Columbiat

University High School
Irvine, California
USA

21st Annual International Space Settlement Design Competition
Proposing Team Data 2014

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Names, [grade levels], and (ages) of 12 students currently expecting to attend the Finalist Compe
(we request that participants be at least 15 years old, and not older than 19)

Al Chang [12] (17)	Alex Chung [10] (15)
Taehun Kim [12] (17)	Aurnov Chattoadhyay[10] (15)
Kristina Shia [12] (17)	Harrison Ku [10] (15)
George Hu [12] (17)	Josh Jia [10] (15)
Jein Park [11] (16)	Sandeep Kambhampati [10] (15)
James Gui [11] (16)	

Names of two adult advisors currently expecting to attend the Finalist Competition:
Mr. Chang   Mrs. Son

I understand that if our Team qualifies for the International Space Settlement Design Finalist Competition July 25-28, we will be expected to finance our own travel to/from Titusville,

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Responsible Teacher/Advisor Signature	Date

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University High School ISSDC 2014

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Tiffany Huang
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Andrew Park
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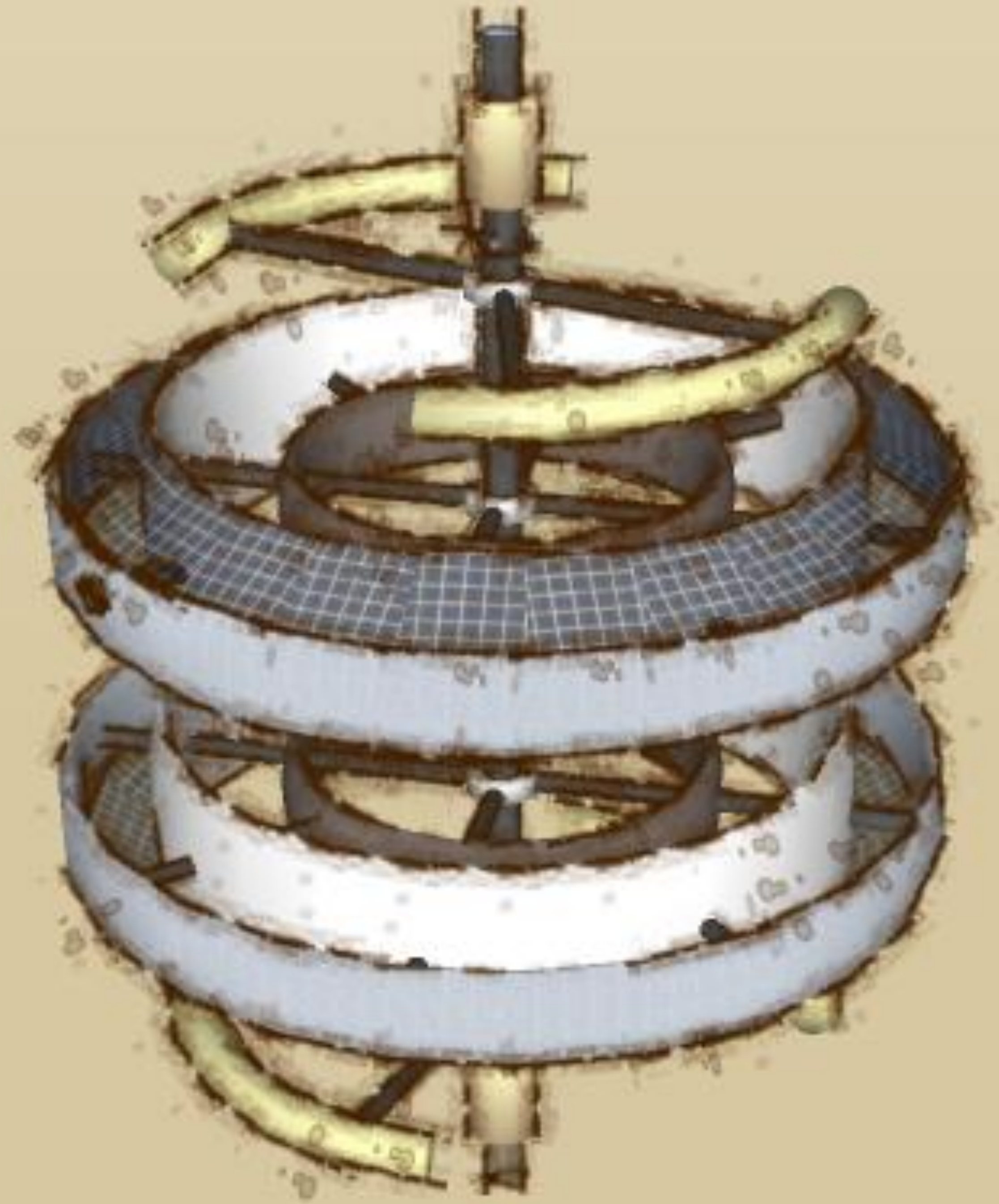
Alex Chung
Josh Jia
Sandeep Kambhampati
Harrison Ku

1.0 Executive Summary



1.0 Executive Summary

Outer space has always been a place for exploration – not only just for new materials, but also for new areas of technology and innovation. At Columbiat, we actively guide both areas of exploration.

One of the most notable features of Columbiat is its groundbreaking success at implementing a fully functional space elevator. The space elevator extends all the way from the settlement to the surface of the moon, which will facilitate transport between moonbound settlements and Columbiat. This feature is integral for Columbiat's functioning as the ideal "Singapore -in-orbit" - a center of commerce and entrepreneurship in space.

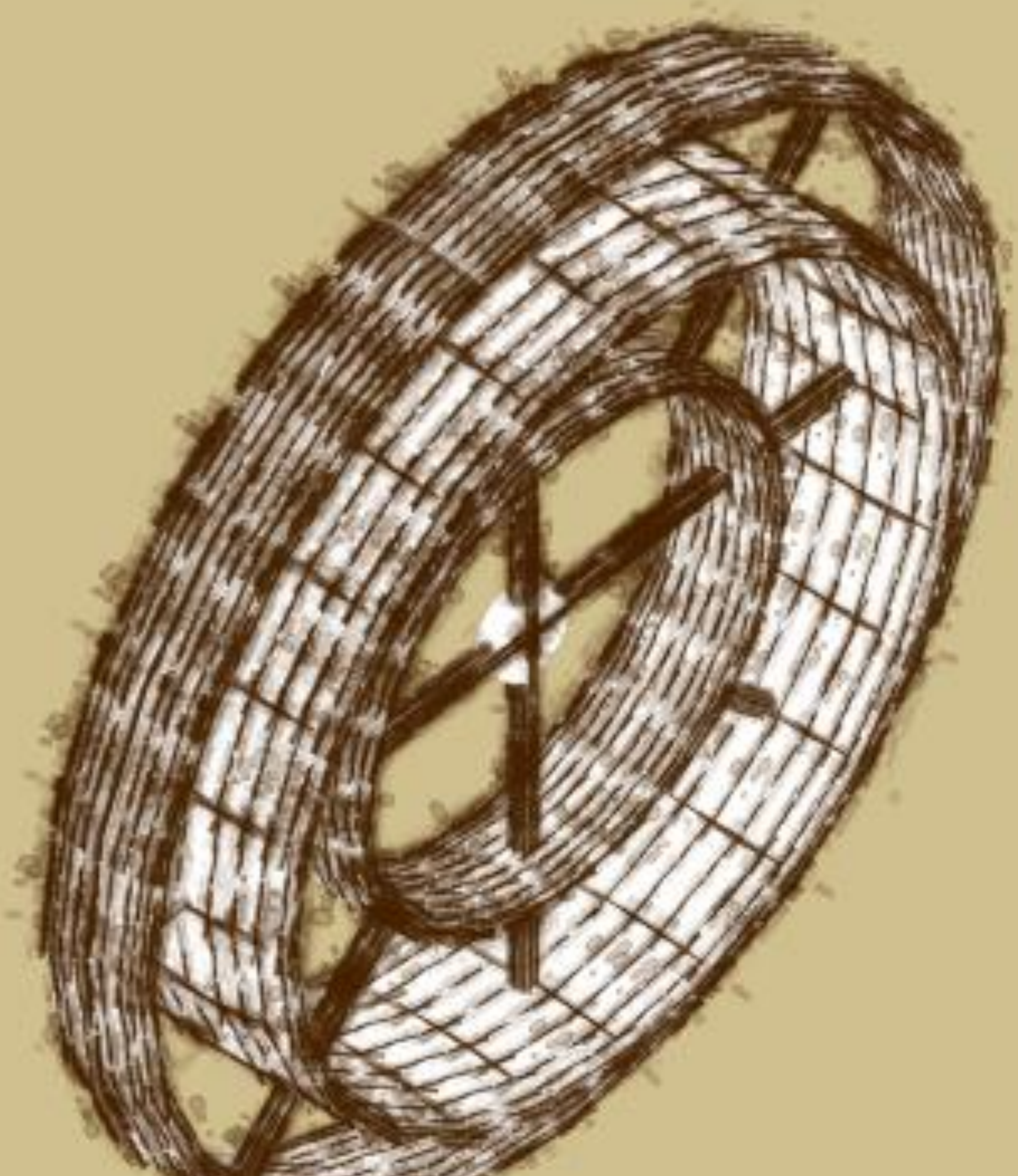
At Columbiat, we also strive for technological innovation. Throughout the settlement are a variety of new technologies that serve to make the lives of the residents easier. Columbiat ensures that its residents are comfortable in by:

- Providing a safe and pleasant living environment (including natural views of the Earth and the Moon) for both full-time and transient populations
- Developing facilities and infrastructure necessary to build and operate the settlement and its communities at the maximum efficiency level
- Maintaining a high quality of life, which includes accessible food, comfortable housing, access to entertainment, and natural sunlight
- Building a variety of information processing systems and robots that will store data securely and improve the overall efficiency of the settlement
- Hosting various commercial and industrial ventures, including three very specialized types of ports (one for raw materials, one for passengers or cargo, and one for ship maintenance)

Columbiat provides a place where people, as well as businesses, can thrive. Not only do the efficient technologies and innovative designs add to the overall convenience of the residents, but the variety of ports and the encouragement of foreign trade also improve the commercial and industrial aspects of the settlement. Although Columbiat may have humble beginnings, it will succeed because of its focus on both the residential and the industrial sectors.

At Columbiat – the settlement of the future – one can succeed.

2.0 Structural Design



SECTION TWO: Structural Design

2.1.1 Settlement Description

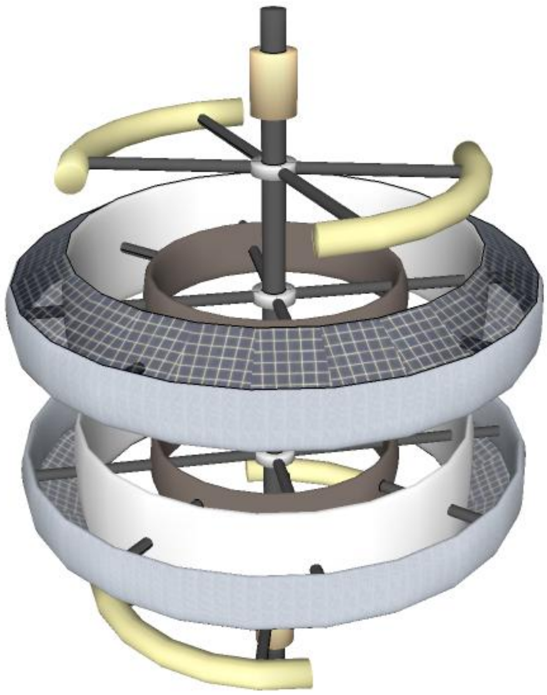


Figure 2.1.1 Settlement Overview

The Columbiat Settlement has ten major separable volumes and two additional docking stations, all located along a long central axis. Six of these volumes are large concentric tori arranged in two central tiers of three tori each. Tier 1 (containing Epsilon, Zeta, and Eta 1) rotates in the clockwise direction and Tier 2 (containing Epsilon, Zeta, and Eta 2) rotates in the counterclockwise direction, both at the speed of 1.025 revolutions per minute. In each tier, there are 8 radial spokes that connect the three concentric tori, making transit between the different tori much easier for our settlement's residents and visitors. The four other volumes are quarter-tori that spin in pairs above and below the central tiers. Beyond these quarter-tori, there are two docking stations (Beta 1 and 2) located at the ends of the central axis.

The 0.50g tori (Epsilon 1&2) at the center of both tiers are dedicated to business and storage purposes. The close proximity of these tori to the central axis allows for easy movement between the two regions. Supplies and materials that arrive at the docking stations can easily be brought to Epsilon via the central axis, and the banks and storage facilities in Epsilon can quickly process all transactions. These tori also house sub-earth level gravity research facilities, and high-end entertainment parks that take advantage of the inner tori's low gravity.

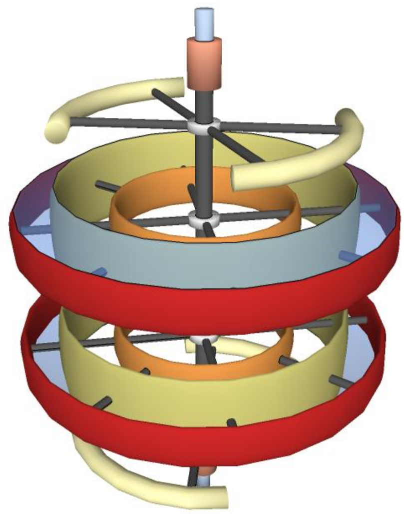


Figure 2.1.2 Settlement recolored for clearer understanding

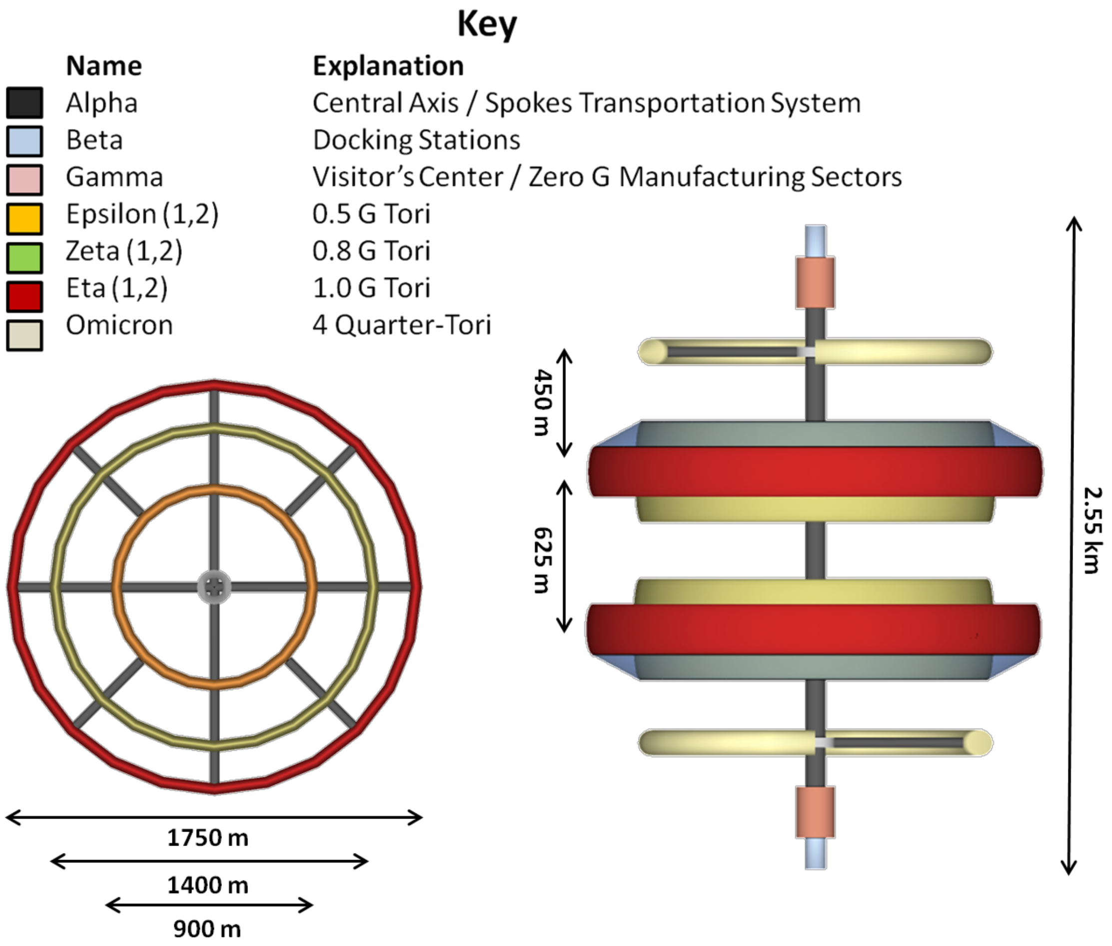


Figure 2.1.3 Settlement Dimensions

The second torus from the center and the outermost torus, each at 0.80g and 1.0g, respectively, are home to integrated residential and agricultural areas. These outer tori will also contain open areas where auxiliary construction projects and entrepreneurial endeavors can be undertaken. Radial spokes, as mentioned above, allow for quick transportation from the outer tori to the innermost tori. The uses of paired-quarter tori, which we call Omnicrons, will be expanded in the Business Section"

All separatable volumes of Columbiat will be pressurized at 1.0 atm to create an environment most similar to the Earth with the exception of the central axis, spoke transportation systems, the ports and the 0g manufacturing centers. The central axis and the spokes transportation systems will be maintained at low atmospheric pressure to maximize transportation speed between areas in need. The ports and the 0g manufacturing centers will have some facilities at vacuum to maximize the possible storage time for goods sensitive to air.

By spinning the settlement's major rotational volumes in two opposing directions, we can avoid using costly rocket-propulsion systems to maintain rotational velocity, and instead use a motor-like electromotive mechanism that spins the volumes from the central axis. The initiation of the rotation however, will be undertaken in part by small rocket-propulsion systems to minimize structural stress on our settlement. By using these small fuel-based propulsion systems, we would be able to distribute forces evenly all around our settlement and evenly exert torque about the central axis. Once our settlement's angular velocity reaches 1.00 rpm with a margin of error of 2%, we will shut down the rocket propulsion system and maintain our angular velocity by the use of our aforementioned motor-like spin mechanism. Since the mechanism is electrically powered, the rotational power output can be fine-tuned to consistently maintain the ideal angular velocity. The central axis, 0g manufacturing sections and various port facilities remain as non-rotating sections.

At the interfaces between the central axis and the spokes, where rotating and non-rotating faces meet, there is small nodule that houses the settlement's electromagnetically powered motor. This structure enables the settlement's rotation to be facilitated by dispersing the stress of the newly added angular momentum through a longer length of the spoke than just at the inner tip of the spokes.

Fluid-based resources such as water will be allocated and connected to the higher-gravity sections in a way that resembles a water tank. The inertial reactionary force that acts against the centripetal acceleration of the settlement will naturally draw the water towards the outer tori.

2.1.2 Hull Components

Due to the settlement's placement at the L1 Lagrange point, frequent impact by debris as well as harmful exposure to radiation are both factors which the following hull components will reduce the impact of for the settlers. Most components are placed in order to minimize radiation exposure of the settlers, while three meters of polyethylene foam is placed to reduce impact damage to the rest of the hull components. The following list of materials used for hull components are in order from exterior to the interior side of the settlement.

Materials (from outside)	Purpose	Thickness
Raguard	Primary Radiation Shielding	1.00 x 10^-3 m
Aluminum 7075-T6 Alloy	Structural Support, Efficient heat dissipation	1.50 m
Borated Polyethylene	Secondary Radiation Shielding	0.500 m
18Ni2400 Maraging Steel	Structural Support	2.00 m
Titanium 6.6.2 Alloy	Structural Support	3.00 m
Aerogel	Thermal Insulation	0.500 m
Water	Secondary thermal Insulation, Tertiary radiation shielding	1.00 m
Silicon Buckystructure	Gas leak prevention / Structural Support	0.500 m
Lunar Regolith	Provides Earth-like soil environment	5.00 m

Figure 2.1.4 Hull Components

Table 2.1.1 Hull Components

Columbiat's outermost hull will be coated with a thin layer of Raguard to shield the rest of the settlement from high-energy cosmic radiation. Adjacent to this outer layer will be a mesh-compound layer of aluminum 7075-T6 alloy that will act partly as a structural support for the rest of the settlement and as a heat-sink for the outer layer of the settlement if a side facing the sun were to be overheating. Encased in this layer of aluminum will be a layer of Borated polyethylene, which will further protect the settlement from low-energy radiation, and titanium 6.6.2 alloy and 18Ni2400 maraging steel will be utilized for further structural support. The settlement will be protected by layers of silica aerogel for thermal insulation, liquid water to abate temperature fluctuations, silicon buckystructures to prevent the escaping of the settlement's atmospheric gasses in case of a hull breach, and lastly a layer of Lunar Regolith to give an earth-like soil on which the settlement will be established.

