NORTHDONNING HEEDWELL

Columbiat

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section

1.0

executive summary

Section 1 : Executive Summary

IN THE WORKS of filmmakers, novelists, and enthusiasts the world over, the idea of settling in space has long presented itself as a vision to behold. Now, in 2044, **Northdonning Heedwell** is pleased to present a proposal to make this vision a reality. Following in the footsteps of its predecessors Alexandriat and Bellevistat, **Columbiat** will be a center of business, trade, and fast-paced activity in space. Columbiat will combine the cosmopolitan society of Singapore with the tight-knit bustle of New York and the luxury of Dubai to create an appealing environment for businessmen and families alike willing to explore a new frontier in space colonization.

Among its many virtues, Columbiat boasts a novel design, catering to both experienced space travelers and adventurous tourists. Major innovations in its structure include:

- A **commercial disk**, dubbed *Isengard*, whose ports for space vehicles and state-of-the-art repair facilities will cater to various incoming and outgoing ships around the clock
- A viewing **observatory**, *Polaris*, which will offer breathtaking views of space to tourists and residents alike
- Two **adjustment modules** for first-time arrivals, *Luna 1* and *2*, at half of the settlement's gravity will allow for visitors to acclimate themselves easily to the new environment
- A **terminus** to provide facilities for the end of a potential lunar space elevator
- The latest advances in economically- and environmentally- friendly **living, work, and recreation,** including microgravity attractions and aeroponically-grown vegetation

At its peak, Columbiat will be able to provide facilities for 22000 full-time residents, plus a transient population of up to 5000. Its two main tori, *Terra* and *Gaia*, will house the full-time residents as well as the majority of Columbiat's business and trade operations. In its orbit at **L2**, Columbiat will be constantly involved with Alexandriat and Bellevistat, as well as working to support new ventures into space. Operations and maintenance on Columbiat will be largely automated, in order to allow the humans on the settlement to work in other sectors including business, trade, research, and experimentation. Intricate contingency plans have been woven together in order to ensure the strength of these automated systems as well as the safety of the residents of Columbiat.

Once approved, construction of Columbiat will commence immediately; Northdonning Heedwell estimates that Foundation Society members will be able to move into the facilities in January of 2064 and the settlement will be open to all colonists by September of 2064. The settlement's full-time population will be established as soon as July of 2065.

Columbiat's aim is to provide residents, businessmen, and tourists with the comforts of home while pushing the limits of a new frontier in space colonization. In time, Columbiat will blossom into a bustling trade and commercial hub for space settlements, providing golden opportunities for entrepreneurs and creative minds of future generations. In the pages following, Northdonning Heedwell presents its design for Columbiat: the future of space commerce, culture, and colonization.

section 02

structural design

SECTION 2 : STRUCTURAL DESIGN

IN DETAILING THE structure of Columbiat, Northdonning Heedwell has carefully taken into account the utmost safety of the residents and the maximum efficiency to reduce costs and environmental impacts. The result is an innovative design marking a step forward in space designs.

2.1 External Configuration

2.1.1 Exterior Design

Figure 2.1.1: Overall External View with Helios Solar Panel Satellite

Columbiat will consist of two pressurized counter-rotating residential tori, *Terra* and *Gaia*, maintained at one Earth gravity and connected to the stationary *Central Axis* by spokes. At one end of the *Central Axis, Polaris* provides natural views of space for tourists while protecting them in a safe environment. The settlement's adjustment modules, *Luna 1* and *Luna 2*, will be a maintained at one half Earth-gravity to allow for a smooth transition from zero gravity to one Earth gravity. *Aurora* allows for a steady stream of natural light into the two tori and can double as solar panels for extra energy during "nighttime" in the tori by turning over its slats of mirrors to reveal solar panels mounted on the back. *Isengard* provides repair and docking facilities for visitors and cargo ships, while its side facing the sun is coated with solar panels for maximum energy absorption. This end of the *Central Axis* also harbors the *Terminus* for the future space elevator. In addition, any other energy needs are supplied by the system of the four satellites *Helios* (only one is shown), which beam energy to Columbiat.

Several factors were taken into account when designing the structures. Oval shaped cross-sections were chosen for the tori to minimize unnecessary volume and air. Two tori were chosen instead of one large torus in order to provide redundancy: if one torus is damaged and in need of repair, the other can operate independently. *Aurora*'s panels are inclined at 60 degrees from horizontal to maximize the amount of light striking *Isengard*'s solar panels while still being able to provide *Gaia* and *Terra* ample natural light. *Aurora's* and *Isengard*'s solar panels efficiently use any solar energy striking the settlement; *Luna 1* and *Luna 2* have been placed behind *Isengard* as to not interfere with light absorption and also because these two adjustment modules are much more efficiently lighted by artificial light and do not require mirrors or sunlight for lighting.

Sections:	Dimensions:	Total Surface Area:	Total Volume:
Polaris	Radius = 100 m	125 663.706 m^2	4 188 790.205 m^3
Central Axis	Radius = 50 m Height = 1 200 m	392 699.082 m^2	9 424 777.961 m^3
Aurora (Mirror/Solar panels)	Radius Top = 100 m, Bottom = 205 m Height = 335.07 m	521 661.460 m^2	N/A
Pressurized Counter-Rotating Rings *Terra* and *Gaia* *Dimensions are per ring*	Radius = 900 m Height = 204.812 m Thickness = 75 m at the widest Circumference = 5 654.867 m	1 287 952 m^2	68 222 705.51 m^3
Luna 1 and *2* *Dimensions are per segment*	Radius = 447 m Height = 200 m Thickness = 75 m at most Length = 887.5 m	197 399.20 m^2	10 455 613.05 m^3
Port Isengard	Radius = 800 m Height = 50 m	4 222 300. 526 m^2	100 530 964 m^3
Terminus	Height = 50 m Width = 120 m at widest Length = 110 m at longest	49 400 m^2	26 000 m^3
Helios Satellite System (2 Solar Panels each for four satellites)	Width of one panel: 592 m Height of one panel: 100 m	1184000 m^2	N/A

Table 2.1.1 Dimensions for Major Components and Satellites

2.1.2 Construction Materials and Radiation Debris Penetration Protection

To ensure quality radiation and debris penetration protection, Columbiat will be shielded with a variety of materials, carefully chosen for their specific properties as summarized below:

Material	Usage	Properties
Borosilicate Glass	Window panes Polaris Observatory	Low coefficient of thermal expansion, resistance to thermal shock, shatter resistant.
Demron Cloth Layers	Radiation shielding for junctions of different structural components	Flexibility allows for protection against X-rays, gamma-rays, and other nuclear radiation at junctions and joints of components.
Inconel 718 Ni-Cr Superalloy	Structural support Junctions of components	Outstanding strength, resistance to corrosion, and high durability.
Liquid Hydrogen	Radiation shielding for hull components	Minimizes secondary particle showers.
Polyethylene	Radiation shielding for hull components	Lightweight, high hydrogen concentration provides radiation protection while minimizing secondary particles.
Ra-guard	Radiation shielding for hull components	Effective radiation protection against X-rays, wide range of applications due to its ability to be coated

	Window panes Polaris Observatory	onto different surfaces. Transparency allows for window pane coating.
Regolith (Lunar and terrestrial)	Growth medium Radiation shielding for hull components	Radiation protection, as well as growth medium for plants.
Silica Aerogel	Radiation shielding for hull components Window panes Structural support Polaris Observatory	High thermal insulation, outstanding radiation protection qualities. High porosity allows for reinforcement with other materials for added durability.
Silicon-Carbide Structures	Meteorite protection Structural support Inner structural component	Provides heat resistance, high tensile strength, and shatter resistance.
Titanium Grades 5 & 6 Alloys	Structural support; smaller inner and outer parts	Ready availability, stability, and weldability

Table 2.1.2 Radiation Protection and Construction Materials for Major Hull Components

Radiation and Debris Protection for Components:
Standard radiation protection for components is depicted as follows:

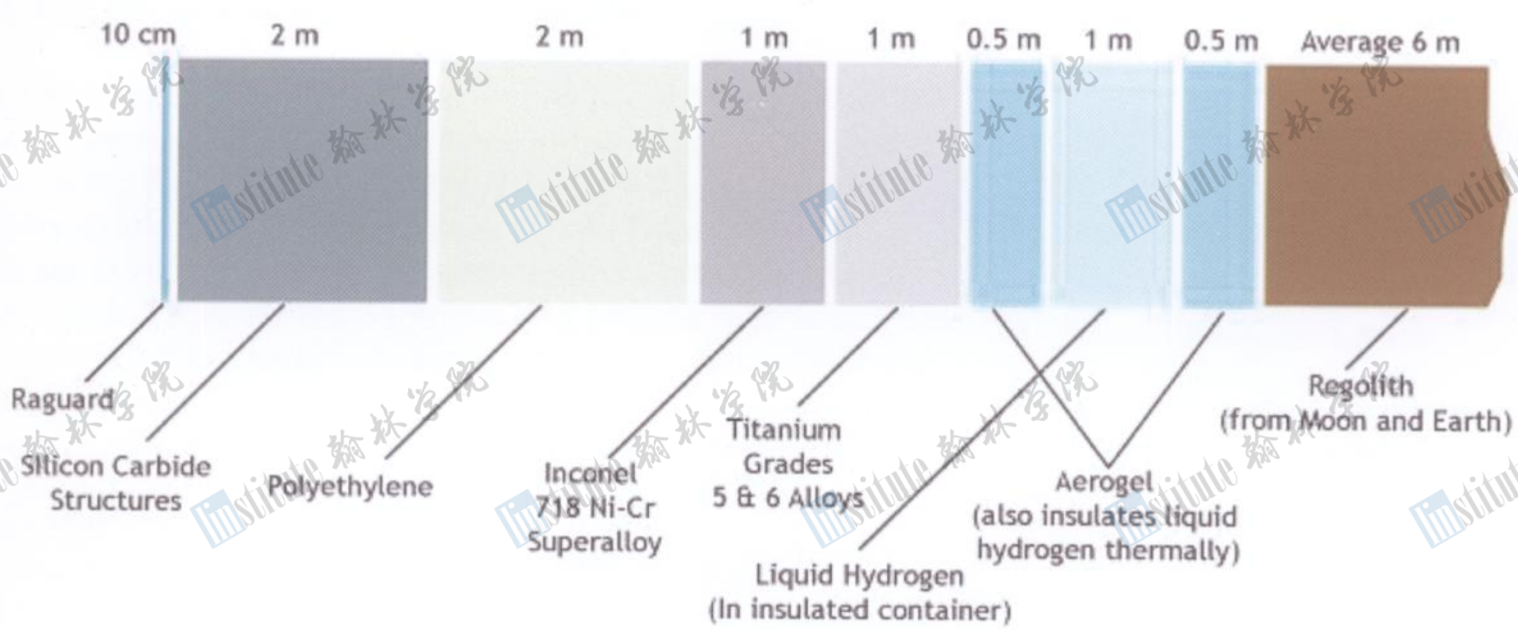


Figure 2.1.2 Standard Hull Components Shielding (not to scale)

The shielding is about 14.10 m thick. *Isengard* is an exception to this as it also has solar panels covering its side that faces the sun, as are the spokes or *Central Axis*, which do not include liquid hydrogen due to combustion concerns and difficulty of storage. The liquid hydrogen is maintained close to the regolith, so that in the case of a leak it is easily accessible and quickly patched up.

Junctions:
At junctions where components are joined, Demron cloth layers will be used in order to provide flexibility and movability. For junctions, Ni-Cr Superalloy will also be used as it is highly resistance to corrosion and provides durable support for moving parts, such as the rotation motors for the tori.

Windows and Polaris Observatory:

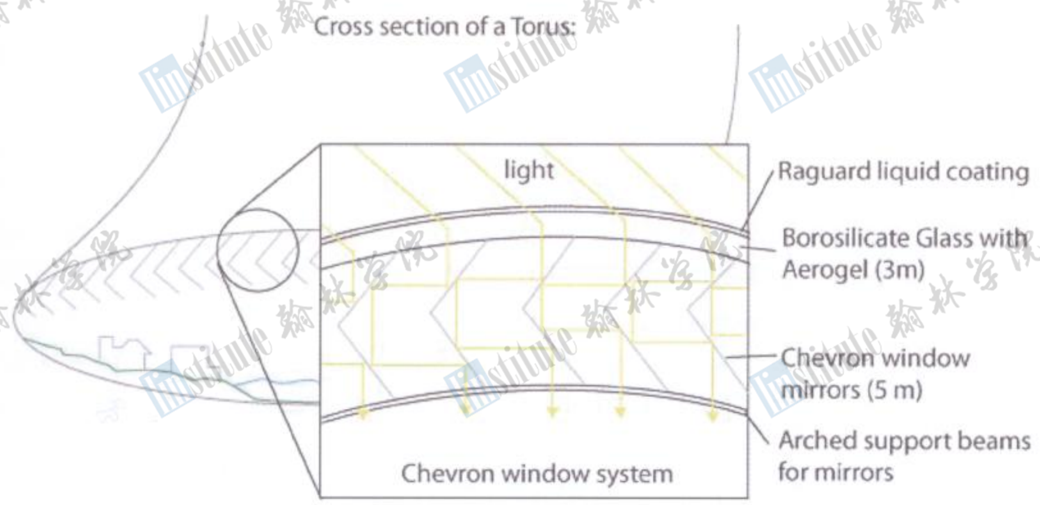


Figure 2.1.3 Window Radiation Protection

In *Polaris* and windows in *Gaia* and *Terra*, window panes will be glazed with Raguard as a first defense against cosmic radiation. If penetrated, window panes composed of borosilicate glass fused with aerogel will provide more resistance against radiation, as well as debris penetration. In addition, for *Gaia* and *Terra*, Columbiat will also use chevron-styled windows (Figure 2.1.3). Light rays will be directed perpendicular to the surface of the settlement as it passes through the first two barriers, and will then be able to reflect off the zig-zag pattern of mirrors. Since radiation cannot bounce off mirrors, they will be trapped. The structure of chevron windows can also provide support for the settlement.

2.1.3 Artificial Gravity and Rotation Rates

a_c = acceleration towards center of mass
v_t = velocity of object(in meters/second)
r = radius (900m per torus)

Gaia and Terra will be maintained at one Earth gravity while Luna 1 and Luna 2 will be maintained at half of Earth's gravity. The *Central Axis*, *Isengard*, and the *Terminus* will operate at zero gravity to allow for efficient transportation. *Polaris* will also operate at zero gravity for the entertainment of tourists. Since humans cannot withstand 3 rpm for long periods of time, and the Coriolis Effect increases with a greater rotation speed, Gaia and Terra will simulate gravity by rotating at .9965 rpm. Luna 1 and Luna 2 will rotate at almost exactly 1 rpm; however, due to their shortened distance from the *Central Axis*, they will only produce one half G.

Given that:
The centripetal acceleration due to velocity is $a_c = (v_t)^2 / r$
And that $v_t = 2\pi r/p$, and centripetal acceleration = 1 g = 9.8 m/s^2

We have: and p = 60.213
So it takes about *60.213 seconds* for one revolution

Using proportions, $\frac{6.0213}{60} = \frac{1}{x}$
x = *0.9965 rpm*

Using the same calculations, but with a_c = 4.9 and r = 447 m, the rotation rate of Luna 1 and Luna 2 equals to 1 rpm.

The tori are counter-rotating to provide stability to the structure. By simulating the gravity of Earth, residents, tourists, and animals will be able to easily adjust to the settlement. To those people who still need time to adjust between zero gravity and full gravity, they may temporarily reside in the adjustment modules.

The artificial gravity will be generated by a rotating motor that is powered by a xenon ion propulsion system. Central Processors in the axis will monitor the rotating sections to ensure constant rotation rates and maintain the settlement in L2 orbit. Attitude control (always facing the sun) will be provided by control movement gyroscopes.

