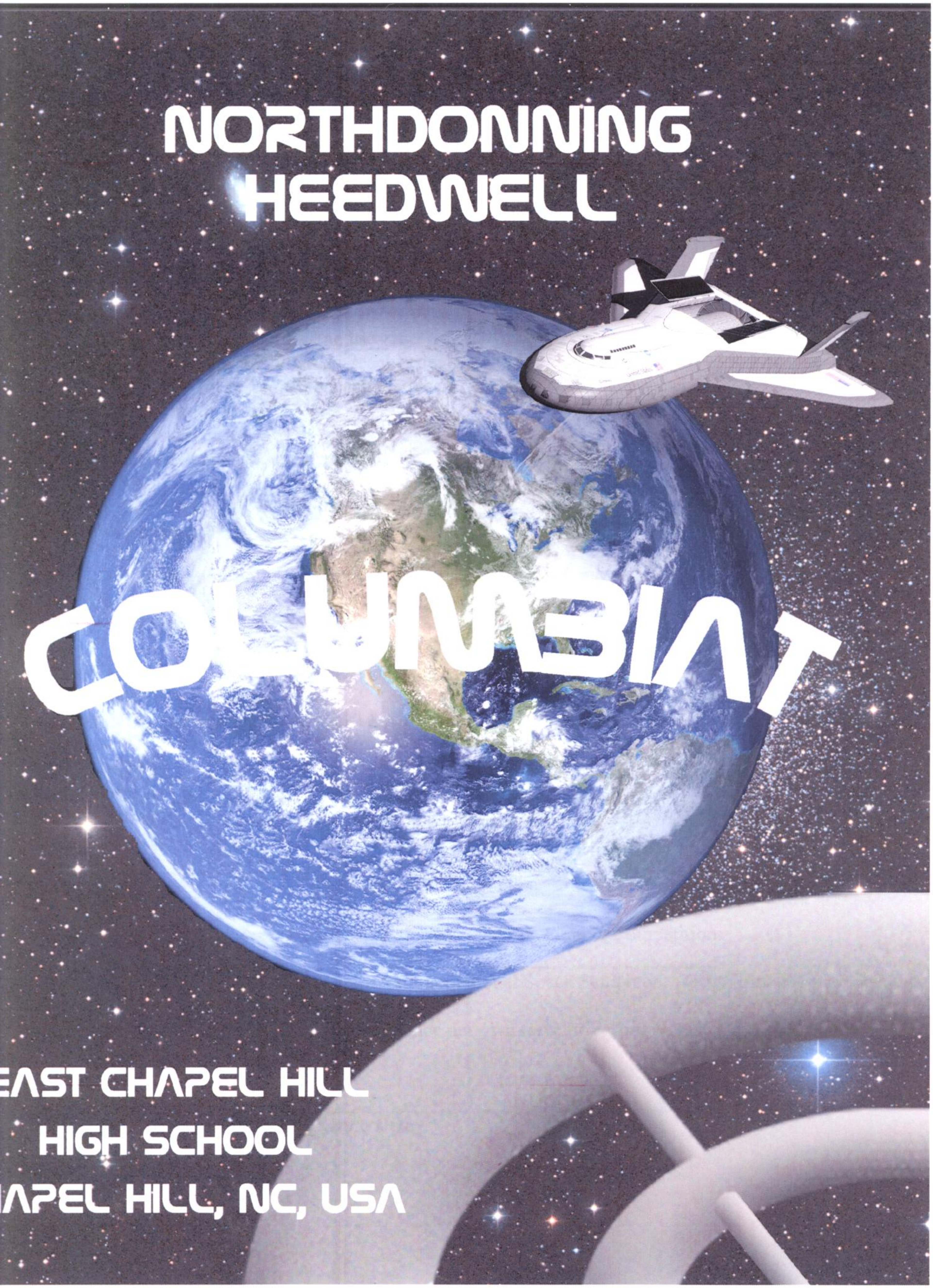
NORTHDONNING HEEDWELL



COLUMBIAT

EAST CHAPEL HILL
HIGH SCHOOL
HAPEL HILL, NC, USA

1.0 Executive Summary

By the request of the Foundation Society, Columbiat will be established as a "Singapore-in-Orbit", serving as both a docking station for cargo ships and a metropolitan utopia for its inhabitants. With the growing populations on both Alexandriat and Bellevistat, the Columbiat space station aims to alleviate some of that overpopulation. As a thriving business and banking area, Columbiat will become a premier destination for business executives and customers alike. Not only does the station have enough room for the estimated 25,000 expected citizens, but it has even more room for expansion, for both the residential and commercial sectors.

The station consists of two tori and a central cylinder. The outermost torus is where the residential and commercial sectors reside. The inner torus, which is half the distance away from the central axis as the outer torus, has an average acceleration of ½g, making manufacturing tasks much simpler. The cylinder, located at the middle of the station, is the docking area for incoming and outgoing ships; it also functions as a repair station for those ships.

One of the most innovative processes that occurs frequently on the station is the cleaning of robots. Lunar dust's extremely small size and lack of moisture (along with other attributes) makes it difficult to just wipe off, so a more advanced cleaning methods are used. For large robots with a minimal amount of crevasses, an electric curtain, made out of a set of parallel copper wires, brushes the dust off of them. Smaller robots with many cracks and spaces are exposed to microwaves, thereby melting the dust; by using a centrifuge, the melted substance is flung off of the robot. Because the remains of both processes are rich in iron, silicon, and other elements, they are harvested and used to make new materials, literally putting into practice the cliché, "One man's trash is another man's treasure."

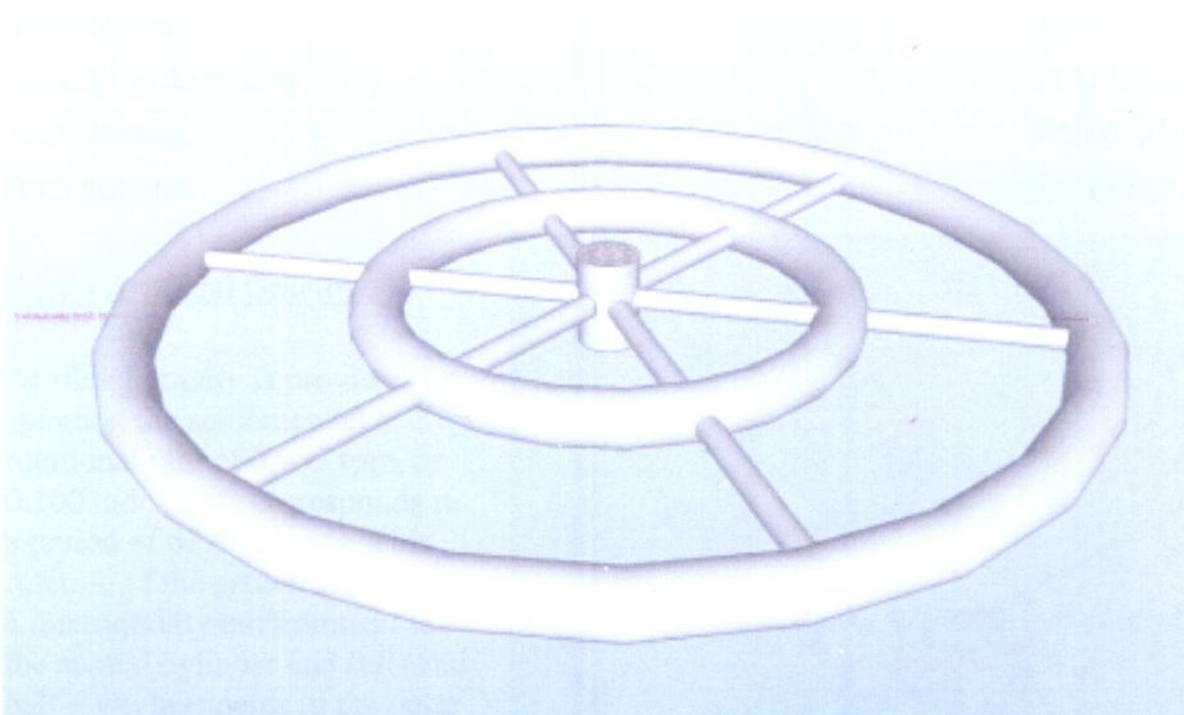
New citizens and visitors will be amazed by the conveniences that will be available to them during their stay at the Columbiat. To ease the time required to commute from one location to another, a free maglev system travels around the circumference of the station, taking approximately two minutes to travel from one station to the next. On top of that, there is only a three to four minute wait between trains. Even with such an efficient system, traveling by train may not be necessary since most of the residential areas are located in close proximity with shops and dining areas. Within a mere four to five minute walk, inhabitants can reach most of the facilities necessary for their quotidian lifestyles. The delivery of packages and online purchases is also much quicker than systems on Earth. With an efficient bar code system and twenty-six distribution centers, packages are guaranteed to reach their recipient within three business days, compared to the five days it takes for a package to reach the recipient's doorstep on Earth.

One of the most exciting opportunities available to everyone on the station is an education at the Grameen School of Business. This school is named after the Grameen Bank, which is a famous community development bank known for developing the concept of microfinancing. The school aims to educate future generations about how responsible financing can bring about positive feedback in the community. Because of the school's location in the thriving financial district, students will be exposed to many of the aspects involved in commerce, whether it is in space or on Earth. Through a four-year program at this school, graduates will be prepared to put their newfound knowledge into practice as economists, sales managers, and much more. While it is inherent in the nature of the station that the station's school system specializes in business education, students will have the option of attending Columbiat College. Here, they will be provided with three years of classroom-based learning, followed by a year of on-the-job training in the field of their choice. One of the station's most unique features, biodomes, assists in this kind of training. These areas recreate ecosystems on Earth. While they are open to the public, these areas will be particularly useful for students who wish to study subjects like environmental science.

Spending a long night at class or a long workday may make life stressful for inhabitants on the Columbiat, but there are plenty of entertainment options on the station to relieve them. Most of the venues available to people on Earth, like shopping malls and movie theaters, are conveniently constructed adjacent to residential communities. There is also a wide range of athletic facilities, such as tennis courts and pools. One of the most unique opportunities in space is the chance to experience gravitational accelerations that are smaller than that on Earth, so it would only seem logical that inhabitants would want to take advantage of that fact; therefore, there is a multitude of "antigravity" activities within the inner torus in which the station's inhabitants can take part.

2.0 Structural Design

Columbiat is comprised of two tori which surround a central cylinder. The structures are connected by 6 evenly spaced passageways radiating from the central hub. There is a landing platform at each end of the central cylinder for the arrivals of passenger spacecrafts and cargo ships. Adjacent to the landing platforms are 8 docking bays used to load/unload passengers and cargo.



2.1 Exterior Design

The station's exterior will have (from outside to inside) 3.29 cm of aluminum, 1.39 cm of polyethylene boron, and 5.32 cm of some sort of titanium, leading to a total thickness of .1 m. Water will flow through pipes along the interior of the walls. The first two layers will provide radiation shielding, while the titanium will provide structural support.

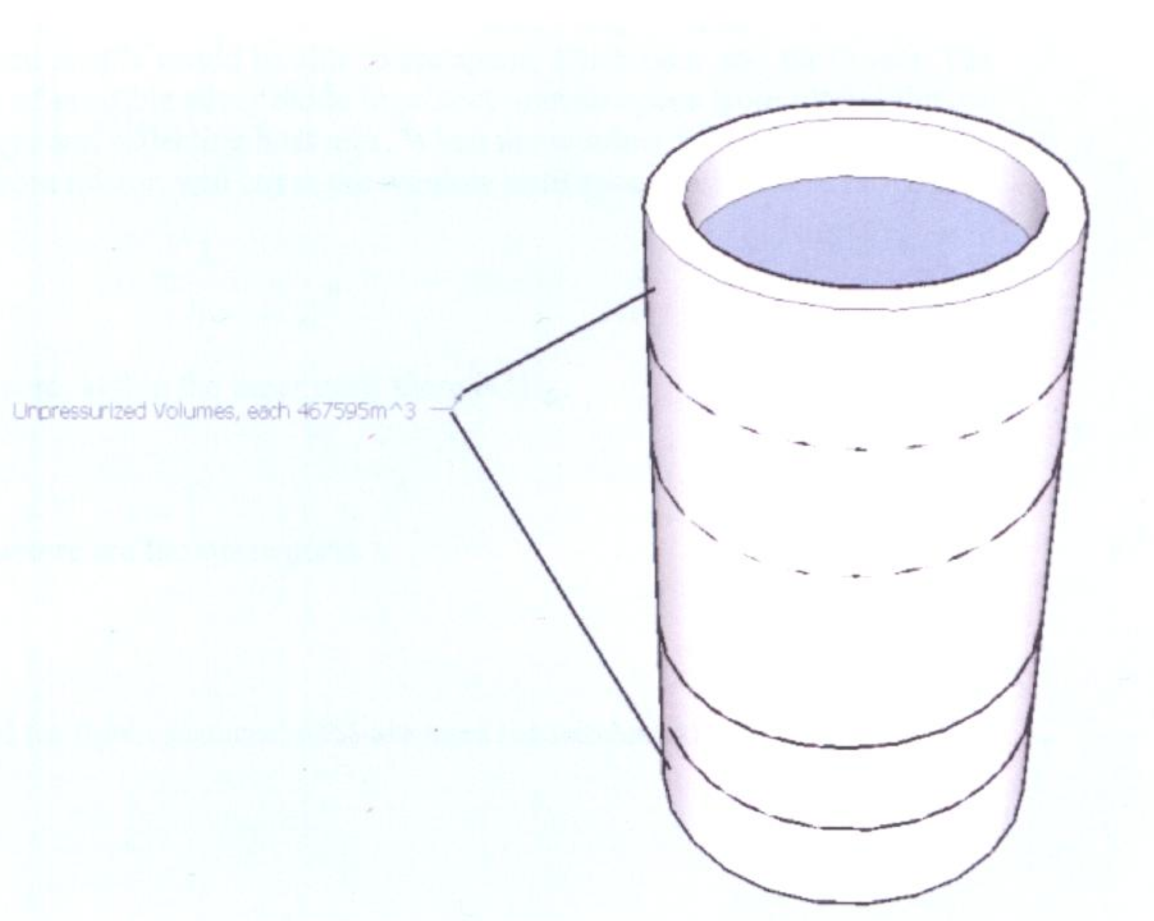
2.1.1 Volumes

Cylinder	**Measurements**
Inner radius	50 m
Outer radius	50 m
Inner height	200 m
Outer height	200 m
External surface area	78790 m^2
Inner volume	1570800 m^3
Total volume	1578700 m^3
Inner Torus	**Measurement**
Average radius from the center	490.0 m
Average circumference	3079 m
Inner radius	55.0 m
Outer radius	55.1 m
External surface area	1065900 m^2

Inner volume	29258392 m^3
Total Volume	29364883 m^3
Outer Torus	**Measurement**
Average radius from the center	980 m
Average circumference	6157 m
Inner radius	55 m
Outer radius	55 m
External surface area	2131751 m^2
Inner volume	58516785 m^3
Total volume	58729767 m^3

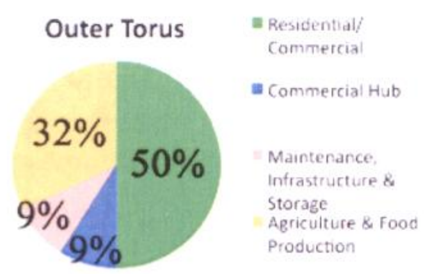
2.1.2 - Artificial Gravity

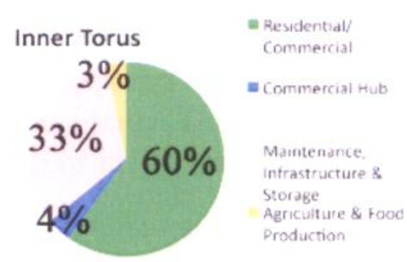
Artificial gravity is provided by spinning the settlement at a rotational rate of 0.955 rpm, or 0.100 rad/s. This corresponds to a period of 62.9 seconds. This rotation of the settlement renders a microgravity environment in the central cylinder and full- and half-g environments in the outer and the inner tori, respectively. There is a constant gravitational gradient within each torus due to the decreasing distance from the spin axis. On the outer torus it varies from a high of 10.3 m/s^2 on the outermost down surface to a low of 9.3 m/s^2 near its inner radius. Similarly, the inner torus has a gradient from 5.4 to 4.4 m/s^2.

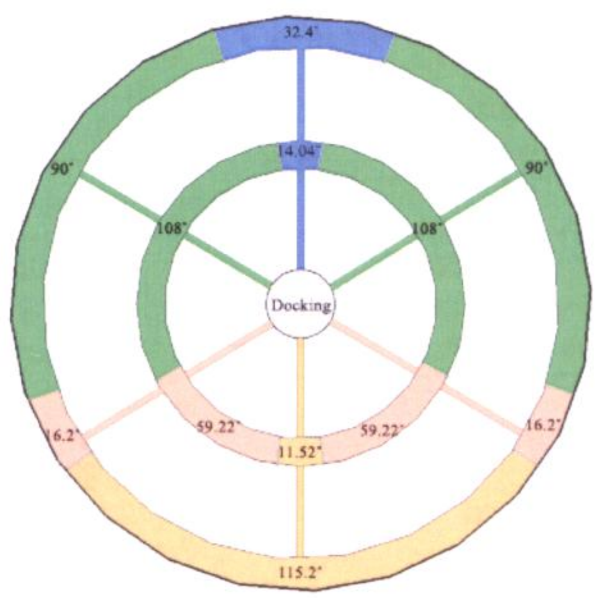


2.1.3 – Pressurized/Unpressurized Volumes

The entire structure is pressurized except for the docking facility, whose landing bays are open to space. Additionally, the docking bays are large scale airlocks where ships are, berthed, serviced, and decontaminated.







2.1.4 – Radiation and Debris Penetration

The settlement's exterior surface is designed for both structural integrity and for protecting the settlement from radiation and debris. Our sun's cosmic rays consist mostly of protons and alpha particles, which have energies as high as 100 MeV. These particles are rather easily blocked by materials rich in hydrogen and other low mass elements, such as water and plastic, namely polyethylene/boron (Ref xx2). The polyethylene boron and aluminum will be used to shield the station from radiation. Polyethylene boron is especially effective for shielding against accelerated neutrons, while the aluminum is better for stopping accelerated protons without spallation.