2.2 Internal Arrangement

Our settlement comfortably accommodates its 25,500 residents. Taking into account each resident's spatial needs based on people's needs living on Earth, Columbiat was calculated to be ample space to provide a luxurious experience for a city in outer space.

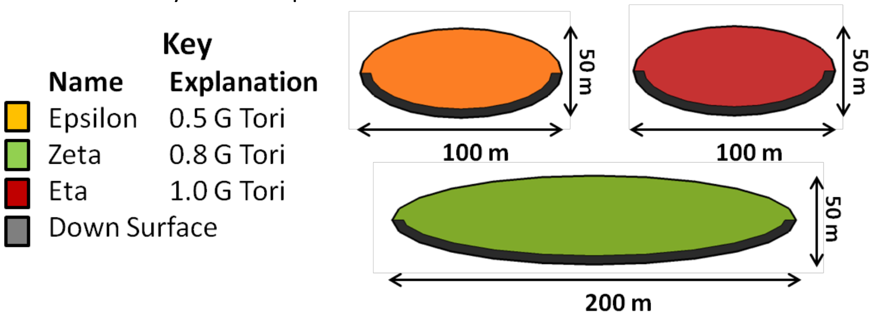


Figure 2.2.1 Cross section dimensions and down surfaces

From a Stanford study of major Earth cities, we calculated the proportion of business and agriculture present to the number of residents in each city. We assumed this proportion is the equilibrium for a flourishing and populated city, and calculated the appropriate total down surface allocation for each sector in Columbiat.

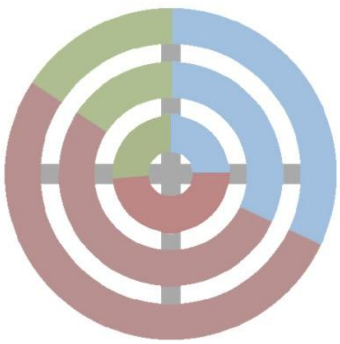


Figure 2.2.2 Percentage Allocation - Red-residential; Blue - agricultural; Green - operational

We also took into account Columbiat's unique needs. As the Singapore in space, Columbiat will have specialized business and industrial sectors that make up a significant 33% of the settlement. Because the quarter-tori are easily accessible to the ports, they will specialize in intersettlement commerce and house factories that manufacture transportable and in-demand goods.

The most habitable outer torus in each tier will have economic towers that control trade within and beyond the settlement. The Wall Street in space will be in the outer torus of Eta 1, and the both Eta 1 and 2 will house the business buildings of the resident entrepreneurs of Columbiat. These skyscrapers will utilize vertical space and thus do not dominate the down surface area of the colony.

Each middle torus will have space allocated toward both intrasettlement and intersettlement commerce, and each inner torus will have manufacturing plants that produce goods and materials needed to sustain Columbiat's residents and maintain the settlement's infrastructure. The inner tori manufacturing plants will also produce buckystructure elements that are best welded in their low gravity environment.

Despite this heavy focus on business and manufacturing, residents of Columbiat will enjoy a beautiful skyline. Our human factors division ensures that the environment in each torus is not only natural and habitable but also enticing to prospective residents.

The residential sector will take up 44% of Columbiat's down surface area. Around 47% of the allocated residential space will be in the near-Earth environment of the outer tori. Families with children are recommended to stay in the outer tori, especially since a reasonable portion of each is dedicated to educational institutions. Businessmen working on the Wall Street and in other business buildings live in both permanent housing and hotels in these tori. Hotels here are also provided for the tourists who visit Columbiat for its breathtaking skyline and its engaging recreational parks located in Epsilon 1 and 2, which they can easily access via the transportation spokes.

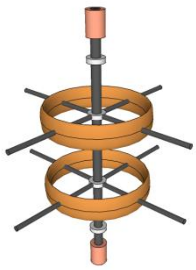
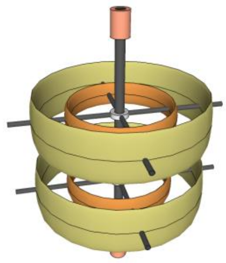
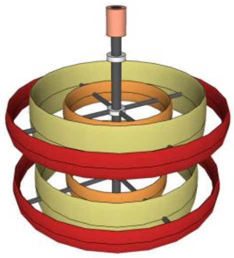
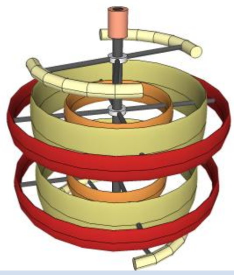
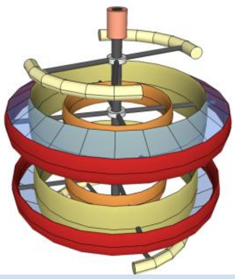
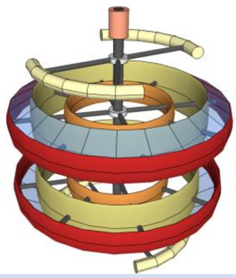
The middle tori house 43% of the allocated residential space and are reserved mainly for those employed in commerce. The inner tori has 10% of the allocated residential space and houses hotels for the 2000 to 2500 transient population who help provide the colony with manufacturing and research.

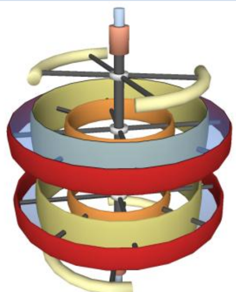
The agricultural sector is allocated throughout the settlement and takes up 15% of the down surface area. Columbiat's use of tiered aquaponics greatly reduces the amount of down surface needed per kilogram of agriculture produced. Most of these aquaponics sites are in the middle tori, though a portion will be in the outer tori to be directly accessible by the majority of residents, cutting transportation costs, and to serve as a necessary backup in case of catastrophe.

Compart-ments	Specialization	Each 1.00g Tori		Each .80g Tori		Each .50g Tori		Quarter-tori	
		Surface Area (m^2)	Allocation %	Surface Area (m^2)	Allocation %	Surface Area (m^2)	Allocation %	Surface Area (m^2)	Allocation %
Agricultural	In Vitro Food Production	63,718	2.72%	247,391	7.01%	27,876	2.45%	-	-
	Plant Growing	150,159.	6.41%	328,914	9.32%	40,847.	3.59%	-	-
	Food Processing	24,128.	1.03%	150,693	4.27%	37,548.	3.3%	-	-
	Subtotal	238,006	10.16%	726,999	20.6%	106,272	9.34%	-	-
Residential	Residences	570,184	24.34%	644,065	18.25 %	9,671	0.85%	2,431	0.73%
	Hospitals	144,068	6.15%	112,931	3.2%	24,008	2.11%	-	-
	Hotels	200,993.	8.58%	126,342	3.58%	176,363	15.5%	-	-
	Commercial Buildings	190,452.	8.13	184,573	5.23%	7,623	0.67%	-	-
	Recreational Space	228,401	9.75	166,221	4.71%	105,476	9.27%	-	-
	Schools	196,074	8.37%	150,693	4.27%	-	-	-	-
	Subtotal	1,530,175	65.32%	1,384,828	39.24 %	323,142	28.4%	2,431	0.73%
Industry & Business	Manufacturing	8,667	0.37%	44,819	1.27%	366,266	32.19 %	220,422	66.17 %
	Intrasettlement commerce	66,763	2.85%	496,194	14.06 %	103,997	9.14%	41,006	12.31 %
	Intersettlement commerce	72,620	3.10%	577,717	16.37 %	70,772	6.22%	-	-
	Entrepreneurship	287,903	12.29%	33,879	0.96%	-	-	-	-
	Refinement	5,622	0.24%	18,704	0.53%	20,253	1.78%	7,728	2.32%
	Subtotal	441,577	18.85%	1,171,316	33.19 %	561,289	49.33 %	269,157	80.8%
Operational	Storage	40,995	1.75%	43,408	1.23%	16,384	1.44%	-	-
	Transportation	54,347	2.32%	58,583	1.66%	13,653.	1.2%	-	-
	Scientific Research	13,352	0.57%	101,285	2.87%	108,662	9.55%	61,526	18.47 %
	Waste Management	24,128	1.03%	42,702	1.21%	8,419	0.74%	-	-
	Subtotal	132,824	5.67%	245,979	6.97%	147,120	12.93 %	61,526	18.47 %
Total		2,342,584	100%	3,529,124	100%	1,137,826	100%	333,116	100%

Table 2.2.1 Percentage Allocation of down surfaces per tori

2.3 Construction Process

	
Step 1 - Central spoke (Alpha) and port facilities (Beta) are constructed with internal temporary power source.	**Step 2** - Rotationary bearings are built in to allow for Columbiat's rotating structures.
	
Step 3 - Extension spokes are constructed from the aforementioned bearings.	**Step 4** - Epsilons (1, 2) and Zetas (1, 2) are constructed on their respective tiers.
	
Step 5 - Etas (1, 2) are constructed on their respective tiers and two additional bearings are constructed in preparation for the construction of Omnicrons.	**Step 6** - Omnicrons A and B are constructed near the two outer edges of the central axis, Alpha.
	
Step 7 - Solar panels are constructed between the two tiers' Eta and Zeta to serve as the settlement's long-term power source.	**Step 8** - Extra extension spokes are constructed on both of the tori for additional transportation systems



Step 9 - Artificial gravity is supplied by rotating our rotationary volumes (Epsilon, Zeta, Eta, and Omnicron).

Table 2.3.1 Construction Sequences

2.4 Port Facilities

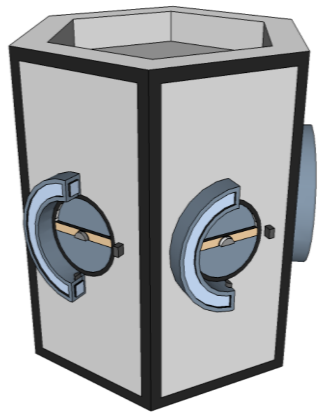


Figure 2.4.1 Port Facility

The port facilities (colored blue in Figure 2.1.2 and 2.1.3) will be placed on the ends of the axis, and consist of six circular docking points arranged equally around a hexagonal port interface. A space transportation control center will be placed in the center of the cross-section. As the axis is not rotating like the tori, placing the facilities there will allow for the safest and most convenient docking.

The six docking points will each be assigned a specific purpose, with four serving as cargo ports, one serving as a passenger port, and one serving as a reserve port. Each docking point will have its own loading area, where the cargo or passengers can be exchanged from the settlement to the ship and vice versa. The loading areas will be placed on the outer edges of the docking points, and converge to a central transport and storage center in the interior of the settlement. All docking points will also be connected to a large internal space where damaged ships can be sent to for emergency repairs.

Future expansion will take place at the other end of the rod, where the same arrangement of docking points can be constructed. These points will be allocated based on the developing needs of the settlement, and could either be for cargo or passenger docking. The long-term plan of Columbiat is to have ten fully functional docking points with two repair centers.

2.5 Space Elevator

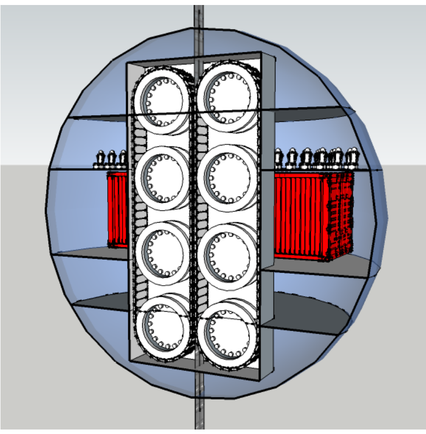


Figure 2.5.1 Cross section of Space Elevator cab

Transportation between Columbiat and the moon (where elevators to other settlements will be located) will take place via the Abbott space Elevator, which extends from the southern docking port of Columbiat to its mounting point on the moon's surface in the Ptolemaeus Crater. This crater is located at the center of the near side of the moon, at a point that is collinear with the position of the Columbiat settlement in L1 and a corresponding point on Earth's equator. Loads will be transported along the ribbon of the elevator using a free-electron laser power beaming system, an efficient and reliable method of energy transport. The ribbon itself will extend in a straight line from the moon, through the settlement, to a point in space that is the same distance from Columbiat as the moon (this additional length of ribbon serves as a counterbalance).

The elevator consists of docking points on Columbiat and the moon, and a single 1-meter wide, 1-centimeter thick ribbon that spans the distance in between. This ribbon will be composed of silicon bucky-structure, which is very strong with a tensile strength of over 100 GPa. The two faces of the ribbon will be completely smooth and act as a low-friction track for an elevator cab to move along. This cab will be attached to the ribbon with clamping double-sided wheel system. There will be a total of eight large wheels with a 3.5-meter diameter and 1-meter tread length, with four arranged adjacently and externally tangent to each other on both sides of the ribbon. The wheels will be arranged symmetrically on each side of the ribbon, with the tread touching the ribbon. The tread of these wheels will also be completely covered with a continuous layer of track, similar to how a tank's wheels are covered. The wheels and track will be completely contained inside an partitioned 2-meter by 8-meter by 17-meter box in the elevator. The hole will be large enough to fit only the wheels and the ribbon that the wheels will move along, forcing the wheels to be fit tightly against the ribbon.

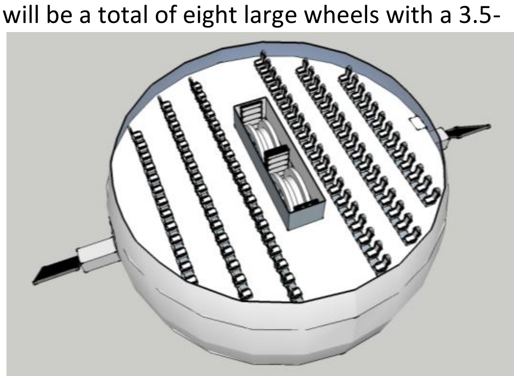
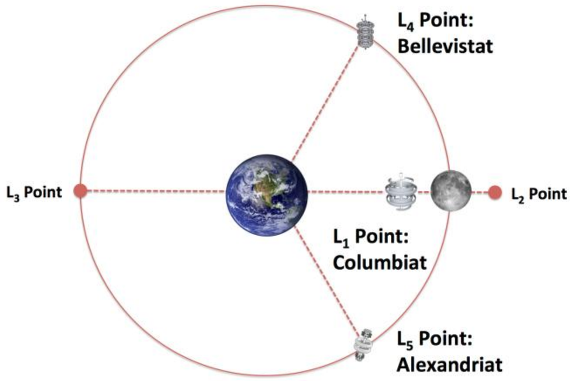


Figure 2.5.2 *Seating inside cab*

3.0 Operations and Infrastructure

Section Three: Operations and Infrastructure

3.1.1 Orbital Location and Specification



Columbiat will orbit around the Earth-Moon L_1 Lagrangian Point, approximately 340,000 km from the Earth and 60,000 km from the Moon. This orbital location complements Columbiat's role as the terminus of a space elevator to the lunar surface, as well as the Foundation Society's vision of Columbiat as a "Singapore-in-orbit." In addition, Columbiat's orbital location complements the orbital locations of existing space settlements, such as Alexandriat at the Earth-Moon L_5 Lagrangian Point and Bellevistat at the Earth-Moon L_4 Lagrangian Point.

Figure 3.1.1: Orbital Location and Specification

3.1.2 Sources, Transportation, and Storage of Construction Materials and Equipment

Material or Equipment	Amount	Source	Transportation	Storage
Silicon Buckystructures	1.06×10^7 kg	Moon	Princeton	Epsilon
Silica Aerogel	5.42×10^3 kg	Moon	Princeton	Epsilon
Titanium 6.6.2 Alloy	9.73×10^6 kg	Moon, Earth, Asteroids	Princeton, Yale	Epsilon
Boron Nitride Nanotubes	1.80×10^6 kg	Earth, Alexandriat	Princeton, Yale	Epsilon
Carbon Nanotubes	1.80×10^6 kg	Earth, Alexandriat	Princeton, Yale	Epsilon
Hollow-Core Fiber Optics	4.00×10^8 kg	Earth, Moon	Princeton	Epsilon
Polyurethane	3.45×10^4 kg	Earth	Yale	Epsilon
Lunar Regolith	3.87×10^5 kg	Moon	Princeton	Epsilon
Aluminium 7075-T6 Alloy	1.14×10^7 kg	Earth, Moon, Asteroids	Princeton, Yale	Epsilon
Multijunction Solar Panels	2.11×10^6 m^2	Alexandriat, Earth	Harvard	Epsilon
Water	7.00×10^6 L	Alexandriat, Earth	Harvard	Epsilon
Electronics	7.50×10^4 kg	Alexandriat	Princeton	Epsilon
Borated Polyethylene	4.64×10^4 kg	Alexandriat, Earth	Princeton, Yale	Epsilon
Atmospheric Gases	2.90×10^{11} L	Earth	Harvard	Epsilon
18Ni2400 Maraging Steel	6.22×10^7 kg	Asteroids, Earth, Moon	Princeton, Yale	Epsilon
Raguard	5.50×10^3 kg	Earth	Harvard	Epsilon

Table 3.1.1: Sources, Amounts, Transportation, and Storage of Construction Materials and Equipment

3.2.1 Atmosphere, Climate, and Weather Control

Columbiat's atmospheric composition will be similar to that of Earth's, although trace gases will be eliminated to reduce costs and ease maintenance. To further reduce costs, atmospheric pressure in most areas in Columbiat will be maintained at 0.80 atm; in the manufacturing and agriculture sectors, however, atmospheric pressure will be maintained at 0.60 atm. Atmospheric composition in these sectors will be based on the specific needs of that particular sector.

HEPA filters, ultraviolet treatment, and ozone treatment will continuously purify Columbiat's atmosphere. Air pollutant detectors, containing spectrometers and spectrophotometers, will be located strategically throughout Columbia and detect any air pollutants, which will be absorbed using nanoparticle sponges and removed with combustion burners. In addition, excess carbon dioxide will be absorbed using polymer sponges, and will undergo the Bosch reaction. Oxygen will be generated through the electrolysis of water, as well as with chemical oxygen generators based on lithium perchlorate. Humidifiers and dehumidifiers will maintain a comfortable level of humidity within the settlement, while a network of heat sinks and sources connected with buckystructure coolant tubes will maintain an optimal temperature level in various areas of the settlement. Finally, "weather parks" in residential areas will simulate weather phenomena, such as rain, snow, and fog.

Manufacturing Sector Atmosphere

	Nitrogen	Oxygen	Carbon Dioxide
Percent (%)	71.93%	28%	0.07%
Pressure (atm)	0.43158	0.168	0.00042
Weight (kg)	26578998.32	7454894.48	28625.35425
Volume (m^3)	34693951.61	13505222.37	33763.05593

Agricultural Sector Atmosphere

	Nitrogen	Oxygen	Carbon Dioxide
Percent (%)	80.25%	19.695%	0.055%
Pressure (atm)	0.4815	0.11817	0.00033
Weight (kg)	39868497.48	11182341.72	42938.03137
Volume (m^3)	58060397.96	14249215.43	39792.17

Normal Atmosphere

	Nitrogen	Oxygen	Carbon Dioxide
Percent (%)	74.96%	25%	0.04%
Pressure (atm)	0.59968	0.2	0.00032
Weight (kg)	149286203.7	56901282.12	125182.8207
Volume (m^3)	163053857.3	54380288.6	87008.46176

Table 3.2.1: Atmospheric Composition and Requirements on Various Areas of Columbiat

3.2.2 Food Production

	Traditional	Aeroponics	Hydroponics	Aquaponics
Efficiency	4	6	6	**9**
Cost	5	7	6	**5**
Waste	4	6	6	**9**
Water Usage	3	9	6	**6**
Productivity	5	7	7	**9**
Maintenance	4	5	6	**5**
Total	25	40	37	**43**

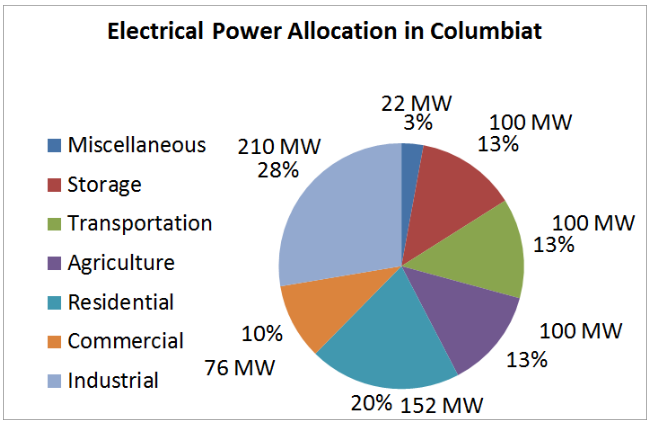
Table 3.2.2: Trade Study of Food Production Methods

Columbiat will use conveyor-belt aquaponics technology, a novel combination of hydroponics and aquaculture, to produce and harvest fruits, vegetables, grains, and fish. Aquaponics systems do not suffer from the limitations of hydroponics and aquaculture systems, and adopt the main advantages of both systems. Most fruits, vegetables, and grains will grow on trays floating on circular nutrient water tanks containing high-protein fish and crustaceans. By the end of each cycle around the water tank, crops in the tray will be planted, grown, and ready for automated harvest. Meanwhile, fish and crustaceans in the water will be grown and harvested, with effluents in the water serving as fertilizer for the crops above. Other crops will grow in porous vermiculite-buckystructure polymer trays in rotating cylinder carts that periodically dip into a water-based nutrient trough.

