste until we run out of space and release them to the outer space when we have to.

Chapter IV - Power

IV.A. Solar Power

In the station, the main source of power will be solar power. We will benefit from this unlimited energy opportunity as much as we can. Sun power is one of the biggest advantages of having a station built in space

- In one second, the Sun generates 3.86 x 10^{26} joule of energy. In terms of power, this much energy means, 3.86 x 10^{20} MW.
- The solar spectrum consists of three regions; the waves with wavelengths smaller than 0.4 μm occupy 9%, the waves of wavelengths between 0.4 and 0.7 μm occupy 45%, and the waves of wavelengths bigger than 0.7 μm occupy 46% of the solar spectrum. It is this the last region of the solar spectrum (46%) than provides the thermal energy of the Sun.
- The solar constant, which is the solar radiation that falls on an area in space is 1.353 kW/m^2, whereas on Earth this value is 1.100 kW/m^2 [75]

IV.A.a. Fundamental Aspects of Solar Power

Photo-voltaic means light-electricity, so the *photovoltaic (PV) cells* transform the energy in the sunlight to electricity. The PV cells are made of *semiconductors*. The most commonly used semiconductor in these cells is Silicon, Si. The atomic number of Silicon is 14, so there are four valence electrons on its outer electron shell. Silicon shares 4 atoms with the neighboring atoms to become stable. As a result crystals are formed. When energy is given to these structures, some of the shared electrons can break apart and contribute to the conductivity of the material. Since the conductivity of a material depends on the "free" electrons it has, Silicon in this crystalline structures is a poor conductor. All of its electrons have formed covalent bonds, so they cannot move around. Silicon is slightly modified to increase its conductivity, by adding some Boron and Phosphor atoms in it, that is, by doping it[76].

N-type Doping:

The atomic number of Phosphorus (P) is 15, so there are five electrons in its outer electron shell. Phosphorus uses four of these electrons to form covalent bonds with the neighboring Silicon atoms, but one electron does not form any bond. This electron thus can easily break apart and increase the conductivity of the material. Since the Phosphorus-containing materials carry negatively charged particles more commonly than the positively charged ones, they are called n-type semiconductors, and this kind of doping is called n-type doping [76].

P-type Doping:

As for the semiconductors containing Boron atom, they have electron deficiencies because the atomic number of Boron is five. This means that the last electron shell of Boron contains 3 electrons, all of which form covalent bond with the Silicon atoms. However, one place in the Silicon atom is left unfilled. Since the electrons passing by would tend to attach to

these 'holes', these parts act like positive charge carriers. That is why, these kinds of semiconductors are called p-type semiconductors, and the doping with Boron is called p-type doping [76].

In short, in the p-type region, there are holes from the acceptor impurities, and in the n-type region, there are extra electrons. Unless these semiconductors are in contact, they are both neutral. The junctions made by connecting the p-type and n-type semiconductors are called **p-n junction**. In a p-n junction, some of the free electrons in the n-region diffuse across the junction and combine with 'holes' to form negative ions. This causes the negatively charged particles to accumulate on the p-type semiconductor and the positively charged particles to accumulate on the n-type semiconductor. The depletion region created in the n-type semiconductor inhibits any further electron transfer. Other electrons from the n region cannot migrate across the junction because they are repelled by the negative charges on the p region and attracted by the depletion areas in the n region. When sunlight strikes to a p-n junction, the photon absorbed by either region, forces the electrons migrated to the p region to diffuse across the junction and pass to the n region. However because the internal resistance of a semiconductor is high, the electrons with low energies move very slowly. If on the other hand, a conductive wire is placed near the junction the electron transfer would progress much quicker. Thus, an electrical current is supplied from the p-n junctions that make up the PV cells. The problem is how to connect the wires. Not to prevent the photon absorption, the wires generally cover the upper face of the solar panels like a cage, and they completely cover the bottom part of the panels [77].

In order to meet the vast energy requirement of the PINTA space station, creative and economical methods must be used. In this project, we offer several convenient ways to overcome the energy handicap.

IV.A.b. Bifacial PV Panels

Instead of using only one face of a solar power, it would be much reasonable to benefit from both sides of the panel. For this reason, we are going to use bifacial PV modules in the station. Besides the fact that there are no serious difference in the cost of monofacial and bifacial PV modules, bifacial modules can produce 5-20% more energy. It is also very advantageous that bifacial PV modules are transparent for infrared radiation, and have lower operating temperatures, in comparison to monofacial ones. One disadvantage is that the number of wires which could be connected to the panels would be less than monofacial PV modules. The first solution to increase the efficiency could be to make the wires thinner so that more sunlight could be absorbed, but it should not be forgotten that as the wire gets thinner, its internal resistance goes up and causes heat losses. We must be attentive about this aspect too [78].

IV.A.c. Multijunctions:

Another way to improve the efficiency of the PV panels is to place several p-n junctions on top of each other and create a multijunction system. In order to understand how such an arrangement would increase the efficiency, we should first know the relationship between the energy and absorption of the photons.

In space, the light that strikes the PV panels contains photons with different wavelengths. The energy of a photon can be defined in terms of its wavelength as shown;

$$E = hc/\lambda \quad (5)$$

Where;

E; is the energy

c; is the speed of light in vacuum (300,000 km/h)
h; is the Planck constant (6.62 x 10^{-34} J/s)
λ; is the wavelength of the photon.

The Energy band gap of Silicon used in the p-n junctions is 1.80 x 10^{-19} J. The photons with higher energy levels are absorbed by the junction, and as explained previously they create an electric current. The photons with lower energy levels however, cannot be absorbed and they pass through the junction without contributing to electric generation. In this way, a big amount of the light is wasted. Nevertheless, if a junction with a lower energy band is placed under the high-energy junction, the photons with lower energies would be absorbed too, and they would increase the energy production of the PV module [(79)]. With the multijunction technique, the efficiency is going to be increased, and we will cope with the energy requirement more successfully.

IV.A.d. Alternative Materials in PV cells

Improving the efficiency of the solar panels plays a crucial role in sustaining the life within the station. Another way to improve the efficiency is using alternative materials in PV cells. Silicon can be used in various forms, including, single-crystalline, multicrystalline and amorphous. Single-crystalline solar cells have the highest efficiency in energy conversion, which can reach to 25% when produced in laboratories, in industrial cells the efficiency has reached to 15%. However, it has the highest cost as well. They are made of 99.9% pure silicon. Multicrystalline solar cells are slightly less efficient than single-crystalline solar cells, but they are also cheaper.

Amorphous silicon is used in a new technology concerning the solar cells called 'thin-film' technology, in which, by using very thin layers of the semiconductor material the cost can be reduced. Moreover, amorphous silicon cells are more tolerant to radiation. However, the efficiency of amorphous silicon is low when compared with crystalline silicon cells. When produced in laboratories the highest efficiency it has reached is 13%, where as the industrial solar cells have efficiency less than 10%.[(80)]

Type	Typical module efficiency [%]	Maximum recorded module efficiency [%]	Maximum recorded laboratory efficiency [%]
Single crystalline silicon	12-15	22,7	24,7
Multicrystalline silicon	11-14	15,3	19,8
Amorphous silicon	5-7	-	12,7

Types of Silicon [(80)]

On the other hand, it is not compulsory to manufacture the PV cells from Silicon. Different elements are also used in the modules. As a semiconductor is Gallium arsenide, (GaAs) could be used. It has many advantages, for example, its efficiency, which reaches to 25-30%. Gallium Arsenide cells are very insensitive to heat, meaning that cells temperatures can be very high. Moreover, they are highly absorptive and immune to radiation damage. However, GaAs is even more expensive than single-crystal silicon, since gallium is very rare on Earth and arsenide requires careful handling [81]. However, with the advances on the field, gallium arsenide panels are being used more frequently, a recent example being the satellite SMART-1 which was launched to the moon in 2003, and served for 3 years. [150]

Moreover, Cadmium telluride (CdTe), and Copper Indium Diselenide (CIS) are other alternatives, yet they are highly toxic. Cadmium and its compounds, which are used in making cadmium telluride PV cells, can be toxic at high levels of lung exposure.

Considering all these alternatives, we decided to use the gallium arsenide solar cells. We believe their production costs will decrease in the future and their efficiency is well worth the cost (so does the ESA, as seen with SMART-1).

In order to minimize the harmful effect of PV cell production we must make the productions in closed areas, providing full security for the habitants of the settlement.

IV.A.e. Solar Tracking Systems

To increase the efficiency and come up with reliable and safe methods on the PINTA solar panels, we considered the technologies applied on the terrestrial solar panels too.

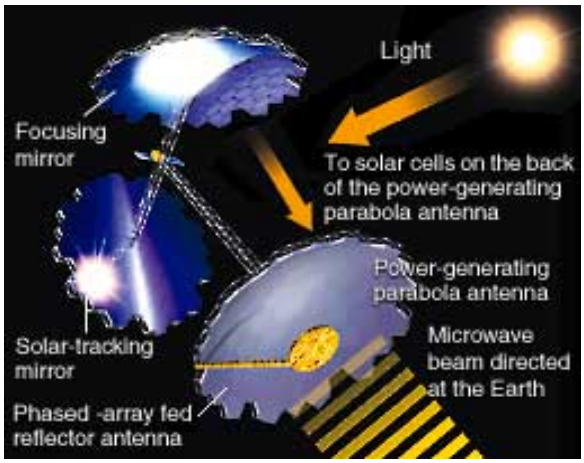
Solar tracking systems can make a big effect on the performance of the solar panels. According to Vladisav Poulek and Martin Libra, in a fixed solar panel the energy loss can reach up to 30%, whereas with track angles more than 60 degrees this loss can be lowered to zero. Today many techniques are used in the tracking systems, but we thought the one developed by Poulek and Libra to be the most suitable to our station.

The work principle of the tracking system is simple. As the sun moves from the east to the west, angle of incidence of solar radiation on sensing/driving cells increases until power of the driving DC motor, connected to these cells, is high enough to move solar collectors. Then the angle of incidence starts to decrease until the power of the DC motor is lower than that necessary to move solar collectors. Additional solar cells, placed in the same panel, enables backtracking of the tracker from any position. By benefiting from this technology, the energy generating mechanisms can be greatly improved [78].

IV.A.f. Solar Power Satellites (SPS)

The solar panels can be mounted on the station, which will minimize the costs, since it does not require extra materials to build a new arrangement. In this case we may benefit from optical concentrators, which use a lens or mirror system that focus sunlight on the PV cells to increase the electrical output. With this system we can reduce the cost, because the PV cells in this module will use a small amount of the expensive silicon materials than other PV technologies.

However, Solar Power Satellites should be preferred. The radiation shield on the station will not leave space for PV modules. Also by placing the SPS in the orbits of the Earth, we could benefit from the Sun power more.



The SPS contain solar cells that convert the sunlight into electricity, which is beamed to the station or the Earth in the form of microwave. An SPS consists of three parts. First, a lens focuses sunlight to the photovoltaic cells. The large array of the photovoltaic cells makes up the second part of the SPS. The electricity produced by the solar cells is then transferred to the third part, where the electricity is converted into power beams in the form of microwaves [82]. These beams will be directed to the station, where they will be converted to electricity. The beams may be directed to Earth, on which the receptor dishes will transform the beams back into electricity. Thus, besides providing energy to the station, extra financial resources could be created by simply selling energy to the Earth (and/or other colonies in the future). When directing the microwaves to the Earth is the issue, an important obstacle should be considered. In order to benefit from the beams, specific receivers must receive them. This means that the SPS should stay directed on fixed points on the Earth. The Geosynchronous orbit (GEO) would serve best for this purpose. Some of the SPS could be located at the GEO to stay in contact with the Earth, and some of them could work on the L5 point to be near the station. The speed of an object traveling in this orbit is calculated to be 853 km/h (See Chapter I - Location of the Station), whereas the SPS staying at L5 will merely move. Therefore when manufacturing the two satellites, we should make sure that the satellite to travel at GEO is resistant to high speed.

IV.B. Nuclear Power

So far, we mentioned about the sources supplying the energy required for the daily life of the population. However, the station also needs a vast amount of energy for the electromagnetic shielding against radiation. Moreover, sunlight might not be always available, due to the eclipses or other environmental conditions, not to mention any possible temporary and/or permanent damages any part of the solar power system could encounter. Therefore, we prefer to use another source of energy, nuclear energy, in the station to overcome these problems, as well as using it as a backup. The usage of nuclear energy will be very beneficial in the PINTA space station, because there will not be problems like the preservation of the nuclear wastes, or the isolation of the high temperature produced after a nuclear reaction, which are both huge problems against nuclear power production on Earth. However, the issue that limits the usage of the nuclear energy is the transportation of the nuclear fuel from the Earth. Even though this means an extra financial burden, we believe its benefits are worth its cost.

Today, around 17% of the total energy production in the world is done by nuclear plants [83].

IV.B.a. Mass-Energy Equivalence

The reason why the nuclear reacts produce such enormous amounts of energy can be explained by Einstein's famous theory of special relativity. Energy is released when the protons and neutrons in a nucleus adopt a more stable arrangement. The change in energy that follows such a rearrangement can be found by comparing the masses of the nuclear reactants

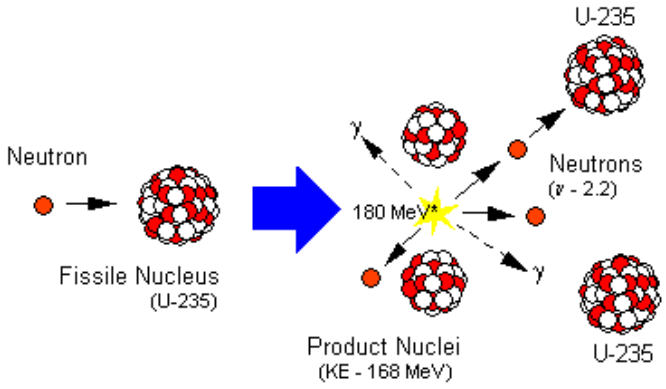
with the masses of the nuclear products. Einstein's theory of special relativity tells us that, the mass of an object is a measure of its energy content;

$$E = mc^2$$

Even in strong exothermic reactions, mass loss is very small therefore, the energy produced is small. However, in a nuclear reaction, the energy changes are very large; the corresponding mass loss is measurable (at least a fraction of c) [84].

IV.B.b. Nuclear Fission

In the nuclear reactors of the PINTA space station, fission will be carried out as the nuclear reaction type. Nuclear fission is the breaking of a nucleus into two or more smaller nuclei of similar mass. Because fission reactions release huge amounts of energy, they are used to generate electricity in nuclear power plants. The energy release in fission can be calculated by subtracting the total mass of the fission products from the mass of the starting materials. The change in mass is then converted to a change in energy by using Einstein's equation [85].



Thorium and Uranium are the main fuels of nuclear reaction. Uranium is preferred as the nuclear fuel even though it is rarer than Thorium on Earth. However only 0.7% of the natural Uranium is actually fissile, which means that it tends to split when neutrons crash with Uranium atoms. Uranium has three naturally occurring isotopes, U-234, U-235 and U-238. Natural uranium contains a very small amount of U-235 (its natural abundance is 0.72 %, the remaining part being mostly U-238(99.275%) and a very little amount of U-234 (0.0058%)) [148]. U-235 is the isotope being used in nuclear reactors, due to its ability to cause rapidly expanding fission chain reactions, ignited by the hitting of a single neutron. In order for the reaction to sustain itself, there should be a minimum amount of mass. This mass is called the critical mass. To provide it, the amount of U-235 in the nuclear fuel has to be increased externally. This process is called the enrichment of uranium. At the end of the fission reaction, the neutron particles that are released achieve very big velocities. However, the neutrons required to split the atoms must move slower than those released with fission, so that their chance to be captured by an atom is higher. For this purpose, **moderators** are used to slow down the neutrons. [86] The uranium required will be shipped from the Erath to the space station. As the mining technology develops, it will be possible to gather uranium from the moon and/or other planets.

The rate of the nuclear reaction should be kept below a certain level; otherwise, the reactor will become too hot, meaning it will get faster and out of control, causing great and irreparable damage (as in nuclear weapons). Control rods are used to prevent this. These are made of neutron-absorbing elements such as boron and cadmium. They will be inserted between the fuel rods, they will control the number of neutrons available for creating fission, and so they will control the rate of reaction.