2.2 Interior Design

In a cross-section of the tori, the middle 50 m will be used for living space and the top and bottom 30 m will be used for down surfaces and other uses. In the outer torus there will be a huge window covering a certain section of the torus through which people would be able to see space, Earth rises and Earth sets. The glass is covered with a few nanometers of invisible silver oxide to protect interior space from ultraviolet rays and intense heat by filtering UV rays and reflecting heat rays. When the window will be directly faced to the sun, protective shielding, made from mirror, will cover the window until space station will move to a safe angle relatively to the sun.

2.2.1 Micro-Gravity

In the cylinder there is micro g around zero, and in the inner torus there is ½ g.

2.2.2. Unpressurized Facilities

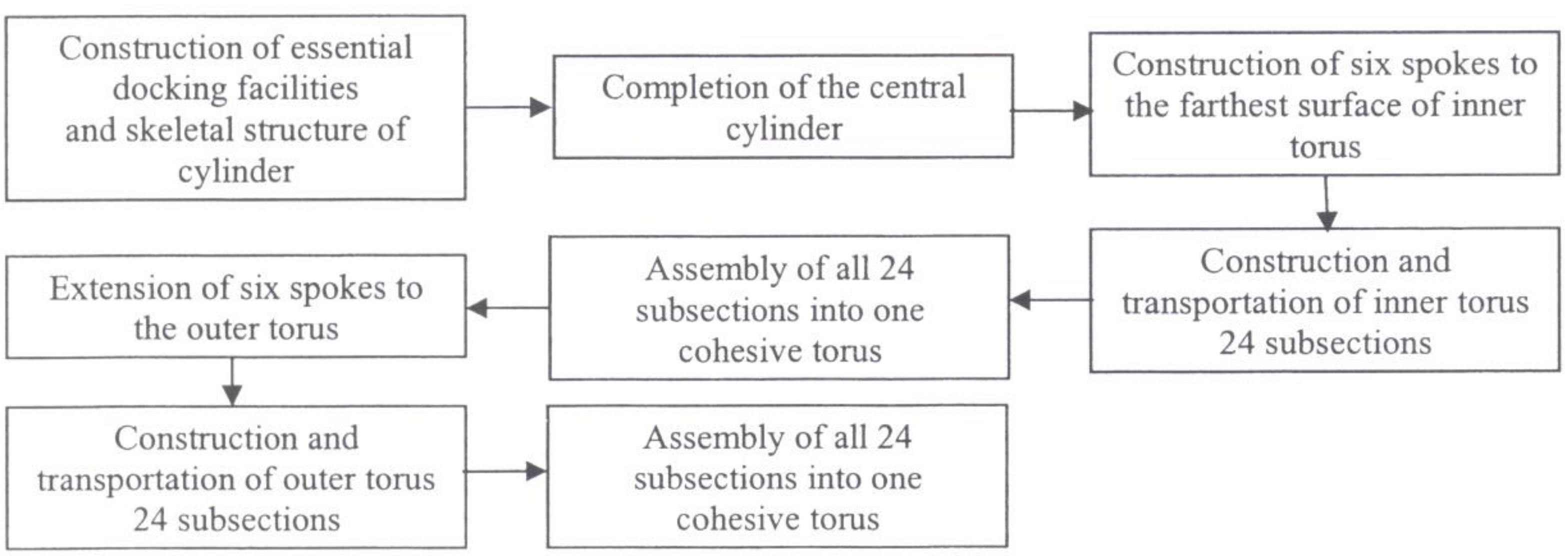
The only unpressurized parts of the structure are the space ports.

2.2.3 Down Surfaces

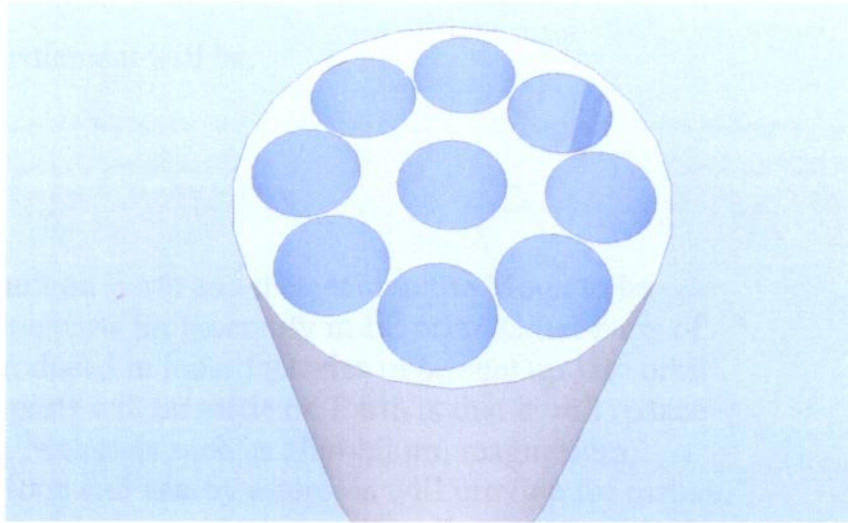
For the space used in tori, 27% are used for down surfaces, 50% are used for residential area, and another 23% are for other uses.

2.3 Process of Construction

First, major basic parts will be constructed on the Earth. Then this equipment will be sent to the Moon. Factories will be built and used to produce water and other materials on the Moon for the space settlement. Then, the major parts will be sent into orbit. After Columbiat is inhabitable (filled with oxygen and other gases, spinning mostly about 2g and having necessary supplies), it will be occupied with residents. Then there would be a travel back and forth between Earth and Columbiat to recycle waste from or bring new developed supplies to Columbiat.

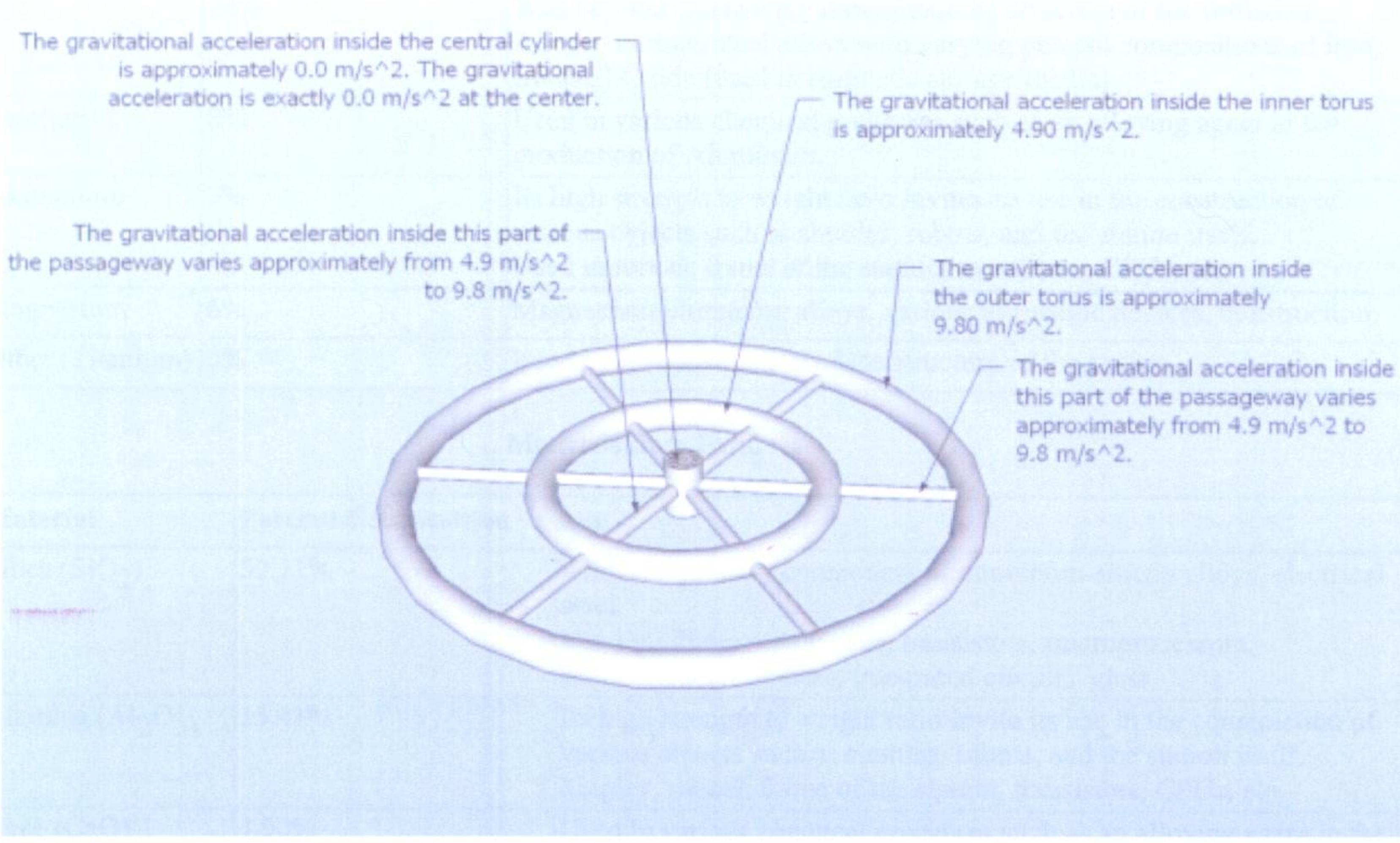


2.4 Port Facilities



There will be 1 entrance port in the center of each end of the cylinder and 8 exit ports at equal intervals around each entrance port. The cylinder will be divided into 5 layers. The top layer, where the ships first enter the cylinder, will be used for docking. The next layer will be used for cleaning and repair, and the center layer for transportation, loading, unloading, boarding, etc. The fourth layer will be like the second and the fifth like the first. Each section except for the layer devoted to the docking purpose would have 8 "cells" around the entrance in order to house the ships while they are cleaned, repaired, loaded, unloaded, and prepared for the exit launch. The mechanism of docking is as follows: the space settlement rotates at the angular speed of 1 rad/s, and the spaceship would be supposed to also rotate at such rate of angular speed, slowly decreasing the distance between the ship and the settlement's entrance. After the ship has come close enough to the entrance, the robotic arms at the entrance would gently "grab" the ship and bring it to inside the entrance in order to prevent any sort of collision between the ship and the space settlement. The ship's entrance is followed by the sorting process, in which the ship is sent to one of the cells by rail tracks. Then, the ship will descend into the middle layer where it is unloaded, loaded, etc. Afterwards, the ship will move into the second or fourth layer and be cleaned and repaired in order to be prepared for exit from the space settlement. The ship is then moved outside the cylinder. After the ship is completely outside the cylinder, the door is closed behind it and the ship launches toward Earth or Moon.

2.5. Varying Gravity



3.0 Operations and Infrastructure

3.1 Construction and Operations

The three sources of materials for the Columbiat Space Settlement will be:

- The Earth
- The Moon
- Near Earth Orbit (NEO) Asteroids
- On-orbit Facilities (Bellevistat/Alexandriat)

Many of the larger parts of the space settlement will be built on Earth and then sent to the Moon to be stored and modified. Lunar facilities will then prepare these parts for assembly in L2 orbit. Other parts of the station that can easily be made on the moon will be produced in lunar factories to be sent up into orbit where they will be assembled. The reason that not all the parts will be made on Earth is that it will reduce the cost and energy of sending various parts into L2 orbit. Materials such as aluminium, magnesium, calcium, iron, silicon, and oxygen will be mined on the Moon and nearby asteroids will provide for carbon, iron, nickel. Since the station does not have any heavy industry, many of the metallic alloys such as steel will need to be produced in Lunar processing centers or at Bellevistat or Alexenadriat. Main construction equipment will consist of unmanned robots with a few manned spacecraft (see section 5.1.5) The manned construction spacecraft will launch directly from Earth to the moon where they will rendezvous with the construction robots and other space settlement parts from the Moon (see section 6).

Material	Percent Composition	Use in Station
Oxygen	42%	Oxygen used for respiration in the station's atmosphere and life support system, propulsion systems of robots and shuttles, found in various oxides, used in various industrial processes
Silicon	21%	Alloys: a primary component of aluminum-silicon alloys, electrical steel. Electrical Applications (automations): Photovoltaic cells, transistors, microprocessors, semiconductor devices, integrated circuits Construction material: Glass
Iron	13%	Will be used extensively throughout the structure of the settlement. Alloys: Various steel alloys with varying percent compositions of iron, Iron(III) Oxide (used in magnetic storage media).
Calcium	8%	Used in various chemical processes such as an alloying agent in the production of Aluminum.
Aluminium	7%	Its high strength to weight ratio invites its use in the construction of various objects such as shuttles, robots, and the station itself. Used in robots, frame of the station, transistors, CPUs, etc.
Magnesium	6%	Magnesium-aluminum alloys, various electronic devices, construction.
Other (Titanium)	3%	Used in the construction of the structure of the station.

Materials from Earth

Material	Percent Composition	Use
Silica (SiO_2)	59.71%	Alloys: a primary component of aluminum-silicon alloys, electrical steel. Used in: Photovoltaic cells, transistors, microprocessors, semiconductor devices, integrated circuits, glass
Alumina (Al_2O_3)	15.41%	Its high strength to weight ratio invite its use in the construction of various objects such as shuttles, robots, and the station itself. Maglev, robots, frame of the station, transistors, CPUs, etc.
Lime (CaO)	4.90%	Used in various chemical processes such as an alloying agent in the

		production of Aluminum. Water Treatment
Magnesia (MgO)	4.36%	Magnesium-aluminum alloys, various electronic devices, construction.
Iron(II) Oxide (FeO)	3.52%	Will be used extensively throughout the structure of the settlement. Alloys: Various steel alloys with varying percent compositions of iron
Iron(III) Oxide (Fe_2O_3)	5.43%	Magnetic Storage Media
Titanium Dioxide (TiO_2)	0.60%	Used in the construction of various structures.

Construction Equipment

Equipment	**Purpose**	**Amount**	**Origin** (Earth/Moon/Asteroid/ on-orbit facilities)
Construction Robot	To assemble the station in L2 orbit and all other operation of construction (see section 5.1.5)	12,000	Earth/Moon/ Bellevistat/Alexandriat

Primary Materials

Cylinder:

Material	**Thickness (dr)**	**Density**	**Amount**
Aluminum	.0329 m	2700 kg/m^3	9635083 kg
Polyethylene Boron	.0139 m	940 kg/m^3	1417224 kg
Titanium	.0532	4506 kg/m^3	26025484 kg

Inner Torus:

Material	**Thickness**	**Density**	**Amount**
Aluminum	.0329 m	2700 kg/m^3	113411914 kg
Polyethylene Boron	.0139 m	940 kg/m^3	16681752 kg
Titanium	.0532 m	4506 kg/m^3	306056663 kg

Outer Torus:

Material	**Thickness**	**Density**	**Amount**
Aluminum	.0329 m	2700 kg/m^3	226823829 kg
Polyethylene Boron	.0139 m	940 kg/m^3	33363505 kg
Titanium	.0532	4506 kg/m^3	612113326 kg

Total Amount of Materials needed for Exterior Design of the Settlement:

Material	**Amount**	**Source**
Aluminum	349870826 kg	Earth/Moon/Bellevistat
Polyethylene Boron	51462481 kg	Earth
Titanium	944195473 kg	Earth/Moon

Material	Amount	Source
Steel	5184000 kg (amount in 96 aircraft carriers)	Earth/Moon
Copper	19774926 kg (99317 houses in station)	Earth
Silicone/Silicate	1486752 kg (wafers .001m thick)	Moon

Total Volume: 128991405 m^3

3.2 Infrastructure for Activities of Residents

3.2.1 Atmosphere/Climate/Weather Control

A primary purpose of the space settlement is to provide a livable and healthy environment for the inhabitants of the station. The fact that the station is an isolated and artificial climate allows for variability in the composition of the atmosphere, which allows improvements to meet the needs of the people living on the station and activities performed throughout the station. Artificial precipitation will not be included on the station due to infeasibilities in resource management and energy consumption. The relative humidity of the station will be kept at a constant 50%, and the temperature of the station will be 20 degrees Celsius, with a variation of five degrees depending on the "season."

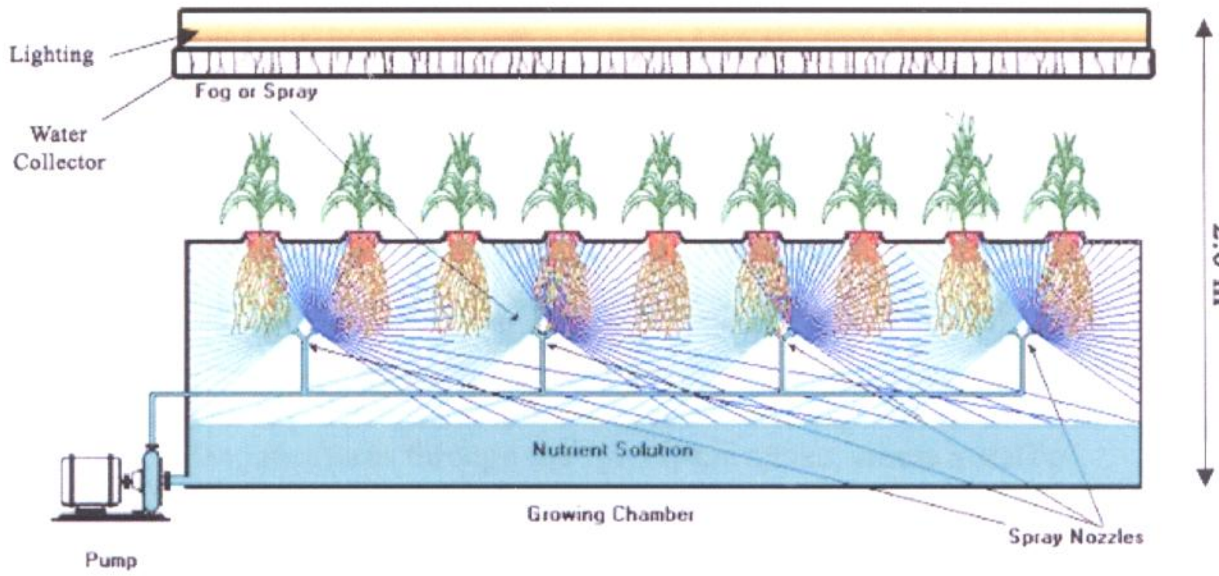
Gas	Pressure (kPa)	Percent Composition
O_2	22.7	44.6%
N_2	26.6	52.3%
CO_2	<.4	<.8%
Water Vapor	1	2%
Total Pressure	50.8	

One can see that the pressure of the proposed atmosphere is less than 50% the pressure found on Earth. This pressure causes no discomfort to humans. A beneficial consequence of a lower pressure is that it allows the space settlement to be operated without the need of transporting large amounts of gases from Earth to the station. A partial pressure of oxygen (pO2) was chosen "to provide a high enough partial pressure within the alveoli of the lungs (~13.4 kPa or ~100 mm Hg) for good respiration, but also low enough to avert losses in blood cell mass and large changes in the number and distribution of micro-organisms, such as bacteria". The presence of nitrogen in the atmosphere, which most organisms are unable to directly convert into any particular useful compounds, was chosen because the necessity of an inert gas in the atmosphere to prevent any respiratory problems. The contributions of oxygen and carbon dioxide to respiratory health are numerous; in addition, there will be a slightly higher partial pressure of CO_2, which will enhance the stations agricultural productivity.