Automated robots will supervise all aspects of food production, and conduct regular inspections to ensure quality control. 24-hour LED lights at specific wavelengths will optimize crop growth and harvesting efficiency. Furthermore, in vitro meat will provide proteins and variety to the settlers' diets. Harvesting will be fully automated, with harvesting robots programmed to detect ripeness by size, color, and chemical factors with stereovision "eyes" and chemical "noses". In addition, these robots can also detect diseases in crops with microfluidics technology. Similar robots will harvest high-protein fish and crustaceans. Harvested food will then be transported by conveyor belts to a central processing plant for packaging and distribution.

Fresh food products for immediate distribution to restaurants and grocery stores will be packaged in reusable biopolymer containers. Surplus food will be freeze-dried, vacuum-sealed, and sent to central storage units. Surplus food will provide a 60-day backup supply for emergency scenarios. Robots will handle delivery of the food to grocery stores and restaurants, which will distribute the food as needed and sell food to people individually. The amount of food allotted to each person will be limited to minimize food waste, although people will be allowed to make a request for additional food if necessary.

3.2.3 Electrical Power Generation, Distribution, and Allocation



Primary electrical power generation for Columbiat will come from multijunction buckystructure photovoltaic cells, based on gallium arsenide and graphene technology. Photovoltaic panels will cover approximately 1,500,000 square meters and generate 500 MW of power. Secondary electrical power generation will come from four fission fragment reactors located in the manufacturing sector of Columbiat, producing 250 MW of power. Tertiary power generation will come from the combustion of biogas derived from anaerobic digestion (refer to Section 3.2.5), producing 10 MW of power.

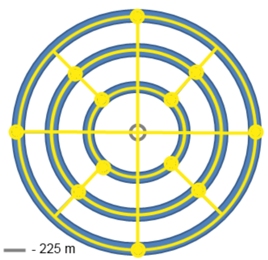


Figure 3.2.2: Map of Electrical Power Lines and Storage Stations

Excess electrical power will be stored in high-density batteries and capacitors based on molten salt, carbon nanowire, and buckystructure technology. These batteries will be located throughout Columbiat will have a total power capacity of 5 GW and maintain an emergency power supply for up to 6 months. Buckystructure wires and transformers will provide AC electricity of varying voltages throughout Columbiat.

3.2.4 Water Management

Columbiat's water filtration system will filter water condensate as well as liquid and solid wastes in three stages. First, screen filters will filter out most solid debris, while chemical coagulation and flocculation will eliminate any remaining suspended particles in the water. Second, nanofiltration will remove chemicals as well as capture up to 99.99% of biological contaminants. Third, reverse osmosis filters with activated carbon will effectively remove any remaining chemical and biological contaminants. Water will additionally be purified with UV and ozone treatment, while iodine and fluoride will be added for public health purposes.

275 L of water will be allotted per capita per day, and a total of 2,500,000 L of water will be circulated throughout Columbiat to serve human, agricultural, industrial, and other uses. Another 2,500,000 L of water will be stored for emergency purposes in tanks located throughout the settlement.

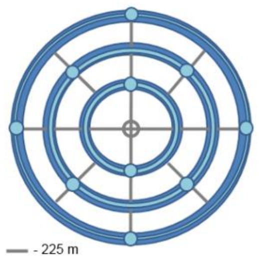


Figure 3.2.3: Map of Main Water Lines and Storage Stations

3.2.5 Household and Industrial Solid Waste Management

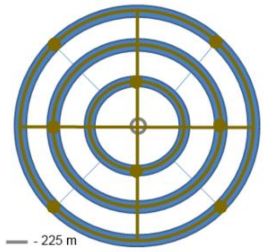


Figure 3.2.4: Map of Household and Industrial Solid Waste Management and Storage Stations

Automated collection of household wastes will transport waste to central waste processing centers located throughout Columbiat and separate it into biodegradable waste and recyclable waste. Biodegradable waste will undergo anaerobic digestion in bioreactors based on genetically-modified algae and bacteria to produce digestate, wastewater, and biogas. The resulting digestate will be processed into usable materials such as fertilizer and fiberboard. Wastewater will be recycled into clean, drinkable water (refer to Section 3.2.4). Biogas can be burned as fuel to supplement the energy needs of Columbiat. Recyclable items will be separated and recycled or reused accordingly, and the few non-recyclable items that remain will be converted into syngas and slag with plasma arc gasification.

3.2.6 Internal and External Communications Systems

	Visible	Ultraviolet	X-ray	Gamma	Radio
Cost	5	4	**3**	1	5
Data Transfer Volume	2	3	**4**	5	2
Interference Resistance	2	3	**4**	5	2
Practicality	1	3	**5**	1	3
Total	10	13	**16**	12	12

Table 3.2.3: Trade Study of Communication Systems

Internal communication on Columbiat will be based on three main systems: public communication, personal/private communication, and peer-to-peer information sharing. All residents and visitors will have access to portable tablets and computers to facilitate communication and collaboration. A centralized intercom system will make general announcements to residents of specified areas around Bellevistat. In addition, public announcements and messages can be sent to tablets and computers. Individuals will be able to communicate with each other using portable tablet devices with videotelephony, voice-over IP, and online chat systems. Finally, the intranet system will carry out data transfer for file and information sharing through wired networks based on high-speed fiber optic cables, in addition to wireless networks based on "Super Wi-Fi" technology.

Columbiat will use external X-ray communication systems, chosen for its resistance to interference during coronal mass ejections and solar flares. Buckystructure and graphene antennas will transmit and receive information that will be transferred through an array of satellites for accurate data transfer. Bellevistat will use a backup communications systems based on ultraviolet rays. Finally, satellites will be insulated with buckystructures to mitigate interference from radiation, as well as to shield the satellites from space microdebris.

3.2.7 Internal Transportation Systems

To enhance health, walking will be the primary means of transportation in Columbiat. Moving walkways will be placed along the entire length of each torus for convenience. Pod-based trams will run through each of the concentric tori, providing inter-torus and intra-torus travel. The tram will also run through Bellevistat's tiers with high-tension buckystructure cables to provide transit and transport between levels. Furthermore, buckystructure bicycles will be provided for both transportation and recreation.

For the transportation of goods, equipment, and heavy machinery, an additional tram system will travel throughout the settlement. These trams will be reinforced with buckystructures to handle large loads. A pneumatic tube system will also facilitate the transport of goods, equipment, and heavy machinery throughout Columbiat.

3.2.8 Day and Night Cycle Provisions

Columbiat will follow day/night cycle comprising 12 hours of daytime and 12 hours of nighttime in residential areas to complement the biological circadian rhythm. Organic LED lights simulating sunlight will slowly turn on during “sunrise”, and gradually dim during “sunset”. In addition, fluctuations in temperature and humidity will complement day/night cycles. Finally, electrochromistic smart glass on the exterior walls of each torus will automatically adjust the amount of incoming solar radiation to match day/night cycles.

3.3 Construction Machinery and Equipment

Figure 3.3.1: Construction Robot

Construction of Columbiat will be done by automated robots to significantly reduce manual labor while economically maximizing productivity.

Construction robots will be modular and covered in buckystructures that have thermal insulating qualities to protect from solar flares. They will also be efficacious and versatile; the robots will have special features to target smaller areas of construction. Security breaches in robots will not be a problem because only the higher-tiered users will be able to control robots.

Multiple robots will be utilized throughout the structure and will also work together. The main Brown construction robots will build the exterior of the settlement. Then, the Stanford internal construction robots will do interior finishing. During construction, Princeton transportation bots will be continuously delivering materials to the respective robots. When there are minor structural lapses with one of the buildings such as a breach in the wall, Dartmouth external repair robots will apply buckystructure patches that will immediately fix the defect. Finally, Uchi (intra-settlement transport) bots will be in charge of transfer large and heavy materials, primarily furniture, at the convenience of residents. For transport between Bellevistat and other locations, such as asteroids, the Moon, Alexandriat, and Earth, we will use a combination of the Princeton, Yale, and Harvard transportation shuttles.

With diversified functions, intuitive innovation, and efficient form, construction robots will make Columbiat a first-rate, safe settlement.

Name/Type	Description	Dimensions (L x W x H)	Quantity
Brown (Main Construction/External Construction)	Browns are modular robots that contain interchangeable parts for versatility. Its height is adjustable to adapt to different environments. They are also huge robots that can connect different sections of structures together, useful for early, large-scale construction of the settlement structure.	1.5m x 2.5m x 3m (extendable to 5 m)	200
Princeton (Transport from Columbiat to Bellevistat, Moon, Alexandriat)	Princetons will short-range transport material between storage sheds and robots. These robots will be made out of titanium steel alloy for maximum strength and will be able to carry up to 500 kg of material.	Maximum payload: 7.5m x 30m	30
Yale (Transport from Columbiat to Earth, asteroids)	Yales are additional transportation bots, except they are a long-range system.	Maximum payload: 7.5m x 27.5m	30
Harvard (Transport of gases and liquids)	Similar to Princetons and Yales, Harvards transport gases and liquids between settlements, Earth, moon, and asteroids.	Maximum payload: 50m x 10m	20
Dartmouth (External Repair)	With a layer of buckystructure to protect them from space debris and solar flares, Dartmouth is able to maintain the external structure.	1m x 1m x 3.5m	150
Penn (Small Internal and Infrastructure Repair)	“Termite”-style robots will constantly navigate infrastructure, including electrical wiring, water pipes, and gas pipes. If they find a short circuit or some type of leak, certain “carrier” Penn will deploy necessary repair materials and other repair Penn will swarm the area and quickly fix the problem.	7cm x 2.5cm x 1cm	1,000
Stanford (Internal Construction)	Repair robots are refitted from main construction robots. They are used to construct buildings, set up the different floor plans and put in gas, water, and electricity fixtures.	1.75m x 1.5m x 2m	250
Mitt (Unloading)	Mitts will unload material like ores and shipping containers outside the settlement at docking bays. Within these docking bays, Washingtons make processing and transportation more feasible.	2.75m x 5m x 2m	50

Uchi (Intra-settlement Transport)	Uchi is capable of transporting materials within the settlement, moving large objects otherwise difficult to carry.	4m x 2m x 1m	100
Columbia (Robot Inspection Crawlers)	Columbia are network based robots equipped with buckystructures that deal with structural damage.	7cm x 3cm x 1cm	100

Table 3.3.1: Descriptions, Dimensions, and Quantities of Automated Construction Robots

3.4 Propulsion Systems

	Electromagnetic	Electrostatic	Laser	Solid	Liquid
Efficiency	7	**9**	**10**	5	3
Power	4	**3**	**5**	7	9
Cost	5	**8**	**9**	6	7
Total	17	**20**	**24**	18	19

Table 3.4.1: Trade Study of Propulsion Systems

	Electrostatic Propulsion	Laser Propulsion
Propellant Type	Carbon Nanotubes	Hydrogen
Thrust Strength	700 N	800 N
Propellant Storage	Epsilon	Epsilon

Table 3.4.2: Propellant Type, Thrust Strength, and Propellant Storage of Secondary and Primary Propulsion Systems

Due to Columbiat's location at the relatively unstable Earth-Moon L1 Libration Point, any orbital deviation will lead to gradual drifts from its designated location. Therefore, we will use laser propulsion to keep our settlement in a stable orbit. We have chosen heat exchanger thrusters for this purpose due to their cost efficiency relative to power. Heat exchanger thrusters have an efficiency near 100% due to their versatility with any laser wavelength. For fuel, we will use hydrogen propellant because it is cheap and more readily available than any other propellant. Using hydrogen, heat exchanger thrusters are able to provide 600-800 seconds of specific impulse individually which would provide enough force to keep the station in the Earth-Moon L1 point. In addition, nanoparticle field extraction thrusters (nanoFETs) will act as the backup thrusters. These thrusters are extremely versatile due to their adjustable force and varying fuel efficiency. Compared to other types, nanoFETs produce more thrust while using less power than any other thruster of its kind.

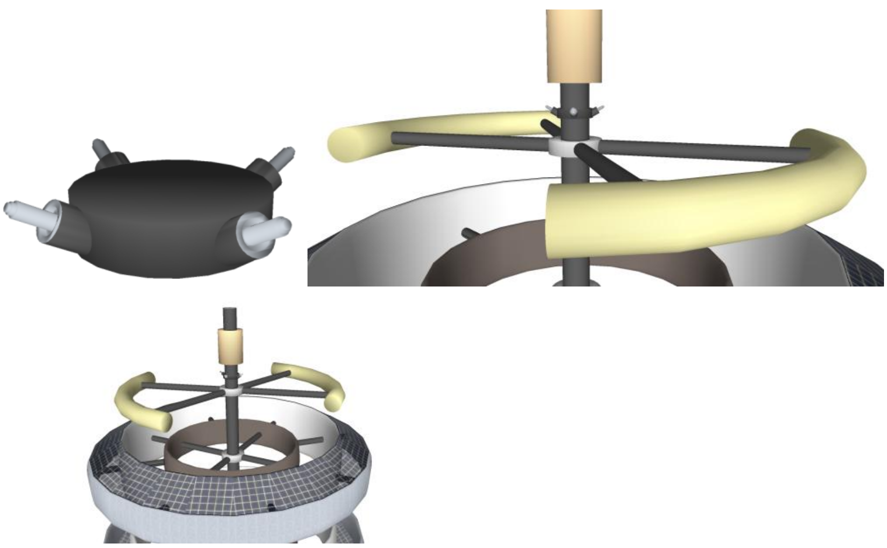


Figure 3.4.1: Propulsion System Location and Interface with Structure

3.5 Space Elevator Cab

The Abbott Space Elevator's cab will consist of a 80-foot diameter sphere constructed from a composite of buckystructure, carbon nanotubes, and titanium. The cab will contain enough space to accommodate up to 100 passengers and two standard cargo containers (15 feet square by 80 feet long) simultaneously. The cab will contain multiple levels specialized for accommodating passengers, cargo, equipment, and support systems. The cab's attachment to the ribbon has been described previously in Section 2.5.

To power the movement of the cab, the elevator will employ free-electron laser power beaming technology. Laser beacons will be set up at the base of the anchor tower on the moon and at the circumference of the docking station on Columbiat. The beacons will be lined up with each other, and with the photovoltaic cells on engines of the elevator cab. To power the cab, the beacons will be activated and transfer energy to the cells, which will then convert this energy to power the motor of the cab. The cab will have reversible locking pads to ensure that it travels in the correct direction at all times.

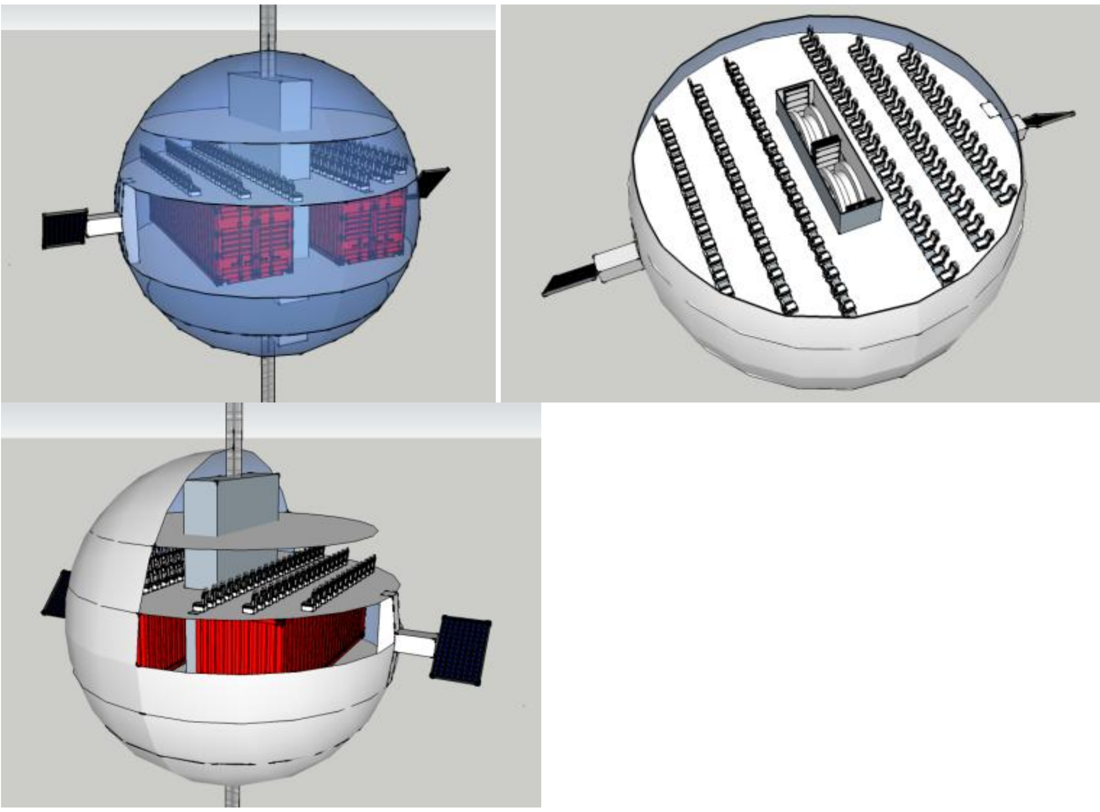
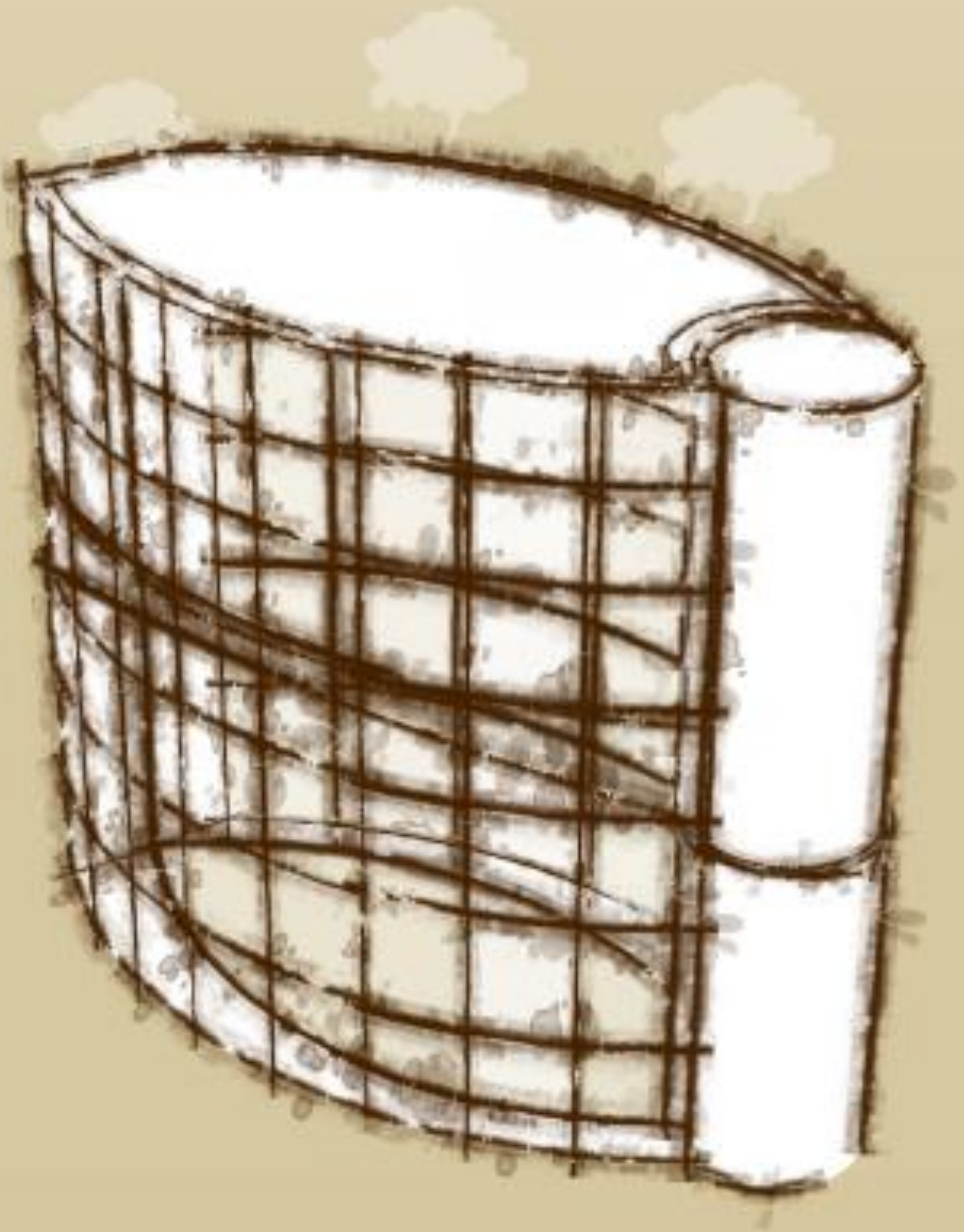
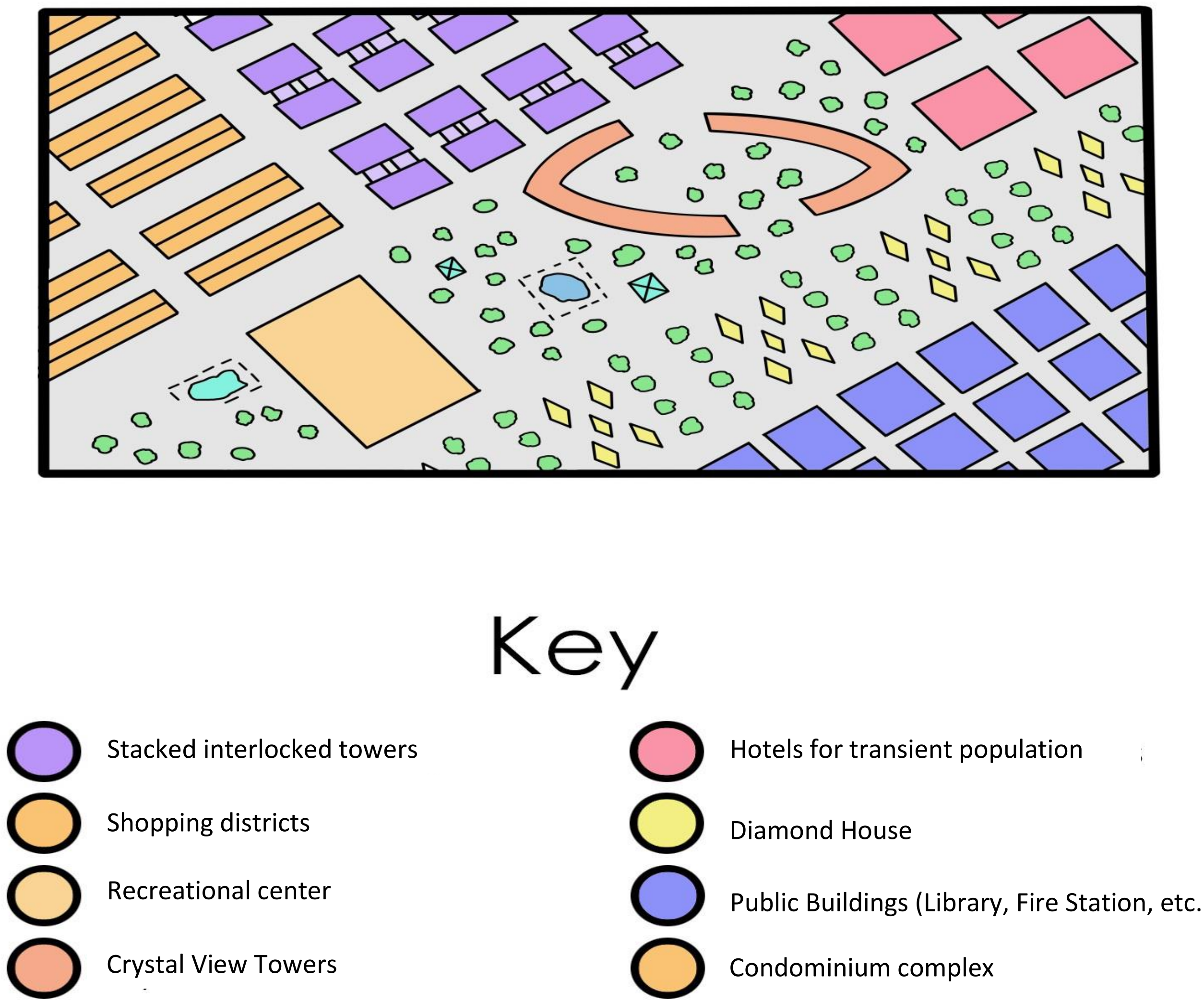


