

PROJECT **EXODUS**

LIVING BEYOND

By: Pranavsai Gandikota

Ithaka International School – Class X
Individual Project (9-12 Grade Section)



IMAGE OF EXODUS, MODELED BY PRANAVSAI GANDIKOTA

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EXECUTIVE SUMMARY

“The way to get started is to quit talking and begin doing.”

-Walt Disney

A quote by Disney was what started me to begin making this project. For many years living in space was just a thought, but as time goes, it is getting closer and closer to actually initiating the idea into a reality. Though we may not be there to witness it, once a plan has been made the future will depend on us to make another path for mankind to go to, in-case of a peril to the earth.

I am contesting as an individual project from Ithaka International as a Class X (10th Grade) student. My name is Pranavsai Gandikota and I am 16 years old. In this project, I aim to get my ideas presented for a space settlement which I have chosen to name **Exodus** along with different conditions and proposed ideas we can apply in the making. I participated in this competition because for me, it felt as an opportunity to learn more about how space settlements work. I have learnt a ton of information along the way which has seemed very fascinating for me. Now starting off, let's begin with the basic necessities.

Basic Necessities

What are the basic necessities of life? Well for starters, we need a source of food, water, clean air, and certain nutrients to live. Besides this we also need things such as electricity, entertainment, medical care, security and most importantly shelter. (But to Note: Moral acceptance, and cooperation of the city would also be important). These are all points to consider to have in a space settlement. And so, on the basis of these necessities, I have proposed a Space Settlement Station to hold life to hundreds, thousands, to millions of people and after several years, the whole population onto a hub named Exodus, a new home.

What Is Exodus?

It is a ship I have designed which would be able to sustain life outside earth for the future to come. In order to put forth my plans for **Exodus** I have divided the core aspects of making Exodus a reality into several sections, or chapters should I say, covering each part of the project and how I have planned to implement it taking all factors into consideration and the sustainability for the future.

To start off, why did I pick the name Exodus? Exodus means the mass departure of people, or in exact terms “a going out”, a departure or an emigration. And since space travel will one

day come to a point where its masses that go out of Earth, I believe it suits the project well. It is also an expedition for the humans to seek further information about the history of the solar system and may perhaps even increase the interest of people to learn more about it. By leaving our earth, we will be able to take up many new researching missions, such as a closer look at space in our everyday life with no atmospheric interference, with a beautiful view outside, A place where solar energy and nuclear can be utilized to its potential and a place where everyone can live in harmony with a whole city, town or even country that we, humans, have created. Exodus will serve as a gateway to stay safe in case an irreversible disaster may take place.

The chapters I have chosen are:

1 – Location and Setting Up of Base, where I give a summary of why we should consider space settlement, and why asteroid settlement in particular. Which asteroid, as well as the plan on how the materials will be taken to the base or taken from the environment to first get a basic environment with a source of air, water and nature. Here I aim at creating a base habitat with plants that grow as well as a way to achieve asteroid mining to obtain resources to build the homes and power factories.

2 – Structure. Here I discuss what shape would be suitable for the ship, why and how Exodus will generate artificial gravity, as well as a information on how Exodus will plan its inner structure and outer structure. These include placements of solar panels, outer radiation protection, asteroid collision withstanding ensurance and the inner area structure (home placements, drainage system, farming and much more).

3 – Living Conditions and Livelihood -In this chapter, I will discuss about the homes, entertainment, biomes, wildlife, and jobs. Here I will present a plan on how homes are to be built in Exodus, the division of the biomes in Exodus, the ways of entertainment, and the concentration of the jobs on the ship as well as the probable reason for the shift in jobs into the different sectors. I will also discuss weather and temperature regulation to meet the different living beings in the ship. There will be certain controlled environments to ensure differently adapted organisms can adapt easily. Water and oxygen recycling and generation, their certain methods and processes will be covered here too.

4 – Mining and Power Generation – In this section, I will cover the several mining zones Exodus plans to exploit, the minerals which are mined and how certain minerals are planned to be used for the ships benefit and growth, power generation plans and how solar panels will be placed and energy will be produced.

5 – Economic Feasability – deals with the overall cost estimate of the project and how the different factors might affect the total cost. It also has a summary of how it can be achieved even though a project of this big might be quite expensive.

Conclusion: An overall sum up of what I have learnt while making the project as well as a wrapping to my plan of Exodus.

1 CHAPTER I – LOCATION AND SETTING UP OF THE BASE

1.1 Location

1.1.1 Why Space Settlement?

Space settlement is done so that we can ensure a long-term insurance of a place to go to, in case of a huge threat to the current global population such as

- Nuclear Holocaust
- Super volcano Eruption
- Asteroids (A place to go to in case of a collision of earth with another celestial object)
- Diseases and etc.



It is a new homeland for us humans to live on.

Earth Exploding, Image Credit: Simulation made by Avik T.

1.1.2 Why Not Planet Settlement?

Now if we were to colonize in space it would mean carrying a lot of things from earth, and to do this into another planet would not be so economically feasible.

Let's take Mars as an example. Mars, being the closest compared to the gas planets or other planets that are too close to the sun, also has demerits such as:

- toxic soil and radiation
- low gravity (which is unchangeable)
- and cold temperatures - (around -60°C or about 213K) (according to space.com) leading to immediate freezing
- water here isn't stable due to the conditions present.

Elon Musk has also dreamt of Mars colonization and has been planning on it too indeed, and has estimated that the cost would be a whopping **\$10 trillion** which is about an eighth of the cost of the global economy according to a tweet by him.

These may be problems on other celestial bodies, but some bodies offer better benefits in comparison.

Though colonizing near Earth can be done, it would be easier to colonize on the moon at a lower price, but then it would only serve as a secondary reserve in case the Earth cannot hold the whole population. We can also make settlements on Earth itself vertically utilizing the area above the ground to make a secondary settlement area. But here I don't aim at just making an extension for Earth, but rather a place where people can go to in case of a peril to Earth (such as the ones mentioned before).

1.1.3 Why an Asteroid in Particular?

Looking like a chunk of rock or ice, these masses have valuable metals which in the asteroid belt alone has **\$700 quintillion** worth of resources (according to NASA). With all these resources, we would be able to obtain metals to build, extract water, and produce electricity.

Extra Info About Nasa Space Settlement Plan:

"NASA has also devised plans to send humans to asteroids and learn about the electrical environment that explorers may encounter. The Solar System Exploration Research Virtual Institute (SSERVI) has developed models to predict solar wind, radiation, and asteroid surfaces with funding from NASA's Lunar Science Institute (NLSI)."

Source: sservi.nasa.gov – Space Settlement Plans

1.1.4 Which Area Should We Colonize? Why?

The two main belts in our solar system are the Kuiper and the asteroid belts.

In which the **Kuiper belt is not really ideal** for space colonization compared to the asteroid belt for the following reasons:

1. It's quite far to reach making it uncomfortable for humans to travel for such distances for a long period of time, even if ships that can go quite fast are created.
2. Being near the edge of the solar system, the sunrays will not be as warm as near earth, leading to freezing conditions. But this can be fixed with a controlled atmosphere. (On the downside, making this would cost a ton)
3. Since it's on the edge of the solar system, in case any outer force or body were to crash in, the first spot to hit might be where we have settled.

Thus, I have chosen the asteroid belt as the site for a human civilization to grow being fairly closer compared to Kuiper belt, with tons of rich minerals to extract from and a place which has less excessive coldness compared to the other areas beyond. And as the asteroids are quite far from each other, some being even 1 million km away from each other, collision with an asteroid will be of lower chances, and even if it does collide, the ship will be able to avoid it before coming close as well as withstand minor damages.

1.2 Setting Up of The Base

The centre of the Torus will be the first to get launched. It will sustain basic life functions and will work a bit like the ISS (International Space Station). It will first use the Earth's orbit to propel itself and will then head off on a journey to Mars. Upon reaching the Mars orbit, the ship will use the orbit to propel itself near the asteroid belt and will stop a few miles from the asteroid belt. As it is close to the asteroid belt, it will be able to take the resources from the belt using resource rich asteroids such as 16 Psyche. To prevent damage from asteroids, the settlement will be placed at a distance from the asteroid, and will also have a strong outer shell to protect against even minor asteroids. The ship will move along with the orbit of the asteroid belt. This may make the years longer, but it will not be a big effect for the ships living conditions except for temperature.

1.2.1 Stage One - Launching First Base

The first part of Exodus would be placing the base centre at a certain spot. This would start off with a sphere which will be launched along with a rod like structure which would serve as a network and communication. The sphere will serve as an agriculture ground, which will later grow as the rest of the parts are added. After the base reaches orbit at the asteroid belt, it will propel towards the asteroid and find a suitable spot near the asteroid. This part will be equipped with sensors to detect the paths of other asteroids to change direction before collision to avoid damage. After it has settled, the next phase would be sent. While the trip goes on and as it reaches the destination, there will also be plants grown simultaneously for food as well as an extra supply of food and fuel to last around 2 years.

1.2.2 Stage Two - Connecting the Second base to make a Torus

The next stage is connecting the different parts of the Torus to make the bigger Torus, the assembly will be done in space. The parts of the ship will be sent in quadrants. Each quadrant will be launched a certain year. It will take around 7 years for all the quadrants to reach the base and for it to be connected. Here using a reusable rocket may take a longer time and may need more maintenance, but can save a lot of money. The fuel will be refilled with minerals and fuel on asteroids which are quite powerful to last a longer time. As the weight of the main quadrant will be out, we can use the extra capacity to hold fuel for the journey back. Once the living area is all connected, it's the time to make the inner living area have an atmosphere or an area which has around the same composition of gasses here on Earth. After all the living conditions are satisfied, it comes to stage three.

1.2.3 Stage Three – Bringing the Civilization to Life

At this point the whole settlement will be at its location and all the living conditions should be met. After all this is in check, it's time to bring the population in. This stage will comprise of around 10 years where 3 years would be bringing the population to the station and the rest making homes for settlement and setting up jobs for everyone to start a livelihood.

1.2.4 Stage Four – Future Expansion

After several years have passed and the first homes have been set up with everything functioning, it will be possible for more to be constructed with the help of resources we can collect from asteroids. With the help of the resourceful materials, we get from the asteroids, we will be able to expand our current civilization with many smaller settlements near the main one to sustain an even higher population creating a new era of space settlement and living.

2 CHAPTER II – STRUCTURE

2.1 Artificial Gravity

2.1.1 How Can We Make Artificial Gravity?

The structure of Exodus will be based on the ability to produce artificial gravity, hence giving it a torus shape from the outside. We can produce the artificial gravity with the help of a centripetal force. Exodus will be gathering the momentum for the ship to make a centripetal force by using side jets which will assist the ship in creating a centripetal force a bit like a top. The ship will also have certain side engines to keep the whole hub from going off course or losing direction.

Since the movement of Exodus is centripetal, with a shape of a torus, life will not be able to live on the horizontal side, but rather on the vertical sides as shown in the image below to make sure that people will be able to walk on the ground and not fall since the force is in a direction outward, instead of up and down or inward as it is on earth.

Here the floor is placed horizontal to the floor (bottom area). This won't work as the centripetal movement would cause us to move toward the outer area (the right side)

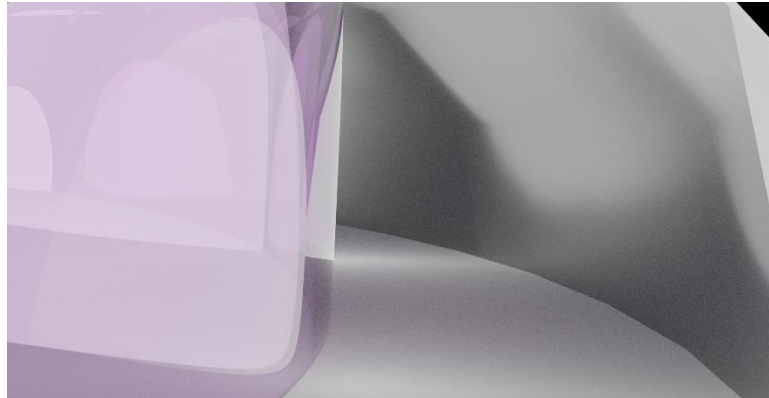


Image By Pranavsai G. Basic model Structure that will not be followed in Exodus.