2.1.4 Pressurized/Non-Pressurized Volumes

Terra, Gaia, Polaris, Luna 1 and *Luna 2* will be maintained at 101.3 kPa to simulate the atmospheric pressure of Earth for the comfort of residents and easy adjustment. With minimum human activity in the *Central Axis* and spokes connecting rotation regions to the axis, these areas will be unpressurized to save energy and resources. Due to its constant exposure to space, the majority of *Isengard* will remain unpressurized to prevent the potentially excessive usage of air. However, one section of *Isengard* will be pressurized to allow tourists to enter the settlement without needing to adjust to a non-pressurized atmosphere. Since operations in the *Terminus* are automatic, it will be unpressurized.

2.2 *Internal Arrangement*

2.2.1 Central Axis:

The *Central Axis* will supplement the storage systems of *Isengard, Gaia,* and *Terra* by providing storage for agricultural and wholesale products. It will be the center for transport by using the Magnetic Railway System to connect all parts of the settlement. Spokes, each with a radius of 25m, extend from the central axis to *Gaia* and *Terra* to provide stability to these tori and to allow transportation between the sections. To enable such transportation, each spoke will have a two-way transportation system – the Sky Ferry System. Due to its microgravity environment, the central axis will contain a sector for low-gravity experiments. The *Central Axis* will also harbor the control systems which control the operations of the settlement.

Central Axis (%; S.A. in m²)

Commercial Storage- 28; 11,8752.2023
Control Systems-5; 21,205.75041
Transportation-20.5; 86,943.57668
Experimentation and Zero-G Research-10; 42,411.50082
Waste and Water Management Center- 10; 42,411.50082
Industrial Storage-26.5; 112,390.4772
Total Down SA: 424,115.0082m²

Table 2.2.1 Central Axis Allocation

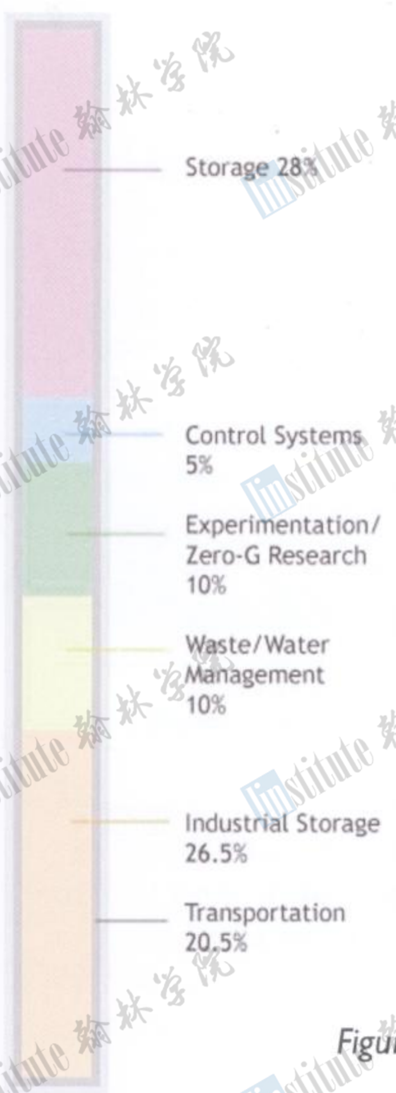


Figure 2.2.1 Central Axis

2.2.2 Pressurized Rotating Tori *Gaia* and *Terra*: Torus [each] (%, S.A. in m²)

Residential/Commercial Areas: (53.461)
Residences-8.017; 92,848.162
Hospitals-4.749; 55,000
Hotels-1.439; 16,666.667
Offices and Banks-1.266; 14,666.667
Recreational and Open Space-14.246; 165,000
Schools-4.749; 55,000

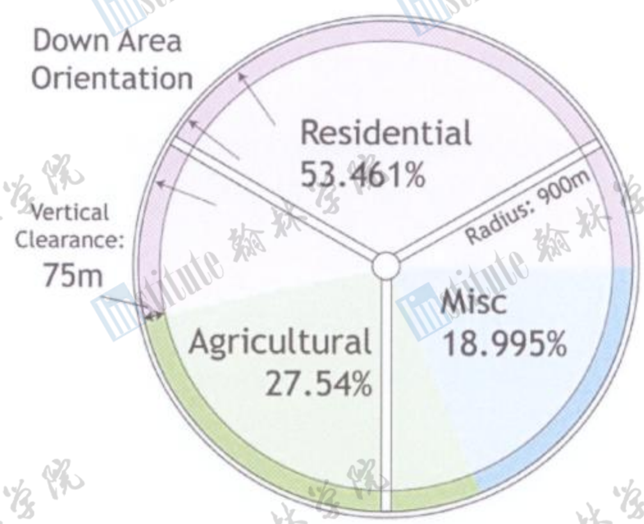


Figure 2.2.2 Overhead View of one Torus

Service Industry, Shops, and Transportation-18.995; 220,000
Agricultural Areas: (27.543)
Animal Raising-6.648; 77,000
Plant Growing-9.498; 110,000
Food Production-11.397; 132,000
Miscellaneous Area-18.995; 220,000
Total Down S.A. each-1,158,181.496

Table 2.1.2 Torus Allocation

The majority of the residents and tourists of Columbiat will reside in these tori. *Gaia* and *Terra* contain all of the agricultural areas and majority of the commercial and residential areas. To simulate an Earth environment, both *Gaia* and *Terra* will include shops, gyms, recreational activities, theaters, and other activities for the inhabitant's enjoyment (For more detailed descriptions on entertainment, see sections 4.1 and 5.3.4) These tori will also contain research facilities and industries that need Earth gravity to operate. In the event that one torus becomes damaged or any other way uninhabitable, the other torus and *Luna 1* and 2 can temporarily support all residents and tourists until repairs are complete. If both tori are damaged, emergency living space will still be available in *Luna 1* and *Luna 2*. It is not likely that all three residential areas are damaged at the same time due to their separation. To allow transportation between the tori without having to go through the zero-g *Central Axis*, *Gaia's* and *Terra's* will be connected by the Magnetic Railway System. (For a more detailed description on transportation, see 3.2.7)

2.2.3 Luna 1 and Luna 2

Adjustment Module [each] (%, S.A. in m^2)

Residential/Commercial Areas
Residences-56.338; 100,000
Hospitals-7.042; 12,500
Recreational and Open Space-14.085; 25,000
Service Industry, Shops, and Transportation-16.901; 30,000
Business-5.634; 10,000
Total Down S.A. each-177,500

Table 2.1.3 Module Allocation

Luna 1 and Luna 2 will act as adjustment modules operating at 1/2g for new inhabitants to become accustomed to Terra's and Gaia's Earth Gravity environment. (For more information about Luna 1's and Luna 2's operations, see Section 2.5.)

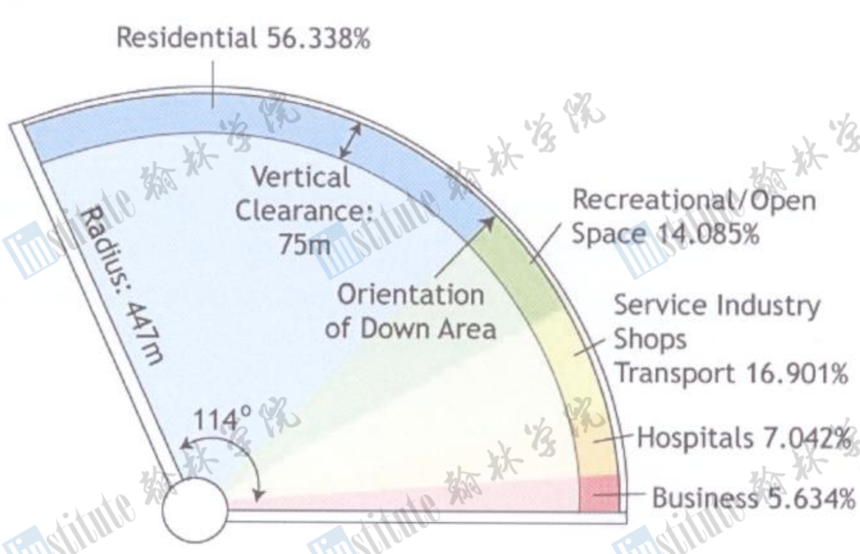


Figure 2.2.3 One Adjustment Module Area Allocation

2.2.4 Polaris and Space Elevator Terminus

Polaris is an observatory for the entertainment of the tourists and residents, where they will have a natural view of the Earth, moon, and other parts of space while being protected from radiation. All the surface area and volume in *Polaris* will be used for the observatory.

The Space Elevator Terminus will serve as the Space Elevator port. Once per month, the Space Elevator will arrive at L2 orbit and enter the *Terminus* where robots will transfer the cargo inside the Elevator into *Isengard's* commercial disk. (Refer to Section 7.1 for more specific details) Nearly all the down area in the Space Elevator Terminus will be for the Space Elevator Dock.

2.2.5 Isengard

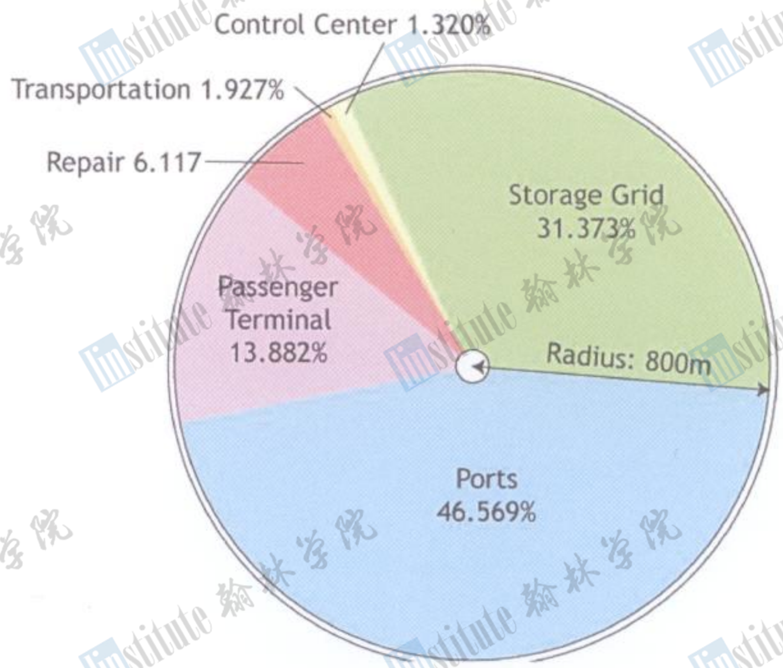
Isengard (%, S.A. in m^2)

Storage Grid-31.373; 628,318.531
Control Center-1.320; 2,643.650
Transportation-1.927; 38,585.830
Repair-6.117; 122,500
Port-46.569; 932,664.242
Passenger Terminal-13.882; 278,053.063
Total Down S.A. -2002765.316

Table 2.1.4 Isengard *Allocation*

Figure 2.2.4 Isengard Disk Area Allocation (Aerial View)

*Vertical clearance is 50m



Isengard is the commercial disk of Columbiat. It will operate as a storage facility, a docking area, a repair center, and ports. Cargo ships coming into Columbiat will enter through the ports of *Isengard* and unload their cargo through the use of clamps. This cargo will then be kept in the Storage Grid until conveyor belts transport the goods to their specified destinations. Tourists and others who enter the port do so via the Passenger Terminal, which is pressurized in order to eliminate the need of doing preliminary breathing exercises. For more information on *Isengard*, see sections 2.4, 5.4 and 5.5.

2.3 Construction Process

Because the construction of a space settlement is a lengthy and arduous task, it is crucial to follow logical steps during the construction process to maximize efficiency. We have proposed the following steps of construction (note that only one of the Helios satellites is shown):

	Phase 1: Estimated length of time: 3 years. The *Central Axis* and *Helios* are constructed. The power generated by *Helios* will be used by the *Central Control System and Communication systems* in the *Central Axis* to monitor the construction process.
	Phase 2: Estimated length of time: 5 years. External structures of *Luna 1* and *Luna 2* will be assembled on the *Central Axis*. They will support the construction teams and engineers who will monitor Columbiat's building process. *Luna 1* and *Luna 2* will not be rotated until construction of Columbiat is complete so workers and engineers will not need to adjust between half gravity and zero gravity.

	Phase 3: Estimated length of time: 6 years. *Isengard* will be constructed around the *Central Axis*. These ports will begin to operate due to necessary trips back to Earth to restock on supplies. The storage system in *Isengard* will also begin to operate to allow these supplies to be stored.
	Phase 4: Estimated length of time: 1 year. *Aurora* will be constructed along with the spokes later connecting to *Gaia* and *Terra*.
	Phase 5: Estimated length of time: 7 years. The two pressurized tori, *Gaia* and *Terra*, will be constructed and attached to the spokes. The tori and the rest of the settlement will be connected through the Magnetic Railway System. Construction of the internal environments of *Gaia*, *Terra*, *Luna 1*, and *Luna 2* will also begin in the latter part of the phase.
	Final Phase: Estimated length of time: 1 year. *Polaris* and the *Terminus* are connected to the ends of the *Central Axis*. All operations of the settlement will be tested and debugged. The construction of Columbiat is now complete and the settlement is self-sufficient. Residents are now welcomed into Columbiat. *Estimated date of completion:* July 2065

2.4 Ports

Columbia's docking facility and ports, *Isengard*, will be concentrated on an 800 m radius flat disk. The disk is divided into five sections, four of which are commercial ports and one which is a pressurized passenger terminal connecting to the *Central Axis*. All sections are in zero gravity in order to decrease the energy needed for transportation. A specialized section for long term ship repairs is isolated from all other sections in order to decrease contaminants in the disk. The middle section is the storage grid. On the ceiling of the disk (not shown) is an intricate network of 16 clamps used for the transportation of resources. These clamps ensure a pathway for the transport of goods

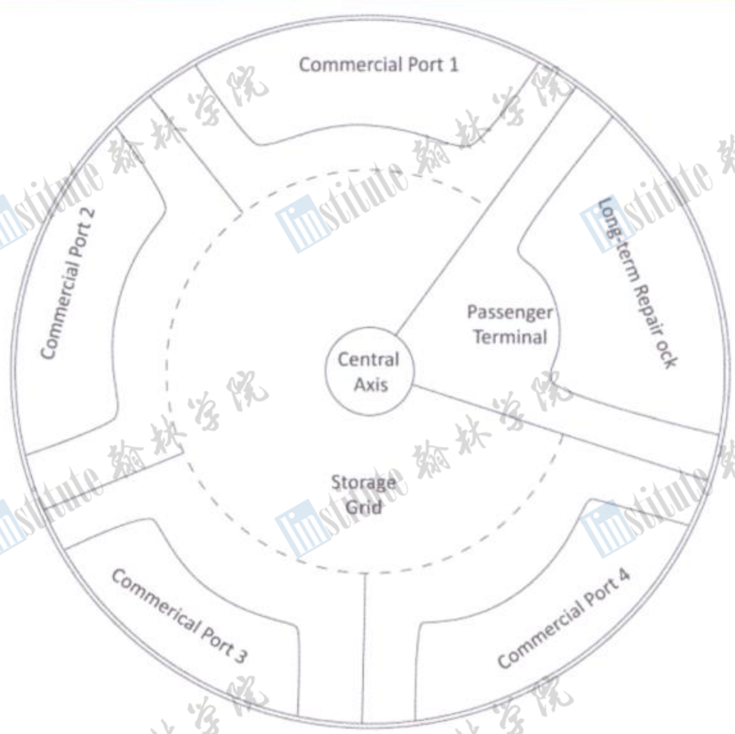


Figure 2.1.5 Down Area Allocation for Isengard

from the docks to the storage grid. For more information, see sections 5.4 and 5.5.

2.5 Microgravity Sections

Figure 2.1.6 Luna 1 and 2

Luna 1 and 2 serve as adjustment modules that function to adapt tourists and long-time space travelers to Gaia's and Terra's stimulated 1 Earth-G. This section creates ½-G to provide a comfortable transition. Luna 1 and 2 also rotate at about 1 rmp as to not cause nausea when one is transferred from Luna to Gaia or Terra.