Figure 3.5.1: Space Elevator Cab

4.0 Human Factors



4.1.1 Community Design



Columbiat’s community design plan will be designed according to the pattern illustrated above. The community layout is organized in diagonal rows to provide long lines of sight for its residents. The community will also cater to the needs of residents from diverse ethnic backgrounds. Specific portions of the community have been designed for “rural” housing while other portions of the community have been allocated to “urban”, higher-density housing.

Sections will be provided of lower atmospheric pressures for residents who are suited to it. Before arriving, they will have a choice to opt for a different gravity (1g or 0.8g) and/or different atmospheric pressure (1.0 atm, 0.8 atm, and 0.6 atm) settlement section. All three pressure requirements will be available on each of the outer torii, but the 0.5g torus will not be used for human housing areas. Housing will *not* be provided on the 0.5g settlement due to the substan4ally lower gravity, however, recrea4onal areas and other areas open to the public will be available as well as low-g research centers for professionals.

4.1.2 Consumables Data

The table belows details expected consumption of consumables on the settlement. The figures provided are susceptible to change based on population deviations from the expected population. These consumables are expected to be regularly available in stores across the settlement.

Consumable	Amount (R)**	Amount (T)**
Food	1,756,562 kg/yr	20,960 kg/yr
Water	43,201,400 kg/yr	1,963,700 kg/yr
Oxygen	2,107,875 kg/yr	23,752 kg/yr
Hygiene Products	481,800 kg/yr	5,475 kg/yr
Pharmaceuticals	40,150 kg/yr	455 kg/yr
Paper Products*	100,980 kg/yr	1,148 kg/yr
Clothing*	4,415 articles/yr	100 articles/yr
Shoes*	3,000 pairs/yr	100 pairs/yr
Electronics	27,000 items/yr	600 items/yr
Kitchen Appliances	1,630 items/yr	50 items/yr
Furniture	65,000 items/yr	1595 items/yr
Research Materials	5,500 items/yr	62.5 items/yr

***Figures may vary; figures are estimates**

****(R) = Residents (23,000) , (T) = Transient (2,500)**

Item	Source
Chairs, Tables	Plastic, imported
Food (meat)	Raised in settlement
Food (vegetables)	Grown in settlement
Paper	Initially imported, recycled
Glass	Manufactured from silica, recycled
Linens	Imported

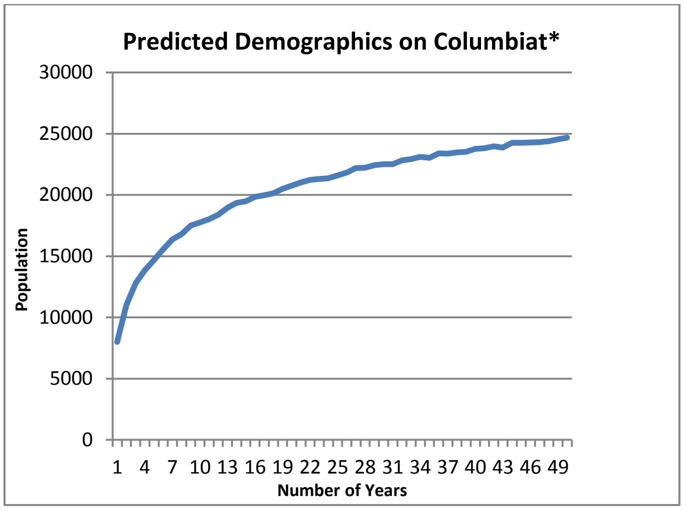
The settlement will provide all kitchen appliances and furniture upon purchasing a home in Columbiat. Everything will be furnished with default options but residents may select upgrades before arriving that will meet residents when they arrive. Food and nondurable goods will be provided at supermarkets near residential areas. Consumables transported to the settlement will first be sent to central warehouses on the settlement where they will be sorted by robots. Upon sorting, the consumables will be distributed to retailers across the entire settlement.

4.1.3 Psychological and Physical Health Considerations

Psychological Factor	Description	Proposed Solution

<table>
<tr><td>Solipsism Syndrome</td><td>When the environment becomes too artificial or controlled, people no longer believe that they exist in reality; the present world seems to be a dream because events are either too predictable or the landscape is too artificial</td><td colspan="2">• Long lines of sight and a distinct horizon will prevent a “theater” landscape
• Real life foliage and vegetation that grows will allow residents to observe natural growth
• Periodic changes in temperature and artificial weather to provide realistic sense of unpredictability</td></tr>
<tr><td rowspan="4">Cultural Blending</td><td rowspan="4">The settlement is intended to be an international settlement. As such, people from various cultures will reside on the settlement.</td><td colspan="2">Columbiat will offer settlers three distinct types of community settings:</td></tr>
<tr><td>Individualistic (rural)</td><td>- Community will mainly consist of small, single-family structures
- House will have reduced square footage, but will have larger yards and gardens, and, hence, increased separation</td></tr>
<tr><td>Mutualistic (suburban)</td><td>-Condominium complex with communal floors to encourage cooperation between neighbors</td></tr>
<tr><td>Homogenistic (urban)</td><td>-Apartment towers located in center of community
- Apartment communities will be located near banks and business parks</td></tr>
<tr><td>Coriolis Effect</td><td>Gravity on the settlement will be maintained by constant centrifugal rotation. Repeated sharp turns on the settlement can cause residents to experience nausea and dizziness</td><td colspan="2">• Community design in diamond grid pattern prevents sharp turns</td></tr>
<tr><td>Anhemia/Sensory Deprivation</td><td>Living in an enclosed area for extended periods of times can cause mind and body connections to lose sensitivity</td><td colspan="2">• Create illusions of space with large windows in residential buildings
• Allow the entrance of houses to be high-ceiling entrances</td></tr>
<tr><td>Physical Health Consideration</td><td>Description</td><td colspan="2">Proposed Solution</td></tr>
<tr><td>Low G-Environment</td><td>Extended exposure to low-G environment can lead to preliminary muscle wastage and bone brittleness</td><td colspan="2">• Exercise facilities will be located in higher-G environments
• Higher-G provided placing gyms at an extended radius off the central torus</td></tr>
</table>

4.2.1 Demographics

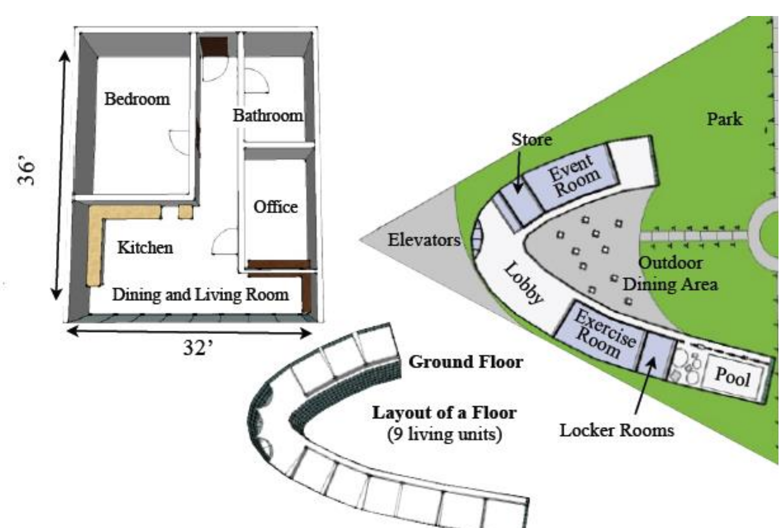


**Transient population has already been factored in; model based on a target population of 23,000 full-time resident and 2,500 transient residents*

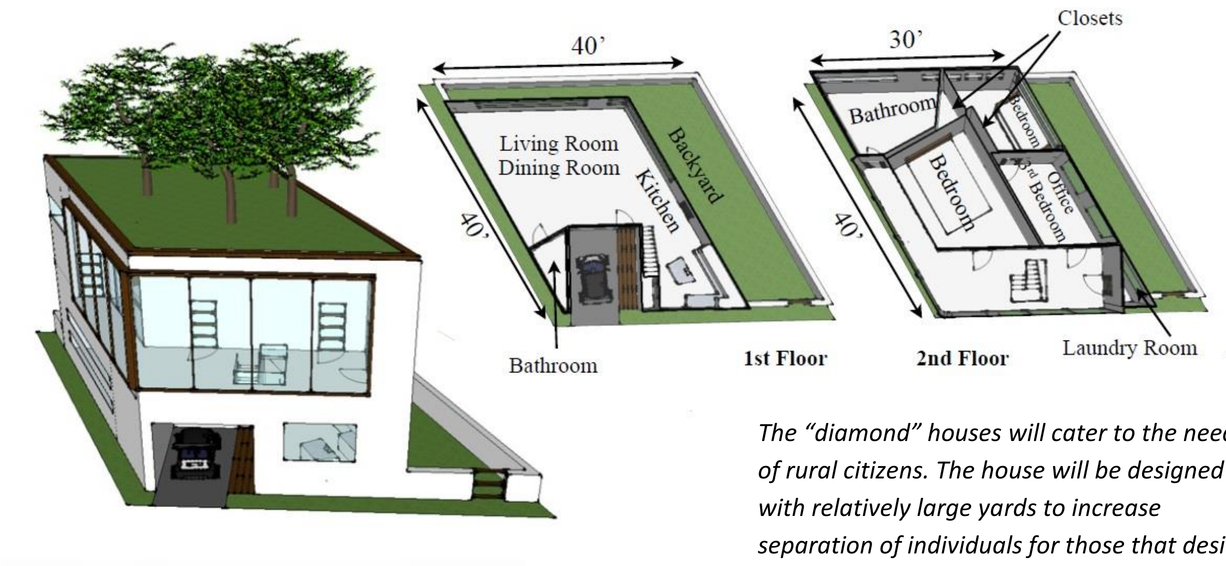
4.2.2 Housing Options on Columbiat

House Type	Residency Type	Average Square Feet	Number of Buildings	Number of People per Building	Number of People Housed
Interlocked Apartment Towers	**Single/Couples/Transient**	**1000-1500**	**80**	**250**	**20,000**
Crystal View Towers	**Single/Couples/Transient**	**1000-1500**	**15**	**500**	**7500**
Single Family Condominium Complex	**Family Housing**	**1200-1600**	**400**	**3**	**1200**
Single Family Diamond House	**Families Housing**	**1000 - 1200**	**350**	**3**	**1050**

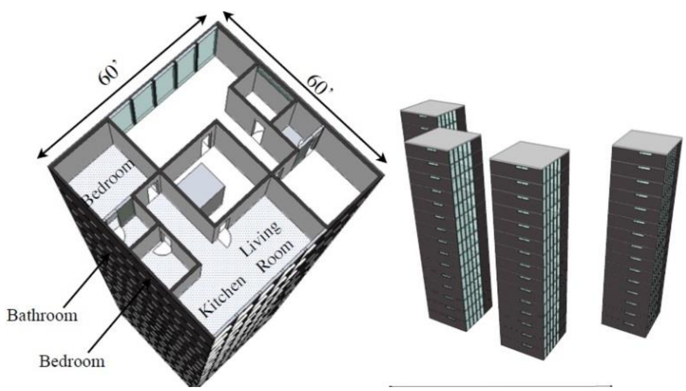
Crystal View Towers



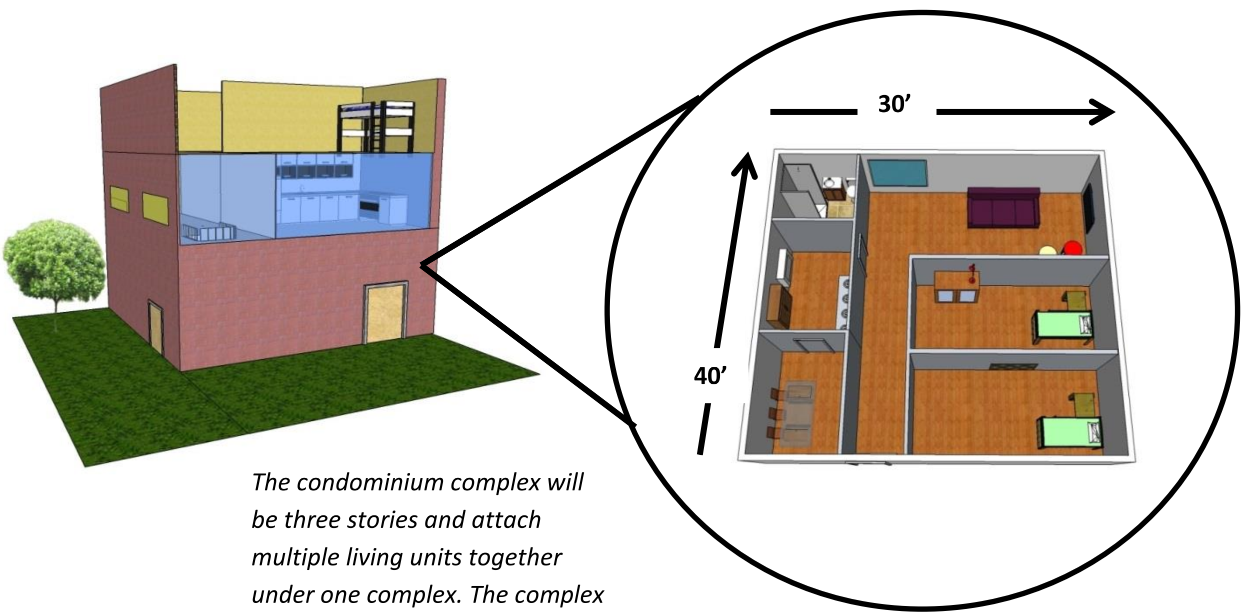
The Crystal View Towers will be located at the center of the settlement design and will, thus, serve as the urban center of the settlement. Since Columbiat will serve as a major trading center, the crystal towers will be located near banks and other financial institutions



The "diamond" houses will cater to the needs of rural citizens. The house will be designed with relatively large yards to increase separation of individuals for those that desire independent living.



Stacked interlocked apartment buildings will be located on the periphery of the center of the urban district. The 80 interlocked apartment buildings located on the settlement will serve as the main source of housing



The condominium complex will be three stories and attach multiple living units together under one complex. The complex will have a communal floor to encourage cooperation among the residents

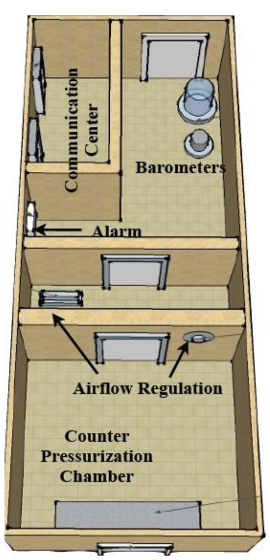
4.2.3 Furniture

The design for housing aims to efficiently house citizens in minimal use of space. In order to maximize the amount of furniture in a small amount of space, we will make the furniture foldable and replaceable so it can be manipulated to fit into the wall. To expand the furniture the pressing of the button causes the expansion of the furniture. When furniture is not expanded, there is available floor room for the residents which can be useful if a resident needs space to perform space taking activities such as yoga exercise or dance. This customization makes the housing plans appear spacious and makes the storage of furniture extremely space efficient.

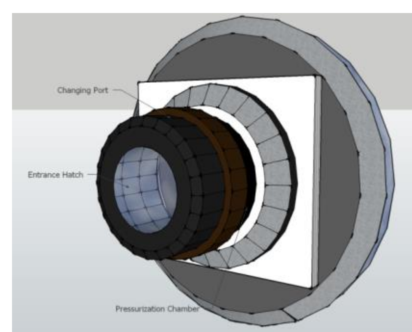
Furniture will be used that is highly conventional while taking up very little space. The bedding will be combined with a desk to create an efficient unit. This unit will be like a bunk bed, however the bottom bunk will be replaced with a half closet and half desk unit. This compartmentalized use of small space will maintain comfort without using too much space. The bathroom will also use a space conserving design that has connects the sink combined with shower in walling and the toilet. Consequently, all the components of a bathroom can fit into a smaller area. Together these space conserving innovations through furniture choice will be effective in reducing space needs for residents while maintaining comfortable life style.