Another beneficial consequence of having fewer gases present in the settlement's climate is that fewer resources will need to be allocated to replenishing the climate. While some of the station's oxygen will be produced by the plants within the agricultural sector, most of it will need to be produced by the electrolysis of water. A major component of the station's climate control will be devoted to removing excess CO_2 from the atmosphere of the station. Any gas that is not able to be produced reasonably on the station, such as N_2 and some of the O_2, will have to be transported to the station either from Earth, the colony on the Moon, or the other two space settlements. To ensure that the climate of the station is always within the aforementioned standards, a climate moderating system will be implemented within the station. This system will be fully automated and will monitor the following: overall barometric pressure within the different parts of the station, the partial pressures of each gas, the temperature throughout the station, the humidity, and the percent composition of each gas.

The major two concerns of maintaining the proper percent composition of each gas will be ensuring that there is neither too little nor too much of each gas in the atmosphere. The easier of the two problems to solve is when there is too little of a particular gas. When this occurs, the moderating system will periodically injected a particular gas into the ventilation system of the station (there will be canisters of unused gas throughout the station) which through fans and pressure differences will distributed the gas to the desired area. To remove excess gas, particularly CO_2, the gas will need to be filtered into a scrubber system, which will remove the gas from the air through contact with a scrubbing solution such as water. Scrubbers and electrostatic precipitators (devices that remove particulates by inducing and electric charge) will also be used to remove any other unwanted pollutant found in the air of the station, such as particulates, unwanted odors, and harmful gases.

3.2.2 Food Production



Main Picture from: http://www.odec.ca/projects/2005/lees5s0/public_html/Hydroponics_files/image006.jpg

Agriculture on the space settlement is centered on the concept of vertical farming. The obstacles faced in farming is space resemble those on earth; these include the scarcity of resources and most importantly the lack of land. Vertical farming is a viable solution that minimizes both problems. By creating feasible environments for crops to grow indoors, a building of multiple stories can take advantage of the limited space. Productivity can be maximized by implementing permanent lighting inside which virtually allows for nonstop growth and development. High pressure sodium lighting will be used to stimulate an environment with enough light intensity. Conserving and reducing the use of resources is imperial to the sustainability of a space community. In order to further conserve area, traditional soil farming will be replaced with a method known as hydroponics. This method involves farming crops in nutrient rich water, where the nutrient content will be monitored by the conductivity of the water using a conductivity meter. The water will be flowing continuously at a shallow depth so that the plants receive adequate water, nutrients, and oxygen. Hydroponics is also advantageous in that additional irrigation and fertilization are not required. Near the ceiling will be a collecting system that accumulates the evaporated water resulting from transpiration, which will be fed back to the water system to be reused for farming. The collecting system will consist of cooled pipes that attract water vapor; the water can then be gathered as it drips off the pipe. Rice, maize, wheat, and soy beans will be the primary crops grown because of their high yield and nutritional value. Furthermore, the hydroponics system of farming increases crop yield by about 4 times the traditional yield per unit area. Each person will then only require about 1200 m^2 of farm land per year. A height of just two meters will be needed on each level, yielding a total volume of 3.025×10^7 m^3 or 35.9% of the outer torus.

The crops will grow at approximately the same rate and reach equal ripeness at approximately the same time since all factors in their growth are controlled completely by the station. They will then be harvested using an automated harvester running along the agricultural floors (see section 5.3.2) and brought to one of two central storing and processing areas near the end of the agricultural sections bordering infrastructure and storage. Here, they will be processed into various foods (see section 4.1.7) and distributed throughout the station using the ADS.

Additionally to the crops mentioned above, select, small plantations of varying fruits will be grown in certain areas of the agricultural sector, and harvested in similar ways to the primary crops mentioned above.

The primary livestock will be domesticated pigs (*Sus scrofa domesticus*) and chicken (*G. gallus domesticus)*. Raising domesticated pigs and chickens brings about several key advantages. They do not need much space and require only a simple diet of grain and water. In addition, the domesticated pig has high nitrogen contend in its organic waste that can be utilized in farming and also converted to methane and water vapor using anaerobic bacteria. The water can be reused for farming crops and methane converted into electricity. The livestock will be kept on concrete platforms so that liquid waste can easily drain into the waste system.

Pigs will be used completely for meat, and there will be an automated system for determining readiness according to their weight using scales. Pigs that are deemed mature enough will, after being inspected for health, be moving onto an automated conveyor belt leading to a slaughter system similar to automated systems on earth (using automated electrical stunning, scalding, evisceration, and processing). A small group of female pigs as well as two male pigs will be kept separate to reproduce and maintain populations. Most hens will be harnessed for egg production in an automated process using platforms and egg collectors. A certain number of hens will be allowed to roam in a separated area where they can be fertilized by a rooster, in order to ensure continuing reproduction. Male poultry not used for reproductive purposes will be raised in a similar fashion as pigs and their meat will be obtained using an equivalent automated system as the pigs. Eggs and meat will be sorted, processed and then distributed along with crops using the ADS throughout the station.

Unhealthy or exceedingly injured animals who's illness would not affect humans upon consumption will be rushed to the slaughter system and processed to prevent excessive use of resources, like is done on earth. Other sick animals will be transported to the inner torus through the agriculture spoke, where a staff of veterinarians and facilities will be available.

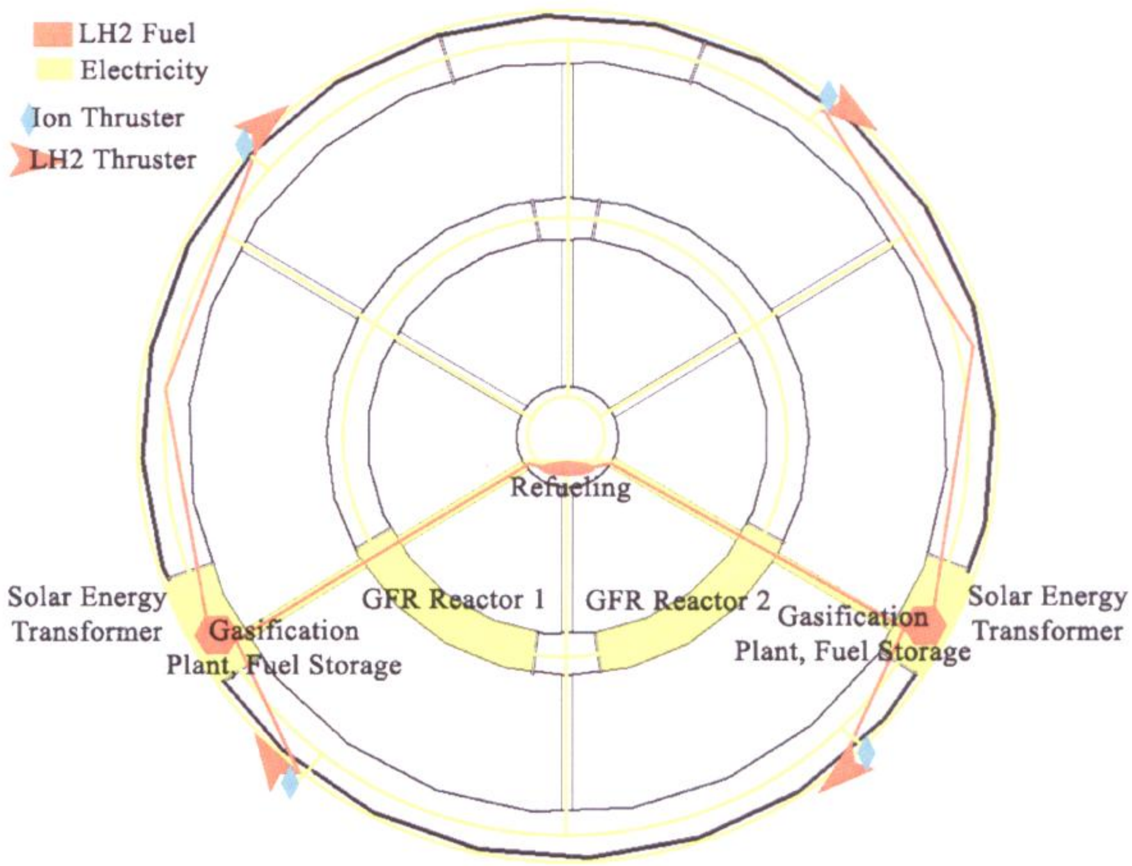
Foods that cannot be produced on the station, like fish, milk, other crops and other animals will be imported from earth or other space stations and sold at higher prices as luxury items. Milk products can be produced at less expense if milk is imported in powdered form. Commercial contractors will be used to prepare and sell meals from the station-native, as well as imported foods. These will be sold directly to households and companies as well as in restaurants, etc. Competition between different contractors will ensure high quality and variety of meals from basic foodstuff.

3.2.3 Electrical Power Generation

The main sources of electrical power production for the station will be nuclear power and photovoltaic technology. Additionally, plasma arc gasification will be used to power waste management, fuel shuttles going to and from the station and chemical thrusters on the station.

The station will utilize generation IV gas-cooled fast fission reactors (GFR) using helium as coolant. The reaction of GFRs is sustained by fast-neutrons. The advantage of using fast-neutrons, which move with an energy of around 1 MeV, is that they do not require a moderator, such as water. The lack of a water moderator eliminates the chance of steam explosions because there is no water to suddenly transform into vapor. The fuel for the reactor would be ceramic coated kernels of uranium or plutonium, also known as cercers. A consequence of the use of fast-neutrons is that the reactors can use different sources of fuel other than uranium such as thorium. Fast-neutrons have a high fission/capture ratio which would minimize the production of nuclear waste in the station and allow the reactor to act like a breeder reactor, since they breed more fissile fuel than is consumed by the reactor. GFR's also use gases such as helium or carbon-dioxide as their coolant. The advantages of gas coolants are that gas does not absorb neutrons, increasing the duration of the reactor's fuel before refueling is needed. This, along with previously mentioned advantages, results in a several year span after the first loading before any subsequent refueling is needed. GFRs produce 1200 MWe of energy with an efficiency of about 48%.

The station will feature two of a reactor in each of the two infrastructure sections in the inner. The power grid from these reactors will extend mostly along the water and waste grids throughout the station. Maintenance will be performed both by human employees and through automation. The reactors will be refueled with fissible material from Earth every 15 years. The relatively small amount of nuclear waste produced by these reactors will be stored on location in a safe area until the refueling ship arrives, at which point it will be exchanged for new fuel from the ship (See Section 3.3.1). Any additional waste that could not be reused, recycled, or used in gasification will also be placed on this ship. The ship, now automatically steered, will then accelerate towards the sun, effectively disposing of the waste on board and of the radiation it had encountered due to storing of radioactive fuel. This method was deemed to be the most effective and practical way of dealing with radioactive and hazardous waste, as all other options include either the possibility of waste going into orbit around a stellar object, possibly causing further pollution, or contamination of a possibly harvestable or habitable area like the Moon, Earth or other stations.



Another abundant source of energy, easily harnessed in space with the use of photovoltaic technology, is solar energy. Photovoltaic cells take advantage of the photoelectric effect which describes the ejection of electrons from matter after absorbing energy from photons. A typical photovoltaic cell is usually made out of a semiconductor such as silicon and utilizes its crystalline structure. Impurities are introduced into the silicon structure, one of which has an excess of electrons (n-type which usually consists of a phosphorus impurity) and the other has a lack of electrons (p-type which usually consists of a boron impurity). An electric field is induced on the silicon and when photons cause electrons to move across the two surfaces, doing work, a current and a potential difference is created, which results in power.

A problem with photovoltaic cells is their efficiency. Electromagnetic radiation is made up of a large range of different wavelengths, and photovoltaic cells can only harness a certain spectrum of energy, the materials band gap, and the rest of the photons with higher energy are lost. A solution to this efficiency problem is to use multi-junction solar cells, which layer different photovoltaic material, usually with the material that absorbs the highest band-gap on top.

Type of Power Generation	**Total Power Output (KWh)**
Generation IV Gas Cooled Fast Fission Reactor with Helium Coolant	1,500,000 per generator
Plasma Arc Gasification of Waste	21,000 for 21 metric tons of garbage

Solar Cell Power Production (DC power supply):

To calculate how much energy would be produced from our photovoltaic array, the solar intensity I, W/m^2, must be calculated around L2 orbit.

$$I \propto \frac{1}{r^2} \Rightarrow \frac{I_o}{I_{L2}} = \frac{r_{L2}^2}{r_o^2}$$

$$\therefore I_{L2} = \frac{I_o r_o^2}{r_{L2}^2} = 1330 W/m^2$$

I_o (solar intensity at Earth)= 1355 W/m^2 $r_o = 1.5\times10^{12}$ m $r_{L2} = 1.52\times10^{12}$ m

Once the solar intensity is known at L2, the energy absorbed by the solar cell can be calculated by multiplying the solar intensity by the area covered by the cell $(E_a = A \times I_{L2})$. Finally the total electrical energy that the photovoltaic cell produces can be calculated by multiplying the total energy absorbed by the efficiency of the cell which is assumed to be 40% $(E = E_a \times .4)$.

I_0	1366 W/m^2
I	1330 W/m^2
Surface Area	532938
Efficiency	40%
Total Electric Power	280,000 KWe

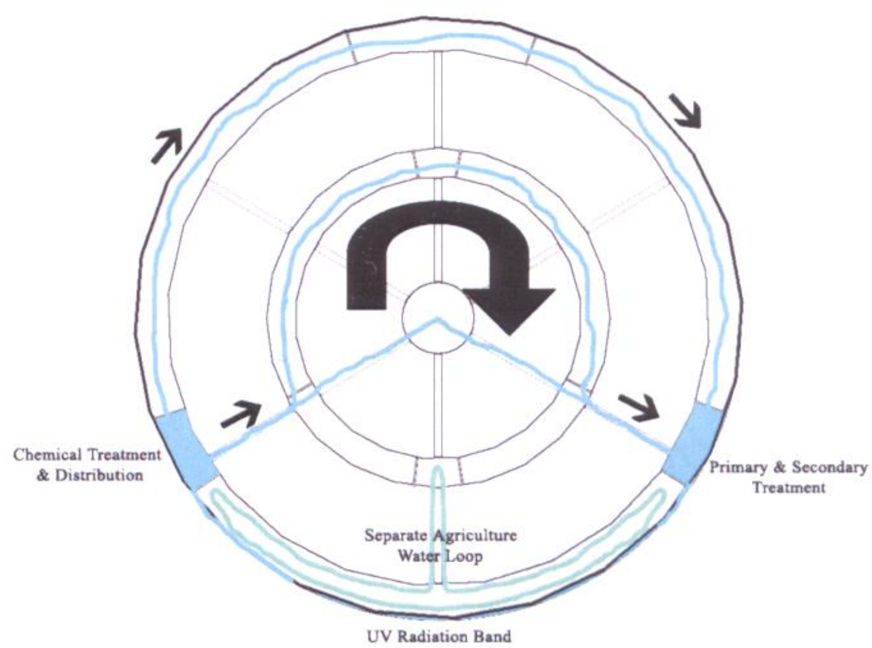
Most of the station will run off of sinusoidal AC currents because of the ease with which most generators, motors, and transformers operator under a varying voltage and to reduce energy loss to thermal heat ($P=I^2R$) when transporting the power throughout the station. The DC power produced by the solar cells will be converted into AC in the electrical facilities using DC to AC converters. The Voltage and Frequency of European and most of African and Asian electricity distribution is utilized due reduced current and accordingly less thermally dissipated energy, as well as compatibility with the majority of earth's electronics (as this is an international station). Electricity will be distributed using a three-phase electric power system of cables running along the sides of the torus from the different generators, to their respective locations.

Area of Use	**Type of Current**	**Voltage**	**Frequency**
Residential Sector	AC	240V	50 Hz
Agricultural Sector	AC	240V	50 Hz
Commercial Sector	AC	240V	50 Hz
Infrastructure (Environmental Control Systems)	AC	240V	50 Hz

Area of Use	kWh per Day			Use
Residential	1930 kWh per day per person	132.5 MWh per day		Lighting, Heating, Miscellaneous Energy Uses (computers, cooking, etc.)
Commercial	135.3 MWh per day			Lighting, Heating, Miscellaneous Energy Use
Agricultural	5802 kWh per acre per year	15.9 kWh per day per acre	36.8 MWh per day (2312 acres)	Automated agricultural services, Supporting plant life, Irrigation, Harvesting
Water Treatment	4,630 kWh/MG treated			Primary/Secondary/UV radiation treatment
Waste Management	Will produce enough energy to power itself; therefore, it will not be connected to the power grid and will be self sustaining.			Gasification of waste
Maglev Train	23 kWh/100km (electric car) which is about 4 people, multiply by 100 (apprx. 400 people at any time) to get 230 kWh/100km, 18 km of tracks			Transportation around the station
Ion Thrusters	119444 kWh/kg of exhaust			Propulsion System

3.2.4 Water Management

Water is important for all life that will be found on the station and because of this an adequate water treatment system must be implemented within the station. The water treatment plant will be located on either side of the agricultural sector of the torus and will utilize numerous methods of water treatment, primarily membrane bioreactors and ultraviolet radiation. The agricultural sections will utilize their complete own circulation loop of water and processing techniques due to largely biological waste (See Section 3.2.2).



The first phase of water treatment that the waste water will undergo is primary treatment, which will utilize many lower energy and passive technologies whose purpose is to remove many of the large macroscopic waste found in the sewage water. The water will enter the water treatment facilities located in the infrastructure section of the station through pipes that run throughout the entire station. The station's primary treatment process consists of removing any of the larger contaminants by filtering the water through a series of bar screen and then allowing the water to sit in a sedimentation tank where any grit and particulate matter could settle out of the sewage.