Here the floor is placed in the same path as the torus, hence any centripetal force would move the people outward which here is the floor. So, the people will be able to stand normally. **The brown is the floor** and the rest is the ship (purple is the glass with radiation and harmful ray filters).

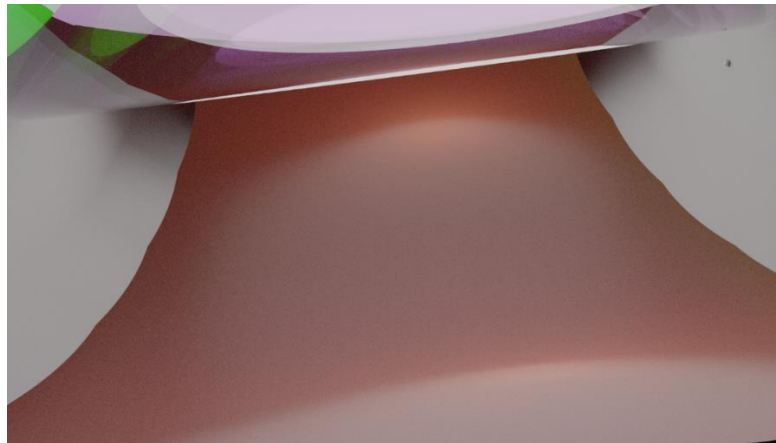


Image By Pranavsai G. Basic model of the inner Exodus Structure

2.1.2 Impact of Artificial Gravity on Humans

Let's say we didn't have gravity and we were left with minimum gravity from the ship. In this case, since there is a smaller force on our body, our bones would not fully develop especially for children. With no exercise we can lose our bone and muscle power and we would be much weaker to do any task. Hence artificial gravity is an important part. It is also important that we be able to replicate the force as the earth applies on us to ensure normal growth of the body. In case we have little to no gravity, we would soon experience the following:

1) bone loss from a negative calcium balance;

This happens when the loss is more than the intake. This results in bone loss and a higher risk of fractures. Bones also get weakened if there is a low food intake or if we are underweight.

2) atrophy of antigravity muscles;

According to NASA (Muscle Atrophy), It is said that an astronaut can lose up to 20% of their muscle mass just in five to eleven days. This is quite a lot. Atrophy is termed as the shrinkage of muscle or nerve tissue. Anti-gravity muscles are the muscles which are required to hold us up against the force of gravity to maintain posture. Hence, they get the name antigravity muscles. In order to prevent damage to these muscles it is important to

exercise them and keep them in utmost shape every day. Hence there will be a certain part of the day in Exodus which is dedicated to exercise. Those on the ISS spend almost two and a half hours exercising to prevent muscle atrophy according to NASA.

3) less plasma volume as well as fluid shifts;

According to a study done taken from the *National Library of Medicine* “Antigravity suit inflation: kidney function and cardiovascular and hormonal responses in men” and research from *VA Convertino*, it was noticed that there was a decrease in plasma. The experiment was as follows: 5 men and 2 women were taken as the members of the experiment and one kept as constant while the others in different situations of inflation of an antigravity suit. It was noticed the Plasma decreased.

Hypovolemia: is when a decrease in liquid portions of blood takes place and our plasma is very low.

4) cardiovascular deconditioning (which later causes orthostatic intolerance.)

Where a shift in blood volume or a change in the function of structure of the heart as well as the blood vessels happens as a reaction to microgravity.

Hence it isn't worth the risk of neglecting the gravity levels. Nasa has also started the NASA Life Sciences Division to look into methods for providing artificial gravity.

In Space astronauts lose weight quite fast, and hence it is important to maintain the body weight by eating well and exercising daily. As space has no gravity to pull the food down, most of the food ends up flying around in the stomach resulting in astronauts feeling full faster.

This antigravity also makes your body fluids not just settle down as on earth but rather move around your body such as the face and head. [A majority of our body is fluids (almost two thirds).] This causes the astronauts faces to look swollen in zero gravity also known by the name the “puffy face syndrome”



➤ Astronaut on Earth and in space (with puffiness) on left and right respectively (Peggy Whitson)
Image Credit: NASA

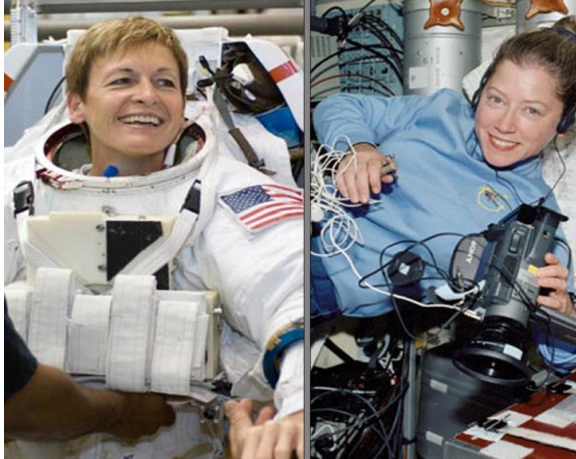


Image Credit: Nasa, On NBC news "Female commanders set for landmark mission"
"[<https://www.nbcnews.com/id/wbna20761344>].

The astronauts here (Peggy Whitson and Pamela Melroy) are on different places. (Left) on earth and (right) in space. You can see how people faces get puffed up in space.

Since we are simulating an environment like earth, we need to make a gravitational force around 9.8 m/s^2 (derivation shown below). The gravity in every part of Earth is not the same. Like how gravity decreases the higher we go higher up and increases as we fall back down. The same will be in Exodus with more force at the outer area.

As we will use centripetal force, a higher torque would help in creating more gravity. In order to keep this gravity in check and same at all times, certain measuring docks will be set up to regulate the spin of the ship and gravity. As there is no air resistance in space, once the ship starts spinning at a certain speed, it will continue to spin in the same speed forever unless any other celestial body were to collide with it, such as an asteroid. (But there will be thrusters to regulate the spin)

In order to get a spin on the ship, we can either use

- A bodies' gravitation pull, and set orbit around the body and then take a boost to move around,
- Or we can burn fuel to start a spin using Newtons 3rd Law where for every action there is an equal and opposite reaction. So, if we push back, we can move forward. This would be a better method as we don't have any big bodies to rotate around except a few asteroids and we also are residing near asteroids and will be able to get the fuel from them nearby.

As *The European Space Agency* says, all of Newton's laws are important in making living possible and being able to get work done in space. Such as a thrust of the ship, the force required for mass etc.

The gravity on earth is 9.8 ms^{-2} , to derive this we use the formula

$$F = G \frac{m_1 m_2}{r^2}$$

Radius of earth (R)= 6.37×10^6 m

Mass of earth (M)= 5.97×10^{24} Kg

Gravitational constant (G)= 6.673×10^{-11} Nm²/Kg²

'a' becomes 'g'

$$g = \frac{GM}{R^2}$$

By putting the values of 'G' 'M' & 'R' we have

$$g = \frac{6.673 \times 10^{-11} \times 5.97 \times 10^{24}}{6.37 \times 10^6}$$

And we hence get $g = 9.81 \text{ m/s}^2$ approx., which is the amount of gravity we need to generate on Exodus.

The same principle can be used on other bodies too, including Exodus, to be able to calculate the gravitation formed by the centripetal force. A similar 9.8 ms^{-2} (or around) gravitational force will need to be simulated.

The gravity should not exceed 5g (limit is 9g where at this point you blood will flow to your feet and your chances of survival will be low in even a small time) and should instead be maintained at 1g.

Torque is the force which causes a rotation upon a certain axis. Generally used in explaining how a door works, but it can also be applied in respective to the ship.

Now here as the force is applied along the tangent, it will move the ship hooked on the centre. To not have the ship go out of control, the thrusters on both sides would have to propel at equal amounts which would be kept at constant as there is no air interference here in space (other than asteroids which may collide).



Top view of Exodus – Image Credit: Modelled by Pranavsai G.

Now let's talk about the shape of the Torus and the math behind this...

The Stanford Torus Proposed 10000 occupants will have a radius of 1.8km or 0.9km outer radius according to a Study in 1975.

This means using our 7:25 measure (ratio later discussed below in structure), we would have

$$\frac{7}{25} = \frac{x}{0.9}$$

$$\frac{7(0.9)}{25} = 0.252\text{km Inner Radius}$$

$$4\pi^2 (0.9) (0.252) \approx 8.94 \approx 9$$

Approx. 9km Surface Area for 10,000 and 18km for 20,000

By substituting the values and solving with respect to 20,000 occupants, we get

- **0.35km (350m) as the Inner Radius**
- **1.25km (1250m) as the Outer Radius**

Now as we will take some members at start then 20,000 occupants after, we would rather consider the distance from the centre of the axis to the outer ring is 1.25km

2.2 EXTERNAL AND INTERIOR STRUCTURE OF THE MOTHERSHIP

2.2.1 External Structure



Components of Exodus, Image Credit: Pranavsai G.

2.2.1.1 Torus design

First of all, since Exodus will depend on centripetal force for its gravity, it would need a spherical shape. Either a sphere or a torus would be good for this. Now which one would be better?

Well first let's compare on the basis of the area they can hold. The reason I have taken the area first before volume is because the population would be living on the outer wall of the shape in order to prevent being throw around during the centripetal force.

Suppose

1.8km (diameter) = 10000 people (as the Stanford torus proposed idea [NASA])

Then in order to fit the world population in case of an emergency, then we would need the radius to be as follows:

$$\frac{10000}{\text{World Population}} = \frac{0.9\text{km}}{x\text{km}}$$

Taking World Population was 10 billion by the future 2100

Then the ship would need about:

$$\frac{10000}{10000000000} = \frac{0.9\text{km}}{x\text{km}}$$

$$\frac{1}{1000000} = \frac{0.9\text{km}}{x\text{km}}$$

$$x = 90000\text{km}$$



A 3D Sphere

The radius of the earth is about 6357km. Since we won't need much space at start and we can later add on to the ship as years go by as we will not take the whole population to space!

let's take the radius as 5000m

2.2.1.1.1 The Case of a Sphere

If we were to take a sphere, then the surface area would be
 $= 4\pi r^2$

Taking $r = 5000\text{m}$, then the surface area would be:

$$\begin{aligned} 4\pi r^2 &= 4(\pi)(5000 \times 5000) \\ &= 314,159,265.4 \text{ m}^2 \end{aligned}$$

Here the rotation on an axis will only provide gravity to the central to side areas but not as much on the pole. Which means those on the pole may fall off to the sides other than the axis of rotation. And most of the gravity will be concentrate in the equatorial region of the sphere.

2.2.1.1.2 The Case of a Torus

Now taking the case of a Torus:

- Using demos (a graphing calculator) An ideal ratio for the torus inner and outer ratio would be **7:25**, This would ensure that the outer ring would give a broader area for humans to settle on as well as provide a sky.
- The formula for the Surface Area of a Torus is $(2\pi r)(2\pi R)$ or in other words $4\pi^2 Rr$.

