NORTHDONNING HEEDWELL

BELLEVISTA

UNIVERSITY HIGH SCHOOL | IRVINE, CA | USA

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1.0 EXECUTIVE SUMMARY

SECTION 1: EXECUTIVE SUMMARY

The following proposal is a design for a new advancement in space colonization. Following its predecessor Alexandriat, **Bellevistat** will be an industrial center, tourist attraction, and above all, a comfortable residence for its permanent population of 18,000. Bellevistat will be able to support this and an additional transient population of 1,000; it also has the capacity to expand and develop further for future ventures. It will be constructed over a period of 24 years, from the time of the awarding of the contract to the time when Bellevistat reaches its final permanent population. In addition, the colony will only take 12 years to completely reimburse the costs of construction through exports and tourism.

Bellevistat offers residents the highest standards of living and is almost completely self-sufficient. Bellevistat will be maintained through eco-friendly and efficient ways. It has two rings, Gemini and Tethora, which simulate Earth-like environments for the comfort of its inhabitants. The rings each have 3,915,941.058m^2 of down area and a vertical clearance of 100 m to provide ample living space.

In addition, Bellevistat offers residents:

- Simulated Earth gravity of 1G for maximum comfort and easier adaptation for visitors.
- Simulated 24 hour day-night cycle, created through the rotation of mirrors.
- A wide variety of environments, landscapes, and neighborhoods.
- Zero-G recreation and space ventures, as well as spectacular views of space and Earth.
- The latest technologies for living, working, and recreation.
- Reliable communication systems that allows inhabitants to stay in contact with Earth.
- Higher and more environmentally safe standards of living to use resources more efficiently and sparingly.

Bellevistat will also serve as a major industrial hub in space. In its orbit at L4, the colony will utilize specialized mining robots to harvest ores from asteroids, taking the utmost care to allow only purified ore to proceed into areas of the colony occupied by humans. The colony's attachment to a small asteroid allows for trade with Earth and Alexandriat, as well as with colonies predicted to spring up in the future once Bellevistat is completed. Bellevistat will manufacture a wide variety of materials that are difficult to produce on Earth. This can be sold or traded with Earth to produce revenue needed for its maintenance and repair.

Maintenance and repair of Bellevistat will largely be done by robots, supervised by human workers. This allows humans to spend more time on other tasks such as research and experimentation. Bellevistat includes sophisticated experimental areas in both zero-gravity and full Earth-gravity regions. Residents and tourists alike will be able to experience the exotic offerings of space while living in conditions that closely emulate the comforts of home.

Northdonning Heedwell proposes Bellevistat as the epitome of modern living, comfort, and technology. The colony will serve as a 'springboard' for new colonies, allowing for further development of these ideals; by the time it is fully completed on **July 24, 2052**, Bellevistat itself will already be in high demand for trade, transport, and tourism. The design proposed in the following pages displays the extent to which the prosperity of the colony will extend, not only in wealth but in culture, diversity, and advancement.

2.0 STRUCTURAL DESIGN

SECTION 2: STRUCTURAL DESIGN

2.1 External Configuration

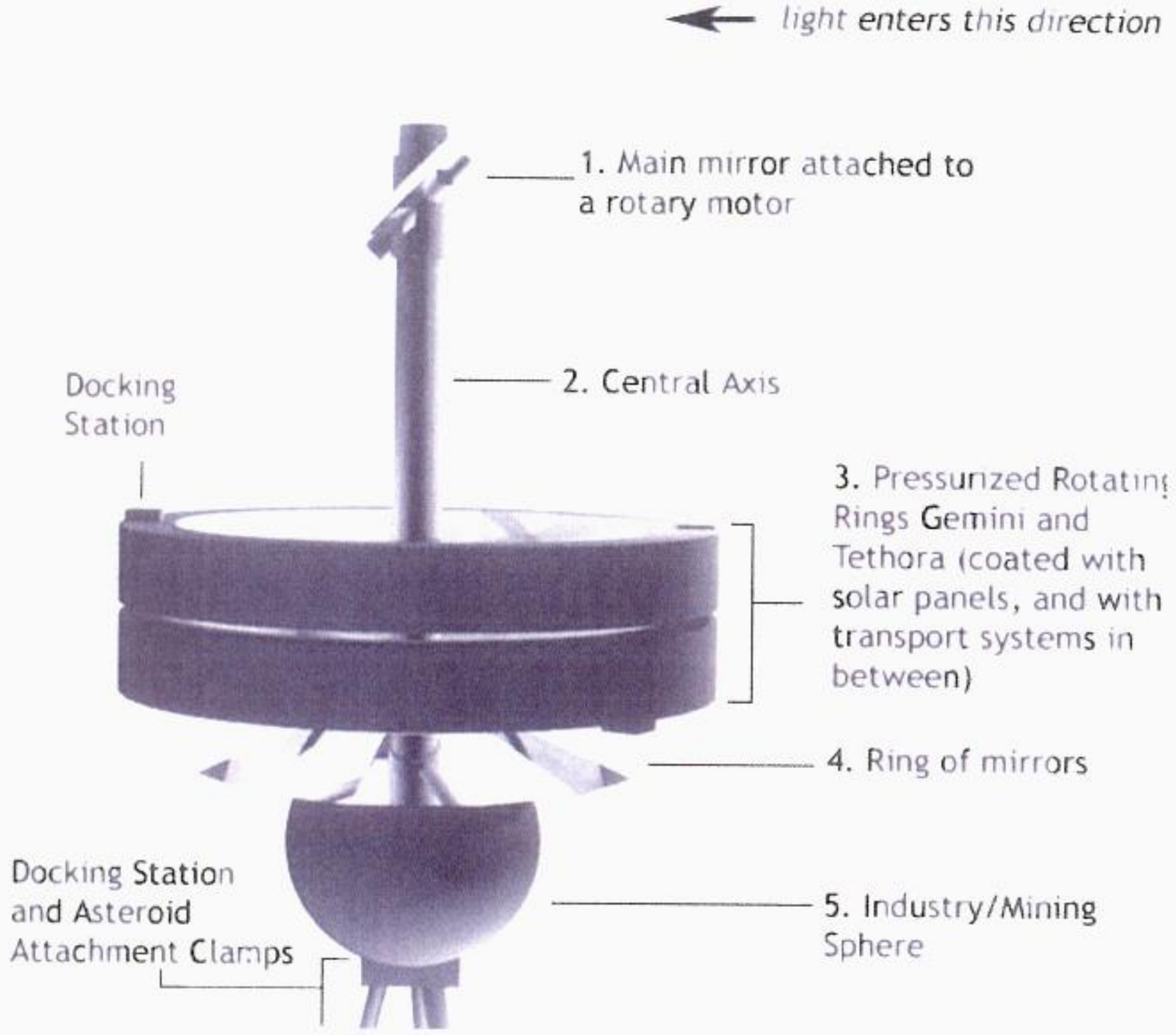


Figure 2.1.1

2.1.1 Exterior Design

The colony Bellevistat will consist of two pressurized counter-rotating rings, Gemini and Tethora, containing all residential and agricultural areas and an industrial sphere, connected by a stationary central shaft around which the settlement operates. There will be two mirrors that reflect light into the pressurized rings.

Many factors were considered when designing the overall structure. Rings were chosen instead of tori because tori waste volume. Two rings were chosen over one because if one ring is damaged, the other would be able to operate independently while repairs are made. The rings are coated with solar panels to maximize use of surface area. Also, the sphere was placed at the end of the settlement so as to not interfere with light directed from the mirrors to the settlement.

The dimensions for major sections are as follows:

Sections:	Dimensions:	Total Surface Area:	Total Volume:
1. Central Axis	Radius = 73.955m Height = 1800m	1,327,073.127 m^2	30,928,400.506 m^3
2. Main Mirror	Radius = 900m	2,544,690 m^2	NA
3. Pressurized Rotating Rings Gemini (top) and Tethora (bottom)	(Per ring, excluding Solar Panels) Radius = 913.955m Height = 231.095m Thickness = 113.955m	(Per ring) 3,829,887.498 m^2	(Per ring) 133,657,654.1 m^3
4. Ring of Mirrors	Distance from two opposite mirrors: Top = 600m Bottom = 1,307.1m Width of one mirror: Top = 155.291m Bottom = 330.392m Height of whole structure = 146.45m Side length of one mirror = 338.268m Height of one mirror = 326.742m	952,158.654 m^2	NA

5. Industrial/Mining Sphere	Radius = 405.909m	2,070,461.816 m^2	690,153.939 m^3
6. Solar Panels on Rings Gemini and Tethora	(Per Panel) Length: 1m Width: 1m Total number of panels: 2,529,357	2,529,357 m^2	N/A

Table 2.1.1 Major Structural Components and Attributes

2.1.2 Production of Artificial Gravity

The sphere and central axis are both major transportation and storage systems, thus, they are both in 0-g to maximize efficiency and also to save energy and resources. Gemini and Tethora are the only sections in Bellevistat that operate at 1g. Because humans are unable to adapt to environments rotating at more than 3 rpm (revolutions per minute), Bellevistat simulates gravity by rotating at a rate of 0.996 rpm.

Given that:
The force due to rotation is $F = mv^2/r$
And that $F = ma$, and acceleration = 1 g = 9.8 m/s^2

We have: $9.8 = (4\pi^2 \times 900)/p^2$, and p = 60.21
So it takes about 60.21 seconds for one revolution
Using proportions, 60.21/60 = 1/x, we get x = to 0.996 rpm

F = force due to rotation
m = mass of object
v = velocity of object ($2\pi r/p$)
r = radius (900m)
p = period of rotation (in seconds)

The rings are rotating in opposite directions to provide stability to the structure. A simulated environment of 1 Earth-gravity makes it easier for visitors to adjust, and certain animals require 1g to carry out life processes properly.

Artificial gravity for each ring is produced by the rotation of a motor around the central axis. The motor is powered by energy harvested from solar panels. Central processors in the axis and in the rings will monitor rotation rates.

2.1.3 Pressurized/Non-pressurized Environments

Gemini and Tethora will maintain pressurized environments to simulate Earth's atmosphere. The sphere will also be pressurized for the convenience and comfort of workers. The central axis will be non-pressurized to save energy and resources. A non-pressurized environment in the central hub will provide more safety as combustible gases are not present. However, if the emergency living space in the axis is needed, air will be provided for in that chamber.

2.1.4 Debris Protection and Shielding

Bellevistat will use a variety of shielding materials to ensure safety for its residents.

Material	Use; Rationale
Titanium Matrix Composite-- Inconel 625	External structural elements; chosen for its outstanding strength, resistance to corrosion, and excellent durability
Aluminum Silicon-Carbide Whisker Matrix Composite	Internal structural elements and external support structures; chosen for its high tensile strength and low coefficient of thermal expansion
Borosilicate Glass	Used in manufacture of windows; chosen for its resistance to thermal shock and high strength

Carbon Nanotubes	Used for intrinsic support and protection from debris; chosen for their versatility and great strength
Silica Aerogel	Used for insulation against heat loss and radiation; chosen for its strength, low density, and insulation properties
Lunar Regolith	Provides radiation shielding; easily accessible from Bellevistat and effective shield
Demron cloth layers	Provide radiation shielding in junctions of different structural components; chosen due to their effectiveness while being lightweight
Liquid Hydrogen	Provide radiation shielding; chosen for its ability to refrain from participating in fissile events in presence of radiation.

Table 2.1.2 Structural Materials and Uses

Radiation Shielding for Interior Volumes:

Total Shielding thickness: 13.955 m**

Multiple layers of carefully selected materials will reinforce the infrastructure of the colony and provide protection against harmful radiation and debris.

The spokes will have a central transportation passageway, surrounded by various radiation shields, as well as communication lines and pipelines. Liquid hydrogen will not be included in the spokes due to combustion concerns.

**Solar Panels coating the exterior of the rings are not shown.

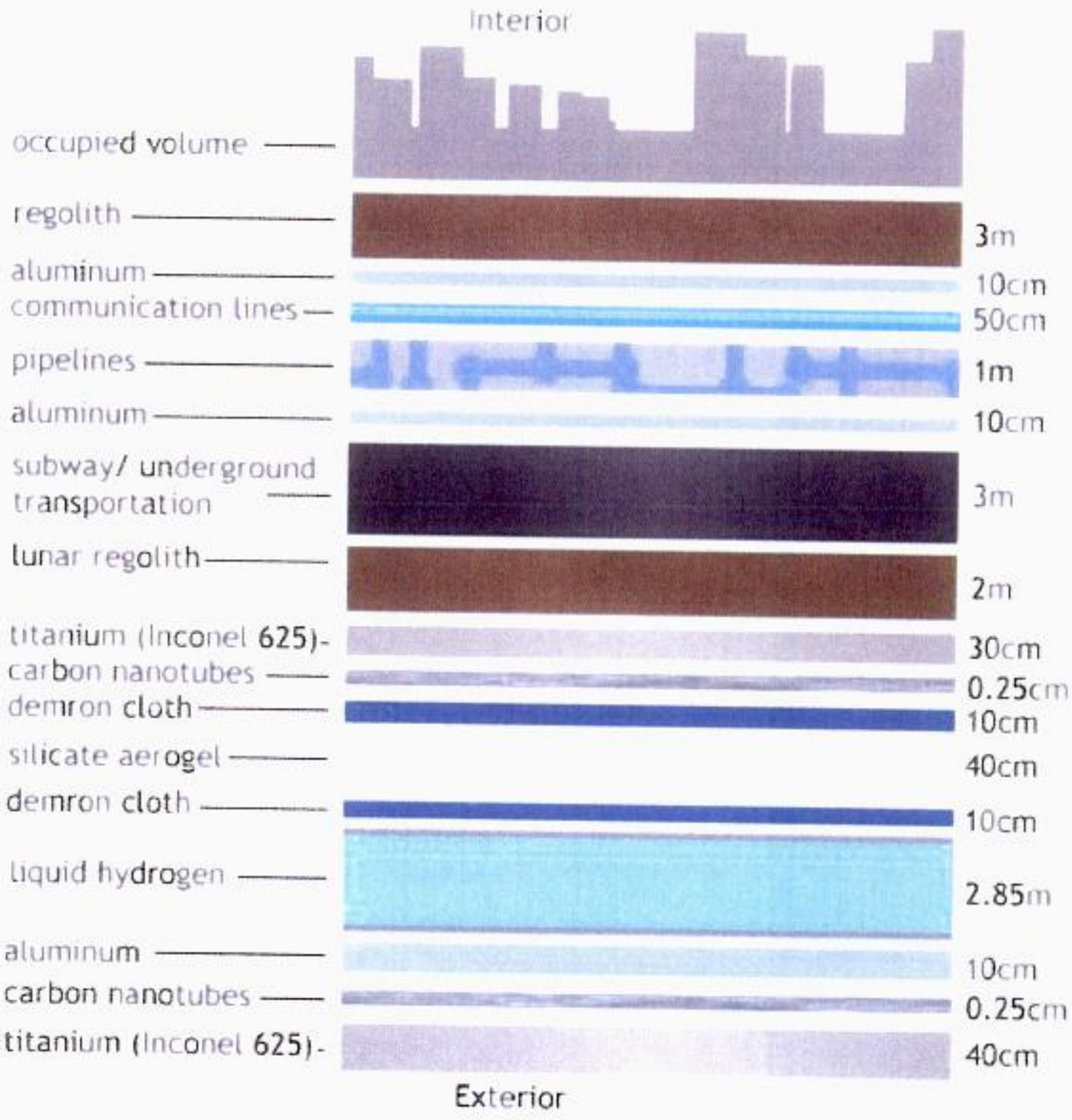


Figure 2.1.3 Shielding for Interior Volumes (not drawn to scale)

Radiation Shielding for Windows:

Two layers of borosilicate glass will provide fortification to the windows of Gemini and Tethora, while the silicate aerogel layer will shield inhabitants from harmful radiation. Because the windows are turned inward, a significant amount of radiation is already deflected by the thicker shielding for the ring.

Figure 2.1.2 Windows for Rings

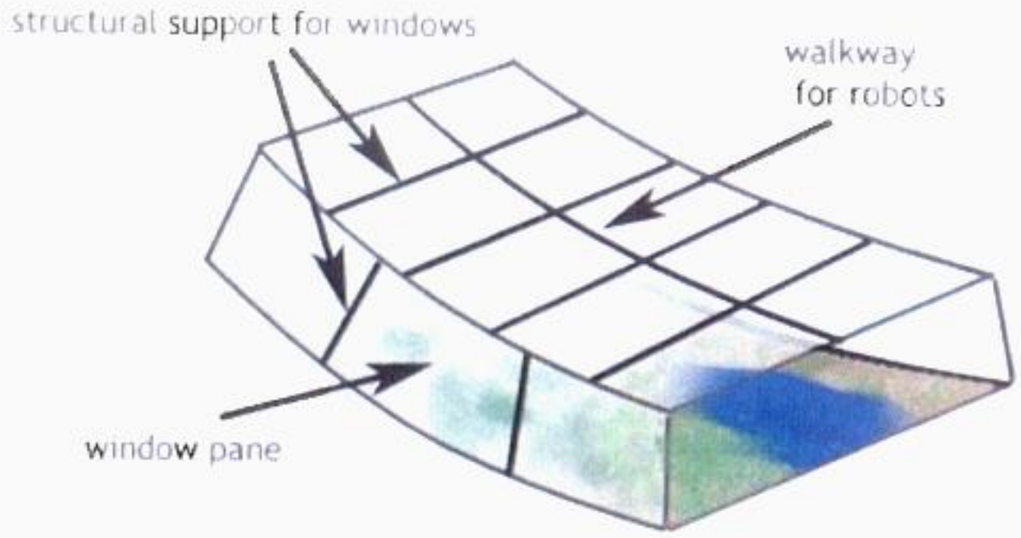


Figure 2.1.3 Section of a Ring

The glass will be made in sections. It will also have structural support, as shown in figure 2.1.3. A walkway will run down the central structural beam. This will be used by robots that monitor the condition of windows. If damage on the windows is found, the robots can immediately begin work to fix it.