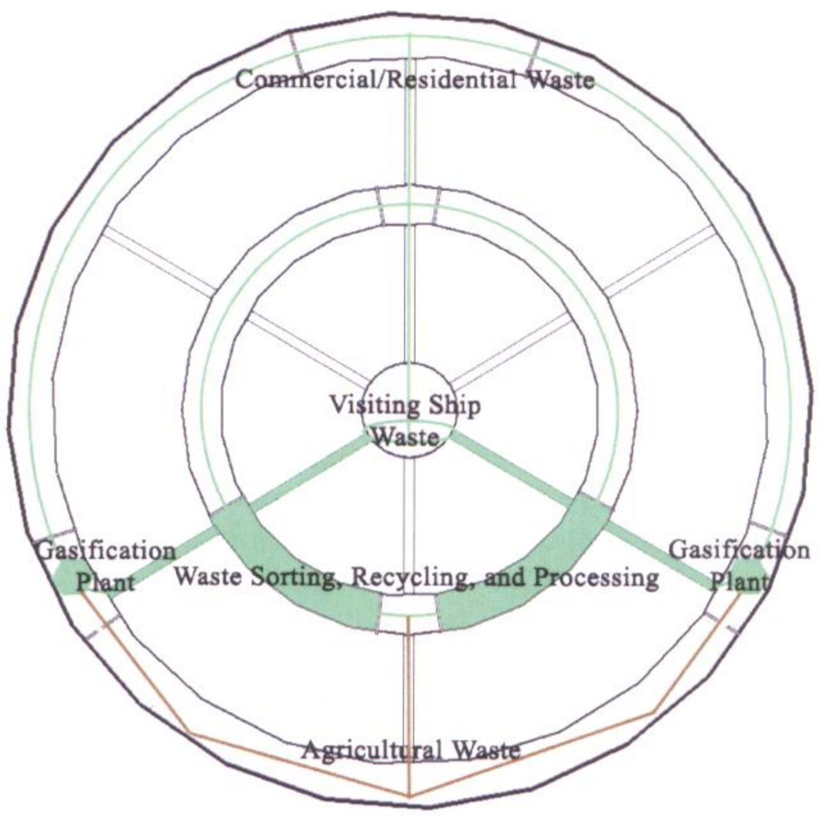
The secondary treatment of our wastewater would take advantage of membrane bioreactor (MBR) technology. This technology combines the processes of activated sludge treatment and ultra filtration membranes. The MBR process immerses membranes into aeration tanks where some of the sludge produced from the sedimentation process is present. This sludge contains anaerobic bacteria which in the bioreactor will consume most of the organic material present in the sewage. The sewage water is then forced through a semi permeable membrane which will remove any remaining bacteria and contaminants. An advantage of MBR technology is that it permits elevated biomass concentrations in the reactor allowing for very effective removal of both soluble and particulate biodegradable materials at higher loading rates.

After this process most of the water would be considered acceptable for most non-potable uses; however, our station will implement one final process to ensure the safety of our water supply.

The accessibility of ultraviolet radiation from outside the station in the form of UVA, UVB, and UVC bands invites the use ultraviolet radiation as a tertiary treatment. After the water has been treated in the primary and secondary treatment plants, the water will be pumped across the outer wall of the agricultural section of the torus in order to be exposed to ultraviolet radiation, which will sterilize and kill any remaining bacteria in the water. In order to obtain the optimal amount of ultraviolet penetration fused quartz (or fused silica) will be used as a layer between the water and the outside of the space settlement. The reason fused quartz was chosen was because it has a very low metallic impurity content meaning it is transparent to most of the ultraviolet spectrum. It is also relatively tough with values of 5.3 – 6.5 on the Mohs scale. However, a possible problem with pumping water through the outside layer of the torus is that it will be exposed to extremely low temperatures, which could freeze the water running through the system. To alleviate this problem, the inner surface of the pipe (the part not exposed to the ultraviolet radiation) will be heated to 20° C (the temperature of the water entering the system so that the water will not expand) in order to prevent freezing. The water will also be kept in constant motion through this section with pumps, which will also prevent the freezing of the water.

After the water has been exposed to an adequate amount of UV radiation the water will be sent to a chemical treatment facility where any chemicals, such as fluoride or chlorine, will be added. When the water is deemed potable, it will then be pumped throughout the station to those who need it. Any water not in use in the commercial or residential section will be stored in the infrastructure section of the station, near the chemical treatment facilities. Circulated water will be circulated throughout the station and will run in pipes of cleaned and dirty water along other infrastructure needs. Toilets will have a two-flush system to distinguish between solid and liquid waste. Solid waste will be delivered to the waste treatment system instead of the water management system.

3.2.5 Waste Management

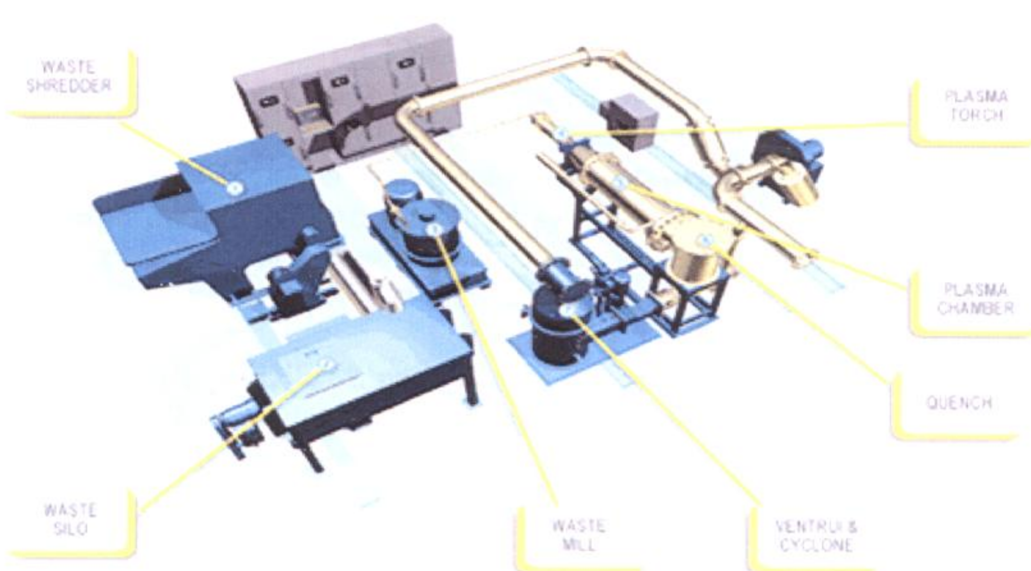


The waste management system of the commercial and residential sectors of the station will consist of a system of waste and recycling chutes which, through pneumatically powered tubes, transport all waste to a central handling station in one of the two operations sectors in the outer torus. Recycling will consist of glass, paper/cardboard, metals, plastic, textiles, electronics, etc. Of these, glass, paper, plastic, organic, as well as auxiliary waste chutes will be in each apartment complex and commercial area. It is the household's/company's responsibility to utilize this system according to its designated use. Initial scanners near the chutes will determine any blatant misuse or misplacement of the system. Specialized wastes, such as electronics, batteries, and textiles, are brought to larger chutes near respective goods-transportation pick-up stations. Such wastes are more seldom produced and it is therefore both inefficient and unnecessary to include recycling chutes in every household and commercial center. Certain wastes or recyclables, such as aluminum, will not be available for common use on the station due to their high production and refinement costs.

The chutes, using pressure differences and artificial gravitational forces, transport the recyclables and wastes to a central sorting and management station in one of the operations sectors, where they will be scanned and reanalyzed to ensure correct placement. They will then be sorted automatically according to recyclability. Whole items are cleaned and reutilized, while non-reusable items are broken down, recycled, and reutilized for production/industry. Waste from the commerical and residential areas that not recycled or reused, are sorted according to substance. Biodegradables and organic wastes that can be harnessed for nitrogen and other nutrients are introduced into the agriculture section and used as fertilizer.

Plasma arc gasification is applied to any other materials in two gasification facilities in the infrastructure sections of the outer torus. Plasma Arc Gasification is a highly efficient way of breaking down virtually any material, except highly radioactive, into a synthetic gas consisting largely of carbon dioxide and hydrogen, which will be utilized as a highly combustible fuel/energy source for chemical rockets and thrusters. The other byproduct of this method is a solid waste, mostly slag, which will be used as fertilizer and for manufacturing purposes. Plasma arc gasification, unlike incineration of wastes, does not require oxidization, saving this valuable resource for the station. It only requires high temperatures to achieve pyrolysis, which will come from the end product itself, as a specific amount of the produced syngased will be harnessed for electrical power. The rest of the syngas will be used to refuel visiting ships and on-station chemical thrusters with liquid hydrogen fuel.

Plasma Gasification



http://science.howstuffworks.com/plasma-converter.htm

The primary means of reducing waste throughout the station, however will be waste minimization through education and conservative use. Chutes from individual households and companies will track the amount of waste produced, and reward owners/groups evidently making an effort to reduce their wastes. Campaigns throughout the station will encourage residents and visitors to conserve whenever possible and only dispose when absolutely necessary, and when disposing to obey the station's recycling system. This can have an immense impact on eliminating and reducing waste whenever possible.

3.2.6 Communication Systems

3.2.6.1 Internal communication

The space station will feature one primary network system for all internal communications. Connections can be made to both an internal station network and earth's internet. Both networks will be accessed over high-speed Wi-Fi with access points placed covering the entire station. The Wi-Fi network will use mesh networking similar to municipal wireless networks on earth, with access points located approximately 100 access points located at 100 m separation along the maglev tracks (since these are the center of the tori), and along the center axis of the cylinder. These routers will then be interconnected with a system of fiberoptic cables that will also lead to three distinct central server stations, on each torus and the cylinder.

Every household and company will, depending on needs, receive a certain amount of portable, wireless enabled, multi-touch displays/communications devices which will enable direct access to the system. These will not have any storage capabilities beyond basic operating systems, as all data, programs, and files will be stored directly in a "cloud" at the three server stations and streamed directly to the device, when needed.

This will simplify maintenance and technology and allow universal access throughout the station. Individuals on the station will have their own network account available directly from their portable device, which will enable access to all personal files and data, as well as specific applications, communications, and network capabilities depending on account level. This account will also carry all important information on health, employment, residence, etc... and will serve as identification throughout the station. The portable devices will have a high-speed direct connection that can be plugged into multi-touch displays throughout the station, allowing them to serve as a wireless receiver with an external display. All households and companies will be supplied with one or more of these displays, and these will be the primary form of household entertainment through games, television, internet, etc... streamed directly from the network, through the device into the display. The devices, which will include camera and phone, among other capabilities, will also serve for any communication, whether text-based, visual, or audial, and these can be amplified using the previously mentioned display and speaker systems.

The device can also be used to locate any person according to the receiver's proximity to different access points. This capability can be used for search purposes, as well as supplementary information. The account used for this system includes specific information about residence, as well as the supplying of goods. Using the individual account, it is possible to order specific goods or foods, instead of buying them in an actual store, and they will then be delivered to a location near the household using the magnetic automated distribution system. The location of the account holder can be used to determine an ideal time to deliver articles like food, to ensure freshness.

Every resident of the station will also have an implanted chip measuring their vital signs, as well as specified probes depending on specific diseases or conditions (measuring blood-sugar for diabetics, etc...). These, coupled with environmental condition detectors (measuring temperature, air chemistry, pressure, smoke, etc...) will be used in a completely separate wireless system of communications reserved specifically for emergency situations. EMS, law enforcement and other emergency service providers will receive any distress calls, as well as live emergency information from an automated system monitoring conditions of all residents and locations throughout the station. The portable receiver can also be used to report an emergency with this separate network, and its location will immediately be reported with the call.

Since this centralized, single, system of communications is especially vulnerable to technical failure or impairment, three server stations, one on each cylinder, will be used, containing the exact same information and data, essentially providing two back-ups in case of any failure.

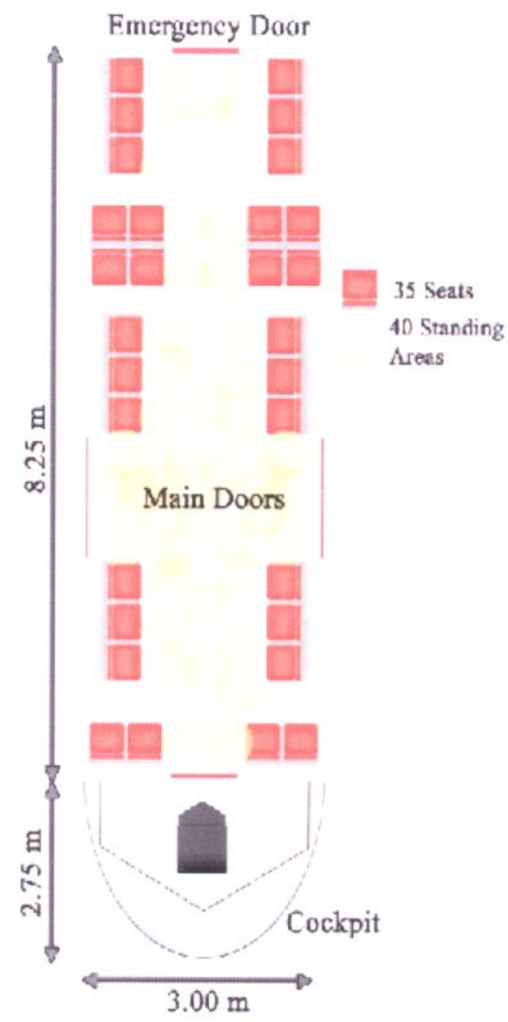
3.2.6.2 External communication

External communication to other space-stations, spacecraft, and earth (including connection to earth's internet) will be provided with a combination of both laser-communication as well as radio signals using satellites similar to the Deep Space Network employed by earth-based missions. Receivers and transmitters will be located near each of the server stations on each part of the space station, as well as allover the outside of the outer torus, to serve as back-up in case of failure and to increase signal strength. Cooperation with various space agencies on earth, as well as the other stations will greatly increase the amount of radio antennas and satellites with which communication can be accomplished, significantly strengthening the system.

3.2.7 Internal transportation systems

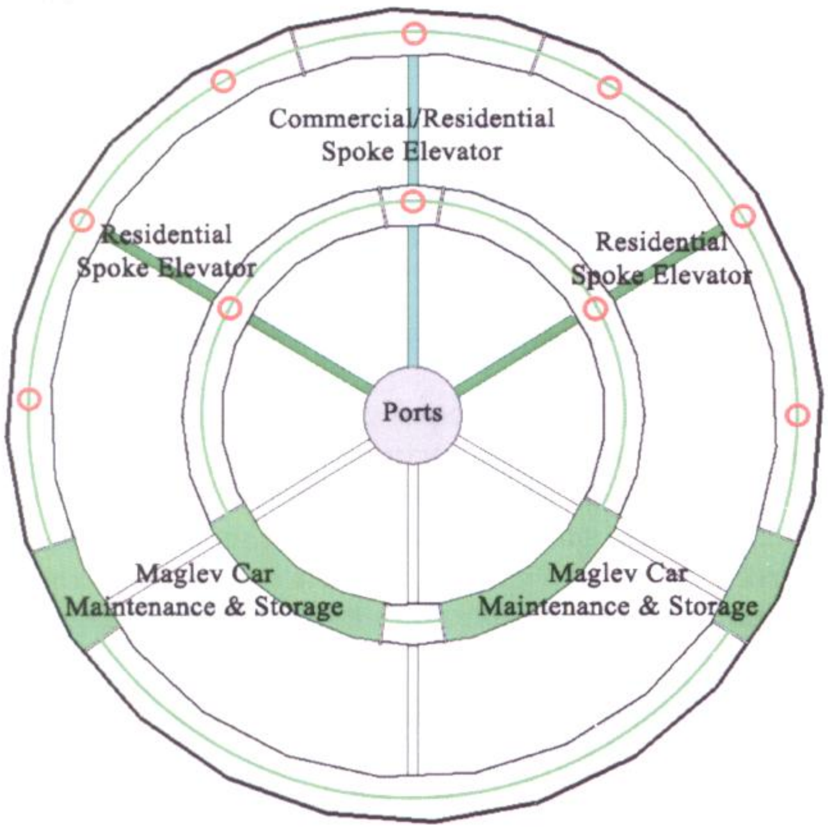
3.2.7.1 Personal Internal Transportation

The primary method of human internal transportation for the outer and middle torus will be superconducting magnetic levitation trains. This free, public, transport system will be used instead of a personal transportation system to simplify individual maintenance and repairs, avoid traffic and congestion on the station floors, and encourage exercise and maintain health. In each torus, two oppositely



Some designs taken from Eliron Cheung (http://www.onelittlecog.com/wp-content/uploads/2008/04/subway_mo2.jpg) transporting tracks will run in a loop parallel to each other and all sides of the respective torus, slightly elevated from the center platform of each torus, through the middle or sides of that platform. The outer torus will feature 7 stations placed 30° apart in the residential and commercial areas, lined up with the respective spokes. The inner torus will feature 3 stations placed at the residential and commercial spokes, 60° apart. This will result in stations being placed approximately 500 m apart from each other throughout the station, a reasonable walking distance of a maximum of 250 m from any residential or commercial point in the torus.