The *Luna* adjustment modules are only open at certain amounts of times, in correspondence with flight schedules. During activity, *Luna* rotates at 1 rpm, creating ½ Earth-G. It is lighted by artificial light, as tourists and/or future residents will not permanently reside in there, and as it is cheaper to provide artificial light than to erect another mirror structure. Temporary residents will have ample space for recreational activities to adjust to larger gravities. Local hospitals are also available as the health of each adjusting resident is very important and requires regular checkups.

During its periods of dormancy, *Luna* completely shuts down to prevent wasting resources. All power and water is turned off, waste is cleared out, and *Luna*'s segments cease to rotate. The preparations ensure that the modules will maintain their conditions for long periods of time.

section

3.0

operations and infrastructure

Section 3 : Operations and Infrastructure

3.1 Locations and Transportation of Materials

Material	Source	Transportation	Storage
	Construction		
Inconel 718 Ni-Cr Superalloy	Earth, Bellevistat	Asgard; Aaru	Commercial disk
Silicon-Carbide Whisker Matrix Composite			Commercial disk
Titanium Grades 5 & 6 Alloys			Commercial disk
	Radiation Protection		
*Borosilicate Glass**	Bellevistat	Aaru	Commercial disk & central axis
*Silica Aerogel**	Bellevistat	Aaru	Central axis
Lunar Regolith	Moon	Elysium	Used directly and not stored extensively due to dust contamination
Demron cloth	Earth	Elysium	Central axis
Ra-guard	Earth	Asgard	Central axis
	Operations		
*Electronics**	Bellevistat & Alexandriat	Aaru	Central axis and tori
*Silicon solar cells**		Aaru	Commercial disk
Low-density polyethylene	Alexandriat	Aaru	Commercial disk
Dinitrogen tetroxide	Earth	Elysium	Commercial disk
Helium-3			
Deuterium			
Hydrazine			

*Most or all will be manufactured on-site once operations are fully underway

Table 3.1.1 Locations and Transportation of Materials

3.2 Infrastructure

3.2.1 Air Composition & Climate Control

To provide for the health of the residents, as well as psychological comfort, Columbiat's air composition will be similar to Earth's. Pressurized air will be provided in all components except for the central axis, the space elevator terminus, and the unpressurized portion of Isengard. Trace elements have been eliminated from Columbiat's atmosphere for cost and convenience. High levels of carbon dioxide will be prevented from accumulating by means of the Sabatier reaction alumina catalyst reactor: $CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$. The methane will be broken down into solid carbon and $2H_2$; the hydrogen will be reused in the reaction. The water will be electrolyzed for regeneration of oxygen. This cycle will provide efficient recycling of gases as well as generate some of the required water for the settlement.

Component	*Pressure (kPa)*	*Percentage*
N_2	53.043	52.362
O_2	45.266	44.685
CO_2	.797	0.787
Water Vapor	.199	1.969
Total	101.3 kPa	

Table 3.2.1 Atmospheric Compositon

Columbiat will experience "seasons" through gradual changes in temperature. Though these changes will be slight, because of Columbiat's equipment, they will provide a familiar Earth-like environment, psychologically. The temperatures will span from 25 °C in the summer, to 20 °C in the fall, then 15 °C in the winter before returning to 20 °C in the spring. The seasons will be in three month cycles, like February – April for spring or November – January for winter.

To further simulate an Earth-like environment and provide familiarity for residents, artificial rain will fall on areas where humidity has increased. Water vapor will be collected on condensation plates above the communities and deposited in pressurized water containers; hidden sprinklers throughout the facility will then spray this on the residences.

3.2.2 Food Production

Animal	Allotment (g/day)	Other Advantages
Cattle (Bos taurus)	0.29	-Milk provides dairy products, including butter and cheese -A cow's grazing leaves the grass roots intact for easy regrowth, rather than constant rotation of pastures as with sheep
Goat (Capra aegagrus hircus)	0.6	-Provides milk for consumption -Thick hair can be used in commerical manufacture -Small and relatively lightweight -Does not require extensive grazing land
Japanese quail (Coturnix japonica)	10	-No adverse effects of low-gravity observed on bird or eggs -Small, easy to maintain, economical
Trout (Oncorhynchus mykiss)	35	-Freshwater fish; no special water treatment required -Able to thrive in small lakes or ponds

Table 3.2.2 Animal-Derived Consumables

Food Harvesting

Animals will be raised in their respective sections of the rings and slaughtered by machine. Animals are a necessity in the residents' diet due to the workload on Columbiat and the low-gravity conditions residents will frequently experience.

Plants will be harvested mechanically. Plants from aeroponic tiers will be harvested by automated collectors to be transported for packaging and storing. Allotments for plants have been derived from the NASA 1975 studies, altered sufficiently for the needs of the residents of Columbiat. In addition, care has been taken to allot additional vegetables to be used in animal feed. This will be dried upon harvesting and distributed accordingly to animals.

Plant	Allotment (g/day)
Soybean	200
Wheat	225
Rice	125
Fruits	100
Vegetables	100
Corn	940

Table 3.2.3 Plant Allotments per Capita

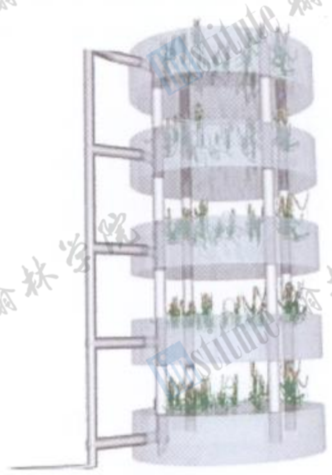


Figure 3.2.1 Aeroponic Tiers

Food Storage

Food will be freeze-dried and vacuum sealed for storage. Food sufficient for 9 months will be stored in the central axis, while food sufficient for 6 months will be stored in the rings, as well at the commercial disk. In addition, any surplus food will be stored in the food storage grid in the commercial disk.

Food Packaging, Delivery, and Distribution

All food will be packaged by machines, in medium sized reusable boxes, while liquids will be packaged in reusable pouches. Used containers will be deposited at community centers, to be collected and reused.

Upon packaging, food will be delivered to the different areas of Columbiat, by means of the underground goods transport system. There, restaurants, grocery stores, and community centers will be able to pick up the food and use or distribute it. Any food that has not been used in a restaurant, or sold in a grocery store, for 3 days will be freeze dried and vacuum sealed, to prevent spoiling.

Food Selling

Food distributed to grocery stores may be bought using a person's card/credits. The amount of food purchasable will be limited, in order to minimize food waste. If one needs to purchase a greater quantity of food, permits are available for this purpose.

Food Growing

The majority of Columbiat's food will be grown using aeroponic technology. Aeroponics will allow for plentiful production of plants without the water concerns of hydroponics or the extra expense and weight of transporting Earth soil to the colony. Plants will be grown on large, tiered structures, and segregated for environmental control. The large tiers will enable the nutrient-filled mist to propagate through several layers of plants rather than just one, saving surface area as well as water. Although much of the required lighting for plant life will come from the windows of the ring, additional low-pressure sodium vapor lamps will be provided for plants in dimmer, more isolated areas of the ring.
For the psychological needs of the residents, each resident will be allotted a small space in which he may grow plants of his choice in soil. Food growth will be largely automated, with regular inspection for quality. Animals will be raised with care in fields; animal feed will be grown separately from plants for human consumption. Animal byproducts will also be used in supplying many human food necessities.

3.2.3 Power

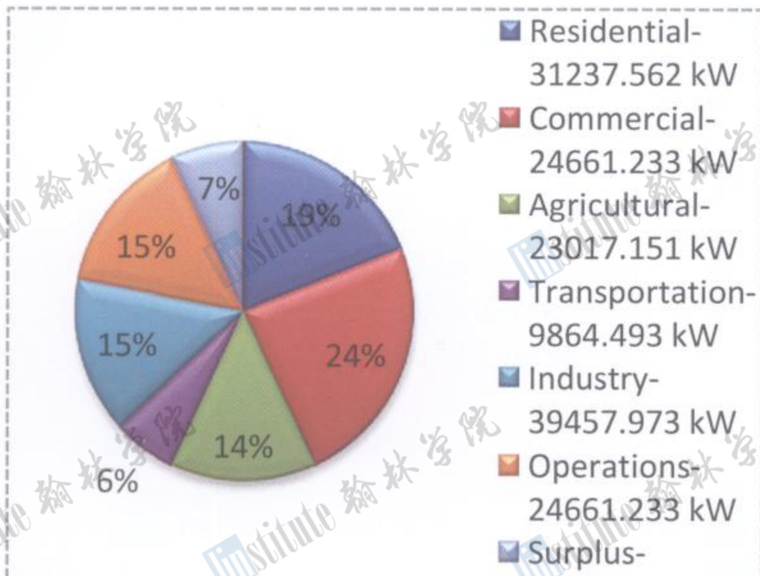


Figure 3.2.2 Energy Allocation

To store energy, there are two components that will be required. First, the space settlement's source of energy will be primarily derived from solar power, collected from the use of four solar panel satellites in orbit around Earth, referred to as *Helios*. There will also be solar panels covering the commercial disk and the underside of the *Aurora* mirror system. These solar panels with three types of collectors, known as flat-plate, focusing, and passive collectors, will then collect the sun's radiation and convert the energy to both electricity and heat. Second, it will be critical to store the derived energy. There will be lithium-ion batteries to accumulate excess energy when the sun's rays are at maximum strength. The settlement will also contain a backup supply for emergency purposes as well as for times when the stored energy is not sufficient. A portion of this solar energy will be suitable for heating intentions. Heat energy will also be stored in phase-change or heat-of-fusion units, both of which use chemicals to alter solids into liquid form, at which the liquids can be retransformed to solid forms to use the stored energy. Most of these deriving and storing energy processes will occur in the central axis. After successfully converting and storing this energy, wires will be secured underground and inside walls out-of-sight, connecting the power sources to the residential tori and around the entire space settlement.

Figure 3.2.3 Helios

To maximize energy output and consumption, several devices will be manipulated to conserve the most energy. Almost every kind of appliance or light fixture will be energy efficient to reduce the demands of energy and save costs. For example, family appliances will each contain gadgets to monitor temperature and other power expenditure areas. Other home improvements will include insulation, modernized windows, and air-sealed rooms. In all business offices and residential homes, the lights will be sensor-sensitive and thermo-sensitive. The lights will automatically switch off after 10 to 15 minutes of no movement and no heat detection in a room.

3.2.4 Water Management

Water Requirements

10.76 liters per person per day will be provided to the citizens of Columbiat. For a settlement of 27,000 people, the total amount of required water will be 290,250 liters. The total amount of water on Columbiat will be 600,000 liters, taking into account the needs of food production and other functions. Water will be transported from Bellevistat and Alexandriat, 100,000 liters during each construction phase, then continuously recycled. This is to prevent excess transportation costs from Earth, as the two settlements are closer to Earth and will long have accumulated a sufficient water supply to aid Columbiat in aggregating water. Approximately 90% of the water will be recycled, leaving 540,000 liters of usable water. Every 6 months, water will be brought in from Bellevistat and Alexandriat to replenish the water supply.

Figure 3.2.4 WST

Water Management and Treatment

The waste water from the waste treatment will undergo a pH adjustment to 7.0; it will then be flocculated using $Fe(OH)_3$. Water will further undergo sedimentation, filtration, and disinfection. The purified water will then be fluoridated with sodium hexafluorosilicate (Na_2SiF_6) at a level of 0.8ppm as per many municipalities' requirements on Earth for tooth and gum health before being circulated through the colony. Water will be stored in 50 tanks throughout the settlement. Each water storage tank (WST) will have the capacity to hold 12,000 liters of water.

WSTs in Central Axis: 20 (240,000 Liters)
WSTs in each torus: 10 (120,000 Liters)
WSTs in Isengard: 10 (120,000 Liters)

Waste and Water Movement

CPVC pipe networks will be used to move waste and water throughout the settlement. CPVC pipes will be placed alongside the Sky Ferry, which will be connected to the underground pipe network in the tori. The underground pipe network will be placed around the underground goods transport. Then, smaller CPVC pipes will be connected to buildings to transport waste and water.

3.2.5 Household & Industrial Waste

Solid Waste Treatment

The WWTC (Waste and Water Treatment Center) will be located in the central axis. Waste will undergo anaerobic digestion, where it will be broken down into digestate, waste water, and biogas. The digestate will be used as a soil conditioner while the waste water will then undergo further treatment for recycling. The biogas will be composed of methane, carbon dioxide, nitrogen, hydrogen, hydrogen sulfide, and oxygen. The CH_4 will be broken down into carbon and $2H_2$, while Carbon dioxide will be broken down by means of the Sabatier reaction in an alumina catalyst reactor: $CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$. The hydrogen sulfide will then undergo a chemical reaction with potassidum at high temperatures to produce hydrogen and potassium sulfide for safety.

3.2.6 Communication

Internal Communication Systems

Internal communication will have three major facets: mass communication, sectional communication, and individual communication systems will be implemented on the settlement. Mass communication will take place via intercoms placed throughout the settlement. The intercom system can take announcements from control stations located in each torus and the docking disk, which can be accessed by authorized personnel. In addition, these announcements will be e-mailed via the settlement's internal internet system to each individual. Sectional communication will take place only within sections of the settlement, so that announcements can be isolated in the case of an emergency in one specific area. Individual communication will take place through voice over IP (VoIP) systems. Networking for larger amounts of data, especially in business sectors, will be provided for by compact fiber-optic networks that can efficiently provide high transfer speeds.

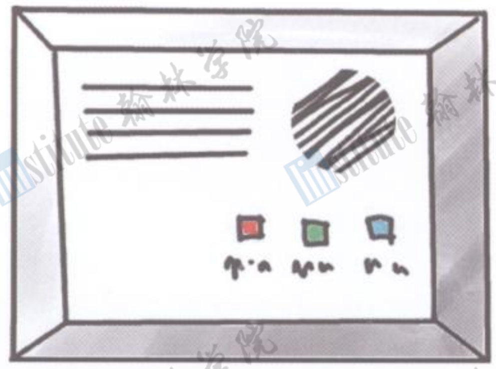


Figure 3.2.5 Intercom Station

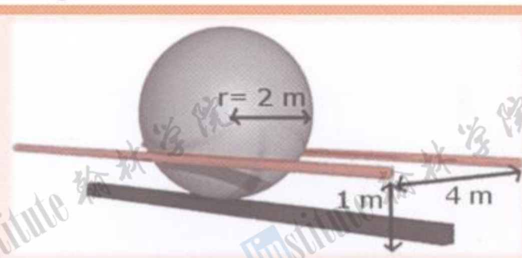
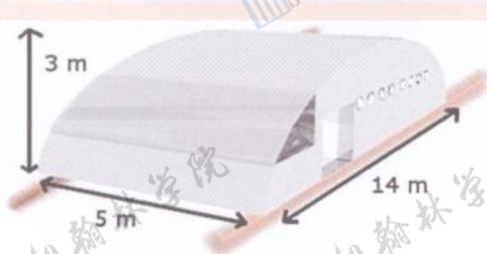
External Communication Systems

Communication to and from Earth, other satellites, and space colonies will take place via lasers. Lasers provide the highest transfer speeds for long-range communication and do not utilize excessive energy. In the event of a failure in the laser communication system, backup radio satellites will automatically begin relaying information.

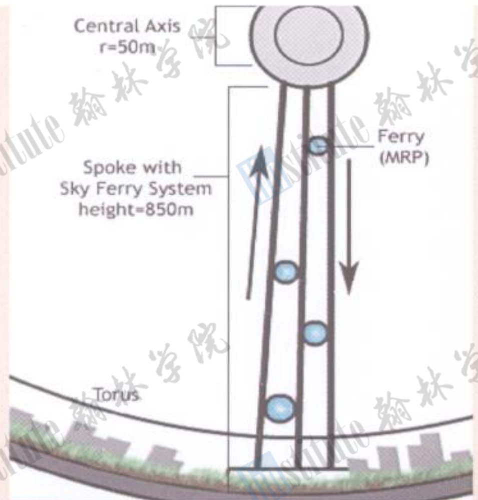
3.2.7 Internal Transportation Vehicles and Corridors of Access

All vehicles will use *electrorheological fluid* for braking and shock absorbing purposes. The fluid will create an effective brake, especially in the event of an emergency failure of the magnetic fields controlling the vehicles; sensors will activate an electric field within any vehicle and apply sufficient compressive pressure in order to turn the fluid viscous and stop the vehicle.