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

$$R = 5000m$$

$$r = 1400m$$

$$= 4\pi^2 (5000)(1400)$$

$$= 276,348,923.2 \text{ m}^2$$

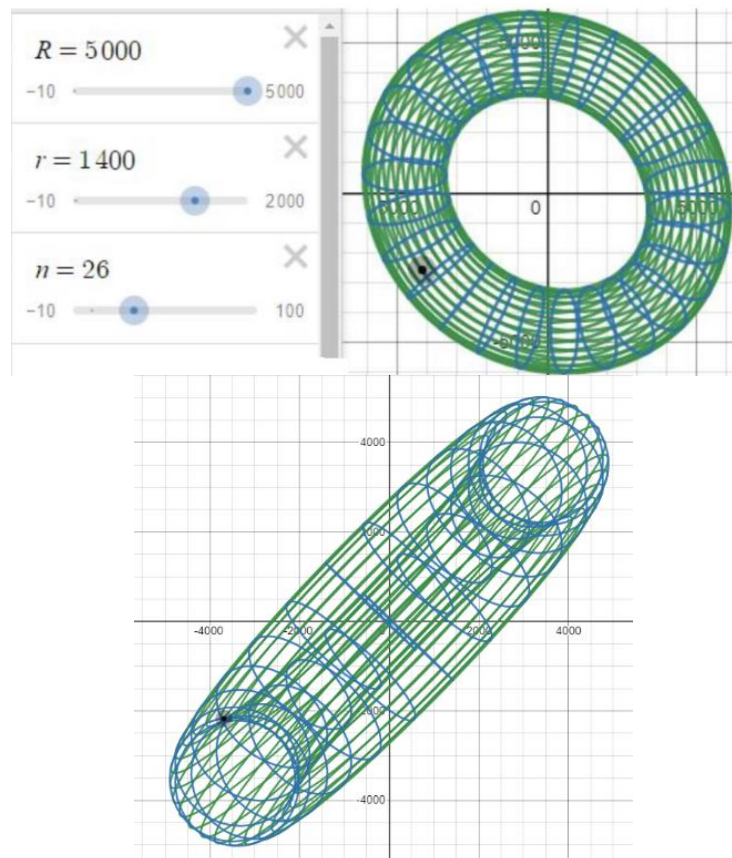


Image Credit to Desmos Graping Calculator at [desmos.com](https://www.desmos.com),

2.2.1.1.3 Conclusion

Now comparing the torus and a sphere we get that the sphere has a larger surface area, but the useful area would be less. Whereas the torus offers a smaller area but more advantages. Along with this, a smaller area means it would have a less chance of collision with the outer space objects.

The following are a few points summarizing a torus:

1. The rotation of a circular object on an axis can help create a centripetal force for creating artificial gravity
2. A round outside would mean an even protection in all sides from any collision, and a torus would cover less volume to ensure less collision
3. It would allow solar panels to be evenly distributed around the outside and extra mirrors or reflectors to direct sunlight in in the inner area.
4. The inner area can also be used for other purposes such as an energy generation plant, or a ship docking and launching area, as well as a bridge connecting one side to another in an elevator type shuttle.

2.2.1.2 How much area is required for the population?

Taking the minimum per person to live as 500-600, then an apartment/condo of 2 or 4 would be 1200sqft or 2400sqft respectively as per *South Down Homes* says

if we were to have a total of 10000 – 20000 people at start, we would need around 8000000-12000000sqft of space for just homes.

Taking shops into mind, there will be several shops running with many small ones and several big stores. On average if a big retail store wants to be set up, it would need 250000sqft or less if it can be built vertically into floors like a mall. Now suppose we have 20 big stores and 100 small stores of around 2000ft then we would need another $(250000*20+100*2000)$ 5,200,000sqft.

In addition to this, Exodus also will add parks, and recreational areas like theaters and theme parks. This would require 399300sqft for a theme park (2 of them) (to hold 2400-5000 people at once), 20,000sqft per theater (4 in the ship), recreational area, parks and greenery making up another 3,690,000sqft total. Which adds up to $(399300*2+80000+3,690,000)$. Now adding the business buildings with around a 100sqft for a worker and extra hallways, we would have around 10000 workers working in buildings, so we would have around 2,000,000sqft for office buildings. (The rest of the workers will work in other areas like near docking stations or labs). All these add up to a total of 23,768,600sqft or 23 million sqft (2.2sqkm approx.) required for 20,000 occupants on the ship. (Based on average area values changed on needs of Exodus)

If we add a grace area with extra land to make it 30 million it would be sufficient for even 40,000 occupants (with a few million sqft added in product with the population). Now sticking with 20,000, we won't require such a huge area, but we might need quite a few more additions to make the population capacity higher. And perhaps later move on to Mars or make several more colonies nearby once the first one goes successful.

Now using the total area of the living part of the ship to be 23 million sqft, we can take the whole torus to be 30 million sqft with its inner torus and sphere included (as an estimate). It would much more if external parts are added along with it (such as docks and researching satellites).

2.2.1.3 Exodus Ship Health Indicator Light System (ESHILS)

All around the ship, you may notice some green lights on the edges. These lights serve not only as a visual appeal, but their main purpose serves to tell the health of the ship. Green as you may be able to guess, means the ships health is good. But red on the other hand means there is an error present in the system. The ship is divided into four parts, with each part having its own monitoring system and airlocks. So, if one part of Exodus gets affected, the rest wouldn't have to worry about any malfunctions on their area. You can also see these green rings around the central torus, thrusters, ship docking stations as well as the networking tower (the upper ball with a light) all to serve this purpose. ESHILS will also be used inside Exodus as indicators too. They will either function with automatic system checks or with manual input (in emergencies).

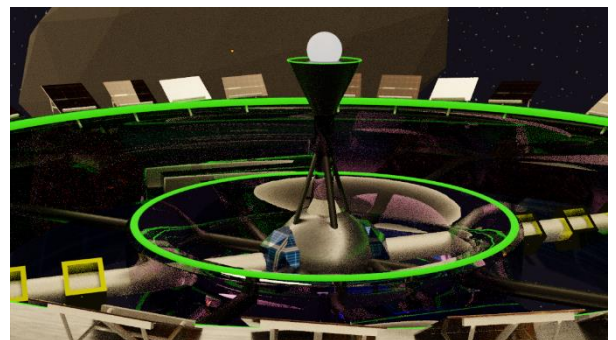


Image Credit: Pranavsai G. Image of Central Tower with ESHILS installed (green rings).

2.2.1.4 Explorer Ship Docking Stations (Egg Stations)

An estimated 4 docks will be made for space crafts and small shuttles to travel to the nearby asteroids for mineral extraction and exploration. Here we have chosen Psyche 16 and later on Ceres as the main asteroid for our mineral extraction for Exodus. The docking stations would constitute about 10% of the ships space being mostly on the outer edge. These stations will have several garages to store ships on them. The docking stations will also serve as a place for people to work at especially in the maintenance section. There is one per quadrant. They will have doors which are air sealed to not let any vacuum affect the inside of the ship, as these stations will be open to space. We would hence need a suit to enter this area. They will be called **Egg Stations** for their shape. (Labeled in chart at 2.2.1 start).

2.2.1.5 Central Hub (HUGO), Network Tower (DARA), Sender/Receivers (LUNA)

Hugo, German for mind, is the name given to the central hub. This hub will be the first human filled ship to reach Psyche 16 and Ceres too later on extension. Hugo will have plants growing in it to support the small number of passengers onboard. It will also have places for humans to sleep in during the building phase. **Dara**, Hebrew for wisdom, is the network tower. It will provide connections and tv networks later on. It is the main brain of the ship which has a multi backup system to ensure high reliability. It will regulate all parts of the ship and make sure there is no problem in any part. If any problem is reported, Dara will be the first to get notified to let us know about the problem. **Luna**, Spanish for moon, is the sending and receiving device, is named Luna for its look as a moon. It will be used to transmit data from Earth and back at start, and later will be used to communicate between other ships. It will also have a network provider for the occupants to use.

2.2.1.6 Shield Against Radiation and Cosmic Rays

Radiation is can be split into ionizing and non-ionizing radiation as explained on EPA - Radiation Basics:

2.2.1.6.1 Non-Ionizing Radiation

Can move atoms around and cause a vibration but can't remove the atoms. These include light, microwaves etc. They have lower frequencies.

2.2.1.6.2 Ionizing Radiation

Has energy to remove electrons out of atoms in a process called ionization. This radiation has the ability to affect atoms in living organisms with a health risk of damaging DNA and tissues. This can be seen on a Xray. It is also seen in radioactive decay. It has a higher frequency

Of the types of Ionizing radiation, the ones we should be worried about the most are GCR and SCR radiations (according to the Canadian Space Agency's article 'How Radiation Affects our Body'). The types of radiation that humans can face in space include:

GCR (Galactic Cosmic Rays)

Galactic Cosmic Rays are generally formed from outside the solar system most likely from supernovas. Composed of electrons, protons as well as ionized nuclei, they have the ability to penetrate barriers like our skin and clothes, and it would hence need a few feet of concrete or dense lead.

SCR (Solar Cosmic Rays) [or Solar Radiation from the sun]

It is the rays ejected during solar flares and coronal mass ejections (CME) (made up of electrons, protons and helium nuclei). Produced in the corona (outer layer of the sun) of the sun when a part of the solar magnetic field reconfigures itself.

Forbush Decrease is when the SCR are in an increased number resulting in a decrease in the GCR since the solar wind and magnetic field from the solar flare (or CME)) helps in moving (sweeping) the GCR away.

2.2.1.6.3 What are the effects of radiation on us?

Well, it has energy to break DNA molecules which can kill cells leading to health problems with acute or chronic effects.

Acute Effects include: Diarrhea, blood changes, nausea, vomiting.

Chronic Effects include a nervous system damage or death.

This radiation can cause a mutation in the genes resulting in a skip or a mutation of a generation.

There have been certain limits set for the amount of radiation per person set by the Canadian Space Agency. The Radiation Health Working Group (RHWG) is responsible for setting the limits of radiation exposure.

Single-strand breaks (SSBs), double-strand breaks (DSBs), related base damage (BD), or clusters of these forms of damage can all be caused by ionizing (IR). One of the most serious types of DNA mutation is double-strand breaks. All of these modifications can result in cell death or mitotic failure as per the information from Wendy J and David Pederson in “Journal of Cellular Physiology” Vol. 231.

Making A Protective Layer on the Ship to Protect us From the Rays

The sun will produce very high and powerful rays which can damage our skin if prolonged to it, hence it is important to have a boundary which can filter the radiation and provide the useful sunlight for us which we can use (only in limited amounts) to get natural vitamin D (this is a very small quantity, hence we need supplements) and sunlight for agriculture. On earth we have an atmosphere and ozone to look after this but on Exodus it is necessary to create a medium which can take in the suns energy and produce solar energy as well as give some light to the towns and cities inside as well as for farming.

In order to achieve this **ultraviolet-stabilized polycarbonate** (or hydrogen-rich shielding) will be used in shielding the ship. This material also ranks as a good protector in benchmarks. As we launch from Earth which is closer to the sun, it will have more radiation or intensity in comparison to near the Asteroid belt (which is further away), hence there would be more layers of protection in the first base when sending it (with people), whereas a smaller layer of shielding (in comparison to the center) is enough in the rest of the ship (bigger Torus) since radiation would be less, but not neglectable further away from the sun. We also won't have any people on board while taking parts to the destination.

2.2.1.7 Whipple Shields and Thrusters

As space has debris around which is always floating, it is important to prevent against any collision with them, hence there will be a series of Whipple shields to protect the ship from this damage. These shields will be scattered across the ship in areas which are most

vulnerable such as near the center and 8 around the Torus with a large size. In areas of solar panels, the panels will be coated with a thick glass which is able to resist minor damages without cracking. Below the solar panels will be a thick self-healing material layer followed by a hard metallic covering (of layers of metal) to prevent the structure from breaking.

There will also be thrusters to maintain the certain velocity of the ship preventing it from slowing down or speeding up from any collisions also serving as a way to get to the preferred centripetal motion to get the desired gravity (as there is no air resistance in space, once the ship starts spinning, it will continue to spin). These thrusters will also serve as a method to maneuver the station to avoid any damage.

Tungsten metal will be used to make these thrusters, supercooled liquid methane (or kerosene) and LOX will be used as propellants (hydrogen and hydrazine will also be used as fuels in some launches) for thrusters as well as launches from Earth.

2.2.1.8 Agriculture and Industry Hubs

The green rectangular prisms, are the Agriculture Hubs and the blue ones are industry. The agriculture hub named the **Artemis Center** (for growth), will serve as the area where all the food for the entire settlement will be grown. Each step will consist of different vertical steps to different plants with systems to maintain temperature and humidity in each step. There is an elevator which will go between each step of the 3. It is the same case in terms of the Industrial hubs. Each rectangle will consist of several industries (all together named the **Brahma Center** (for creation)). Around 20 Industries can work in the cuboids. Other minor industries can be set up in the actual main torus as well, but the main manufacturing will take place in the Brahma Center.