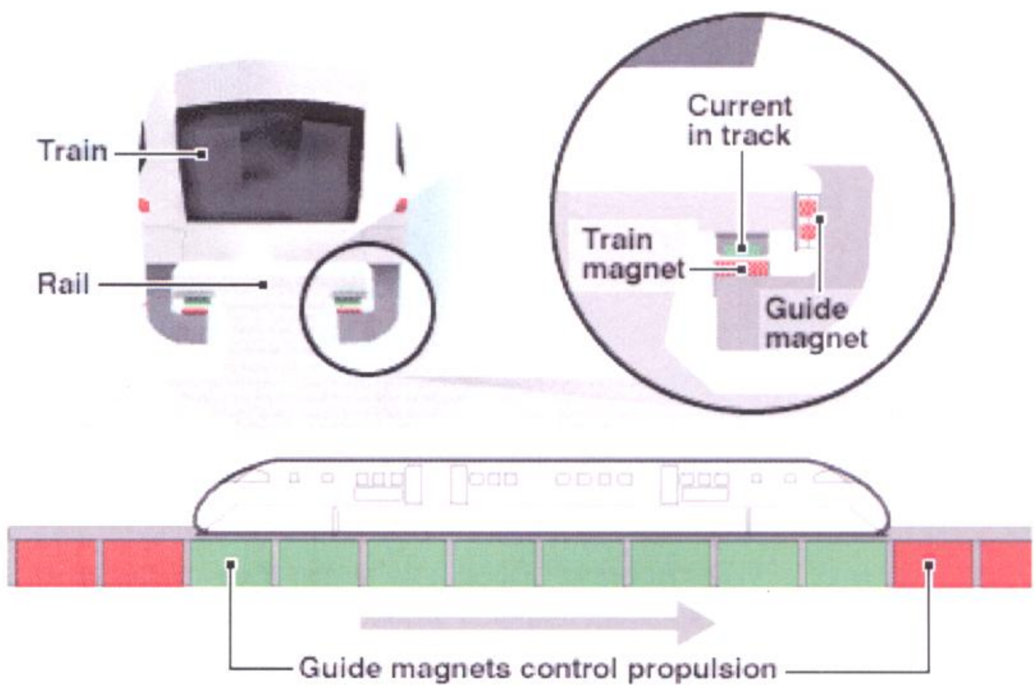
The stations will feature a simple system of traction elevators depending on use and capacity of the station, as well as live time displays, system information, local governmental/information services, and limited commercial development. In these sections, trains will travel at a maximum of 10 m/s, resulting in station to station travel times of approximately 1 minute.



The trains on each torus will pass a vacuum tunnel through the infrastructure and agriculture sections, in which there will be no stops. The tunnel is vacuumed to further reduce drag and increase efficiency, resulting in maximum speeds of 25 m/s. The time from the last to the first station through these tunnels will then be approximately 2 minutes and 1.5 minutes for the outer and inner torus respectively. At the beginning of the trains entering the infrastructure sections on each of the tori, there will be switches to repair and maintenance facilities inside the sectors.

The station will feature a total of 8 equally constructed maglev train cars. On the outer torus, there will be a total of 4 cars in operation at any time, two cars running approximately 180° apart in each direction. For the inner torus, 2 trains, one in each direction, will continuously be operating. This results in a maximum waiting time of 3.5 to 4 minutes, a reasonable transport system. There will be one extra car on each torus stored in the repair and maintenance facilities, which will be utilized in the case of breakdown or repair of any of the other cars on the respective torus.

The cars will be 3 meters wide, 11 meters long, 3.5 meters tall. A 3 x 8.25 meter passenger area has room for a maximum of 30 seating and 45 standing passengers at peak capacity. This, with the number of trains and frequency of revolution, is realistic for a station of approximately 25000 inhabitants. The back of the train will have an emergency exit and the front 2.75 meters will consist of a cockpit and engine, manned by a single conductor. Human conductors because they are more reliable to act in emergency situations and potentially tell passengers where to go.



http://newsimg.bbc.co.uk/media/images/42118000/gif/_42118168_maglev_train_inf416x260.gif

Superconducting magnetic levitation trains were chosen due to their high efficiency and reduced noise (both due to lack of rolling resistance), easy maintenance (due to limited moving pars), speed, and reliance only on electrical energy, reducing needs of imported fuels. The trains will use an Electro-dynamic Suspension system with superconducting magnetic coils, similar to the existing *JR-Maglev* system employed in Japan.

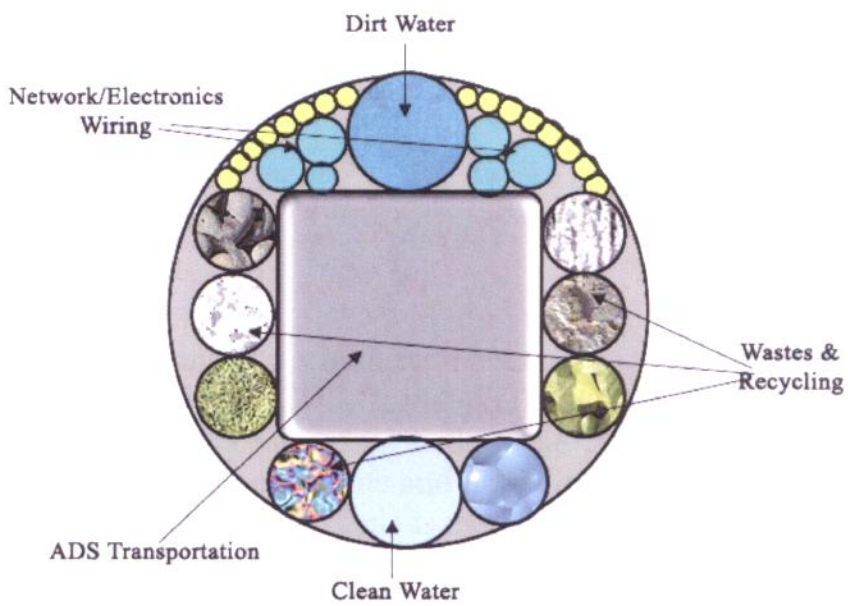
3.2.7.2 Internal Transportation and Distribution of Goods

Transportation of goods and materials will also utilize an Electro-dynamic Suspension system with superconducting magnetic coils with 4 tracks looping around in the allotted infrastructure space below the lowest platform. These tracks will be connected to a network of pneumatic tubes, running along the sides of the torus, through the platforms and to all housing and commercial complexes. An automated system of barcodes on externally equal containers will be used to distribute all goods, including food, to their designated locations. This system is called the ADS, Automated Distribution System. Systems of waste transportation, coming directly from garbage and recycling chutes, as well as electricity, network communication, and water management will also run alongside these tubes in a similar system, leading down to the central infrastructure section at the bottom of each of the tori. Human entrances to this system will be located at the main goods and operations management stations. One of the four magnetic levitation tracks will be used for maintenance and repairs by humans inside the system.

3.2.7.3 Emergency Internal Transportation

Emergency transportation (repairs, EMS, and law enforcement services) will utilize a separate, reserved system of personal transportation consisting of chargeable, wheeled, electric vehicles and transports which drive on paved, marked, surfaces on each of the platforms in each of the tori. The vehicles have the approximate same dimensions and equipment as earth-based ambulances and will run in both directions on lanes that are 5 meters wide, parallel to the side of the torus. Warning lights and sounds will indicate an approaching vehicle and alert bystanders to move out of the way.

3.2.7.4 Inter-Tori and Cylinder Transportation



Transport along the spokes connecting the two tori and the cylinder will consist of traction/cable elevators assisted by electric motors. This system takes advantage of the produced artificial gravitational force in the "down" or outside direction. Since this force will decrease as elevators approach the center, an automated system of hoisting that establishes constant speed (especially for human transportation) will be utilized. Along the sides of these elevators, the goods, maintenance and infrastructure systems, pneumatic distribution system, water management, waste management, network communications, etc... will run. Throughout the station, the will be 6 spokes, separated by 60° will each have individual functions and purposes. The spoke from the commercial hub will feature large "people mover" elevators as well as numerous commercial and goods transporters. The primary function of the two residential spokes will be to transportation of people between the spokes. The two infrastructure spokes will include the main inter-section transportation of goods and utilities like water, waste, etc... The agriculture spokes will be used to transport food to the other torus as well as providing livestock veterinary services and food replenishment for visiting ships.

All the spokes will be cylinders 10 meters in diameter, and will feature at least two elevators for their respective functions. One elevator will continuously run between the two tori, or the inner torus and cylinder, respectively. The other elevator will continuously run between the cylinder and outer torus without stopping at the inner torus.

3.2.8 Day/Night Cycle Provisions

Lighting is crucial to any hospitable environment; however, the long term residency of Columbiat not only requires an adequate indoor environment, but also a living area that will provide the residences a "home away from Home." With this concern in mind, Columbiat will make use of multiple lighting systems to provide the residence with a living space that will mimic the different types of lighting found on Earth.

The station will run on a 12-hour day/ 12-hour night cycle. The type of artificial light would be determined by the uses of each particular section of the station. The main benefit of this centralized approach is that it will conserve the energy used throughout the station; it has been shown that artificial lighting is one of the main consumers of energy. A way that the station would be able to implement such an approach would be to measure the luminance (luminous intensity per unit area) of light needed for different activities in the residential and commercial sectors of the station. For example non-automated industrial activities that require high precision would need a higher luminance than the corridors of the station. The primary means of lighting, however, will be LED lights, advantageous for their high efficiency and low temperatures.

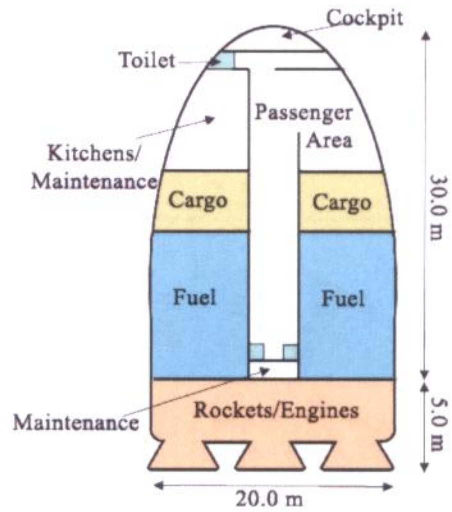
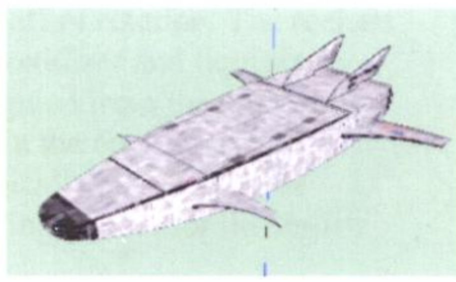
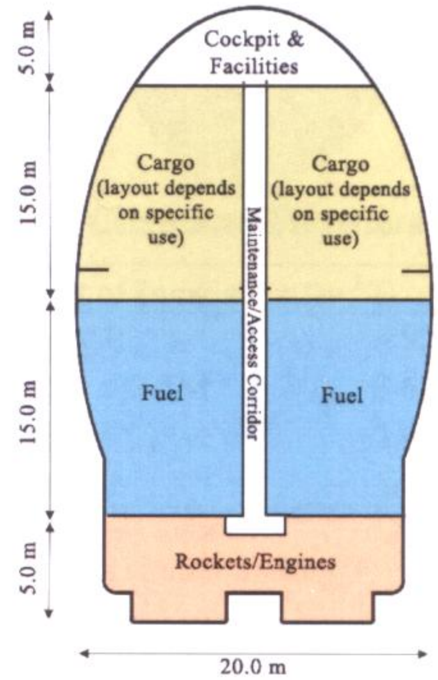
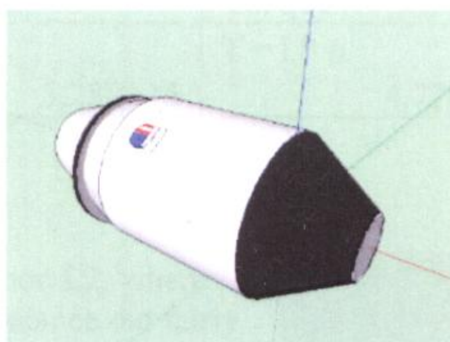
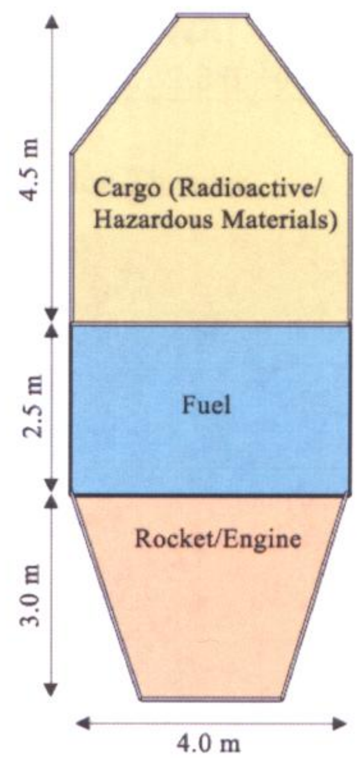
While UV radiation in high doses is harmful to human health, it is still beneficial for most living organisms, including humans. UVB radiation has been shown to induce the production of Vitamin D in humans and most humans find the presence of natural light pleasing. To be able to provide for both of these concerns the Columbiat space settlement will provide a projection of natural images of Earth's sky in the residential sectors and a sun exposure room located in the commercial hub of the station.

Most residents would most likely want actual exposure to UV radiation and that would be provided by a "sun exposure" room set up in the commercial sector of the station. The main attraction of this room would be a window that would provide residents a clear view of space, and the lighting of the sun that is there. Exposure in this room would be limited to only a half an hour stay because of the fear of too much radiation; however, the purpose of this room would be for such an exposure. Because of this purpose, the window would be made out of fused quartz because of its transparency to most UV bands (see water management).

3.3 On-orbit Infrastructure

3.3.1 Vehicles

The station will feature three distinct contracted transports alongside a multitude of commercially developed transports that may be visiting. These are named CST-P, CST-C, and CST-RH (Columbiat Space Transport, -Personal, -Cargo, and –Radioactive-Hazardous, according to their use). For propulsion, all transports will employ bipropellant rockets using liquid hydrogen as fuel and liquid oxygen as an oxidizer, similar to NASA Space Shuttles. An advantage of using these fuels is that they can be produced on the station using gasification processes and the oxygen filtration/production systems (See section 3.2.5). Additional disposable rockets will be required for exiting earth's atmosphere. The CST-P and CST-C have collapsible wings to ensure entrance into docking facilities on stations. The wings are necessary primarily for re-entrance and landing on earth. The CST-RH does not return to earth but gets accelerated into the sun, so it has a very simple design and does not feature wings. Any additional transportation will be developed commercially over the station's lifetime.

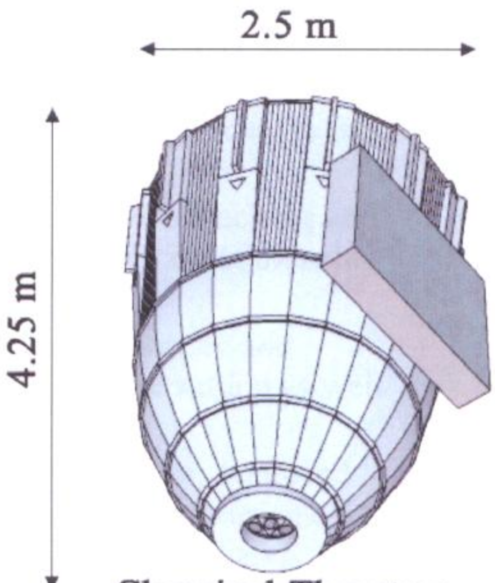
Transportation Type	Name	Dimensions	Crew	External View	Internal Layout
Personal	CST-P	W: 20 m, H: 15 m, L: 35 m, Span: 40 m	2 pilots, 2 on-board engineers, 2 security officers, 4 flight attendants		
Goods and Materials	CST-C	W: 20 m, H: 10 m, L: 40 m, Span: 40 m	2 pilots, 3 on-board engineers		
Radioactive and Hazardous Materials	CST-RH	W: 4 m, H: 3 m, L: 10 m	none		

3.3.2 Satellites

The station will be in contact with a multitude of different communications satellites in various geocentric and lunar orbits from various commercial telecommunication agencies, research agencies, public facilities, etc, on earth. Satellite designs according to the varying organizations and companies will be utilized for the station, similar to present communications satellites.

3.4 Propulsion systems

3.4.1 Artificial gravity



Chemical Thrusters

Upon the completion of the space settlement, 8 chemical rockets built on the outer torus (4 pairs located on the same plane and separated 90 degrees from each other, see picture) will each apply a tangential force for 2 hours in the same direction to provide angular acceleration of the space settlement. This rotation will be the source of gravity inside the outer torus. Once Earth gravity inside the torus has been achieved, the chemical rockets will be turned off and only used for future corrections or emergency turn-off of rotation. The rockets will be bipropellant rockets using liquid oxygen as oxidizer and liquidized Hydrogen initially brought from earth and later supplied from the gasification as fuel. Hydrogen will be converted to liquid form in the operations and infrastructure sectors after gasification and cryogenically stored near the rockets. It has the a very high specific impulse making it ideal for the thrusts required to rotate the station up to 1 rpm.

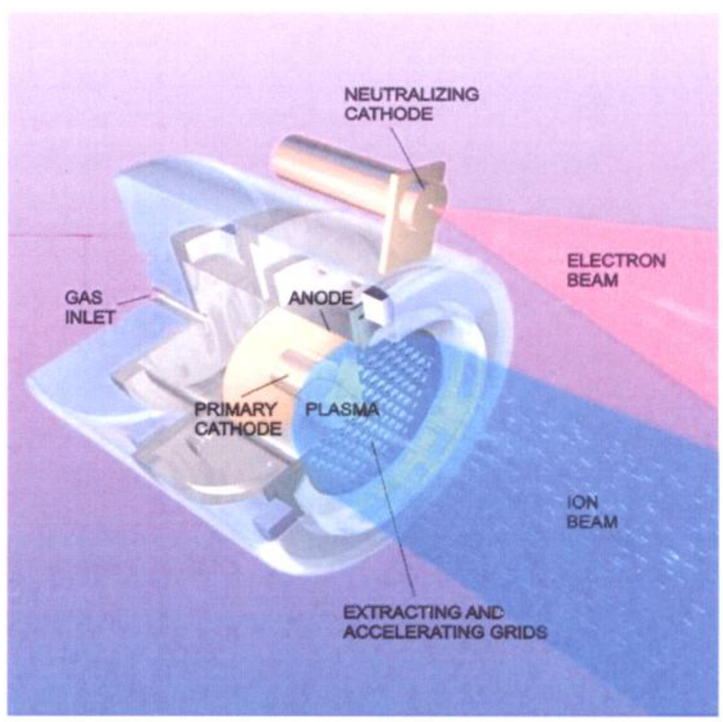
	Approx. Volume (m^3)	Approx. Mass (kg)	Moment of Inertia (kg*m^2)	
linder	1.58E+06	4.72E+07	0.5MR^2	5.92E+10
ner Torus	2.94E+07	8.77E+08	((3/4)*R^2 + r^2)*M	3.62E+14
ter Torus	5.87E+07	1.75E+09	((3/4)*R^2 + r^2)*M	2.91E+15
okes	8.13E+04	2.43E+06	0.5ML^2	5.21E+12

The masses were found by dividing the volume of each sector by the volume of a Nimitz class aircraft carrier and multiplying by this vessels mass, since such a ship uses similar materials and has similar density to the station.