The main form of transportation within Columbiat will be *walking* in order to ensure that the population gets a sufficient amount of exercise without needing to be monitored. In the event that a person is unable to walk, wheelchairs and bicycles will be available to them throughout the settlement.

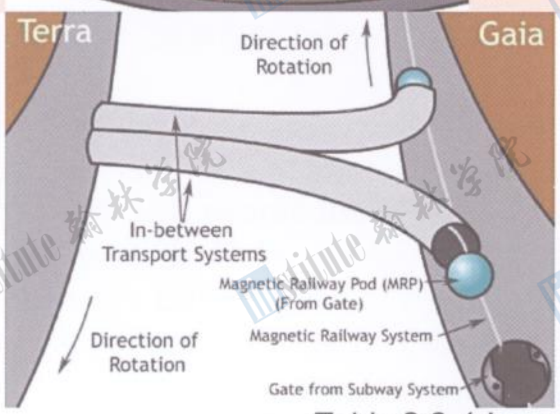
Vehicle Name	Image	Details
Magnetic Railway Pod (MRP)		Pods will be used to transport *goods* as well as *people* between the *central axis* and *tori*. The gravity in the pods can be adjusted to meet the needs of the user: cargo will use lower gravity than people for ease of transport. Pods will use *magnetic levitation* technology to carry its passengers.
Underground Goods Transport System (UGTS)		The Underground Goods Transport System will be used to carry goods and large cargo beneath the pedestrian floor of the tori. The UGTS will greatly facilitate the transport of large goods.

Sky Ferry MRP Elevators



In order to transport people between the 1g tori and the stable central axis, a *Sky Ferry* system of MRPs will be utilized. The Sky Ferry will use MRPs to transport residents from stations in the tori through the gravity-controlled spokes and into a rotating motor surrounding the central axis. Passengers will then be able to use rotating walkways to step onto the stable platforms of the central axis. The return trip to the tori utilizes the same procedure in reverse.

Between-Ring Ferries



Transportation between the pressurized rings will utilize a separate railway system for convenience. The system will be fixed to one ring (Gaia) while simply 'trailing' on the parallel, counter-rotating torus (Terra); MRPs will move back and forth between the tori using a railway line on the outside of the non-attached torus. Pods will be able to access the railway line through pod gates located in the same area as the UGTS.

Table 3.2.4 Internal Transportation

3.2.8 Day/Night Cycle

Providing residents with natural solar lighting is important to Northdonning Heedwell in the construction of Columbiat. In the two residential tori, sunlight will be reflected in by way of the *Aurora* mirror system below the observatory. The circadian cycle will be controlled by rotating panels on the mirrors, which will gradually turn over the course of a day to reveal solar panels on the reverse side of the mirror panels. The use of solar panels will ensure that the settlement will never become completely dark, as they will still reflect some light. In addition, they will collect solar energy while the mirrors are not in use.

3.3 On-Orbit Infrastructure

3.3.1 Vehicles

Name	Destinations	Schedule	Number Required	Fuel	Status in Contract
Asgard	LEO to Columbiat (cargo & people)	Biweekly (staggered flights)	50	LH_2	Commercial
Elysium	LEO to Columbiat (cargo only)	Weekly (staggered flights)	50	LH_2	Included
Aaru	Columbiat to other colonies	Daily	20	LOX, RP-1	Included
Celia	Exploration	Varied	5	Hydrazine, N_2O_4	Commercial
Firdaus	Space tug	Whenever necessary	10	LOX, RP-1	Included

Table 3.3.1 Vehicles for External Transport

3.3.2 Satellites

Name	Quantity	Purpose	Status in Contract
Helios	4	Solar power; beam energy to Columbiat; energy collector located on observatory	Commercial
LComm	5	Laser communication	Commercial
RComm	4	Radio backup communication	Included in contract

3.4 Propulsion and Station-keeping Systems

In order to properly maintain orbit at L2, Columbiat will employ the **XIPS** (Xenon-Ion Propulsion System). The system is advantageous in that ion propulsion requires much less overall fuel than the conventional chemical thruster, thus saving payload mass, cost, and increasing thruster life. Columbiat will use Boeing's 601HP and 702 thrusters in its operation. The colony will utilize eight thrusters on each torus and four on each end of the central hub for a total of 24 thrusters. Four of the ion thruster systems on each torus will operate in six-hour cycles and will be supplemented by a propelling motor in the central hub, which will run on solar power and operate every other cycle. The other four thrusters will serve for redundancy in the event that a thruster fails. The thrusters on the central hub, primarily 702 thrusters, will run for only 1 hour each day for station-keeping purposes. In addition, the central hub will be equipped with automated monitoring systems which will keep track of the station's immediate position and will be able to correct for variations in orbit outside of the thrusters' normal operating times. In the event of an emergency in which the automated system fails to activate, the system can be overridden with the appropriate authorization and the settlement can be manually brought back into orbit. The xenon propellant will be stored as a gas in tanks directly opposite the thrusters inside the corresponding torus or hub to allow for quick and facilitated access to refuel. Refueling will be automated and humans will handle the xenon systems as little as possible so as not to disrupt operations. In addition, backup tanks will be kept stored in the middle of the central hub in the event that restocking fuel does not arrive in time to replenish the supply of xenon.

Figure 3.4.1 XIPS Interface on Central Axis

3.5 Provisioning and Maintenance Services

3.5.1 Food and Agricultural Replenishment

Dry foods on Columbiat will be transported in prepackaged boxes to visiting ships. Each biodegradable box will contain enough freeze-dried food to sustain ten adults for one week. Fresh food will also be supplied to crafts from excess agricultural production; each craft will be supplied with enough fresh food for the following week.

3.5.2 Livestock and Veterinary Services

Each dock will be supplied with 2 veterinary specialists, with at least one on call at any given time. Food for livestock will be provided for an additional cost; this will be provided from excess dry agricultural production. Livestock will be quarantined and not allowed to enter the settlement unless specifically approved for restocking of settlement supplies; livestock will not be allowed off their respective spacecraft if it is determined that they are carrying a disease or are potentially harmful to the settlement.

3.5.3 Engine Overhaul

Two crew members will be on call in the port facilities in the event that an engine needs specialized repairs. There will be an automatic manual engine check every time the ship docks if the ship has a prepaid tag as a part of their scanned license; otherwise, the engine check will be automated. Manual engine checks will be available to all ships upon request. If the crew wishes to perform its own maintenance, appropriate supplies and facilities will be provided in the docking areas. Refer to *Section 5.5* for additional information regarding overhaul.

3.5.4 Fueling

Different types of fuel will be provided depending on the information in the ship's registration license. No self-refueling will be allowed; fuel will be provided by automated systems to ensure that precious supplies are not wasted. Extra fuel will be provided in secure containers available for purchase upon request.

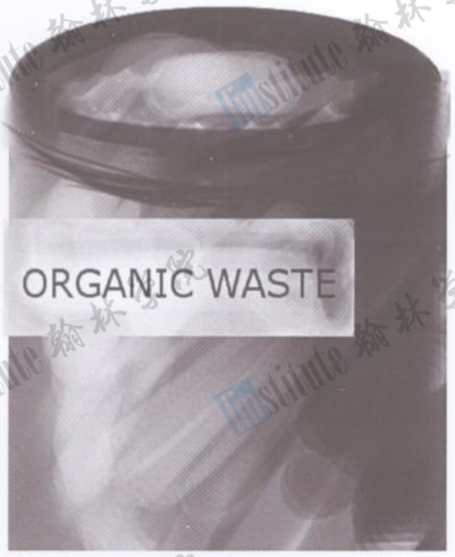


Figure 3.5.1 Organic Waste Disposal Chute

3.5.5 Waste Disposal

All waste will be sorted by the ship's crew members and deposited into separate labeled chutes that will then transport the waste to be recycled and destroyed as needed.

3.5.6 Water

Waste water will be recycled by the settlement. A ship's water will be replenished depending on the size of its crew and the length of its journey; if extra water is needed for the ship's operations, it will be provided at the refueling stations.

3.5.7 Supplies for Living Areas

Furniture for ships will be derived from excess on-site construction, which will be distributed to ships according to their needs. Only basic furnishings will be provided to ships; spacecraft that require specialty or customized items will have to notify the settlement at least four days prior to their arrival on the settlement and pay an extra fee once the requested furnishings are collected. No repairs will be carried out on furnishings unless the repair is minimal; heavily damaged furnishings will be collected and recycled.

section

4.0

human factors

Section 4 : Human Factors

IN CONSTRUCTING COLUMBIAT, Northdonning Heedwell intends to create an environment suitable in which humans can live comfortably in an Earthlike setting while maintaining the exotic nature of a space settlement.

4.1 Community Design and Amenities

Columbiat will have all the amenities of modern communities on Earth. The common services one could expect on Earth will also be available on Columbiat. The mall on the settlement and the myriad other outlet stores will cater to those of retail oriented interests, providing all the goods normally obtainable in retail chains found on earth; these include shoes, clothing, electronics, and other such consumer products. Movie-lovers will have ample opportunity to indulge their passion; Columbiat's four large movie theaters and one zero-gravity theater will serve the theater-going public. Those with interest in electronic gaming will be pleased with Columbiat's large arcade (located within the mall) and several cyber cafés. The literarily inclined can flock to the public library. Columbiat will have a concert hall to house future performances. Several parks provide open spaces; gyms will allow exercising and the playing of sports with basketball courts, tennis courts and indoor soccer stadiums. Connoisseurs of food will have plenty of locales to frequent, with all the fine dining, restaurants and cafes on the space station. Other unique forms of entertainment will be available on the settlement.

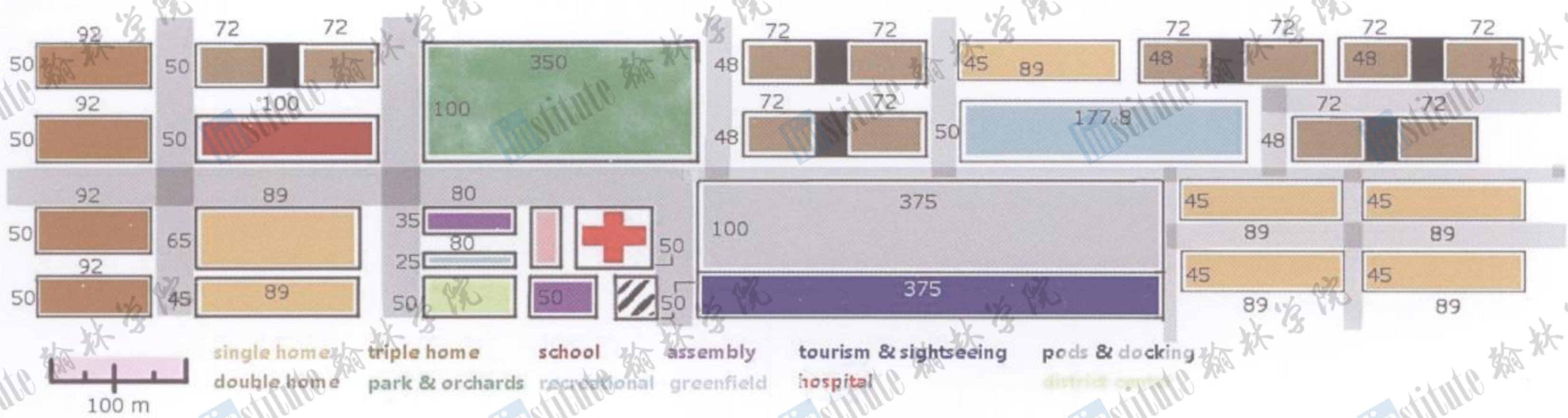


Figure 4.1.1 Interior Map

4.1.1 Major Consumables

Type of Consumable	Approximated Quantity (on hand)
Pharmaceuticals	6 month supply of all generic and documented prescription drugs
Paper and Writing Utensils	See below
Clothing	See below
Light bulbs- fluorescent	500,000,000 bulbs in use; bulbs replaced every 4.5 years
Research Materials	1 month supply of materials for all sanctioned experimentation
Toiletries	1 year supply of toiletries for each resident
Cleaning Supplies	1 year supply

Figure 4.1.1 Major Consumables

The need for paper and other writing utensils will be drastically reduced by the extensive use of computers within Columbiat; as a result such supplies will imported on the basis of necessity from Staples Inc.

Replenishment of clothing will be left to several clothing companies (Levi's, Nike, Macy's) with which the settlement will have exclusive contracts to handle the clothing needs of the settlement (including replenishment). Special clothing, as required by certain cultures or religions, may be requisitioned through the use of special forms.

Residential buildings will be clustered around a central point, in which there will be a general store for distribution of necessary consumables.

Type of Furniture	Approximated Quantity (in units)
Tables (of varying sizes)	40,000
Desks	50,000
Chairs (of varying types)	110,000
Sofas	23,000
Beds	[illegible]
Televisions	25,000
Dressers	24,000

Table 4.2.1 Interior Amenities

4.2 Residences

The primary supplier of furniture for the settlement will be IKEA. Residents will be able to requisition additional desired items of furniture by completing and submitting the proper forms; approved requests will be ordered at resident's expense.

Columbiat will have a unique residential arrangement. Married couples and families will live in units designed for such an arrangement. The majority of the single residents of Columbiat will live in a unit shared between two people, to conserve space. Roommates (of the same gender) will be matched by a program that compares personality compatibility based on information a person enters about his personality, although special requests for living arrangements will be given consideration. Accommodations will be made for singles who desire to live alone, but the rent on such units will be significantly greater, giving people a financial incentive to live in a shared unit.

Figures 4.2.1 Residential Floor Plans

4.3 Safety in Microgravity Volumes

Various measures will be taken to ensure the utmost safety of people in microgravity environments.
-Spacewalking safety: Spacesuits of all but the most highly trained professionals will be tethered to hooks on the central hub to ensure that no one drifts off into space. Protocol will be to attempt to maintain three points of contact with the space station to ensure maximum stability.
-Extravehicular Activity:

- People and robots performing repairs will be tethered to rails around the tori and central axis. These rails will have attachments for the robot's wheels or the person's feet; the attachments are free to move about the rails but will not detach from them.
- Magnetic shoes will be available in storage bins at the entrance to all low-gravity components for safety. The walkways of the walking areas in low gravity environments will have magnetic strips beneath the surface to hold the shoes down.
- Most exterior hull maintenance will be performed by robots. In the event that it becomes necessary for a human to perform exterior repairs, they will be securely tethered to a point on the hub. Additional physical and magnetic tethers will be placed along the hub at various increments as a safeguard in the event that a person drifts from his original location.