IV.B.c. Nuclear Fusion

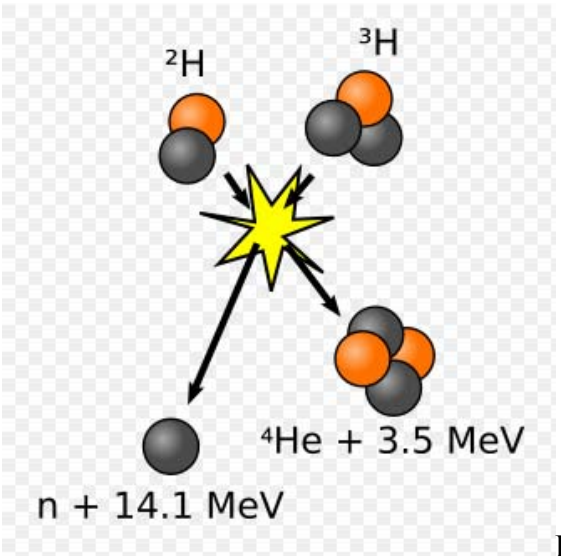
Nuclear fusion is the process of multiple nuclei joining together to form a heavier nucleus. It is the main process that fuels the stars, including the Sun, causing them to emit all forms of electromagnetic radiation, from microwaves to gamma rays. It will take a big amount of energy to force two nuclei to fuse, however; the particles released in this process generally cause very huge amounts of energy to be released (in accordance with Einstein's theory of special relativity, $E=mc^2$), especially in light elements, resulting in an exothermic process. The resulting energy is incomparably greater than chemical reactions, due to the ionization energies being much lower than the binding energies of protons and neutrons (13.6 eV for hydrogen and 17 MeV for a deuterium-tritium reaction respectively).(152)

A certain minimum amount of energy is required for fusion to occur (similar to the critical mass requirement of fission reactions). This energy is used to overcome the electrostatic repulsion between the two nuclei. This energy is called the Coulomb Barrier. It is calculated by the formula:

$$U_{coul} = k\frac{q_1\, q_2}{r} = \frac{1}{4\pi\epsilon_0}\frac{q_1\, q_2}{r}$$

where k is the Coulomb's constant, ε_0 is the permittivity of free space, q_1 and q_2 are the charges of the interacting particles and r is the interaction radius. (151) It is obvious that the Coulomb Barrier is the smallest for isotopes of hydrogen, since they contain only a single positive charge. For a deuterium-tritium reaction:

$$^2_1\mathrm{H} + ^3_1\mathrm{H} \rightarrow ^5_2\mathrm{He} \rightarrow ^4_2\mathrm{He} + ^1_0\mathrm{n} + 17.6\ \mathrm{MeV}$$



Deuterium-Tritium reaction(152)

The intermediate element ^{5}He is highly unstable and decays to ^{4}He, releasing a neutron and a total energy of 17.6 MeV.

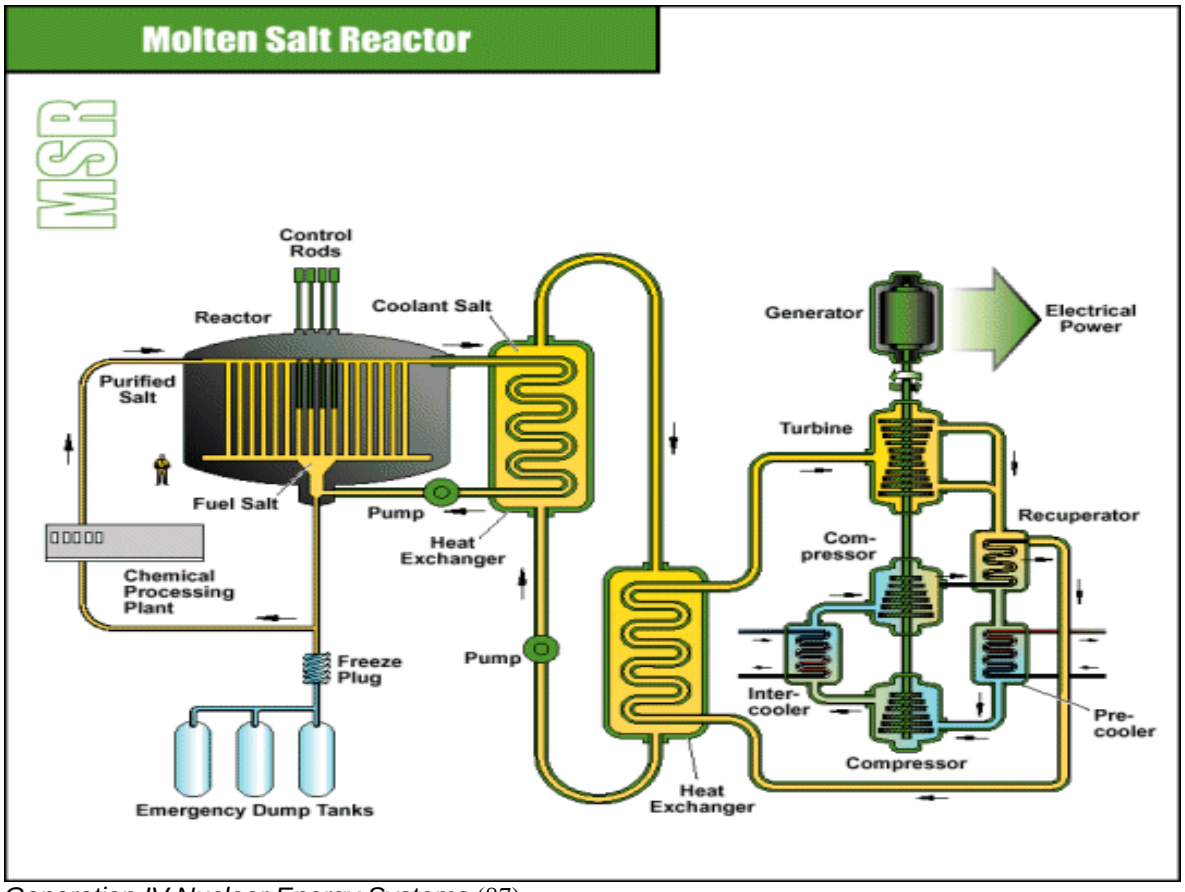
The method called hot fusion will be used for fusion power production. This method requires very high temperatures and pressures applied on the fusion fuel, providing it with the energy to overcome the Coulomb Barrier. This heating process will be done with heating a

plasma by paassing large electrical currents through it. Then a chain reaction will begin, creating a source of fuel. One gram deuterium will release $3*10^8$ kJ with this reaction. (153)

There are certain problems with fusion power generation. First, the neutrons produced during the D-T reaction will hit the reactor materials around it. This may cause the ionization of some of the electrons of these material, as well as x-rays being emitted. Furthermore, these electrons and x-rays could escape the reactor, resulting in high radiation doses around the station, not to mention the usable energy being lost. At the required operation temperatures, any known wall material would melt. Therefore, the plasma should be contained from the walls, only heating the fusion fuel.

IV.B.d. The Nuclear Fission and Fusion Reactors

Recently, new fission reactor types are designed, known as Generation IV Nuclear Reactors. Among the six new reactor models that have been developed, we find the Molten Salt Reactor (MSR) model most convenient for the settlement. The Molten Salt Reactor system produces power within a coolant system containing molten salt. Salt can be obtained from the Moon; however, it requires to be processed in order to be used in the reactor. Therefore, we will bring the salt from the Earth. In the MSR system, the fuel is a circulating liquid mixture of sodium, zirconium, and uranium fluorides. The reactor can produce a power of 1,000 MWe. The system has a coolant outlet temperature of 700 degrees Celsius, possibly ranging up to 800 degrees Celsius, affording improved thermal efficiency. In addition, molten fluoride salts have excellent heat transfer characteristics and a very low vapor pressure, which reduce stresses on the vessel and piping. Thus, the power obtained from the Molten Salt Reactor can be used in emergencies when sunlight is not available, and it can provide the power needed for the electromagnetic shelter of the settlement. Moreover, with the heat released from fission we can partly solve the problem of temperature maintenance inside the settlement.



Generation IV Nuclear Energy Systems (87)
February 24, 2005

Besides producing electricity, we could benefit from the thermal energy of the reactor in maintaining the temperature inside the station.

We plan to use the fusion reactor DEMO (Demonstration Power Plant) for fusion power production. Although it has not been built yet, it aims to produce 2 GW power. It will be based on the predicted success of the reactor ITER, which is being built in Southern France and will produce 5000 MW for at least 500 seconds [154]. DEMO will be the first commercial fusion power reactor. It is planned to be built within 20 years.

DEMO provides the temperature with heating plasma by putting current through it, raising its temperature up to 100,000,000 C [155]. To contain the plasma from the reactor's walls, a magnetic confinement will be used. A device called tokamak will be used for this. A tokamak is a machine which produces a toroidal (doughnut-shaped) magnetic field for confining a plasma, invented by Soviet physicists in 1950s [156]. This will pull the plasma away from the walls of the reactor. Furthermore, the neutrons produced (which carry the energy produced during the reaction) will not be affected by the magnetic field due to their lack of charge. However, the electrons and x-rays will be contained in the magnetic field, preventing them to create a radioactive environment around the station. The power production process will work in these steps:

- The tokamak containment vessel will have a lining composed of ceramic or composite tiles containing tubes in which liquid lithium will flow.
- Lithium readily absorbs high speed neutrons to form helium and tritium.
- Lithium is processed to remove the helium and tritium.
- Helium and tritium are added in carefully measured amounts to the plasma.
- This increase in temperature is passed onto (pressurized) liquid water in a sealed, pressurized pipe.
- The hot water from the pipe will be used to boil water under lower pressure in a heat exchanger.
- The steam from the heat exchanger will be used to drive the turbine of a generator, to create an electrical current [155].

Since we are in empty space, we could provide a vacuum for the reactor very easily, resulting in a more effective work environment. The fusion reactor will be placed next to the fission reactor (see Chapter IV.B.e). Deuterium is easily found in seawater, as well as in any form of water. Tritium is radioactive, and on Earth, it is industrially produced by the reaction:

$$^{6}_{3}\mathrm{Li} + {}^{1}\mathrm{n} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{3}_{1}\mathrm{T}$$

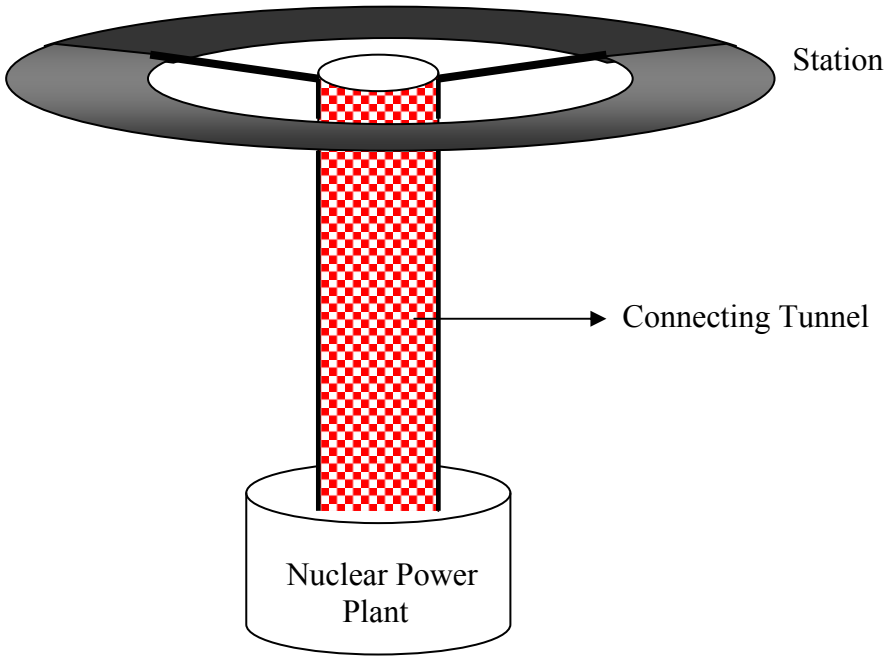
Lithium is found in the moon; therefore it could be mined from there. Tritium naturally occurs with the interaction of solar cosmic rays with the atmosphere as well:

$$^{14}_{7}\mathrm{N} + {}^{1}\mathrm{n} \rightarrow {}^{12}_{6}\mathrm{C} + {}^{3}_{1}\mathrm{T}$$ [157]

Due to its relatively short half-life (12.32 years), the amount of naturally occurring tritium is negligible on the Earth. However, this process will be more convenient to use on the station as it is on the Earth.

IV.B.e. Safety Issues, Placement and the Verdict

Considering the safety issues concerning the nuclear fission reactors, we conclude that they are suitable to use in the station. In comparison to the use of fossil fuels, nuclear reactors are extremely safe in space. In a possible case of a meltdown and/or an uncontrollable chain reaction, the problematic reactor could be launched away from the station into deep space. The prime concern would be for those working in the nuclear plant. To minimize risks, radiation doses will be controlled by use of remote handling equipment. By providing a strong physical shielding and limiting the time workers will spend in the area we can ensure low risks. However, the threat of the nuclear reactor for the inhabitants of the station will be very low because of the design we developed to locate the nuclear plant.



As indicated on the diagram above, the nuclear reactors will be placed at the bottom of a tunnel containing the turbines. The heat generated from both of the reactors will turn the turbines and electricity will be generated. The upper part of the tunnel occurs at the center of the torus-shaped station. By channels connected to the turbine, the electrical power can be transferred to the station. This design ensures to minimize the risk factors of using a nuclear power supply, because in an emergency situation, the power plant can be detached from the turbines and by rockets mounted on the structure can be sent into deep space, where it can be annihilated without damaging the Earth or the station.

The main plan is to use the fusion reactor as the main nuclear power supply, and use the fission reactor as a backup. Several facts have been effective on this decision. First, the fusion reactor doesn't have as much chance of a nuclear accident as a fission reaction, since it requires an initial energy to begin. Cutting off the current of the plasma will be enough to prevent most of the possible dangers. Furthermore, it is incomparably easier and cheaper to provide the fusion fuel; deuterium and tritium, than the fission fuel; sodium, zirconium, and uranium fluorides. They could be provided from places other than the Earth as well. This will help the self-sufficiency and economy of the settlement. Another advantage of the fusion reactor is that the resulting products are not as radioactive as the fission by-products. However, it has its disadvantages as well. First, commercial fusion power production has never been done successfully on Earth. All of our hopes depend on the predicted scientific developments, namely the success of ITER and a successful, working design of DEMO to be produced. On the other hand, fission reactors are being built for over 50 years (even though the Molten Salt Reactor is an experimental one, it could be replaced with another working one very easily). It is much more expensive to build a fusion reactor than a fission reactor. Nevertheless, the price will eventually be lower for fusion power production, since the fuel costs are much lower. Finally, it is not a good idea to use the fusion reactor only, considering that it is highly experimental and any major problem could result in a disabled radiation

shield, resulting in imminent deaths of all the inhabitants. Therefore we decided to keep the fission reactor as a supporting/backup reactor.

IV.C. Heat Generator

An alternative way to generate power is using solar thermal energy. We will place a parabolic dish of mirrors on the center of the torus, which will focus the sunrays onto a boiler and then send the vapor through the generator, which will convert the solar power into electricity. This type of power is renewable and efficient. Moreover, besides generating power, the thermal energy of the Sun can be used to maintain the optimum temperature inside the PINTA space station.

IV.D. Fuel cells

Lastly, other than solar power and nuclear power, fuel cells will be used as an alternative source of power, in the PINTA space station.

A fuel cell generates electricity directly from chemical reactions, as in a battery, but in this mechanism, the reactants must be continuously supplied. The advantage of this is that the only product of the cell reaction is water, which is drinkable. No pollutants are generated from the reactions.

Fuel cells are also very efficient in the sense that little waste heat is produced. However most of the engines that burn fossil fuels such as natural gas or coal to generate electricity are so inefficient that no more than 30% of the energy released by combustion is actually used to do work [84].

Many types of fuel cells are possible, yet in the space station the use of phosphoric acid fuel cell would be the most convenient type. This type shows promise for combined heat and power systems (CHP). In such systems, the waste heat is used in heating the houses or workplaces. Moreover, the efficiency in a CHP plant can reach 80%[84]

Phosphoric acid fuel cell:
Anode: $2H_2(g) \longrightarrow 4H^+(aq) + 4e^-$
Electrolyte: $H_3PO_4(aq)$
Cathode: $O_2(g) + 4e^- + 4H^+ \longrightarrow 2H_2O(l)$ [84]

IV.E. Power Distribution

In all sorts of energy plants, the electric energy that is produced is not usable unless they are adjusted for the electronic devices. They usually come in high voltages, and their voltages change during their way to our homes.

Electricity distribution is the penultimate process in the delivery of electricity, in other words the part between transmission and user purchase from an electricity retailer. Distribution networks are typically of two types, radial or interconnected. A radial network leaves the station and passes through the network area with no connection to any other supply. This is typical of long rural lines with isolated load areas. An interconnected network is generally found in more urban areas and will have multiple connections to other points of supply. These points of connection are normally open but allow various configurations by closing and opening switches. The benefit of the interconnected model is that in the event of a

fault or required maintenance a small area of network can be isolated and the remainder kept on supply. (88)

Characteristics of an electricity distribution line include:

* AC or DC - Virtually all public electricity supplies are AC today. In cases of a requirement to use DC power such as in electric powered trains, telephone lines and industrial processes such as aluminum smelting, they either operate their own generating equipment or have equipment to derive DC from the public AC supply.
* Voltage, including tolerance (usually + or - a certain percentage)
* Frequency (50 Hz and 60 Hz are most common)
* Maximum current that may be drawn
* Phase configuration (single phase, split phase, polyphase including two phase and three phase)

In our space settlement, radial networks are used between the residential areas and the industrial areas, whereas interconnected networks are used in residential areas, very similar to the general policy of energy distributors in earth.