Total Moment of Inertia (kg*m^2)	Torque (N*m)	$F_{thruster}$ (N)
	T = I * α	F = T/(8R)
3.28E+15	4.77E+10	2.88E+06

3.4.2 Orbit Maintenance

Ion Thruster



http://www.plasma.inpe.br/LAP_Portal/LAP_Site/Figures/PION_3D_In

The space settlement will be placed at the Earth-Moon L2, where gravitational forces from large interstellar objects balance out fairly well so that the settlement will orbit the sun without much interference. This Lagrangian point is located on the far side of the Moon, approximately 1.5 million kilometers from the Earth.

Ion thrusters, each one positioned at the same location as the chemical rockets, will be used to maintain the space settlement in L2 orbit. Ion thrusters are more advantageous than traditional chemical rockets because the fuel has a high charge to mass ratio, giving relatively high rates of acceleration with less fuel. Using hydrogen as a propellant, an ion thruster can achieve thrusts of 60 N with a specific impulse of 6,000 seconds, which indicates high efficiency. The hydrogen for this use will also come mainly from gasification processes of wastes and be stored and transported in the same way and same location as for the chemical rockets.

Although the thrust generated is not as high as the thrust generated by chemical rockets, orbital corrections are going on continuously so that large amounts of thrusts will not be needed. This method also prevents rapid changes in angular momentum of the station and high accelerations, preventing inhabitants on the station from feeling any noticeable affects of orbit correction.

3.5 Provisioning and Maintenance of Visiting Ships

Food and Agricultural Replenishment	The Agricultural sectors of the station will produce an excess of food and agricultural requirements like fertilizer than what is required by the station. The agriculture spoke elevators and the ADS will be used to transport restocking to the restocking and maintenance areas for ships in the cylinder. (3.2.2)
Livestock Veterinary Services	Any livestock in need of veterinary services will be unloaded in the restocking and maintenance area and transported to the inner torus veterinary service station using the agriculture spoke elevator. (3.2.2)
Engine Overhaul	Engine Overhaul and Maintenance will be performed in the maintenance and restocking area both by qualified engineers and technicians from the station as well as automated techniques (5.#.#)
Fueling	Fuels, including hydrazine, nitrogen trioxide, helium-3, and deuterium, produced using gasification processes on the station and imported from other stations and earth, will be stored on the cylinder near the maintenance and restocking area, and used for refueling of ships as necessary. (See Diagram)
Liquid and Solid Waste Disposal	Large Chutes leading into the stations central waste processing and recycling system will be placed throughout the maintenance and restocking areas on the cylinder, where any waste from visiting ships will be taken care of in the same way as station-based waste. (3.2.5)
Water Replenishment	Water from visiting ships will be pumped into the circulating water treatment system of the station. Replacement and replenishment water from this system will then be drawn from the circulating water. (3.2.4)
Replacement of common items in living areas	Common and necessary items in living areas can be supplied from excess items on the station, originally manufactured on another station or on earth. They will be transported to the maintenance and restocking area using the ADS. Utilized items from visiting ships will be recycled for use on the station.

4.0 Human Factors

4.1.1 Psychological Factors

Human psychological needs include community interactions, suitable living environments, and entertainment, among other luxuries for mental stability. As for community entertainment, a theme park will be constructed in the low-g environment; in the main residential area, movie theaters, music stations, and shopping malls will be available to the public. The low-g environment games will include rock climbing, bungee-jumping, and basketball. To add more excitement for athletic events, there will be various sports competitions held among inhabitants.

Since proper g-levels are not attainable in all parts of the station, living in them could have many negative health effects, like hindering the growth of bones. To avoid this condition, all of the inhabitants will be required to regularly go the gym and attend mandatory exercises classes, which range in strenuousness from yoga to kickboxing. All the inhabitants will also be required to spend a certain amount of time in the outer torus, which has a proper g environment.

4.1.2 Housing

Columbiat will offer state-of-the-art housing to all its residents, regardless of income level. Residents will live in apartments appropriate for their family status and situation. The apartments will range in size from simple one bedroom apartments to large family suites. All apartments will be spacious and comfortable, with equal access to amenities and other station facilities. Each apartment will be located near a maglev station, a few restaurants and shops, a distribution center etc. The apartments will offer a high degree of independence to residents, while making life more convenient for them. For example, residents will have their own kitchens, but may choose to eat at a diner or restaurant within a few hundred meters distance. All apartments are located in the commercial and residential sector, allowing residents a quick transit to work and unlimited access to the station's countless shops, restaurants and businesses.

4.1.3 Education

The education system aboard the Columbiat will model the standard education system in the United States. It will contain facilities ranging from preschool care to graduate school. The number of children under age 18 will be relatively low compared to Earth. Approximately 5% of the residents will be under 18; this means that education facilities will be built originally to hold 1,100 students. The exact distribution of the student population is unknown, but the schools will be built to expand within five to ten years according to the inevitable growth of the resident population. The structure of the schools will be to separate each grade K-12 into lower, middle, and upper schools. The complex for all schools will originally be in the same area, called simply the "school," but in order to keep the students in an environment surrounded by their peers the lower, middle, and upper schools will be physically separated. The Columbiat will feature two schools of higher education: a college and a business school. The college system will provide three years of in-school learning, and one year of applied learning at a job or internship, coordinated by Columbiat College. The Grameen Business School will be built to become the premier graduate business school in space. It will be located in the financial district of the Columbiat giving the greatest opportunities to learn and apply business principles to the exploration and colonization of space. Understanding the best method for building an economy in space will be integral to the Columbiat and the Foundation Society in general. The Grameen School will train economists in an environment literally unlike anything on Earth.

4.1.4 Entertainment

At Columbiat, a wide range of entertainment will be provided. For example, buildings where people on Earth usually spare their time, such as movie theaters, shopping malls, and bowling allies, will be constructed on the space station to gratify the nostalgia of terrestrial activities. Various activities will also be held in the community centers. Community centers will be built at the popular sites that are within a reasonable distance. Various events, such as game contests and festivals, will be held in these community centers on holidays.

High-technological and relatively expensive entertainment systems will also be provided at the community centers, for example, virtual reality stations. Dangerous sports such as car-racing and football are replaced by virtual reality to satisfy the hunger for speed and physical impact but prevent deaths and casualty. Activities that require large amount of resources and spaces, such as golfing and jet flying, will also be provided through virtual reality. Other programs, such as walking and tactile simulations, will serve for educational purposes for infants and children.

Many visitors wish to experience a zero-gravity environment; on the colony, a portion of the space station will be reserved for an antigravity theme park. In the park, various rides and games will be featured, for example, weightless bumper bubbles and rock-climbing. A free-floating area will be provided for people who just want to float around and relax.

In addition, biodomes will be constructed for aesthetic, educational, and environmental purposes. These biodomes will serve as a site for relaxation and extensive study on various subjects, such as biology and environmental science. An ideal and sustainable environment with a balanced number of different organisms can be created in the biodomes.

4.1.5 Medical

Along with many trite diseases that attack people on Earth, residents of Columbiat might be exposed to newer and possibly more dangerous diseases because Columbiat's new environment might give rise to possible microbes that are unknown to humans on the Earth.

There will be two general hospitals, each taking care of the residents and the non-residents, respectively. The aforementioned separation of patients aims to increase the rate and the quality of the treatment. Two general hospitals, being the biologically cleanest regions inside the settlement, would also serve as the places for quarantining the patients with serious, contagious illnesses. Other than the aforementioned general hospitals, other several specialized clinics would serve the various needs of the residents and the non-residents. However, since the space is limited, it will be reasonable to set up a restriction on numbers of clinics. Such restriction on the dental clinics would be three clinics. Restrictions on other kinds of clinics shall be determined by the joint committee of the authority of Columbiat and the experts from the two general hospitals.

4.1.6 Public Areas Providing for Open Space

Columbiat will provide numerous recreational areas for its resident's enjoyment. As on earth, there will be different natural environments and playgrounds, but Columbiat will also feature facilities for a wide variety of sporting events, such as soccer, basketball, football, hockey, baseball and cricket, to accommodate visitors from all over the world. There will also be more tranquil settings for the inhabitant's relaxation and spiritual welfare, such as zen gardens, exotic biodomes, and isolated park areas. A large portion of the station's area will be dedicated to these recreational facilities, in order to encourage residents to become active and lead a balanced and healthy life. Besides recreational areas, there will be public spaces for communal interaction. The paved walkways and plazas will be lined with cafes, shops and restaurants and will be fitted to accommodate visitors and residents alike. These areas will emulate earth's city environments as closely as possible, in order to create a sense of comfort and familiarity in the new and unusual setting of space.

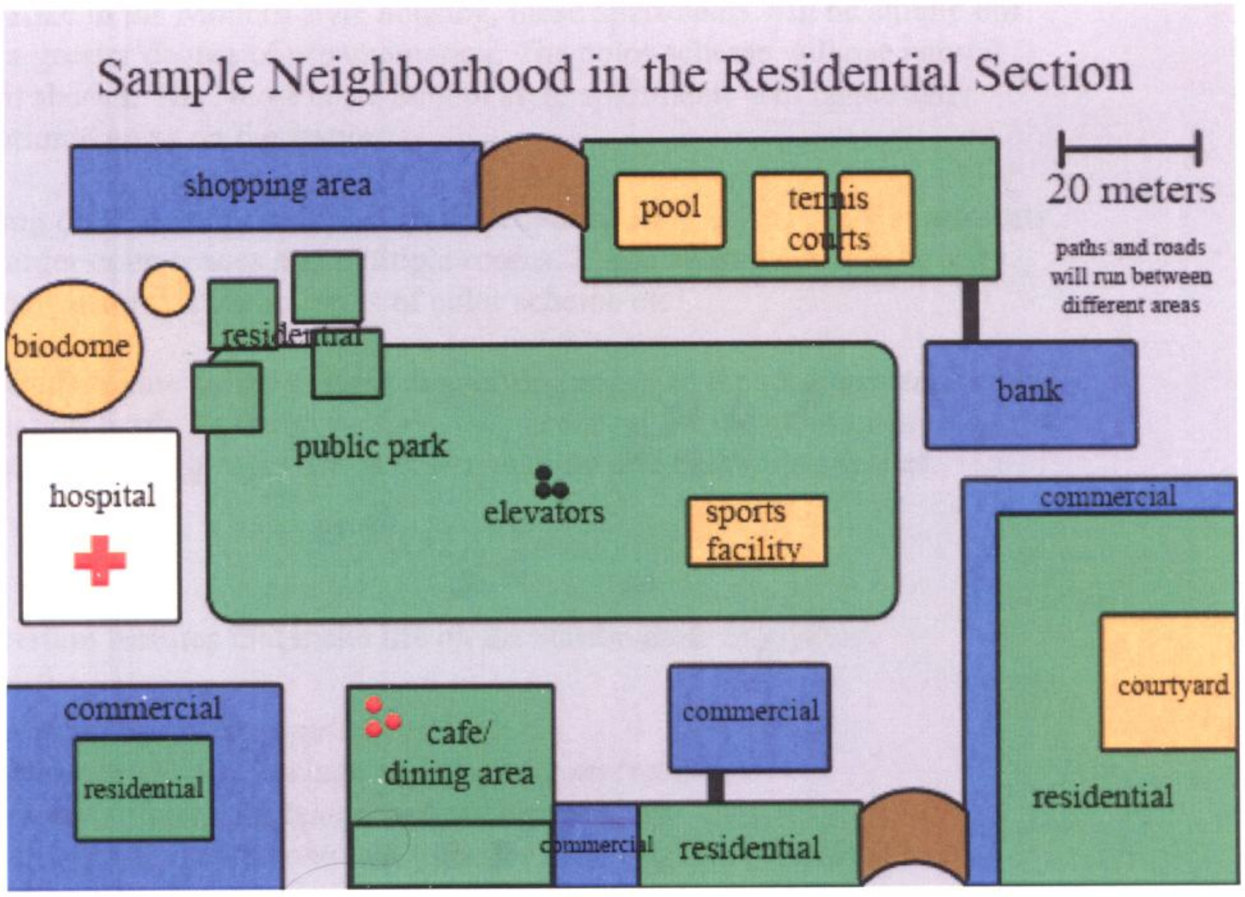
4.1.7 Consumables

4.1.7.1 Method of distribution

There will be 26 distribution areas in the station, serving 400-750 people each. They will be conveniently located in residential and commercial areas and will be connected to Columbiat's transportation system of magnetically driven tubes within the framework of the Electro-Dynamic Suspension System within the lower levels of the station. The wares will be distributed according to bar codes assigned to individual residents.

4.2 Residential Design

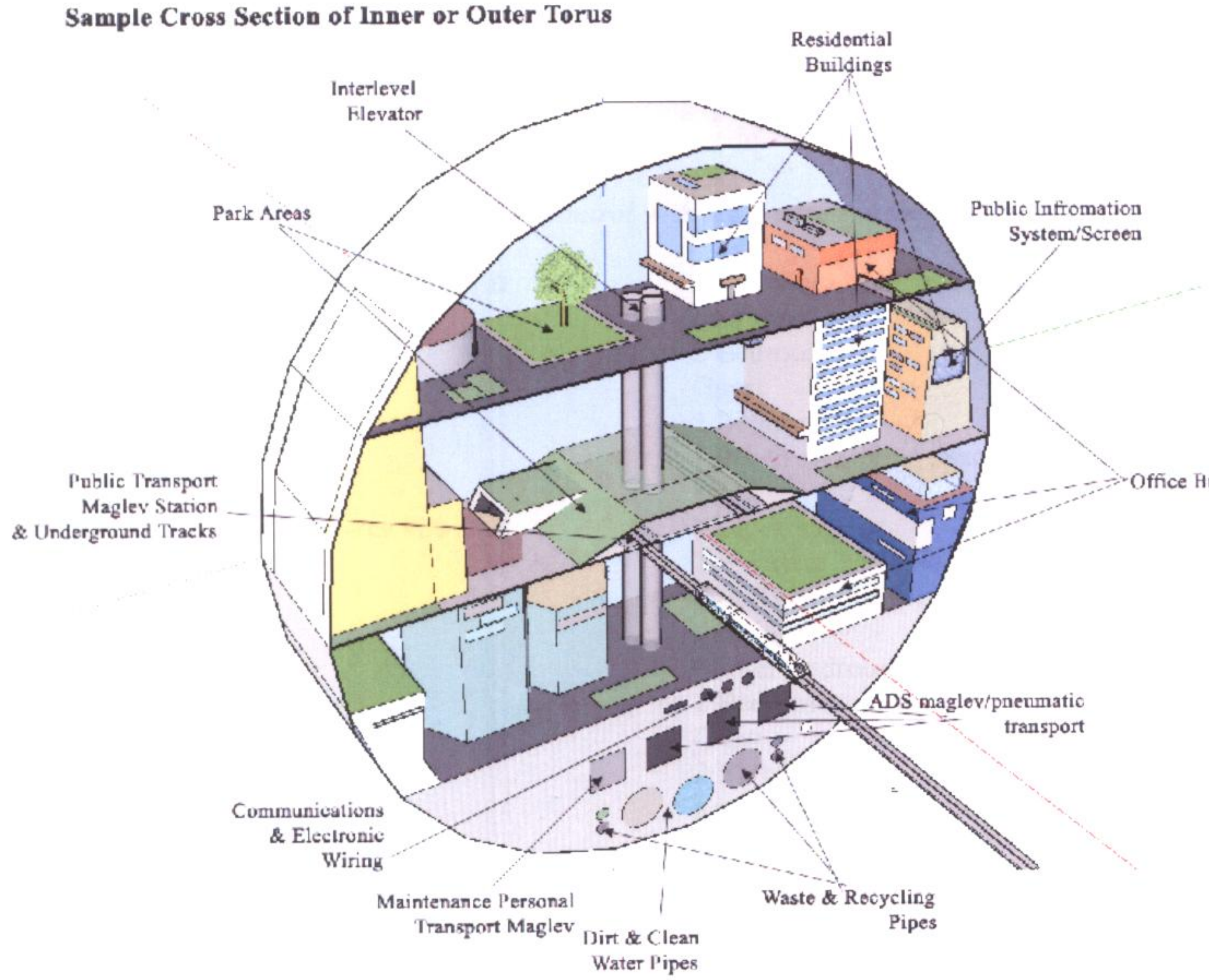
4.2.1 Neighborhood Styles



Columbiat will feature housing in three distinct architectural styles, to offer residents a higher level of choice regarding their living conditions. Neighborhoods will be arranged to suit different needs. According to family status, workplace etc., residents will be able to pick apartments and houses that are the most accommodating to their personal situation.

One set of apartments will be built and furnished according to modern and post-modern style. These apartments will be characterized by elegant simplicity and a lack of

Sample Cross Section of Inner or Outer Torus



ornamentation, and will be built according to the simple principle of "form follows function". The color scheme will be simple and elegant, making use of metallics, black and shades of white.

For residents looking for a more naturalistic style, the station offers a revived form of the late 19th and early 20th century Prairie School, an architectural style that relies on horizontal lines, panoramic windows and integration into the landscape. Like in the Modern style housing, these apartments will be simple but elegant, although they will feature a greater degree of ornamentation. The color scheme will use natural tones; browns, white and other light shades. The Neo-Prairie School style apartments will be partially integrated into the parks and recreational areas on the station.

The most traditional housing offering on the station will be a classic contemporary style. These apartments will be very family friendly, with larger open spaces and multiple rooms. These apartments will be very well lighted, and allow for individual customization in terms of color scheme etc.

The three architectural styles on the station are suited to meet the varying needs of the residents and offer excellent housing reminiscent of that on Earth. At the same time, they are ideal for the close quarters of the station by reducing necessary space, eliminating superfluous ornamentation and combining spaces.