Figure 4.3.1 Foot Rail

4.4 Spacesuit Design

4.4.1 Donning Procedure

1) Disassemble space suit (refer to suit stowage)
2) Reduce pressure in airlock antechamber to .7 atmosphere
3) .5 hour of 100% oxygen pre-breathing to reduce nitrogen concentration in blood and tissues
4) Put on Maximum Absorption Garment
5) Put on Liquid Cooling and Ventilation Garment (LCVG)
6) Attach EMV Electrical Harness (EEH) to inside of Hard Upper Torso (HUT)
7) Attach arms of suit to HUT
8) Connect Display and Control Module (attached to HUT arm) to EEH and Primary Life Support System (PLSS-pre-attached to back of HUT)
9) Coat inside of helmet with anti-fog spray; attach visor to helmet
10) Attach the in-suit drinking bag to its location within the HUT
11) Connect communications carrier assembly (CCA) to the EEH
12) Put on the lower torso assembly (LTA)
13) Establish radio contact with base and ensure functionality of EEH and PLSS
14) Put on HUT
15) Attach tubes of LCVG to PLSS
16) Attach EEH to PLSS
17) Connect LTA to HUT
18) Don CCA
19) Put on comfort gloves, secure oxygen mask over face, lock on helmet (oxygen flow should commence once helmet is properly secured)
20) Lock on outer gloves
21) Check suit with robot to ensure donning has been performed correctly; robot will also assess functionality of EEH, PLSS, CCA and other suit systems
22) Enter airlock and reduce pressure in airlock to .3 atmosphere to check for leaks in suit

4.4.2 Doffing Procedure

1) Upon entering airlock, wait for pressure to be raised to .55 atm (indicated by a chime)
2) As astronaut removes suit, pressure will steadily increase to the normal pressure in the settlement. This is done to reduce the chance of decompression sickness.
3) Remove Outer gloves, comfort gloves, helmet; disconnect visor from helmet
4) Detach CCA from EEH and remove it
5) Detach LTA from HUT
6) Disconnect EEH from PLSS
7) Disconnect LCVG from PLSS
8) Remove HUT
9) Detach EEH from inside of HUT
10) Remove in-suit drinking bag from inside of HUT
11) Step out of LTA
12) Remove LCVG
13) Remove maximum absorption garment
14) Reattach helmet, LTA and HUT to prepare suit for stowage
15) Leave airlock
16) Return suit equipment to personnel for stowage
17) Report to on-site med-bay for medical diagnostic

4.4.3 Materials Used in Suit

- Nylon Tricoat
- Spandex
- Urethane coated Nylon
- Dacron
- Neoprene Coated Nylon
- Mylar
- Gortex
- Kevlar
- Nomex
- Demron

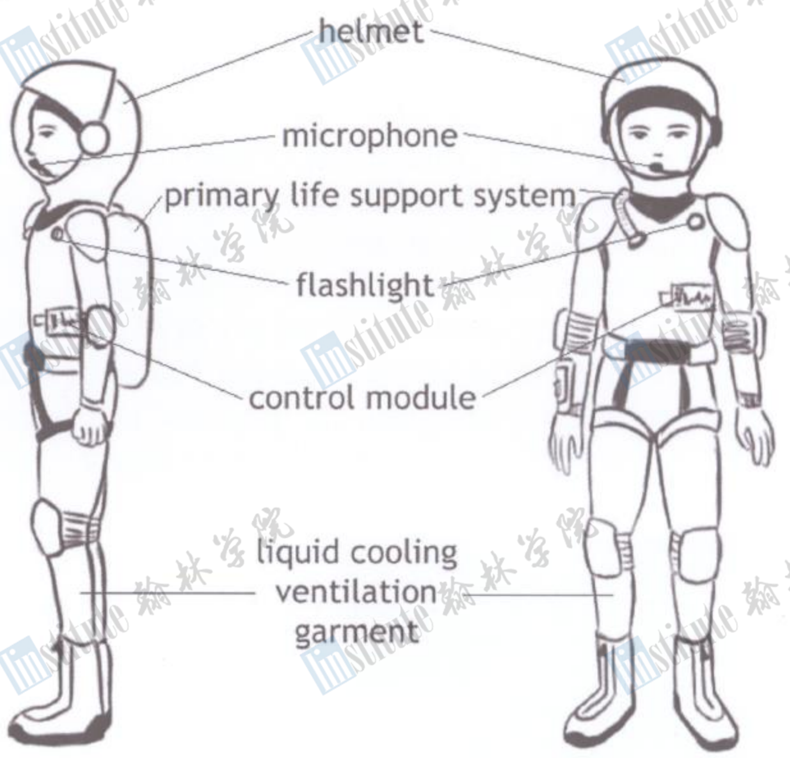


Figure 4.4.1 Spacesuit Design

The mixture used in the space suit air tanks will be a heliox mixture (79% helium, 21% oxygen) to minimize potential effects of oxygen narcosis and the chance of decompression sickness. Though 100% oxygen has been used in the past, we feel that the potential dangers of respiring pure oxygen, such as neurological damage, cardiac damage, potential alveolar collapse, potential seizures, and oxygen's narcotic effect, outweigh its benefits.

The pressure within the suit will be about .55 atmospheres of pressure to allow the astronaut full mobility while inside. However, to ensure a proper Alveolar-arterial concentration gradient, the astronaut will be wearing an oxygen mask around his nose and mouth that will be attached to the EEH (EMU Electrical Harness). The mask will alternately pressurize to one atmosphere during inhalation and depressurize to .5 atmospheres during expiration (the mask's connection to the EEH will allow it to synchronize its cycle of compression and decompression to the astronaut's respiration rate) to ensure the astronaut has an alveolar gas pressure similar to the one he would have were he at sea level on Earth, which will allow for maximum efficiency of respiration.

4.4.4 Spacesuit Storage

Each individual space suit will be stored in an individual cell (slightly larger than a phone booth) that is attached to an axis with the ability to rotate. The suit will be stored with the HUT, Helmet, LTA and gloves all attached together (external components of the suit will be stored fully assembled), with the EEH and LCVG hanging on the side walls of the cell. The MAG, CCA, in-suit drinking bag and comfort gloves will be stored in a footlocker against the back wall of the cell. The complete assembly of the outer layer of the suit during storage will make it more expedient to either remove the suit from or return the suit to storage. The placement of the individual cells on a rotating axis conserves space and expedites the removal/return of multiple suits from/to storage.

4.4.5 Airlock Operation

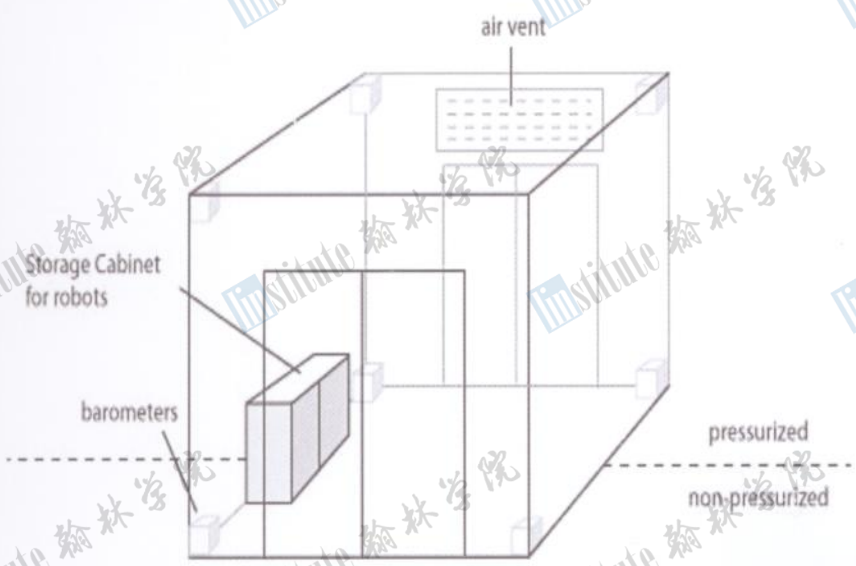


Figure 4.4.2 Airlock between Pressurized and Unpressurized Sections

After an astronaut has finished donning his suit, a checker robot will examine the suit, checking the suit for lack of external damage and linking up to the suit's electronic systems to ensure their functionality. After the robot has completed its examination, an alarm will sound and air will be vacuumed out of the airlock via a vent in the ceiling until the pressure of the airlock is .3 atmospheres (as confirmed by the barometers in each corner of the room). The robot will then assess the suit for leaks. Should the suit pass inspection, a second alarm will sound and the remainder of the air within the airlock will be removed. When it has been confirmed that all air has been removed, the door to the exterior of the settlement will open. By using this procedure, air loss to space should be negligible.

4.5 Visitor Accommodation

For a chart of potential security issues and contingency plans for each, please refer to *Section 5.2.3*.

A large hotel will be provided to the most important visitors, with tourists and other transient visitors being stationed in either the adjustment modules or in temporary residences in the two tori.
In the event of an unanticipated security issue, a state of emergency will be declared in the settlement. Residents will be confined to their homes and transient visitors will be confined to their hotel rooms for the duration of the emergency. All human security personnel will be assembled in the security headquarters of the settlement for debriefing and security animatronics will be programmed to follow the emergency protocols that the situation demands. The appropriate response to the situation will then be determined by the settlement's chief of security.

Figure 4.5.1 VIP Hotel

To unobtrusively monitor visitors, a GPS lapel pin will be given to each visitor with an ID number at the beginning of their stay. It will be able to monitor his or her location and activity and will be destroyed three months after the visitor's stay to ensure that no personal data is left in the colony, thus clearly ensuring the privacy of transient residents.

For Medical Quarantine procedures and facilities, refer to *Section 5.5*.

section

5.0

automation design

Section 5 : Automation

COMBINING INNOVATION WITH EFFICIENCY, we at Northdonning Heedwell have developed automated systems which fit and often exceed the needs of our residents. By providing for everyday needs of those on board, we will facilitate an environment which eases life and ensures safety. The computers provided are fitted for specific tasks, the robots are practical and the networks are secure. The automated systems on Columbiat will be at the pinnacle of technology.

5.0 Computing Systems

System	Specifications	Specifications
iBuddy	Refer to Section 5.3	
VAIO® LV Series PC/TV All-in-One	For every 5,000 square feet, there is a small workstation area containing VAIO LV Series PC/TV All-in-One for basic user functions including e-mail, messenger, TV and Internet access. Though basic, they are relatively cheap and do not take up excess space.	24" XBRITE LCD, 4GB RAM, 500GB hard drive, Blu-ray Disc™ playback, 256MB NVIDIA Graphics, HDMI™ in and TV tuners
Dell XPS 435	The Dell Precision T5400 Workstation provides adequate speed and reliability for all management functions including security, finance, scientific research and database management. Computer technicians, economic managers, laboratories and database managers will be provided with these PC's. Specifications vary for each group.	24" Widescreen Panel LCD 750 GB Hard Drive expandable to 3 TB, 2.66 GHz Processor 6GB Expandable to 32 GB RAM
Dell Studio Desktop	In hotels and in stores, this desktop is used for basic functions including quickbooks and logs of hotel guests.	19" Flat Screen LCD 500 GB Hard Drive expandable 4 GB Expandable to 12 GB 2.33 GHz Intel Core Duo Processor
Server: Dell Poweredge 2410	This server technology is designed specifically for durability in remote locations and provides reliability and a strong backup system. Provided for in 24 U racks.	Height 47.2" (1119.9mm) Width 23.9" (607mm) Depth 39.4" (1001mm) Weight 240lbs (108.9kg) Max. load 1,200lbs (544.3kg)
Dell/EMC CX3-80	Each unit can store up to 383 TB of data providing adequate storage space to include all of the information that is to be stored to the space station's memory. 20 such units will be necessary to hold enough of the information. Also, this Dell Storage system is compatible with the Poweredge server system. Networking Oracle database and server management technology are most suited for this settlement.	Up to 256 servers Up to 480 drivers Scales to 353 TB

Table 5.0.1 Computing Systems

Future of Data Storage

Holographic storage is the future of high capacity data storage. It stores data through the recording multiple images in the same area utilizing light at different angles. Holographic data storage provides us with the ability to store large amounts of data often exponentially more than current options. As of now, the current limits of holographic data storage are at about 500 GB per square inch. However, the theoretical limits are about tens of terabits per cubic centimeter. Holographic data storage has the ability to be especially archive huge amounts of data. The Write Once approach also allows for optimum security.

5.1 Construction Systems

Name	Functions	Dimensions
PAWF Robot	This robot specializes in the placement and attaching of the hull sheeting. This is for on site construction of large sheeting on the settlement.	10m x8m x2m
UT Robot	It specializes in the installation of utilities and transportation infrastructure within the settlement. It is a variation of the interior finishing robot and includes a special Omnitool which functions in the fixing of transport pods and the tools which install utilities in residential and office areas.	2m x3m x2m
The Interior Finishing Robot	This robot is given the task of fixing in settlement problems. Equipped with a choice of two specialized Omnitools, this robot can fix small household problems like broken appliances. This robot can fix problems with wiring and electricity as well. These robots have sensory eyes that check 2048 points of reference to identify the items that require repairs.	3m x2m x 2m
The Exterior Finishing Robot	Larger than the interior finishing robot, the exterior robot includes welding tools, wrenches, drills and an array of special tools. The robot, in order to protect itself from the vacuum and the stray particulate matter in space, will have a strong steel exterior and joints made of clay reinforced by carbon nanotubes. The exterior robot is also able to repair the exterior after solar flare damage.	5m x4m x4m
Building Robot A 	This robot incorporates many different features. Building Robot A is a welding Robot that is specialized in completing large scale junctions. It functions by stationing itself on the specified regions and then works from there. There is 360 degree maneuverability on this type of welding robot.	6m x 4m x4m
Building Robot B 	This robot's main function is placement. It essentially carries and holds the materials in place for the other robots to work. Its stationing mechanism allows it to attach and then its turret mechanism allows for the movement of the positioning clamp.	10m x5m x4m

Omnitool 	The Omnitool is analogous to a Swiss army knife, only for a robot. The Omnitool is an especially versatile part of the robot. It includes hammers, drills, and magnetic clamps. The Omnitool attaches all of these components onto a rotating turret. The robot equipped with this tool has the ability to choose which tool is necessary for completing the task at hand. With the Omnitool, we are able to increase efficiency on the settlement robots. The Omnitool, pictured at left, is a cylinder-shaped appendage for the robots.	1m x .5m x.5m

Table 5.1.1 Construction Automation

Transport and Delivery System

The Transporter (1.5 m x 2m x 2m)

The cargo on board will arrive and be transported in 5m by 5m by 5m boxes. Each cargo box will have a specific barcode. The robot will have an optic scanner, which will essentially function as its "eyes" and will be able to read the barcode of each box. This robot will have telescoping clamps which will be able to grab each box. The Transporter implements a system which works in both microgravity and normal gravity. In microgravity, it propels itself using ion thrusters, whereas in normal gravity, it does so using motorized wheels.

5.2 Maintenance, Repair, and Safety

Maintenance Robot	The robot has the ability to diagnose errors in robot function using a special optical unit (Using different wavelengths to scan each time, provides a comprehensive 3-D visual). These autonomous robots have the ability to make medial repairs. Also, in case of a software malfunction, they can plug in to the nearest maintenance computer and feed information to technicians. It has a special jack on the surface of the automated system that the maintenance robot is trying to fix.	1m x1m x2m
Safety robots	Safety robots will be deployed in case of an emergency or if the suspect has been located. Equipped with tranquilizer darts, which have specifically measured dosages to prevent manslaughter; these robots can subdue the criminals. Also, in highly sensitive areas, robots will have strobe light cannons. By sending out concentrated strobe lights at high frequency, it can blind the target specifically for 3 to 15 minutes while inducing nausea and headaches.	1.25m x1.25m x1.5m

Table 5.2.1 Maintenance and Safety Automation

Safety Systems

- All public areas have surveillance cameras for security personnel. When entering and leaving the residential and industrial areas, people are subject to baggage check. The penetrating scanners look for questionable objects and traces of harmful chemicals or substances. These scanners will be operated by government and security personnel only. In case of a crime, the suspect's information is fed into the system and special face-recognition surveillance units are activated which attempt to identify the current locations of the suspect.

Maintenance Robots and Systems

- Furthermore, there is surveillance of the conditions within the space station. Any abnormalities in temperature and efficiency levels of the machinery will trigger a response from maintenance robots. In the agricultural sectors, the system will check for the maintenance of environmental changes including humidity.

Solar Flare Immunity

- Within the space station, data transfers and communication will be on a wireless network. In case of a solar flare, the network will be reverted to fiber optic cable communications within the space station. Communications with Earth will be halted and sent only in periods of decreased solar flare activity.
- As for the external automation, it will include Ra-guard protection

Location of Computer Systems

- The central server and supercomputers will be located within the central axis of the settlement. The wireless network will be present throughout the settlement and fiberoptic connections will be available to business, operational crew and government workers.
- The majority of robots will stored in like robot storage facilities distributed strategically around the tori. Spare parts will be categorically placed throughout the storage grid. Repair robots will be dispersed throughout the settlement and a large portion of them will be located in the repair facilities of each port. After the construction process ends, many of the initial builder robots will be disassembled and parts will be reused in future construction ventures.