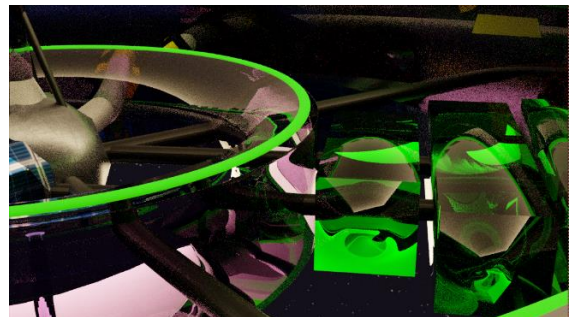


Image Credit: Pranavsai G. Image of Artemis Centre

2.2.2 Internal Structure

2.2.2.1 Inner Drainage and Piping System

Drainage is a big part of the ship. This will include all the toilet waste, the bathtub or shower water, sink water, industrial water and much more. To ensure that the drainage system will work efficiently in Exodus, I have decided to focus on the main sources of drainage and how we should handle it.

How drainage is divided

The drainage will be divided into toxic water, semi clean water, clean water, and toilet water.

- **Industrial Toxic water** is the water released from industries containing harmful chemicals. Hence before letting it out, it is important to clean and purify the water to an extent. But since water supply is limited, industries will be promoted to use other sources to carry on industries unless highly required.

- **Toilet water**, is the water which is flushed down from a toilet, and since the water is already dirty, any other dirty water which isn't as highly dirty as the Industrial water will be sent here. Where it is undergone under a purifying cycle to be sent back in two paths, where one leads to a pond or another into another cleaning chamber which is sent to homes as potable water.
- **Clean water** is the water which gets dropped when we are filling our water bottles or cups from the water dispenser. (It is the water which gets wasted without being used)
- **Semi Clean water** is the water with soap which comes from washing dishes, or from showers, or bathroom sinks. This water is cleaned to remove the soaps and is sent along with the clean water to be purified and sent to homes as clean drinking water. In homes, there will be two sinks in the kitchens. One sink will serve as a sink for basic cleaning, water dispensers, and other purposes which do not use any harsh chemicals, but instead just basic soap or handwash drain.

Water recycling is a big necessity, and instead of using cleaning substances on all the water, here on Exodus we will only use it for the water which is actually suitable for drinking and not industrial water. Because as water gets continuously filtered, it is also important to keep maintenance and the efficiency of the filter in mind. Where more water would mean a smaller lifetime for the filter. So, to reduce the work done by the filters, I have split the dirty water and clean water depending on the amount of purifying they need.

2.2.2.2 Ship Sections

The ship will be divided into four parts with an airtight seal between each part and only a door to pass through. This is so that in case of an emergency and any part of the ship breaks down, it won't affect the other parts of the ship. Suppose a hole forms in one part of the ship, then the vacuum won't give any effect to the other parts of the ship with the help of an air tight seal.



Image Credit: Pranavsai G. Image of Exodus 4 Quadrants

2.2.2.3 Home Placements and Extracurricular activity Hub Centers

Since the floor is curved, it would mean the homes would either have to be constructed in a curved path, or a flat plane should be installed as a base before building a home on top. Homes will be places in a grid path with roads between the homes. About 20 homes will be in each row from center to outwards which can grow if extensions are made. As different homes are different sizes, the area occupied by each home can vary so the number of homes cannot be a fixed number. There will also be apartments to hold those who cannot afford to own homes. Home furniture and inside design will be talked about later on

Not just living, but places to go to work, or to simply have fun are also necessary. Job buildings will be constructed and a few headquarters will be made depending on the necessities of companies. There will also be space for building places that serve food as well. All these will be later discussed in Chapter III.

3 CHAPTER III – LIVING CONDITIONS & LIVELIHOOD

3.1 HOMES

3.1.1 Overall Look of the Homes

Houses on Exodus won't be much different from Earth, except there will be a higher promotion of building multistory homes (or condominium to be particular) to hold a higher population in a limited area. There will also be apartments for people to live in. At start a majority of the homes will be apartments (prices of homes below). Later on, personal houses will also be built along with condos.

There will be a higher number of laboratories, research centers and testing centers along with the homes to aid in learning more about space as well as develop new methods of living.

3.1.2 Interior Design

Now as most of the living areas will be apartments, here is a summary of how the prices might be as well as the models of rooms.

3.1.2.1 Bedrooms and Bathrooms

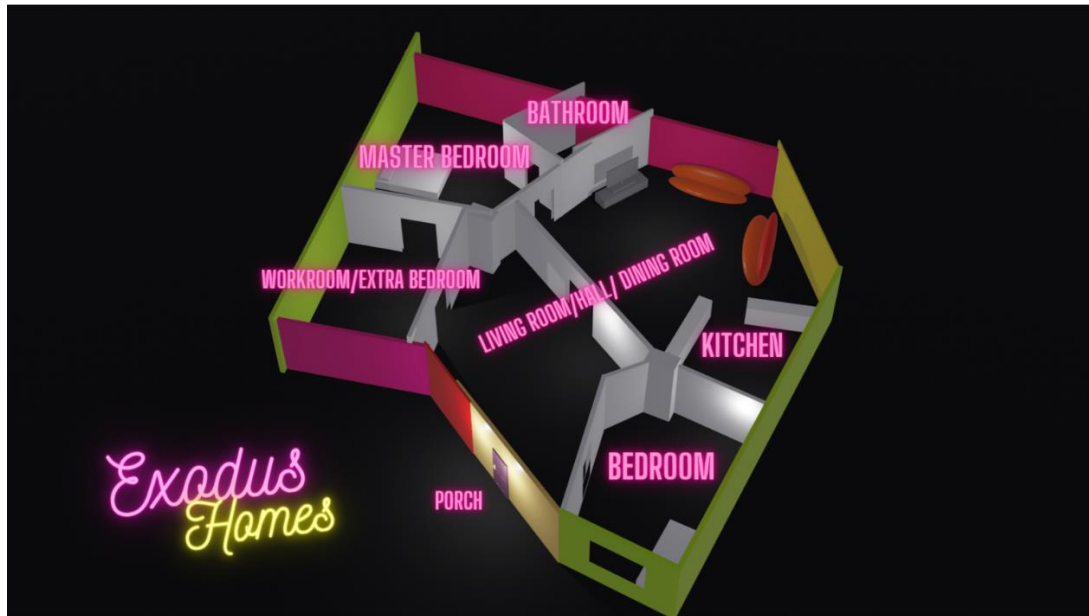
The number of bedrooms will depend on the families moving in or the wish of the buyer.

Family Members	No Bedrooms	Cost (Per Month)
2	1	\$2200(approx.)
3	2	\$3500 (approx.)
4	3	\$4500 (approx.)

As the time goes by the cost of living will also increase (or decrease), but the salary made in the work done in the stations will be in par with the cost of paying rent. After a majority of the population gets settled, the homes will be available for permanent purchase. During construction homes can be picked and designed as our wish so they can be built for us as per our preferences. The bathrooms will be design in a way so that all the bathrooms in the whole should connect into several drainage pipes which will connect to an exit hole where the waste will be converted into fuel or sent out of the ship. The bathroom will consist of a shower area, and toilet, like the master bathrooms that we have here on earth. When buying or renting homes, the price will depend on the number of bedrooms and bathrooms. In a home there will be either 1 bathroom in a family of 2. Or 2 bathrooms in a family of 3 or 4. There can be more upon the wish of the wish of the builder. As well as a master and normal bedroom for the children and adults



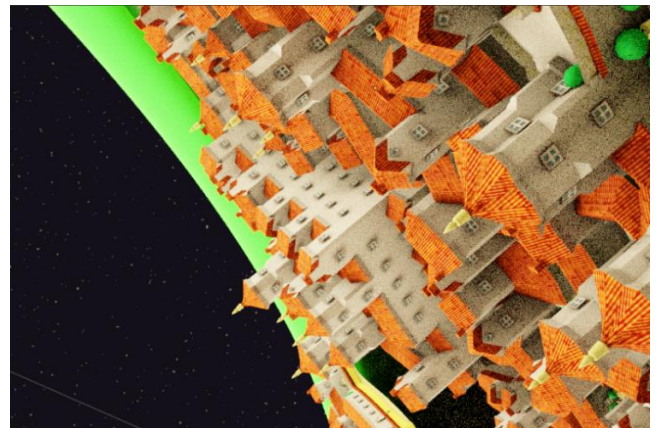
Exodus Condos [(1 story) (multiple stories will also be made) – Image 1 – kitchen and hall, Image 2 – Outside Condos connected in a circular shape, Image 3 – Master bedroom.], Image Credit: Modeled by Pranavsai G.



Labelled image of Exodus Interior Components, Image Credit: Pranavsai G.

3.1.2.2 Hall/Living Room/Dining Room

This area will consist of an area to sit, as well as an area to dine. The area between the porch and living room is also part of the house and will be used as a hallway and an extension to the rest of the hall. There will be an opening between the area with an arc. The sides of the hall near the porch will be used as an area which connects all the other rooms into a big one. The shape of the house is like a triangle, hence making it a good choice in case we want to connect all the homes together into a circular type structure as show in an image above. With a tv and a sofa, it would be a perfect spot for relaxation!



Vision of Exodus Homes in large towns (multistory) Image Credit: Pranavsai G.

Town model by Sebastian Sosnowski with CC use permission

3.2 ENTERTAINMENT

Exodus takes entertainment into high consideration for the comfort of the people. There will hence be

- Several parks around with gyms for people to keep their fitness. These include swimming pools, baseball grounds, bowling allies and many other competitive places for sports. Exercise is compulsory for everyone, leaving a few exceptions, due to the importance of staying fits in a micro gravity environment.
- Open theater centers and indoor theaters for people to watch movies
- 2 amusement parks through the ship, which may grow as extensions begin to be made.
- A tv station will be built for the whole of the ship, as well as smaller tv channels for local news

- Playrooms, and Malls will be open. There will be a start of 8 malls in the whole ship evenly spread out for everyone to be able to access them.

3.3 BIOMES AND WILDLIFE

3.3.1 Wildlife On Exodus

In Exodus I have planned to not take any animals at the first phase of settlement (rather will be taken in Stage 4 in future expansion). But since humans have bonds with their pets and in order to not completely wipe out other species, there will be pets and other domestic animals raised in the ship (as per the wish of the owner). Several reasons for not bringing animals being:

- More focus will be taken on settling humans before making a whole biome for animals.
- Making a biome for animals will be more expensive in addition to the basic environment.
- Adding animals in a biome also means that we would have to make multiple habitats suitable for each living organism, and we also need to take their growing conditions, temperature and food into consideration along with the huge human settlement issues.
- Creating wildlife means we need a whole food cycle to run in Exodus. And this should take place along with the human settlement without affecting us civilians.

In creating a food cycle, we need to take all the proportions of each and every animal into consideration. This means if there is more of one animal the following animal may get dominated and the upper animals might perish. Let us dive further in with an example of this scenario:

3.3.2 Keystone Species

Ecosystems have many parts to them. Let's take the animals for example. In an ecosystem keystone species make up a big and important part. Keystone species are organisms which help decide the whole ecosystem for other animals are dependent on it to ensure an equal balance in the ecosystem. These species are divided into three sections:

1. Predators

These are the animals which feed on prey. They are an important in keeping the animal population in check. Let's take a dolphin and a fish as an example. Here the dolphin eats the weaker and more vulnerable fish while the others escape. This helps in preventing the over population of the fish as well as serves as a food source for the dolphin. The overpopulation of fish would result in insufficient food for all the fishes. It will also reduce the available grass or organisms in the water that the fish eat if they grow in number. Hence a predator is a necessity in an ecosystem. Examples are lion, tiger, sharks, snakes, dolphins.

2. Ecosystem Engineers

These animals will change the environment to help them grow. This change can be a creation or destruction which in turn also helps other organisms. Such examples are beavers, woodpeckers and birds. Beavers take tree twigs and other dead tree parts to build their dam. This in turn clears the land for other new trees, and also helps in directing the water into certain paths to give other organisms water/plants to grow. Woodpeckers also help in drilling holes into trees for them to live while also making holes for cavity nesting species.