4.2.2 Home Design

All apartments are equipped with certain features that make life on the station more enjoyable:

- *Fully equipped kitchens, with all necessary appliances.*
  Ovens, microwaves, countertops etc. will include self-cleaning mechanism
- *High Tech Home entertainment system with integrated ceiling speakers*
  also includes a user-friendly mobile holographic interface for shopping, ordering food and services
- *Direct Food and Item delivery through the station's cargo system*
- *Adjustable Climate control, to manipulate airflow, temperature, humidity etc.*
- *High-Pressure Showers*
- *Laundry Chute and collected automated washing system*
  Clothing assorted and returned according to barcode
- *Semi-automated 24 hour security system*
- *Semi-automated deoxygenating Fire Control with life system scanner*

1 Bedroom Apartment (1A) - ca 740 sq ft
Features:
Bedroom w/ wardrobe
Bathroom
Kitchen and living space
Wall Storage
Total area: 4,590,000 sq ft

2 Bedroom Apartment (2A) – ca 900 sq ft
Features:
2 Bedrooms
Bathroom
Kitchen and living space
Study
Wall Storage
Total area: 3,700,000 sq ft

2 Bedroom Midsize (2M) – ca 1060 sq ft
Features:
2 Bedrooms
Guest
2 Bathrooms
Kitchen and living space
Study
Wall Storage
Total area: 3,255,000 sq ft

Family Suite (FS) – ca 1600 sq ft
Features:
Master Bedroom
2 Bedrooms
Guest
2 Bathrooms
Kitchen and dining room
Lounge
Study
Wall Storage
Total area: 3,150,000 sq ft

approx #:	Households	1A	1A+*	2A	2A+	2M	2M+	FS	FS+
Family	1125							1500	500
Married	6750			3000	1000	2250	750		
Single	5625	4500	1500						
	13500	6000		4000		3000		2000	
	15000								

Total Residential area:
14,695,000 sq ft or 1,365,000 sq m

4.2.3 Furniture

Furniture will be shipped to the station in the form of materials and pieces, and will be assembled on site. Much of the station will feature a very minimalist furniture style, which is characterized by less furnishing in general and a greater simplicity in design. Common furnishing materials will include wood, metallics and plastics. It will be possible to reuse some of the construction materials and to reconfigure industry to produce a small proportion of the furniture.

Item	1 Bedroom	2 Bedroom	Midsize	Family Suite	Total (Office)	Total (station)
Kitchen Cabinet	2	2	2	2		30,000
Sink	2	2	2	2	86	30,086
Shower	1	1	1	2		17,000
Toilet Unit	1	1	2	3	250	22,250
Desk	1	1	1	2	125	17,125
Bookcase	1	1	1	5	85	23,085
Chair	5	5	6	11	1800	91,800
Double bed	1	1	2	2		20,000
Bedside table	1	1	1	2		17,000
Entertainment System	1	1	1	3	57	19,057
Coffee table	2	2				20,000
Sofa	1	1		1		12,000
Computer workstation			1	1	1760	6,760

4.3 Safety

4.3.1 Exterior Environment

Work outside the space station and in the open bays of the cylinder has all the risks inherent to space travel: low-g, radiation, and micrometeoroid impacts. Workers whose primary duties are within the central cylinder will also have longer exposure to the low-g environment. Reduced gravity particularly affects the muscular skeletal system through decalcification of the bones and overall muscle atrophy, including the heart. As a first line of defense, time spent in these environments by any person will be limited. Secondly, periodic blood panels will be drawn to monitor for elevated levels of calcium and protein, indicative of bone loss and muscle atrophy, respectively. Exercise and time in higher gravity areas will mollify these effects.

Space weather, principally solar particles, is monitored by a network of satellites within the inner solar system. No exterior work by humans will be conducted during time of elevated radiation. Robots will be used for most the exterior work. EVAs conducted by humans will typically be done under tethered conditions from access ports nearest the point of interest. Some regions will require untethered access. This will be done in concert with robots and with humans using Manned Maneuvering Units (MMUs).

4.3.2 Interior Environment

The habitat would have to be internally divided into rooms to conserve air for special cases such as a huge meteor created a hole in the wall. These rooms would contain emergency pressure suits, extra air bottles and an epoxy for plugging the hole. Inside the settlement, there would be padded walls to assuage the bone impact.

Spacecraft designs and operations must meet standards that serve to eliminate, or at least diminish, ignition-energy threats. These requirements cover the usual practices of electrical bonding and grounding, electrical and thermal overload protection, working-pressure relief settings, and similar safety procedures. For fire extinguishers, Halon 1301 is very efficient because it chemically inhibits combustion reactions. Halon 1301 does generate toxic and corrosive products, but in standard discharge rates, the product concentrations are very low. The ionization detectors of the Shuttle and its payload-bay laboratories (Spacelab, for example) are the first smoke detectors designed specifically for installation in spacecraft. An aerodynamic separator causes particles larger than about 2 μm (dust, perhaps) to bypass the ionization chamber. The flow through the inlet separator and the sensing chambers is created by an internal fan, a vane pump, which may also promote the sampling effectiveness in the non-convective environment, although the manufacturer states that the fan is solely for particle separation.

4.4 Equipment

4.4.1 Spacesuit

4.4.1.1. Prototype

The spacesuits for non gravity-controlled environments will be biosuits of polymer, nylon and spandex with nickel titanium wire laces that will hold the suit together. A skintight model will provide a superior level of flexibility and mobility than contemporary soft-shell pressurized suits. The new suit will consist of a gas-pressured helmet, up to five layers of one-pieced skintight fabric to achieve an ideal counter-pressure, a hard-shelled torso, knee caps and elbow caps for protection and a backpack containing an oxygen tank and computer systems. (Support for the body comes from the lines built into the layers. The lines lock with lines in the skin that don't extend when moving and act as an exoskeleton}. Thermal control will be achieved by incorporating a semi-permeable membrane that will collect perspiration from the wearer. In addition, the biosuit will provide additional safety, as every puncture made from small particles can be covered with a bandage and isolated so the rest of the suit will be unaffected.

4.4.1.2 Storage

Spacesuits will be individually and personally made for any inhabitants on Columbiat that have jobs requiring working in the non-gravity-controlled environment. Spacesuits will be stored in transit stations between the gravity and non-gravity environments. Here, they will be protected and regularly inspected and maintained. After inhabitants return from outside work and missions, the suits will be cleaned and sorted according to the station's Personnel Identification System (PIS).

4.4.1.3 Donning/Doffing

When donning the spacesuit, the flexible skintight inner-piece will be donned first. The layer of clothing will be extremely tight; therefore, zippers will provide the room for donning and doffing. Zippers will be placed on the back of the torso extending from the neck to the waist, on both arms extending from shoulders to wrists and on the legs extending from thighs to ankles. The next pieces to don would be the hard torso shell and the kneecaps and elbow caps. The torso shell will be connected at the crotch buckled at the shoulder when donning. The backpack and the helmet will then be connected to the torso shell. Donning of the helmet will be the final step. Doffing of the spacesuit reverses the process of donning.

4.4.2 Airlock

An airlock is a device which allows people or objects to enter and exit the space settlement. It contains two airtight doors in series which do not open simultaneously, which helps to minimize the air loss. The airlock can also act as a connection between two different pressurized environments. When a person enters/exits it, the airlock changes the pressure slowly to help with internal air cavity equalization and to prevent decompression sickness. For our space settlement, the airlocks are going to be located on the top part of the cylinder internally. The top is open always, so the spacecraft can come in and out anytime. Therefore, the pressure and air will always be zero. Once the craft enters, they will be placed on one of the eight of docking spaces, where the walls will come up to completely seal that particular region. Then, the chamber will be pressurized and supplied with air, so that people can get off from the rocket when they reach the center floor. Therefore, it will help to minimize the air loss at each use, because only the particular docking stations that are used will be closed. Each level of the central cylinder has a height of 40 m and a diameter of 100 m, resulting in a volume of 1570795 m3 (each floor with no air/pressure has radius of 50 m and height of 40 m). When the doors opening directly to outer space are opened, air will be lost.

4.5 Tourism

There will be hundreds of tourists visiting Columbiat at a given time. To make the visitors feel comfortable, there will be a lot of accommodations provided: information centers, hotels, restaurants, shopping malls, transportation and communication agencies, and convenient stores.

Information centers will have guiding agents who will be able to help visitors any time. Guiding agents will guide the visitors to hotels and restaurants if necessary. The major goal of the information centers is to show the different aspects of the space settlement. The information centers will be located at sites easily seen.

Various businesses on the station will attract the visitors with a variety of services. There will be various kinds and qualities of hotels and restaurants. Visitors may choose the different sizes of rooms, depending on their affordability. Variety of restaurants will be offered, such as Chinese and Italian.

To control the flux of visitors entering and exiting the station, Columbiat will have some security measurements. Each visitor should have a specific purpose of visiting, and they should be identified through networks with other space stations. History of visitors will be kept in the database including their health information and insurances. Each visitor will be given an ID which allows Columbiat to identify their location; however, for privacy, the specific information about the location will be limited to the street the visitor is on or the name of the building he or she is in. IDs will provide health information and the current condition of the visitor.

Information centers will be required to educate the visitors with basic safety rules. In case of fire and other disasters, all automatic systems (i.e. elevators, escalators, and automatic doors) will be shut down and the manual system will be turned on. Emergency lights guiding the way to building exit. The air pressure will be monitored all the time, and if there is a lack of amount of air it will be supplied quickly through ventilators.

In order to prevent any disease spreading, medical history of the visitors will be obtained by Columbiat in advance. If necessary, medical quarantines of the visitors will be provided. There will be hospitals and pharmacies.

4.5.1 Security

As one of the first space settlements, legal and governing issues will arise quickly. The most efficient way to model the government is to balance the civilian residents, the business interests, and the interests of the investors on Earth. In terms of internal legal issues there will be a law code established by a representative assembly of the residents on the settlement that will be written before they embark for the settlement. Furthermore, a system of courts will be established that will have the supreme responsibility of creating precedents of how law differs on a space colony compared to law on Earth. Because of the nature of a space settlement, the law will need to be able to adapt to changing needs. Particularly important is enumerating the jurisdiction of courts in the settlement itself. The most effective way to deal with jurisdiction is to set up a system of lower courts to deal with everyday problems, a system of appeals, and a supreme court that deals with problems not resolved by the lower courts. Also, the Supreme Court will rule on legal battles of space expedition outside of the settlement, and will hear cases that deal with Earth-based interests bringing suit against interests based on the settlement. Accounting for the size of the colony, there should be a council based governing system. Anyone should be able to campaign to be on the council, but there will only be a given number of council-men. The council will be led by an executive, who will be referred to as the "Governor" of the settlement. The council will have a representative for each thousand people on the settlement, beginning at about twenty-two. In addition to the elected council-members, there will be two correspondents from Earth and a representative from Northdonning Heedwell that have voting power on the council. The founding constitution of the government will be adopted via a referendum of all of the citizens on the settlement; furthermore, any amendments will be passed by the referendum.

The high value of the settlement makes security and safety a priority. Therefore, there will be two organizations to ensure the security of business interests and the safety of the people. The first is a civilian based police force that will deal with everyday concerns among the civilian residents of the settlement. The second is a professional military organization that will be at the direct disposal of the governing council. The reason for a professional military is that military expansion into space is inevitable and it is our prerogative that the citizens of our settlement will be able to protect themselves. In the future, the value of space settlements will rise as resources on Earth are expended, so exploring and understanding military capabilities in space is becoming ever more important. Military technology often drives innovation and essentially opens up new markets for exchange of ideas in cyber-space and space warfare. One aim for the military organization is to drive investment from Earth and otherwise because the potential for new fighting technology in space is ever-expanding. At first it will be primarily experimental, but as costs decrease and the need for a military increase, the production of military space-craft will be at our disposal. Eventually military ships in space will be important in claiming new territory in the solar-system, protecting mining sites, and protecting the main settlements.

5.0 Automation Design and Services

Many computers and robots will be needed in order to construct, maintain, and expand Columbiat. Even though much of the construction and maintenance will be automated, there will be some manual labor involved in tasks that cannot be automated. Some construction materials will be transported from the Earth, the Moon, and the pre-existing settlements.

5.0.1 Computer System Characteristics

The station will be equipped with six servers; three of those servers will serve as back-ups. Individuals will have their own personal handheld-computer devices which can be connected to a larger screen and used to access the system. There will be approximately 12,000 personal handheld devices and 20,000 laptops for office use and visitors. Only the laptops will have CD/DVD drives that can be used to transfer data to and from an external storage device. Wireless routers will be located throughout the station to connect to the network. All of the data will be stored on the servers specifically assigned to individuals. Accounts for children will be much more limited than those for adults. These computers will have all the software necessary for office work and data protection.

5.1.1 Automation for Transportation

Before beginning the construction of Columbiat, some modular lunar faculties will be built for the purposes of constructing smaller parts and gathering materials. These hemispheric lunar facilities will be constructed from lunar soil and each facility will have its own automated launching and landing site. Along with these lunar facilities, construction materials will be transported from Alexandriat and Bellevistat. The ships leaving from the two stations will be automated using their current launching systems.

5.1.2 Delivery of Materials

Materials will be delivered to the construction site from lunar facilities using transportation shuttles designed specifically to carry pre-constructed parts. These construction ships will also carry robots and various other tools to the construction site; some ships will also provide space for the workers to live during the earlier phase of construction.

5.1.3 Interior Finishing

Interior house finishing will consist of painting, carpeting, and tiling the floor. Rooms will be decorated according to their purpose; for example, kitchens and bathrooms will have tiled floors rather than carpet. The windows on the exterior will be made of lunar glass which contains sufficient amounts of lead to provide protection against radiation; windows on the interior will be made of regular glass.

5.1.4 Chart describing Construction Robots

Task	Robot
Welding on exterior and interior	Weldo
Installing Windows on interior	POD
Transporting Materials inside the station	Transporter
Flooring: Tiles	PO

*These robots will be transformable, meaning that once the work on the outside is complete, their thrusters can be taken off and tires can be installed so that they can be used to finish the interior.

Weldo: This robot will be used to weld materials on the exterior surfaces of the station. Around 12,000 Weldos will be needed. These robots will be powered by ion thrusters and will be controlled remotely from the inside of the construction shuttle or station.

Transporter: This will be a heavy-duty robot to transport materials inside the station. It will be programmed to deliver their load to specified locations; once there, robotic arms will take off the cargo from transporter. It has an electronic motor, which runs on rechargeable batteries, as its main source of propulsion.

POD: This robot will mainly be used for holding materials in place while Weldo robots weld and hold windows and doors in place. As mentioned above, the thrusters will be removed and tires will be installed to make it work on the inside.

5.2.1 Backup Systems and Contingency Plans

The station may be susceptible to external damage due to collisions with foreign bodies moving at speeds fast enough to penetrate the outer hull. Small meteoroids pose little or no threat to the Earth because most of them burn out in the atmosphere due to friction, but since there is no friction in outer space; therefore, no forces will be present to slow them down. Objects as small as 10 g, upon collision with the station, may cause a pressure wave harmful to anyone in the vicinity. Even though the probability of colliding with a major asteroid is very small, the station will be equipped with radar and rockets. The radar will use radio waves to detect any approaching objects and calculate their relative paths and speeds. If the approaching objects pose a threat to the station, computers will be used to perform exact calculations to fire the external chemical thrusters (see section 3.4.2) to change the course of the station or release rockets to destroy the looming objects. The station will be equipped with two types of rockets so that the course of the station can be changed, if it is not permissible to destroy the approaching objects; however, if it is permissible to do so, controllable rockets that carry kinetic star-like penetrating devices will be used. During the flight, they line up one after another at an optimal distance, and in such an arrangement penetrate into an asteroid. These rockets will be located all around the station so that oscillatory motion is avoided during the launch.

Additionally, the continuous use of ion thrusters around the outer torus will result in the ionization of the area surrounding the station, providing effective protection against any charged particles that could pose a threat.

One of the main components that will be outside of the station and may need to be repaired is the solar panels. A special robot that can be controlled from the inside of the station will accomplish this task. The robot will be able to replace one solar panel at a time. There will be space for holding a new solar panel on the top of the robot and a space for holding the old solar panel being replaced on the bottom. Since the station will be rotating, the robot will "walk" on the tracks along the solar panels designed specifically for the robot. The robot will be equipped with four arms. The two smaller arms will be used to tighten or loosen the screws for solar panels and the larger arms will be used to replace the solar panels. A laser will be employed to align the robot into the proper position. For its movement outside of the station, the robot will be equipped with four thrusters on the back.

All repairs on the inside will be conducted manually, and where appropriate, automatic tools will be enhanced. Robotic arms and earth-like small scale construction cranes will be used to lift heavy objects. There may be "bugs" in the distribution system (see section 5.4) which might lead to deliveries to incorrect addresses. For such packages, the barcodes of the packages will be re-read. If there is a discrepancy, the proper personnel will be notified and an official will be dispatched to fix the problem. A sample code will be given to the officer to check for scanner accuracy. Once the problem has been identified, the malfunctioning scanner will be either repaired or replaced.

5.2.2 Location of Computers and Robots

All the robots that are to be sent to work outside the station will be located in the cylinder because of the available low g environment and openings to the outside. All other robots will be located in their appropriate storage compartments next to their respective work areas. There will be several storage spaces throughout the station that contain tools to make small on-site repairs. Critical medical equipment such as defibrillators, stethoscopes, electronic thermometers, glucometers, etc. will also be available at several locations around the station.

5.2.3 External Robot Durability

All repairs on the outside of station will be performed by remote-controlled robots. On the inside, repairs will be done manually, and where appropriate, use of automatic tools will be encouraged. There will be a designated number of robots that will be allowed to work along the station's external surfaces during solar flares; if these robots get damaged due to flares, they will be discarded and replaced. These robots will have electronic systems durable enough to survive a massive influx of high energy particles. Like satellites, these robots will use semiconductors based on silicon-carbide substrate rather than plain silicon. The silicon-carbide based chips are much more robust and can handle a much wider range of operating conditions (in temperature, vibrations, etc.). A modest amount of shielding will also be provided for the robots. These robots will also have built-in redundancy. Repair robots will use multiple simultaneous pathways to duplicate each calculation or each bit of information at least three times. If a random error occurs, it will most likely not affect all of the pathways at the same time. So, if one of the data streams is not in accord with the other two, it will simply be ignored. We will also employ error detection and correction techniques, such as convolution and Reed-Solomon codes which not only detect errors in a stream of data, but can also fix the error and recover the original data. Along with all these measures, we will properly ground the robots so that any induced current is properly dispersed without damaging any devices. Before sending out the robots out for work, station operators will make sure that the functionality of the station will not be hindered due to their loss.