At the generating plants the energy is produced at a relatively low voltage of up to 25 kV (Grigsby, 2001, p. 4-4), then stepped up by the power station transformer to a higher voltage for transmission over long distances to grid exit points (substations). It is necessary to transmit the electricity at high voltage to reduce the percentage of energy lost. For a given amount of power transmitted, a higher voltage reduces the current and thus the resistive losses in the conductor. Long distance transmission is typically done with overhead lines at voltages of 110 to 765 kV.

However, we do not have to use overhead lines. Our torus shape and the relatively small size of the settlement allow us to use other methods.

Since we use the surface of the torus as a conductor to create an electromagnetic field for radiation protection, we can also use the same surface to transfer electricity around the torus. The power transmission inside the torus will be provided by the use of transformers at each point where the electricity enters inside the torus.

2 kW per person is the required power.[89] However, taking a possibility of an increasing demand into consideration, we take this requirement as 4 kW/person. Since our settlement is designed to support a population of 10,000 people, the total power requirement becomes 40 MW.

Therefore, an additional power of 40 MW is required to be transmitted from the surface of the torus.

We already calculated the necessary current and power required for the electromagnetic shield, but now we have to take the power distribution into consideration.

$$U_H = \frac{B^2 V}{2\mu} \quad (89)$$

The power required for the electromagnetic shield is 50,769 MW (see Chapter V.B.a.) , and the required power for other parts of the station, as well as the inhabitants, is 40 MW. Adding these two, the total power of the transmission lines must be 50,809 MW.

i = 15722906.4095 A

This is the total current required to provide both the electromagnetic radiation shield and the power distribution. With this method, we both saved space and reduced our costs. However, since a huge current will be flowing from the torus, it should be covered with superconductive coil and the voltage should be increased as much as possible, in order to minimize the energy loss.

Then the transformers will resume the power distribution. For practical purposes such as compatibility with the devices produced on earth, the plugs in homes will provide both a 220 V AC 50 Hz current and a 110 V AC 60 Hz current. Interconnected networks will be available in residential areas, whereas radial networks will be used in agriculture and industrial areas. The transformer numbers and specifications will be determined according to the network types. In order to prevent blackouts, three secondary main lines (lines that take their power directly from the surface of the torus) will be built and the current will be divided among them. In case of a short circuit problem in one of the lines, the other ones will carry all of the current and therefore the risk of a blackout is minimized. This is especially important because unlike on earth, nearly all life support systems use electricity and without electricity, the colonists will be dead very quickly. First of all, the electromagnetic shield will be lost, and the colonists will suffer a great dose of radiation. Therefore, two precautions are taken against power loss. First of all, a small electric structure will be built in order to keep the vital systems running. This structure will include a few generators and batteries. In addition, the colonists will be warned in case of a blackout and they will go to the emergency shelters. For those who will work for repairs, a few spacesuits will be provided (but not too much, since they cost enormously high). In addition, if the problem is caused by the solar panels instead of the power supply lines, the backup nuclear reactors will be turned on and will provide temporary energy.

Chapter V – Radiation Shielding

V.A. The Need for Shielding – The effects of radiation

In space, a great deal of radiation is emitted. Radiation can be classified in two types: Ionizing and Non-Ionizing radiation. Since Non-Ionizing radiation has a relatively lower energy, they are not our concern.

V.A.a. The sources of radiation

i. Galactic Cosmic Rays

Galactic cosmic rays (GCRs) are the high-energy particles that flow into our solar system from far away in the Galaxy. GCRs are mostly pieces of atoms: protons, electrons, and atomic nuclei which have had all of the surrounding electrons stripped during their high-speed (almost the speed of light) passage through the Galaxy. Cosmic rays provide one of our few direct samples of matter from outside the solar system. Galactic cosmic rays differ in their composition and origin from solar cosmic rays, which are mostly protons and helium nuclei accelerated by solar activity. The mean energies of galactic cosmic rays also are much higher than the energies of solar cosmic rays. [90]

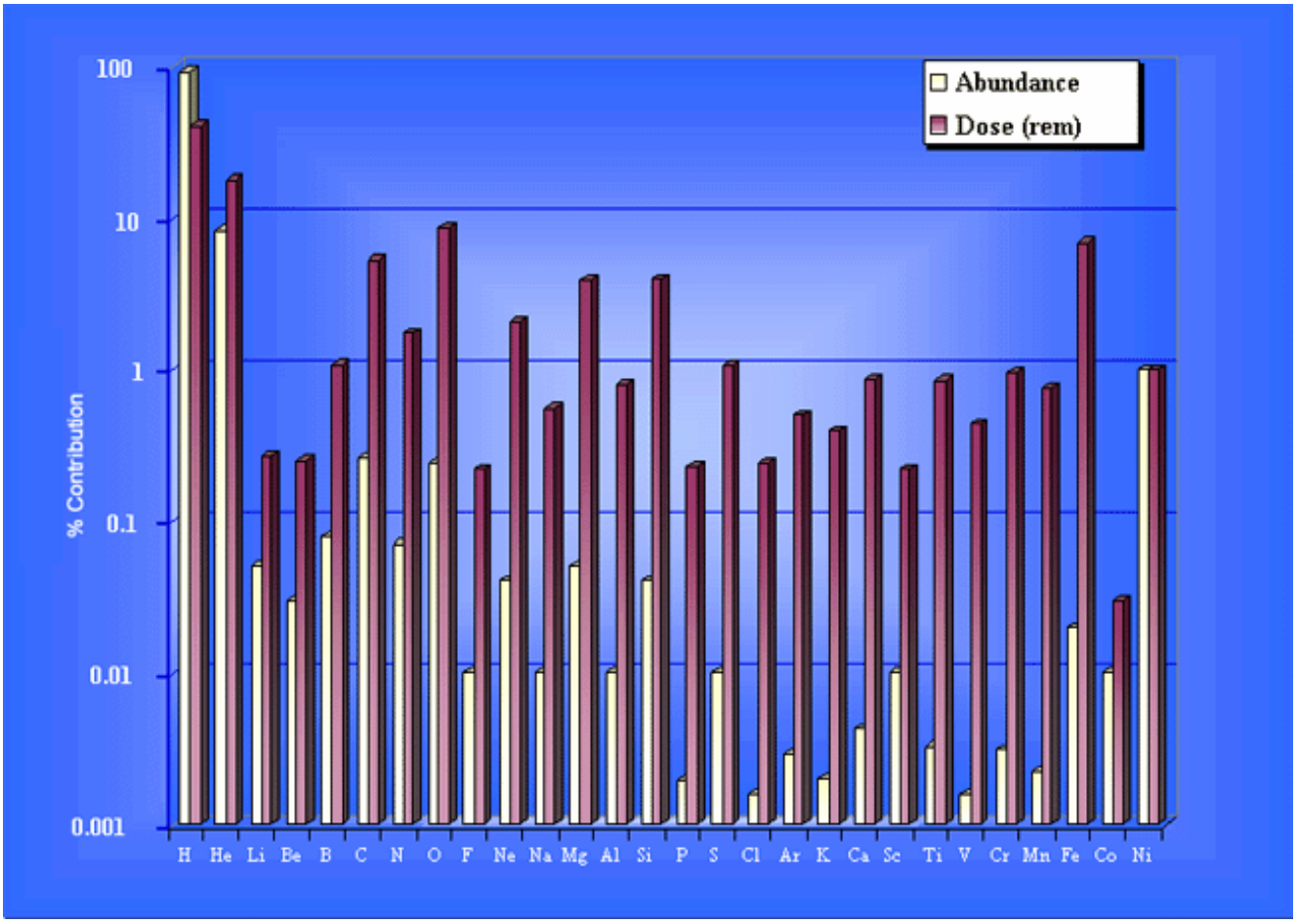
ii. Solar Cosmic Rays

Solar cosmic rays (SCRs) are atoms that are associated with solar flares. SCRs are a type of cosmic ray. They move away from the Sun due to plasma heating, acceleration, and numerous other forces. Flares frequently inject large amounts of energetic nuclei into space, and the composition varies from flare to flare. The mechanisms involved in producing a solar flare can be better understood by studying the composition and charge of these particles. [2] Most are made of protons; these rays are relatively low in energy (10-100 keV). The average composition is similar to that of the Sun itself. The name *solar cosmic ray* itself is a misnomer, but it has stuck. High energy (MeV and above) cosmic rays come mainly from outside the solar system, while the particles in the solar case are energized near the Sun's surface by the action of magnetic fields. The misnomer arose because there is continuity in the energy spectra, i.e. the flux of particles as a function of their energy, because the low energy solar cosmic rays fade more or less smoothly into the galactic ones as one looks at higher and higher energies.

While most solar radiation is electro-magnetic radiation, the sun also produces particle radiation, solar cosmic rays, which vary with the solar cycle. Most are made of protons; these rays are relatively low in energy (10-100 keV). The average composition is similar to that of the Sun itself. High energy (Mev and above) cosmic rays come mainly from outside the solar system, while the particles in the solar case are energized near the Sun's surface by the action of magnetic fields. Solar cosmic rays vary widely in their intensity and spectrum, increasing in strength after some solar events such as solar flares. Further, an increase in the intensity of solar cosmic rays is followed by a *decrease* in the galactic cosmic rays, called a Forbush decrease after their discoverer, the physicist Scott Forbush. These decreases are due to the solar wind with its entrained magnetic field sweeping some of the galactic cosmic rays outwards, away from the Sun and Earth. [91]

V.A.b. The Effects of Radiation

Radiation has severe effects on human health. The primary radiation sources in outer space are the galactic cosmic rays (GCR), protons and electrons trapped in the Earth's magnetic field, and the solar particle events (SPE). The background radiation of the GCR permeates interplanetary space and includes 85% of protons, 14% of helium and about 1% from high-energy (E) and high-charge (Z) ions called HZE particles. Though the HZE particles are less abundant, they posses significantly higher ionizing power with a greater potential for radiation-induced damage and greater penetration power.



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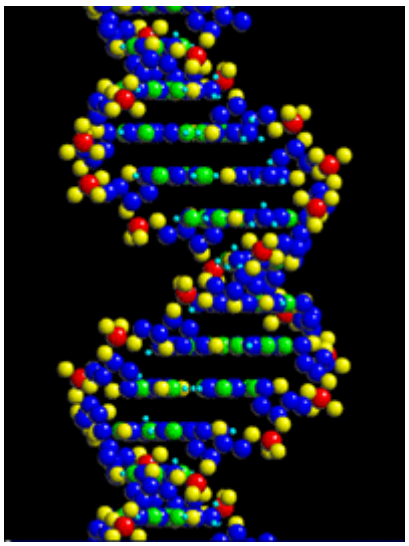
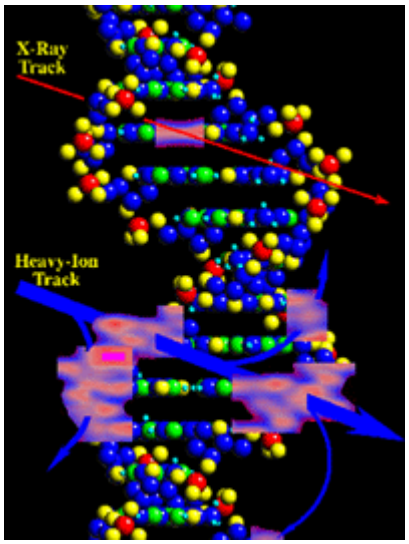
The basic unit of the living organism is the cell. Within the cell, the deoxyribonucleic acid (DNA) molecules contain the information required for the synthesis of intracellular proteins, for cell reproduction and for organization of the tissues and organs. The diameter of a cell is typically of the order of 1/1000 inches. Inside the cell's nucleus, the DNA is tightly wound into a tiny double helix, thousands of times smaller than the cell.



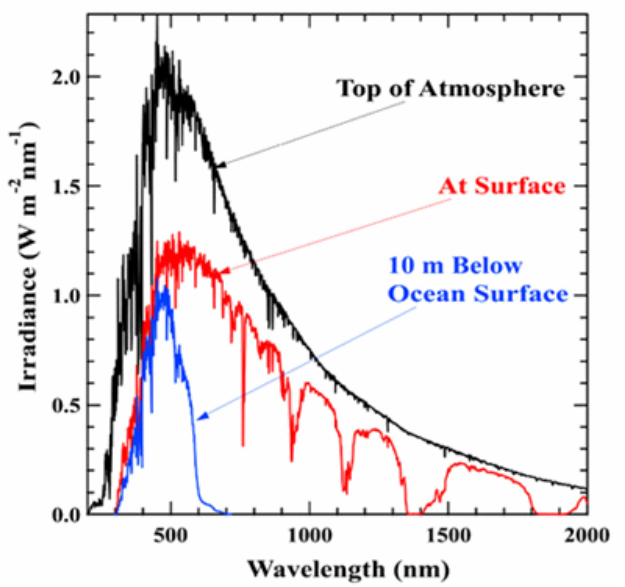


Ionizing radiation has a direct effect on DNA leading to single strand breaks (SSB), double strand breaks (DSB), associated base damage (BD), or clusters of these damage types. The initial damage caused by the HZE particles at the cell level and to the tissue is unique

compared to the damage caused by the terrestrial radiation such as x-rays or gamma rays. Because of their high ionization density, HZE particles also can cause clusters of damage where many molecular bonds are broken in the tissue along their trajectory. The cell's ability to repair DNA damage becomes impaired as the severity of clustering increases leading to DNA deletions and other forms of mutations. The long range of the HZEs allows for the potential damage along a long column of cells in tissue. Since HZE particles are rare on Earth, the prediction of biological risks to humans in space must rely on fundamental knowledge gathered from biological and medical research. However, HZE particles are more abundant in space, therefore additional protection is required.

In addition to the hazardous effects of radiation on human health, it also damages the structure of the settlement itself. Considering all these, it is an obligation to provide a good enough protection from radiation if the settlement is to survive.

V.B. Shielding



V.B.a. The requirements

One part of space facing the sun receives 1390 W/m^2 from sunlight.[93]
This is nearly twice the amount of the energy received from sun on the earth's surface, which is 747 W/m^2. [93] The graph on the left shows solar radiation as a function of wavelength.

In order to calculate the total amount of radiation to be shielded from, first we need to calculate the total area of the torus.

Our formula is: [(94)]

$$A = 4\pi^2 Rr = (2\pi r)(2\pi R)$$

R=4000m and r=500m.

A = 78,956,835 m^2

If 1390 W falls on 1 m^2, then;

1390 x 78,956,835 = 109,750,000,700 W

is the total energy caused by solar radiation per second (Watt= Joule/second).

However, we know that we cannot block all of the energy coming from the sun. In order to imitate the living conditions of earth, we should set our electromagnetic shield in such a way that an energy of 747 J/m^2 per second falls inside our torus.

Therefore:

747 x 78,956,835 = 58,980,755,750

Then:

109,750,000,700 W - 58,980,755,750 ≈ 50,769 MW

V.B.b. The Shield Type and Calculations

There are two types of shields; active and passive shields.

An active shield is a electromagnetic field. Since most of the radiation from sun is emitted as positively charged alpha, beta and gamma particles, a electromagnetic field will repel those positively charged particles.

A passive shield is merely a material blocking the particles. However, the existence of high energy particles might require the use of a material that is less permeable and therefore is bigger in mass. In addition, the use of windows will not be possible on the torus, because unlike earth, the torus has a diameter of 50 meters in the inside. On earth, the earth's magnetic field and the atmosphere work together to prevent these particles from reaching the earth. However, since we have the same atmosphere composition on earth but a much less volume, it will not be possible for the atmosphere to reduce the radiation effectively. A windowless torus will result in a sunlight less environment, which will not only affect the colonists' psychology, but make it impossible to make use of this great energy source called the Sun. Therefore, we will attempt to use a electromagnetic active shield only, if possible.

According to our previous calculations, the total radiation which the torus must be protected against has a total energy of 50,769 MW.

Since Power=Work/time, this is the amount of energy which the torus must be shielded against in one second. By definition, the energy of a magnetic field for linear materials and a constant volume is:

$$U_H = \frac{B^2 V}{2\mu}$$

Where B is the magnetic flux density, V is the volume and μ is the magnetic permeability of space.

μ of space=$1.25663706 \times 10^{-6}$ m kg s^{-2} A^{-2}

The volume of torus is:

$$V = 2\pi^2 R r^2 = \left(\pi r^2\right)(2\pi R).$$

V = 19,739,208,800 m^3

Hence:

58,980,755,750 = B^2 x 19,739,208,800 / (2 x 1.25663706 × 10^{-6})

B= 0.0027404 T

$$F = \frac{B^2 A}{2\mu}$$

Where A is the surface area.