2.2 Internal Arrangement: Allocation of Down Area

(Total Down Area: 5,222,752.496m²)

Central Axis (%; S.A. in m²)
Industrial Storage- 35; 237,504.405
Agricultural/Wholesale Storage- 10; 67,858.401
Experimentation and 0G Research - 8; 54,286.721
Control Centers- .5; 3,392.920
Transportation- 11; 74,644.242
Subsystems- 2; 13571.520
Recreation- 3; 20,357.520
Emergency Living Area- 30.5; 206968.124
Total Down SA: 678,584.013

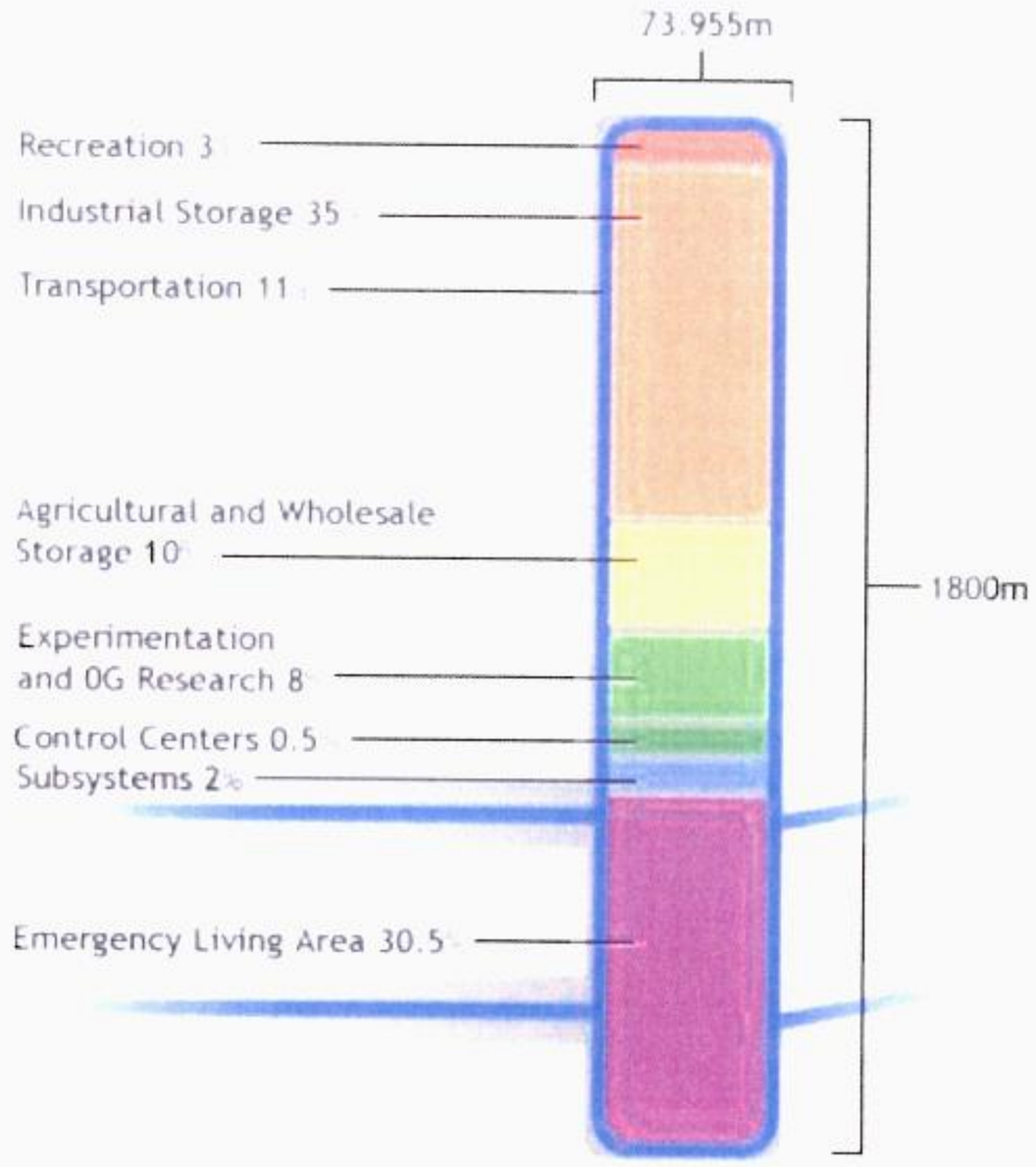


Figure 2.2.1 Central Axis (not drawn to scale)

2.2.1 Central Axis:

The central axis will contain all agricultural and wholesale storage, which provides for a concentrated place for emergency food and supplies. The shaft will also be the center for transport, both between the counter-rotating rings and the industrial sphere. Spokes, each with a radius of 25m, will be extending from the central axis to rings 1 and 2 to provide stability as well as transportation between the axis and the rings. Each spoke will have a two-way transportation system – the Sky Ferry System. Due to its microgravity state, the central shaft will contain area for low-gravity experimentation and recreation. It will have the central control elements and power supply of the station.

2.2.2 Pressurized Rotating Rings Gemini and Tethora:

These rings are areas in which all inhabitants of Bellevistat will reside. They contain all residential, commercial, and agricultural areas, as well as research facilities and industries that need 1g to operate. Both rings are coated with solar panels on the outside to maximize efficiency and provide solar energy. Two rings are chosen as opposed to one because if one ring is damaged, the other can provide additional living space for a short period of time as repairs are made. In the event that both Gemini and Tethora are damaged, emergency living space can be found in the central axis. Transportation between Gemini and Tethora is provided by pods on magnetic railways. Four docking stations (two on each ring on opposite sides of the rings) provide a convenient docking and landing area for visitors as well as imported supplies and trade from Earth and Alexandriat. *(For a detailed description on transportation, see section 3.2.4)*

Rings [each] (%; S.A. in m^2)
Residential/Commercial Areas: (55%)
Residences- 20; 261,362.288
Schools- 1; 13,068.114
Hospitals- 2; 26,136.229
Shops- 1; 13,068.114
Offices- 0.5; 6,534.057
Assembly Halls- 3; 39,204.343
Recreation- 2.5; 32,670.286
Open Space- 25; 326,702.860
Agricultural Areas: (31%)
Plant Growing- 20; 261,362.288
Animal Raising- 5; 65,340.572
Food Processing- 3; 39,204.343
Drying Area- 3; 39,204.343
Miscellaneous Areas: (14%)
Service Industry- 3; 39,204.343
Mech. Subsystems- 1.5; 19,602.172
Transportation- 5; 65,340.572
Docking- 0.5; 6,534.057
Control Center- 1; 13,068.114
Experiment/Research- 19,602.172
Greenfield- 1.5; 19,602.172
Total Down S.A. each- 1,306,811.438

Figure 2.2.2 Overhead View of a Ring

2.2.3 Industrial/Mining Sphere:

Sphere (%; S.A. in m^2)
Heavy Industry- 49; 945,967.348
Industrial Storage- 40; 772,218.243
Control Center- 0.5; 9,652.728
Docking- 0.3; 5,791.637
Transportation- 7.5; 144,790.921
Subsystems- 2.7; 52,124.731
Total Down S.A.- 1,930,545.607

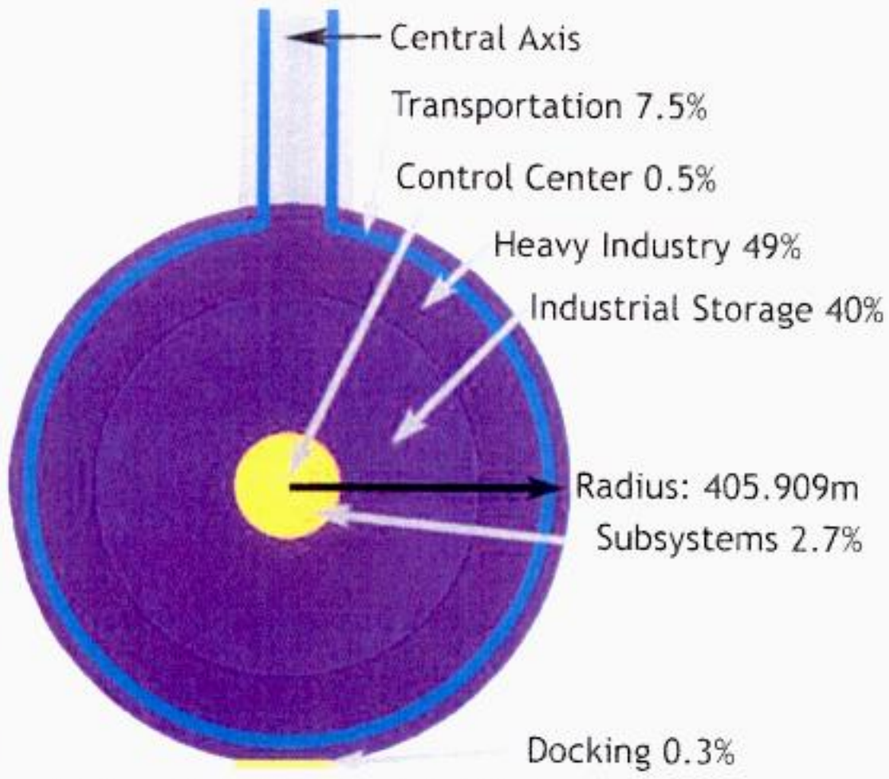


Figure 2.2.3 Industrial Sphere

The sphere will be the industrial center of Bellevistat, where all heavy industry (ore refining, processing, etc.) and storage will take place. A docking station on the bottom of the sphere will be specifically designed for the

specialized ore bins that will arrive from mining robots, as well as for trade with Alexandriat and Earth. Its isolation the end of the settlement allows for a microgravity environment without disrupting the lives of the animals and humans. The sphere contains its own control center and energy supply. In the event that the sphere is damaged, emergency storage in the Central Axis can be provided and Bellevistat can continue trade by using docks attached to Gemini and Tethora while the sphere is being repaired.

2.3 Construction Process

Because the construction of a space settlement is such an intense and difficult project, it is vital that all construction processes will be done in a series of logical steps with maximum efficiency. We have proposed the following steps for construction:

Phase 1: Estimated length of time: 3 years. The Central Axis is assembled, along with spokes later connecting to Gemini and Tethora. Communication systems and the Central Control System in the Central Hub will be set up to monitor the construction process.

Phase 2: Estimated length of time: 3 years. The Mining/Industrial Sphere will be attached to the end of the Central Axis. The sphere will temporarily support construction teams and engineers that will monitor the building process of Bellevistat. The dock at the end of the sphere begins to operate due to frequent trips back to Earth for more needed supplies.

Phase 3: Estimated length of time: 4 months. The Main Mirror and its rotary motor will be attached using robots at a 45-degree angle.

Phase 4: Length of time: 6 months. The ring of mirrors will be constructed with the help of robots.

Phase 5: Estimated length of time: 6 years. The two pressurized rings, Gemini and Tethora, will be constructed and connected to the spokes. Docks will be attached onto the rings. The Magnetic Railway System will connect the rings to each other as well as the rest of the settlement. Solar panels on the rings will be installed. Construction of internal environments can now begin.

Final Stage: Residents are welcomed into the settlement. Attachment and mining of an asteroid can now begin. The construction of Bellevistat is complete and the settlement is now self-sufficient.

Figure 2.3.1: Phase 1

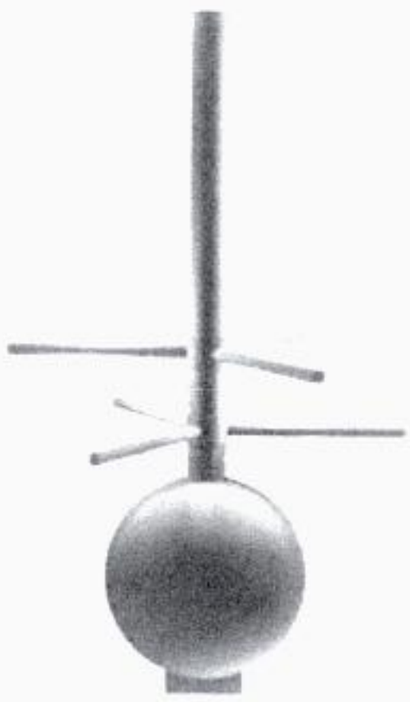


Figure 2.3.2: Phase 2

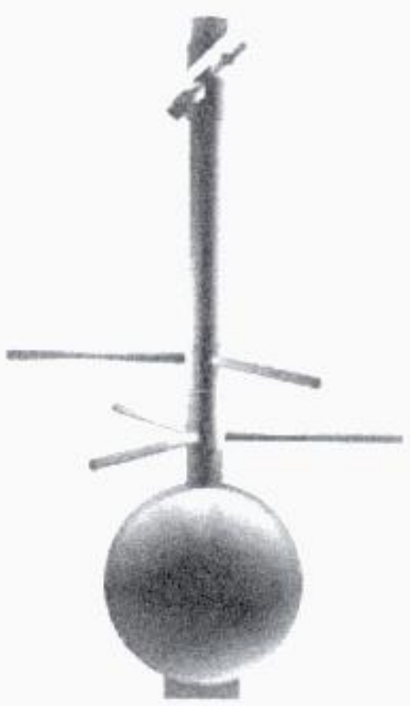


Figure 2.3.3: Phase 3

Figure 2.3.4: Phase 4

Figure 2.3.5: Phase 5

Figure 2.3.6: Final Result

2.4 Mining of Asteroids

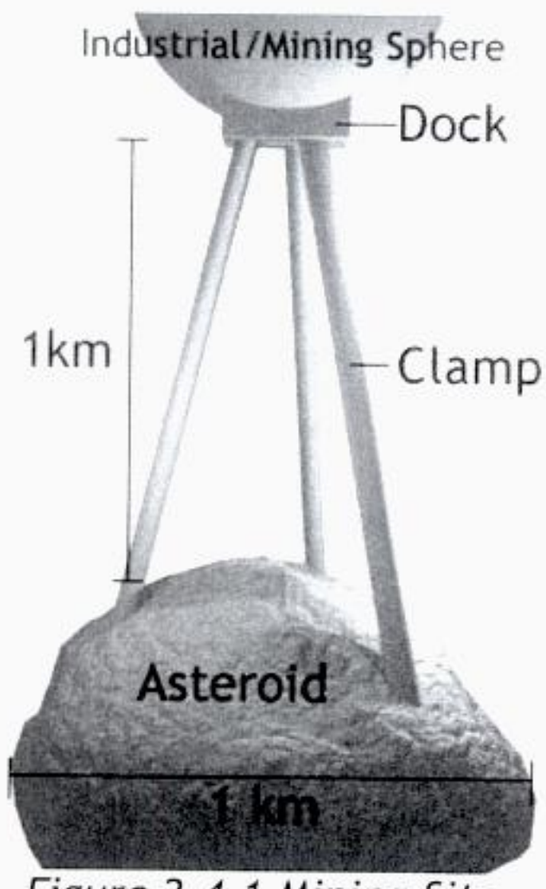


Figure 2.4.1 Mining Site

2.4.1 Structural Attachments and Mining

Bellevistat will harness supplies from a captured asteroid orbiting in L5. The asteroid will be captured by three clamps, fired from the industry sphere. These clamps are magnetized and will extend outward upon contact to dig better into the asteroid's surface for better grip. The asteroid will then be hauled in at a distance of 1 km to the settlement **(see Section 7.1.1)**, reducing transport time yet providing enough distance to prevent dust exposure.

Specialized mining robots will be the main workers harvesting ore. These robots have a "skirt" made of biodegradable plastic to prevent dust from rising from the asteroid and harming the settlement. This "skirt" will be frequently replaced to ensure more safety.

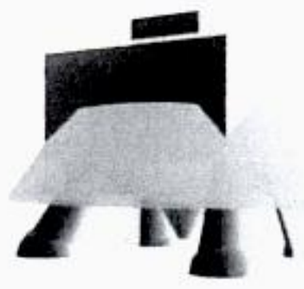


Figure 2.4.2 Mining Robot

The robots will collect mined ore in specialized bins attached to their top. A manned pod powered by thrusters will then come from the dock on the bottom of the sphere and collect the bin. The robot will acquire a new bin and continue to mine. The pod will travel back to the dock and deposit the ore in the sphere for further refining.

2.4.2 Minimization of Asteroidal Dust and Locations of Refining

The first line of defense against asteroidal dust will be the plastic "skirts" on the mining robots themselves. In addition, the transport crates will have microscopic pores to filter out dust particles. Aquamarine pods **(see Section 3.3.1)** will carry crates to a specialized chamber in the sphere's docking station, where further purification will take place. Dust will be ejected from the dock from a portal separate from the station. The dust-free ore will then be taken into the industrial sphere to be refined and processed.

3.0 OPERATIONS AND INFRASTRUCTURE

SECTION 3: OPERATIONS & INFRASTRUCTURE

Northdonning Heedwell places prime importance on the safety and comfort of Bellevistat's residents. Interior vehicles and designs have thus been developed for optimum convenience while remaining efficient and practical. In addition, specifications for Bellevistat's environment have carefully been chosen with the residents' interests in mind.

3.1 Construction Materials Sources

3.1.1 Orbital Location and Rationale

Five advantageous points for settlements exist in the area between the Earth and Moon: the Lagrange libration points of L1 through L5. Bellevistat will be placed in orbit at the L4 Earth-Moon libration point. This location has been chosen for its unusual orbital stability; the least amount of energy will be needed to keep the settlement in orbit here. L1, L2, and L3 each have unstable orbits; the orbits at L4 and L5 are much more stable and reliable. The decision to place Bellevistat at Earth-Moon L4 takes into account the placement of the previous colony *Alexandriat* at the Earth-Moon L5 orbit. Bellevistat will have an advantage in having an entire orbit for itself: operations including those of rockets, shuttles, external robots, and local mining operations will be facilitated if those of another colony are not in the way.

3.1.2 Sources of Materials and Transportation

Table 3.1.1 lists sources of materials as used in the initial phases of construction.

Material	Source	Transportation	Storage
	Structural Materials		
Titanium Matrix Composite-- Inconel 625	All metals initially brought from Earth; manufactured onsite once mining can commence	Carnelian; Aquamarine	Central Axis and Industrial Sphere
Aluminum Silicon-Carbide Whisker Matrix Composite			
Titanium Grades 5 & 6 Alloys			
Borosilicate Glass	Earth; materials from asteroids will later be used for manufacture	space shuttles and Carnelian	External construction apparatuses; rings
Electronic Equipment	Alexandriat	Topaz	Industrial Sphere
Carbon Nanotubes	Earth; Alexandriat	Carnelian and Topaz	Central Axis
Silica Aerogel	Earth until manufacturing sites can be established; afterwards, silicon from asteroids will be used for on-site manufacture	Carnelian and Aquamarine	Immediate use and export
Lunar Regolith	Moon	Aquamarine	Central Axis
Demron cloth layers	Earth	Carnelian	Immediate use; stored in external construction apparatuses
LOX (Liquid Oxygen)	Alexandriat	Topaz	Docking Centers
Liquid Hydrogen	Earth	Carnelian	Industrial Sphere
Hydrazine	Earth	Carnelian	Docking Centers
Dinitrogen tetroxide	Earth	Carnelian	Docking Centers
	Residential Interiors and Amenities		
Balsa wood	Earth; grown onsite	Carnelian; MRPs	Rings
Bamboo	Earth; grown onsite	Carnelian; MRPs	Rings

Vinyl Composition Tiles	Alexandriat	Topaz	Industrial Sphere
Unplasticized Polyvinyl Chloride	Alexandriat	Topaz	External construction apparatuses; rings

Table 3.1.1 Materials and Sources

3.2 Community Infrastructure

3.2.1 Food Growing, Harvesting, Processing, and Distribution

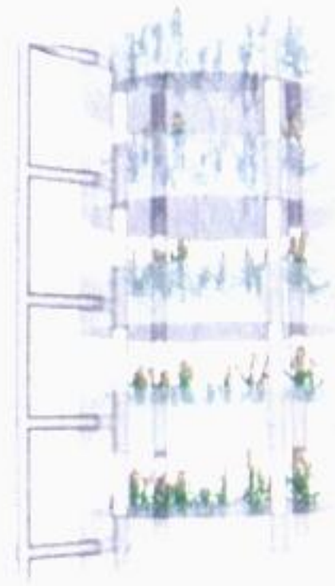


Figure 3.2.1 Tiered Aeroponic Misting System

Food Growing

The majority of Bellevistat'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.