5.2.4.1 Authorized Personnel Access to Critical Data

In order to ensure that there are secure and safe computer operations, the station will have two servers. One of them will be used on daily basis and the other one is to be kept as a back up during emergencies. Regular checkups will be conducted to ensure proper functionality of both servers. As for accessing critical information, only certain personnel will have access to any information pertaining to the operation of the station. If any actions, concerning the safety of residents or the station, such as changing the course of its orbit, are to be taken, there must be a consensus between authorized persons. All the authorized personnel will have swipe cards and passwords. These authorized personnel only need their own swipe cards and passwords in order to make minor changes such as changing the atmospheric pressure, composition of air, etc. inside the station. But, if the task is grave, as mentioned above, they would need to have a consensus among them and they will electronically sign the agreement by swiping their cards and entering their passwords. All the information about any personnel logging into the system and making any kind of change will be recorded and periodically reviewed to make sure any unauthorized personnel are not accessing crucial information.

5.2.4.2 Emergency Robot Commands via Personnel

As for access to robotics and command computers, same security procedures, as mentioned above, will be implemented. The only difference will be that more inhabitants will have access to these than to the crucial information concerning the station. For example, robots that are to be used for agricultural purposes, all authorized workers will have access to them. These workers will also have access to command computers controlling tasks such as watering time, pesticide spraying, etc. The only time, there would need to be a consensus is when sending the robots outside the station during a solar flare or other harmful environment.

5.2.5 Minimum Requirements

Task	**Robot/Computer**
Repairing Solar Panels	Solar-Cleaning Robot
Monitoring approaching objects	Radar
Maintenance of station: Course calculations, environment control, processing log-in information, releasing ion-thrusters, etc	Server 1-Devoted to operations of station
Robotic Control	Computers located in the warehouse control center
Tightening or Loosening of nuts/bolts, drilling holes for nuts/bolts	Automated-Attachable Vice-grips, electronic drills
Cleaning Floors	Roombas (See Section 5.3.1)
Cleaning Showers	Automatic Shower Cleaners (See Section 5.3.1)

Monitoring Levels of Atmospheric Gases	Gas Detectors, Smoke Detectors
Temperature of Nuclear Reactors	Electronic Thermometers
Harvesting	Harvester Robot
Slaughtering/Processing live stock	Slaughter Machine (Similar to Earth)
Egg harvesting and processing	Poultry System (Similar to Earth)
Photovoltaic Cells	Direction changed by motors
Water Treatment/Distribution	Volume distributed, monitored by computers, treatment include UV radiation etc.

5.3.1 Maintenance and Routine Tasks

The station will need to be kept clean to provide the inhabitants with a healthy atmosphere. To do so, we will have roomba type vacuums to clean the floors and automatic shower/toilet cleaners to clean showers and toilets. There would be an established cleaning time for each section of the station and if needed, the residents will be asked to temporarily leave the area to be cleaned. Then, the roombas will be released to vacuum the floor. Similarly, the toilet/shower cleaners will be set up to automatically clean the showers and toilets at specific times. These shower cleaners will spray a cleaning solution in all four directions, followed by a rinse with water. The same procedure will be employed for toilets.

Water leaks will not only cause wastage of water, but also cause internal damage such as rust and flooding in the station. To prevent water leaks, water pressure at various places in the station will be monitored. Computers will calculate the theoretical pressure that should be at a specific location and then compare it to the actual reading from the sensor. If there is a significant difference, a maintenance person will check for leaks and fix them. Also, since nuclear reactors will be on board, we will need to closely monitor the temperature of the helium gas, control fission rates, etc. We will have electronic thermometers in the surrounding water that feed the readings to a computer, which will take any actions necessary. The computer will control the reaction rates depending on how much electricity is being consumed within the station. If a reactor functions abnormally, the computers will shut down the reactor and a thick protective casing will be put on the reactor.

We will also need to monitor the atmospheric gas composition of the station, since improper levels of certain gases can be hazardous to human health. Several sensors to detect different gases will be installed so that any fluctuations in the levels can be caught and corrected.

5.3.2 Reduction of Manual Labor

As there will be many monotonous and strenuous tasks on the station, it will be necessary to automate as much as possible to reduce the amount of human labor. One such task is the upkeep of crops. They will need to be planted, watered, and harvested. To plant the crops, we will use remote-controlled mobile robots. They will have four wheels to straddle the rows of soil, and one in the back to smooth out the top of the rows. Each one will have a compartment for seed storage as well as a small scoop to dig out the top layer of soil. These robots will be filled up with a certain number of seeds depending on the needed amount of crops and the space allotted. They will travel down the rows, scoop up an amount of dirt (the amount varies with the type of crop), drop one seed, and then put the dirt back down. The robot will roll on to the next spot, and as it does, the fifth wheel in the back will roll over the previously planted areas, smoothing out the rows. Since the different crops will require different lengths of space between the individual plants, the robots' wheels will be programmed to make a certain degree of rotation between planting. Once the robot reaches the end of the row, the remote control will be used to put it in reverse and bring it back to the beginning of the row, where it will be shut off and stored until the next time for planting.

The next part of the crop phase is watering. We will use a system of pipes to spray water equally over the crops for varied lengths of time, depending on the needs of the particular plant. A timer will be employed to control the intervals between the watering times and how long the water stays on. Again, these times will vary, due to the changes in crop types. And in case of a failure, there will be pressure sensors in place to recognize any major changes in water pressure (see section 5.2).

The final stage of the crop cycle is harvesting. To do this, we will use several different machines that have two blades and two bins, one of each on each side of the machine. The robots will have three wheels, and will travel between two rows, so they can harvest two rows at one time. The blades will spin constantly, and after they slice through each plant, the plant will fall down into the container below. After the robot finishes harvesting one row, it will also have a remote control function so an overseer can turn off the blades and turn the robot around. The robots will return, deposit the crops into large bins, and from there they will be properly stored.

5.3.3 Privacy of Personal Data

The general public will have access to computers on the station and the assigned server through their accounts, which will be created upon their entrance in the station. The residents will be given electronic chips (swipe cards) along with their own passwords, which they will use to access computers and various other facilities in the station. Individuals on station will have their own network accounts accessible directly form their laptops or portable devices, which will enable access to all personal files and data, as well as specific applications, communications and network capabilities depending on account level. This account will also carry all important information on health, employment, residence, etc. and will serve as identification throughout the station. Not all the residents will have access to every application available on the computers. For example, a student will not have access to any of the programs that office workers use; if one wants to add any program to his account, he will be expected to submit a request, and authorized personnel will make a decision.

5.3.4 Community Computing

Individuals will be able to use their hand-held devices (see section 3.2.6.1) and laptops/computers to access the system network. Almost all of the connections made to the system network will be through the wireless network but there will be a wired network as a back up. If any outside computer is to be used to access the network, it must be configured to meet the requirements to connect to the network. Any outside computers will be scanned for viruses and Trojans before allowing access to the system network. (see section 3.2.6.1 for wireless network)

5.4.1 Unloading and Loading

The central cylinder of the space station will be the location in which all visiting ships will arrive, load, and unload. Both the loading and unloading processes will occur in the side hangars, and will involve both automatic and human-powered procedures. However, the main concern with these processes is that they will have to be carried out in a microgravity environment. For this reason, we will use a system of cables to carry the cargo around the cylinder. Workers will load the cargo from the ships onto the cables, and from there the cargo will be transported along the cables to the first of two warehouses for temporary storage. Manual labor is necessary for this first step because of the different sizes and shapes of the cargo. The overall unloading system will be very similar to the luggage system currently used in airports.
The system to load the cargo back onto ships will be much like the unloading process, but in reverse. The outgoing cargo will be taken from the second warehouse and placed on the same type of cables. Manual labor will again be used, for the same reasons of varying sizes and shapes of packages. After workers load the cargo onto the cables, the cables will carry them into the docked ship, where more workers will unload the cargo.

5.4.2 Inventory Management

The cargo coming into the settlement will be first sorted according to its destination using the bar code found on the package, which is divided into sections. The first section of the barcode will specify whether the cargo is incoming or outgoing. The second section will determine the final destination of the package. For the incoming packages, this will specify to which torus the package is traveling and for outgoing packages, this will specify to which port the package is traveling. The next section of the barcode will specify one of the four sections of each torus to which the package is headed. However, there will be no equivalent in the outgoing cargo for this section of the barcode. The next section will specify the contents of the packages so that proper storage techniques can be employed. Finally, there will be an urgency section of the bar code, which will specify how urgently the station needs the item (e.g. a 10 for fresh water, versus a 2 for clothes).

5.4.4 Automated Cargo Handling Systems

After the packages have been sorted according to their destination, they will be placed on maglev trains that will transport the cargo to the necessary torus and section. These sections of the tori will encompass a depot, in which all the packages will be placed. In order for residents to obtain their needed packages, they will travel to the depot where they will use their ID cards to pick up whatever supplies they are allotted or need to do their work.

5.5 Robot Repairs

For the cleaning and maintenance of robots, one major concern in the space dust that would accumulate in many of the nooks and crannies of the robots. This dust clings to objects for various reasons from the structure of the particles with its many jagged edges that can get caught on objects to the slight charge of the particles. These ferrous particles cannot be removed by any normal cleaning methods.

Based on the size of the robot or object to be cleaned, we could use one of two different ways to clean them. One way to remove space dust from very large robots would be to use an electric curtain which would take advantage of the slight charge of the particles to remove them. The curtain would be simply a series of parallel copper wire that would act as electrodes and pull the dust from the machinery. This removed dust could be melted down with the use of microwaves to be used later to create new parts for robot repairs or any other constructional need.

We could foresee problems with smaller, more complicated robots that do not have only smooth surfaces and cleaning them with a curtain because they would have more small nooks and crannies that the dust could get stuck in and the curtain may not be able to remove all this dust well enough. For this we would melt the dust particles while they were still on the object with a microwave source. This would be done in a large centrifuge built to for robot cleaning. The centrifuge would spin fast enough for the molten iron to separate from the object and run down the walls of the centrifuge to collect two receptacles at the bottom of the centrifuge. The robots would be secured near the center of the centrifuge with cross harnesses. This centrifuge would be large enough so that 4-6 robots could be cleaned in one run.

To prevent spread of the lunar dust and other contaminants from the ships, we will include a preliminary cleaning of all ships. The ships will be cleaned very quickly with our electric curtain method in the initial docking area. This will ensure that none of the space dust will find its way around the station. The initial docking area will be self-contained so that the spread of dust can be limited. Robots on the other hand will not be cleaned in this area and will have to be sent to the inner torus to be cleaned with our centrifuge method. To limit the spread of dust the robots will be transported in closed containers that are able to be cleaned easily with our electric curtains if contaminated with dust. After all of the robots have been properly cleaned, they will stay in this area of the inner tori for maintenance and repairs.

6.0 Schedule and Cost

6.1 Construction Schedule

Northdonning Heedwell will approach the construction in three main phases: the first for the inner cylinder, the second for the inner torus, and the final for the outer torus. While the cylinder will be constructed floor by floor, the construction of the tori will be divided into twenty-four subsections, with each piece containing 15° of the full circle. According to estimations, the time from the reception of the contract award to the first citizen arrivals should be a little more than fifteen years. The entire population should in the station by December 2062.

Deadline date	Event
May 7th, 2044	Contractors receive contract award
October 2044	Minimum docking and airlock structures completed
April 2045	Entire central cylinder completed
October 2045	Spokes constructed to the farthest edge of the inner torus
October 2049	All twenty-four sections of inner torus assembled and transported to site
April 2050	Sections of inner torus connected and attached to spokes
October 2050	Spokes to the outer torus completed
October 2056	All twenty-four sections of outer torus assembled and transported to site
June 2057	Sections of outer torus connected and attached to spokes
October 2057	Suitable environment and life support established
December 2059	Residential communities constructed and ready for arrivals
December 2062	Estimated population of 20,000-25,000 settled into homes

6.2 Occupation Schedule:

Phase	Description
A	As construction continues, a variable amount of personnel in charge on construction will be on-scene, in space in order to oversee the process.
B	After construction of Columbiat's life support systems, approximately 2,500 employees and staff will board the station. This group will be necessary Foundation Society employees, as well as operational engineers to install and test all infrastructural systems.
C	Once Columbiat begins to achieve self-sufficiency, private business and investment employees will board the station. These personnel will prepare for the arrival of their workforces. This phase will contain approximately 4,000 workers, and during this point the process for acclimating residents to the space environment will be perfected. In addition, a small number of cargo ships will begin to travel to Columbiat.
D	All employees from companies on Columbiat will come aboard, considering the number of people in this process; it will take multiple voyages between Earth and the settlement. Each group of voyages will contain 4,000 to 5,000 residents.
E	The families of workers already aboard Columbiat will join them. Columbiat will reach the full initial population estimate of 22,000 in this phase.
F	The final phase of occupation will consist of any residents not already on board the station In addition, this phase will include tourists coming to the settlement, as Columbiat gets accustomed to tourists coming and going from the settlement. In this phase, Columbiat will attain self-sufficiency, and assume its role as an economic and financial hub.

Employee Task	Quantity of Employees
On-site construction of exterior	1,200
Material transportation	150
Engineering	1,100
Construction of transportation system	250
Installation of communication system and networking	1,000
Nuclear plant operation	500
Construction of water treatment facilities	200
Construction and expansion of commercial sector	1,000
Medical response, law enforcement, etc.	2,000
Business	6,000
Technology maintenance	3,000

Altogether, the final cost of the Columbiat is will be $150,833,943,000 USD.

Expense	Cost
Exterior of central cylinder	$99,765,000
Exterior of inner torus	$1,142,062,00
Exterior of outer torus	$2,284,124,000
Employment for construction	$149,659,000
Launches	$31,500,000,000
Agriculture	$2,450,000
Water and waste treatment facilities	$23,118,000
Power generation	$9,2500,000,000
Communication devices and systems	$14,000,000
Schools and education supplies	$82,000,000
Human and goods transportation systems	$1,203,000,000
Residential facilities	$1,840,000,000
Commercial facilities	$2,760,000,000
Recreation	$5,000,000,000
Landscaping and biodome management	$7,000,000,000
Automation of construction	$5,117,040,000
Station maintenance	$187,032,000
Computer resources	$12,250,000
Total	$150,833,943,000

7.0 Business Development

Columbiat, as a "Singapore-in-Orbit", will be an economic hub with ever-expanding business opportunities and unmatched potential for expansion. It will provide prime space for Headquarters of not only the Foundation Society, but also all major business ventures into space. There will be ample room for development, and the financial sector will have free-flowing capital for new and innovative entrepreneurial efforts. Conservative estimates of area for business and finance will allow at least doubling the size of the financial sector within a decade because of the abundant area in the Columbiat's outer torus.

7.1 Cargo handling

Columbiat will be a major commercial and industrial shipping hub. The cargo handling system on the station will be able to handle the incredible amounts of cargo that will come through the station. Because Columbiat is a major shipping hub, both outgoing and ingoing wares and materials will need to be handled on this station.

7.1.1 Terminal Facilitates to handle Space Traffic

The station will feature an elegant and luxurious terminal for passenger transit. This terminal will be equipped to handle large amounts of passenger volume, which will increase as more settlements are constructed and populated. The facilities will provide for every need of the sophisticated traveler, offering hundreds of dining and entertainment options. A plethora of activities will be made available to short and long-term visitors.

7.2 Office Space

Columbiat will provide much needed office areas for early entrepreneurial ventures in space. As a growing urban center, the office facilities on Columbiat will serve various purposes. The primary purpose for office facilities is as an administrative center where the Foundation Society and major corporations can move their headquarters to for in-space operations. Although Columbiat will not be the focus of heavy industrial production, the formation of office facilities will be to make Columbiat a center of trade. The physical office facilities on Columbiat will be the newest and most advanced facilities possible, and given the slowly growing emphasis of space colonization, the offices will provide a flexible environment for new business. The financial sector will be on the outer torus between the two residential areas. This will provide sufficient space for administrative offices as the settlement opens, as well as area for expansion as new business are created in space and the growing opportunities draw new investment. The outer torus appropriates 59% of its area to commercial and residential real estate. The actual set-up of the offices is at the discretion of the owners of the property. In order to facilitate its purchase, all offices will have adjustable and movable walls, so that the floor plan may be changed and adapted to changing needs. The businesses that have already expressed interest in placing their offices on the Columbiat will have the opportunity to design their real estate as soon as they sign their contract with Northdonning Heedwell. The upper third of the outer torus will be divided into ten floors of ten meters in height each.

7.3 Facilities for Banks

The on-board banking system will be established with an infrastructure similar to Automatic Teller Machines. Monitors will be placed around the station where people can access their accounts with use of their Columbiat ID card and pin number or password for their account. No paper money will be used on the station, but instead, the ID cards for citizens of the Columbiat and their pin numbers will allow citizens to make purchases in a method similar to the credit card system on Earth (but not necessarily based on a credit system). The ID cards will be compatible with all on-board banks so that citizens can hold multiple bank accounts with their single card. The ID cards will be called the "Maverick" cards. As tourists and ships crews enter the Columbiat for the first time, they will be issued ID cards based upon their level of clearance.

7.4 Provisioning and Maintenance for Visiting Spacecraft

All spacecraft will dock in one of two docking stations located at each end of the cylinder. All maintenance and needs of the ships will be fulfilled within one of sixteen docking ports within the hubs.

7.4.1 Fueling Services and Space Traffic

Columbiat will be equipped to handle sixteen spacecraft at any one time, eight passenger vessels and eight cargo vessels. The passenger craft docking and cargo craft docking are located on opposite ends of the cylinder. For each of these spacecraft holding facilities, automated systems will accustom all passengers and cargo. All ships will be refueled and restocked once moved from the main docking hub to one of the sixteen storage facilities.

7.4.2 Maintenance and Routine Care of Spacecraft

The initial docking area will be self-contained so that the spread of debris is limited. All incoming spacecraft will be cleaned very quickly using the electric curtain method in the initial docking area. This will ensure that no space or lunar dust will escape from the decontamination areas in the station. Extensive steps will be taken in order to ensure incoming personnel safely and comfortably adjust to the station. Incoming personnel will be readjusted from the zero gravity environment experienced during travel to the normal gravity environment by living for one day at half gravity in the inner torus. This time at a reduced gravity will ensure that all incoming personnel experience no physical problems in adjusting to station life.

7.4.3 Excess Agricultural Production and Storage

Columbiat will produce an abundance of food to ensure that all visiting ships may be provided for. The storage and transportation of the food will be highly efficient because the agricultural section of the outer torus will be connected to the cylinder with a dedicated transportation spoke. Local food storage will be located in the cylinder, but the amount of food being produced will be carefully planned in order to reduce excess food.

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