Our surface area is 78,956,835 m^2.

F = 0.0027404^2 x 78,956,835 / (2x 1.25663706 × 10^{-6})

And we find that F= 235,923,022.4 N

$$F = iBL$$

Where i is the current and L is the wire length (the perimeter of the torus - 2π4000 in this case).

235,923,022.4 = i x 0.0027404 x 2π x 4000

i= 3,425,441 A **≈ 3.43 MA**

This is a huge current, however, it is not impossible to provide. A nuclear reactor can easily provide it.

In conclusion, a magnetic field created by a current of 3.43 MA will deflect 50,769 MW of the radiation. Therefore, a passive shield is not necessary. However, in order to provide the current required for the active shield, we would use the surface of torus as a conductor. A current flowing on the surface will not only create the electromagnetic field, but it will also be useful in the power distribution.

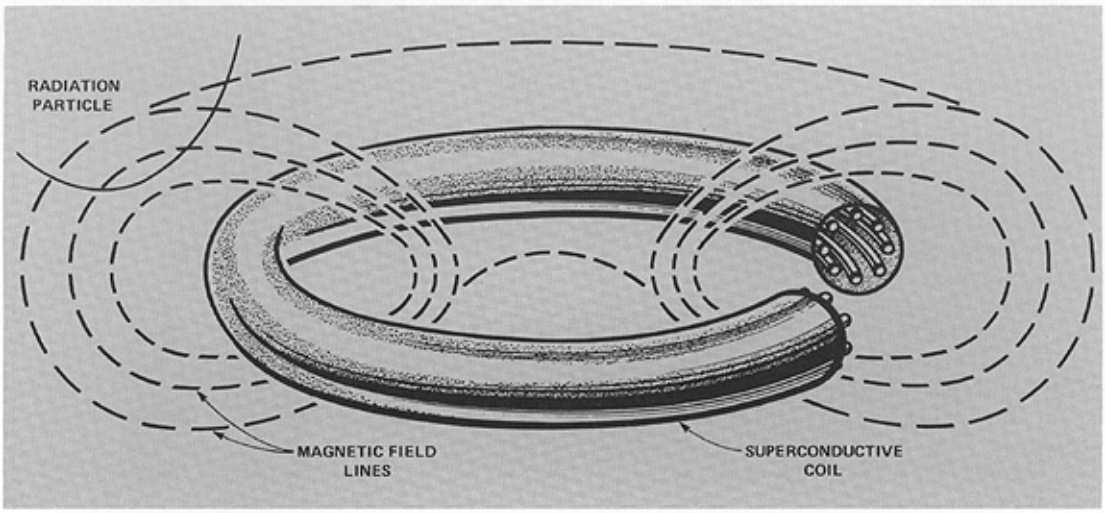
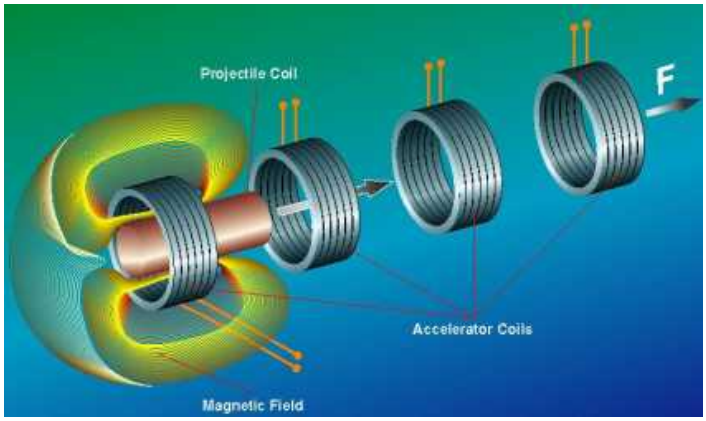


Figure 4-5.– *Magnetic shield around a torus.*

(95)

Chapter VI - External Transportation

VI.A. Transportation between the Moon and the Station



The lunar ores after extracted from the crust of the Moon will be sent directly to L5 for further processing. Mass Drivers will be used to meet this transportation need. A Mass Driver uses no fuel at all. It shoots a steady stream of small fiberglass containers of lunar materials into orbit to a 'Mass Catcher'. The containers by the time they arrive to the orbit will have slowed down, almost to zero speed. Although this technology seems promising and cheap, it is still risky and requires further investigation (96).

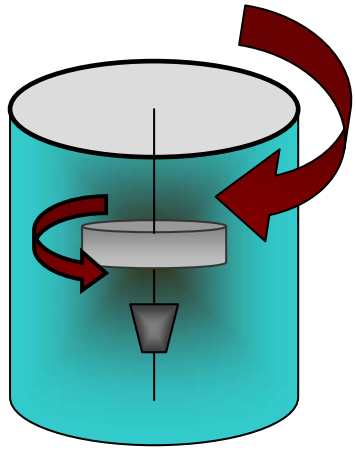
As seen in the picture in the mass drivers there are a series of torus shaped electromagnetic coils. The first coil as the conductive object passes through it is given electricity so that it repels the object, and the second coil is energized so that it attracts the object. Likewise when the object passes through the second coil, the second coil switches to repulsion and the third attracts the object. In this way, the object is propelled through the coils.

Alternatively, chemical rockets can be used. Because of the low gravitational pull of the Moon, and lack of atmosphere, launching rockets from the Moon will not require too much expense. Moreover, the hydrogen-oxygen rocket fuels, mostly (86%) consist of Oxygen, which is very abundant on the lunar crust.

VI.B. Transportation within L5

As stated in the previous sections, in the project lunar extraction facilities are not supported very much. Instead, the people working on the construction of the station will meet their requirements from the temporary residences established in space within the L5 point. Small construction vehicles will be used as well as manufacturing machines reducing the minerals from the lunar ores. A small vehicle model is presented in this part of the project. This new technology, although is still on the phase of imagination, combines different technologies used in today's spacecrafts. It is thought to be very convenient for short-term missions, because of the save of energy it promises.

A widely used technique in monitoring a satellite's direction, the reaction wheels, had been the starting point of the model. However, today in order to propel a spacecraft in space, fuel is consumed. Alternatively, electrical energy is preferred, which gets its power from the solar panels, yet the simpler the mechanism is, the reliable it will be. The reaction wheels on the other hand, demonstrating a smart use of the Newtonian Laws, only provide a change in the angular position of a spacecraft. When turning the reaction wheel, the spacecraft turns in the opposite direction, but does not undergo a forward motion. Our aim in this model was to benefit from the work principle of the reaction wheels to come up with an energy saving solution to change a satellite's location, besides just rotating it around its axes. In this model we made use of electromagnets, powered by PV cells. The following diagrams will help to understand the model.



1. Let's first understand how a reaction wheel would work in a single dimension. For this purpose, in the example we have drawn a cylindrical case for a satellite, in which contains a motor revolving on an axle passing through the center of the cylinder. On the axle, as shown on the diagram, there is an aluminum plate, working as the reaction wheel. As the motor on the axle turns counter clockwise, the case of the satellite will turn on the opposite direction, that is, clockwise.

Rotational Dynamics, Torque and Rotational Inertia
The angular acceleration of a rotating body is proportional to the net torque applied to it;

$$\alpha \propto \Sigma\tau \ ^{(97)}$$

which corresponds to; $\alpha \propto \Sigma F$; Newton's second law for translational motion.
Relating the angular acceleration, α, to the tangential linear acceleration, a_{tan}, we have; $a_{tan} = r\alpha$. If $\Sigma F = ma$, and $\tau = rF$, then;

$$F = ma$$
$$= mr\alpha$$

when we multiply both sides with r to find the torque, we obtain;

$$\Sigma\tau = (\Sigma mr^2)\,\alpha \ ^{(97)}$$

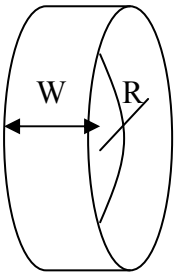
The sum, Σmr^2, represents the sum of the masses of each particle in the body multiplied by the square of the distance of that particle from the axis of rotation. This quantity is called the **moment of inertia (*I*)** of the body. Thus, we get;

$$\Sigma\tau = I\alpha$$

This equation is valid for an object revolving about a fixed axis. This is actually is the translation of Newton's second law to the rotational motion. As it is seen the moment of inertia of a body does not depend only on its mass, but also on how the mass is distributed with respect to the axis. Therefore, different equations are given for differently shaped objects, unless the objects are regularly shaped in terms of their dimensions.

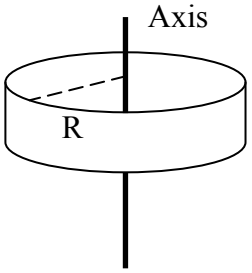
In the diagram drawn above, if we neglect the small sized motor, there are principally two shapes; the outer surface of the satellite, a thin hoop with width (1), and a solid cylinder rotating on the axle [97].

(1)



Thin hoop of radius R, and width W;
$I = \frac{1}{2} MR^2 + 1/12\ MW^2$ [97]

(2)



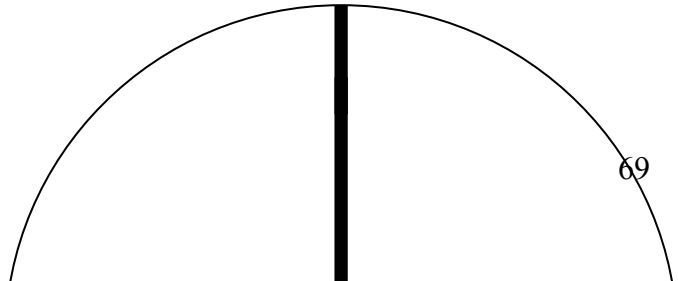
Solid cylinder of radius R;
$I = \frac{1}{2} MR^2$ [97]

Finally, we can find how much the cylinder plate will turn the satellite, by putting the values of the cylinder's mass, the hoop's mass and their radii to the equation;

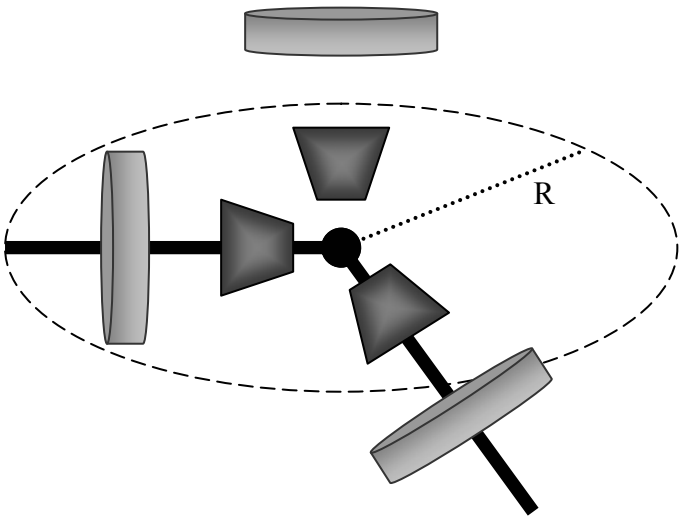
$$(\tfrac{1}{2} M_1R_1^2 + 1/12\ M_1W^2)V_1/(t \,.\, R_1) = \tfrac{1}{2} MR^2\, V_2/(t \,.\, R)$$

where;
M_1; is the mass of the outer shaft of the satellite
R_1; the radius of the satellite's shaft
M; the mass of the solid cylinder
R; the radius of the cylinder
V_1 **is** the tangential speed of the shaft
V_2; is the tangential speed of the cylinder

2. Having explained the rotational motion in one dimension, we can know apply the same technique to three dimensions, as we will do in the satellites of this model.



For a uniform sphere of



radius R, the momentum of inertia is;

$$I = (2/5)MR^2$$

Just as we did in the previous example, we can write the torque of the cylinder on each axle, and this time equate it to the torque of the cubical shaft. However when there are three axes, the other two axles, which will turn with in the same direction as the turning axle, will contribute to the torque created by this axle. Since in three dimension, these axles are positioned perpendicular to each other, as one axle turns, the other two, having the same masses and the same distances to the center of the cube, with form a this hoop of radius R, with no width.

The thin hoop of radius R, formed with the rotation of the other two axles, has a moment of inertia in the equation of; $I = MR^2$. Thus to find the net torque acting in the system, we should add the torque created by the other two axles to the torque of the cylinder rotating on the principal axle.

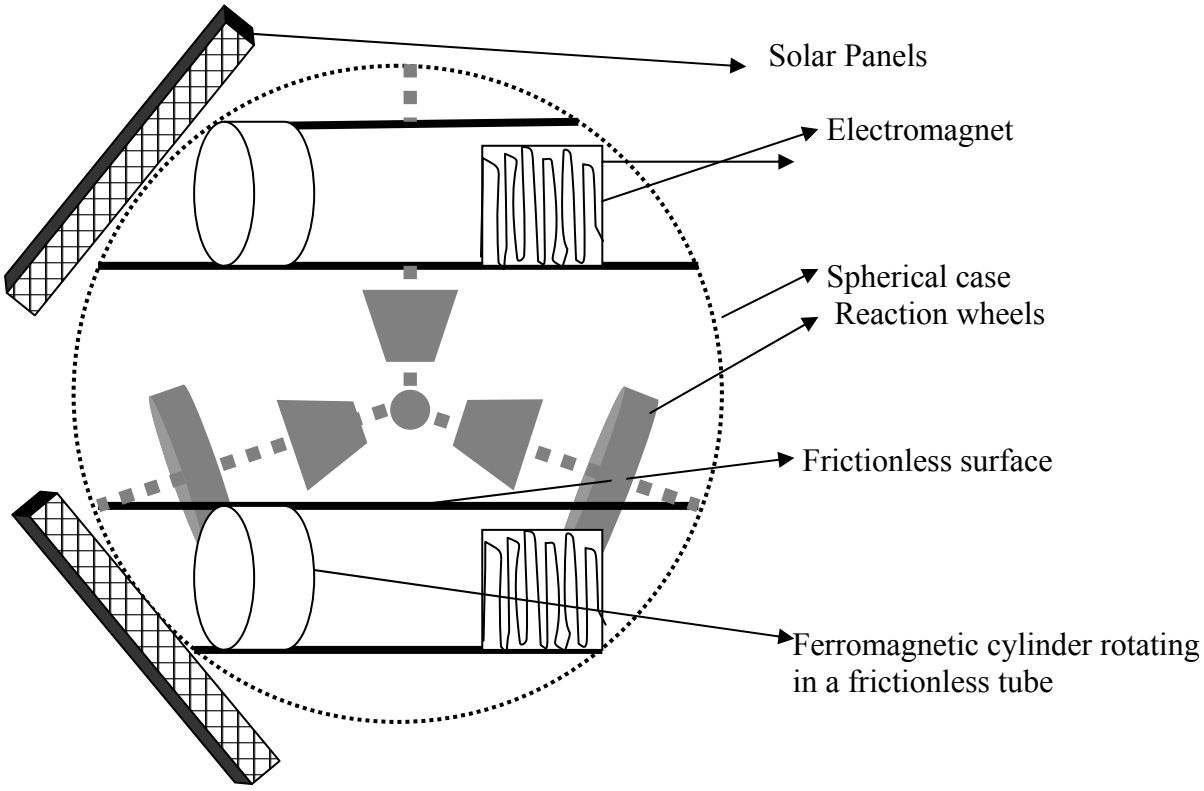
- ✓ For the project, we made an experiment to test the efficiency of the reaction wheels, and determined that they were 81% efficient. The prototype prepared to test the one dimensional motion of a reaction wheel is shown below with the pictures;

In the prototype created to test this phenomenon, servomotors are used. These motors do not rotate continuously, but their rotation can be manipulated by sending coded pulses. This is called Pulse Coded Manipulation, and the 'code' of the pulses refers to the different durations of the pulses. The length of the pulse (e.g. a 1.5 millisecond pulse) will determine how far the

motor turns. Servos were convenient to use for a small model, but of course in the real one, the spacecraft are going to be controlled via radio waves.

- The details of the Experiment are given in the **Annex 1**

3. So far we have explained how to apply the reaction wheel principle to a three dimensional shape. The interesting part of this model, is rather on the mechanism to propel is forward. As we mentioned earlier this is going to be done with the use of electromagnets. Based one more time, on Newton's third law of action-reaction forces, a magnetic field will be created at certain times, and inside the satellite ferromagnetic substances will be subjected to these magnetic fields. The objects will move within the satellite in such a way that the movement will create a reaction force, and will lead the satellite to move in the opposite direction of the object moving inside it.