5.2.1 Authorized Access

Authorized access will be based on fingerprint passcards. These cards will be person specific and only respond to the fingerprint of that particular person. These swipable cards will also require personal identification numbers (PIN) to authorize actions. In high security areas, on top of surveillance, there will be retina scanners and special morphing codes based on genetic algorithms.

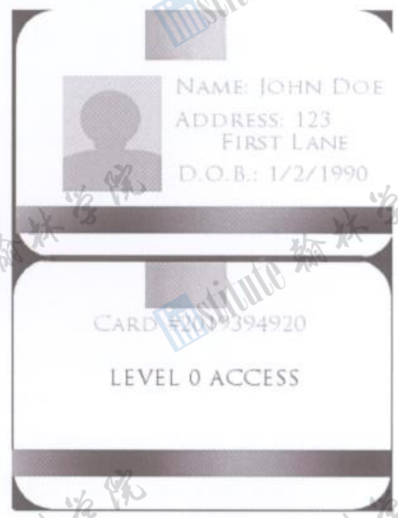


Figure 5.2.1 Passcard

5.2.2 Access Levels

There are a total of seven access levels in the settlement as specified:

Access Level	Access*
1	Basic community computing, residents under the age of eight
2	Community computing as well as house functions, residents age eight and over
3	Commuters who will have to leave the residential areas within the settlement; generally working adults
4	Government Officials; access to data services, residential and industrial services
5	Technicians; access to repair and maintenance robots, technician pods, and computing areas where necessary
6	Highest ranked Operations Crew; have access to all facilities necessary
X	Basic community computing; Tourists

Table 5.2.2 Access Levels

5.2.3 Contingency Plans

In case of emergencies, we have provided in-depth plans of coping with the possible repercussions such abuse will have on our automated systems while providing for ways of protecting people through automated systems.

Emergency	Automated Systems Protection	Residents Protection
Fire	In areas with machinery sodium bicarbonate (baking soda) dust is deployed.	In residential areas, alarms sound and then sprinklers activated. Residents will be evacuated to a safe distance from the area of fire.

Atmospheric Disturbance	If an atmospheric disturbance interferes with machinery functions, then the automated system will be temporarily shut down until atmosphere is corrected in that area.	In a residential area, alarms will sound and residents will have to put on gas masks while they are evacuated to a different sector. Meanwhile, the atmospheric imbalance is fixed through climate controls.
Hull Damage	In the case of such an issue, the affected automated systems will be checked by the maintenance robots and responses will be decided accordingly.	Residents will be evacuated from breached area and alarms will sound in the given sectors.
Data Storage Malfunction	Backup servers will contain a copy of the data and a log of all of the basic functions in the settlement.	There is a data storage center on Earth and all of the settlement communications are logged on separate storage devices.
Solar Flare Protection	All of the exterior systems are protected by radiation protection as indicated in Section 2. In periods of solar flare activity, communications revert to fiber optics.	Provided when leaving the ship, through our space suits. Generally, people will be encouraged to abstain from leaving the settlement during periods of solar flare activity.

Table 5.2.3 Contingency Plans

5.3 Livability on the Space Settlement

Living in space, poses some of the steepest challenges for humans and the automation we will be providing will greatly aid in the facilitation of a more amiable space environment for the inhabitants. By combining a unique human interface system within each residence with a host of automated services, we will allow humans to familiarize themselves with their surroundings and enhance their extraterrestrial experience.

Name of System	Functions/Specifications
Human Interface Unlimited (HIU)	This in residence operating system incorporates the house into the computing experience. This Operating System is activated by voice controls of the residents of that house. This system incorporates both entertainment and utilities of the home and fuses them into an easy to use home control center. A guardian, maid, entertainer and organizer, it turns the home into a truly multifaceted experience. It includes full controls over the cooking range, washing machines, refrigerators, thermostats, lights and other utilities both through iBuddy palm pc's as well as in home through voice activation. The OS can be displayed in the living room via projections and controlled in other rooms via installed interactive touch screen panels. Video gaming or movie watching, the HIU is connected to various entertainment options through a connection to the onboard movie and video game database.
iBuddy	A personal handheld computer, the iBuddy is every resident's assistant, guide and communications device. The iBuddy, with a handy touch screen and docking capabilities. It provides the user options to access their home appliances, work, and map of the settlement as well as communicate with other uses.
QuiKlean	A small circular robot which doubles as a vacuum cleaner and floor washing and drying utility. Its circular shape allows for optimum maneuverability and its ball bearing movement apparatus provides 360 degrees of mobility.
SpaceRange	This is a specially made kitchen appliance range which incorporates an

	induction cooktop, microwave and a fridge.
Medical Assistant One (MAO)	Medical assistant robots provide access to first aid kits and have the capacity to perform basic first aid functions. It includes a feature which contacts necessary medical personnel in case of dire emergency or sets up an appointment. It incorporates a spectroscopic scanner which can diagnose for basic ailments.

Table 5.3.1 Livability Automation

5.3.2 Privacy Systems

Privacy of data and transaction involving computers will be ensured through the implementation of data security systems on personal computing systems and physical protection for on-site servers. There will also be a systematic order of access levels to distinguish which parts of the ship are accessible to which personnel. With the use of fingerprint-activated pass cards, we will be able to ensure safety in case of lost cards. The cards will be used for entering the home, tracking finances, signing in for work, and activating robotic services in certain areas. As there is a large amount of sensitive data to be stored on these cards, the fingerprint activation will be extremely discerning. By using 128 references for the fingerprint scan, misuse will be extremely difficult to achieve. In conjunction with the access cards, certain areas will require additional identification measures such as retina scanners and passkeys to enter. Each user will be given a security suite with tools such as firewall, virus scan, and spam blocker on their personal computers. With the use of laser communication interference between the signals being sent from the settlement to earth will be minimal. For sensitive information, special encryption will be implemented, so sent signals cannot be easily deciphered.

5.3.3 Computing Access

In residential communities, there will be computing access hubs in select locations (One hub of 8 computers per 1000 people). Other than that, in residence HIU will be ubiquitous. Each member above 8 years of age will have a personal iBuddy. Human Interfacing Robots will provide direction the lost souls on board and aid them in medial tasks such as small repairs as well as emergency contacting.

5.3.4 Networking and Bandwidth

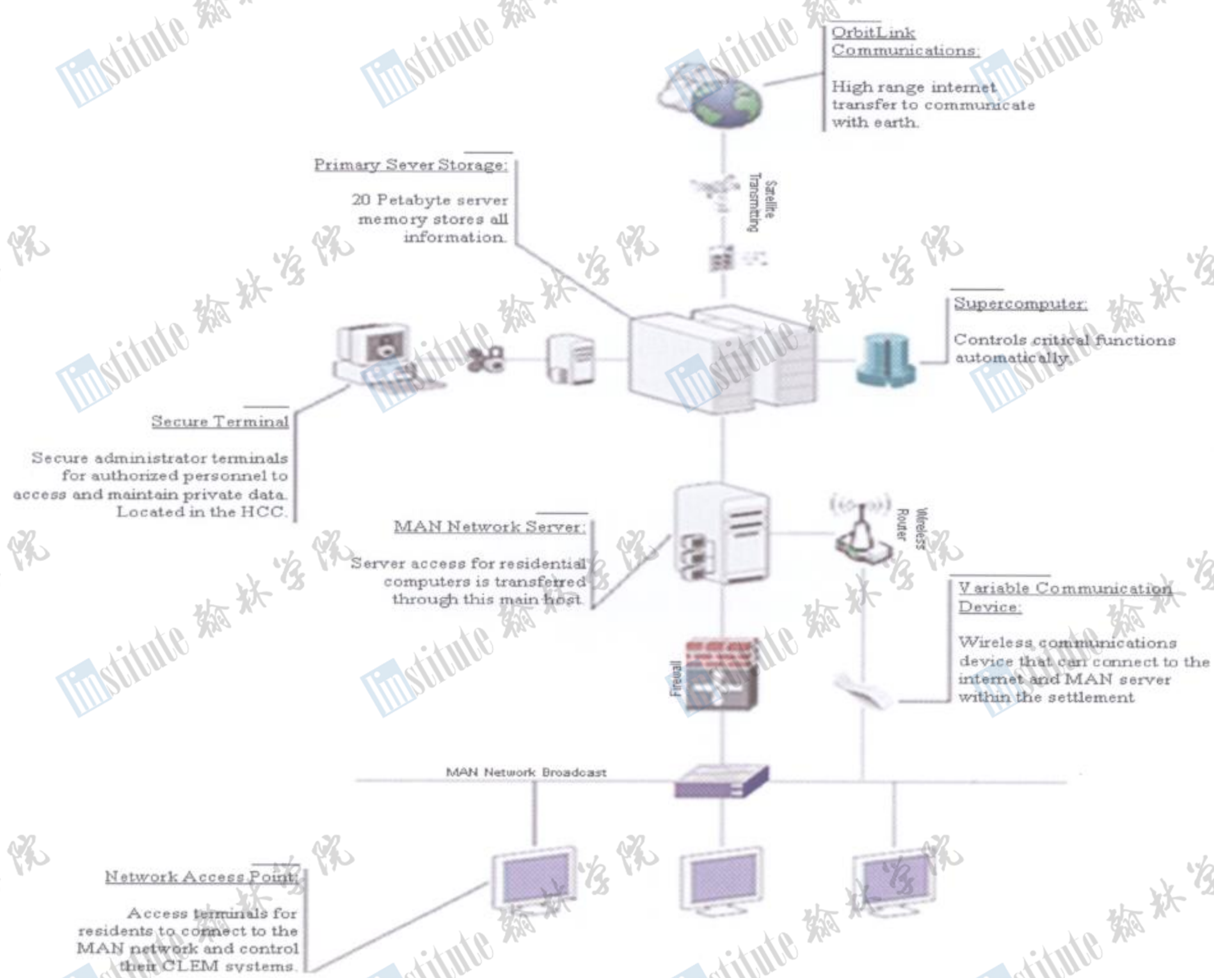


Figure 5.3.1 Networking

Purpose/Target	Type of Connections	Speed
Industrial	Secure Fiber Optics	6 Tbps
Commerce, Space Stations	Secure Fiber Optics Network	6 Tbps
Residential	Secure Wireless; Secure Fiber Optics	6 Tbps
All other Traffic	Secure Fiber Optics Connecting	6 Tbps

Table 5.3.2 Networking Speeds

5.4 Automated Cargo Handling System

5.4.1 Inventory Management System

Element	Description
Storage Grid	• Located in the center of Isengard, the commercial disk • Shaped as a cylinder that is 500m in radius and 50m in height • Utilizes electromagnetic prongs to store and eject materials
Computer	• Serves as the central computer for the storage grid • Coordinates the locations of the storage boxes and reads the barcodes for each box to determine what is contained in each • Arranges requests for storage and for withdrawal • Consists of the complete inventory that is stored in the storage grid
Cargo Boxes	• Made from steel and holds 125m^3 of materials at maximum • Structured as a cube with side lengths of 5m • Coated with Velcro on top and bottom to fasten to loading ships, ensuring that boxes do not float away • Contains barcode on side that codes for what type and how much of a material is in the box • Stockpiled in storage grid, transported along conveyor belt, moved by storage grid prongs as well as overhead clamps
Overhead Clamps	• Sixteen overhead clamps in each port grab boxes and transport them to and from ships, conveyor belts, and storage grid • Large enough to grab onto the boxes • Connected to an intricate railway on "ceilings" of ports • Each reads barcodes on cargo boxes, transmits information to central computer, and "knows" where to store or eject materials
Conveyor Belt	• 5.5 m wide with numerous large carts to secure cargo boxes • Once overhead clamp places box into cart on conveyor belt, interrupts laser-based sensor system and activates metal mesh • Transports boxes to the tori through the central axis and vice versa • Circles the storage grid to decrease distance • Moves through Port 4 to enter central axis; enters Port 1 to enter back to storage grid

There will be an entire set of each of the above in every commercial port. Although there will be a storage grid and overhead clamps in the passenger terminal, the other features of the inventory management system are absent there due to lack of heavy freight traffic. Instead, all cargo that the passenger terminal deals with will be handled by mobile transporter robots.

5.5 Repair

After reaching the space settlement near the docks, ships will enter the air-locked, unpressurized Cleaning Facility, an area that precedes the unloading zone. Cleaning robots, equipped with a lint-roller-like apparatus, will remove foreign particles, such as dust contamination, from the exterior of the ship. After the lint-roller robots clean each part, another group of robots will use biodegradable plastic film to cover each part of the incoming ship and remove the remaining particles through the principle of electrostatic charge. The film will be stored in large rolls and can easily be dispensed by that group of robots. Along the walls of the Cleaning Facility will be recharging booths especially for these robots. Ships will then proceed to an unloading area.

The trapezoidal facility at the center of each port will be situated between the incoming and outgoing traffic lanes. The bases of the trapezoidal facility will be approximately 800 meters along the edge of the port and 425 meters on the side near the fueling and storage area. The height of the trapezoid will be around 200 meters, leaving a 100 meter corridor-like border for ship and cargo movement. Completely quarantined from the rest of the dock, the highly compartmentalized center ensures the safety of the entire settlement by decreasing possible transmission of foreign particles from passengers and livestock. The central area will be also be closed off from the rest of the port to maintain the integrity of the port itself.

The first compartment, called the Health Center, serves as a pressurized quarantine region for the incoming crew and passengers. Five doctors and two veterinarians per repair center will be available at all times to run regular check-ups on the incoming crew and livestock. Helper robots - which are programmed to carry out basic tasks such as measurements - and medical supplies will be available in this compartment. Should any disease or anomaly be detected, the check-up area will immediately isolate itself through the use of sealing doors. Humans will then proceed to a customs area for legal processing.

After the appropriate immigration processes are completed, passengers will enter a sealed-off region, where infrared light will be emitted to sterilize the environment. They will enter a capacious elevator that will transport them to an underground level, and a pod-system in each repair facility will transport both humans and livestock through the central axis to their destination. Crew members of a ship may choose to return to the check-up their ship in the repair facility. In the adjustment modules, crew members will enjoy entertainment that is parallel to that enjoyed by permanent Columbiat residents and will be located near those temporary living quarters. These temporary living quarters can house up to 5,000 transient visitors.

A large portion of the central repair sector, called the Repair Facility, will be dedicated to ship and robot examination and repair. Human technicians, assisted by robots, will check the engines and conduct any other necessary repairs. Ships are then linked to a central computer system and undergo various diagnostic tests, including X-ray screening for damage, check-ups for the ship's own navigational system, and engine testing. Two engineers will also be available at all times for required inspection and adjustments. If the crew feels it necessary, they may also request other repair services through the computer. Ships that need prolonged examinations and repairs will be moved to a separate repair area.

A section of the Repair Facility will be specialized to serve robots. First, a defunct robot will be transported to the Repair Facility. Lint-roller robots will clean off all debris from that robot; then, an X-ray machine and a computer will diagnose the robot's issues. Repair robots within the compartment will replace damaged parts and reinstall software for the damaged robot. Parts will be supplied by the storage grid, which also has the capacity to store spare parts for all models of all robots that come in contact with Columbiat.