Food Harvesting

Animal-Derived Consumables:

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 Bellevistat and the low-gravity conditions residents will frequently experience.

Animal	Allotment*	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 3.2.1 Animal-Derived Consumables

*Allotments are number per capita per annum, based on NASA's 1975 studies and nutritional requirements.

Plant	Allotment per capita (g/day)
Fruits	50
Maize	950
Rice	150
Sorghum	320

Plant-Derived Consumables:

Plants will be harvested mechanically. Plants from aeroponic tiers will be harvested by automated collectors to be transported to the Food Packaging and Processing Centers **(FPPC).** Allotments for plants have been derived from the NASA 1975 studies, altered sufficiently for the needs of the

Soybean	500
Spices	20
Vegetables	50
Other	800

Table 3.2.2 Plant-Derived Consumables

residents of Bellevistat. 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.

Food Storing

Reserve food is freeze-dried and vacuum-sealed in the FPPC for storage. Food sufficient for eight months will be stored in the central axis; food sufficient for five-month shortages will be stored in the community centers of each ring as well as in the industrial sphere. Vehicles will each carry a 40-day, freeze-dried food supply.

Food Packaging

Food will be packaged in the FPPC by machines in large, reusable containers made of low-density polyethylene **(LDPE)** for immediate distribution. The used containers will be deposited by the residents in bins located throughout the rings and collected every two days. Liquids will be packaged in reusable pouches. Packaged food for restaurants will be distributed in freeze-dried portions, to be rehydrated when needed.

Food Delivery and Distribution

Containers of food will be distributed upon packaging to sectors of Bellevistat by means of the IMTS system **(see Section 3.2.4).** Grocery stores, district centers, and restaurants will then be able to utilize shuttles and moving walkways to deliver this food to clients.

Food Selling

Food distributed to grocery stores can be bought by means of the colony's card system; money will be on a debit system rather than a credit system and community centers will provide reserve food in times of emergency. Customers will be limited in the quantity of food they purchase to minimize food waste; permits to purchase large amounts of food may be obtained for special events. Food that has been in a grocery store for four days will be vacuum-sealed and placed in storage to prevent spoiling.

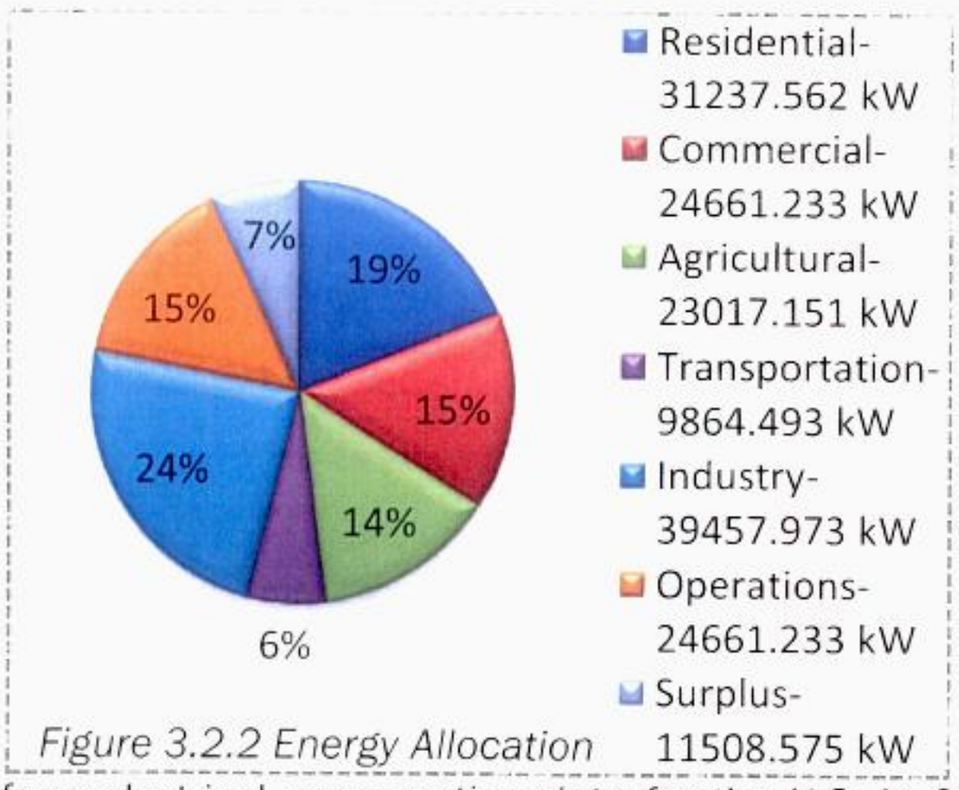


Figure 3.2.2 Energy Allocation

3.2.2 Power Generation and Distribution

Power Generation

Power on Bellevistat will rely on solar panels to take advantage of the full sunlight reaching the settlement. Solar panels will be made of **polycrystalline cells**, which have a conversion efficiency of 11-13% but have low production costs, making them ideal for use and production on the settlement. Each panel will be able to provide **130 Watts**; the panels will cover a total area of 2,529,357.25 m^2. In total, these panels will generate **164.408 MW**. The settlement will be angled so that each solar panel receives maximum sunlight at any given time. Amounts of allocation for this power have been derived from electrical consumption data for the U.S. in 2000. Surplus electrical energy will be stored in **lithium-ion batteries**, the best for this purpose due to their high power density. Energy will be distributed throughout the settlement with battery backups in each major component; a power failure in one section will immediately activate these batteries to provide energy for that sector for up to one week.

3.2.3 Internal and External Communications

Internal Communication Devices

Type of Technology	Description and Advantages	Network Bandwidth
Fiber-Optic Network	Fiber-optic networks provide high transfer speeds and are space-efficient. Bellevistat's network uses optical amplifiers to increase the speeds up to 14Tb/sec. Fiber optic networks are also very secure.	The system currently has the capacity to facilitate speeds up to 2.56 Tb/sec.
Station-Wide Intercom System **(SWIS)**	The intercom will be used for station-wide announcements and can be accessed by residents with access level 3 or higher. The intercom may be used to communicate with the entire station or certain segments. It may be accessed from any control center.	Not Applicable
Wireless Local Area Network **(WLAN)**	The Local Area Network will be fed by Internet ports with routers in the walls. The Local Area Network is exclusive to registered users; it must be accessed using passcard numbers.	Speeds range between 60 Ghz to 6 Tb.

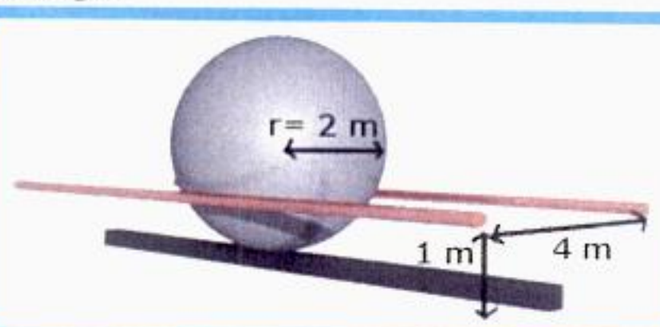
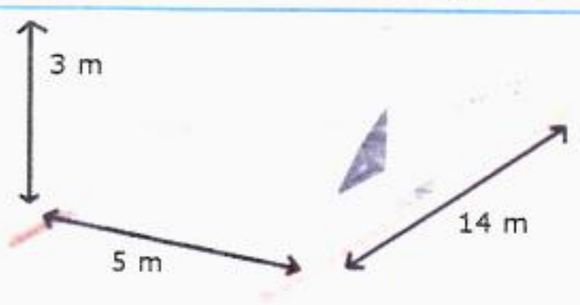
External Communication Devices

Type of Technology	Description and Advantages	Network Bandwidth
Laser-based communication devices	Laser-based communication is relatively inexpensive. Lasers are hard to intercept, unlike radio wave technology; this renders them better for use in the colony. Two beams will be utilized- a transmitting beam and a reception beam with a hub on the colony.	Connection speeds range from 6 terabytes to 14 terabytes per second. The round-trip for information takes 2.7 seconds. Transmissions occur every half hour.

A system of 5 satellites will be used for communication between Earth and Bellevistat. This system consists of two fully functioning satellites which redirect laser signals from Earth to Bellevistat and another which handles incoming traffic from Bellevistat and redirects it to Earth. In case of a malfunction in the system, a third communication satellite is commissioned to take place of the malfunctioning system. If an issue arises with the laser technology and communication ceases, an additional two backup satellites will begin radio transmission between earth and the space station to re-initiate communication. This will be a last resort as radio technologies are less cost effective and are easier to intercept.

3.2.4 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.

Vehicle Name	Image	Details
Magnetic Railway Pod (MRP)		Pods will be used to transport **goods** as well as **people** between the **central axis** and **rings**. 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 (maglev) to carry its passengers.
Internal Mass-Transit Shuttle (IMTS)		Shuttles will act as an "underground" subway system within the colony's major components. They will use **magnetic levitation**. Reserved shuttles will be used to carry goods throughout Bellevistat.

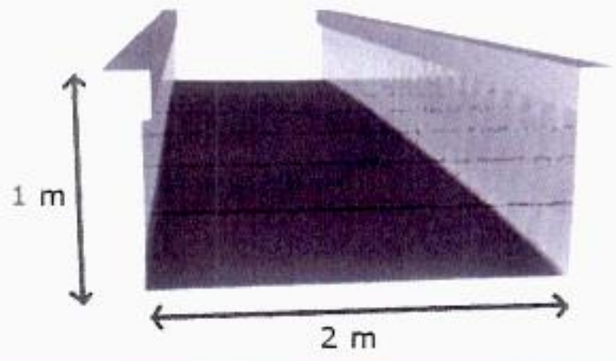
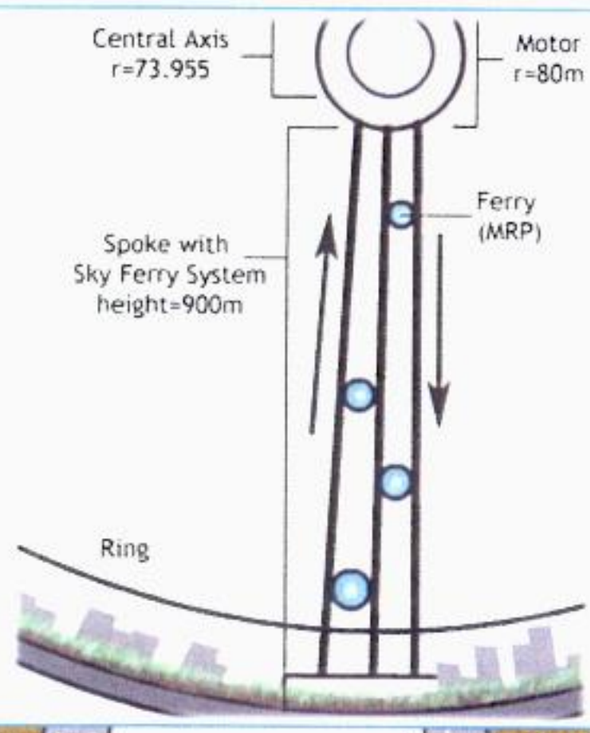
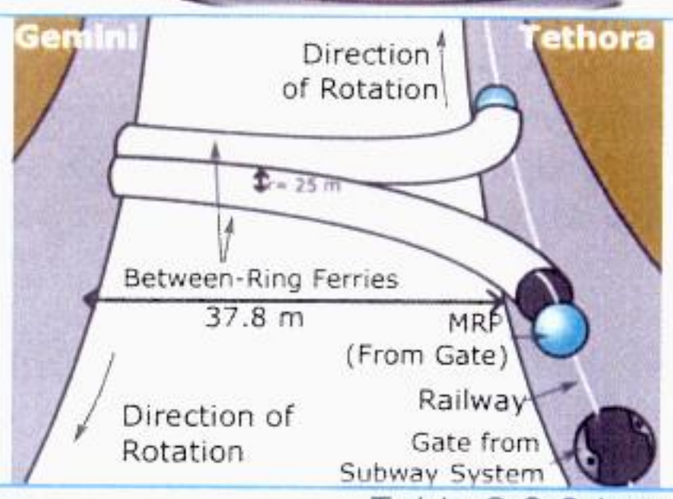
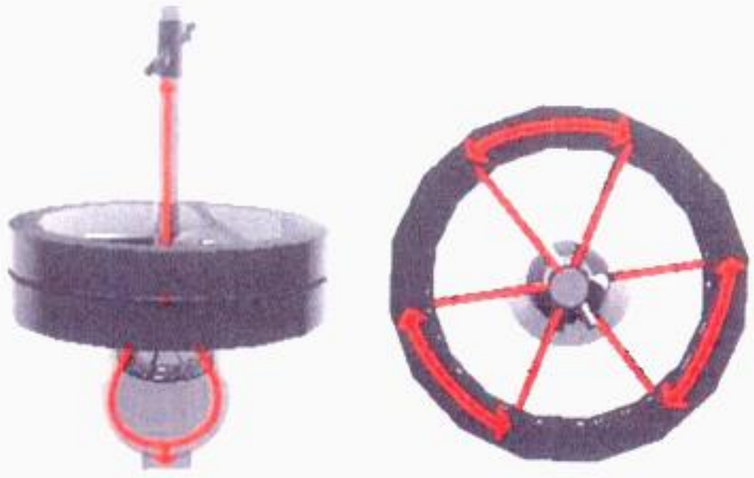
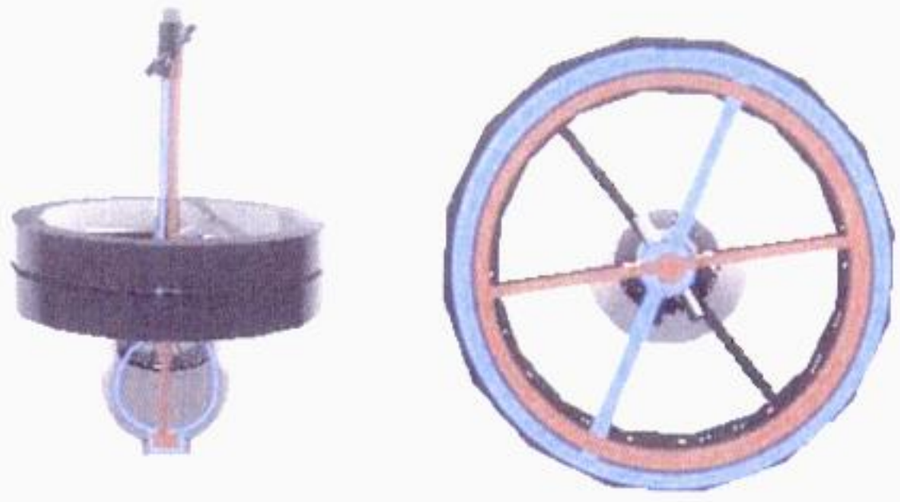
Moving Walkways		Due to Bellevistat's comparatively small dimensions, the main form of local transport will be **walking**; moving walkways will be provided at intervals throughout in order to facilitate this. Walking will also automatically provide residents the necessary exercise for working in low-gravity conditions.
Sky Ferry MRP Elevators		In order to transport people between the 1g rings 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 rings 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 rings 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 (Gemini) while simply 'trailing' on the parallel, counter-rotating ring (Tethora); MRPs will move back and forth between the rings using a railway line on the outside of the non-attached ring. Pods will be able to access the railway line through pod gates located in the same area as the subway-shuttle system.

Table 3.2.3 Internal Transportation



Figures 3.2.3 Corridors of Access (Side and Top View)



Figures 3.2.4 Routing of Waste and Water

3.2.5 Air Composition/Climate and Weather Control

Bellevistat's air composition will be similar to that of Earth's, to provide for the health of the residents as well as psychological comfort.

*Atmospheric water vapor content is highly variable due to the actions of the residents and the constant use and recycling of water; however, Bellevistat's atmospheric water vapor content will be regulated between 2 and 4 percent to prevent excessive humidity by sensors located throughout the colony.

Trace elements in Earth's atmosphere have been eliminated from Bellevistat's atmosphere for cost and convenience. A Nitrox32 mixture has been used in place of Earth's normal air composition to reduce costs and risks of combustion.

High levels of carbon dioxide will be prevented from accumulating by means of the Sabatier reaction in an 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. Nanobots will periodically cleanse the reactors of accumulated carbon (graphite) to be used in other parts of the settlement.

Gas	Percentage	Quantity (m^3)	Source
Nitrogen (N_2)	64	160,803,277.3	Earth
Oxygen (O_2)	32	88,441,802.51	Moon; electrolysis
Carbon Dioxide (CO_2)	.04	107,202.185	Combustion
Water Vapor (H_2O)*	Variable (2-4)	Variable	Vaporization

Table 3.2.4 Atmospheric Composition

The air pressure in the rings and industrial sphere will be half that at sea level on Earth, or 0.5 atm.

Bellevistat, like Earth, will experience "seasons" by means of gradual changes in temperature. Due to temperature limitations of much of Bellevistat's equipment, these changes will be slight; however, they will be psychologically significant to the residents in providing a familiar, Earth-like comfort. Temperatures will span from 25 °C in the summer, to 20 °C in the fall and 15 °C in the winter, returning to 20 °C in the spring. This gradual, regulated temperature change will not cause harm to the Bellevistat's normal functions while providing a sense of normalcy.

To provide further comfort and familiarity to the residents, artificial rain will fall on areas of the colony when the humidity increases. 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.

3.2.6 Waste Management Facilities

Household and Industrial Waste Recovery

Aluminum, plastic, and paper products will efficiently be recycled through ubiquitously installed recycling containers. Used or damaged electronics will be deposited at community centers, where they will be taken apart to be used by repair robots and technicians. Food waste will be compressed into compost for landscaping.

Biological and Other Waste Treatment

Biological waste will be disposed of from homes by means of vacuum-operated facilities. This waste will then be transported to a waste and water treatment center **(WWTC)** to be treated thoroughly along with runoff water. After sanitation and compression, this waste will be reused as agricultural fertilizer and manure. (See section 3.2.4 for routing of waste and water.)

Figure 3.2.5 UWST

3.2.7 Water Management Facilities

Water Requirements

60 liters per person per day will be provided to the residents of Bellevistat. For a settlement of 19,000 people, the total amount of required water will be 1,140,000 liters. The total amount of water on Bellevistat will amount to 1,500,000 liters, taking into account the hydration needs of machinery and infrastructure. Water will be derived initially from Earth in deposits of 75,000 liters each during Bellevistat's construction phases, and then recycled

continuously, being replenished less frequently once the total amount of water required has reached Bellevistat. Approximately 90% of the original water will be recycled through the WWTC system; this leaves 1,350,000 liters of recyclable water.
Water will be stored in 40 tanks throughout the facilities. Each usable water storage tank **(UWST)** will have the capacity for 37,500 liters of water.