As the diagram above explains, the solar panels placed on the satellite will generate electricity to the coils. As current passes through the coils, the iron on which the coil is wrapped will create a magnetic field, and affect the motion of the ferromagnetic ball, by either attracting or pushing it away. Let say, the balls are in the position shown above; if magnetic field is created in the tube, the ball will start to move toward the electromagnet. Thus, the satellite will move to the left. The satellite would continue to move to the left even after the magnetic field perishes, since there is no force acting on it in space. If the speed of the spacecraft is desired to increase, the spacecraft, with the reaction wheel positioned z-axis, can be turned for 1808. Thus, this time the magnet and the ball will be on the left side, attacked to each other. If with a switch the direction of the current passing through the coil is changed the magnetic poles will change too, and the electromagnet this time will push the ball away. The ball going to the right, will make the spacecraft move to the left again, and will contribute to the speed of the vehicle. In short, with the cooperation of the reaction wheels and magnetic fields, the spacecraft can move further by rotating continuously for 1808.

- ✓ Further improvements to increase the efficiency of the system can be done by using the solar tracking technologies applied on the solar panels of the houses.

VI.C. Transportation between the Earth and L5

Chemical Rockets:

In the transportation between the Earth and the Moon, the traditional technologies, chemical rockets will be used. Although we could use alternative propellant systems such as nuclear propellants, we don't want to take risks when launching the rockets from the ground. Even though it will cost more, it is better to take care of the safety issues, and prevent and danger to the environment.

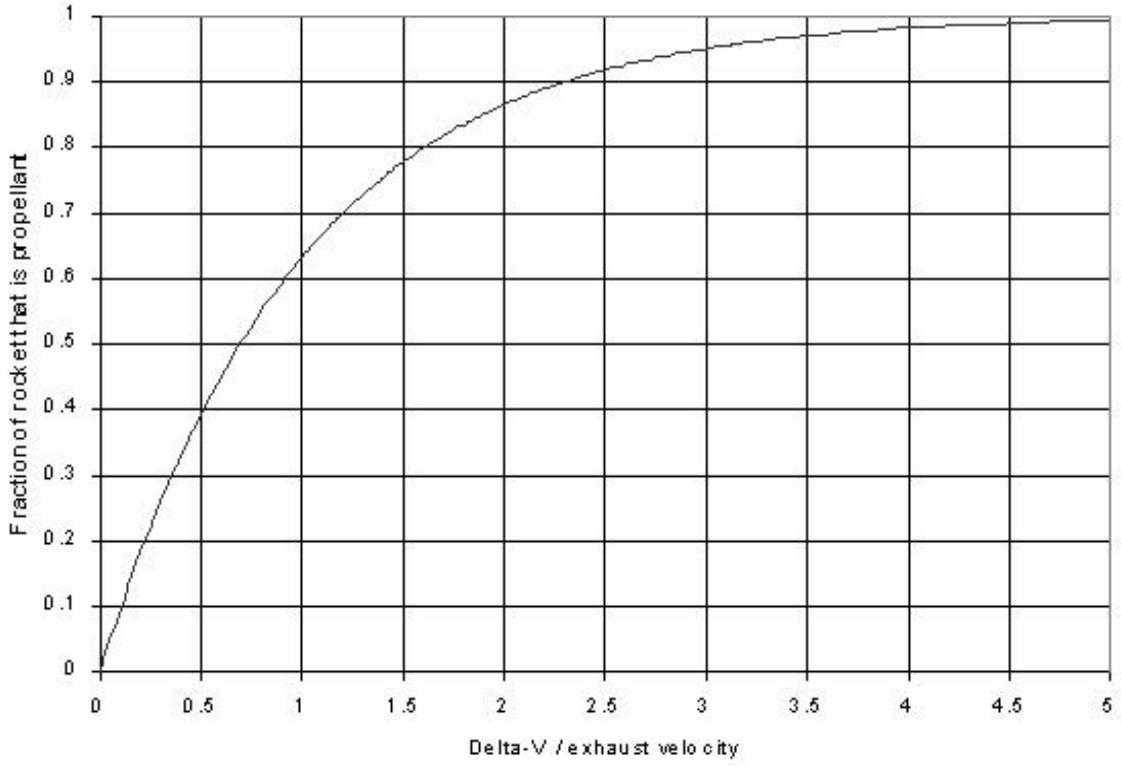
Generally, in the propulsion systems the thrusters should provide a force 1.2 times bigger than the weight of the spacecraft they are propelling [(98)].

Rockets generally use liquid propellants. Although the liquid propellants require a complex system of pumps and piping, they generate greater lifting power, than could be obtained from the combustion of the solid propellants. The solid propellants have smaller, and lighter combustion chambers. On the other hand, solid propellants, for a short time can provide great thrusts; therefore, they are going to be used in the first stage of the multistage rockets, as it will be explained later. Both the solid and liquid propellants contain more than one substance, one of which is an oxidant, in other words, an oxygen-producing substance. The oxidizing substance in the fuel allows the burning process even at high altitudes where the oxygen level is low.

As it is known for the rockets to go out of the atmosphere they should reach very quickly to the escape velocity. It is not possible to reach this velocity by increasing the time of combustion, which will require a huge amount of fuel that already consists most of the rockets weight. Therefore, multi stage rockets will be used. In this system, as each rocket detaches itself from the main body progressively. The main body starts its own combustion at the moment when the previous stage has reached its maximum speed, and detaches the previous stage. In this way, the dead weight of each burned out rocket stage is removed, so that the next rocket continues to flight lighter and unburdened by useless structure. The rockets that will carry people or material to the station will use solid propellants in the first stage, and liquid propellants in the main stages due to their abilities to provide lower thrusts as well as high thrusts when maneuvering the rocket[(99)].

There could have been many ways to achieve grater speeds if the increase in the speed wouldn't have caused extremely high temperature within the rocket. The thrust fore is directly proportional to the pressure in the combustion chamber. Therefore the combustion chambers of the motors to be used in the propulsion systems must be resistant to pressure levels ranging from 35 bar to 70 bar[(99)].

If we note the velocity of a rocket as Delta-V, which can be measured in m/s or km/h, with the graph below we can see the relationship between Delta-V and the proportion mass of the propellant required to the total mass of the rocket. For example, to achieve a Delta-V of



1.5 times the exhaust velocity, the rocket must be 78% propellant. Then the remaining 22% can be everything else - payload, fuel tanks, mechanical support structures, engines, fuel pumps, guidance computers etc. (100)
So in the rockets, highly efficient propellants should be used.

Specific Impulse and Propellant Types:

The specific impulse (*I*sp) of a propulsion system is the change in momentum per unit of propellant. The higher the specific impulse, the less propellant is needed to gain a given amount of momentum. Therefore, a propulsion system is more fuel-efficient if the specific impulse is higher(101).

Propellant	Exhaust	Typical Isp (seconds)
zinc/sulfur	zinc sulfide	240
aluminum/ammonium perchlorate	*	287
hydrazine/nitrogen tetroxide	*	313
ethanol/oxygen	water/carbon dioxide	330
methane/oxygen	water/carbon dioxide	370
hydrogen/oxygen	water	465

* contains many chemicals in exhaust.

As it is seen hydrogen/oxygen and methane/oxygen propellants are very efficient, so they will we mostly used as rocket fuels.

Aerobrake:

The transportation between the Earth and the station includes also the vehicles returning to the Earth. The launch of these vehicles will be much easier since they will essentially not need any fuel to be propelled, but to achieve speed a small amount of fuel can be supplied to these rockets. However, this time the main challenge is how to prevent the vehicle from burning out by the atmospheric friction, or from achieving too much speed. For this problem, the "aerobraking" technique will be used. This is essentially the use of atmospheric friction to manipulate the speed of the spacecraft when returning to the Earth(102). In this technique the key point is the heat shield of the aerobraking vehicle, which should be able to withstand high temperature and pressure. The heat shield can be manufactured from lunar sources. The aerobraking tiles will be made of silica (SO_2), which is commonly present on the lunar crust.

Determining the Speed of the Rockets

First of all, this is an extremely expensive process, since the distance between the destination and the source is very big and huge masses are involved in the process. (Here, in this section, destination stands for the settlement, whereas the source stands for the earth/moon/mars/other planets, depending on the location of the ores.) Ignoring the gravitational attraction between the rocket and objects other than the destination and the source, here is a way to determine the launching speed of the rocket:

* Let the launching speed=, **G** = gravitational constant, $\mathbf{M_S}$ = mass of the source,

* $\mathbf{M_R}$= mass of the rocket including the ores, $\mathbf{R_S}$= radius of the source, $\mathbf{h_S}$= height of the rocket above the surface of the source and **X**= the distance between the destination and the source

* Then $\mathbf{0.5M_RV_L^2 - GM_R\,M_S/(R_S+ h_S) = - G\,M_R\,M_S/X}$ (Using the laws of gravitational potential energy)

* $\mathbf{0.5\,V_L^2 = GM_S/\,(R_S+ h_S) - G\,M_S/X}$

* $\mathbf{V_L^2 = 2GM_S\,(1/\,(RS+ hS) – 1/X)}$

* $\mathbf{V_L = \sqrt{(2GM_S\,(1/\,(RS+ hS) – 1/X))}}$

* Given the mass of the earth, the moon, mars or any other source, the gravitational constant, the radius of the source and the distance between the destination and the source, this speed can be calculated.

* **The energy needed to reach this speed can be found very easily:**

ΔKE: $\mathbf{1/2M_RV_L^2 = GM_R\,M_S\,(1/\,(R_S+ h_S) – 1/X)}$

* The same equation and method can also be used for the transportation of other materials, such as hydrogen from Mars.

VI.D. Intergalactic Transportation

Ion Rockets:

For long distances, such as a travel among galaxies, an alternative and promising way could be used besides the conventional rocket types. These rockets are called the ion rockets. The ion rockets use a small electrostatic particle accelerator to accelerate ions to very high velocities. These rockets have very low thrust, meaning that they push a spacecraft very gently. Therefore, they are unsuitable for lifting payloads. However, their advantage is the low energy consumption. They can go for miles with a small amount of fuel; so they can be preferred for very long distances.

In the rockets providing interplanetary transportation, the energy source will again be the solar power. The power from the solar panels will drive an ion thruster, which strip the electrons from the Xenon atoms, leaving the atoms as ions that are positively charged. Electrical forces then accelerate the ions with higher speed from the chemical rockets, without needing high temperatures. The energy could be supplied from the nuclear reactions, if the safety issues are eliminated[(102)].

So far, several successful results have been achieved from the ion propulsion, as in the Deep Space 1 launched on 1998 and SMART 1 launched on 2003. The temperature factor and the minuscule weight of the fuel in comparison to the traditional rocket fuels makes the ion rockets very attractive for long term missions in space.

In the PINTA space station, ion rockets will be used, in this way the station can serve to scientific observations, and huge steps toward exploring the deep space can be taken via the station.

Chapter VII – Social Life

VII.A. Residential Design

Description of the space station

In the space station, everything will be artificial and in the control of man. This is harmful for human physical and psychological well being. Therefore the sense of artificiality should be reduced.

In an artificial environment, people will feel as if they are in a dream, since nothing around them is real. This is a philosophical theory called Solipsism Syndrome. This syndrome generally can be seen where there are 24-hour nights or the majority of the day is in darkness. The people who are in Solipsism Syndrome feel uncomfortable, lonely and separated from others because life is a dream for them, even their friends are the part of the nightmare. In addition to Solipsism Syndrome, the psychology of the settlers can be ruined because they are caught in a limited place. For these reasons people can feel claustrophobic and upset in the station. This can reflect on their personality as being aggressive, quarrelsome, restless and depressed. These problems should be considered carefully and the design of the space station should be done accordingly.

As the torus won't have a lot of trees near the buildings and animals inside it or watercourses among the torus which could make people calm and feel the artificiality less, several things stated below, can be taken into account while designing:

1) The plan and design of the settlements in the space station should aim for flexibility and aesthetic quality.

2) The Earth is circular in shape, so people can't see beyond the horizon. There are limits to what the human eye can see. These limits make people feel that they are living in a place much bigger than it actually is. In the torus shaped space station there should be higher and lower altitudes. This will create a vision similar to the one people have on Earth.

3) Each dwelling should have at most 2 or 3 flats in order to prevent people from having psychological disorders such as claustrophobia.

4) The recreation areas/parks/open places should be built. (In the space settlement, there could be only one big bathroom area including the toilets for all the people. However those kind of common places they will all share can create arguments between the people, so less common places like that will be better.)

5) Psychological help: periodic meetings with psychologists/pentatonic music in the buildings/entertainment can be useful.

6) Nuances such as the types of the equipments each habitant uses or the color of the buildings and the differences in the decoration of the private places etc. will reduce the sense of the loss of privacy. Considering these small touches that can break the monotony, we will give flexibility to the design too.

7) The differences among the settlers should be supported. In addition, taking the responsibility of something (a pet of the person's choice or a child) or an aim (to be an expert in his job/ to discover new things etc) can alleviate the solipsism, too. For those who have professional aspirations, a competitive atmosphere should be created.

VII.A.a. The Buildings

We will organize our colony so that the 10000 people will be divided into 10 "towns", with each town consisting of a 1000 colonists. The buildings are designed in the same style for all of these ten towns. Each town will consist of the same set of buildings, all of which will be made of a material resistant to fire. All the buildings will be interconnected in order to provide easy access to every public building. Every town will consist of two libraries, an observatory, two hospitals, two theater halls, two movie theaters, two art galleries, two local newsrooms, four restaurants, a People's Council, two emergency departments and 1000 houses for the colonists.

- Houses

The minimum amount of private space a colonist will be given is 30 m^2. The residency related parts of the towns will be separated from the town centers and housing will be arranged so that people don't group together, which can disturb the homogeneity of the society. Each house will be private and someone other than the owner can only enter a house if he's granted the permission by the owner. The owner is expected to take all the responsibility of his house. The houseowner can have a pet if he wishes to. In fact feeding pets is encouraged since it develops the sense of responsibility of a person. The owner can also decorate every part of his house in whichever way wishes. Every house will have a laptop which will serve as a media center.

Since people will live close to where they work, they will only need to use a bike for their transportation needs. Each house will come with a bed, a wardrobe, a table and a bathroom. Even though controlling the supply of water is harder when people have thousands of private bathrooms, we will have private bathrooms since it is considered as a vital part of privacy. Also, public bathrooms are the ideal places for diseases to spread. The wardrope and the desk will be parts of the room and won't be seperate as pieces of furniture. This will help us manage the space more efficiently. The desks will be made of glass because the glass desks do not look bulky and give less of a claustrophobic feeling. There will not be a kitchen in the houses but there will be a mini-fridge for snacks, drinking water and medicines.

- Libraries

A library will contain 90 seats, 47,000 books, 340 film/music CDs, 23 computers(ref.2). A library with these features takes up 700 m^2 of area, but our libraries will take up only 400 m2 since every book will be burned on CDs and be digitized.

In the libraries, the important articles from the Earth and the local newspaper of the settlement will be recorded day by day. The libraries will have web-based databases, so the inhabitants can reach the informations about the books and download them to their laptops. This mobility of information will also hopefully lighten the feeling of isolation.

The libraries will be the hearts of the towns, since everyone will need to use them, regardless of their jobs. The libararies will play another crucial role in establishing the communication between earth and the space station. The librarians will inform the townspeople in the town about the new books, which can easily be done via e-mails or newspapers or flyers. They are also supposed to lay groundwork for public-days. In these days, the libraries will be used like a recreation areas, like platforms. People can come and explain their ideas about everthing in here, or can show and describe their discoveries/invention. There can be literature/poetry/science days which people can discuss

ideas or events and socialize. In addition, the libraries can organize chess competitions or likewise competitions.

- Schools

The areas of the schools will be based on the child population in the community. The kindergarten, elementary, junior high and high school educations will be given there. However, there will also be other courses in other buildings which will serve educational purposes. The schools will be connected to the library buildings.

VII.A.b. Recreational Areas

A cinema center will occupy an area of 70 m^2. Movies made on earth as well as movie made in the space station will be featured in these buildings. However, all the equipment needed for the movie theater will be in the theater hall. The employees of the cinema center and the theaters will work cooperatively (The light technicians, stage machinists for theaters and artists for films) Also like the other centres there will be lessons (such as photography, the history of cinema, learning how to make movies etc) in the movie theaters.

- Theater Halls

The theater halls will actually feature operas too. The halls will have the capacity of seating 550 people and will need 880 m^2 of area. The theater halls will consist of two storeys. In the first storey will be the backstage, the stage and most of the seats. In the second storey will be the administrative rooms, a room that controls the lights and other projection related matters, and a balcony with some seats. The tickets will be free and on a first come-first serve basis.

The theaters and operas will have many functions. The first and the most obvious one of these functions is presenting plays. Again, like the movie theaters, plays from the earth and plays by station playwrights can be performed. Again like theaters theaters will offer acting, directing etc. courses. Similar courses will be offered by the opera artists. Dancing lessons can also be offered by theater artists. These courses will help the inhabitants of the space station specialize in their hobbies. The musical directors of the operas will also organize the music that will be played in public places. Musical education will be given and the citizens will be encouraged to play music, form bands etc.