Multipurpose bed frame will also provide storage drawers and desk

4.3.1 Airlock Safety System



Airlocks on Columbiat will maintain a constant pressure on the settlement and prevent the escape of oxygen whenever crew members exit or enter the settlement. In addition to regulating the pressure of the settlement, the airlock will also control the oxygen flow in the settlement. Oxygen gauges will constantly monitor oxygen levels to insure a steady supply of oxygen into the settlement. The airlock entry port consists of a spacesuit changing station where maintenance crew members can easily don spacesuits as they exit the settlement. By using a gradual pressure transition, the airlock allows crew members to adjust to the low pressure environment as they change into their spacesuits and eliminates the concern of extreme pressure changes. The airlock will also include barometers which will monitor pressure as well as an alarm system that would alert maintenance crew members should the pressure of the settlement begin fluctuating.



Entrance to the airlock as seen from outside the settlement

4.3.2 Space Suit

The spacesuits designed for exterior mobilization and settlement repairs will utilize the latest "bio-suit" technology. Unlike traditional gas pressurization suits, the bio-suit uses mechanical counter pressure to maintain a pressurized environment for the wearer. By pressurizing in response to the wearer's movements, the mechanical counter pressure suit is skin-tight, elastic, and does not interfere with the wearer's agility. Since the expected use of space suits would mainly be for external settlement repairs, the bio-suit is advantageous as it allows the wearer to move freely in his or her tasks.

The spacesuit will also be designed to protect the user from unsafe levels of radiation in space. By layering the bio-suit with Kevlar armor, the Kevlar will serve as protection against both radiation and small debris. Kevlar, along with thin aerogel coatings on the bio-suit, will be used as the main source of insulation on the suit

In the event of the space-suit rupturing, the bio-suit can be easily repaired by the wearer. The wearer will be required to take elastic bandages with them so that any tears in the suits can be temporarily patched.

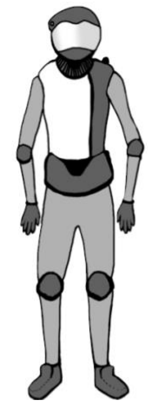


Illustration of the Bio-suit

Donning/Doffing Procedures of Space Suits

The following set of procedures must be followed by personnel in order to properly don and doff spacesuits.

Donning Procedures

1. Personnel enters airlock; airlock uses gas pressurization to maintain a safely pressurized compartment
2. Robots designed specifically for donning and doffing help personnel put on the elastic Bio Suit layer over their skin
3. Personnel finally attach gloves, boots, and helmets which are all distinct auxiliary protective gear
4. Personnel can now safely exit the settlement through the airlock hatch

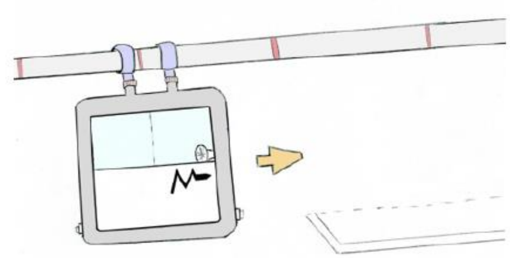
Doffing Procedures

1. Personnel enters airlock system through the safety hatch; airlock maintains suitable environment for doffing
2. Robots assist personnel in removing the bio suit
3. The spacesuits are stowed in a specific compartment for spacesuit stowage; personnel pass through airlock into settlement

4.3.3 Exterior Transport System

The Morphing Transport System

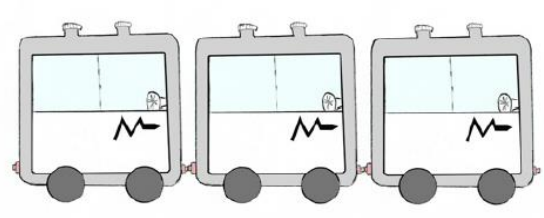
-Transport in locations outside artificial-gravity is done via a hanging-rail system with transport boxes
-Can be used inside and outside of artificial gravity
-Each box can be connected to others or stand alone
-Attached boxes can be of different types, from uncooled storage containers to human transport systems



Boxes attached to hanging rail approaching designated platform

"Morphing"

-After reaching designated platform, storage box is "unscrewed"
-Human transport boxes are attached to special magnetic "wheels"
-Used for outer-settlement transportation and repair work
-Cars can be manually or electronically driven



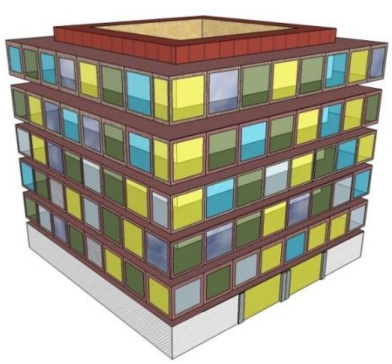
Interconnected boxes with magnetic wheels attached

4.4.1 Passenger Arrival and Departure

Passengers arriving to the settlement will enter from a chamber that offers stunning views of the earth from the settlement. The view will serve as both a visual attraction and also provide visitors with the opportunity of experiencing the “view of earth from space” that astronauts have long acclaimed.

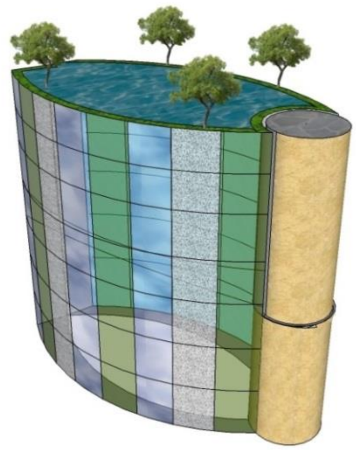
4.4.2 Hotels and Visitor Accommodations

Columbiat will have two types of hotels for visitors and tourists. The more economical option is a multi-story, courtyard-style hotel. The hotel will house visitors and tourists, and, also, provide meeting rooms and shops in the courtyard level of the hotel. Columbiat will also offer a luxury hotel option. The lower levels of the luxury hotel will provide rooms for social gatherings and receptions. Buffets and restaurants will also be located on the lower levels of the luxury hotel. The highest few levels of the hotel will be luxurious penthouse-style rooms that provide scenic views. On the roof of the hotel will be a skating rink that is available to all visitors.

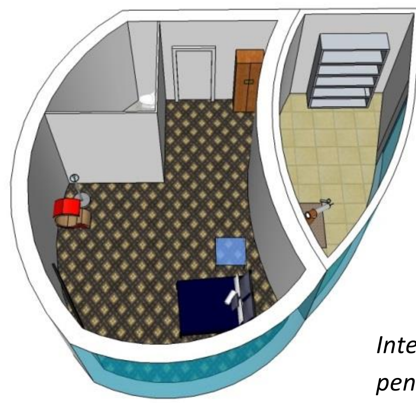


Exterior view of a typical courtyard hotel building on the settlement

Interior view of the courtyard of a hotel building; the courtyard serves as the central lobby of the hotel where visitors will initially check-in



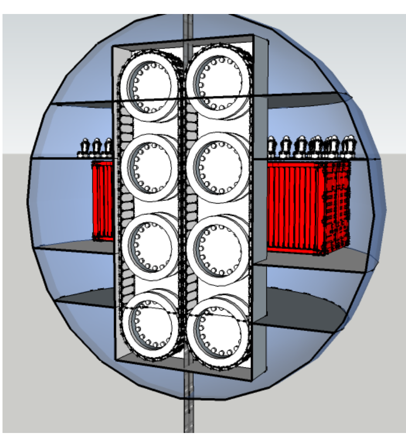
Luxury hotel building will offer scenic penthouses with views of the entire settlement. A large ice rink will be located at the top of the hotel settlement

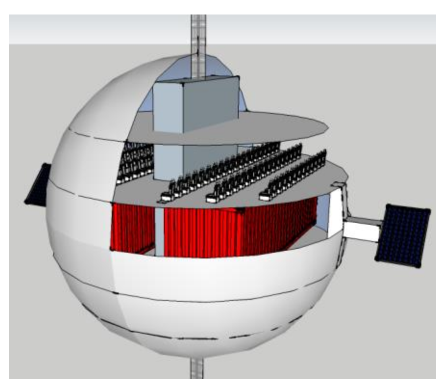


Interior look inside a penthouse room in the luxury hotel; each penthouse room will also have a separate observatory with telescopes for viewing the settlement.

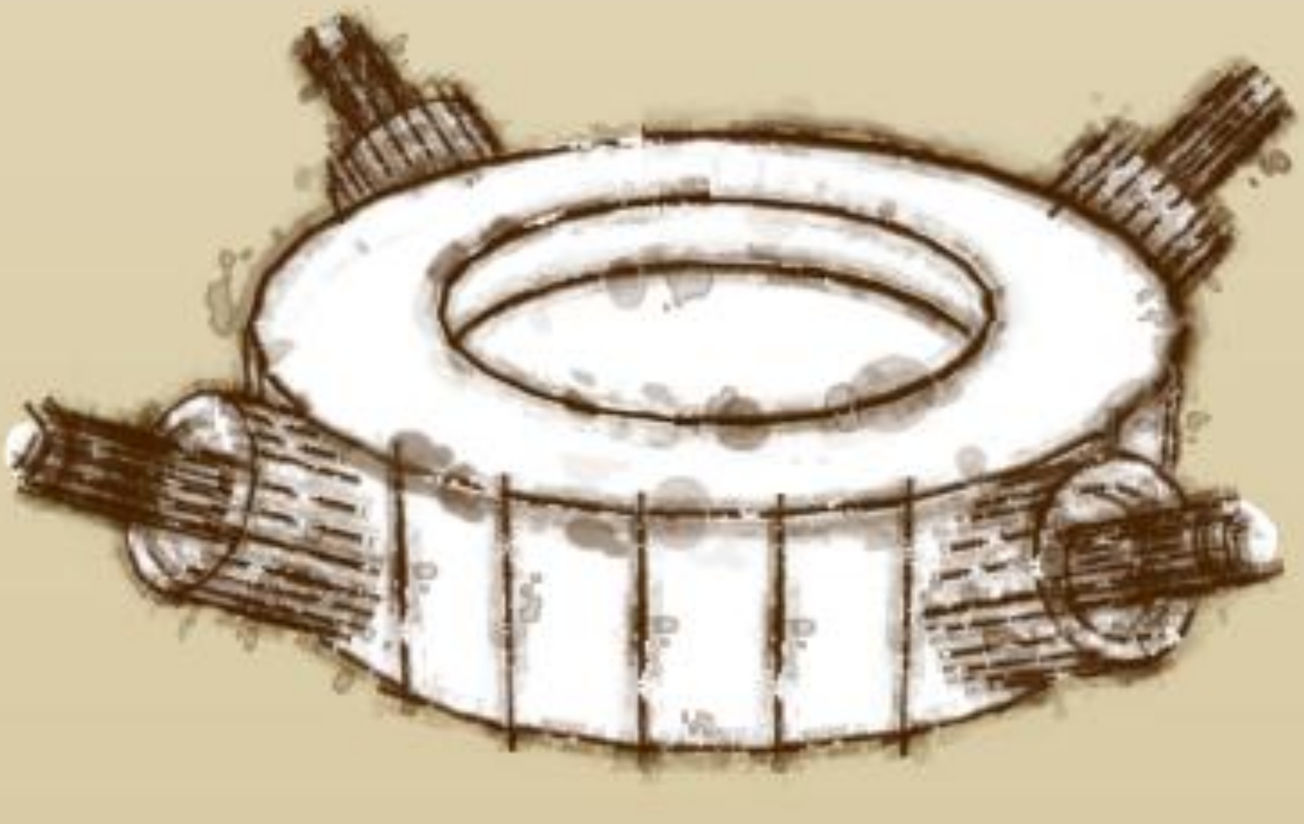
4.5.1 Space Elevator Design and Accommodations

To maintain good psychological health, passengers must be provided with a wide variety of entertainment options during their space elevator ride to and from the settlement. Each seat comes with an individual entertainment screen. Through this screen: users may select from a wide variety of T.V. shows, movies, play online games, check their emails, and continue working. This provides a convenient relaxed method of travel for 100's of passengers. Additionally, students have available magazines, newspapers, board games, and there is even a zone for little children to play. To add to the relaxed atmosphere and luxury of Columbiat, the seats can be inclined to form beds. To make the elevator feel like earth the top ceiling can be changed in color corresponding to times of day. There are a wide variety of online provided services on the .plane such as personalized service, delivery of food, and available bathrooms. Together these factors make the trip entertaining and enjoyable.





5.0 Automation Design



Section 5: Automation Design

5.1 Construction, Maintenance, and Repair

5.1.1 Table of Construction, Maintenance, and Repair Robots

Name/Type	Description	Dimensions (L x W x H)	Quantity
Brown (Main Construction)	Brown is a modular robot that contains interchangeable parts. It has adjustable height to adapt to different environments. They connect sections together, for large-scale construction of the settlement structure.	1.5 m x 2.5m x 3 m (extends to 5 m)	200
Princeton (Transport from Columbiat to Bellevistat, Moon)	Princeton is in charge of short-range transport of material between storage sheds and robots. These robots will be made out of titanium steel alloy for maximum strength and will be able to carry up to 500 kg of material.	Maximum payload size: 7.5 m x 30 m * 5 m	30
Yale (Inter-settlement Transport)	Yale are additional transportation bots, except they are a long-range system.	Maximum payload size: 7.5 m x 27.5 m * 5 m	30
Harvard (Transport of Gases and Liquids)	Similar to Princeton and Yale, Harvard transports gases and liquids between settlements, Earth, moon, and asteroids.	Maximum payload: 50 m x 10 m	20
Dartmouth (External Repair)	With a layer of buckystructure to protect them from space debris and solar flares, Dartmouth is able to maintain the external structure's integrity.	1 m x 1 m x 3.5 m	150
Penn (Small Internal and Infrastructure Repair)	Penn is a robot that constantly navigates electrical wiring, water pipes, and gas pipes. If they find a breach or leak, Penn will deploy necessary repair measures and alert other Penns to swarm the area and quickly fix the problem.	7 cm x 2.5 cm x 1 cm	1,000
Stanford (Internal Construction)	Stanford is a robot refitted from main construction robots. It is used to construct buildings, set up the different floor plans and construct gas, water, and electricity fixtures.	1.75 m x 1.5 m x 2 m	250
Mitt (Unloading)	Mitt will unload material such as ores and shipping containers outside the settlement at docking bays. Within these docking bays, Mitt makes processing and transportation more feasible.	2.75 m x 5 m x 2 m	50
Uchi (Intra-settlement Transport)	Uchi is capable of transporting materials within the settlement, moving large objects.	4 m x 2 m x 1 m	100
Columbia (Inspection)	Columbia is a network-based robot equipped with buckystructures that deals with structural damage.	7 cm x 3 cm x 1 cm	1500

Construction of Columbiat will be done by automated robots to significantly reduce manual labor while economically maximizing productivity.

Construction robots will be modular and covered in buckystructures that have thermal insulating qualities to protect from solar flares. They will also be efficacious and versatile; the robots will have special features to target smaller areas of construction. Security breaches in robots will not be a problem because only the higher-tiered users will be able to control robots.

Multiple robots will be utilized throughout the structure and will also work together. The main Brown construction robots will build the exterior of the settlement. Then, the Stanford internal construction robots will do interior finishing. During construction, Princeton transportation bots will be continuously delivering materials to the respective robots. When there are minor structural lapses with one of the buildings such as a breach in the wall, Dartmouth external repair robots will apply buckystructure patches that will immediately fix the defect. Finally, Uchi (intra-settlement transport) bots will be in charge of transfer large and heavy materials, primarily furniture, at the convenience of residents. For transport between Bellevistat and other locations, such as asteroids, the Moon, Alexandriat, and Earth, we will use a combination of the Princeton, Yale, and Harvard transportation shuttles. Please refer to 3.3 for more construction processes.

With diversified functions, intuitive innovation, and efficient form, construction robots will make Columbiat a first-rate, safe settlement.

5.2 Automation for Maintenance, Repair, and Safety

5.2.1 Solar Flare Emergency Robots

Figure 5.2.1 - Emergency Robot
Termite-like robots that can repair structural and electrical damage

During solar flare activity, specialized robots would be utilized for emergency external repairs. These robots would have an outer coating of lead in order to protect against harmful hard x-rays during these solar flares. These specialized robots would be miniature and could fit into one's palm. These robots would immediately go into effect and would not need instruction as speed is extremely critical during emergency situations. The robots would use swarm intelligence, working together based on a set of pre-programmed simple rules in order to achieve the complex repair tasks required. These robots would be outfitted with alternating layers of reardonium, aluminum, and insulating foam to create a Faraday cage to protect the inner electronics.

Systems that are exposed to solar flare damage could also be equipped with this Faraday cage to mitigate any damage. Silica aerogel would also be used as electrical insulation to protect electrical components. Since the majority of damage from solar flares occurs when components are damaged by high current and high-energy particles, so the aerogel insulation will greatly decrease this possible issue. If a solar flare is predicted to occur, the robots could apply additional protective silica aerogel and Faraday cages to the parts of the settlement that would be in the path of dangerous particles from the solar flare. Solar flares can lead to damage to crucial electronic components, including disrupting transformers and other systems. Any electrical damage that destroys electrical connection can be fixed with silicon buckystructure material that will be used to maintain proper circuitry.

Robots will work externally with buckystructures, while all buildings and structures will be outfitted with this material as well. This unique buckystructure has the combined effects of the space-tolerant shielding and the thermal insulation variants by having alternating layers of each "fabric".

5.2.2 Accessing Data

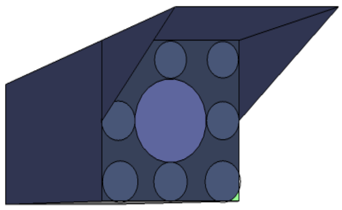


Figure 5.2.2 Communications Laser
Center circle: laser
Smaller circles: photodiodes

Authorized personnel will access critical data and command computer/robot systems using laser communication. This laser communication will use free space optics, rather than cables, allowing high speed communication with little construction. This form of communication will be up to 6 times faster and use up to 50% less power, with a much greater bandwidth. Laser communication is deal for space applications because the main disadvantage is interference from pollution, but this is not an issue in space. With high bit rates, laser communication will allow effective transmitting of data and command operations. Personnel will be equipped with a device that can convert information into light form and vice versa, a laser, and a photodiode receiver system. Data systems will be equipped with a similar device allowing two-way communication. This form of communication can be used between personnel as well.

5.2.3 Security Systems

Columbiat will utilize a 3-layer security system. The security system is designed to work from great distances to accommodate for the fact that authorized personnel may not be able to maintain a physical connection to the data systems they are trying to access. The first layer will be a biometric security system. This system will consist of an optical retina scanner that scans the retina of authorized personnel. Each person has a unique pattern of blood patterns on their retina that the scanner recognizes. This is advantageous because it is inconspicuous and works from a distance, and furthermore it is stable, unique, reliable, and non-invasive. The second-layer will consist of a voice recognition system. Authorized personnel will be given a specific phrase that is changed monthly, and furthermore the modulation of their voice will be analyzed to detect who is speaking in order to prevent security breaches. The voice recognition system will be calibrated to the specificity that a simple recording of the code phrase will not warrant access. A recording of the phrase would include interference/lower quality and this would be detected by the recognition system.

Furthermore, the final layer will consist of a 16-digit code associated with the laser communication device. Before the data is transmitted from the system to the personnel's laser communication device, the communication device will automatically send a 16-digit code that is specific for each device. A receiver on the data systems will contain a database of the various codes assigned to personnel and will allow access if the code sent matches one on the database. The code will be kept undisclosed, and only the manufacturer of the devices will know the codes. Any attempts to break past security will immediately result in the notification of authorized personnel who can respond and contain the breach.

5.2.4 Computing Systems

The computing system in Columbiat would consist of a main quantum computer that all other personal devices/computers would be connected to through a cloud network. This quantum computer would use a qubit system to achieve much faster processing power. Furthermore, the RAM of this main quantum computer and all other devices would use magnetic charge as opposed to electric charge to achieve much higher processing power.