3. Mutualists

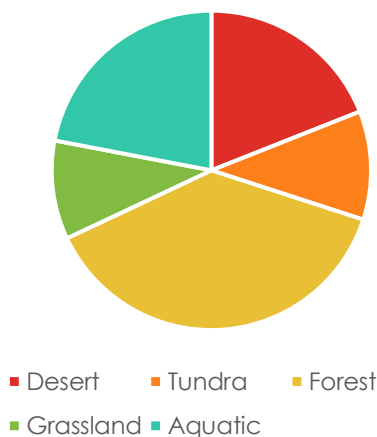
These are organism which interact with each other in turn helping each other. For example, take an oxpecker. This animal lives on top of animals such as a zebra or rhino and feeds on the ticks of the animal. This helps the animals stay itch free at the same time feeding the oxpecker. Other examples are bees too which take pollen and nectar to make food as well as helping in spreading plant fertility. (We will have bee farms and other types of farms on Exodus as time comes)

3.3.3 Biomes

Suppose human settlement has been brought to its fullest, then bringing animals would be the next development. Since it isn't possible to bring every animal, I have decided to make the majority of the diet vegetarian leaving meat as a luxury for a few. Though meat farms do have a potential to grow If proper areas to sustain these animals is made. If we did have to make certain biomes, the concentration and features would be as follows:

Biomes	Temperature	Percentage of Ship
Forest	50 F (10C) – 70F (21C) [Depends upon type]	38
Tundra	-30 to 20 F or (-34 to -6 C)	11
Desert	38C to -3.9 C during nights (100F to 25F)	19
Grasslands	-20 to 30 C	10
Aquatic (Marine)	Depends upon height of water	22

Biome Concentration



(According to NASA)

This will mostly not be implemented at start, but may be implemented after in Stage 4 when more civilizations will be built with certain areas reserved for them.

3.4 NUTRITION

3.4.1 Diet

As said before, nutrition on Exodus will mostly compose of vegetables. And in order for all nutrients to reach us, our diet would have to consist of the following:

- **Carbs**
- **Proteins**
- **Fat**
- **Fiber**
- **Vitamins**
- **Minerals**
- **Water**

Now we shall talk about what types of foods we can eat in Exodus as well as how some are important for us especially in space.

3.4.1.1 CARBOHYDRATES

These are foods which are used for energy or glucose. And this energy is important for workers in Exodus, especially those who perform manual labor which involves more amount of effort and work. Carbs are present in almost every food except a few (meats). Since we have taken a vegetarian diet, the food we will be taking will be

- **Grains:** Rice, Wheat, Oats, Barley, Cornmeal, other cereals.
- **Legumes:** Peas and Beans such as chickpeas, peanuts, black beans, kidney beans, etc.
- **Vegetables:** Sweet potatoes, corn, beetroots, carrots and other veggies.

Many recipes can be made with just these base ingredients.

3.4.1.2 PROTIENS

Since meat is only a luxury, it is important to cover the purpose meat mainly serves. Which is protein. To get equivalent protein as meat, it is important to eat protein rich foods such as:

- Almonds
- Oats
- Broccoli
- Guava (one of the most protein rich fruits)
- Seitan
- Tofu
Tofu contains nine essential amino acids, it is also packed with rich protein
- Lentils
- Beans
- Hemp

Protein is important in space since a long flight can cause muscle atrophy as well as bone mineral density loss. As NCBI says, it is recommended that protein intake is 12%-15% of total energy intake

3.4.1.3 FAT

Some Sources of fat for astronauts are:

- Avocados
- Chia Seeds
- Flax Seeds
- Nuts
- Tofu or Soybeans
- Coconut
- Oils (Coconut, Olive, Avocado, Vegetable, etc)

These will be the alternative for the meats such as beef, pork, lamb, chicken or fish which also give fats.

3.4.1.4 FIBERS

Sources of fibers are:

- Beans
- Broccoli
- Avocado
- Whole Grains
- Apples
- Dry Fruits etc.

3.4.1.5 VITAMINS:

Vitamins such as D and K and C are important in space, as astronauts have bone and muscle mass loss so vitamin D, vitamin K and calcium are vital. The rest of the vitamins are important too.

Vitamin D:

Even though humans can make their own vitamin D from sunlight, in space since the Ultraviolet rays are strong, there are special shields to block the rays. This prevents us from making vitamin D, so it is necessary to take supplements or grow plants.

- There are only a few fruits with vitamin D of which Orange is the best choice for vitamin D other than dairy products.
- Another source of vitamin D is Almonds
- Soy Products
- Oat Milk
- Mushrooms

Another way of getting vitamin D would be a UVB (Ultra Violet) lamp which simulated sunlight to help create vitamin D, but the risks include skin cancer like how we may get it out in the Sun. This is used in case of deficiencies.

Vitamin C:

“An Orange a Day Keeps Scurvy Away” as said on the Nasa site in the article on Aug 3, 2015 talks about how nutrition is very important for a mission to be successful. The previous missions which didn’t take care of nutrition resulted in Scurvy as the cause of death. Hence Vitamin C is definitely important.

Foods with Vitamin C are:

- Citric fruits (lemons, limes, oranges and grapefruits are examples)
- Tomatoes
- Guava (they have a high concentration of vitamin c, which is in fact more than an orange! They also have calcium, fiber and iron.)
- Potatoes
- Pineapples

Some of their benefits include:

- Helps maintain cartilage, bones, teeth
- Helps in growth and development
- Repairs body tissues and provides immunity
- Essential to form collagen

Some problems of a deficiency (Scurvy) in Astronauts are generally:

- Weight loss
- Muscle Pain
- Dehydration
- Constipation
- Calcium loss
- Potassium loss
- Motion Sickness
- Fatigue

Extra Info

Scurvy can be found out by weak gums, bruises or rashes which was a big problem for sailors in 18th century who didn’t have enough Vitamin C.

Vitamin K:

In space it is used to counteract the loss of bone mass in microgravity. It is important in making proteins that are required for blood clotting, as well as the building of bones. Lack of this results in bleeding, poor bone development, a higher chance of a cardiovascular disease or even osteoporosis.

Foods with vitamin K include:

- Leafy Vegetables (kale, spinach, mustard greens, romaine, lettuce)
- Veggies such as brussels sprouts or broccoli, cabbage or cauliflower

- And meats such as eggs fish liver etc. (but meat will not be a main source of this vitamin on Exodus.

Avocado is a fruit rich in this vitamin

3.4.2 Nutrients We Cannot Obtain Without Meat And their Alternative:

Being a vegetarian, some advantages are

- It is good for our heart (as we eat food which will promote heart health)
- Reduces a risk of cancer (especially female ones)
- Prevents diabetes
- Gives a lower BP
- Decreases some asthma symptoms
- Decreased Osteoporosis rates (It had been noted that countries with more population in vegetarian diets had less osteoporosis.

But not all nutrients can be obtained from plants alone. Some nutrients we can't get from meat are as follows:

Vitamin B12

It is a vitamin found mainly in fish, meat, dairy and eggs. Dairy products include cheese, yogurt etc. In case we don't have sufficient animals at start to produce it for everyone, we will have to depend on supplements for this vitamin.

Creatine

Some is stored in our muscles and much in our brain. It is an energy reserve for muscles provide more strength and mass. Since it is found in animal tissue, we will need to depend on supplements if we want it, it is not essential we take it. Creatine need not be taken as supplements because our liver can produce it. But as a study done says (in the National Library of Medicine), vegetarians have less creatine.

Carnosine

It is important for body functions. It is formed in our body from amino acids, but as before, those who eat more meat have more of it. Carnosine prevents muscle fatigue.

Docosahexaenoic Acid (DHA)

DHA is important for mental health as well as brain functioning and development. Made from omega 3 fatty acids, it can be found in fish and micro algae. But since we need a vegetarian alternative, good sources of DHA would be walnuts, algal oil (a source of omega 3 fatty acids from algae), chia seeds or flax seeds.

Heme Iron

Obtained mostly from red meat, and is an iron which gets absorbed more. It isn't pleasant in vegetarian diets and hence there is a larger risk of anemia (iron deficiency)

(As a Healthline article written by Atli Arnarson points out)

3.5 JOBS, CURRENCY AND METHODS OF WORK

3.5.1 Sectors

3.5.1.1 Primary Sector

Farming is going to be the main source of food production. A majority of the diet is vegetarian as mentioned above and meat only for a few who can afford it since not many animals can be brought at start. Since most of the diet is vegetarian, it also means we need to get protein, vitamin B12, iron, zinc and other nutrients in different ways. As we have talked about the crops required before in the *Nutrition* Section. Let us focus on how crops are to be grown on Exodus in the Artemis Center. Here in space, we have two main ways of growing crops which will be used:

3.5.1.1.1 Hydroponics

This is a type of agriculture which uses mineral nutrient solutions instead of soil to grow crops. This can be used in case no soil is found. This technique has many merits and demerits.

Merits of Hydroponics:

- They use less space. If this technique is used in a vertical way, we can save a huge percentage of cropping space.
- They use less water. Since the plants are grown in water and don't need constant watering, the water used will be much less than in traditional agriculture. This will be helpful in conserving water especially since water is required for other parts of the ship.
- With correct conditions, it produces more produce.
- It doesn't need much labor except for maintenance time to time.
- Reduces growing time and produces higher quality food with fewer pests
- And most greatly needs no soil!

Demerits of Hydroponics:

- It is expensive to set up. Being more expensive than normal farming, since it needs a whole system to be set up for it to work.
- Its vulnerable to power cuts. The machine depends on electricity to power lights, fans, water pumps. And if no other sources of power are available during power cuts for a certain time, then it can affect the plants if not checked in maintenance.
- Plants get affected quicker and waterborne diseases are more likely to occur since it is grown in water.

3.5.1.1.2 Aeroponics (a better method)

Another type of agriculture which like hydroponics, gives a better yield than soil farming. It gives healthier plants, has a lower cost to run while on the other hand hydroponics is easier to manage as well as set up. It has almost the same demerits as hydroponics.

Merits of Aeroponics:

But the difference between aeroponics and hydroponics is that instead of being immersed in water, they will be grown in air with a timed spray of a solution rich in nutrients. **This is an even better method as less water is used.** According to NASA, plants can even grow up to 3 times faster in aeroponics compared to soil. Being suspended in air, they will also have a better supply of oxygen which the plants submerged won't get.

Asteroids as a source of Soil

Asteroids can be used as a source of soil for growing our crops on Exodus. C-type asteroid to be exact. (According to NewScientist and NewsWise).

C-type asteroids are carbonaceous which means they contain carbon. They also have hydrogen, nitrogen and other minerals, metals and also have a bit of clay and rock in them. These are the essentials of a plant. By adding the nutrients its deficient in, we will be able to grow crops on the asteroid soil. We can either bring it on ship, or build farmer hubs on the nearby asteroids itself. Even though it still is to be developed (and maybe not fully productive), soon we may be able to exploit asteroids to grow crops too.

3.5.1.2 Secondary Sector

Secondary or the industry or manufacturing sector in other words is very important in making the products from the primary into other goods. Here on Exodus, there will be a limited number of huge industries and several smaller ones at the Brahma Center. Pollution control in bigger factories may be a problem but those can be treated in certain ways.

Since Exodus is in space, most of the manufacturing will be for either making homes, products for home use, food, luxury, or for building parts to extend the spacecraft even further. There will be satellite manufacturing for sending research satellites as well as for tv.

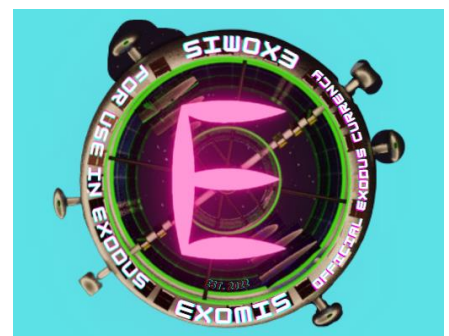
Materials such as metals like aluminum and titanium, iron and other materials to make circuits can be extracted from the asteroids present near the ship. These asteroids will serve as a rich source.