- Shops

The shops and offices will be connected to the theater hall and the art gallery. There will be ten shops that will sell clothing, shoes, decorative items etc. Each shop will take 40 m^2, which uses up a total of 400 m^2.

- Art Galleries

An art gallery's total area will approximately be 200 m^2, but since it will consist of two storeys it will occupy only 100 m^2 in the torus. The personnel of the art galeries (graphic artists, artists, architects, designers, web designers, dressmakers, sculptors...etc) are expected to assist in the towns' construction, designing of the streets and the new buildings while

taking into consideration the psychological effects of each design. Artsists should also give courses as in other buildings.

The art gallery employees will design the newspapers. They will also design the posters of new books, plays and movies. The theater hall and the artists will be in close contact since the artists will help the décor of the plays and operas. Art galleries will also offer courses in realistic represtations of the human body and other forms of painting.

- Newsroom

A newsroom will occupy an area of 70 m^2. This building will be the place where the actual computer system is. Every person in the station will be given an account and with which they can read the newspaper. The newspaper will be a cooperative effeort of the web designers and the artists. The settlers will also be given an e-mail adress for communication purposes. All other buildings will be connected to one another by the network.

- Observatories

The observatories will take up 3,000m^2, but since they will consist of three storeys, they will only take up 1,000 m^2 on the torus. The word observatory might be a misnomer since the observatories will be the centers of every branch of science from biology to astronomy. Like other specialized buildings, the observatories will offer advanced courses in science.

- Restaurants

A resturant will take up approcimately 300m^2 on the torus. The restaurants will have three sections: the dining hall, the food silo and the meal preparation place. A big public restaurant is useful in that it enables easy controlling of water and food supplies. This way, people don't get to waste the very valuable water in their own kitchens. The only food items that can be kept in the houses will be snacks which will be given out by the restaurants periodically.

The agricultural area will be close to the restaurants, which will reduce the cost of the transportation of food from the fields to the restaurants. There will be shortcuts to the restaurants from all buldings.

The restaurants will have a capacity of 125 people, and there would be four restaurants. Therefore, they will work in shifts. Restaurants will also be places where people can listen to relaxing music and just socialize.

VII.A.c. Health Care

- Hospitals

According to A Design Study, (ref.3) a hospital with a capacity of 50 beds for 10,000 people should occupy approximately 2900m^2 or 58m^2/bed including the administrative, nursery, diagnostic, obstetrical, surgical, circulation facilities and service. So, for 500 people including

same departments of the hospital, the total area of a hospital with 3 beds should take about 174 m^2. Hospitals should also offer both psychological and physiological check-ups.

- Emergency Departments

These small departments will provide emergency transportation (i.e. ambulances), will function as the police and fire department. It will also have radiation shelters and will be connected to the network around the settlement in order to inform settlers in case of an emergency and give instructions. Drills will be conducted regularly.

VII.A.d. Political Institutions

- The People's Council & The Municipal Assembly of People's Power

This will be the local body of administration, and it will function according to articles 66-72 of the constitution. It will consist of a single building, and these councils will meet in turns.

VII.B. Internal Communication

Communication is a very important issue, especially in such a space settlement. Since the population is not very high, it is possible (and unavoidable in some cases) to use hi-tech equipment for providing the communication needs of the citizens.

For internal communication, we first need to determine our needs.

VII.B.a. Individual Communication

For the people's own communication needs, a mobile phone system will be a good solution for various reasons. First of all, mobile phones are user friendly and practical (easy to use and carry). Furthermore, it is fast and speeds up the overall communication process. In addition, mobile phones are relatively cheap.

Since every citizen over 15 will be provided with a laptop, there is no need for establishing an expensive network such as the 3G networks. A simple GSM network will be enough.

The diameter of the torus is approximately 1730 m. A typical GSM base station could support ranges up to 1-10 kilometers, whereas huge ones support more than 30 kilometers of range [(118)]. Apparently small base station should do it, however, due to the complex structure of the settlement, as well as the electromagnetic shield outside the torus, two base stations will be used for backup. Since there are only 10,000 people in the settlement, a typical GSM 900 network will be more than enough.

VII.B.b. Communication between working stations

Since all the working stations (that is, factories, offices, government organizations etc.) will be equipped with necessary computer infrastructure, the communication requirement is merely a computer network solution. A wireless network for is capable of complying the requirements for communication inside working stations. However, due to the size of the

settlement, it is neither practical nor healthy (due to the effects of radiation on human health) to use wireless network throughout the entire settlement. Instead, wireless connections to local servers and a WAN connection between these servers will be much more useful.

For the workstations, IEEE 802.11g will be the protocol for wireless network. This protocol operates at 2.4 GHz frequency and provides a maximum speed of 54 Mbit/s. [119] Since 1 Mbit=10^6 Bits and 1 Byte= 8 bits, this corresponds to 6750 KB/s or approximately 6.59 MB/s. This speed should be enough for everybody.

For the communication between workstations, it is not possible for the current LAN technology to provide the range required. Therefore, we need to use a different approach. A Wide Area Network (WAN) is a good solution. The WAN connection will connect the servers of each workstation, and the computers of the workstations will be connected via Wireless LAN.

The typical range for wireless network is 150-300 feet (50-100 meters) indoors and up to 1000 feet (330 meters) outdoors. [120] Since we should consider the settlement as "indoors", we are going to take the range as 50 meters. This range is enough for the vertical communication (the height inside the torus is 50 m). The diameter of our torus is approximately 1730 m ($2\pi 275=1727.875959$). Therefore 35 wireless adaptors will cover all of the station, providing every bit of the station with high speed wireless network connection.

VII.C. Population

VII.C.a. Introduction

Designing a controllable and suitable population is one of the most important steps in forming a comfortable community. This problem can be solved from many different perspectives, ranging from sociological to economical points of view. Let's have a look at the fundamental relationships we should consider:

- Population during construction **VS**. Population after construction
- Size of the settlement **VS.** Population
- Population Composition **VS**. Occupations
- Gender and age regulations
- Food/water/energy/industrial/educational supplies, self sustainability **VS.** Population Growth Control, Dangers of overpopulation
- Cultural diversity, common language problem, social relations

VII.C.b. Population during construction VS. Population after construction

First of all, we need to define the composition of the population according to our needs. For example, during the construction phase, the role of legal, economical, educational, and administrative affairs will not be as crucial as the issues of engineering, architecture, construction, maintenance, transportation, food preparation and healthcare. Therefore, the composition of the settlement should be regulated primarily to satisfy our needs. After the construction period is over, the composition then can be re-adjusted, so that a balanced community is created.

During the initial phase of construction, people who work on the following areas will form the majority of the population: [138]

Engineering 25% (Communication with the Earth will also increase efficiency)
- Aerospace
- Computer Science- Mathematics
- Structural
- Mechanical
- Electronics

Architecture 15% (Communication with the Earth will also increase efficiency)

Healthcare 10% (Communication with the Earth will also increase efficiency)
- Physicians of all types (orthopedists, cardiologists and internists have major importance)
- Laboratory & Experimentation
- Nursery and other non-physician personnel

Construction personnel 20% (Communication with the Earth will also increase efficiency)

Cleaning, Maintenance, Production of Necessary Materials 10% (Communication with the Earth will also increase efficiency)

Food Preparation 10% (Communication with the Earth will also increase efficiency)
- Dieticians and other personnel

Preparing the settlement for the first non-professional inhabitants (Smaller than other branches) 10% (Communication with the Earth will also increase efficiency)
- Structural (designing the location, size of houses/streets and etc.)
- Economical – Industrial (providing a controlled establishment of all branches of business)
- Agricultural (feasibility experiments, designing the location of farms, parks and etc.)
- Educational (Preparation of educational materials)
- Sociological (Creating a diversity of cultures/languages)
- Production (Supplying the needed materials for the initial population)

Clarifications:
- All inhabitants will be trained for outer-space conditions before they arrive at the settlement. Inhabitants of the initial construction phase will have extra orientations.
- As the construction phase is continuing, some inhabitants will be replaced by permanent inhabitants.

VII.C.c. Size of the settlement VS. Population

The population will be eventually about 10,000 **after the construction period is over**. Reaching this number will take time, since a small population will start living in the settlement. This means 150m^2/person.

The population during the construction phase will be about 2000. This number will slowly increase with the gradual transport of inhabitants. The initially arriving inhabitants will mostly be experts on their areas.

VII.C.d. Final Population Combination in Terms of Occupation

We will have four main branches of occupations: (139)

1- **Agriculture 5-7% of population**
2- **Industry 18-22% of population**
3- **Service 57-63% of population**
4- **Maintenance and Control of the Settlement 13-16% of population***

***Note:** While deciding on these percentages, we analyzed the population compositions of following countries/organizations: Switzerland, USA, Australia, EU, Turkey, Brazil, Russia, S. Africa, Japan, and China. (139)

1-Agriculture: 5-7% of population

Agricultural Management, distribution of products
Agricultural Trading
Farming- Production
Building of forests, enriching the ecosystem of the settlement by increasing the diversity of plants
Agricultural research for development and protection of the settlement

2- Industry 18-22% of population

Industrial Management, distribution of products,
Industrial Trading
Establishment of factories that do not harm the ecosystem
Production
Industrial research on transportation, energy source and management

3- Service Maintenance and Control of the Settlement 13-16% of population

Business, financial operations, sales
Computer science
Mathematical and general science
Architecture and structural engineering
Healthcare
-Physicians of all types (balanced), nursery etc.
-Production and development of medical devices/ systems
Education, libraries, Cultural Variety Centers, Language Education, Art Society Literature Centers
Scientific Development Centers
Sports and Arts of all kinds
Recreation, tourism
Media, Communication with the Earth
Food preparation & distribution
Transportation of materials and inhabitants
Office, administrative issues,

4-Maintenance and Control of the Settlement 13-16% of population

Engineering of all types to control all of the life support systems
Structural maintenance, control
Government duties, affairs with United Nations
Financial Inspection of all economic affairs
Inspection of population growth, social affairs
Legal issues
Protection of the settlement
Other non-expert personnel to reinforce these seven areas

Clarifications:

- All these sectors will be a combination of expert and non-expert personnel.
- Inhabitants of age 18-55 will be asked to work in an appropriate sector.
- University students will not have to work, but can take part time jobs if they prefer.
- Inhabitants over 55 will not have to work. They will be entitled to retire. However, especially scientists, engineers, artists and other qualified and experienced citizens will be encouraged to participate in the education of the young generations as paid part-time jobs. In the case of emergency workforce requirements, which will be decided by the People's Councils, they might be asked to do mandatory labor. No "mandatory labor" can last more than 3 months and longer than 40 hours per week.
- Inhabitants under 18 will be trained in appropriate areas.

VII.C.e. Gender and age regulations

The first inhabitants that will move to the settlement will be half male and half female. The inhabitants of the initial construction phase will also have the same ratio.

Age percentages*:

0-14 age 22-26%: Since younger inhabitants' adaptation to the conditions in the space settlement will be much easier, a young population is needed to create a new community. In order to maintain a stable and controlled population growth, this percentage will not be kept too high. (139)

14-55 age 65-69%: In order to make scientific and social developments, a large adult population is needed. This is also important for the stable growth of the population. We should also make sure that an important part of this population (%5-10) will join the old population as some inhabitants are born and some die. (139)

+55 age: This population will mostly consist of experts, artists and sociologists who can train the young generation. (139)

***Note:** While deciding on these percentages, we analyzed the population compositions of following countries/organizations: Switzerland, USA, Australia, EU, Turkey, Brazil, Russia, S. Africa, Japan, and China. (139)

VII.C.f. Food/water/energy/industrial/educational supplies, self sustainability VS. Population Growth Control, Dangers of overpopulation

During the initial construction phase, supplying food, water, energy and other needs will be difficult since the service systems will not be working with full capacity. Therefore, we should take some precautions such as transportation of some these materials. However, since

this process is very expensive and time/energy consuming, we will mostly concentrate on lightweight materials that can be kept fresh for a long time. As soon as the agricultural, industrial and servicing systems start functioning, they will be able to supply the required materials for the whole population.

One of the biggest obstacles we need to tackle is the issue of overpopulation, which is population's exceeding the *carrying capacity* of an environment. The main criteria is not the density of population. Instead, overpopulation is directly related to the amount of resources per individual. (140)

Overpopulation is dependent on these factors**:** (140)

- ***Increases in birth rates,***
- ***Decline in mortality rates***
- ***Decrease in the amount and productivity of resources (food, water, fuel, education, electricity, healthcare, transportation, waste management and etc.***

Overpopulation can have deleterious consequences: (140)

- ***Low quality of life***
  - **** Low economic status***
  - **** Low level of literacy***
  - **** High rate of unemployment***
  - **** Insufficient land to live on/cultivate***
  - ****High crime rates***
- ***"Environmental degeneration"*** *(140)*
- ***Shortage of resources***
- ***Serious conflicts among groups of people***

Considering the difficulties of transportation, communication and the relatively small size of the settlement, we can conclude that overpopulation might have destructive effects on our community. Therefore, following precautions should be applied strictly:

* Control of birth rates
- Max two children per family
- Usage of long term contraceptive methods like vasectomy and tubal ligation.(141), p.545
- Encouragement of short term contraceptive methods like condoms.(141), p.545
- Precautions for infant deaths, improvement of healthcare service

*Control of death rates
- Improving healthcare facilities
- Prohibiting the act of freezing dead bodies to -198^{0}C and re-heating them in the future to heal some currently mortal diseases

* Control of migration:
- Avoiding the population to exceed 10000 with the effect of incoming tourists
- Improving the quality of life to avoid excessive amount of migration to the Earth or other settlements.

* Development of industrial and agricultural resources
- Supporting experiments and researches that aim to improve the productivity of all these sources as well as finding new sources of energy, food, water and etc.

- Improving education facilities in order to raise qualified personnel for these sectors.
- Prohibiting any industrial or agricultural activity that can be harmful to the ecosystem in any way

VII.C.g. Cultural diversity, problem of common language social relations

Although it is possible to have inhabitants form various countries, we need to have at least three common languages, which can enable the inhabitants to communicate without having any problems. Since Chinese, English and Spanish are the three most commonly spoken languages, they are more suitable for this.

One of our long term aims should be to create a new generation with its own unique culture. To accomplish this, we have to embrace any cultural elements from every culture form our own culture by using our compassion and humanist emotions. By focusing on the blending power of arts, sports, science and literature, we can add one more piece to the intricate mosaic of cultures.

VII.D. Government and The Constitution

Constitution of the Republic of PINTA, 2007 (127)

CHAPTER I

POLITICAL, SOCIAL AND ECONOMIC

PRINCIPLES OF THE STATE

ARTICLE 1. PINTA is an independent, sovereign, secular, social, democratic, state of people which respects human rights, organized with all and for the good of all as a united and democratic republic, for the enjoyment of political freedom, social justice, individual and collective well-being and human solidarity.

ARTICLE 2. The official name of the state is Republic of PINTA and the official language is English.

ARTICLE 3. In the Republic of PINTA the power lies in the people, from whom originates all the power of the state. That power is exercised directly or through the assemblies of People's Power and other state bodies which derive their authority from these assemblies, in the form and according to the norms established in the Constitution and by law.

When no other recourse is possible, all citizens have the right to struggle through all means, including armed struggle, against anyone who tries to overthrow the political, social and economic order established in this Constitution.

ARTICLE 4. The state recognizes, respects and guarantees freedom of religion.

The Republic of PINTA is a secular state. Any religious institutions are separate from the state.

The different beliefs and religions enjoy the same consideration.

ARTICLE 5. The state:

a) - maintains and defends the integrity and the sovereignty of the country;

- guarantees the liberty and the full dignity of man, the enjoyment of his rights, the exercise and fulfillment of his duties and the integral development of his personality;

- consolidates the ideology and the rules of living together and of conduct proper of a society free from the exploitation of man by man;

- protects the constructive work of the people and the property

- directs in a planned way the national economy;

- assures the educational, scientific, technical and cultural progress of the country;

b) as the power of the people and for the people, guarantees

- that every man or woman, who is able to work, have the opportunity to have a job with which to contribute to the good of society and to the satisfaction of individual needs;

- that no disabled person be left without adequate mean of subsistence;

- that no sick person be left without medical care;

- that no child be left without schooling, food and clothing;

- that no young person be left without the opportunity to study;

- that no one be left without access to studies, culture and sports;

c) works to achieve that no family be left without a comfortable place to live.

ARTICLE 6. All state bodies, their leaders, officials and employees function within the limits of their respective competency and are under the obligation to strictly observe democratic legality and to look after the respect of the same within the context of the whole of society.

ARTICLE 7. In the Republic of PINTA rules the system of economy based on the people's ownership of the fundamental means of production and on the abolition of the exploitation of man by man.