UWSTs in Central Axis: 15 (562,500 liters)
UWSTs in Industrial Sphere: 9 (337,500 liters)
UWSTs in each Ring: 8 (300,000 liters)

Water Conservation and Treatment

The utmost care will be taken to conserve water on Bellevistat. The aforementioned WWTC systems will thoroughly purify waste in order to extract the maximum usable water from it. Waste will be subjected to high heat and pressure to remove harmful bacteria quickly. The resultant water will then 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 mixed with sodium hexafluorosilicate (Na_2SiF_6) at a level of 0.8 ppm as per many municipalities' requirements on Earth for tooth and gum health before being circulated through the colony.

3.2.8 Day/Night Cycle Provision

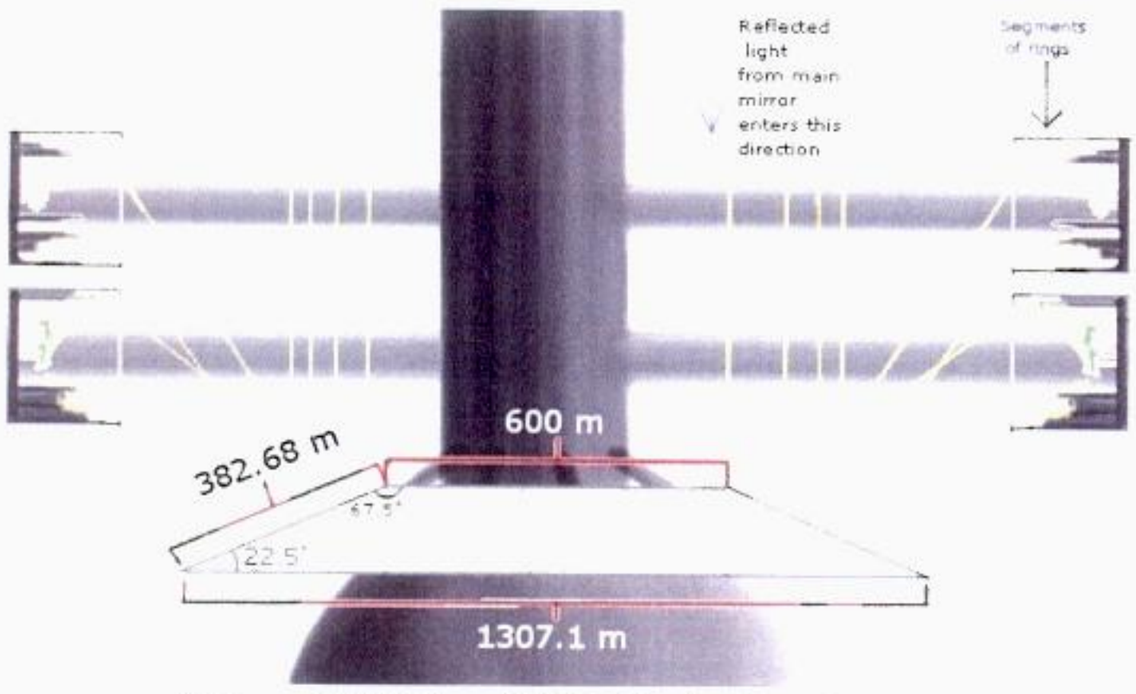


Figure 3.2.6 Day/Night Cycle Provision

A 24-hour day and night cycle will be provided for the rings by means of a series of paneled mirrors near Bellevistat's industrial sphere. The paneled mirrors will be able to turn on spokes throughout the 24-hour cycle; the undersides of the mirrors are a non-reflective surface to minimize the amount of natural light entering the colony. At "noon" the panels will be fully turned onto their mirror side; they will slowly rotate throughout the day until they are fully on the side without mirrors at "midnight." The central axis and industrial sphere will both be artificially lit to match the day and night cycles of the rings.

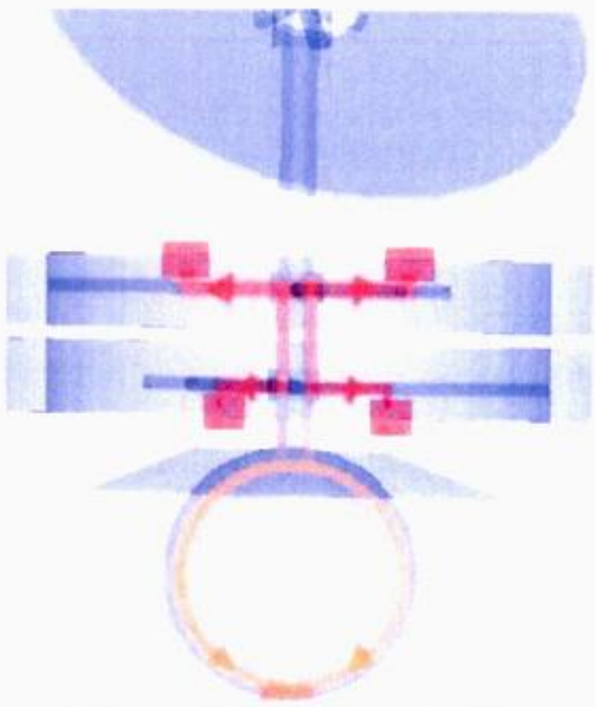


Figure 3.2.7 Export Map

3.2.9 Export to Port Facilities

Goods and cargo will be transported from the industrial sphere to the central axis manually; the **MRP** system **(see Section 3.2.9)** will be used to transport goods from the central axis to the port stations on the rings. Larger loads will simply be exported through the port on the industrial sphere.

3.3 Space Infrastructure

3.3.1 Vehicles for Settlement Operation

Bellevistat's central axis will be assembled by means of launching units of it in shuttles to Alexandriat, from where they will be flown to the L4 orbit. The axis will be assembled robotically. After Phase 1 is completed, workers will be able to complete construction on-site.

Vehicle Name	Number Required	Destinations	Fuel	Payload volume	Schedule	Status in Contract
Aqua-marine	500	Bellevistat–Asteroids (ore transport)	LOX, RP-1	125 m^3 (carried in 5m x 5m x 5m crate)	Daily flights	Included
Topaz	30	Bellevistat–other settlements	Hydrazine, N_2O_4	22,500 m^3 50 passengers	Every 2 weeks	To be developed commercially
Zirconia	15	Shuttles–Bellevistat (space tug)	LOX, RP-1	12,000 m^3	Whenever necessary	To be developed commercially
Tourma-line	5	Interplanetary explorer	Hydrazine, N_2O_4	8,000 m^3	Bimonthly (mission durations variable)	Included
Carnelian	50	LEO–Bellevistat (large cargo transport)	LH_2	36,000 m^3; 150 passengers	Weekly (staggered flights)	To be developed commercially

Table 3.3.1 Vehicles for Operation

Figure 3.3.1 Aquamarine

Aquamarine ore transport vehicles will fly back and forth between Bellevistat's industrial sphere dock and the asteroids being mined. They will be able to pick up the mining robots' ore crates and return them to the colony to be refined; they will then pick up empty ore crates and return to the mining site to deliver the crates to the robots. The vehicles will be operated by means of thrusters on three sides and one human in the front part of the vehicle.

The Topaz transportation vehicles will enable transport between Bellevistat and Alexandriat as well as future space settlements. Northdonning Heedwell envisions the Topaz spacecraft as being one major export of Bellevistat to up-and-coming colonies.

Zirconia space tugs will be used in the event of damage to a spacecraft. Repair robots aboard the vehicle will be able to then access the damaged spacecraft and repair it; if the spacecraft is beyond repair, it will be flown to Bellevistat by means of a claw attached to the back of the Zirconia vehicle. In addition, Zirconia will be the means of transport for repair robots sent to repair damages to Bellevistat's outer structure.

Tourmaline explorers will be used to periodically explore other planets and large asteroids in search of materials and resources which can be used for operations on Bellevistat.

Transportation from Earth to LEO (Low Earth Orbit) will utilize esxisting space shuttle designs. An initial launch site will be set up in LEO as a midway point for these vehicles' cargo, called Terradock. Terradock is

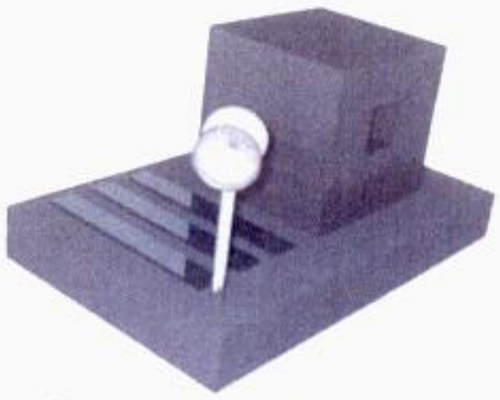


Figure 3.3.2 Envisioned Terradock Site

envisioned as an LEO launch point with runway strips for the Carnelian vehicles and a control center from where it is manned. Terradock will have a satellite system to communicate with Earth as well as Bellevistat. The payloads of these vehicles will then be picked up by the Carnelian transport vehicles and flown to Bellevistat. Terradock will be the launch site for these vehicles as well as the drop-off site for reentry vehicles transporting goods to Earth. Once the major portion of construction is complete, the Carnelian vehicles will double as passenger transporters for the residents and personnel of Bellevistat.

3.3.2 Satellites Required

Five laser communication satellites will be set up for Bellevistat: two **main laser satellites**, one **backup laser satellite**, and two **radio satellites**. These will be set up in the final phase of construction for accurate placement.

3.4 Locations for Agriculture

3.4.1 Agriculture for Human Consumption

Residents of Bellevistat will be allocated small amounts of land near their homes in which to cultivate a few plants of their choosing. Orchards will be placed in parks and open spaces from which fruits will be collected biweekly by caretakers and may be picked manually. The incorporation of agriculture into the residential and commercial landscapes allows for more efficient land use throughout. The sheer amount of food required for human consumption as well as the aeroponic methods of growing food limit the amount of plants which may be grown in residential and commercial areas. However, many aeroponic tiers **(see Section 3.2.1)** will be dispersed throughout each residential sector; they will also provide aesthetic touches to commercial areas with their modern construction. In this way, residents will have control over many of the foods they consume without the extra work of having to grow and care for all of their required food.

3.4.2 Agriculture for Fauna

Plants for animal feed will be grown in separate areas in the agricultural sectors of the rings. These plants will also utilize aeroponic tiers for efficient growth; robots will collect these crops for later distribution to animals. Small sectors of land will be allocated to animals which require grazing; the majority of animals will be fed crops that have already been harvested and processed to remove any possible contaminants.

3.5 Interior Design

3.5.1 Furniture Design

Furniture on Bellevistat will be conservative yet comfortable and economical in view of the cost needed to supply all the residents. To sidestep many of the costs of importation from Earth, much of the furniture on Bellevistat will be made from materials easily found on the asteroids being mined. Instead of utilizing cutting-edge technology, furniture will be lightweight and simplistic. Balsa wood, which is lightweight and easily transported, will be used in European-styled neighborhoods for light furniture like tables. Bamboo, a long-lasting wood (3-7 year lifespan) which regenerates without a need for constant replanting, will be used in Asian-styled homes for tables, chairs, and other furniture. Bamboo is also a practical choice because it requires only minimal fertilization when planted.

Residents of Bellevistat will sleep on comfortable, air-filled mattresses, which can be easily deflated when not in use to minimize waste of area. These mattresses will be placed on lightweight bed frames which can be folded into a home's walls when the mattress is deflated. Area-efficient workstations will be placed in each home; these are designed to conveniently hold the residents' laptops and passcards and be a home's source of access to the colony's LAN network while remaining extremely compact.

3.5.2 Interior Finishing

Bellevistat's home interiors will be designed to save energy and be cost-efficient during installation. All homes will have carpeted interiors to minimize heat loss. Underneath the carpet, the floors will be covered with vinyl composition tiles. These tiles are ideal for Bellevistat due to their high resistance to damage, easy installation, and low cost. Vinyl tiles are also easily replaceable in the event of damage to a home's floor. Each home will use vinyl tiles of 0.318 cm thickness and dimensions 30 cm x 30 cm. In addition to this, home exteriors will be painted in dark colors to maximize absorption of heat.

3.5.3 Plumbing Specifications

Water pipes will be made of unplasticized polyvinyl chloride **(uPVC)**. This material is very durable and pressure-adaptable; the latter is a very important characteristic because the pipes will have to hold in both the pressurized rings and sphere and the unpressurized central axis. uPVC is also long-lasting and economical. This material will be used throughout Bellevistat in all plumbing to keep a uniform and easily maintained and repaired system.

3.5.4 Kitchen Design

Kitchens in a typical home in Bellevistat will be free-standing rather than built into a room. This allows for more use of room space; a resident who wishes to utilize the kitchen room for another purpose can easily roll the kitchen units out of the way. This also cuts down greatly on time needed for residential construction, as the kitchen units will be pre-assembled and shipped to the colony rather than being constructed into the residence on-site. A free-standing kitchen will combine cabinets, a refrigerator, a cook top, drawers, a sink, and a convenient cutting board into two mobile units. This method is much more economical than building a kitchen into the home; it is easily reparable or replaceable in case of any damage and will not cause the colony to incur the additional cost of repairing the home itself.

4.0 HUMAN FACTORS

SECTION 4: HUMAN FACTORS

Keeping in mind the importance of quality of life for future residents of Bellevistat, special considerations have been made in the design. Various steps have been taken to maintain a feeling of the traditional comforts of Earth. Various amenities and resources will be provided to ensure high standards of life for all citizens.

Mirrors will direct natural sunlight into the settlement, and will simulate a day-night cycle. An observation site on each ring will provide a natural view of Earth and space.

4.1 Community Design

4.1.1 Residential Sectors

In both rings, the residential sectors will be placed lengthwise in 3 separate partitions. Along the 5742.549 m length will be three evenly spaced residential sectors of 1099.835 m each, with agricultural sectors of 814.017 m each. This alternating pattern of residential and agricultural sectors provides for easier interaction between the two sectors, as well a shorter commute for agricultural workers.

4.1.2 Psychological Factors

Psychological factors must be taken into consideration for the citizens of Bellevistat. A community will be designed with environments similar to Earth. Air pressure and gravity will be set to near-Earth values, allowing for ease of transition as well as improved health. Additionally, a day-night cycle of 12 day hours and 12 night hours will take place throughout the settlement, simulating conditions on Earth. The communities will be constructed to resemble Earth's, while simultaneously displaying the marvels of space. A variety of recreational activities will also be available for citizens to cope with boredom.

4.1.3 Community Layout

Residential sectors shall be laid out as such:

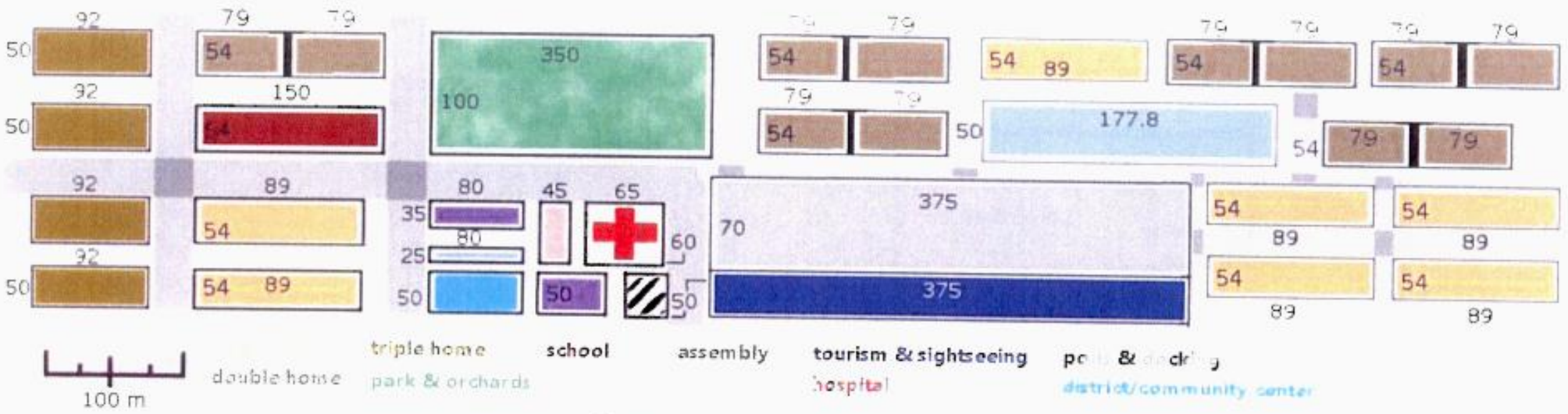


Figure 4.1.1 Community Layout

Land Use	Percentage	Description
Residential	40.616%	Placed throughout each sector to provide living space for citizens. Will include several different designs, intended for single citizens living alone and with others, as well as married couples and their families.
Park/Orchards	13.770%	Provides for recreation while maintaining an appearance of nature. Orchards will also provide an area for the growth of fruit trees.
School	2.950%	Provides education for the colony from kindergarten students to vocational training.
Recreational	4.285%	Includes various centers strictly for recreational purposes, providing entertainment for the citizens.
Assembly	2.557%	Provides a large hall for the use of large gatherings or meetings.

Greenfield	10.328%	Empty space set aside for future development of the settlement.
Hospital	1.534%	Serves as center for medical treatment for regular medical checkups as well as emergencies.
Tourism	7.377%	Will provide temporary residencies for visitors of the settlement, while also providing amenities and other locations of interest to the tourists.
Docking	0.845%	Area set aside for ferry from central axis to ring, as well as a small amount of storage for materials transported through here.
Shopping Center	1.573%	Area for citizens and visitors to shop and dine. Will include several shops forming a service industry.
Transportation	4.873%	An (~8 m) wide strip placed along the facing edges of rings Gemini and Tethora to service the pods that travel between both rings. Moving pathways will be spaced throughout the settlement to provide for ease of transportation. Additionally, several spaces will be reserved as stations leading into and out of the underground railway system.
Offices	1.062%	Area for desk-related jobs, including the regulation of commerce and government.

Table 4.1.1 Land Use

4.1.4 Consumable Distribution

Food from the agricultural sector will be sent through reserved shuttles on the underground railway system. From here, it can be unloaded to the docking area, whereby it can either be transported to the central axis for storage, or to the shops, schools, and hospital.

4.2 Residential Design

4.2.1 Residential Design

To support the various demographics, Bellevistat will feature three types of residences.