3.5.1.3 Tertiary Sector

Services on the ship will mostly be as it was on Earth, except there will be a higher concentration of people in maintaining the export of materials made in the secondary sector to help extend Exodus. Here when I mention maintain, it is also important to note, there will be paths in the ship to help transport materials in a fast medium which is completely automated. This will help people take up other jobs than just building the ship such as IT or recreational management etc. There will be numerous scientists working on finding best and newer methods to take up new extracts from the discoveries as well as more constructors to help build. There will also be healthcare in this sector. Each person on the ship will have an identification card used to track their health records. The healthcare groups will consist of the highest trained professionals to ensure everyone is healthy and happy.

3.5.2 Currency

There will be a new type of currency called Exomi (Exomis Plural). They will be used in purchases and trade in the ship. A majority of the trading will take place digitally, though notes will also be used for quick cash. There will be several banks and financial institutes to manage the money and keep track of all transactions with high security and privacy. Each Exomi will be worth around 2 USD. The values mentioned in dollars above will all be converted into Exomi currency except for transactions from the Earth to Exodus (like how currency is changed between countries).



3.6 WATER AND OXYGEN GENERATION AND RECYCLING

3.6.1 Water Generation

3.6.1.1 A Big Water Source

Asteroids have in fact been shown have some signs of water (in the form of ice) or at least the elements required to make water. Taking Ceres for example, it has been said that there is water seeping in the asteroid with about 50% volume of water and 73% rock by mass according to Wikipedia. Astronomy.com also says that it has pockets of water and has also been talked about in the potential for previous life on Ceres in the Nasa Solar System Exploration section about Ceres.

There are also several other asteroids like this which can serve as a place to obtain water which can later be filtered. Once perfected, it could be a great way to obtain water and recycle in Exodus.

3.6.1.2 Water Pathways

Water is a main part of human existence as well as plant and animal existence, it is vital to be able to produce potable water as well as water for plants to grow. In order to ensure efficiency, Exodus will split the clean water into two pathways like how drainage was split.

The first pathway will have potable water for consumption and domestic purposes and the second for industries and irrigation. This water will be produced or recycled in the following ways (apart from asteroids):

3.6.1.3 Water recycling and Purification (Using Reverse Osmosis)

Once Water has been made to a certain amount, this water will be recycled, either using drainage water (Like in the ISS, but in large scale), waste water or the water that has seeped through the soil and has formed underground after several years. Water will be collected in ducts and split into drinking and other purpose water. The drinking water will be sent through several filtration systems with RO filters as its main for the potable water. Rather than giving each home one filter, we will produce the potable water in a pipe which will connect to all the homes sinks for consumption.

The RO filter will have RO+UV+MTDS for filtering the water.

The steps will be:

1. Sediment Filter
2. Carbon Filter
3. Reverse Osmosis Membrane
4. Polish Filter

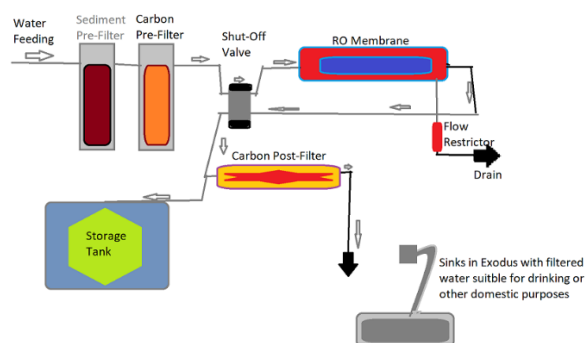


Image Credit: Made by Pranavsai Inspired from BOS (Best Osmosis System)

In order to ensure no problems in the filter hub, there will be an autonomous maintenance of filter along with a monthly check up by hired members. There will be 10 hubs evenly distributed around the ship so the water can be efficiently filtered and sent evenly to the areas.

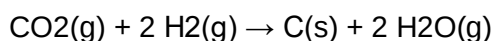
3.6.1.4 The Sabatier or Bosch processes (Water production)

This Process Is really useful in producing hydrogen and water with the help of gases and elements for use in Exodus. It is a way to produce and recycle water as well as oxygen and hydrogen for other purposes.

The Sabatier and Bosch Process is helpful in oxygen recovery from carbon dioxide through chemistry helping the Space Station reduce oxygen bottle and rather make our own Oxygen or water for use and later recycle them for use. As SAE International says.

Sabatier and Bosch Process:

The Bosch Process forms the following:

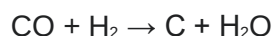


This is made of two parts.

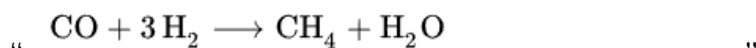


And a reverse water gas shift reaction (**WGSR**) takes place: (Water gas or syngas is a mix of Carbon Monoxide and Hydrogen) (fast step) (above)

The Below reaction is a Rate Determining Step (**RDS**) (RDS is normally the slowest step which has the most influence on the reaction rate.) Here water is produced.

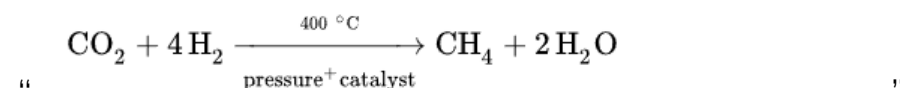


The Reaction below may take place too:



(Or)

Here aluminium oxide(alumina) is a catalyst (below) (it is exothermic)



(Formulas derived from Wikipedias Bosch Reaction and Sabateir Reaction Page and Information about the processes from Nasa's "International Space Station Water System Successfully Activated" article)

Extra Info:

The Bosch reaction is a chemical reaction from carbon dioxide and hydrogen which in turn produces carbon, water. As well as a 10% return of heat.

The creator is a German chemist, Carl Bosch.

According to Guide House Insights, this process produces carbon dioxide equal to almost 1.2% in the world.

3.6.2 Oxygen Generation

Oxygen is the next vital thing most living organisms need. Exodus will be producing it with the help of

3.6.2.1 Cryogenic Distillation

Cryogenic Distillation is when Nitrogen and Oxygen are separated from air (According to Chemical Engineering World's article "Cryogenic Distillation of Air"). Here the components with low boiling points are distilled at low temperatures selectively. This method produces products of high purity. But downsides include high energy utilisation. But this can be fixed by using coal and sunlight as an energy source for the factory with the emissions being sent into a section of the ship (Exodus) where CO₂ is absorbed and rest released. This will be achieved with **chlorella vulgaris**. [(Source: "Science Direct – Cryogenic Separation ").]

Extra Info: *Chlorella vulgaris* is a bacterium which is able to soak up CO₂ from the atmosphere. In an experiment, it was cultivated for 8 days in 3% CO₂ and 31.8 mgCO₂/m³/day of CO₂ fixation had taken place

[According to research by Sayadi, M. Shabani, and Rezaei] in "Proceedings of the International Academy of Ecology and Environmental Sciences"]

3.6.2.2 Vacuum Pressure Swing Absorption (VPSA)

This process separates air into its components on absorption. Here gases bind with materials at different pressures. Another method is PSA (pressure swing absorption) oxygen plants, which makes oxygen for different industries, but VPSA is used more in producing higher oxygen in comparison, but is also costlier. This process can produce more pure Nitrogen and Oxygen in comparison to Cryogenic processes. This process is also more energy efficient compared to PSA as *TriMechIndia* says.

3.7 WEATHER, DAYLIGHT CYCLE AND TEMPERATURE REGULATION

3.7.1 Introduction

In space temperatures can go really high, or really low. There is no perfect temperature. Hence it is important to be able to match the temperatures on Exodus with a suitable one. It is important that our climate is also good as well as having a proper day cycle.

3.7.2 Daylight Cycle

Since daylight cycle is important in Exodus for people to sleep and wake and follow their circadian rhythms. Exodus will rotate once per minute to create artificial gravity. This can depend upon its size and the speed it needs to rotate to create enough gravity. But it definitely not be a 24-day cycle as we have on Earth. To overcome this problem, we would need to install lights which will function all day and turn off at night (so schools and offices can function as usual in their proper hours). Exodus is divided into four quadrants, and of these quadrants, two of them will have day while the other two have night. Several reasons I have chosen to do this is because it would allow one to work in a day shift while the other can cover the night shift. Another reason, is that it would also be a lower burden on the solar

panels equipped with only half of the population using the electricity at a time leaving the rest for a battery to charge as backup.

3.7.3 Weather

We will have seasons, as the orbit around the sun is a bit elliptical, we would have hotter and colder times. We won't have any rain or thunder as we do on Earth, and we won't need them as we will have hydroponics and aeroponics practiced. The rivers that flow will also be sent from a source, rather than rain. There will of course be humidity in the ship to ensure that the atmosphere stays a bit moist and not too dry to prevent any harm to life living there. Humidity will be kept around 60% RH.

3.7.4 Temperature Regulation.

Of the basic necessities of life, the four main requirements are oxygen, nutrients, the right temperature and atmospheric pressure. The air around should also be at a certain temperature not too cold or hot. So, the temperature will be set from 69F-78F depending on the amount of sun coming from outside. This temperature is for the outdoors, to simulate a temperature like earth. Homes will have their own air conditioning. There will be maintenance of humidity as well to make sure the occupants don't go dry from the surroundings. For ensuring the temperature, Active Thermal Control Systems (as used on the ISS) will also be installed per quadrant in sections and the central areas.

3.7.5 Atmosphere and Pressure

3.7.5.1 Importance of Maintaining Pressure Balances

In our body, there is a certain air pressure require for our lungs to function efficiently. Having a higher air pressure results in hyperventilation and a low pressure will reduce the efficiency of the lungs. So, it is important to form a proper pressure with the help of gasses to sustain life. This can be done with a cabin pressurization system.

3.7.5.2 Atmosphere

The atmosphere is made up of 21% Oxygen and 78% Nitrogen as well as 0.04% of Carbon Dioxide, 0.93% Argon with bits of other gases too. It also has water vapor. (Taken from Space.com). It is vital that the atmosphere remains homogenous. In order to make sure the pressure is the same in Exodus, we will have the same percentages of gases as Earth in the ship as well. This gas will be recycled in the ship as it is done on Earth. Different ways of recycling it would be through photosynthesis from plants for oxygen (as well as minor Carbon dioxide), carbon dioxide from humans and mineral extraction gasses sent into a gas regulator (which absorbs the gasses and splits them into appropriate mixtures to match the percentages of each) which is always maintained at all times through-out Exodus.

Apart from pollution, a nuclear power plant has good uses too, one would be to provide energy, and the other to provide heat. As we are quite far from the sun at the asteroid belt, we would have freezing temperatures. In order to prevent the ship from frost, the heat from the nuclear plant can be conducted around and can also be used to make hot water for other purposes.

4 CHAPTER IV – MINING AND POWER GENERATION

4.1 MINING ZONES AND MINERALS MINED

As Science Alert (from 'sciencealert.com') says, the asteroid Psyche 16 would make a good place for mineral extraction. Ceres is also a mineral and resource rich asteroid suitable for mining.

4.1.1 Main Asteroids

4.1.1.1 Ceres

Ceres is an asteroid in the asteroid belt, about 952 km in diameter and is the largest known asteroid in our solar system as well as the only dwarf planet in our inner solar system.

Ceres also been found to have water in the form of ice seeping from the inside according to an article by *PBS NOVA*.

It also has hills of ice which has melted and refroze from an asteroid several million years ago as *Michael Greshko reported from National Geographic*.

Hence Ceres would be a good asteroid to settle nearby as it is a C-Type (carbon) as well as a G-Type (clay) asteroid with useful materials.

4.1.1.2 Psyche 16

Psyche 16 is also another interesting asteroid to mine. Named after a goddess, this asteroid is said to have worth of almost \$10,000 quadrillion according to an estimate by Lindy Elkins-Tanton. In the asteroid belt, it is an asteroid with large quantities of iron, gold, platinum and nickel. Worth more than 135,000 times than all the money in the world, it is said to have contained enough iron to collapse the world's economy! The iron will come of good use when making parts and internal structures. The other rare minerals can also be used as fuels if sufficient amounts are found. All these metals can be used in making the machinery of the ship. Hence Psyche 16 would in fact be a good place to settle nearby.

NASA is also planning on going to discover Psyche 16 in August of 2022 planned to reach around 2026 (Taken from *NASA "Journey to a Metal World"*). By learning more about Psyche 16 we can decide what we need to take, and what we can find there.