In PINTA the state encourages all of its citizens to work at their full capacity within the limits of the predesignated working conditions (these working conditions will be prescribed by law) in order to maintain a healthy economical structure which will be used to provide the citizens with a good standard of life. The state also integrates the principle of providing every citizen with the requirements for a good life standard, taking the principle of equality into account.

ARTICLE 8. State property, which is the property of the entire people, comprises:

a) the lands that do not belong to small farmers or to cooperatives formed by them, the plant and animal resources in the Republic's maritime economic area, and means of communications;

b) the factories, chief means of transportation and all those enterprises, banks and facilities, as well as the factories, enterprises and economic facilities and scientific, social, cultural and sports centers built, fostered or purchased by the state and those to be built, fostered or purchased by the state in the future.

Property ownership may not be transferred to natural persons or legal entities, save for exceptional cases in which the partial or total transfer of an economic objective is carried out for the development of the country and does not affect the political, social and economic foundations of the state, prior to approval by the Council of State or its Executive Committee.

The transfer of other property rights to state enterprises and other entities authorized to fulfill this objective will be prescribed by law.

ARTICLE 9. The state organizes, directs and controls the economic life of the nation according to a plan that guarantees the programmed development of the country, with the purpose of strengthening the economical system, of increasingly satisfying the material and cultural needs of society and of citizens, of promoting the flourishing of human beings and their integrity, and of serving the progress and security of the country.

The workers of all branches of the economy and of the other spheres of social life have an active and conscious participation in the elaboration and execution of the production and development plans.

ARTICLE 10. The state directly administers the goods that make up the property of the entire people's, or may create and organize enterprises and entities to administer them, whose structure, powers, functions and the system of their relations are prescribed by law.

These enterprises and entities only answer for their debts through their financial resources, within the limits prescribed by law. The state does not answer for debts incurred by the enterprises, entities and other legal bodies, and neither do these answer for those incurred by the state.

ARTICLE 11. The state controls and directs foreign trade. The law establishes the state institutions and officials authorized to:

- create foreign trade enterprises;

- standardize and regulate export and import transactions; and

- determine the natural persons or legal bodies with judicial powers to carry out these export and import transactions and to sign trade agreements.

ARTICLE 12. The state recognizes the right of every citizen to legal ownership of their homes and personal property necessary to survive, as prescribed by law.

Citizens may only incorporate their properties to third persons with the previous authorization of the competent state body and fulfillment of the other legal requirements. They may also sell their properties, swap them or transfer them for another title to the state, or to each other in the cases, forms and conditions prescribed by law, without detriment to the preferential right of the state to the purchase of the land while paying a fair price.

Land leases, sharecropping, mortgages and all other acts which entail a lien on the property or cession to private individuals of the rights to the land which is the property of the citizens are all prohibited.

The state supports the citizens' individual production which contributes to the national economy.

ARTICLE 13. The state guarantees the right to personal ownership of earnings and savings derived from one's own work, of the dwelling to which one has legal title and of the other possessions and objects which serve to satisfy one's material and cultural needs.

Likewise, the state guarantees the right of citizens to ownership of their personal or family work tools. These tools may not be used to obtain earning derived from the exploitation of the work of others.

The law establishes the amount of goods owned by a person which can be seized.

ARTICLE 14. The state recognizes the right of political, mass and social organizations to ownership of the goods intended for the fulfillment of their objectives.

ARTICLE 15. The state recognizes the right to legal ownership of joint ventures, companies and economic associations which are created as prescribed by law.

The use enjoyment and disposal of the goods owned by the above-mentioned entities are ruled by that prescribed by law and by accords, as well as by their statutes and regulations.

ARTICLE 16. The state recognizes the right of citizens to inherit legal title to a place of residence and to other personal goods and chattels.

The law prescribes the cases, conditions and ways under which the goods of cooperative ownership may by inherited.

ARTICLE 17. The expropriation of property for reasons of public benefit or social interest and with due compensation is authorized.

The law establishes the method for the expropriation and the bases on which the need for and usefulness of this action is to be determined, as well as the form of compensation, taking into account the interest and the economic and social needs of the person whose property has been expropriated.

ARTICLE 18. Anybody who suffers damages unjustly caused by a state official or employee while in the performance of his public functions has the right to claim and obtain the corresponding indemnification as prescribed by law.

ARTICLE 19. The state the environment and natural resources. It recognizes the close links they have with sustainable economic and social development to make human life more rational and to ensure the survival, well-being and security of present and future generations. The application of this policy corresponds to the competent bodies.

It is the duty of citizens to contribute to the protection of the waters, atmosphere, the conservation of the soil, flora, fauna and nature's entire rich potential.

CHAPTER II

FAMILY

ARTICLE 20. The state protects the family, motherhood and matrimony.

The state recognizes the family as the main nucleus of society and attributes to it the important responsibilities and functions in the education and formation of the new generations.

ARTICLE 21. Marriage is the voluntarily established union between a man and a woman, who are legally fit to marry, in order to live together. It is based on full equality of rights and duties for the partners, who must see to the support of the home and the integral education of their children through a joint effort compatible with the social activities of both.

The law regulates the formalization, recognition and dissolution of marriage and the rights and obligations deriving from such acts.

ARTICLE 22. All children have the same rights, regardless of being born in or out of wedlock.

Any qualification concerning the nature of the filiation is abolished.

No statement shall be made either with to the difference in birth or the civil status of the parents in the registration of the children's birth or in any other documents that mention parenthood.

The state guarantees, through adequate legal mean, the determination and recognition of paternity.

ARTICLE 23. The parents have the duty to provide nourishment for their children; to help them to defend their legitimate interests and in the realization of their just aspirations; and to contribute actively to their education and integral development as useful and well-prepared citizens for life in a collective society.

It is the children's duty, in turn, to respect and help their parents.

CHAPTER III

EDUCATION AND CULTURE

ARTICLE 24. The state orients, foments and promotes education, culture and science in all their manifestations.

Its educational and cultural policy is based on the following principles:

a) the state bases its educational and cultural policy on the progress made in science and technology and universal progressive pedagogical tradition;

b) education is a function of the state and is free of charge. It is based on the conclusions and contributions made by science and on the close relationship between study and life, work and production.

The state maintains a broad scholarship system for students and provides the workers with multiple opportunities to study to be able to attain the highest possible of knowledge and skills.

The law established the integration and structure of the national system of education and the extent of compulsory education and defines the minimum level of general education that every citizen should acquire;

c) the state promotes the positivist education of the new generations and the training of children, young people and adults for social life.

In order to make this principle a reality, general education and specialized scientific, technical or artistic education are combined with work, development research, physical education, sports, participation in political and social activities and military training;

d) there is freedom of artistic creation as long as its content does not provoke any form of violence towards any group/part/nationality of the citizens and/or the state.

e) in order to raise the level of culture of the people, the state foments and develops artistic education, the vocation for creation and the cultivation and appreciation of art;

f) there is freedom of creation and research in science. The state encourages and facilitates research and gives priority to that which is aimed at solving the problems related to the interests of society and the well-being of the people;

g) the state makes it possible for the workers to engage in scientific work and to contribute to the development of science;

h) the state promotes, foments and develops all forms of physical education and sports as a means of education and of contribution to the integral development of citizens;

j) the state promotes the participation of the citizens, through the colony's social and mass organizations, in the development of its educational and cultural policy.

ARTICLE 25. The state and society give special protection to children and young people.

It is the duty of the family, the schools, the state agencies and the social and mass organizations to pay special attention to the integral development of children and young people.

CHAPTER IV

EQUALITY

ARTICLE 26. All citizens have equal rights and are subject to equal duties.

ARTICLE 27. Discrimination because of race, skin color, sex, national origin, religious beliefs, and any other form of discrimination harmful to human dignity is strictly forbidden and will be severely punished by law.

The institutions of the state are responsible for educating everyone from the earliest possible age in the principle of equality among human beings.

ARTICLE 28. The state consecrates the right that all citizens, regardless of race, skin color, sex, religious belief, national origin and any situation that may be harmful to human dignity:

- have access, in keeping with their merits and abilities, to all state, public administration, and production services positions and jobs;

- can reach any rank in the Armed Forces and in Security and internal order, in keeping with their merits and abilities;

- be given equal pay for equal work;

- have a right to education at all national educational institutions, ranging from elementary schools to the universities, which are the same for all;

- be given health care in all medical institutions;

- live in any sector, zone or area and stay in any hotel;

- be served at all restaurants and other public service establishments;

- use, without any separations, all means of transportation by sea, land and air;

- enjoy the same resorts, beaches, parks, social centers and other centers of culture, sports, recreation and rest.

ARTICLE 29. Women and men have the same rights in the economic, political, cultural and social fields, as well as in the family.

The state guarantees women the same opportunities and possibilities as men, in order to achieve women's full participation in the development of the country.

The state organizes such institutions as children's day-care centers, semi-boarding schools and boarding schools, homes for the elderly and services to make it easier for the working family to carry out its responsibilities.

The state looks after women's health as well as that of their offspring, giving working women paid maternity leave before and after giving birth and temporary work options compatible with their maternal activities.

The state strives to create all the conditions which help make real the principle of equality.

CHAPTER V

FUNDAMENTAL RIGHTS, DUTIES AND GUARANTEES

ARTICLE 30. Work in a collective and sharing society is a right and duty and a source of pride for every citizen.

Work is remunerated according to its quality and quantity; when it is provided, the needs of the economy and of society, the choice of worker and his skills and ability are taken into account; this is guaranteed by the economic system, that facilitates social and economic development, without crises, and has thus eliminated unemployment.

Non paid, voluntary work carried out for the benefit of all society in industrial, agricultural, technical, artistic and service activities is recognized as playing an important role in the formation of our people's political awareness.

Every worker has the duty to faithfully carry tasks corresponding to him at his job.

ARTICLE 31. All those who work have the right to rest, which is guaranteed by the eight-hour workday, a weekly rest period and annual paid vacations.

The state contributes to the development of vacation plans and facilities.

ARTICLE 32. By means of the Social Security System the state assures adequate protection to every citizen who is unable to work because of age, illness or disability.

If the citizen dies, this protection will be extended to his family.

ARTICLE 33. The state protects, by means of social assistance, senior citizens lacking financial resources or anyone to take them in or care for them, and anyone who is unable to work and/or has no relatives who can help them.

ARTICLE 34. The state guarantees the right to protection, safety and hygiene on the job by means of the adoption of adequate measures for the prevention of accidents at work and occupational diseases.

Anyone who suffers an accident on the job or is affected by an occupational disease has the right to medical care and to compensation or retirement in those cases in which temporary or permanent work disability ensues.

ARTICLE 35. Everyone has the right to health protection and care. The state guarantees this right;

- by providing free medical and hospital care by means of the installations of the rural medical service network, polyclinics, hospitals, preventative and specialized treatment centers;

- by providing free dental care;

- by promoting the health publicity campaigns, health education, regular medical examinations, general vaccinations and other measures to prevent the outbreak of disease. All the population cooperates in these activities and plans through the social and mass organizations.

ARTICLE 36. Everyone has the right to education. This right is guaranteed by the free and widespread system of schools, semi-boarding and boarding schools and scholarships of all kinds and at all levels of education and because of the fact that all educational material is provided free of charge, which gives all children and young people, regardless of their family's economic position, the opportunity to study in keeping with their ability, social demands and the needs of socioeconomic development.

Adults are also guaranteed this right; education for them is free of charge and with the specific facilities regulated by law, by means of the adult education program, technical and vocational education, training courses in state agencies and enterprises and the advanced courses for workers.

ARTICLE 37. Everyone has the right to physical education, sports and recreation.

Enjoyment of this right is assured by including the teaching and practice of physical education and sports in the curricula of the national educational system; and by the broad nature of the instruction and means placed at the service of the people, which makes possible the practice of sports and recreation on a mass basis.

ARTICLE 38. Citizens have freedom of speech and of the press. Material conditions for the exercise of that right are provided by the fact that the press, radio, television, cinema, and other mass media are state or social property and can never be private property. This assures their use at exclusive service of the people and in the interests of the society.

The law regulates the exercise of those freedoms.

ARTICLE 39. The rights to assembly, demonstration and association are exercised by workers, both manual and intellectual, women, students and other sectors of the working people, and they have the necessary means for this. The social and mass organizations have all the facilities they need to carry out those activities in which the members have full freedom of speech and opinion based on the unlimited right of initiative and criticism.

ARTICLE 40. The state, which recognizes, respects and guarantees freedom of conscience and of religion, also recognizes, respects and guarantees every citizen's freedom to change religious beliefs or to not have any, and to profess, within the framework of respect for the law, the religious belief of his preference.

The law regulates the state's relations with religious institutions.

ARTICLE 41. The home is inviolable. Nobody can enter the home of another against his will, except in those cases foreseen by law. Any form of violation of the inviolability of the home except those cases foreseen by law will be severely punished by law.

ARTICLE 42. Mail is inviolable. It can only be seized, opened and examined in cases prescribed by law. Secrecy is maintained on matters other than those which led to the examination.

The same principle is to be applied in the case of any forms of communication, including cable, telegraph, telephone and internet communications. Any form of violation of the inviolability of communication will be severely punished by law.

ARTICLE 43. Freedom and inviolability of persons is assured to all those who live in the country.

Nobody can be arrested, except in the manner, with the guarantees and in the cases indicated by law.

The persons who has been arrested or the prisoner is inviolable in his personal integrity. In any case, regardless of the situation, any forms of violation of the personal integrity, including bad physical and/or mental treatment of a prisoner is strictly prohibited.

ARTICLE 44. Nobody can be tried or sentenced except by the competent court by virtue of laws which existed prior to the crime and with the formalities and guarantees that the laws establish.

Every accused person has the right to a defense.

No violence or pressure of any kind can be used against people to force them to testify or vice versa,

All statements obtained in violation of the above precept are null and void and those responsible for the violation will be punished as outlined by law.

ARTICLE 45. Confiscation of property is only applied as a punishment by the authorities in the cases and by the methods determined by law.

ARTICLE 46. Penal laws are retroactive when they benefit the accused or person who has been sentenced. Other laws are not retroactive unless the contrary is decided for reasons of social interest or because it is useful for public purposes.

ARTICLE 47. None of the freedoms which are recognized for citizens can be exercised contrary to what is established in the Constitution and by law, or contrary to the existence and objectives of the state, or contrary to the decision of the people to build and maintain a society of freedom and equality. Violations of this principle can be punished by law.

ARTICLE 48. Every citizen has the right to file complaints with and send petitions to the authorities and to be given the pertinent response or attention within a reasonable length of time, in keeping with the law.

ARTICLE 49. Every citizen has the duty of caring for public and social property, observing work discipline, respecting the rights of others, observing standards of collectivistic living and fulfilling civic and social duties.

ARTICLE 50. Strict fulfillment of the Constitution and the laws is an inexcusable duty of all. The constitution is above all laws, and all laws must be written taking the constitution into consideration.

CHAPTER VI

HIGHER BODIES OF PEOPLE'S POWER

ARTICLE 51. The National Assembly is the supreme body of state power and represents and expresses the sovereign will of all the people.

ARTICLE 52. The National Assembly is the only body in the Republic invested with constituent and legislative authority.

ARTICLE 53. The National Assembly is comprised of deputies elected by free, direct and secret vote, in the proportion and according to the procedure established by law.

ARTICLE 54. The National Assembly is elected for a period of five years.

The period can only extended by virtue of a resolution of the Assembly itself in the event of war or in the case of other exceptional circumstances that may impede the normal holding of elections and while such circumstances exist.

ARTICLE 55. The National Assembly, on meeting for a new legislature, elects from among its deputies its president, vice president and secretary. The law regulates the manner and procedure in which the Assembly is constituted and carries out this election.

ARTICLE 56. The National Assembly elects, from among its deputies, the Council of State, which consists of one president, one first vice president, five vice presidents, one secretary and other ministers.

The president of the Council of State is, at the same time, the head of state and head of government.

The Council of State is accountable for its action to The National Assembly, to which it must render accounts of all its activities.

ARTICLE 57. No deputy to The National Assembly may be arrested or placed on trial without the authorization of the Assembly – or the Council of State if the Assembly is not in session – except in cases of flagrant offenses.

ARTICLE 58. It is the duty of the deputies to the National Assembly of People'' Power to exercises their duties in benefit of the people'' interests, stay in contact with their electors, listen to their problems, suggestions and criticism, and explain the policy of the state. They will also render account to them of the results of their activities, as prescribed by law.

ARTICLE 59. The deputies to The National Assembly have the right to make inquiries to the Council of State, the Council of State or the members of either and to have these inquiries answered during the course of the same session or at the next session. Should those who are inquired fail to comply, an investigation committee will be formed within and by the deputies of National Assembly of People's Power. The authorizations and formation of an investigation committee will be prescribed by law.

ARTICLE 60. It is the duty of all state bodies and enterprises to provide all necessary cooperation to the deputies in the discharge of their duties.