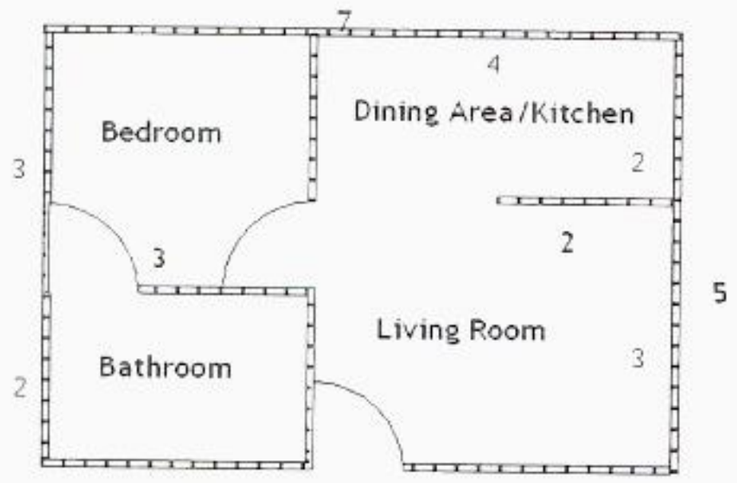


Figure 4.2.1 Single Residence

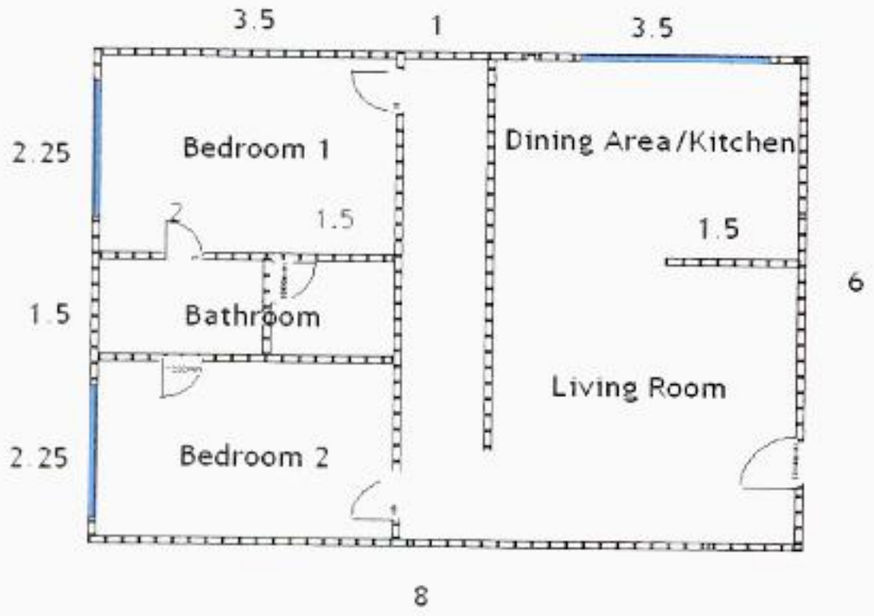


Figure 4.2.2 Double Residence

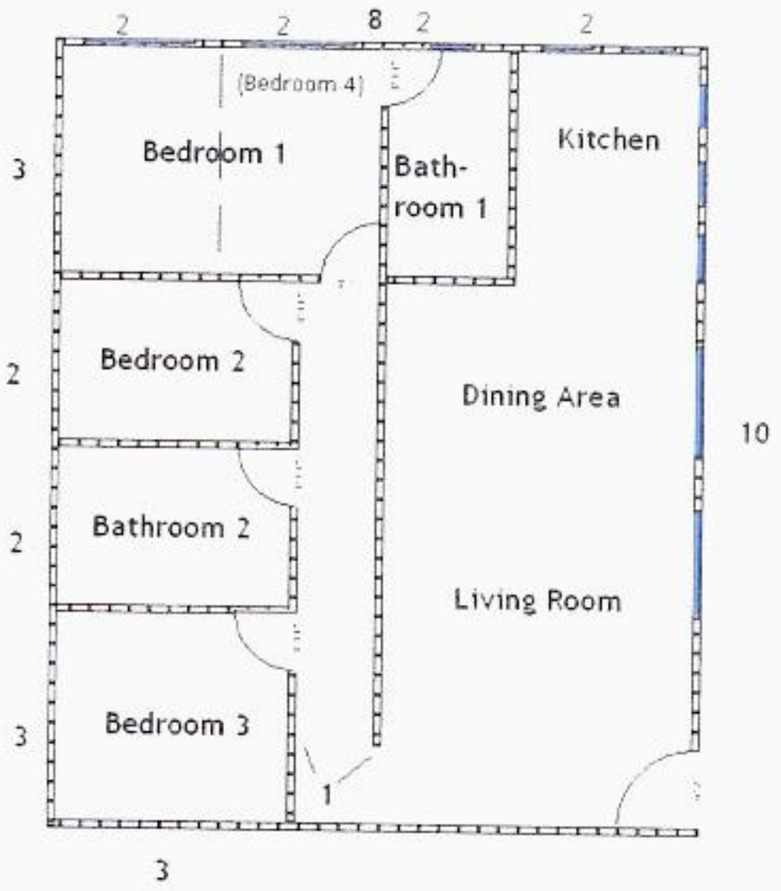


Figure 4.2.3 Triple Residence

4.2.2 Size and Area

Each single residence will be 5 m by 7 m (376.737 ft^2), and will house 1 person. Each double residence will be 6 m by 8 m (516.667 ft^2), and will house 2 (unrelated) people. Each triple residence will be 8 m by 10 m (861.113 ft^2), and will house up to 4 people. The triple residence is intended for families, but can also be converted into a house for 4 single residents by splitting the largest bedroom into two with the addition of an optional wall.

Throughout the entire two rings, there will be 264 house complexes, totaling to 7056 single residences, 4608 double residences, and 1152 triple residences. These can support a maximum of 20,880 people, while the average population will total 19,000.

4.2.3 House Complexes

To provide a sense of community, and allow for establishment of the relationship of neighbors, houses will be placed in complexes.

Triple residences will be placed in attached groups of 4 (2 down, 2 across). Designs will be reflected so that each house will have an external view through windows as well as an entrance into the house. These groups of 4, 16 m by 20 m in length, will be arranged into a 4 by 4 grid with 4 meters space lengthwise, and 3 meters laterally between groups, making a total of 48 triple residences in a 54 m by 92 m space.

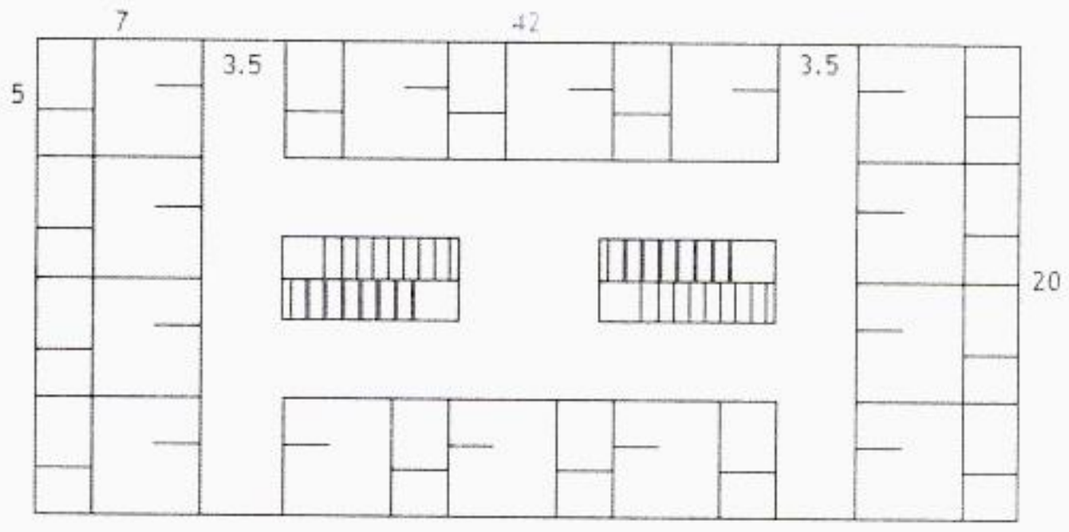


Figure 4.2.5 Single Residence Complex Internal View

Double residences will be similarly placed in groups of 4, with the exception of a 1.5 m hallway splitting two groups of 2 to allow entrance into the houses. In total, each group of 4 houses will be 17.5 m by 12 m. These groups will be placed in a 4 by 4 grid with 3 meters space lengthwise and 2 meters laterally to make a total of 64 double residences in a 54 m by 70 m space.

Single residences will be arranged into a large building complex. 14 residences will make up one story (see Figure 4.2-4), and there will be 3 stories. 4 of these complexes will be arranged evenly over a 54 m by 89 m area, which will have plenty of empty space to make the area seem more open. In total, each of these areas will hold 168 single residences.

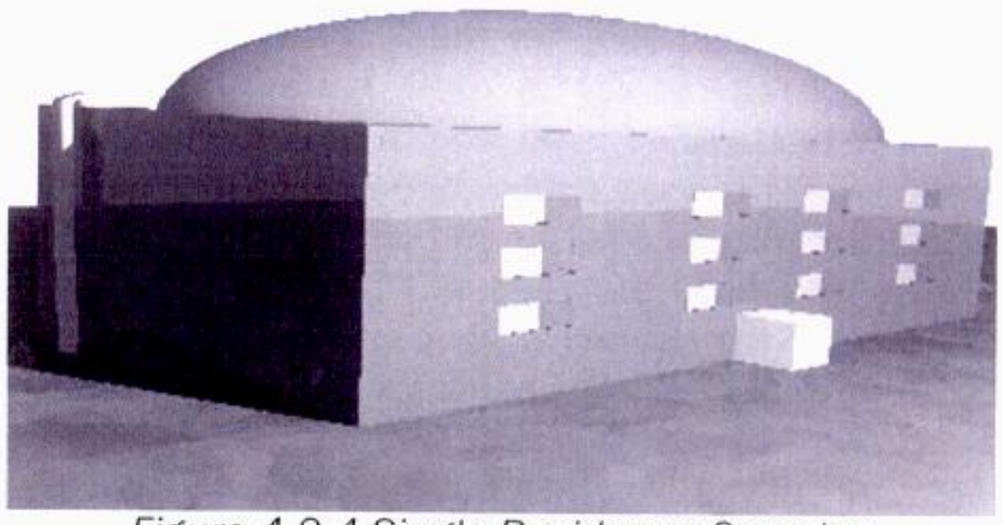


Figure 4.2.4 Single Residence Complex External View (one story)

4.3 Work Environments

4.3.1 Work Sectors

Work Sector	Description	Tools Needed
Education	Teachers will educate children; Professors will give vocational training.	Computers, school supplies, equipment for demonstrations
Agriculture	Farmers will plant crops, providing food for the population of the entire settlement. Livestock will also be raised to provide additional variety in diet.	Water, harvesting machines
Scientific Research	Scientists will experiment within zero-gravity areas, benefiting future explorations in space.	Science equipment (test tubes, scales, test tubes)
Manufacturing	An assembly line of machines will control	Space suits with tether

	manufacturing. Workers will oversee the machines. Some more human-specific work will also be done by workers.	
Technology	Workers will regulate and oversee the technology behind the settlement: robotics, rotation of the central axis, servers.	Computers, robotic controls
Entertainment	Musicians and actors will perform in theatres; athletes will play their sport on their respective fields/courts.	Instruments, microphones, equipment for athletes, fields/courts
Tourism	Guides will give tours to tourist and inform visitors on scenic site, the space settlement, and outer space itself.	Travel vehicles, space suits with tether
Medical	Doctors and nurses will give regular check ups to the residents and tourists.	Surgical or examination tools, drugs, robot to check up on patients
Security	Robots, used for some automation of security, will be supervised by guards. Guards and a police force will be responsible for most security.	Security cameras, defensive weapons
Service Industry	Shop owners and employees service consumers; hotel employees provide comfort for tourists.	Passcard readers, cash registers

Table 4.3.1 Work Sectors and Tools

4.3.2 Spacesuit

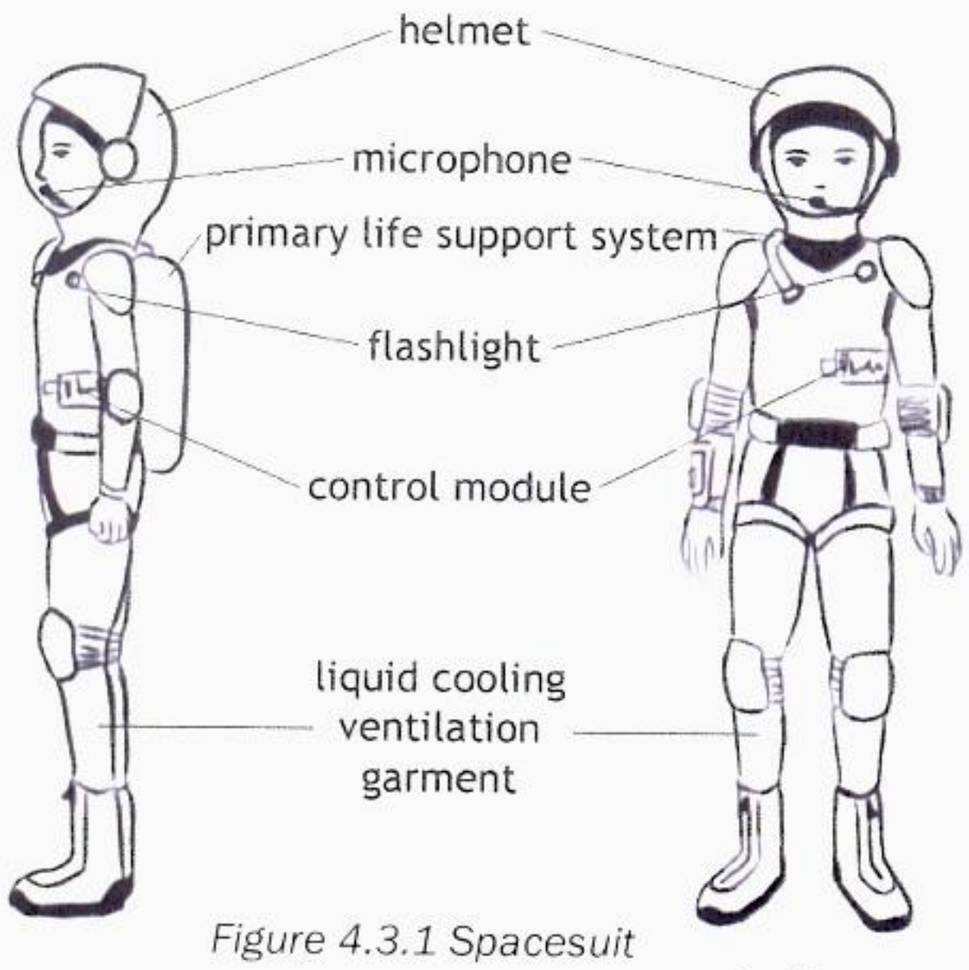


Figure 4.3.1 Spacesuit

The spacesuit will be utilized for unpressurized, low-gravity areas, including the central axis, sphere, and external areas. It will incorporate several features for the convenience and safety of the wearer. Neoprene layers will act to insulate the wearer from the extreme temperatures outside the suit. Mylar film on the outside will act as a reflector of radiation and sunlight for external uses. There will also be several layers of Kevlar to protect from collisions, particularly from micrometeoroids. A final layer in this suit will be the an electric alloy mesh, which uses a Shape Memory Alloy mesh controlled by voltage to generate counter-pressure to offset the pressure of the wearer. This pressure is sent through a viscous gel layer. This gel layer additionally regulates the heat generated by the shape memory layer as well as the wearer and removes the perspiration generated by the wearer.

The helmet will include an anti-glare visor. A thin film of detergent will be applied onto this visor to prevent fogging. Communication will be facilitated through small microphones in the helmet sending localized radio signals to a relay station and other suit wearers. On the control module, the wearer will be able to select their channel/frequency to receive and send signals in, allowing for separate communication between different groups.

On the back of the spacesuit will be several tanks combined into one "backpack." This backpack will consist of 3 tanks: a pure oxygen tank, a lithium hydroxide container to absorb carbon dioxide. Attached here will also be a spot for a durable elastic tether, which will safely attach the wearer to a stable surface if needed.

4.4 Neighborhood Design

Several neighborhood options will be available for residents to choose for their different lifestyles. Each separate residential area will be constructed with different themes, with more popular themes recurring more often.

There will be three main themes present in this settlement. The first, a rustic neighborhood, will have architecture consisting of a rural, country style. This kind of neighborhood will be built in all three types of residences (single, double, and triple). People preferring a traditional aspect in lifestyle will be able to select from these neighborhoods. The second neighborhood will be a modern neighborhood. It too will be in all three types of residences. This neighborhood will resemble urban conditions, while simultaneously emphasizing the new marvels and innovations of space, appealing to the "new age" inhabitants looking forward to the future. The third type of neighborhood will be a child-friendly neighborhood. Since married families will be living almost exclusively within triple residences, these will be placed only within triple residences. Married couples will prefer these as a comfortable environment that they can enjoy with their children.

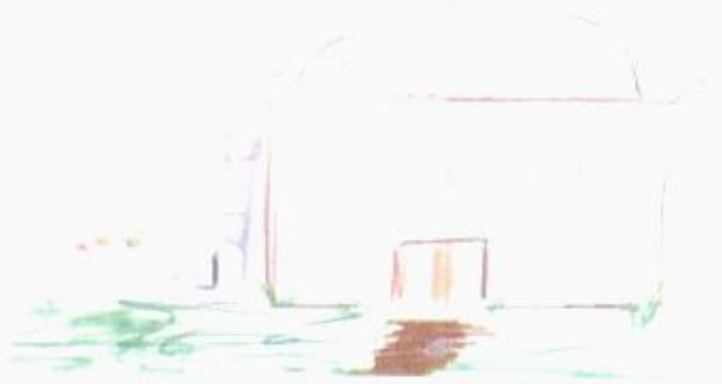


Figure 4.4.1 Rustic Neighborhood

Figure 4.4.3 Child-Friendly Neighborhood

Figure 4.4.2 Modern Neighborhood

In addition to the different styles of architecture, residents will be able to personalize their own home with a choice of interior design. Different materials for furniture and finishing (e.g. balsa wood, bamboo) can be selected to suit personal preferences in style.

4.5 Recreation

Activity	Description
Shopping	Shopping centers will provide for recreation for many citizens. Citizens here can enjoy the service industry, through shopping from several retailers for basic and extravagant products, as well as dining.
Sports/Fitness	A large fitness center will provide facilities for several sports, as well as large gym. This will additionally provide for physical fitness of the citizens. Communities will also be able to form local sports teams which will compete with corresponding teams in other areas.
Movies/Concerts	Residents and tourists can attend various performances, including movie screenings, musical concerts, and shows.
Parks	The beauty of nature, provided at parks, will give a simple form of enjoyment among the complexities of a space settlement.
Home	With the various technologies that are available, residents can easily enjoy themselves within the comforts of their own home. For example, this can be done with TVs and computers.
Cultural Center	A cultural center in each ring will allow residents to enjoy various cultures including their own. Cultural festivals and ceremonies will take place at these areas to celebrate different cultures.
Tourist Centers	Although these areas (see section 7.3), will be intended for tourists, residents will also be able to enjoy these points of interest (museum, amusement park, etc.).