5.2.5 Table of Computing and Networking Devices

Name/Type	Description	Dimensions (L x W x H)	Quantity
Quantum Computer	Large central computer that computes calculations for the entire colony	15 m x 20 m x 25 m	1
Servers	Software and hardware systems that responds to requests across a computer network	.34 m x .48 m x 1.2 m	50
Voice Recognition System	Recognizes voice of authorized personnel	.25 m x .40 m x .18 m	80
Optical Retina Scanner	Recognizes the unique retinal blood patterns of authorized personnel	.35 m x .50 m x .13 m	80
Laser Communication Relay Transmitter	Converts uploaded data into laser beam format and sends it to terminal	.03 m x .05 m x .04 m	2300
Relay Receiver Terminal	Receives pulsed laser beams that transmit data	.5 m x .7 m x .6 m	1000
Emergency Robots	For repair during times of emergency. It can survive solar flare activity with a lead coating and Faraday cage to protect internal components.	.1 m x .3 m x .4 m	35

Uca (Smartphone)	The main personal device is synced to the settlement's cloud in order to communicate with others, and allows for access to various personal applications and systems within the user's home.	.08 m x 13 m x .01 m	1 per settler
WCD (Wearable Computing Device)	An optional accessory for the smartphone, the wearable computing device includes an earbud, microphone, and glasses frame that has a head's-up display visible only to the user.	.03 m x .02 m x .001 m	1 per settler

5.3 Automation for Productivity, Livability, and Convenience

Table 5.3.1 Robots for Routine Tasks

Name / Type	Description	Dimensions (L x W x H)	Quantity
Tyrion (Cook)	Tyrion cooks all meals for citizens upon request and delivers the food to them. Tyrion is also capable of cleaning up afterwards and washing dishes and silverware.	1 m x 1 m x 1.5 m	Two per floor
WashU (Cleaning)	WashU cleans houses and operates on a daily schedule. They will have built in necessary cleaning materials. Its arms will be narrow and flexible to reach into small, tight spaces.	1 m x 1 m x 1.5 m	1 per 3 households
Ross (Work Assistant)	Ross takes care of menial labor like printing, copying, and stapling documents.	.5 m x .5 m x 1.25 m	1 per office building floor
Jorah (Nurse)	Jorah will administer basic first aid to minor injuries. It can only dispense the amount of drugs necessary and prescribed in order to prevent substance abuse.	.5 m x .5 m x 1.5 m	1 nurse per 50 people
Stamper (Warehouse Robot)	Maneuvers on tracks, and programmed to pick up materials stored in the warehouse. Programmed with a map of the settlement and an algorithm to calculate the most efficient route to retrieve goods.	1 m x .5 m x 2 m	200 per warehouse

5.3.2 Automation and Systems for Entertainment

It is of the utmost importance for our settlers on Columbiat to have an enjoyable living experience. As part of this mission, a variety of entertainment sources will be offered to settlers to enjoy during their off time.

Our personal computing device, Uca, will have advanced gaming capabilities. Users will be able to download gaming applications through an app store. Every settler can engage in an interactive, virtual gaming experience by using their Wearable Computing Device (WCD) as a head-mounted display. Essentially acting as a virtual reality machine, users will be able to upload games from their Uca onto their wearable computing device. The camera on the wearable computing device will translate the user's body movements into the games. Thus, they will be able to immerse themselves in any games that developers create.

A WCD for each settler will have a heads-up display with information about time, recent messages from other settlers, and personalized news headlines from either Columbiat itself, other settlements, or the Earth. The display will also be able to communicate with the Uca to provide directions, play music, and call other settlers using attached earbuds and microphones. In order to protect both the WCD and the Uca, self-healing films will be used to prevent scratching and regular wear-and-tear.

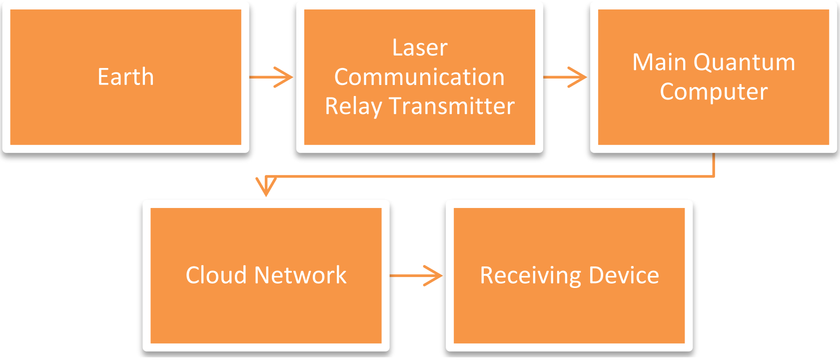
For settlers who prefer a real-world, tangible experience for physical exercise, exercise machines will be provided. These exercise machines will have automated trainer programs which can create a training regimen according to current fitness levels. In addition to typical weight-training machines, treadmills and bikes for cardiovascular training will also be provided. After every workout, the trainer program will output a summary and give recommendations for future workouts. The same training regimen can be continued until the target goal is reached.

Televisions on Columbiat will also have advanced functions. Users will be able to enhance their virtual reality experiences by projecting images onto their televisions and recording what they see. They will be able to conduct voice and video calls over the television as well, enhancing communications capabilities with both other settlers as well as people on Earth.

At Columbiat, we hope to provide a pleasurable environment for all settlers to relax and enjoy themselves.

5.3.3 Server and Network on Columbiat

Figure 5.3.1 Network and Communications Diagram

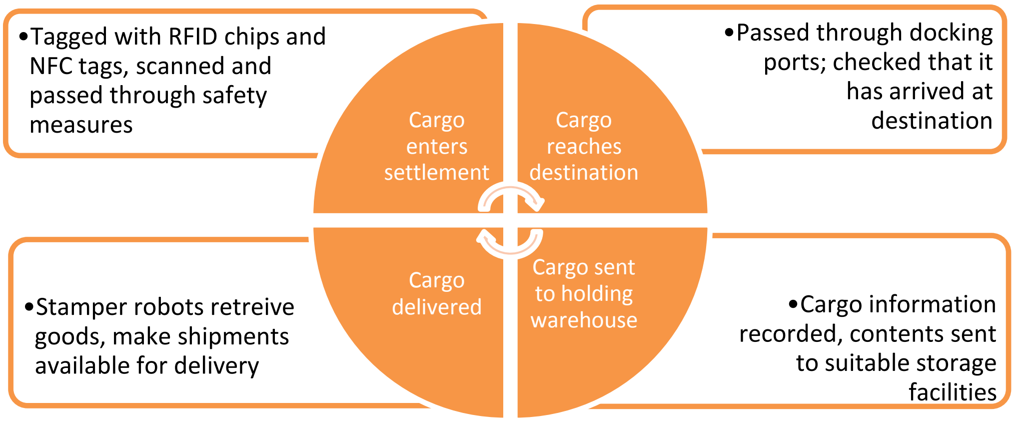


The settlement will be equipped with Wi-Fi router access points throughout the infrastructure, ensuring constant Wi-Fi communication with triple-band IEEE 802.11au connections. All electronic devices will communicate with each other through this infrastructure, connecting the devices together for everything from file sharing to video chatting. They will also connect to the servers, which will handle computations for communication devices using quantum computing. This means these devices can skip the major hardware required to carry out these performance-intensive operations. They will essentially be monitors, while the servers will be the computers. The main servers will be fitted with solid state drives at 750 Exabytes, have 75 Petaflops, and automatically compress (and decompress) data in order to handle the high load. After the compressing and decompressing is done, the final data transfer speed will average 10 terabytes per second. The connection will be stable throughout the network because of the router points laid out throughout the infrastructure, so the bandwidth will never drop below 1 terabyte per second.

Having all devices connected onto the same server will allow them to directly communicate together, enabling direct phone calls, texts, and communication. This will remove the need for a network provider, bad signal, and will instantly connect any device with another one also connected on the settlement's network. This allows these communication devices to be lightweight, low profile, have a smaller energy profile, and handle computations that would not be otherwise be possible for devices of those size.

5.4 Cargo Handling Systems

Figure 5.4.1 - Cargo Handling Matrix



Cargo entering the settlement will first be tagged with RFID chips that will provide the origin, description and quantity of contents, and eventual destination, as well as NFC tags that will only be activated once the cargo reaches its destination. First, non-hazardous cargo will be scanned with infrared and X-rays. The scan will then be run through object-recognition software, and if the objects are not large enough to be identifiable (at least around 0.1 m x 0.1 m x 0.1 m), then the shippers of the cargo will need to provide a random sample of the cargo they are bringing into the settlement. These samples will be tested for a variety of safety measures, and the cargo will be run through the chip-and-tag system once it has been deemed safe.

Once the cargo reaches the end destination, it will pass through one of many docking ports. When the cargo reaches the docking port, NFC chips will activate the NFC tags to ensure that the cargo has arrived in the correct destination. If an NFC tag is unactivated and therefore in the wrong destination, workers will send the cargo to a holding bay to check the contents and intended destination. If required, the cargo will be sent back to the docking port for relabeling.

If the cargo is not being relabeled, it will be sent to a holding warehouse. All cargo entering the warehouse will have the RFID chips scanned, and all information on the quantities of the cargo will be added to the inventory. Then, depending on the contents, the cargo will be sent to different departments of the warehouse that are temperature-controlled, humidity-controlled, especially secure for sensitive materials, etc. All stackable materials will be placed on storage racks along aisles, and along the floors of the aisles are sensors which send information about current location to warehouse robots. As robots take in and retrieve cargo, they will be able to update the system on the location of goods. Three shipping facilities will be available in each warehouse for the robots to send out the materials. Once they reach this point, the robot will alert the receiver of the shipment that their material is available for pickup, and the quantity count in the inventory will be changed accordingly.

5.5 Port and Docking System

Magnetic filters could line the entry of the port in order to reduce the amount of dust on the surface of visiting ships. These filters would attract the metallic iron in the dust particles, preventing dust from entering the settlement.

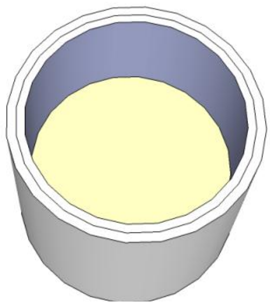


Figure 5.5.1 - Magnetic filter at opening of port

The spread of dust contamination from visiting ships could be prevented by covering the surface of exposed surfaces (especially in the ports) with a dust resistant synthetic layer. This synthetic layer, which would be composed of polypropylene, would be able to release small attached molecules, such as dust particles, due to reduced tactility. All joints and edges would be coated with polyurethane that would act as a sealant and prevent dust from entering any cracks or openings.

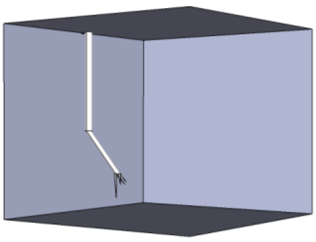
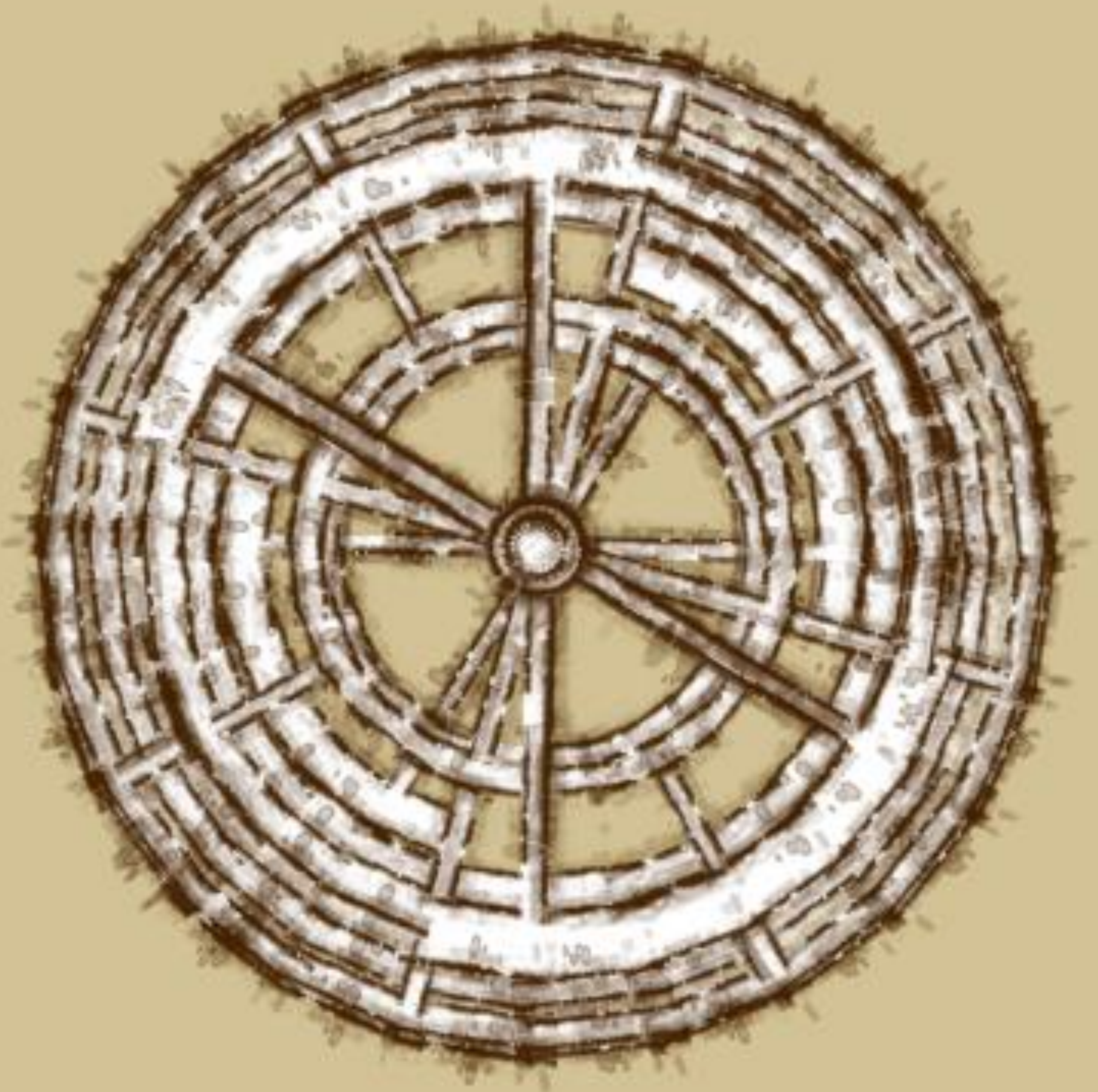


Figure 5.5.2 - Repair warehouse depicting robot arm protruding from ceiling

Robots in need of repair would be shipped to specialized warehouses in vacuum sealed containers to prevent dust from contaminating the settlement. Robot arms would be used for repair that remain in the warehouse reducing the potential for dust contamination on workers. For any structural issues, a silicon buckystructure matrix would be used to reinforce and repair.

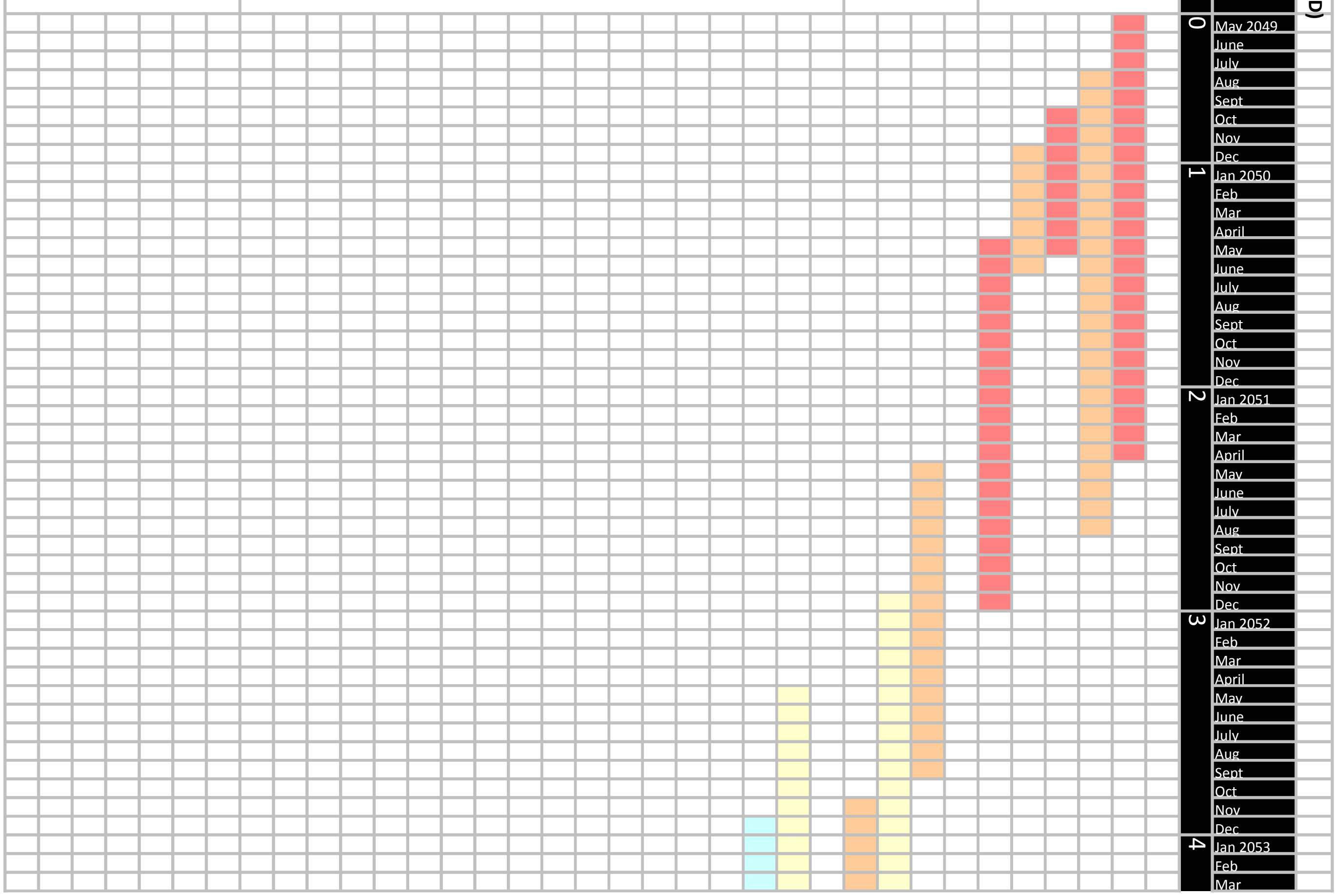
6.0 Scheduling and Cost

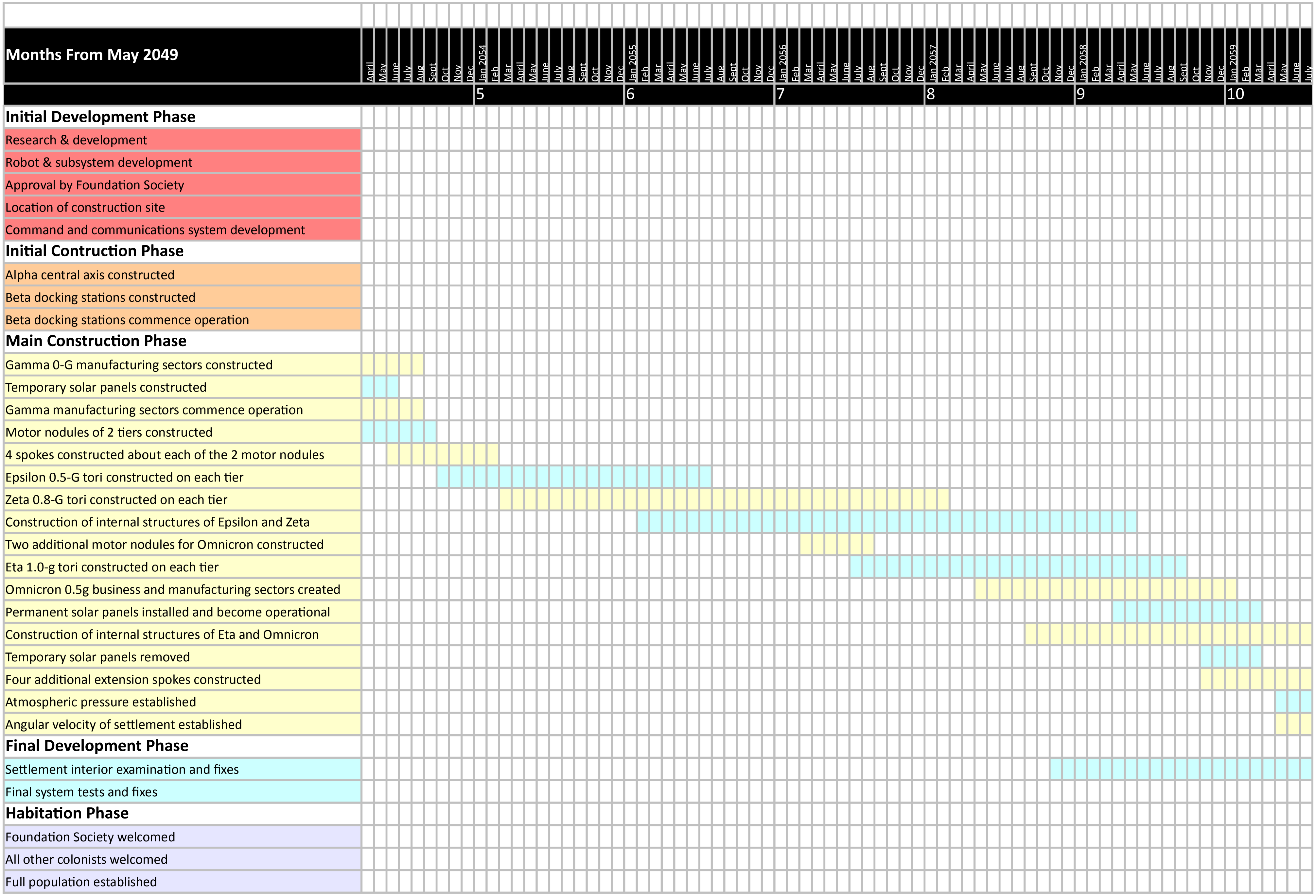


Section Six: Schedule and Cost

6.1 Schedule

Months From May 2049 / Years After 15 May 2049	Workers	Robots	Approximate Cost (USD)
Initial Development Phase			$67,000,000
Research & development	200	N/A	
Robot & subsystem development	250	N/A	
Approval by Foundation Society	N/A	N/A	
Location of construction site	20	N/A	
Command and communications system development	150	N/A	
Initial Contruction Phase			$13,570,000,000
Alpha central axis constructed	50	200	
Beta docking stations constructed	80	170	
Beta docking stations commence operation	30	20	
Main Construction Phase			$52,245,000,000
Gamma 0-G manufacturing sectors constructed	30	80	
Temporary solar panels constructed	30	50	
Gamma manufacturing sectors commence operation	50	20	
Motor nodules of 2 tiers constructed	20	70	
4 spokes constructed about each of the 2 motor nodules	40	170	
Epsilon 0.5-G tori constructed on each tier	60	220	
Zeta 0.8-G tori constructed on each tier	70	250	
Construction of internal structures of Epsilon and Zeta	50	200	
Two additional motor nodules for Omnicron constructed	40	170	
Eta 1.0-g tori constructed on each tier	70	260	
Omnicron 0.5g business and manufacturing sectors created	50	180	
Permanent solar panels installed and become operational	30	80	
Construction of internal structures of Eta and Omnicron	80	280	
Temporary solar panels removed	20	30	
Four additional extension spokes constructed	30	90	
Atmospheric pressure established	N/A	30	
Angular velocity of settlement established	N/A	N/A	
Final Development Phase			$7,500,000
Settlement interior examination and fixes	80	120	
Final system tests and fixes	30	N/A	
Habitation Phase			
Foundation Society welcomed	N/A	N/A	
All other colonists welcomed	N/A	N/A	
Full population established	N/A	N/A	