ARTICLE 61. The proposal of laws is the responsibility of:

a) the deputies to the National of People's Power;

b) the Council of State;

c) the commissions of The National Assembly;

d) the Central Organization of Trade Unions and the national offices of the other social and mass organizations;

e) The Supreme Court, in matters related to the administration of justice;

f) the Office of the Attorney General of the Republic, in matters within its jurisdiction;

g) the citizens. In this case it is an indispensable prerequisite that the proposal be made by at least 1 % of the citizens who are eligible to vote.

ARTICLE 62. The Council of State is the body of The National Assembly that represents it in the period between sessions, puts its resolutions into effect and complies with all the other duties assigned by the Constitution.

It is collegiate and for national and international purposes it is the highest representative of the state.

ARTICLE 63. All the decisions of the Council of State are adopted by a simple majority vote of its members.

ARTICLE 64. The mandate entrusted to the Council of State by The National Assembly expires when the new Council of State, elected by virtue of its periodic renovation, takes power.

ARTICLE 65. In cases of the absence, illness or death of the president of the Council of State, the first vice president assumes the president's duties.

CHAPTER VII

LOCAL BODIES OF PEOPLE'S POWER

ARTICLE 66. The Assemblies of People's Power set up in the political-administrative divisions into which the country is divided are the higher local bodies of state power. Therefore, they are invested with the highest authority for the exercise of their state functions within their respective boundaries. To this effect they govern in all that is under their jurisdiction and the law.

They also aid in the development of activities and the fulfillment of plans of those units in their territory which are not subordinated to them, as prescribed by law.

The local administrations established by these Assemblies direct the economic, production and service entities locally subordinated to them, with the purpose of meeting the needs for economic, health care, assistance, educational, cultural, sports and recreational services of the collective in the territory under the jurisdiction of each.

For the exercise of their functions the local Assemblies of People's Power find support in the People's Councils and the initiative and broad participation of the population and they act in close coordination with the social and mass organizations.

ARTICLE 67. The People's Councils are constituted in cities, towns, neighborhoods and rural areas; they are invested with the highest authority for carrying out their functions; they represents the territory where they carry out their functions and also represent the municipal, provincial and national bodies of People's Power.

They work actively for efficiency in the development of production and service activities and for meeting the needs for health care, economic, educational, cultural and social activities of the population, promoting the broadest participation of the population and the local initiatives to resolve their problems.

They coordinate the work of the existing entities in their field of action, promote cooperation among them and control and supervise their activities.

The People's Councils are made up of the delegates elected in the districts, who must choose among themselves their president. The representatives of mass organizations and the most important institutions in the territory may form part of the Councils.

The law regulates the organizations and functions of the People's Councils.

ARTICLE 68. The entities organized to meet local needs with the aim of fulfilling their specific objectives, are ruled by laws, decree-laws and decrees; by agreements adopted by the Council of State; by regulations issued by the heads of central state administration agencies on matters under their jurisdiction which are of general interest and that require being regulated on a national level; and by agreements adopted by the local bodies to which they are subordinated.

ARTICLE 69. The Provincial Assemblies of People's Power are renovated every five years, which is the delegates' term of office.

The Municipal Assemblies of People's Power are renovated every two and a half years, which is the delegates' term of office.

ARTICLE 70. The term of the delegated to local Assemblies may be revoked at any time. The law prescribes the manner, the cases and the methods in which they may be revoked.

ARTICLE 71. The delegates fulfill the mandate of their electors, in the interest of all the community, for which they must coordinate their functions as such with their usual responsibilities and tasks. The law regulates the manner in which these functions are carried out.

ARTICLE 72. The delegates to the Municipal Assemblies of People's Power have the rights and duties conferred by the Constitution and by law and they are especially obliged to:

a) make the opinions, needs and problems expressed by their electors known to the Assembly and to the local administration;

b) report to their electors on the policies of the Assembly and the measures adopted to resolve the problems posed by the population or outline the reason why they have not been resolved;

c) render account of their activities on a regular basis to their electors, and report to the Assembly or to the commission they belong to on the fulfillment of the tasks assigned to them when they are asked to do so.

ARTICLE 73. The delegates to the Provincial Assemblies of People's Power have the duty to carry out their activities for the benefit of the collective and report on the measures taken by them on a personal basis, according to the procedure established by law.

ARTICLE 74. The Provincial and Municipal Assemblies of People's Power elect their president and vice president from among their delegates.

ARTICLE 75. The administration bodies which constitute the Provincial and Municipal Assemblies of People's Power work on a collegiate basis and their composition, integration, functions and duties are established by law.

CHAPTER VIII

THE COURTS AND THE OFFICE OF THE ATTORNEY GENERAL

ARTICLE 76. The function of administering justice springs from the people and is carried out on its behalf by The Supreme Court and the other courts which the law establishes.

The law establishes the main objectives of judicial activity and regulates the organization of the courts; the extension of their jurisdiction and competence; their authority and the form of exercising

it; the standards that judges must meet, the manner in which they must be elected and the causes and methods for recalling them or for the cessation of their functions.

ARTICLE 77. The courts constitute a system of state bodies which are set up with functional independence from all other systems and they are only subordinated to The National Assembly and the Council of State.

The Supreme Court is the foremost judicial authority and its decisions in this field are final.

Through its Governing Council it can propose and issue regulations; make decisions and enact norms whose fulfillment is compulsory for all courts and, based on their experience, it issues instructions which are also compulsory in order to establish uniform judicial practice in the interpretation and application of the law.

ARTICLE 78. The judges, in their function of administering justice, are independent and only owe obedience to the law.

ARTICLE 79. The sentences and other decisions of the courts, pronounced or enacted within the limits of their jurisdiction, must be obeyed and implemented by state agencies, economic and social institutions and citizens, by those directly affected and by those who do not have a direct interest in their implementation but have the only the duty to participate in it.

ARTICLE 80. For administering justice all courts function in a collegiate form and professional and lay judges participate in them with equal rights and duties.

The judicial functions assigned to lay judges, in view of their social importance, have priority over their usual occupation.

ARTICLE 81. The Office of the Attorney General of the Republic is the state body which has, as its fundamental objective, jurisdiction over the control and preservation of legality by ensuring that the Constitution, the law and other legal regulations are strictly obeyed by state agencies, economic and social entities and citizens; and representing the state in the promotion and exercise of public legal action.

The law determines the other objectives and functions as well as the form, duration and occasion in which the Office of the Attorney General exercises its power.

ARTICLE 82. The Office of the Attorney General of the Republic constitutes an organic unit which is only subordinated to The National Assembly and the Council of State.

The Attorney General of the Republic is given instructions directly from the Council of State.

The Attorney General of the Republic will handle the direction and control of all the work done by his office all over the country.

The bodies of the Office of the Attorney General are organized in a vertical manner all over the country. They are subordinate only to the Office of the Attorney General of the Republic and are independent of all local bodies.

CHAPTER IX

ELECTORAL SYSTEM

ARTICLE 83. All citizens, with the legal capacity to do so, have the right to take part in the leadership of the state, directly or through their elected representatives to the bodies of People's Power, and the

duty to participate, for this purpose and as prescribed by law, in the periodic elections and people's referendums through free, equal and secret vote. Every voter has only vote.

ARTICLE 84. All PINTA citizens over 18 years of age, men and women alike, have the right to vote except those who:

a) are mentally disabled and have been declared so by court (with an appropriate and court-approved medical report) ;

b) have committed a crime and because of this have lost the right to vote.

ARTICLE 85. All PINTA citizens, men and women alike, who have full political rights can be elected.

If the election is for deputies to The National Assembly they must be more than 25 years old.

CHAPTER X

CONSTITUTIONAL REFORMS

ARTICLE 86. This Constitution can only be totally or partially modified by The National Assembly, except for the first five articles, by means of resolutions adopted by roll-call vote by a majority of no less than two-thirds of the total number of members

If the modification is total or has to do with the integration and authority of The National Assembly or its Council of State or the rights and duties contained in the Constitution, or if the president of Council of State finds it necessary, the approval of the majority of citizens with the right to vote is required via a referendum organized for this purpose by the Assembly.

Conclusion

We are glad for having completed such a challenging project as a team. With this project, new understandings, and knowledge we gained, but most of all we realized that if we really wanted to do something we could achieve it, by being determined, and supportive to each other.

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ANNEX

Motion Control in Space without Using Fuel and Benefiting from Newton's Third Law

In the experiment to be conducted, the ratio of rotation of the motor and the case will be determined from the equation below, and based on the results the efficiency of such a system will be discussed.

$$(\tfrac{1}{2} M_1R_1^2 + 1/12\ M_1W^2)V_1/(t\ .\ R_1) = \tfrac{1}{2}\ MR^2\ V_2/(t\ .\ R)$$

where;
M_1; is the mass of the outer shaft of the satellite
R_1; the radius of the satellite's shaft
M; the mass of the solid cylinder
R; the radius of the cylinder
V_1 is the tangential speed of the shaft
V_2; is the tangential speed of the cylinder

Determining the Angular Speed of the Cylindrical Case

The angular acceleration (α), equals to the change in angular speed in a certain time ($\alpha = \Delta w/\Delta t$). Since, in the equation above, the time of rotation will be the same on both sides, they will cancel out. Thus, it will be sufficient only to determine the angular speed.

The angular speed is the angular distance ($\Delta\theta$), rotated in a certain time, and it is expressed as w.

$$w = \Delta\theta/\Delta t$$

While measuring the angular position, as shown in the figure below, trigonometric equations are used.

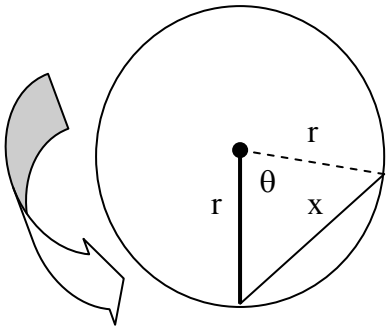


Fig 4

If looked from the top to the cylindrical case, the thick line represents the initial position of the case, and the dotted line represents the final position of the case after turning for 2 seconds. The distance(x) between the two positions is measured with a ruler, then the angle(θ) in between is found

In a triangle ABC, if;

$\cos C = (a^2 + b^2 - c^2)/2ab$ (143) ,

$\cos \theta = (r^2 + r^2 - x^2)/2\ r^2$
from which the value of θ can be found.

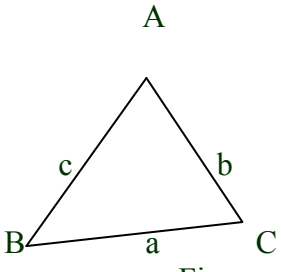


Fig 5

- Radian is used in the experiment as the unit of the angle.

Method:

The prototype includes a servo motor, a cylindrical case, a cylindrical wheel, and an axle, on which the servo motor and the wheel is placed.

As it is known servo motors are able to rotate for a desired distance and they are controlled by coded pulses. They consist of three parts; a motor, a control panel and a potentiometer, which is a variable resistor. The motor turns the servo and the potentiometer synchronously. When the control panels detects that the position is the desired one, it stops the potentiometer. Thus, the potentiometer contributes to the control of the motion of the motor. In this prototype, a microcontroller does the control of the servo. The coded signals programmed in the microcontroller turns the servo. These signals are coded according to their pulse duration. Generally, a 1.5 ms long pulse moves the servo for 90 degrees, to its neutral position. Pulses shorter than 1.5 ms provide a rotation between 08 and 908, and the pulses longer than 1.5 ms provide rotations between 08 and 1808 [(144)]. The servomotor used in the experiment has an angular speed of 55 rpm, and it is supplied with power of 7.5 Volt.

In the prototype, 10 discs (reaction wheels) made from aluminum, plastic and brass are used, and they all have the same radius but different masses. By placing different discs on the axle of the case, I measured how much each disc turned the case. The servomotor is turned for 2 seconds in each time. Then the angular displacement of the case is measured, from which I calculated the corresponding angular speed, as explained in the theory section.

The controlled variable in the experiment is the mass of the disc and the uncontrolled variable is the angular speed of the case. When the data is plotted on a graph the slope of the best-fit line indicated the efficiency of the system as explained later.

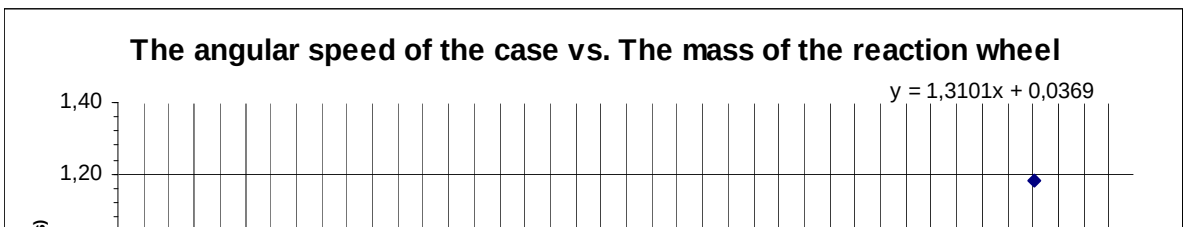
Results

DATA:

Table – 1 The effect of mass on angular speed

Mass of the reaction wheel (kg ±0.001)	Angular speed of the case (rad/s)
0.070	0.17
0.108	0.22
0.144	0.25
0.396	0.42
0.537	0.64
0.176	0.29
0.616	0.76
0.654	0.85
0.686	0.98
0.722	1.18

Graph-1:



Data Analysis:

The linear equation of the graph can be derived from the previous equation of torques;

$$(\tfrac{1}{2}\, m_1 r_1^2 + 1/12\, m_1 L^2)\, \alpha_1 = \tfrac{1}{2}\, m r^2\, \alpha$$
$$(\tfrac{1}{2}\, m_1 r_1^2 + 1/12\, m_1 L^2)\, w_1 = \tfrac{1}{2}\, m r^2\, w$$

$$w_1 = [\tfrac{1}{2} r^2\, w/(\tfrac{1}{2}\, m_1 r_1^2 + (1/12)\, m_1 L^2)] \cdot m$$

$$y = m \cdot x$$

In an ideal experiment, the slope of the best fit line would be equal to the numerical value of the expression, $[\tfrac{1}{2} r^2\, w/(\tfrac{1}{2}\, m_1 r_1^2 + (1/12)\, m_1 L^2)]$. By comparing the value of the expression and the slope of the best-fit line, the percentage error is calculated

If;
r; the radius of the reaction wheel = 3.9 cm $\pm$ 0,1
w; angular speed of the motor = 55 rpm = 5.76 rad/s
$\mathbf{m_1}$; mass of the cylindrical case = 776 g $\pm$ 1
$\mathbf{r_1}$; radius of the cylindrical case = 5.5 cm $\pm$ 0,1
L; length of the cylindrical case = 15.4 cm $\pm$ 0,1

Then $[\tfrac{1}{2} r^2\, w/(\tfrac{1}{2}\, m_1 r_1^2 + (1/12)\, m_1 L^2)] = 1.62$

From $(y_2-y_1)/(x_2-x_1)$, the slope of the best fit line is found to be 1.31

Therefore the %error is;

% error = | real value – experimental value | / real value
= (1.62 – 1.31) / 1.62
= % 19.1

Conclusion and Discussion:

At the end of the experiment, it is observed that the reaction wheel system works with 19.1 % error.

By examining the graph, it can be concluded that several random and systematic errors have been involved in the experiment. The points plotted are a bit scattered, indicating the effect of random errors. The best-fit line does not cross the origin, as it should have, which shows that systematic errors also have involved in the experiment. The possible errors are listed below.

- It is observed that the angular speed of the motor changed according to the mass of the disc attached to it. For example for a disc of 0.616 kg, the motor rotated in 56 rpm, and for a disc of 0.722 kg, it rotated for 54 rpm.
- Although measurements are done twice, parallax error could have involved.
- When the motor started to rotate sometimes it could not achieve the required speed quickly, and when it stopped, because of inertia, it continued to its motion for some time. Therefore, the angular speed changed a little.
- Air friction is ignored in the experiment. However, friction between the axle and the case might have affected the results.
- The cylindrical case is assumed to be hollow, while making the calculations, but actually it contained the reaction wheel and the motor, it was not geometrically ideal. The results therefore cannot be very accurate.

As further improvement, it can be suggested to use a stronger motor, and the mass ratio of the discs and the cylindrical case should be adjusted to obtain better results.

As stated previously the energy source of the system will be the Sun. We could benefit from the techniques in the solar panels used at homes, such as the solar tracker systems. The solar panels of the vehicle will track the Sun so that they will always face the Sun [145].

The model presented in the Project can contribute in many fields of space technology. Since chemical rocket fuels are not used, the space shuttles can be smaller, lighter and more efficient. Such motion control systems can be used in research or military satellites. These satellites, can observe celestial bodies, give data about the atmosphere, contribute in meteorology, or they can be used as spy satellites with military purposes. Moreover the propel system designed in the project can allow long flights beyond our Solar System, giving humankind the opportunity to explore the deep space.