Table 4.5.1 Recreational Activities for Residents

5.0 AUTOMATION
DESIGN AND
SERVICES

SECTION 5: AUTOMATION DESIGN & SERVICES

For the maximum comfort of the residents of Bellevistat, automated systems have been provided for many routine tasks. Computers have been carefully selected to be the most efficient for use on the colony. An innovative system of private passcards allows for access to the amenities of the colony while maintaining a carefully-managed privacy system. All of this and more will earn Bellevistat a reputation for comfort and sophistication while maintaining a position at the pinnacle of technology.

5.0.1 Computers and Specifications

System	Specifications
Sony Vaio SZ Series VGN-SZ650N/C	Each individual at or over the age of 8 has a laptop. Projected number of individuals ages 8 and over is 17,500. The best choice is a durable yet sophisticated laptop- Sony Vaio SZ Series VGN-SZ650N/C. Weight- 3.9lbs. Screen size- 13.3" RAM- 2 GB Memory- 160 GB Processor Speed- 2.2 GHz
Dell Inspiron 530C P.C.	For every 5,000 square feet, there is a small workstation area containing 3 Dell Inspiron 530C's for basic user functions including e-mail, messenger, and Internet access. Though basic, they are cheap and do not take up excess space. Size- 17" screen RAM- 1 GB Memory- 250 GB Processor Speed- 1.60 GHz
Dell Precision T5400 Workstation	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. Size- 19" screen RAM- expandable to 32GB Memory- Expandable to 3 TB Processor Speed- expandable to two processors ranging from 2 GHz to 3.33 GHz
Server: Dell Poweredge 2410	This server technology is designed specifically for durability in remote locations and provides reliability and a strong backup system. 24U Rack Enclosure 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. Up to 256 servers Up to 480 drivers Scales to 353 TB
Networking	Oracle database and server management technology are most suited for this settlement.

Table 5.0.1 Computer Systems Encountered by Humans and Specifications

5.1 Automation for Construction

5.1.1 Automation for Construction

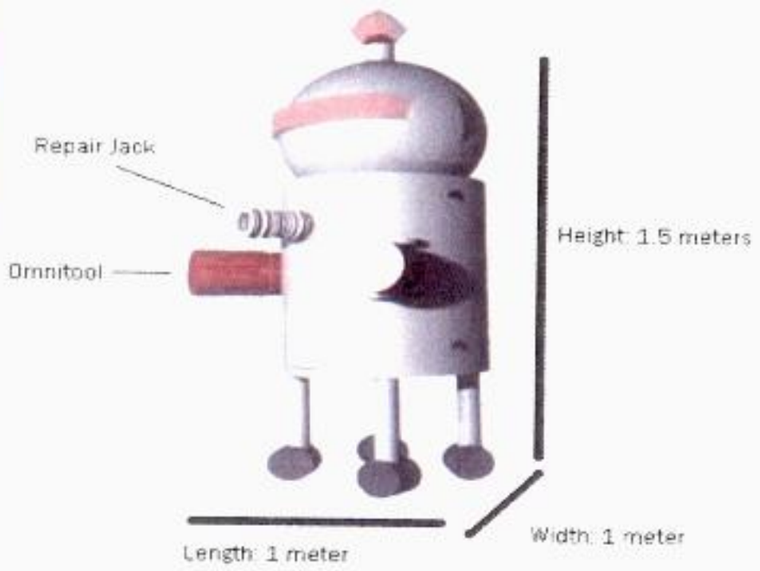
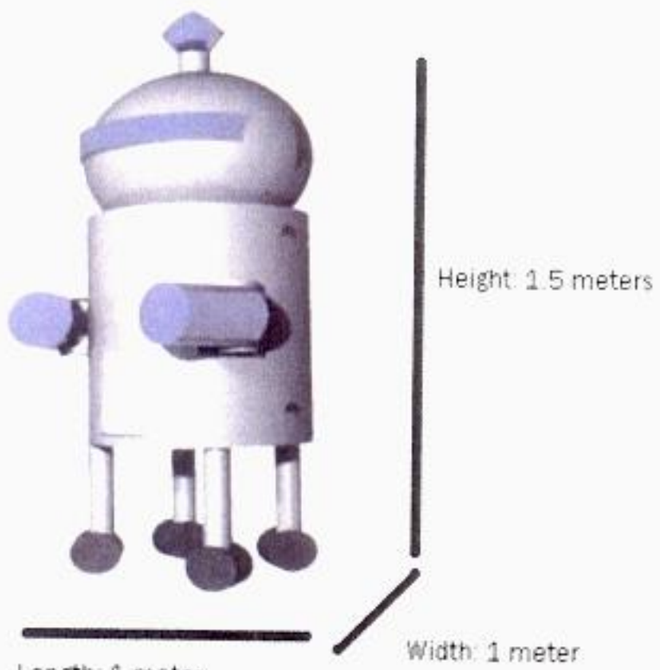
Robot	Image	Functions	Details
Repair Robot	 NOTE: ROBOT NOT DRAWN TO SCALE	Maintain builder robots and other structures	• Equipped with omnitool (**see below**) for repair • Backup batteries on bottom; wire and screws stored in main compartment to fix and reenergize other robots • Sensor "eyes" using 2048 points of reference to determine if anything is in need of repair • Recognition program to find light on top of inert robots (light turns on when batteries are damaged, due to electricity creating a barrier around a radioactive substance that activates when the barrier disappears) • Activated by level 3 access
Builder Robot	 NOTE: ROBOT NOT DRAWN TO SCALE	Construction	• All the features of the repair robot, plus: • Equipped with omnitool for construction • Scanner "eyes" to read unique bar codes on target material, which will provide instructions (bar codes are printed on reusable biodegradable plastics made from corn grown on the settlement) • Activated by **level 2 access**
Specialized Robots	*Same as builder and repair robot, with specialized omnitools (see below)*	Specialization to cover other jobs	• Equipped with **omnitool for special jobs** (i.e. brushes for interior finishing) • **Main compartment** holds different materials

Table 5.1.1 Automated Construction and Assembly Robots

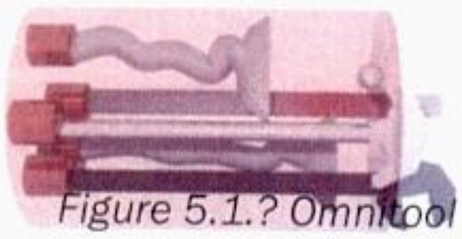


Figure 5.1.? Omnitool (standard)

An **omnitool** is an innovative **robotic limb** inspired by the Swiss army knife that contains many tools such as hammers, drills, and magnetic clamps. Omnitools are controlled by a robot's internal computer. When the computer senses the need for a specific tool, it signals a specific point on the robot's "body" to apply pressure to corresponding copper button on the omnitool. This opens the cap on the front of the omnitool, and the tool needed emerges on a raised cylinder. The standard omnitool can be

utilized for several purposes; if a robot is needed for an even more specific purpose, the omnitool can be taken out altogether and replaced by a new tool. This is economical in that one type of robot can cover several jobs, simply by changing the tool in use. However, repair robots are in their own class, and cannot have these omnitools swapped (for security measures).

5.1.2 Robot Specifications

For all robots, there are plugs for recharging, and a built-in timer dictates when they will return to a charging station to regain energy. All of the timers dictate that the robot return to the recharging station after 8 hours of work (the batteries actually allow for 10 hours, but this is a preventive measure against power outages). The heat loss created by electronic movements will be re-harnessed for more energy. All robots have a main compartment used for storing things required for their jobs. All robots have an alarm light that activates when there is no more electricity flowing in the robot (see above chart, under "Repair Robot: Specifics").

5.1.3 Robot Access and Logging

Builder robots may be activated by anyone who has level two access by using a passcard (see below for details). Repair robots can be activated by anyone who has level two access, but they may only be detained, turned off, and/or repaired (should there be any problems) by those who possess level three access. These events will be logged by the cards.

5.1.4 Transportation using Automation

Bellevistat's central axis will be assembled by launching units in shuttles to Alexandriat. From there, they will be transported to the L5 orbit using Topaz vehicles (please see below). The axis will be assembled robotically. After Phase 1 is completed, workers will be able to complete construction on-site.

Aquamarine vehicles **(see Section 3.3.1)** are small pods with thrusters that are used to take material and maneuver it into the space station. Only one human is required per pod. Pods are all equipped with magnetic grappling hooks to carry their cargo. Pods will be used for both transport and delivery. All pods are equipped with a repair robot in order to fix, if necessary, any cargo containers, the pod itself, or other robots in need of assistance. This is also good for emergency procedure, in which all pods must land and all repair robots be sent into the space colony to fix any errors.

5.2 Facility Automation

5.2.1 Repair, Safety and Maintenance Automation

Field	Robot/System	Specific Tasks
Repair/ Maintenance	Repair robot	Repair robots used for industrial purposes will serve as the robotic maintenance crew. These autonomous robots will have specialized arms which will allow them to make repairs outside of the space station. For internal repairs, a special safety system will provide 24-hour surveillance of the conditions in every area of the space station. If any disturbance in temperature or malfunction of software or similar defect is recorded, special mobile robots will be sent to the sites of disturbance. In case of a software malfunction, these mobile robots will connect to a computer in the area and feed information to the technicians.
Safety	Safety robots	These have penetrating scanners, can locate suspicious objects and compounds that should not appear on settlement (such as bombs). They may only be accessed and activated by technicians and government officials. When a suspect is found, video cameras turn on to track the person's face and appearance. Should the suspect be committing a crime, tranquilizer dart systems (dosage carefully measured to prevent manslaughter) will fire. All access of robots are logged; should the robot be compromised and used to attack, the person using the card will be rendered unconscious and repair robots will attempt to stop and maintain control over the

		compromised robot. Dart systems are controlled by the central computer only.
Solar flare immunity	Optical fiber cables	Immunity will be created only within the station. Earth communications during a solar flare would fail to function in any case because even Earth is disrupted by solar flares. However, communication is essential on the space station, and thus use of fiber optic cables will reduce impact of solar flares, since direct lines cannot be disrupted.
Authorized access	Passcards **(see Section 5.3.3)**	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 swipe 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.
Security measures	Passcards, tumbler-locks (manual)	The major security measure will be fingerprint passcards. Normal locks will also be implemented for added security.

Table 5.2.2 Repair, Safety, and Maintenance Automation

5.2.2 Backup Systems

Repair robots on every pod (since there is one on every pod for maintenance of the pod) will all come to the station during an emergency docking, which forces all pods into autopilot and docks them at the station. The repair robot then leaves the pod and goes onto Bellevistat in search of errors and problems. In case of a central computer crash, reinstallation software found in 20-tumbler fireproof manual safes will be available. There are nine of these safes, one the industry sphere and four on each torus. Backup hardware and replacement parts are also in the safes for emergencies. Should there be a large rent in the side of the station, all repair robots are equipped with four canisters of quick-drying cement in order to patch up the hole. If the repair robots malfunction, the technicians in the space station will take over that job for them. Technicians are trained to do what repair robots can do and more (such as reprogramming and determination of when to evacuate the space station).

5.2.3 Contingency Plans

Since there are many pods and shuttles within the space station, all will be called to the nearest docking facility and shot towards Earth using magnetic and air propulsion. Emergency week-ration packs for four people are located on each pod (since each pod can hold up to four people). There are two-week ration packs on shuttles, and these ration packs hold enough for 50 people, which is the capacity of the shuttle. There are two emergency garages of 75 shuttles, one in the docking station of each torus. These garages are activated by a 30-digit code and a technician's passcard. In the unlikely event that all docks do not function, the natural sectioning of the tori and other parts allow for jettison of areas in order to create an escape route. The second back-up plan is a simple jettison of the critical area, and air locks will prevent the rest of the space station from losing air.

5.2.4 Physical Location of Automation and the Central Computer

Robots are all located in recharging stations. There are four in each torus (the multiplicity is to prevent some type of mass catastrophe). Later, all of these robots will move around to jobs later. The central computer is located in the middle of the central axis.

The central computer can only be accessed by technicians and government agents. The computer is placed in a safe room with 100 tumbler locks. There are three of them in order to access the central computer. When the computer is reached, two technician cards and one government card must be swiped through. A 50 character password and voice recognition of the government official are further required. Further scanning of these people's bodies will make sure there are no suspicious objects.

5.2.5 Access Levels

All activities will be logged. There is no erasure of activities, in case of government fraud. However, information will not be released to the public unless there is government clearance.

The following access levels will be utilized throughout the colony, and will implemented using the passcards:

Access Level	Group
0	Everyone, including young children
1	Everyone above the age of eight
2	All those who must commute away from the residential areas
3	Technicians
4	Government officials
X	Tourists

Table 5.2.? Access Levels for Passcards

5.3 Habitability and Community Automation

5.3.1 Basic Automation for Needs

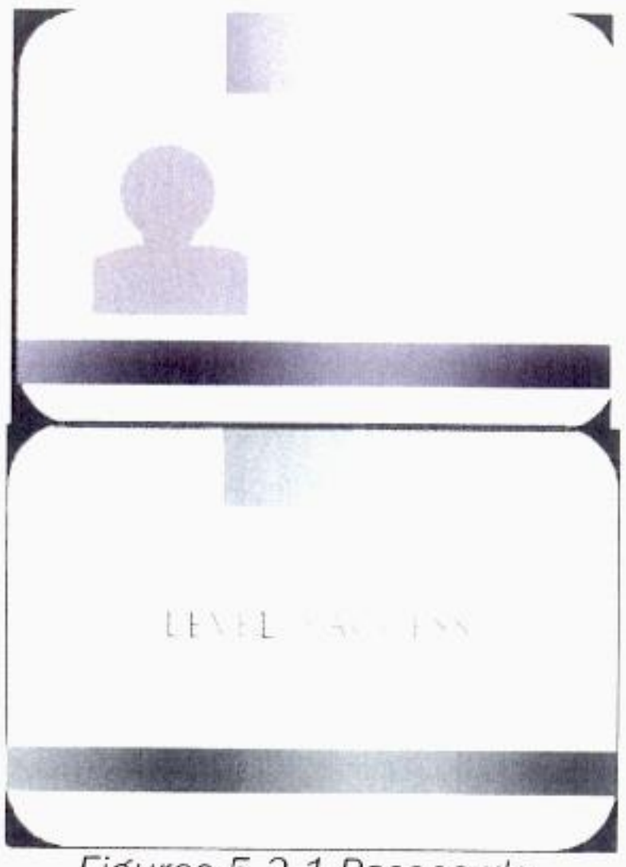
For livability, there are garbage cans that use x-ray spectrographs to determine the structure of waste and place it into recycling bins or trash cans outside. Computers provide most productivity needs within the settlement. For convenience, lights that activate and deactivate using voice commands will be used.

5.3.2 Automation for Maintenance, Routine Tasks, and Privacy

For maintenance and routine tasks, the settlement will purchase small robots to reduce human labor. To clean floors, a "Sweepbot" is most effective. The Sweepbot will use sensors to navigate floors, vacuuming and mopping as needed. Sweepbots run on a store of electrical power and can be recharged by repair robots when they run out. A Landscaper automatically mows the lawn, saving humans trouble. It can be programmed not only to trim lawns, but will also efficiently distribute water to the lawn it passes over. Probes will be implemented in each Landscaper to detect the water levels in certain places; this will minimize water waste for landscaping purposes. For privacy, there are windows that black out when a button is pressed. When the same button is pressed, the windows will revert. Computer screens will have layering that hinders visibility of the screen at the wrong angle, meaning that only the user will be able to see his or her own computer screen.

5.3.3 Privacy of Personal Data

Control of personal data will be facilitated using a revolutionary fingerprint passcard. Within this card contains a log of all activities, such as entering the home, activating a robot, and signing in for work. The card is also used to track finances, for it will be used both as a credit card and as a savings account, where money that is earned will be stored. The huge amount of personal information in one card may be disturbing; however, there is a fingerprint scanner that will use 128 points of reference in order to determine if the fingers are correct. The way it works is that one holds the card normally, and the place where index finger and thumb go is the place that scans them. Only when there is contact will the card activate, due to the rmo-sensors as well. Should an individual have problems such as missing fingers or a stolen card, he or she may go to the card processing center and obtain a new one (all old ones will be nullified and deactivated). These cards are extremely important, and the individual must take caution not to lose it, or else he or she will need to get a new one, a process that may take up to 4 hours. Everyone will be provided with these cards, but not all functions will be open: for instance, a child under the age of 8 will not be



Figures 5.3.1 Passcards, Front and Back

able to access a computer with their card, nor can they turn on any maintenance robot or buy things. However, the information on their cards, such as address, name, vital statistics, and health history, can be used in order to take a lost child back home or immediately treat him or her in the case of an injury.

For computers and other sensitive items, access will also require a username and two passwords, each of 16 characters minimum. Firewalls are in place along every connection line, meaning that all information will pass through multiple firewalls. Furthermore, encryption of data will be constantly used, along with digital signatures and certificates to verify both the sender and the receiver of data.