It is also a M-type asteroid, or a metallic asteroid. These types of asteroids are generally made of around eighty percent iron along with twenty percent other metals such as nickel, platinum, gold, magnesium etc. which can be used for other purposes. (*According to Universe Today*)

4.1.2 Steps To Set Up a Mine

In order to set up a mine, the step needed to be followed are as follows:

Exploration

Step one would be to find a resource rich area. It should be a spot which would be the best place to get maximum minerals. After a certain spot is found to be containing enough minerals to pay off the financial deposits, the plans will start to be made.

Mine Site Designing and Plan

This would include how big we plan on making the mine and how deep we would like to dig into the asteroid. We also need to make a structure which would be able to be detached and perhaps moved to different parts of the asteroid to increase the maximum productivity of a device built. Each area it mines would last quite a long time before a shift is necessary.

Construction

Here there will first be a tunnel made, then following inner tunnels will be made to create pathways. There will have to be transportation, management and maintenance facilities made in order to make sure everything goes properly.

Production

The transportation of Ores from the pits to the crushing and refining to produce clean minerals and metals. Here undesirable substances are removed. Different types and processes of mining are as follows:

SURFACE MINING

- Strip Mining
- Open Pit Mining
- Mountain Top Removal Mining
- Dredging
- Highwall Mining

UNDERGROUND MINING

- **Subsurface Mining**
It is the extraction of metals or fossil fuels from under the surface.
- **Heap Leaching**
This process involves crushing and heaping ore on plastic (or clay) on an impermeable area which is irrigated for a period with a special solution until the desired metals are dissolved and is collected. It has been used for extracting normal and special metals.
- **Flotation**
Used in separating hydrophobic materials from hydrophilic. It has been used in separating copper zinc and lead.
- **Smelting Facilities**
Metals are obtained by heating beyond their melting points, normally in the presence of oxidizing or reducing agents
- **Reclamation**
This step means to restore the land to a neater area instead of leaving the mined area as it is. Leaving it would normally cause soil contamination with toxic acids and metals from underground lowering the PH not allowing plants to grow. Leaving it as it is can affect the land around greatly. But as we don't have vegetation on the asteroids at the moment (such as on Psyche 16), this won't be much of a problem if not practiced.

Other Mining Method

There are several ways to mine asteroids for our exploitation (some mentioned above). For starters

The most common main method will be to drill into the asteroid and collect chunks of asteroid rocks which will later be sent on a conveyor belt into a machine which will be in charge of extracting the useful minerals and metals. This will all be completely autonomous to reduce human interference in the processes leaving scope for humans to indulge in other occupations. There will of course have to be general checks on the extracting centres to make sure all the parts are intact.

- **Thermite Reaction**

It is a technique used in the reduction of metals from their oxides and as a source of heat. It is also called aluminothermic reaction. It is a highly exothermic reaction which is done by the reduction of a metal oxide with the help of aluminium. It gives out a big amount of heat which is even used in welding rails together. The reaction turns iron oxide into molten iron which is later used. We can use the same method in building Exodus.

4.2 POWER GENERATION AND DISTRIBUTION

4.2.1 Main Power Source

Power is a really important part of a civilization. And, the sun is a very great source of energy without burning fossil fuels and other effluents. As we have lived on Earth, solar panels are becoming quite popular and it is possible that one day Earth will use solar completely. And hence I believe that using solar should also be a main source of energy on Exodus.

4.2.2 Dyson Sphere

The sun is a star, and like a light bulb, it shines in many directions. And if we were to capture all its sunlight and use it, it's worth would be more than trillions of times the energy we currently use. This in fact has been proposed by Freeman Dyson (a mathematician) who has come up with the idea of a **Dyson Sphere**. This is a structure which covers the sun in rings harnessing all the energy the sun could provide. It can also be a place where humans can reside on too. But with the current technology and materials we have on Earth, it won't really be feasible to build a whole home and ring on a sun. We would also have problems regarding gravity. It has also been said that other stars with Dyson Spheres may be a sign of intelligent life outside our solar system.

4.2.3 Kardashev Scale

There has also been a scale made comparing civilizations on the power/energy that is harnessed. This is called the **Kardashev Scale**. It divides civilizations into

1. Type 0 Civilization – **Humanity**
Using crude energy and wasting the sun's energy
2. Type 1 Civilization – **Planetary**
Using all of the sun's energy that hits their planet. We are soon getting close to this.
3. Type 2 Civilization – **Stellar**
Harnessing all the energy produced by the star (Making a Dyson sphere or other method)
4. Type 3 Civilization – **Galactic**
Using all the energy produced in a galaxy.

The goal of the future is to be at a Type 1 civilization and perhaps move on to the following types as time and technology advances. On Exodus, the whole ship won't be used for energy absorption as some light will be sent into the ship to provide lighting for those living, so as the scale goes, our civilization would be around a type 0 to 1.

4.2.4 Solar As an Energy Source

4.2.4.1 How do Panels work?

A solar panel is made with the help of many solar cells which are made from silicon or any semi conducting material. They work using the process of photovoltaics to turn light into useable electricity as I will explain later on below. On the ISS, gimbals are used to have the panels always facing the sun. We will apply the same on Exodus with panels equipped with trackers which follow the path of the sun while rotating to have maximum power absorption (talked about later on). It is said that the panels ISS has could power up to 40 homes according to Nasa generating from 84 to 120 kw electricity. The ISS also uses DC or direct current to power itself, but as our scale is much larger, we will use AC to power Exodus.

Photovoltaics: some types of materials can absorb light photons and release electrons which later are captured (free electrons) which results in electricity which can be used. They require a semiconductor (such as silicon) to send the electrons in a positive and negative sides which is later connected in a circuit to be captured in the form of electricity. Cells grouped together are called modules and modules grouped together are called arrays.

4.2.4.2 Types of Panels

As talked about before, we will be using solar energy for a majority of the power on Exodus, hence it is important to choose the right type of solar panels. Three main types of panels are:

- Monocrystalline Solar Panels
- Polycrystalline solar panels
- Thin film solar panels

4.2.4.2.1 Gallium Arsenide Panels

Another type of panel is made with Gallium arsenide which can harness a higher amount of energy than silicon. Hence it is more preferred in space solar panels making it optimal for conversion, but on the other hand, silicon is much cheaper compared to gallium panels. Hence on Exodus, a majority of the panels will be made of silicon, but gallium panels will be used in the areas which receive the most sunlight at the majority of the time, such as near the center hub (center of the Torus) which will have light falling on it at almost all times. And on the top part of the outer torus.

As a majority of asteroids contain more silicon, it would make it easier to obtain silicon than gallium arsenide.

4.2.4.3 Solar Panel Degradation and Efficiency

4.2.4.3.1 Degradation

Solar panels don't last forever. It has also been said by research done by NREL that the panels degrade about 0.5% every year (or even from 25 – 30 years in lifespan [according to *GreenBiz*]) which is subject to change depending on temperatures. As we have no

atmosphere in space, the sunlight will not have any filter or layer to go through resulting in faster degradation.

Efficiency

To get maximum efficiency some steps we can take are:

- Properly installing them at start to capture maximum light
- Cleaning and Maintaining
- Using Panes with higher concentrated Photovoltaic cells
- Installing a strong panel with protection from degradation in the future from freezing or burning temperatures or UV exposure.

(As suggested by ‘*Dynamic SLR*’)

4.2.4.3.2 Solar Tracking Panels

As said before, these are panels which move along with the direction of the sun staying perpendicular to the sun to take in maximum sunlight reducing the light that gets reflected. Vladislav Poulek and Martin Libra have suggested one method which could perhaps double the energy harvested. Their method says that using a solar tracker along with bifacial PV panels, we can have a double photovoltaic energy harvest.

These tracking panels will use energy generated from themselves to move DC motors connected to them programmed to follow a certain pattern as days go by to capture maximum light.

4.2.5 About Nuclear Power Plants

We generally don’t use nuclear power in space as there is no way to let the heat from it out. When we have heat radiating panels instead of solar, we get a lower amount of energy output. Nuclear energy would be more suitable in missions which are to go into deep space, such as for probes.

Nowadays, nuclear plants can provide up to 138,000 MWh everyday as output powering almost 10% of the world electricity. With this type of energy, we would be able to have much more energy than we need to power the ship.

There will also be energy generation using imported uranium as well as substances found on asteroids.

To prevent problems related to heat, there will be a thermal heat reductions system with protection from the sun at all times as suggested by Abe Hertzberg in “Thermal Management in Space”.

5 CHAPTER V – POPULATION, COMMUNICATION AND CULTURE

5.1 POPULATION

In order for everyone to live peacefully with enough room to prosper and grow, it is important to compare things such as:

- The size of the ship with the population
 - The gender balances
 - Population quantity
 - The population and their jobs in different parts
 - The food, shelter, education and all basic necessities available to all inhabitants.
 - Culture among the people, as well as a way to overcome social barriers.
- (All discussed below)

The population will not all move to Exodus at once, rather it will be sent in groups from earth. But the first people to reach Exodus would be the ones who build it. The constructors are an important part in Exodus, but the same person may not be able to work for long shifts, so there will be a set of workers at different times equipped with suits and materials to build. For this we need people to be divided into their jobs based on their importance. Most of the people that will come to the settlement area at start would compose of:

Engineers (30%)

They compose of:

1. Electrical
For building circuits on the ship and taking care of the electrical parts
2. Computer Science
To make software to regulate the ships temperature, oxygen, gases, industries, and settlement health
3. Structural
To build the main ship and ensure structural stability and tensile strength
4. Mechanical
To build the inner structures and communication and travel paths
5. And importantly Aerospace
Who will help in building a space craft, shuttle for travel to nearby asteroids, and in building the outer structure of the ship to help in durability and correct any mistakes in the ship as well as design certain parts of the ship.

Healthcare and Scientists (10%)

1. Doctors who are experts in heart care, bone care, breathing care, to make a constant checkup of the people working there including themselves.
2. Basic checkup members
3. Disease and Illness management crew
(Physicians to be exact which composes of orthopedists, cardiologists, internists etc.)
4. Scientists to research the surrounding environments and give plans to the engineers to build around certain areas to get the most resources we can.

Chefs and Cooks (10%)

It is important to have nutrient rich food for the works to maintain utmost health to work productively, since during the building phase we won't have many resources, most of the materials will be taken in frozen form from earth to feed the workers, and there will be a constant supply drop from earth time to time with materials as well as food along with the plants grown on the central ship for ingredients.

Constructors (30%)

Along with the engineers who will plan out everything and help guide things around, constructors are also important to help carry the material around and actually construct it. Once a base has been set up, several automated bots will be sent to repeat a certain process again and again to form a torus shape, but in order to make sure everything is working well, we need the constructors to go along with the bots to make sure everything is set in air tightly. They will also be required to help build the inner structures and homes. They will also be the testers to make sure the living conditions are in par with the human comfort and suitability.

Inner Structural Design (20%)

The first people brought on the ship will be those who are a resource to the ship.

Such as

1. Agricultural Management

To find areas good for agriculture to flourish as well as the design of farm to utilize space efficiently while making plans to prevent soil fertile from declining and in turn making it last longer for more produce.

2. Production Management

For planning the industrial sectors which are to grow in the future. They will also think of ways to increase production of goods which are important in demand with the wishes of the people at a minimum cost. This includes steps such as planning, organizing and optimizing the industry and its manufacturing. Turning raw material to finished goods.

3. Educational Management

Their role is to make a proper education system which will be implemented through the ship to ensure maximum literacy. They will divide the education into different branches thought the ship with different groups to check on different parts. This will be 4 parts of the ship divided into quadrants each with its own regional statistics on the area's literacy and health. Each of the quadrants will have its own head which will return data about the area's productivity and education to a central office for the ship. All this will be regulated and planned by an educational management.

4. Structural Management and Atmospheric Management

The structural and atmospheric management of the ship will take care of the inside building structure and atmosphere to match the living conditions like earth, they will work with agricultural management to ensure a good climate for the crops. The structural management will also work on developing plans to prevent radiation from entering as well as protecting us from outside dangers that may affect the inside.