Figure 5.5.1 "Lint Roller" Robot

Waste processing will also be highly systematized in the central facility of each port. After waste is deposited into steel boxes designated by barcodes for only waste, waste collection robots in each repair facility will lift the boxes and set the Velcro-surrounded steel boxes onto the cargo-designated conveyor belt. These "waste boxes" on the conveyor belt will then be transported to the waste processing center located in the central hub. The specifics of the transportation process are described in Sections 5.3 and 7.1.

section

6.0

scheduling and costs

Section 6 : Scheduling and Cost

6.1 Scheduling

Years after 7 May 2044	Workers	Approx. Cost ($)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Phase 1		**527009733.8**																
Research & development	120																	
Approval by Foundation Society	N/A			Nov. 2044														
Robot & subsystem development	200																	
Construction modules set up	100																	
Helios satellites set up	70																	
Communication systems set up	50																	
Central Axis constructed	150																	
Phase 2		**131752433.40**																
Luna 1 & 2 constructed	200																	
Interior finishing in Luna 1 & 2	Robotic																	
Phase 3		**395257300.30**																
Isengard constructed	350																	
Ports become operational	N/A																	
Construction supplies transported	60																	
Storage system operational	N/A																	
Phase 4		**131752433.40**																
Aurora mirror constructed	Robotic																	
Spokes assembled	50																	
Phase 5		**658762167.20**																
Construction of Terra	350																	
Interior finishing in Terra	Robotic																	
Construction of Gaia	350																	
Interior finishing in Gaia	Robotic																	
Establishment of atmosphere	N/A																	
Transportation systems established	100																	
Phase 6		**329381083.60**																
Construction of Polaris	150																	
Construction of terminus	100																	
Debugging and final system checks	30																	
Rotation of settlement	N/A																	
Foundation Society moves in	N/A																	
All other colonists welcomed	N/A																	
Full population established	N/A																	

Years after 7 May 2044	17	18	19	20	21
Phase 1					
Research & development					
Approval by Foundation Society					
Robot & subsystem development					
Construction modules set up					
Helios satellites set up					
Communication systems set up					
Central Axis constructed					
Phase 2					
Luna 1 & 2 constructed					
Interior finishing in Luna 1 & 2					
Phase 3					
Isengard constructed					
Ports become operational					
Construction supplies transported					
Storage system operational					
Phase 4					
Aurora mirror constructed					
Spokes assembled					
Phase 5					
Construction of Terra					
Interior finishing in Terra					
Construction of Gaia					
Interior finishing in Gaia					
Establishment of atmosphere					
Transportation systems established					
Phase 6					
Construction of Polaris					
Construction of terminus					
Debugging and final system checks					
Rotation of settlement					
Foundation Society moves in				1.27.2064	
All other colonists welcomed				9.9.2064	
Full population established					7.24.2065

6.2 Costs

See 6.1 Schedule for estimated cost per construction phase

All costs are presented in units of 2009 USD.

6.2.1 Technology

Item	Cost	Quantity	Total Cost	Annual Upkeep	Development Time
iBuddy Laptops	1,350	25,000	33,750,000	1,875,000	N/A
PCs (normal)	800	4,000	3,200,000	300,000	N/A
Servers	20,000	30	600,000	4,500	N/A
Storage (Tech)	45,000	40	1,800,000	6,000	N/A
Business Computers	2,000	2,500	5,000,000	187,500	N/A
Computer Management PC's	3,000	50	150,000	3,750	N/A
Network (all components)	1,750,000	1	1,750,000	1,250	N/A
Science Research PC's	2,000	1,500	3,000,000	112,500	N/A
Builder Robots	350,000	50,000	17,500,000,000	25,000,000	1.5 years
Repair Robots	400,000	24,000	9,600,000,000	12,000,000	1.75 years
Other Robots (Averaged)	450,000	50,000	22,500,000,000	27,500,000	
Omnitool	2,000	150,000	300,000,000	N/A	1 year
Fingerprint Swipe Cards	200	27,000	5,400,000	N/A	1 year
Card Readers	500	176,000	88,000,000	N/A	0.5 year
Central Computer	16,500,000	1	16,500,000	200,000	5 years

Supercomputers	2,500,000	20	50,000,000	400,000	3 years
Storage Grid (Cargo)	12,000,000	50	600,000,000	500,000	4 years
Repair Facility	26,700,000	5	133,500,000	500,000	3 years
Development			75,000,000		
TOTAL COST			50,917,650,000	68,590,500	

6.2.2 Appliances

Item	Cost	Quantity	Total Cost	Annual Upkeep
SpaceRange	20,000	12,500	250,000,000	1,250,000
QuiKlean	300	12,500	3,750,000	625,000
Medical Assistant One	15,000	2,000	30,000,000	350,000
Human Interface Unlimited	40,000	12,500	500,000,000	3,125,000
Compact Fluorescent Lamps	0.30	5,000,000	1,500,000	N/A
Sliding Security Doors	1,250	364,000	455,000,000	683,000
Development			5,000,000	
TOTAL COST			1,245,250,000	6,033,000

6.2.3 Transportation

Item	Cost	Quantity	Total Cost	Annual Upkeep	Development Time
Freight Subway	75,000,000	2	150,000,000	1,000,000	3 years
Magnetic Railways	3,000,000	10	30,000,000	1,500,000	3 years
Space Elevator Terminus	5,000,000	1	5,000,000	25,000	10 years
Railway Pods	250,000	100	25,000,000	100,000	N/A
Asgard	1,500,000	50	75,000,000	50,000	N/A
Aaru	1,500,000	20	30,000,000	20,000	N/A
Firdaus	1,000,000	10	10,000,000	10,000	N/A
Celia	3,000,000	5	15,000,000	5,000	N/A
Elysium	1,250,000	50	62,500,000	50,000	N/A
Development			22,500,000		
TOTAL COST			425,000,000	2,760,000	

6.2.4 Wages

Profession	Number of Workers	Annual Wages	Total Annual Wages
Technician / Engineer	1,500	165,000	247,500,000
Worker (Averaged)	16,500	85,000	1,402,500,000
Government Official	700	120,000	84,000,000
Researcher	1,500	120,000	180,000,000
Teacher	60	65,000	3,900,000

Security Personnel	200	57,500	11,500,000
Planner*	60	200,000	12,000,000
TOTAL Wages			1,929,400,000

*Planners are paid a lump sum of $200,000 each during construction. Their wages are excluded from totals.

6.2.5 Communication

Item	Cost	Quantity	Total Cost	Annual Upkeep	Development Time
Fiber optic cables	15 / meter	25,000 m	375,000	0	N/A
Lasers	6,000	15	90,000	7,500	N/A
Intercom	5,000	1	5,000	750	N/A
Wireless LAN	550	250	137,500	12,500	N/A
Comm. Satellite (Laser)	300,000	5	1,500,000	25,000	3 years
Comm. Satellite (Radio)	275,000	4	1,100,000	16,000	3 years
Development			1,500,000		
TOTAL COST			4,707,500	61,750	

6.2.6 Materials

Material (unit)	Unit Price	Quantity	Total Cost	Annual Upkeep
Nitrogen (m^3)	60.00	229,948,687	13,796,921,192.34	0.00
Oxygen (m^3)	0.300090	126,471,778	37,952,915.74	0.00
Carbon Dioxide (m^3)	0.009889	153,299	1,515.90	0.00
Water (m^3)	1.00	2,145,000	2,145,000.00	42,900.00
Silica Aerogel (m^2)	2.00	1,224,080,001	2,448,160,001.26	550,000.00
Titanium Matrix Composite (kg)	4.20	580,000,000	2,436,000,000.00	300,000.00
Aluminum Silicon-Carbide (kg)	2.00	470,000,000	940,000,000.00	300,000.00
Borosilicate Glass (m^2)	30.00	75,000,000	2,250,000,013.23	1,240,000.00
Carbon Nanotubes (m^2)	15.00	50,000,000	750,000,000.00	1,100,000.00
Demron Cloth (m^2)	300.00	25,000,000	7,500,000,000.00	850,000.00
Liquid hydrogen (kg)	2.20	787,500,000	1,732,500,000.00	30,000.00
Solar panels (m^2)	650.00	2,529,357	1,644,082,050.00	12,646,785.00
Ring Motor	100,000.00	2	200,000.00	1,000.00
Main Mirror Motor	100,000.00	1	100,000.00	1,000.00
Sphere Motor	100,000.00	1	100,000.00	1,000.00
Steel Cargo Boxes	125.00	365,000	45,625,000.00	250,000.00
TOTAL COST			33,538,162,688.47	17,062,685.00

6.2.7 Landscaping

Landscaping	Unit Price	Quantity	Total Cost	Annual Upkeep
Trees	10.00	10,000	100,000.00	5,000.00
Central Lake	1,250,000.00	1	1,250,000.00	30,000.00
Mountains/Valleys	250,000.00	20	5,000,000.00	40,000.00
TOTAL COST			6,350,000.00	75,000.00

6.2.8 Housing

Housing	Unit Price	Quantity	Total Cost	Annual Upkeep	Development Time
Single Residences	200,000.00	7,056	1,411,200,000.00	14,112,000.00	3.5 years
Double Residences	275,000.00	4,608	1,267,200,000.00	12,672,000.00	3.5 years
Triple Residences	350,000.00	1,152	403,200,000.00	4,032,000.00	3 years
Schools	800,000.00	6	4,800,000.00	4,000,000.00	1.5 years
Parks	750,000.00	6	4,500,000.00	4,470,000.00	2.5 years
Hospitals	1,100,000.00	6	6,600,000.00	4,500,000.00	2 years
Assembly Halls	650,000.00	12	7,800,000.00	4,140,000.00	1 year
District/Community Centers	1,350,000.00	7	9,450,000.00	10,150,000.00	3 years
Offices	2,540,000.00	6	15,240,000.00	10,800,000.00	3 years
Museum	1,850,000.00	1	1,850,000.00	1,150,000.00	3 years
Amusement Park	10,000,000.00	1	10,000,000.00	6,130,000.00	4.5 years
Library	1,400,000.00	1	1,400,000.00	500,000.00	2 years
Observation Sites	2,150,000.00	2	4,300,000.00	1,400,000.00	3 years
Hotels	1,050,000.00	6	6,300,000.00	6,000,000.00	2.5 years
Development			100,000,000		
TOTAL COST			3,253,840,000	84,056,000	

6.2.9 Revenue

Construction Costs		Amount of Time to Break Even
Technology	50,917,650,000.00	Calculus
Appliances	1,245,250,000.00	89,402,960,188.47 + 2,108,038,935.00 X =
Transportation	425,000,000.00	12,448,750,000.00 X
Wages (Planners only)	12,000,000.00	10,340,711,065 X = 89,402,960,188.47
Communication	4,707,500.00	X = 8.6457 years
Material	33,538,162,688.47	**9 years to break even**
Landscape	6,350,000.00	
Housing	3,253,840,000.00	
TOTAL	**89,402,960,18847**	
Annual Costs		
Technology	68,590,500.00	

Appliances	6,033,000
Transportation	2,760,000.00
Wages	1,929,400,000.00
Communication	61,750.00
Material	17,062,685.00
Landscape	75,000.00
Housing	84,056,000.00
TOTAL	**2,108,038,935.00**
Annual Revenue	
Tourism	2,448,750,000.00
Recreation	897,500,000.00
Hotels	1,095,000,000.00
Souvenir Sales	456,250,000.00
Net Trade Revenue	7,750,000,000.00
Private Contracting and Advertising	2,250,000,000.00
TOTAL	**12,448,750,000.00**

version 7.0

business

development

SECTION 7 : BUSINESS DEVELOPMENT

7.1 – Transportation Node and Ports

7.1.1 Docking, Warehousing, and Terminal Facilities

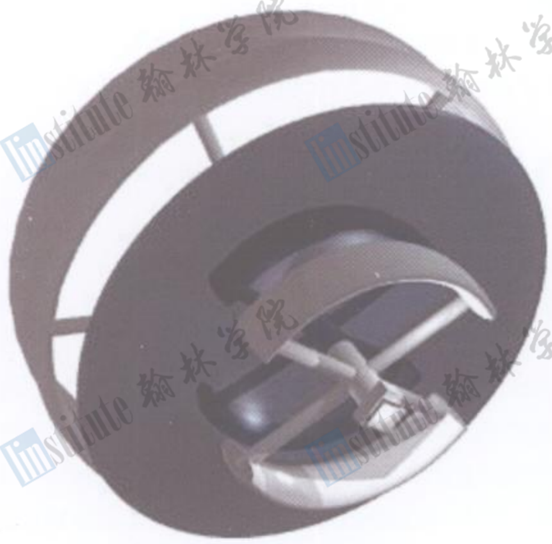


Figure 7.1.1 Commercial Disk- Isengard

Freight ships will be able to dock at any of the four commercial ports located on a specialized, non-rotating disk connected to the central axis; this disk is named Isengard. There is also a passenger terminal; in essence, Isengard will be divided into five equal sections, four for commercial use and one for passenger. The entire area will be subject to microgravity due to the absence of a centrifugal force. Isengard, which has a radius of 800m, serves as the junction for storage and commerce for all Foundation Society settlements and Earth. An area with a 500m radius centered around the central axis will be converted into a storage area, leaving a 300m width for loading and unloading purposes. Out of the 300m width, 10m along the outside will be reserved for the radiation shielding material. There will be enough space along the unloading side of each commercial dock for approximately six ships, assuming each ship is 40m long, 20m wide, and 10m tall. The loading side of each commercial dock will also contain enough space for six ships. The passenger terminal will hold up to 16 ships and will have the same dimensions as the other four commercial docks. For all five docks, ships will enter from the "left" and stop along the perimeter, where robots will unload cargo and place the cargo on the conveyor belt. Consequently, the conveyor belt will enter the storage area, circle around the region, and transfer secured cargo through the central axis to the residential tori. After cargo is unloaded, the ships as well as the passengers and crew will undergo examinations in the central repair center. Details on medical facilities can be found in Section 5.5.

7.1.2 Entertainment Options

There will be a multiplex movie theater which will be a hexagon built around a circular base. This movie theater will have eight screens and be incorporated into the main shopping and entertainment areas within the settlement. The six theaters will have screens of 30 feet height and 70 feet length as well as Dolby Digital Surround. A special attraction of the colony will be a zero-G theater, completely usurping the conventions of theater. By providing a zero G theater, it will allow members of the crew to express their creativity.

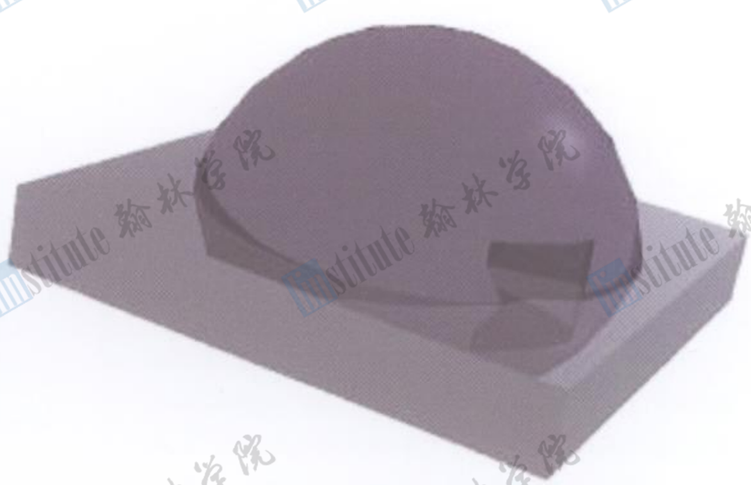


Figure 7.1.2 Zero-Gravity Theater

There will also be gaming cafes, called *Cyberdekk*, which will provide entertainment options for the younger members and the old. The games will have to be played on LAN networks, as transfer lag time from space to Earth would otherwise be too high to ensure a quality gaming experience.

7.1.3 Docking

The loading and unloading portions of the dock will be physically divided by a barrier, to separate both sides and reduce the possibility of collisions. The loading and unloading of ships will also be completely automated. Ships enter the port from the left entryway and are guided to an unloading zone by Columbiat's central computer system. The ship's controls will be overridden by those of Columbiat's to reduce traffic congestion. First, the pilot will voluntarily surrender control of his ship by deactivating its navigational system. Second, a laser receptor on the ship will receive instructions from a mounted laser beam, which sends information by encoding it into the laser beam. The ship will also transmit its vital data, such as model number, time traveled, and other statistics, through a laser aimed at a sensor located below the mounted laser; this vital data become important later at the repair facility, as indicated in Section 5.4. These lasers are the agents of communication between the ship and the main computer on the settlement. Upon reaching its proper unloading position, the presence of the ship disrupts a laser circuit and activates a request for unloading. See Section 5.4 for more detail on the aforementioned loading and unloading mechanisms.