5.3.4 Networking and Bandwidth

Purpose/ Target	Type of Connection	Speed
Industrial	Secure fiber-optics	6 Tbps
Commerce, space-station operations	Secure fiber-optics network	6 Tbps
Residential	Secure wireless; Secure fiber-optics	6 Tbps
All other traffic	Secure fiber-optics connecting both rings	6 Tbps

Table 5.3.1 Connection Type and Bandwidth

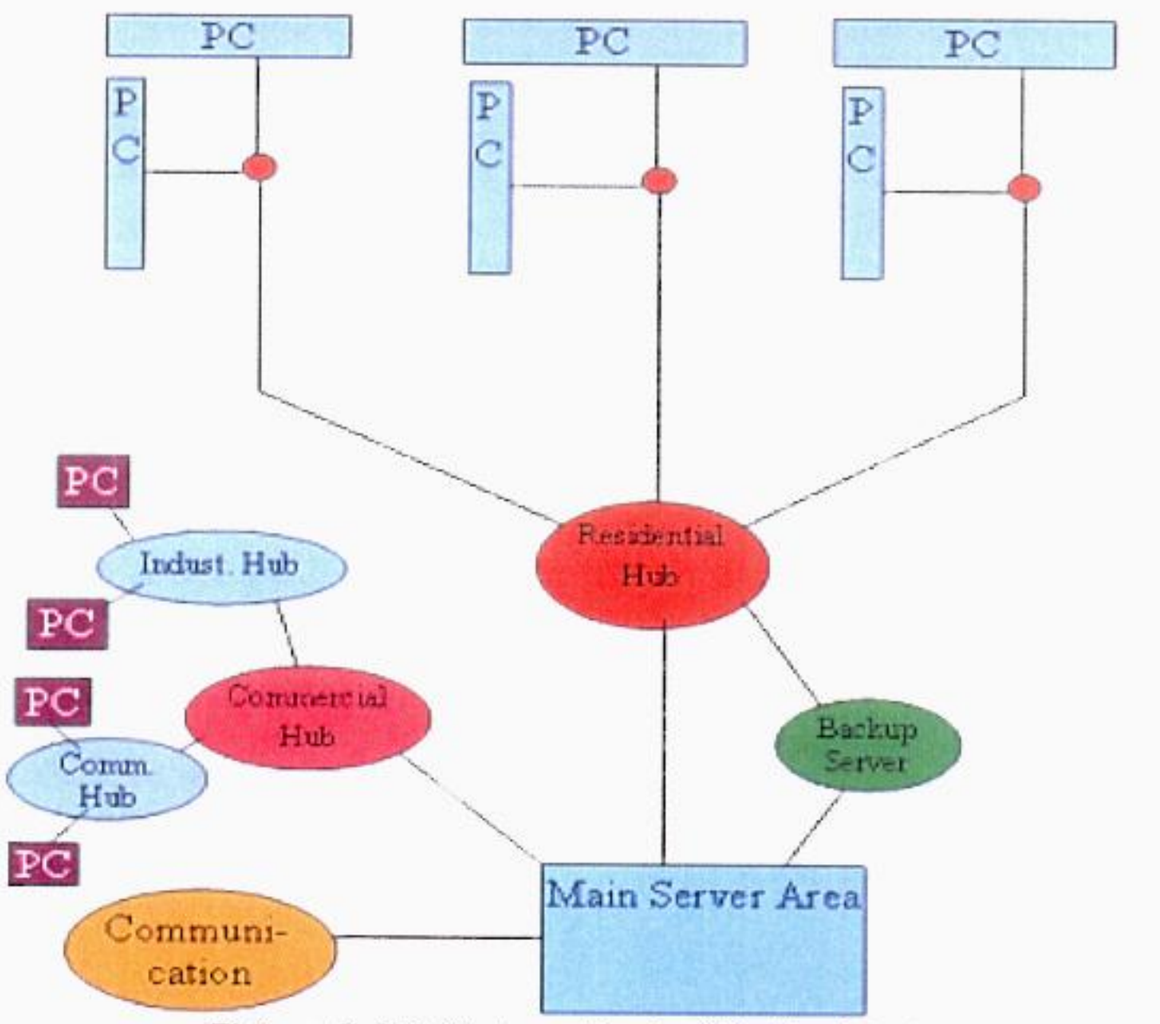


Figure 5.3.1 Networking of Bellevistat

5.4 Automation for Finishing Interiors

5.4.1 Plumbing, Wiring, Lighting, Painting, and Other Jobs

All of these jobs will be dealt with using specialized versions of the builder robot. For instance, for lighting, robots will have magnetic and suction clamps that hold onto light bulbs to screw them in, and the main compartment will hold light bulbs. For painting, different-sized brushes and different paint removers will be equipped. The amount of time needed for all of these jobs, assuming one robot for each job is used simultaneously, will take about three to five hours per residence, dependant on size.

5.4.2 Floor Installation

This robot is a variation of the builder robot. In the main compartment, the robot holds tiles, and the omnitool will apply quick-drying cement to the tile before placing it onto the ground. The robot will do this easily by using

its sensor to detect edges and determine if it has committed an error or not. The robot, in a team with three others of its kind, can finish a typical residence within 4 hours.

5.4.3 Furniture Creation and Placement

Placement of furniture relies on builder robots, which will use suction cups to lift and place the furniture. This will take approximately one hour to complete. Assembly-line-style machines will be set up in the industrial sphere once construction is complete to manufacture some unique furniture for Bellevistat and for export. This furniture will be made from asteroid material rather than conventional Earth-sourced material. The versatile omnitool will be able to aid in making some of the furniture, but the majority of both Earth-based and asteroid-based furniture will be created in the assembly machines.

5.5 Automation for Mining and Transportation of Ore

5.5.1 Specifics of Mining Robots

Mining robots will be equipped with a reverse drill for drilling. These mining robots will use X-ray emission spectra on asteroids to determine what sort of ore they are mining. The benefit of this is that there will be separate bins to place each ore, which will then be placed onto a pod, carried away, and brought back. There is an additional human for every five robots in order to intercept the crates (made of biodegradable plastics) and replace the ones on empty robots (the main operator will alert these workers of any such issues). Only one human main operator is needed, and that operator can stay in the space station, using a wireless interface. Even when this bin is gone, there are two more in order to create a rotational sort of effect. The drill part can rotate, and the legs of the mining robots are telescopic in order to fit the landscape, and will again be equipped with magnetic clamps.

Using the drill, the robot will harvest asteroid ore. This ore will then be placed into a bin, and when that bin is full, a signal is sent out to the human operator, who then orders a pod (specialized for this job) to go pick it up and deliver it. The collection of the ore within the robot works by using the drill to place ore within the robot. Then, a "mill" of sorts will capture the ore and move it into an upper compartment. This compartment will then serve to compress the ore through a crushing mechanism, and then the compressed ore will be placed in a crate, located at the top. A pod will then take away the crate and replace it with another one. When the crate is full, it will send out a signal, using weight as the signaling mechanism.

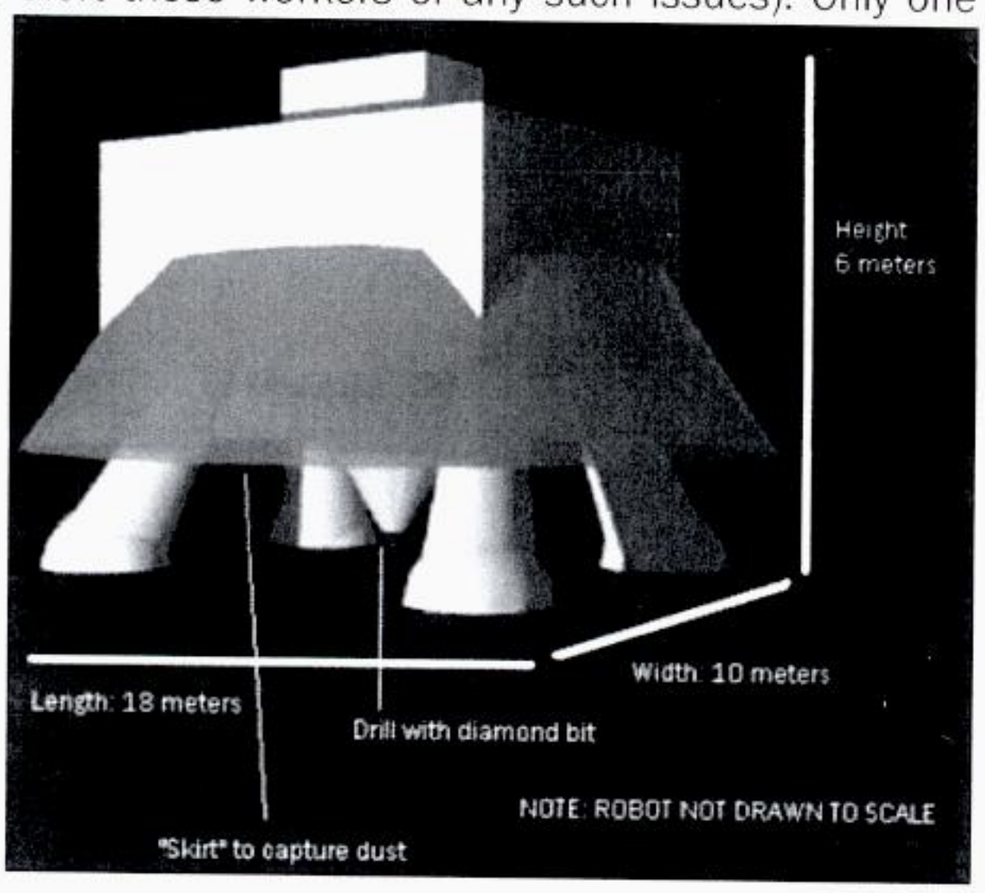


Figure 5.5.1 Mining Robot on Asteroid Surface

Once the robot is sent out, it will not come back, acting instead as a stationary structure with limited mobility in order to access new resources should current ones run out. In the event of failure of the robot, the pods (as standard procedure) have a repair robot that can go and fix the mining robot. The mining robots have dimensions of eighteen meters length, ten meters width, and six meters height. The drill is made of stainless steel and lubricated by graphite. The very tip will be a diamond bit in order to effectively drill. There is a plastic "skirt" to capture dust and prevent it from interfering with the settlement.

5.5.2 Estimate of Fleet Size and Number of Humans Needed

Should there be a fleet of approximately 100 mining robots, about 21 humans will be needed, 20 to capture and replace crates and one to monitor all of the processes. The main operator will be on a 4-hour shift, meaning that six people are needed in a 24-hour cycle.

6.0 SCHEDULE AND COST

6.1 Schedule and Employees Required

Years after 10 May 2028	Employees	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Research & development	70															
Approval by Foundation Society	N/A				Nov. 2032											
Robot & subsystem development	200															
External construction modules erected	150															
Phase 1																
Assembly of Central Axis	Robotic															
of spokes	Robotic															
Communication systems set up	40															
Asteroid mining and refining	Robotic															
Phase 2																
Construction of Industrial Sphere	Robotic															
Shipment of materials to docking areas	140															
Phase 3																
Construction of Main Mirror	140; robotic															
Phase 4																
Construction of Ring of Mirrors	140; robotic															
Phase 5																
Construction of Gemini	380; robotic															
Interior finishing in Gemini	200; robotic															
Construction of Tethora	380; robotic															
Interior finishing in Tethora	200; robotic															
Internal infrastructure tests	50															
Construction of external infrastructure	500															
Final infrastructure tests	60															
Attachment of docks	Robotic															
Installation of solar panels	Robotic															
Final Phase																
Transport of atmospheric gases	100															
Rotation of settlement	40															
Foundation Society members move in	N/A															
Reviews, tests, and minor changes	90															
All other colonists welcomed in	N/A															
Full-time population established	N/A															

Years after 10 May 2028	Employees	16	17	18	19	20	21	22	23	24
Research & development	70									
Approval by Foundation Society	N/A									
Robot & subsystem development	200									
External construction modules erected	150									
Phase 1										
Assembly of Central Axis	Robotic									
Assembly of spokes	Robotic									
Communication systems set up	40									
Asteroid mining and refining	Robotic									
Phase 2										
Construction of Industrial Sphere	Robotic									
Shipment of materials to docking areas	140									
Phase 3										
Construction of Main Mirror	140; robotic									
Phase 4										
Construction of Ring of Mirrors	140; robotic									
Phase 5										
Construction of Gemini	380; robotic									
Interior finishing in Gemini	200; robotic									
Construction of Tethora	380; robotic									
Interior finishing in Tethora	200; robotic									
Internal infrastructure tests	50									
Construction of external infrastructure	500									
Final infrastructure tests	60									
Attachment of docks	Robotic									
Installation of solar panels	Robotic									
Final Phase										
Transport of atmospheric gases	100									
Rotation of settlement	40									
Foundation Society members move in	N/A				3.02.2047					
Reviews, tests, and minor changes	90									
All other colonists welcomed in	N/A						2.28.2049			
Full-time population established	N/A									7.24.2052

6.2 Costs

See Section 6.1 for numbers of employees working in each phase.

Technology:

Item	Cost ($)	Quan-tity	Total Cost ($)	Annual Upkeep ($)	Development Time
Laptops (normal)	1,000	17,000	17,000,000	1,275,000	N/A
PCs (normal)	800	800	640,000	60,000	N/A
Servers	23,000	20	460,000	3,000	N/A
Storage	48,000	20	960,000	3,000	N/A
Business PC's	2,000	600	1,200,000	45,000	N/A
Computer Management PC's	3,000	50	150,000	3,750	N/A
Network (all components)	1,000,000	1	1,000,000	1,000	N/A
Science Research PC's	2,000	1,000	2,000,000	75,000	N/A
Drilling Robots	750,000	1,000	750,000,000	750,000	2.5 years
Builder Robots	400,000	25,000	10,000,000,000	12,500,000	1.5 years
Repair Robots	450,000	12,000	5,400,000,000	6,000,000	1.75 years
Omnitool	2,000	75,000	150,000,000	N/A	1 year
Fingerprint Swipe Cards	500	20,000	10,000,000	N/A	1 year
Card Readers	500	100,000	50,000,000	N/A	0.5 year
Central Computer	10,000,000	1	10,000,000	250,000	5 years
Development			1,250,000		
TOTAL COST			16,394,660,000	20,965,750	

Appliances:

Item	Cost ($)	Quantity	Total Cost ($)
Refrigerators	4,000	12,850	51,400,000
Microwaves	600	12,850	7,710,000
Ovens	1,000	12,850	12,850,000
Dishwashers	1,000	12,850	12,850,000
Countertop Burners	600	12,850	7,710,000
Compact Fluorescent Lamps	0.50	10,000,000	5,000,000
Plasma TVs	1,000	12,850	12,850,000
TOTAL COST			110,370,000

Vehicles:

Item	Cost ($)	Quantity	Total Cost ($)	Annual Upkeep ($)	Development Time
Aquamarine	600,000	500	300,000,000	500,000	2.5 years
Topaz	1,500,000	30	45,000,000	30,000	N/A
Zirconia	1,000,000	15	15,000,000	15,000	N/A
Tourmaline	3,000,000	5	15,000,000	5,000	N/A
Carnelian	1,500,000	50	75,000,000	50,000	N/A
Shuttles	1,500,000	250	375,000,000	250,000	

Development	3,000,000		
TOTAL COST	828,000,000	850,000	

Wages:

Profession	Number of Workers	Annual Wages ($)	Total Annual Wages ($)
Technician	1,000	150,000	150,000,000
Office Worker	9,000	90,000	810,000,000
Government Official	700	120,000	84,000,000
Researcher	300	95,000	28,500,000
Planner	60	200,000 (one time only)	12,000,000
TOTAL Wages			1,072,500,000

Communications:

Item	Cost ($)	Quantity	Total Cost ($)	Annual Upkeep ($)	Development Time
Fiber optic cables	15 / meter	10,000 m	150,000	0	N/A
Lasers	6,000	3	18,000	1,500	N/A
Intercom	5,000	1	5,000	750	N/A
Wireless LAN	600	250	150,000	12,500	N/A
Comm. Satellite	300,000	3	900,000	15,000	3 years
Development			250,000		
TOTAL COST			1,473,000	29,750	

Materials:

Material (unit)	Unit Price ($)	Quantity	Total Cost ($)	Annual Upkeep ($)
Nitrogen (m^3)	60.00	160,803,277	9,648,196,638.00	0.00
Oxygen (m^3)	0.300090	88,441,803	26,540,500.52	0.00
Carbon Dioxide (m^3)	0.009889	107,202	1,060.07	0.00
Water (m^3)	1.00	1,500,000	1,500,000.00	0.00
Silica Aerogel (m^2)	2.00	856,000,000	616,134,300.00	400,000.00
Titanium Matrix Composite (kg)	4.20	580,000,000	2,436,000,000.00	200,000.00
Aluminum Silicon-Carbide (kg)	2.00	470,000,000	940,000,000.00	200,000.00
Borosilicate Glass (m^2)	30.00	75,000,000	2,250,000,013.23	870,000.00
Carbon Nanotubes (m^2)	15.00	50,000,000	750,000,000.00	800,000.00
Demron Cloth (m^2)	300.00	25,000,000	7,500,000,000.00	600,000.00
Liquid hydrogen (kg)	2.20	787,500,000	1,732,500,000.00	20,000.00
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
TOTAL COST			27,545,354,561.82	15,739,785.00

Landscaping:

Landscaping	Unit Price ($)	Quantity	Total Cost ($)	Annual Upkeep ($)
Trees	10.00	10,000	100,000.00	5,000.00
Lakes	250,000.00	3	750,000.00	8,000.00
Mountains/Valleys	250,000.00	20	5,000,000.00	50,000.00
TOTAL COST			5,850,000.00	63,000.00

Housing and Communities:

Housing	Unit Price ($)	Quantity	Total Cost ($)	Annual Upkeep ($)	Develop-ment 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	

Total Construction Costs billed to Foundation Society: U.S. $48,151,547,561.82
Total Annual Costs: U.S. $1,194,204,285.00

Annual Revenue:

Tourism	2,687,500,000.00
Recreation	1,227,500,000.00
Hotels	1,095,000,000.00
Souvenir Sales	365,000,000.00
Mining	2,500,000,000.00
Ore Exports	1,300,000,000.00
Infrastructure Exports	1,200,000,000.00
Private Contracting and Advertising	500,000,000.00
TOTAL	**5,687,500,000.00**

Total Time Required to Reimburse Construction Costs:

48,151,547,561.82+1,194,204,285.00
X = 5,500,000,000.00 X
4,305,795,715 X =48,151,547,561.82
X = 11.18296 years

Accounting for extra expenses incurred by the settlement, it will take **12 years** for the full cost of construction to be reimbursed.

7.0 BUSINESS DEVELOPMENT

SECTION 7: BUSINESS DEVELOPMENT

Bellevistat is envisioned as a "rust belt" in space. Northdonning Heedwell projects Bellevistat to not only be an exciting, enticing tourist destination, but also a major source of production and profits. Bellevistat will generate business through trade with Alexandriat, exports to future colonies, and a large amount of tourism. Bellevistat retains the practical value of profit generation while also being an appealing destination for adventurous travelers.

7.1 Extraterrestrial Harvesting and Refining

7.1.1 Asteroid Mining

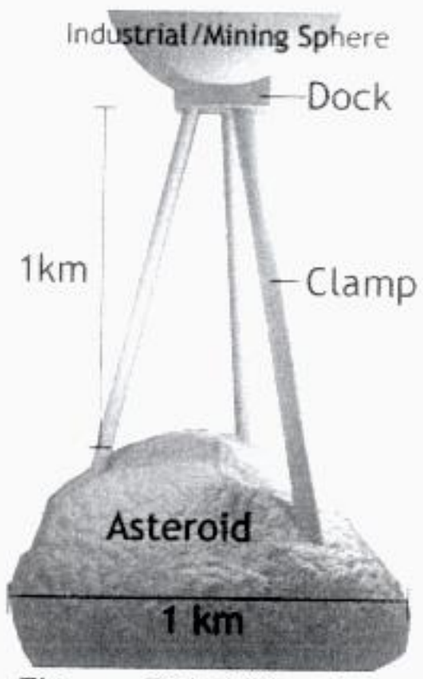


Figure 7.1.1 One-km Asteroid

Bellevistat will harvest ores from captured asteroids approximately one kilometer in diameter. The asteroid will be captured using clamps and placed one kilometer away from the industry sphere. The ore will be extracted using mining robots, as designed from above. The ore will be further refined in the industry sphere of the settlement. The refining process will not use robots, but will instead use efficient large-scale machines.

7.1.2 Re-entry Vehicle

One-way re-entry vehicles will be implemented to carry cargo. The vehicle is in a sphere-cone shape. The exterior will be made from grade 6 titanium, which can withstand extreme temperatures. The nose of the cone will be blunt and made of copper; due to its properties, copper is best suited at the nose. The half-angle of the cone will be at 45 degrees. The crate goes inside of this re-entry vehicle, simply by lifting the sphere-cap and inserting the crate into the cone, then resealing the sphere-cap. The crate will be made from silicon, derived from the asteroid's ore.