Months From May 2049
April
May
June
July
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Oct
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Jan 2054
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May
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Jan 2059
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July
5
6
7
8
9
10
Initial Development Phase
Research & development
Robot & subsystem development
Approval by Foundation Society
Location of construction site
Command and communications system development
Initial Contruction Phase
Alpha central axis constructed
Beta docking stations constructed
Beta docking stations commence operation
Main Construction Phase
Gamma 0-G manufacturing sectors constructed
Temporary solar panels constructed
Gamma manufacturing sectors commence operation
Motor nodules of 2 tiers constructed
4 spokes constructed about each of the 2 motor nodules
Epsilon 0.5-G tori constructed on each tier
Zeta 0.8-G tori constructed on each tier
Construction of internal structures of Epsilon and Zeta
Two additional motor nodules for Omnicron constructed
Eta 1.0-g tori constructed on each tier
Omnicron 0.5g business and manufacturing sectors created
Permanent solar panels installed and become operational
Construction of internal structures of Eta and Omnicron
Temporary solar panels removed
Four additional extension spokes constructed
Atmospheric pressure established
Angular velocity of settlement established
Final Development Phase
Settlement interior examination and fixes
Final system tests and fixes
Habitation Phase
Foundation Society welcomed
All other colonists welcomed
Full population established

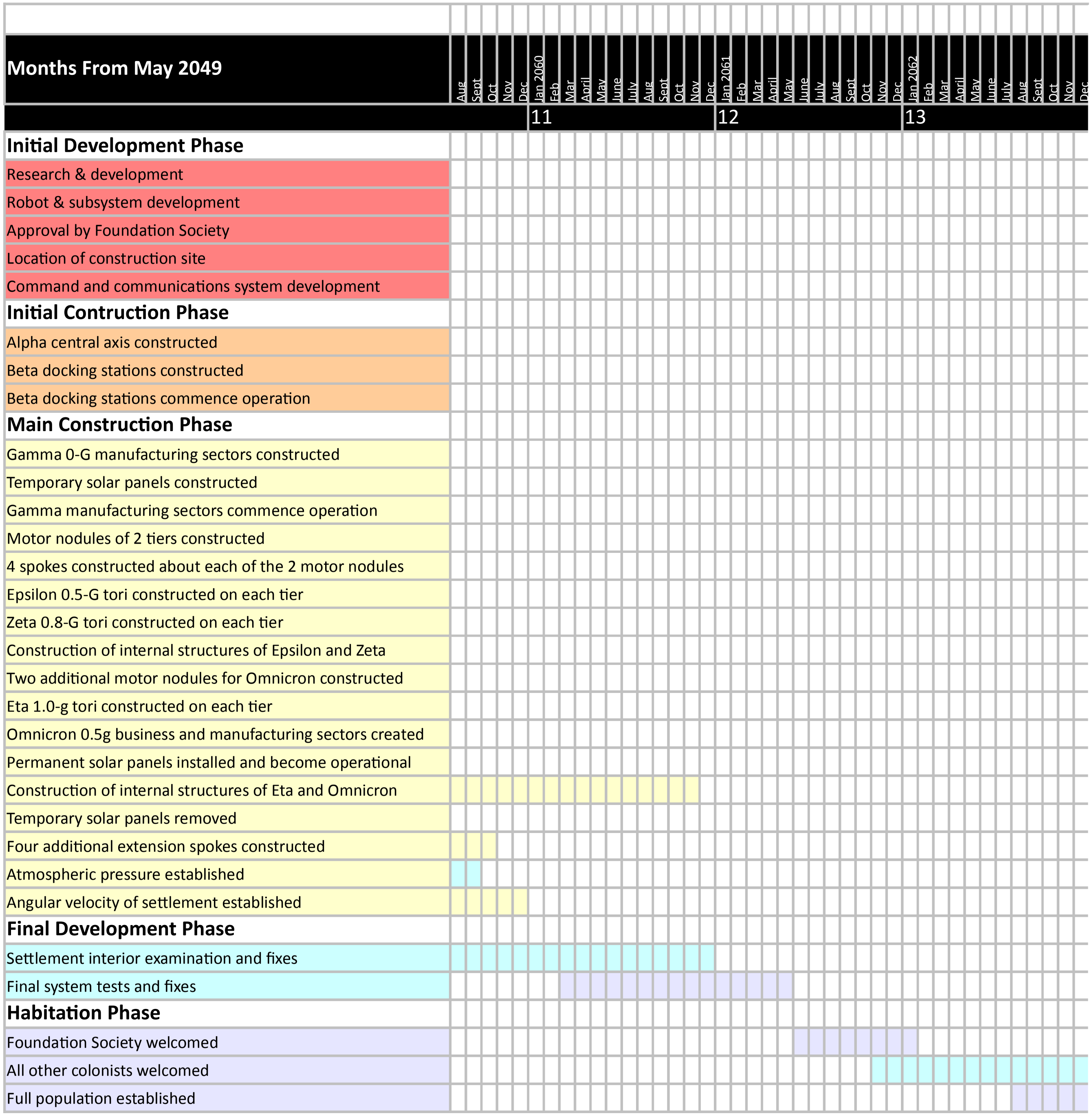


Table 6.1.1 – Construction and Habituation Schedule

6.2 Costs

6.2.1: Technology	Cost	Quantity	Total Cost	Annual Upkeep
Atmospheric Control (Units)	$5,000,000	20	$100,000,000	$13,000,000
Weather Parks (Units)	$3,000,000	20	$60,000,000	$9,200,000
Aquaponics Systems (Units)	$14,500,000	50	$725,000,000	$57,190,000
Biogas Power Generator (Units)	$200,000	4	$800,000	$52,500
Batteries and Capacitors (Units)	$4,500	1,000	$4,500,000	$280,500
Electrical Wiring (m)	$0.12	600,000,000	$72,000,000	$570,000
Water Management System (Units)	$4,620,000	16	$73,920,000	$8,150,000
Water Piping (m)	$0.19	350,000,000	$66,500,000	$600,000
Waste Management System (Units)	$6,700,000	16	$107,200,000	$9,716,000
Bioreactors (Units)	$370,000	25	$9,250,000	$518,000
Paper Production System (Units)	$7,800,000	15	$117,000,000	$3,910,000
Dock Repar System (Units)	$1,890,000	50	$94,500,000	$2,480,000
Kane	$1,500	15,000	$22,500,000	$2,800,000
Magnitude	$3,000	4,000	$12,000,000	$1,700,000
Business Device	$4,500	8,600	$38,700,000	$4,600,000
Bennett (Cooking/Butler)	$30,000	8,000	$240,000,000	$15,000,000
Duncan (Cleaning)	$1,500	3,000	$4,500,000	$800,000
Laybourne (Nurse)	$17,000	230	$3,910,000	$590,000
Chang (Work Assistant)	$22,000	500	$11,000,000	$2,300,000
Star-Burns (Police)	$25,000	150	$3,750,000	$680,000
TOTAL COST			$1,767,030,000	$134,137,000

6.2.2: Transportation	Cost	Quantity	Total Cost	Annual Upkeep
Moving Walkways (Units)	$1,100,000	50	$55,000,000	$1,520,000
Bicycles (Units)	$92	15,000	$1,380,000	$245,000
Passenger Trams (Units)	$15,700,000	12	$188,400,000	$13,000,000
Transportation Trams (Units)	$12,650,000	12	$151,800,000	$11,800,000
Nadir (Moon/Alexandriat Transport)	$2,500,000	40	$100,000,000	$20,000,000
Bauer (Earth Transport)	$4,000,000	40	$160,000,000	$12,500,000
Whitman (Gas/Liquid Transport)	$3,250,000	40	$130,000,000	$25,000,000
Pelton (Unloading)	$500,000	75	$37,500,000	$15,000,000
Slater (Intrasettlement Transport)	$150,000	35	$5,250,000	$4,500,000
TOTAL COST			$829,330,000	$103,565,000

6.2.3: Annual Wages	Wages	Number Employed	Annual Cost
Teachers	$35,000	30	$1,050,000
Technicians	$165,000	1300	$214,500,000
Researchers	$120,000	120	$14,400,000
Industrial Workers	$80,000	7900	$632,000,000
Doctors	$150,000	150	$22,500,000
Commercial Workers	$90,000	8200	$738,000,000
Government Officials	$120,000	650	$78,000,000
Security Personnel	$57,500	200	$11,500,000
Planner	$200,000	60	$12,000,000
TOTAL WAGES			$1,723,950,000

6.2.4: Communications	Cost	Quantity	Total Cost	Annual Upkeep
Communications Devices (Units)	$207	15,000	$3,105,000	$250,500
Fiber Optics Cables (m)	$0.14	200,000,000	$28,000,000	$500,000
Satellite Communication Systems	$1,400,000	4	$5,600,000	$900,000
Servers	$95,000	301	$28,595,000	$3,500,000
Router Points	$900	8	$7,200	$7,900
Relay Point	$700,000	1	$700,000	$13,000
TOTAL COST			$66,007,200	$5,171,400

6.2.5: Materials	Cost	Quantity	Total Cost	Annual Upkeep
Lunar Regolith (kg)	$50	275000	$13,750,000	$1,274,000
Buckystructures (kg)	$9.80	7,500,000	$73,500,000	$7,600,500
Silica Aerogel (kg)	$87.30	3,850	$336,105	$36,200
Water (L)	$20	5,000,000	$100,000,000	$10,000,000
18Ni2400 Maraging Steel (kg)	$16.53	44,200,000	$730,626,000	$37,200,000
Titanium 6.6.2 Alloy (kg)	$11.76	69,100,000	$812,616,000	$68,100,000
Borated Polyethylene (kg)	$56	33000	$1,848,000	$250,600
Polyethylene Foam (m^3)	$324	75000000	$24,300,000,000	$972,000,000
Polyurethane (kg)	$47	24,500	$1,151,500	$192,000
Aluminium 7075-T6 Alloy	$12.65	8,120,000	$102,718,000	$9,640,000
Solar Panels (m^2)	$23	15,000,000	$345,000,000	$12,500,000
Fission Fragment Reactors (Units)	$25,000,000	4	$100,000,000	$5,000,000
Carbon Nanotubes (kg)	$33	1,280,000	$42,368,000	$846,800
Raguard (kg)	$27	7,810	$210,870	$12,500
Nitrogen (m^3)	$60	471267000	$28,276,020,000	$0
Oxygen (m^3)	$0.30	407385000	$122,215,500	$0
Carbon Dioxide (m^3)	$0.01	7155000	$71,550	$0
Food (kg)	$4.82	1,756,562	$8,466,628.84	$0
Hygiene Products (kg)	$1.36	16,627	$22,612.56	$0
Pharmaceuticals (kg)	$12.14	1,085	$13,166.53	$0
Paper Products (kg)	$0.86	102,225	$87,913.08	$0
Cotton (kg)	$1.39	15,841	$22,018.39	$0
Leather (kg)	$1.99	52,226	$103,928.76	$0
Teflon (kg)	$20.55	1,141	$23,447.55	$0
Plastics (building material) (kg)	$1.52	8,852,446	$13,455,718.12	$0
Concrete (building material) (kg)	$0.20	59,603,918	$11,920,783.69	$0
Glass (building material) (kg)	$1.91	4,352,442	$8,313,164.67	$0
Adhesives (building material) (kg)	$0.75	4,233,822	$3,175,366.17	$0
Metals (building material) (kg)	$3.30	7,449,581	$24,583,618.31	$0
Wood (building material) (kg)	$0.57	28,635,822	$16,322,418.47	$0
Photovoltaic Cells (watt)	$1.03	7,000,908	$7,210,934.94	$0
TOTAL COST			$55,116,153,245	$1,124,652,600

6.2.6: Landscaping	Cost	Quantity	Total Cost	Annual Upkeep
Trees	$10	10000	$100,000	$2,000
Grass (m^2)	$8	250000	$2,000,000	$2,000
Packed Soil (m^3)	$2	1187313.409	$2,374,626.82	$1,600
TOTAL COST			$4,474,626.82	$5,600

6.2.7: Construction	Cost	Quantity	Total Cost	Annual Upkeep
Winger (Main Construction)	$500,000	350	$175,000,000	$25,000,000
Perry (External Repair)	$350,000	150	$52,500,000	$7,500,000
Edison (Small Int. Infrastructure Repair)	$1,100	5,000	$5,500,000	$1,000,000
Barnes (Internal Construction)	$250,000	250	$62,500,000	$5,000,000
TOTAL COST			$295,500,000	$38,500,000

6.2.8: Annual Revenue	Total Income
Tourism	$800,000,000
Recreation	$546,666,667
Hotels	$573,333,333
Net Trade Revenue	$5,400,000,000
Manufacturing	$6,800,000,000
Private Contracting & Advertising	$126,666,667
TOTAL REVENUE	$14,246,666,667

6.2.9: Totals	Cost	Annual Upkeep
Technology	$1,767,030,000	$134,137,000
Transportation	$829,330,000	$103,565,000
Wages		$1,723,950,000
Communication	$66,007,200	$5,171,400
Materials	$55,116,153,245	$1,124,652,600
Landscaping	$4,474,627	$5,600
Construction	$295,500,000	$38,500,000
Transportation Costs	$87,117,742,607.73	$4,694,972,400
TOTAL COST	$145,196,237,680	$7,824,954,000
TOTAL REVENUE		$14,246,666,667

Amount of Time to Break Even

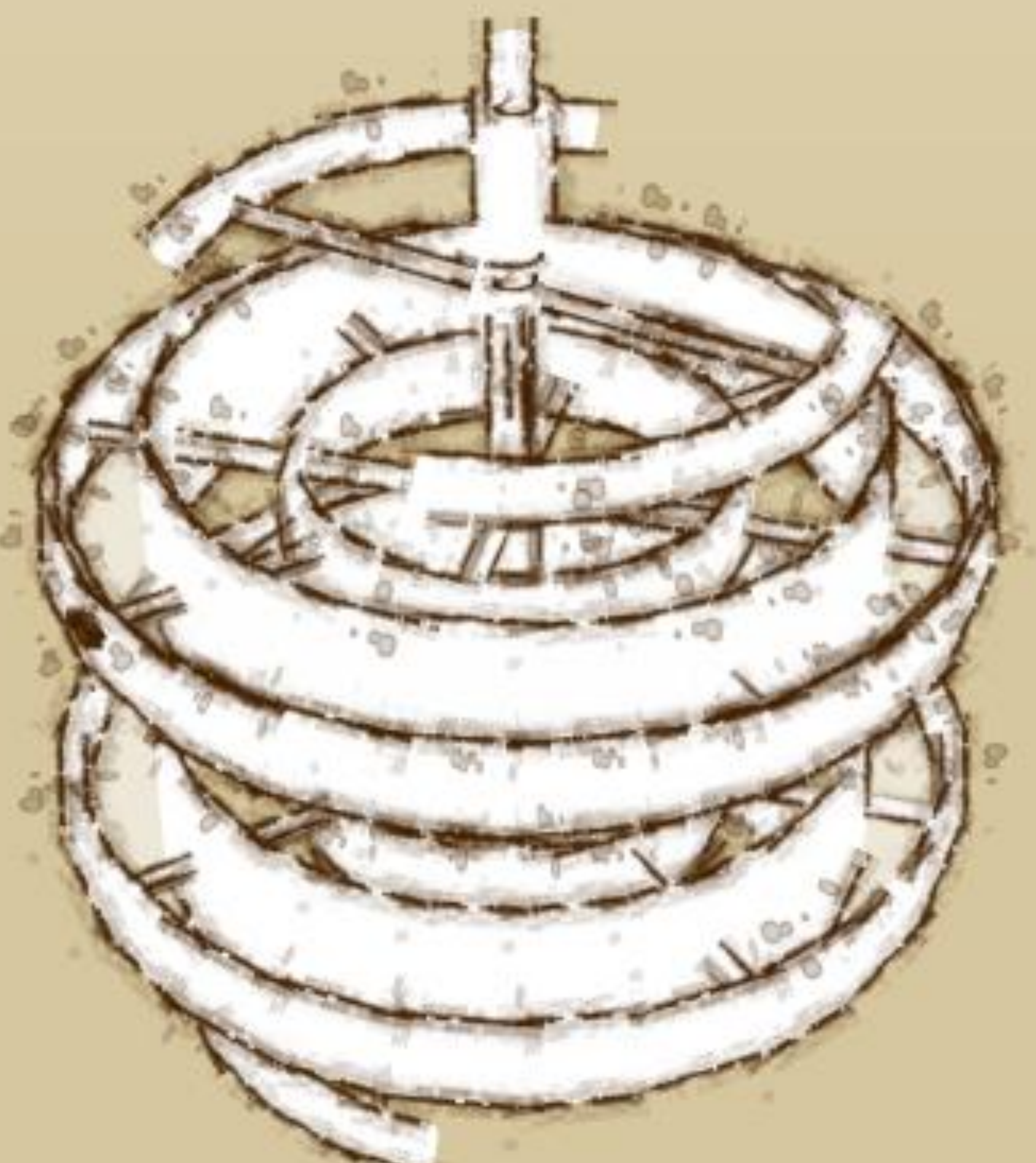
$145196237680 + 7824954000x = 14246666667x$

$145196237680 = 6421712667x$

$x = 22.61020466$

23 years to break even

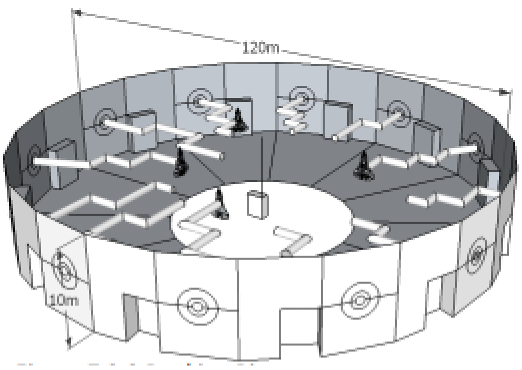
7.0 Business Development



Section 7: Business Development

7.1.1 Docking, Warehousing, and Cargo-Handling

Raw materials gathered from large-scale lunar development and industrial enterprises will be sent to a complex consisting of various pressure and temperature levels to facilitate storage and transportation capabilities. The layers of this complex will consist of a sub-floor, main floor, and storage floors I, II, III, and IV. Spaceships, after being guided into the port via radio waves, will enter the main floor, which will contain eight available compartments, before moving to the subfloor. In the subfloor, space shuttles will undergo cleaning and maintenance procedures to maximize safety for future expeditions.