7.1.4 Space Elevator Terminal Facilities

Columbiat will also contain the terminal for a future lunar space elevator. Although specifics have not yet been designated for the technical aspects of the elevator, the elevator will only transport materials and cargo from the moon, such as water and rock minerals; no livestock or human passengers will be transported. After the space elevator travels from the moon to the L2 location of Columbiat – which is a monthly event – the elevator will detach from its cable, retract its climbers, and propel itself with ions thrusters towards the air-locked terminal at the "bottom" of the settlement, a part of the central axis and below the ports (see diagram for visual). A sensor will detect the presence of the cylindrical elevator and consequently signal the terminal to accept for the elevator. Once the elevator is within the terminal, clasps will position the elevator and secure the structure on a platform. This platform will raise itself until the elevator is slightly below the level of the ports. In this new position, the elevator will be in the central axis, near the storage grids of the port as well as the moving cargo conveyor belts. The sliding door on the front face of the elevator will be unlocked by a complex password that one of the robots assigned to the elevator will know. This "master elevator robot" will enter the central axis from the storage grid, and is programmed to do so every month; only this robot has the encrypted password for the elevator. After the elevator door opens, the master elevator robot will summon other transporter robots to grab onto the cargo boxes inside the elevator and drag them out into the commercial disk, where the overhead clamps in each port will take the boxes and place them in their correct position in the storage grid based on the barcodes on the boxes. The leftover elevator box will be taken to the waste processing center to be recycled into reusable materials.

7.2 Commerce and Financial Center

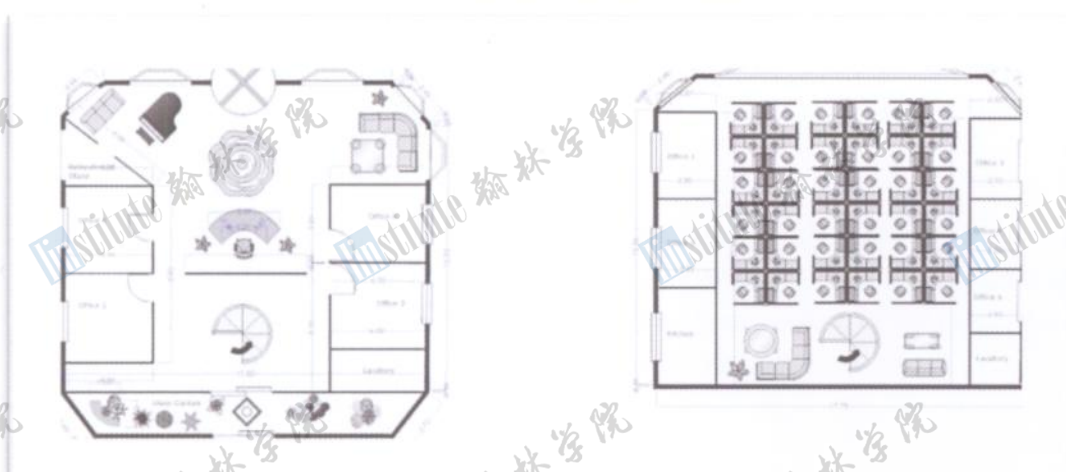


Figure 7.2.1: 100- and 150- person office plans

The commercial center in Columbiat will provide for the extensive business needs of its clients. Both 100-person and 150-person offices will be provided; the former will have 5 floors while the latter will have two additional floors. 30-person office buildings and 5-person field offices will be provided to smaller businesses and centers conducting research.

A building specifically intended for the Foundation Society will also be constructed in the commercial disk. This new facility will have access to the supercomputers housed in the central axis, in order to manage the enterprises of Foundation Society. The facility will also be able to house the 300-person staff and provide food and other basic necessities such as showering facilities. A garden will also be located nearby to accommodate the hard-working members of the Foundation Society.

Figure 7.2.2: 5-person field office

Supercomputers will be housed in the central axis, due to both microgravity and low temperatures, both of which are essential to increasing processor efficiency and speed. Information will be sent both through a wireless connection and fiber-optic cables, and the information will be encrypted. The cables have a transfer capacity of 5 terabytes per second, and the wireless connection has a transfer capacity of 500 gigabytes per second. Most ordinary information will be sent through the wireless connection; the cables will be utilized for secure information, such as confidential plans and supercomputer projects.

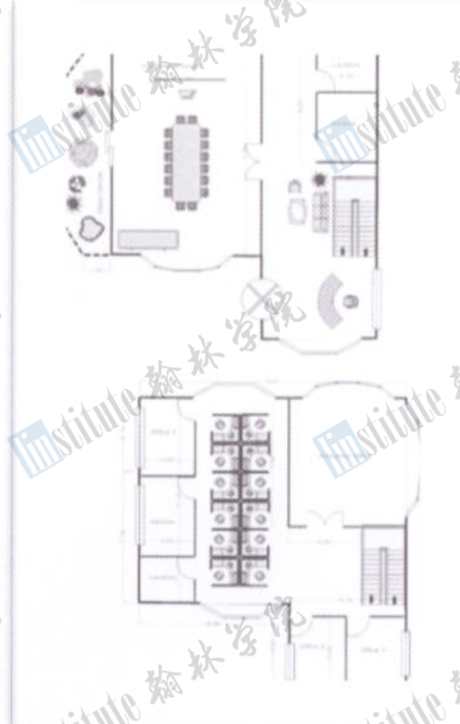


Figure 7.2.3: 30-person office

7.3 Provisioning and Maintenance Base

Columbiat will be able to service myriad types of ships. Columbiat will hold a supply of hydrazine, nitrogen tetroxide, helium-3, and deuterium to refuel ships. All four fuels will be stored in large double-walled tanks under high pressure and low temperatures; each tank will hold only one type of fuel. The tanks will be color-coded and barcoded for what type of fuel they hold. They will be stored in a stable environment, namely at the interface between the storage grid and the commercial ports. Only high access level robots may access the fuel, either to deposit excess fuel or to take out fuel for departing ships. Security cameras will be strategically placed throughout the storage, and temperature monitors will not only monitor the stability of the environment but also detect living beings. Upon detecting a living being, the storage area will completely seal up and quarantine the suspect; consequently, security guards will surround the storage area and capture the suspect for security purposes. It is essential that only robots that have high access levels and that have been recently checked-up by repair robots enter the area; no one else may be trusted to do so.

Cleaning, maintenance, and repairs will be carried out by the repair facility in the middle of each dock. After waste is deposited into steel boxes designated by barcodes for only waste, waste collection robots in each repair facility will lift the boxes and and set the Velcro-surrounded steel boxes onto the cargo-designated conveyor belt. These "waste boxes" on the conveyor belt will then be transported to the waste processing center located in the central hub.

Excess food will be placed in the storage area, which will serve not only as a provisioning facility for ships but also as the emergency provision storage. However, placing all emergency rations in one centralized area is unsafe; hence, each torus will have its own compartment of emergency rations, and each compartment will have enough food to feed 15,000 people for an entire week.

version

8.0

compliance matrix

Section 8 : Compliance Matrix

Requirement	Page Number
1.0 *Executive Summary*	1
2.0 *Structural Design* -Provide residence for up to 24500 residents, with natural views of Earth.	2
2.1 *Exterior* -Identify large enclosed volumes and major structural components. -Specify where artificial gravity will be supplied. -Show interfaces between rotating and non-rotating sections. -Rationalize rotation rate and artificial gravity. -Identify pressurized/unpressurized volumes. -Identify rotating/non-rotating sections. -Specify means for debris/radiation protection. -Indicate functions of each volume.	2 [2.1.1] [2.1.1] [2.1.1] [2.1.3] [2.1.4] [2.1.1] [2.1.2] [2.1.4]
2.2 *Interior* -Specify allocation of down area. -Show drawings with dimensions of residential, industrial, commercial, agricultural, and other sections. -Specify volumes of and state how microgravity and unpressurized facilities will be used. -Show orientation of down area and vertical clearance in each area.	6 [2.2] [2.2] [2.2.4] [2.2]
2.3 *Construction* -Describe construction process and show at least 6 steps of assembly.	8 [2.3]
2.4 *Ports* -Ports must be able to dock and unload/load 4 cargo ships and 1 passenger ship. -Ports must have 1 long-term docking station for emergency repair. -Must have drawing/map showing port areas of incoming/outgoing ships. -Show cargo transfer facilities in a typical docking bay for visiting ships.	9 [2.4] [2.4] [2.4] [2.4]
2.5 *Gravity* -Provide accommodation at half the gravity of primary settlement volumes. -Show lower-g sections on overall settlement drawing and indicate rpm.	10 [2.5] [2.5]
3.0 *Operations & Infrastructure* -Describe facilities necessary for building and operating the community, including business and accommodating vehicles.	11 [3.0]
3.1 *Materials* -Identify sources of materials/equipment for construction/operations (chart). -Identify means of transport for materials (chart).	11 [3.1.1] [3.1.1]
3.2 *Infrastructure* -Identify air composition, pressure, and quantity, and describe climate control. -Describe food production: growing, harvesting, storing, packaging, delivering, selling. -Describe how power will be generated (specify kW), distribution, & allocation. -Describe water management (quantity and storage facilities). -Describe household and industrial solid waste management (recycling, disposal). -Describe internal/external communication devices & central equipment. -Describe internal transport systems (show routes, vehicles, dimensions). -Describe day/night cycle provisions (schedules and mechanisms required).	11 [3.2.1] [3.2.2] [3.2.3] [3.2.4] [3.2.5] [3.2.6] [3.2.7] [3.2.8]
3.3 *On-Orbit Infrastructure* -Identify on-orbit infrastructure (e.g. vehicles, satellites, power plants). -Define which will be included in contract and which will be developed commercially.	16 [3.3.1, 3.3.2] [3.3.1, 3.3.2]
3.4 *Propulsion*	17

-Define propulsion systems required for establishing & maintaining artificial gravity and keeping station at L2. -Show drawings of propulsion systems, locations, interfaces with the structure, propellant types & storage, and type of thrust produced by each propellant.	[3.4] [3.4]
3.5 Maintenance -Chart for provisioning/maintenance services, including warehousing and loading systems, for food and agricultural replenishment, livestock veterinary services, engine overhaul, fueling, waste, and replacement of common living items.	18 [3.5.1 – 3.5.7]
4.0 *Human Factors* -Have natural sunlight and views of Earth below settlement.	19 [2.1]
4.1 Consumables -List major categories of consumables. -Estimate annual replenishment of clothing and paper, and describe sources. -Depict and specify means of distributing consumables (incl. food) to residents. -Provide maps/illustrations of communities with locations of amenities and distance scale. -Identify % of land area allocated to roads and paths.	19 [4.1.1] [4.1.1] [4.1.1] [4.0] [4.0]
4.2 Residences -Provide designs of typical homes, clearly showing room sizes. Offer differentiated neighborhoods to suit a variety of preferences for architecture and lifestyle choices. -Estimate numbers of different types of furniture required and identify sources for furniture. -Provide external drawing and interior floor plan of at least 4 home designs, the area (in sq. feet) of each design, and the number of each required.	20 [4.2] [4.2] [4.2]
4.3 Access & Safety in Microgravity -Provide means for safe access to any location in parts of settlement with low-g, inside settlement or on exterior surfaces.	21 [4.3]
4.4 Spacesuit Design -Provide design of spacesuit for work outside pressurized volumes. -Provide stowage and donning/doffing procedures to minimize air loss. -Provide airlock designs for entering/exiting settlement to minimize air loss. -Estimate amount of air volume lost during each cycle of the above.	21 [4.4] [4.4.1, 4.4.2] [4.4.4] [4.4.3]
4.5 Visitor Accommodation -Show locations and designs of hotels or other accommodations for visitors. -Describe security measures to unobtrusively monitor visitor activity so that visitors do not interfere with the lives of permanent residents. -Provide medical quarantine facilities for visitors. -Include table/chart with anticipated security issues and responses for each and processes for responding to unexpected security issues.	23 [4.5] [4.5] [5.5] [5.2.3]
5.0 *Automation* -Specify number and types of computers, servers, software, network devices, and robots required for facility, community, & business operations. -Include types and capacities of data storage media, collection, distribution, and user access to computer networks in computer system descriptions. -Show robot designs, clearly indicating dimensions and illustrating how they perform their tasks.	24 [5.0.1] [5.0] [5.0]
5.1 Construction -Describe automation for construction (transportation/delivery of materials, assembly, interior finishing). -Include chart/table with automated construction and assembly devices for exterior and interior applications, and their purposes.	25 [5.1] [5.1]
5.2 Maintenance	26

-Specify systems for maintenance, repair, and safety, including backup systems and contingency plans for failures. -Define physical locations of computers and robots. -Provide solar flare protection for emergency robots. -Describe means for authorized personnel to access critical data and command computer/robot systems; include security measures to assure that only authorized personnel have access (and for authorized purposes).	[5.2] [5.2] [5.2] [5.2.1]
5.3 *Livability* -Specify automation to enhance livability, productivity, and convenience. -Emphasize automation for routine tasks, and reduce manual labor. -Provide for privacy and control of private systems. -Describe access to community computing/robot resources from individual homes and workplaces. -Provide drawings of robots/computers on settlement, and diagrams of networks and bandwidth requirements for connectivity.	28 [5.3] [5.3] [5.3.2] [5.3.3] [5.3.4]
5.4 *Inventory* -Provide illustration or chart with inventory management systems and automated loading/unloading systems.	30 [5.4.1]
5.5 *Repairs* -Provide drawings of robot repair facilities, with measures implemented to prevent spread of dust contamination from visiting ships.	30 [5.5]
6.0 *Schedule and Cost* -Provide a schedule with costs through the construction phases of the schedule.	32 [6.0]
6.1 *Schedule* -Describe tasks from time of contract award (May 7, 2044) until customer assumes responsibility for settlement operations. -Show dates when Foundation Society members may move into settlement and when entire initial population will be established.	32 [6.1] [6.1]
6.2 *Costs* -Specify costs associated with design in US dollars without inflation. -Estimate numbers of employees per phase of construction. -Provide charts/tables with separate costs per phase of construction.	33 [6.2] [6.1] [6.1]
7.0 *Business Development* -Design of settlement should be able to add compatible business types easily.	38 [7.0]
7.1 *Transportation Node and Port* -Must have docking, warehousing, and cargo-handling capability to transfer freight between spacecraft (including large-scale industrial cargo). -Must have terminal facilities to handle passengers between Earth, orbit destinations, Moon, and other locations in solar system. -Should be practical as terminus for Space Elevator. -Must offer a wide variety of activities to visitors. -Should have proper quarantine and medical services. -Transient population may reach 5000; must be able to accommodate this.	38 [7.1] [7.1.2, 7.1.3] [7.1.4] [7.1.2] [5.5] [2.1, 7.0]
7.2 *Commerce and Financial Center* -Should have office facilities: 4 150-person offices, 8 100-person offices, 15 30-person offices, 30 5-person offices. -Provide facilities for 3 banks to finance companies, residents, and crews. -Provide facilities for Foundation Society headquarters with 300-person staff managing business, researching, and providing member services. -Provide computing centers with secure networked communications within companies and interconnectivity for data transfer between companies.	39 [7.2] [7.2] [7.2] [7.2]
7.3 *Provisioning and Maintenance Base for Visiting Spacecraft*	40

-Provide fueling service for spacecraft traffic using ports	[7.3]
-Show storage facilities for hydrazine, nitrogen tetroxide, He-3, and deuterium.	[7.3]
-Provide maintenance, cleaning, waste collection, and repair services for visiting ships.	[7.3]
-Have agricultural production, storage, and processing capability in excess to service provisioning needs of visiting spacecraft, and serve as a backup in case of food crises on Columbiat or elsewhere.	[7.3]

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