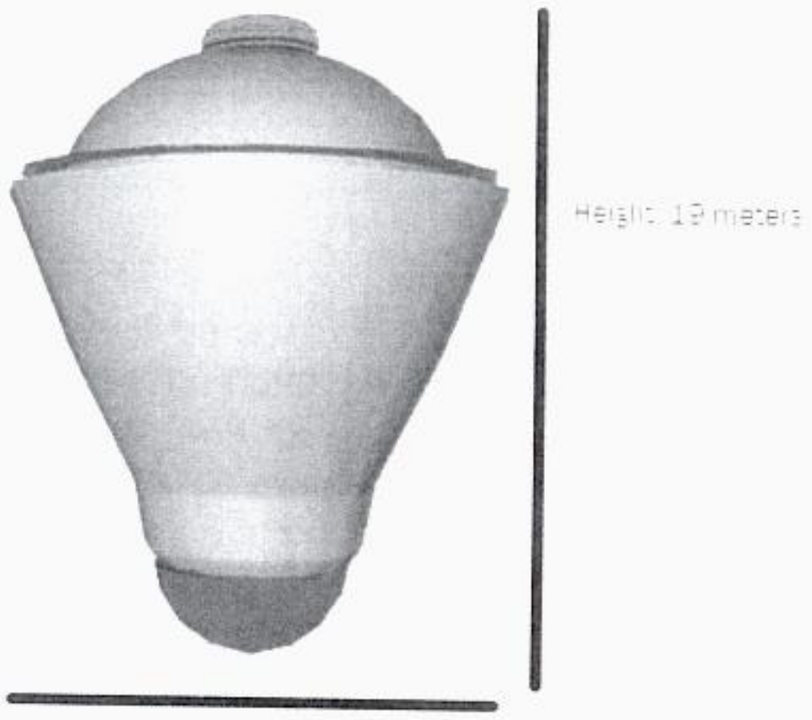


Figure 7.1.2 Re-entry Vehicle

7.2 Facilities for Manufacture and Assembly

Bellevistat will provide facilities for manufacturing and assembly of spacecraft in the industry sphere. As the industry sphere is quite large, its innovative design and creative spacing into many levels allow it to be quite flexible in housing different industries at the same time. Materials mined from asteroids will be used in the manufacture of new spacecraft to aid future Foundation Society construction projects as well as other commercial ventures.

The manufacturing facilities will serve as a supplier for future space construction projects. The silicates derived from the asteroid will provide silicon, which is an essential ingredient of solar panels. Antennas can be easily created from any other ores. Future large projects will be handled easily with the mining capacities of Bellevistat. Furthermore, microgravity can create conditions better suited to the creation of components of large projects, and so some areas of the central axis are potentially open to such purposes of manufacturing. In summary, due to the flexibility and open area in the industry sphere and the central axis of Bellevistat, manufacturing, refining, mining, and other industrial activities can easily adapt and thrive.

The settlement will provide specialized equipment for large-scale space and lunar construction projects. All of this equipment will be created by the machines in the industrial sphere. There will be sufficient space for all machinery needed to create such things, as well as the proper level of technology. Considering that Bellevistat will be renowned for its technological advances, this will not be a problem.

7.3 Tourism

7.3.1 Hotels

For convenience, hotels will be located in the 50 m by 50 m block of the tourist section nearest the docking area in the residential sector. These hotels will be 2 stories tall, and provide comfortable housing for 250 people each. They will additionally provide several amenities for the convenience of tourist, including complimentary hot meals and free brochures and maps to plan a route or tour of the settlement.

7.3.2 Locations of Interest

Bellevistat will have several locations of interest for tourists to go to. These will be initially publicized through advertisements for travel trips to Bellevistat. Once arrived, brochures and maps will lay out a path for visitors to tour locations of interest. Tour guides or hotel concierges will also be available to recommend routes.
Each sector will have its own separate location of interest within its area reserved for tourism. Both rings will include a large observation site. This area will be built with a thick amount of glass, allowing for the viewing of Earth and space around it. Telescopes will be mounted here to increase the ability of observation. Ring Tethora will additionally include a museum and a large shopping center. The museum will focus on the mechanics of the settlement, showing how many components work through interactive displays. The shopping center will be the largest and most significant of the entire settlement. It will include components of a normal shopping center, especially emphasizing souvenir stores and fine dining. Ring Gemini will include an amusement park and a library. The amusement park will be an area boasting several space-themed attractions and accompanying high-grossing food stands. The library, serving as an academic literary escape, will also function as an art exhibit.

Inhabitants will not be barred from these locations; all locations of interest will be open to the public. Similarly, visitors may venture anywhere on the settlement not considered private property. Visitors will be encouraged to visit the theaters within the residential sector to watch a performance. Visitors will be especially encourage to join a guided tour, which leads through all major points of interest in the rings, as well as entering the central axis for zero-gravity entertainment.

7.3.3 Tourist Observation Areas

Tourists will be able to observe mining, refining, and manufacturing operations from safe vantage points, as well as agricultural operations. In mining, a camera at the base of the industry sphere will allow visitors to view the action. In refining and manufacturing operations, there are glass elevators with safety rails and other precautions that will allow visitors a close-up look at such industries. A tour guide will be providing a tour every hour in both of these sectors. In agricultural operations, visitors can simply travel to a farm and take a look at the space-grown crops and animals.

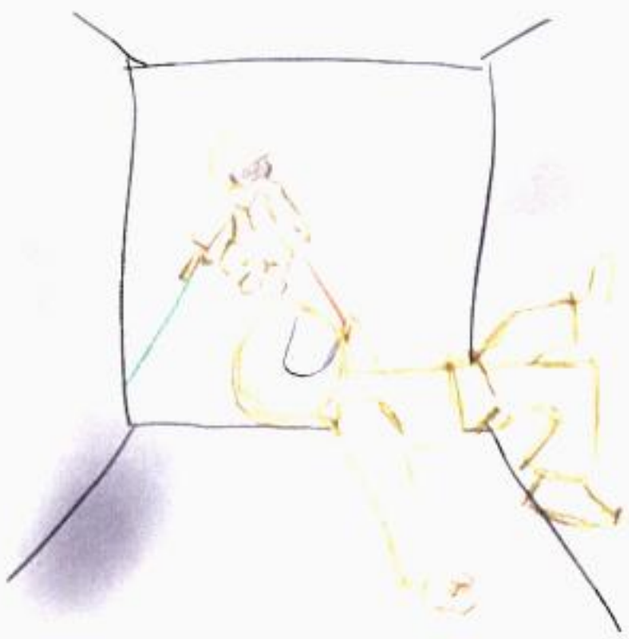


Figure 7.3.1 Players face off in a Battlefield arena

7.3.4 Zero-g Games and Entertainment

The Central Axis will be the center for zero-gravity entertainment, both for tourists and residents. The foremost attraction for young adults will be the **Battlefield**. Players will be split into several teams and issued vests and helmets which have light sensors at target points. Attached to the vests will be "guns" which are used to aim laser beams at the targets of an opponent. Upon hitting an opponent with a laser beam, the shooter earns ten points and the target is "frozen" (his gun is deactivated) for ten seconds. The game will be played in a large, dark room to simulate a space environment, and players will attempt to be the first to freeze all of their opponents or earn three hundred points. The zero-g environment is suitable for many teams; in fact, as many as fifteen teams can occupy one chamber at a time, allowing for a free-for-all or an allied approach.

Bellevistat will offer zero-gravity hopscotch and "moon-walks" for younger children: challenging yet amusing endeavors for adventurous toddlers. In addition, there is zero-gravity capture the flag for children ten years of age and over, in which there are two teams out to capture all twenty of their opponent's flags. The rules remain the same, except there is a greater emphasis on coordination and use of trigonometry in order to achieve goals. In zero-g sparring, two people will be placed in a zero-g room, at the very center. Whenever they touch a wall, they lose a life point, and each person begins with 10 life points. Strategically placed crates are around the room, floating in a three-dimensional space. These crates can be used to propel a person by kicking backwards, or to shove into an opponent to force them to touch a wall. All of these games are completely harmless, for in zero-g, even punches and kicks do not hurt due to lack of force in such environments.

For adults, an opportunity to experience space itself is offered. Upon signing a liability waiver, adults of age 21 and over will go through a short training session. They will then be allowed access to the very top of the central axis, where they will put on a specially designed space suit for tourist excursions and float out into space on five-meter-long tethers. This attraction is projected to be one of the most popular on Bellevistat, due to the rare opportunity presented by it to venture into space.

7.3.5 Access to Communications and Security

Visitors will access communications, computers, and robots by using fingerprint swipe cards, issued to them at the very beginning of their stay. The cards have been designed to prevent unauthorized access and are also made for the security of the individual **(see Section 5.1.2).** Furthermore, they will be issued one temporary username and two passwords each.

8.0 COMPLIANCE MATRIX

NORTHDONNING TEEDWELL

SECTION 8: COMPLIANCE MATRIX

Requirement	*Sub-section*	*Page Number*
1 Basic Requirements		
1.0 The contractor will describe the design, development, and construction of Bellevistat	1.0	1
1.1 The contractor will develop plans for operating and maintaining Bellevistat	1.0	1
2 Structural Design		
2.1 On exterior design drawings, identify large enclosed volumes and their uses	2.1.1	2
2.1 Dimensions of major structural components and design features	2.1.1	2
2.1 Construction materials	2.1.4	3-4
2.1 Volumes with artificial gravity and rotation rates, and means for maintaining it	2.1.2	3
2.1 Rationale for artificial gravity selection	2.1.2	3
2.1 Volumes with low or 0-gravity	2.1.2	3
2.1 Pressurized and unpressurized volumes	2.1.3	3
2.1 Means of providing protection from debris	2.1.4	3-5
2.1 Minimum Requirement-- overall exterior view of settlement with major visible features, showing rotating and non-rotating/pressurized and non-pressurized sections, and functions	2.1	1-5
2.2 Specify allocation of "down surfaces", with labels for residential, industrial, commercial, agricultural and other uses	2.2.1, 2.2.2, 2.2.3	5-7
2.2 Specify volume and function of micro-g and unpressurized facilities	2.1.3 2.2.1, 2.2.2, 2.2.3	3 5-7
2.2 Show orientation of "down surfaces" with respect to overall design, and vertical clearance	2.2.1, 2.2.2, 2.2.3	5-7
2.2 Minimum Requirement-- overall map of interior land areas, with total area of "down surfaces" inside the artificial gravity volumes, and use of these areas; clearly shown dimensions of areas designated for specific uses	2.2	5-7
2.3 Describe the settlement's construction sequence for the major components	2.3	7
2.3 Minimum Requirement-- drawing(s) showing several intermediate steps of construction	2.3	7-8
2.4 Show attachment to and/or construction on an asteroid for harvesting	2.4.1	8
2.4 Include systems to minimize asteroidal dust into settlement areas	2.4.2	8
2.4 Identify location(s) in the settlement/on the asteroid where ore refining will be conducted	2.4.2	8
2.4 Minimum Requirement-- captured asteroid incorporated in overall exterior drawing, and/or drawing(s) of structures on asteroid surface	2.4	8
2.5 Provide 3 widely separated docking facilities	2.1	1
2.5 *Minimum Requirement*-- include multiple docking port facilities in exterior drawing(s)	2.1	1
3 Operations and Infrastructure		
3.1 Identify an orbital location for the colony and reasons for its selection	3.1.1	9

3.1 Identify sources of materials to be used, means for transport of the materials, and storage between arrival and use	3.1.2	9
3.1 Minimum Requirement– chart or table of identifying materials and equipment needed for the settlement construction process, and location and means for their transport	3.1.2	9
3.2 Basic infrastructure for food growing	3.2.1	10
3.2 Infrastructure for harvesting	3.2.1	10
3.2 Infrastructure for food storing	3.2.1	10-11
3.2 Infrastructure for food packaging	3.2.1	11
3.2 Infrastructure for food delivering	3.2.1	11
3.2 Infrastructure for food selling	3.2.1	11
3.2 Structure for electric power generation (specify kilowatts); distribution and allocation of electricity for specific uses	3.2.2	11
3.2 Internal and external communication system	3.2.3	11-12
3.2 Internal transportation system	3.2.4	12-13
3.2 Atmosphere/climate/weather control (identify air composition, pressure, quantity)	3.2.5	13-14
3.2 Household and industrial solid waste management facilities	3.2.6	14
3.2 Water management facilities (specify required quantity and storage facilities)	3.2.7	14
3.2 Day/night cycle provision	3.2.8	15
3.2 Transportation corridors throughout	3.2.4	13
3.2 Diagram and/or map to show export to port facilities	3.2.9	15
3.2 Show dimensions on drawings of vehicles and rights-of-way	[3.2]	[10-15]
3.2 Minimum Requirement– dimensioned drawing(s) showing systems which provide required infrastructure, and their configurations	3.2	10-15
3.3 Identify existing or new on-orbit infrastructure required (vehicles, satellites, etc.)	3.3.1	15-17
3.3 Minimum Requirement– chart or table with space-based infrastructure and vehicles required for settlement operation; which will be developed commercially vs. included in contract	3.3.1	15-17
3.4 Include plants for human consumption in residential and commercial areas	3.4.1	17
3.4 Include growing of animal feed and animals in separate areas	3.4.2	17
3.4 Minimum Requirement– in agriculture description, account separately for production of feed and facilities for animals in drawing(s) and table(s)	3.4	17
3.5 Develop innovative approaches for design and materials of furniture, interior finishing, plumbing and kitchen equipment	3.5.1, 3.5.2, 3.5.3, 3.5.4	17-18
3.5 Minimum Requirement–in chart of materials sources, separately account for materials needed for residential interiors/amenities	3.1.2	9
4 Human Factors		
4.0 Allow for comforts of "home" in space	4.0	19

4.0 Allow for natural sunlight and views of space and Earth to residents	4.0	19
4.1 Provide facilities for services in a comfortable community environment: housing, education, entertainment, medical, parks/recreation, etc.	4.1.3	19
4.1 Specify variety and quantity of consumables and other supplies	4.1.4	20
4.1 Public areas designed with open space and consideration of psychological factors	4.1.2	19
4.1 Specify means of distributing consumables to Bellevistat residents	4.1.4	20
4.1 Minimum Requirement– map(s) and/or illustration(s) with community designs and location of amenities, with distance scale; identify percentage of land for roads and paths	4.1	19-20
4.2 Provide designs of typical homes, with clearly labeled room sizes	4.2.1	20
4.2 Minimum Requirement-- external drawing and interior floor plan of at least one home design; the area (preferably in square feet) for each residence design, and the number required for each design	4.2	20-21
4.3 Provide designs of systems, devices and vehicles intended for human use inside and outside the settlement	4.3.1	21-22
4.3 Identify means for people to move safely about micro-g areas	4.3.2	22
4.3 Provide for spacesuit designs for work outside pressurized volumes	4.3.2	22
4.3 Minimum Requirement-- chart or table identifying major categories of work people will do in and around the settlement; list of tools needed for these tasks	4.3.1	21-22
4.4 Describe and show design styles for at least 3 different types of neighborhoods for preferences	4.4	23
4.4 Minimum Requirement--on interior map(s), identify locations and sizes of different neighborhoods	4.4	23
4.5 Provide a variety of activities, entertainment and recreational options to encourage physical fitness and mental stimulation	4.5	23
4.5 Minimum Requirement-- show and/or describe examples of pastimes for residents	4.5	23
5 Automation Design and Services		
5.0 In computer descriptions, provide types and capacities of data storage media, data collection and distribution, and user access to networks	5.0.1	24
5.0 In robot designs, clearly indicate dimensions and how they perform tasks	[5]	[24-30]
5.1 Describe use of automation for construction: transportation and delivery of materials, assembly, interior finishing	5.1.1	25
5.1 Minimum Requirement-- chart or table describing automated construction/assembly devices, and their purpose	5.1.1	25
5.2 Specify automation systems for maintenance, repair and safety functions	5.2.1	26-27

5.2 Include backup systems and contingency plans in case of failure	5.2.3	27
5.2 Define locations of computers, servers, and critical robots	5.2.4	27
5.2 Provide that emergency robots can survive solar flare activity	5.2.1	26
5.2 Describe means for authorized personnel to access critical data and computers/robots	5.2.5	27-28
5.2 Include security measures to assure that only authorized personnel have access, for authorized purposes only	5.2.5	27-28
5.2 Minimum Requirement--chart or table listing anticipated automation requirements for operation, identifying particular computers/robots to meet each need	5.2	25-28
5.3 Specify automation for livability, productivity, and convenience	5.3.1, 5.3.2	28
5.3 Emphasize use of automation for maintenance/routine tasks: reduce manual labor	5.3.1, 5.3.2	28
5.3 Provide for privacy of personal data and control of systems in private spaces	5.3.3	28-29
5.3 Describe access to community computing, robot resources from individual homes/work	5.3.3	29
5.3 Minimum Requirement-- drawings of computers and robots that people will encounter, diagrams of network(s) and bandwidth requirement for connectivity	5.3.4	29
5.4 Develop automated systems for finishing interiors, including plumbing and wiring, lighting, painting, floor installation, and furniture	5.4.1, 5.4.2, 5.4.3	29-30
5.4 Minimum Requirement--drawing(s) of interior finishing system(s) in operation, with estimated time to complete interior of typical building(s)	5.4.1, 5.4.2, 5.4.3	29-30
5.5 Develop automated system(s) for mining and transporting ores to refineries	5.5.1, 5.5.2	30
5.5 Minimum Requirement-- drawing(s) of mining system(s) in operation, with description of number of human controllers required	5.5.1, 5.5.2	30
6 Schedule and Cost		
6.1 Show time from awarding of contract until completion of settlement	6.1	31-32
6.1 Minimum Requirement-- show dates for duration/completion of major design, construction and occupation, in a list, chart, or drawing	6.1	31-32
6.2 Specify costs for Bellevistat in U.S. dollars	6.2	33-35
6.2 Estimate number of employees per design phase	6.1	31-32
6.2 Minimum Requirement-- chart(s) or table(s) listing separate costs associated with construction phases, and clearly showing total cost billed to Foundation Society	6.2	33-35
7 Business Development		
7.1 Ores harvested will be approx. 1 km in diameter, attached or nearby	7.1.1	36
7.1 Design "one way" re-entry vehicle, from asteroid	7.1.2	36

materials and recyclables, to transport raw materials and space-manufactured products to Earth's surface		
7.2 Provide facilities for manufacturing and assembly of spacecraft for interplanetary and lunar landing applications	7.2	36
7.2 Bellevistat will provide components for solar power satellites, antennas, future settlements and other requested projects	7.2	36
7.2 Bellevistat will provide special equipment for large-scale space and lunar construction projects (cranes, trucks, bulldozers, mining, etc.)	7.2	36
7.3 Anticipate tourists	7.3	37-38
7.3 Show locations of hotels/visitor amenities	7.3	37-38
7.3 On interior maps, show tourist locations and recommended tourist activities	4.1.3	19
7.3 Provide observation points for tourists-- mining, refining, manufacturing operations	7.3.3	37
7.3 Show and describe 0-g games for all	7.3.4	37-38
7.3 Show and/or describe access to and use of communications, computing, and robot resources, including security to prevent unauthorized access	7.3.5	38
8 Compliance Matrix		
8.0 Compliance Matrix-- specify page and subsection where each requirement is addressed	8.0	39-43

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