After everything is built, the rest of the population will soon be brought onto the ship.

Requirements:

Requirements for the inhabitants will be

- For the inhabitants to be trained to be prepared to be able to withstand the space conditions.
- Be healthy in order to be able to lead a peaceful life on the ship

- Know basic first aid for those above 13 years

During the phase of constructions, some members may be sent back and switched out in case some are not able to stay for a long period.

5.1.1 Gender and Age Composition

Here on the settlement, there will be an approximate equal number of males and females living, but during the building phase, it will consist of males or females depending on their skill.

The settlement will consist of the following percentages of age groups

0-15 Years of Age: Each family will be limited to two children in order to avoid overcrowding and its consequences (which will be discussed later on). Because children are the next generation, enough education will be provided to assist them in succeeding in their future careers along with fun places for them to have a memorable childhood. It is critical to have a high literacy rate and a low mortality rate, as well as adequate healthcare and gender, religious, and cultural equality. This will be taken seriously on Exodus. The major goal is for the population to live in peace.

16-60 Years of Age:

This is the working population; hence it is important to keep those in this age group in utmost shape to be productive. There will be extra focus on vocational learning to help them be able to innovate with current technology and help in the betterment of the ship as well as society. Those below 20 won't be forced to work yet, unless they choose to do part time jobs, but rather will be encouraged to get degrees in their professions.

60+ Years of Age:

The age group with the most experience, being a good resource can either retire or help in educating others to learn something new. They will be given a pension every month to live the rest of their lives happily, they will also get passes to enter certain places free of cost.

5.1.2 Over Population

Overpopulation has been a problem in many parts of the world such as China and India. It is hard to keep many people in a smaller space or in other words to exceed the carrying capacity. This normally happens in the underdeveloped regions.

This can **occur** for **numerous** reasons, including:

1. A Decline in the Mortality Rate –

Let us say that 10 children were born in one day, and that 10 adults died in one day, then the population would remain constant, but if 10 children were born one day and only 3 adults die, then there will be a higher number of children (this applied the other way around too). This creates an unbalance between the age groups. And thus, as the death rate declines, overpopulation would be the next.

2. An Increase in Birth Rates –

As more children are born with a low infant mortality rate, there will be a higher number of children born. Though a low infant mortality rate is good, having multiple children at once is not. Since the past years there has been a decline in the birth rates in many countries. Going from 6 children to 2 per

mother in India, and 4 children to around 2 children in the USA (data from 1960 to present).

3. Lack of Female Education

There has in fact been a strong relation between female literacy and lower fertility rates. As females get more educated, they will get to know about the overpopulation crisis more, and with more education, they will be able take up jobs and retain more identity in the society. Hence, they would have a smaller time to give birth to and maintain children along with their goals. But now days not many women are literate. Or even if they are, they don't completely finish their education and rather only go till elementary or middle. A big cause of low literacy is poverty among the people. (Which is high at current)

4. Increase in Health Care

With more improvement in healthcare and medical knowledge, new ways to fix the lives of people, diseases and more has been created and more are yet to be created. Previously with the current technology and knowledge much wasn't possible and not every case would be able to be treated, but as time went by, we were able to create more new ways to make more cures, in turn reducing the mortality rate with more healthy members. And as discussed before, mortality rate and the population count are inversely proportional to each other (more mortality rate, less population and less mortality rate, more population).

5. Immigration

With more people moving into a country, it would have to withstand its population as well as those who moved there. In space, there can be more people that move there, but as everything has a limit, so does the population on Exodus. Once a certain number have reached Exodus, more will not be allowed unless some emigrate or more civilizations are built around.

This results in several consequences, some of which are:

1. Environmental Issues –

As more people grow there will also be an increase in:

- Global Warming
- Environmental Pollution
- Habitat loss
- Land Degradation (Higher intensive farming)
- Resource Overutilization leading to shortage of resources
- Deforestation

2. There will also be a decline in the quality of life

This means there will be:

- a lower economic status (leading to malnutrition and starvation)
- Increased cost of living
- low literacy rates
- more unemployment
- insufficient land
- more crime rates
- an increased amount of conflict among people

With all this in mind, overpopulation is surely a big peril to society and it is hence important to keep a check on it. In order to do this, some precautions that we can take (with respect to Exodus) are:

1. Controlling Birth and Death rates:
 - A. Controlling Birth Rates:
 - Placing a limit of two children per family
 - Promoting contraceptive devices to prevent fertility
 - Such as long-term methods like vasectomy or tubal ligation or Sterilization.
 - Or shorter term like a condom or copper t etc.
 - Improving Healthcare
 - B. Controlling Death Rates
 - Banning the uses of methods to increase one's life beyond the normal cycle. (Which perhaps may become possible one day!)
 - Improving Healthcare

Note: As I have added an improved healthcare, it means that it is important to keep the inhabitants all healthy so they can lead a normal life and no part gets reduced or increased at high rates. Where all natural processes such as birth and death can take place without any problems. And as there is more healthcare, doctors will also be able to help bring awareness to the patients about fertility and population control.

2. Controlling immigration
 - As discussed before, immigration introduces more people than already living in a location
 - By setting a limit to the population to a certain amount, there can only be a limited number of immigrants where more can only come if either an extension is made or if previous inhabitants leave.
3. Improving Education and Raising Awareness

By raising more awareness and increasing education, people will come to realize the problems associated with having too many children and will hence set a limit to their selves to keep their community at a good standard of living.

All this will in turn help reduce overpopulation, leading to an increase in the standard of living, leading to higher education levels (for women especially) resulting in more individuality for women which then leads to a fewer number of children born for her. Hence it creates a cycle which keeps overpopulation from taking place.

5.2 COMMUNICATION

In previous times, letters were used to carry a message, and then later cellular phones and mobiles were created. Here on Exodus, mobile phones would be used more with a new cellular service being made for people in the ship to be able to communicate. There will also be tubes to carry letters in an air vacuum in full speed to different parts of Exodus.

A satellite works on transmitters and receivers, which means we on Exodus and those on earth would need a satellite made just for communication back and forth. Here the status of the ship and requirements will be shared back and forth to get necessary things. NASA uses a DSN (Deep Space Network to send and receive data for long distances. They have in fact used it to communicate with Voyager 1 and 2 which have covered quite a large distance! (Past Jupiter and even beyond our solar system).

This satellite will also work as a way to communicate between explorers on asteroids researching and the main science hub which will analyse this.

At start a GSM system will be set up for both cellular and data support instead of only data in LTE, later as the population grows a bigger setup may be made to withstand the connections of the whole population. There will be about two GSM stations to ensure a reliable network throughout.

Since having too many wireless networks may be harmful for us and any other organisms in the ship, either a LAN or a WAN would be good for use in Exodus. And since the ship is large and big companies need a higher range of network a WAN would be a better choice to go with to connect servers in companies.

A satellite for the GPS will also be made for suitable travel navigation in the ship. Most of the communication towers will be in the centre of the torus with a point which will receive and send information around.

5.3 CULTURE

Culture also plays an important part of Exodus.

5.3.1 Religion

Since a majority of the members of the ships will come from many backgrounds, races, history, culture, religion etc. there will be a big diversity between the people. In order to break the barriers and create a sense of unity, a new flag, new anthem and new festivals and events will take place. Since we are not on Earth anymore, that would mean the day of a new year in Exodus will change.

5.3.2 Flag of Exodus

The new flag will consist of

White – For representing purity and innocence

Green – which means a new beginning, abundance, nature etc. Since it is a new place, we have come to for starting a new life in a new space settlement.

Orange – which represents a change or movement. It normally means autumn (change in seasons) which can also be interpreted as a change. Since it is now a new change in Exodus. It also represents creativity.

Blue – Which represents peace, justice, loyalty and calmness. Where peace will be promoted in Exodus, and hate and violence will be strictly repressed.

Red – It is a color related to importance, bravery, strength



*The above image is the national flag of the inhabitants in Exodus.
Image Credit: Pranavsai G. (10 stars for 10 Parts of ship.)
Made to promote patriotism.*

5.3.3 Language of Exodus

The language here spoken on the ship will be English. Other languages are also allowed for speech but most the signs will consist of English since a majority of the people from the world know how to speak English. Another language can be made, but the process of doing so would take a lot of time and effort of the makers and learners. It would mean a whole new set of letters, grammar rules, punctuation, phonetics, words and much more would have to be made.

5.3.4 National Anthem

As we have made a new settlement, it also calls for a new national anthem. This anthem would have lyrics that represent its people and the journey it has made to come to how it is now. It will talk about how we have successfully started a civilization outside earth, the togetherness, loyalty, and hard work that has been put to make the settlement a reality.

The following song will be the national anthem of Exodus:

O thou Exodus! We have come to a point really high!
 O thou Exodus! We have even passed the sky!
 O thou Exodus! Built from hard work and dedication,
 Through struggle, and fight
 a journey of might
 To form our beautiful nation!
 Built from ground up, so we can peacefully live and stay
 With many cultures and heritage, the story of Exodus
 you can say!
 O thou Exodus! A new home to explore
 O thou Exodus! The wealth of people we store!

5.3.5 Government

There will be a central government for the ship, with 4 divisions among the ship with a main government representative from each section. Each of these sections will further be divided into smaller governments for each city or town. Within these town there will be several smaller localities

1. Central Government
2. Section Government
3. City Governments

The Central Government has the main rule of the ship. It has rulers elected by the people who are limited under the constitution. There will be a legislative judiciary and executive body to run the government with a balance of power like in most current democratic systems now. They divide even further to section governments, a bit like states.

Section Governments take the data from city governments and help in funding the city governments for reform. This government is responsible for making sure the sector is functioning properly in social, political, and economic terms, as well as conducting regular checks on the ships health in their corresponding section.

City Governments are the smaller subparts of the Section government. They will be responsible for basic necessities and nearby healthcare, education as well as entertainment in an area. They will also be the ones in charge of reporting data about the living conditions in their parts to the Section Government for suggestions and funding.

6 CHAPTER VI – ECONOMIC FEASIBILITY

How much would it cost?

The biggest question to ask ourselves before we even start building anything, is also the question which is critical in defining the feasibility of a project. Building a space settlement

would take quite a large sum of money to make this a reality. It will be built in stages to ensure all parts are as strong as they can be to withstand coming generations. We also have to take the travel from Earth to the destination into mind so using reusable rockets as talked about before would be a really good way to reduce travel costs. This has been tried out by SpaceX in its rocket launches and can also be applied here too.

As it is a settlement which will hold the future generations and is one which should last a long time, it is important to take all parts of the ship into complete care and concentration making everything in the best quality we can afford since later renovations to the inner structure won't be able to be done. So, coming to the main question of how much it would cost? In previous years, the worth of currency was low, hence around 1975 the cost for a proposed Stanford Torus would have been about \$191 billion approx. but as time went by, the currency's value has fallen making the price increase due to currency inflation. So as of 2016, it would be almost \$900B according to Robert Walker, which is about \$990B now or basically about \$1 Trillion to make it a reality. Which is a very big sum of money if thought of as a whole, but when split between years, with proper funding and reusable materials such as rockets and transport, the cost can go down a lot. Putting it in perspective, there is almost \$40 trillion dollars (or more) in the world either deposited or hand cash according to RankRed. Is it, therefore, affordable? Maybe not today, but with enough savings, materials, and technology, as well as public support in terms of cooperation and financial donation (especially from those with a substantial sum of money), it could be one day.

7 CONCLUSION

All in all, I believe that it is important that we continue space travel and research and soon enough begin space settlement. As it is a big process, it should be done in steps and may even take several years to get everything done with quality work. Settling in space would be a big step for mankind, and would also be a great advancement in space understanding.

While making Exodus, I used the opportunity to learn a lot more about space than I knew before and have also gotten a bit more interested in what astronauts do to get prepared as well as how different space missions have used their technology to make them successful, the side effects in space, and how each struggle was overcome by NASA. It's been fascinating investigating various topics and learning more and more about each one in depth.

It's exciting to think about how a settlement could someday become a reality.

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THE END



Exodus - Image Credit: Ship Model - Pranavsai G, Background Credit: NASA, Capella Observatory Image of Galaxy