A cylindrical web-like structure will run through the center of this facility. Since the whole complex is kept in zero-gravity, transport robots will be able to easily move through the cylindrical area as well as from floor to floor. Raw materials in the space shuttle will be contained in standard containers measuring 5.4864 meters by 16.764 meters (18 feet by 55 feet). After materials have been unloaded from the space shuttle, the ship will depart to the appropriate maintenance and cleaning area.

Figure 7.1.1 Maintenance Complex

As previously mentioned, the complex consists of four layers of storage. The first floor will have a pressure of 0.5 bar, the second floor with a pressure of 1.0 bar, the third floor with a pressure of 1.5 bar, and the fourth floor with a pressure of 2.0 bar. Each floor will have eight divisions, and each division will have different temperatures. The temperatures will range from 10° C to 30° C, increasing by 5° C increments, then returning back to 10° C.

7.1.2 Terminal Facilities for Passenger Traffic and Recreational Activities

After the passengers have arrived at the facility, they will be directed into their proper destinations through the use of passenger sorting robots. Passengers will be sent to the proper terminals after they have rested and are ready for travel. There will be two types of terminal facilities on the settlement – one for ships bound for long distance travel and one for Earth orbit travel. This facility, kept at 23^{o} C at the pressure .7 ATM, will be cylindrical with a radius of 100 meters and a height of 100 meters. These ports, capable of holding up to 5100 passengers, will be located on each pole of the settlement.

The settlement will include a variety of recreational activities as well as resorts and restaurants for vacationers' and ship crews' comfort and entertainment. Please refer to Section 4 (Human Factors) for details.

7.2.1 Commerce and Finance Center

The New Foundation Society headquarters will be in the center of the finance center of Columbiat, surrounded by buildings for banks. The headquarters will research future expansion locations, oversee each bank's providing member services, and provide a representative body for investments. There will be a hundred representatives managing business and investments from each of the three banks on Columbiat (with 300

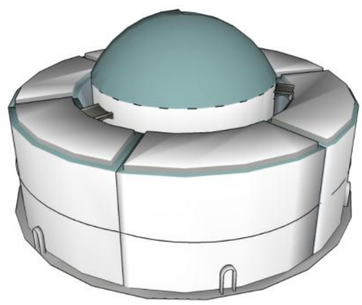


Figure 7.2.1 -Commerce and Finance Center

representatives total). The representatives will advise clients for investing in businesses on Columbiat as well as future long term projects. The headquarters will oversee member services that are provided by each of the banks in their respective buildings.

The three banks stationed at Columbiat will have two major buildings for each bank: one to accommodate bank tellers and computers to regulate the transactions of their customers, and one to support clients. The building accommodating bank tellers and computers will have two floors, with each floor being 1000 square meters. The first floor will be divided up in to two sections. This half will be 150 square meters. The other half will be allocated to eight 100-person offices that will be 850 square meters. The second floor will be used to accommodate four 150-person offices taking up 650 square meters, and fifteen 30-person office room taking up 350 square meters. The employees in the entire second floor will be checking and monitoring all the transactions of their clients to maintain a secure network. The employees on the first floor will be dealing with loans for customers as well as other customer services.

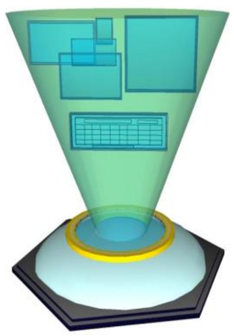


Figure 2.2. Material Information Database

The three banks will each have thirty 5-person field office located in various places of the settlement. These field offices will be placed every kilometer along the rings of each toris on each level to increase availability of the bank of the passengers. This will total up to 30

All of the banks will utilize one main computing center in order to increase interconnectivity between banks. This will enable the banks to efficiently transfer data with each other. This main computing center will be secured through the implementation of anti-hack softwares.

7.3.1 Inspection Crawlers

WiFi thermographic space cameras will be placed every 1,000 feet along the space elevator cables and rotate in cycles in all 3 dimensions. These cameras will be placed within the buckystructure cage, connected using strong electrostatic adhesion. The cameras will use a program to analyze the infrared images from the cameras to automatically detect any possible issues. These cameras will also be connected to the space settlement's cloud network allowing administrators to routinely monitor the cables whenever they wish.

Furthermore, piezoelectricity based sensors will be placed every 50 miles along the cables. These sensors will consist of piezoelectricity films that use electricity to measure any excessive strain on the cables, indicating possibility of damage that can preemptively be dealt with.

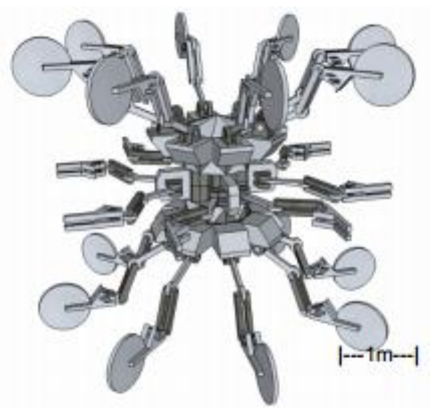


Figure 7.2.2 Inspection Crawlers

In addition, the robot inspector crawlers will be constructed similar to the emergency robots with an outer layer of protective lead to protect from solar flares or other possible disasters. They will carry buckystructure material for repairing any structural issues. Each robot would be based on simple programming rules. By working together using networking, complex tasks could be accomplished, allowing structural issues to be automatically taken care of as they encounter as they traverse the cables. When the cameras or piezoelectric sensors detect possible structural issues, they will automatically instruct the robots through the settlement cloud network in order to deal with the issue.

7.3.2 Maintenance and Repair Systems

There will be ten docks along the length of the space elevator ribbons; each will contain an emergency robot carrier vehicle as well as two inspection crawlers. Ribbon inspection robots will “crawl” along the length of the ribbon to assess the quality of the ribbon before the elevator runs on it. This will ensure maximum safety for passengers as well as optimal working capabilities for the space elevator.

Cameras, air pressure sensors, and thermostats will be placed in the elevators. The video feed as well as the air pressure and temperature information will be sent back to the stations using cables along the ribbon interface. If these sensors detect a change in the elevators, the elevator cab will send a radio signal to the nearest of the ten docks. There, an emergency robot carrier vehicle will be launched from the dock to the cab in order to resolve this problem. If the pressure or temperature cannot be restored, the passengers will be quickly escorted to the emergency robot carrier vehicle, which will enter the nearest robot dock; space shuttles, docked at these robot docks, will transport passengers to the nearest space elevator. Passengers will then be taken to the correct destination.

This completely automated system of monitoring allows any possible damage to be effectively and efficiently detected and repaired. Administrators, located at construction control centers located on Columbiat, will be notified of the condition of the elevators and ribbon interface.

8.0 Compliance Matrix

8.1 Operational Scenario (Appendix A)

Are you an adventurous explorer hoping for excitement? A businessman hoping to expand his business? A weary human hoping to find some peaceful place to retire? Or are you just a normal person tired of the shortcomings of Planet Earth? Do you want to avoid lazy freshmen who are incapable of doing work? Then Columbiat is the place for you! Columbiat features many, many things, including a large amount of entertainment options, convenient transportation, resources for exercising, and possible business expansions. You'll be amazed at the unlimited food choices available at Columbiat. From fish to vegetables, Columbiat offers a diverse selection of exquisite cuisines from around the world. A convenient moving walkway transports people all around the settlement. Amenities are available at every area, security is at a max, and safety is a first priority. Never worry about getting lost: a personalized GPS will take you wherever you want to go. Experience the thrills of floating in the air with a low-gravity entertainment area. See the stars, the moon, and even your very own Planet Earth from a completely unique standpoint as they orbit around you! You'll never get bored of these amazing sights. Come to Columbiat NOW!

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8.3 Compliance Matrix (Appendix C)

Requirements	Subsection	Page
1.0 Executive Summary - The contractor will describe the design, development, construction, and operations/maintenance planning for the Columbiat space settlement in Earth orbit.	--	E1
2.0 Structural Design - Columbiat must provide a safe and pleasant living and working environment for 23,000 full time residents, plus an additional transient population, between 2000 and 2500, of business and official visitors, guests of residents, and vacationers. The design must enable residents to have natural views of Earth and the moon below.	--	S1
2.1 External Configuration - On exterior design drawing(s), identify large enclosed volumes and their uses, and show dimensions of major structural components and design features. - Identify construction materials for major hull components. - Specify volumes where artificial gravity will be supplied, structural interface(s) between rotating and non-rotating sections, and rationale for selection of rotation rate and artificial gravity magnitude(s). - Identify volumes maintained in pressurized or unpressurized environments. - Specify means for providing protection from radiation and debris penetration. - Overall exterior view of settlement, with major visible features showing rotating and non-rotating sections, pressurized and non-pressurized sections, and indicating functions inside each volume	-2.1.1 -2.1.2 -2.1.1 -2.1.1 -2.1.2 -2.1.1	S1
2.2 Internal Arrangement - Specify percentage allocation and dimensions of interior “down surfaces”, with drawings labeled to show residential, industrial, commercial, agricultural, and other uses. - Show orientation of “down surfaces” with respect to overall settlement design, and vertical clearance in each area. - Overall map or layout of interior land areas, showing usage of those areas.	-2.2	S4
2.3 Construction Process - Describe the process required to construct the settlement, by showing the sequence in which major structural components will be assembled. - Specify when artificial gravity will be applied. - Drawing(s) showing at least eight intermediate steps of settlement assembly, and method of initiating rotation for artificial gravity.	-2.3	S6
2.4 Port Facilities - Columbiat’s port facilities must simultaneously dock and unload/load four cargo ships and one passenger ship, with long-term docking for one ship requiring emergency repair.	-2.3	S7

- Allow for future expansion to double this capability - Show interface and configuration, but exclude from price. - Drawing(s)/map(s) showing location of port area(s) for handling incoming and outgoing ships, and cargo transfer facilities in a typical docking bay for visiting ships.		
2.5 Space Elevator - The space elevator will be constructed by extruding viscous buckystructure feedstock through a catalyzing agent to form ribbons of the required dimensions. - When the ribbons achieve the required length, an attachment interface will be formed as a thicker length of ribbon. - Show the attach system to the space elevator ribbon, with specification of the preferred attachment interface dimensions.	-2.5	S7
3.0 Operations and Infrastructure - Describe facilities and infrastructure necessary for building and operating the settlement, including conduct of businesses and accommodating incoming and outgoing space vehicles.	--	O1
3.1 Location and Materials Science - Columbiat will operate at the Earth-Moon L1 libration point, serving as the orbital terminus of a lunar space elevator. - Identify sources of materials and equipment to be used in construction and operations (Earth, asteroids, existing on-orbit facilities, Earth's moon, or elsewhere), means for transporting those materials to the Columbiat location, and storage between arrival and use. - Chart or table identifying types and amounts of the various materials and equipment required for the settlement construction process, and from where and how those materials and equipment are shipped.	-3.1.1 -3.1.2	O1
3.2 Community Infrastructure - Columbiat design will show elements of basic infrastructure required for the activities of the settlement's residents - Atmosphere/climate/weather control (identify air composition, pressure, and quantity) - Food production including growing, harvesting, storing, packaging, delivering, selling - Electrical power generation (specify kilowatts), distribution, and allocation for specific uses - Water management (specify required water quantity and storage facilities) - Household and industrial solid waste management (specify recycling and/or disposal) - Internal and external communication systems (specify devices and central equipment) - Internal transportation systems (show routes and vehicles, with dimensions)	-3.2.1 -3.2.2 -3.2.3 -3.2.4 -3.2.5 -3.2.6 -3.2.7 -3.2.8	O2

- Day/night cycle provisions (specify schedule and mechanisms/operations for providing it). - Dimensioned drawing(s) showing systems which provide required infra-structure, and, as appropriate, their configurations (e.g., show routings of utilities services).		
3.3 Construction Machinery - Show conceptual designs of primary machines and equipment employed for constructing the settlement, especially for assembling exterior hull and interior buildings / structures. - Describe materials, components, and/or subassemblies delivered to the machines, and how the machines convert delivered supplies into completed settlement structures. - Drawing(s) of primary construction machinery, showing how it shapes and/or manipulates raw materials or structural components into finished form.	 -3.3, 5.1	O7, A1
3.4 Propulsion Systems - Define propulsion systems required on Columbiat, for establishing and maintaining rotation of artificial gravity volumes, and station-keeping at Earth-Moon L1. - Show drawing(s) of propulsion system(s), locations and interface(s) with the structure, propellant type(s), propellant storage, and identify thrust produced by each type.	 -3.4	O9
3.5 Space Cab Elevator - Design the elevator cab that will ascend / descend the space elevator ribbon. - The cab must accommodate two standard cargo containers (15 feet square by 45 feet long) and 100 passengers, with acceleration of no more than 1 g and velocity no more than 250 miles per hour. - Show the attachment to the ribbon, and the method of ascending / descending the ribbon. - Drawing of space elevator cab design.	 -3.5	O10
4.0 Human Factors and Safety - Quality of life is important to Foundation Society members, who expect Columbiat to offer community attributes that citizens of Earth's small cities might enjoy. Assure that natural sunlight and views of Earth and the moon below are readily available to residents.	--	H1
4.1 Community Design - Columbiat will provide services that residents expect in comfortable modern communities, variety and quantity of consumables and other supplies, and public areas designed with open space and consideration of psychological factors. - List major categories of consumables; in particular estimate annual replenishment of clothing and paper, and describe source(s).	 -4.1.1 -4.1.2 -4.1.3	H1

- Depict or specify means of distributing consumables (including food) to Columbiat residents. - Map(s) and/or illustration(s) depicting community design and amenities	-4.1.1	
4.2 Residential Zone - Provide designs of typical residential homes, clearly showing room sizes. Offer residents differentiated neighborhoods to suit a variety of preferences for architectural design and lifestyle choices. - Estimate numbers of different types of furniture that will be required for residential and office areas, and identify source(s) of furniture items. - External drawing and interior floor plan of at least four home designs, the area (square feet) for each residence design, and the number required of each design.	-4.2.2 -4.2.1 -4.2.3 -4.2.2	H4
4.3 Safe Access - Designs of systems, devices, and vehicles intended for use by humans outside of artificial gravity volumes will emphasize safety. - Provide means for safe access at/to any location in parts of the settlement with very low gravity environments, inside the hull or on hull exterior surfaces. - Define requirements of spacesuit designs required for work outside of pressurized settlement volumes, including spacesuit stowage and donning/doffing procedures, and airlock designs for exiting/entering the settlement from unpressurized volumes. - Drawings showing examples of handrails, tethers, cages, and/or other systems enabling safe human access to any location on or in low-g settlement areas.	-4.3.1 -4.3.1 -4.3.2 -4.3.3	H6
4.4 Passenger Arrival and Departure -Guests must have a favorable first impression upon arrival. - Show passenger arrival / departure facilities for both the space elevator and ships. - Show location(s) and design(s) of hotel(s) or other visitor accommodations. - Describe security measures to unobtrusively monitor visitors and assure that their activities do not interfere with lives of permanent residents. - Floor plans of arrival / departure areas and public areas of hotels	-4.4.1 -4.4.1 -4.4.2 -4.4.2 -4.4.2	H8
4.5 Space Elevator Design and Accommodations - Show design of space elevator cab accommodations for passengers, including size, configuration, and amenities. - Show seating, privacy, and entertainment for space elevator passengers.	-4.5.1	H9
5.0 Automation - Describe computer systems, robots, and other computing and information management devices for operating the settlement, running its community and businesses, and providing convenience and safety for residents and visitors. - Define physical locations of computers, robots, and support systems for critical functions.	--	A1
5.1 Automation Construction Process	-5.1.1	A1

- Describe use of automation for construction. - Consider automation for transportation and delivery of materials and equipment, assembly of the settlement, and interior finishing. - Show robot designs, clearly indicating their dimensions and illustrating how they perform their tasks. - Chart or table describing automated construction and assembly devices-- both for exterior and interior applications and the purpose(s) of each.		
5.2 Facility Automation - Specify automation systems for settlement maintenance, repair, and safety functions, including backup systems and contingency plans for failures. - Robots required for emergency external repairs must survive and accomplish tasks during solar flare activity. - Describe means for authorized personnel to access critical data and command computer and robot systems - Descriptions of security measures to assure that only authorized personnel have access, and only for authorized purposes. - Specify number and types of personal communication / information devices, computers, servers, software, network devices, and robots required for each automation function - Chart or table listing anticipated automation requirements for operation of the settlement, and identifying particular systems / devices to meet each automation need.	-5.2.1 -5.2.2 -5.2.3 -5.2.4 -5.2.5	A2
5.3 Habitability - Specify automation systems to enhance livability in the community, productivity in work environments, and convenience in residences. - Emphasize automation to perform maintenance and routine tasks, and reduce requirements for manual labor. - Provide for privacy of personal data and control of systems in private spaces. - Describe access to community computing and robot resources from homes and workspaces. - Describe types and capacities of data storage media, data collection, data distribution, and user access to computer networks. - Drawings of automation systems that people will encounter in Columbiat - Diagram(s) of network(s) and bandwidth requirements to enable computer/device connectivity.	-5.3.1 & 5.3.2 -5.3.3	A3
5.4 Cargo Handling - Provide automated cargo handling systems for cargo ships that will completely unload and load, warehouses for temporary storage of goods and bulk materials, and inventory management. - Anything moving in near-Earth space may transfer between vehicles at Columbiat. - Illustration, chart, or matrix showing inventory management system - Illustration of automated unloading/loading system(s).	-5.4	A5

5.5 Port and Docking System - Drawing(s) of robot repair facilities - Illustration(s) of measures implemented in order to prevent spread of dust contamination brought by visiting ships.	-5.4	A6
6.0 Schedule and Costs - The proposal will include a schedule for completion and occupation of Columbiat, and costs for design through construction phases of the schedule.	--	SC1
6.1 Design and Construction Schedule - The schedule must describe contractor tasks from the time of contract award (15 May 2049) until the customer assumes responsibility for operations of the completed settlement. - Show schedule dates when Foundation Society members may begin moving into their new homes, and when the entire original population will be established in the community. - Durations and completion dates of major design, construction, and occupation tasks, depicted in a Gantt chart with monthly increments.	-6.1	SC1
6.2 Costs - Specify costs associated with Columbiat design through construction in U.S. dollars, without consideration for economic inflation. - Estimate numbers of employees working during each phase of design and construction in the justification for contract costs to design and build the settlement. - Chart(s) or table(s) listing separate costs associated with different phases of construction, and clearly showing total costs that will be billed to the Foundation Society.	-6.2	SC4
7.0 Business Development - Columbiat will host various commercial and industrial ventures, which may change with time. - The basic design must be sufficiently flexible to add compatible business types with little configuration change. - Transportation Node and Port: - Docking, warehousing, and cargo-handling capability to transfer freight between spacecraft, including cargo associated with large-scale lunar development and industrial enterprises expected for Mars and the asteroids - Terminal facilities to handle passenger traffic between Earth, Earth orbit destinations, the Moon, and other locations in the solar system - Offer a wide variety of activities to visitors: ships' crews will expect "rest and recreation" options in a big city environment away from the confines of their ships; In-transit vacationers will expect resorts, restaurants, theaters, and amusements - Commerce and Financial Center: - Office facilities to enable businesses to establish a presence in space	-7.1.1 -7.1.2 -7.2.1 -7.2.1	B1 B1 B1 B1 B1

- Interest has been expressed by companies to establish four 150-person offices, eight 100-person offices, fifteen 30-person offices, and thirty 5-person field offices - Facilities for offices of three banks that plan to establish centers to service financial needs of space-based companies, space settlement residents, and ships' crews - New Foundation Society headquarters, with a 300-person staff managing businesses and investments, researching new settlement locations, and providing member services - Computing center(s) enabling secure networked internal communications for each company while providing interconnectivity for transferring data between companies - Space elevator Operations Center: - Construction control center, with views of extrusion mechanism and ribbon interface - Continuous monitoring of ribbon integrity along its entire length, both with cameras and robot "inspection crawlers" - Facilities for and deployment of maintenance and repair systems - Monitoring of passenger experience and safety in elevator cabs	-7.2.1 -7.2.1 -7.2.1 -7.3.1 -7.3.1 -7.3.2 -7.3.2	B1 B1 B1 B2 B2 B3 B3
8: A Operational Scenario - Write a script for a video up to 15 minutes long, showing attributes of Columbiat and the appeal of living in space	-8.1 (A)	CM1
8: B Bibliography/References - Any text or image that is not an original creation specifically for this proposal must be specifically referenced to source materials listed here.	-8.2 (B)	CM2