

BELLESTAT



UNIVERSITY HIGH SCHOOL
LEYTNE, CALIFORNIA, USA

20th Annual International Space Settlement Design Competition

Proposing Team Data 2013

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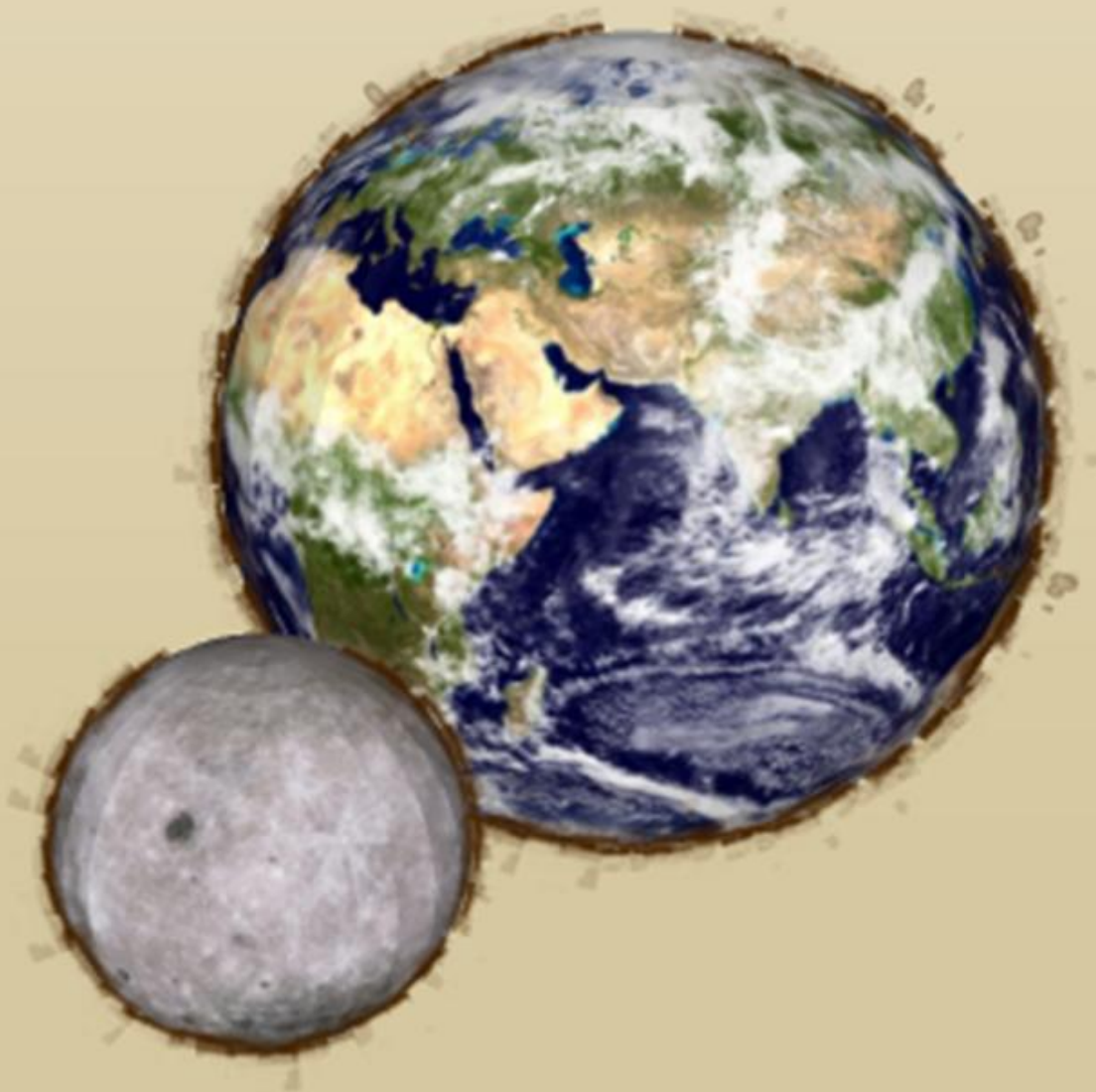
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1.0 EXECUTIVE SUMMARY



SECTION 1 : Executive Summary

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

One of the most major successes at Bellevistat was the discovery of silicon resembling the structure of carbon nanotubes, dubbed “buckystructures.” These buckystructures are strong in tension, can be formed into flexible strands, and can be made into a myriad of permutations – ones that have thermal insulating qualities, ones that conduct electricity, ones that prevent penetration by space debris. We plan to go far beyond the current research being conducted on these buckystructures, to fully realize their true potential.

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

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

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

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

E . O

STRUCTURAL DESIGN



SECTION 2 : Structural Design

2.1.1 - Settlement Description

The Belvestat Settlement has 12 major separable volumes, 8 of which are extensively dedicated to conjoined residential, commercial, and agricultural areas. The settlement consists of 4 tiers of tori. Each tier includes 3 concentric tori and the outer two concentric tori make up the aforementioned 8 separate habitable volumes. Since gravity decreases the closer to the center of the settlement, the inner tori are used for special purposes. At 0.50 g, the inner tori are used mainly for storage of resources such as water and food, sub-earth level gravity research facilities, and high-end entertainment parks that take advantage of the inner tori's low gravity. While most of the 0.50g tori are used for the aforementioned purposes, there are residential areas for Belvestat Settlers who wish to live in this unique low gravity environment. Each of the concentric tori is connected to other tori by 12 radial spokes. Airlock systems along the spokes separate the aforementioned 12 separable volumes in case of an emergency.

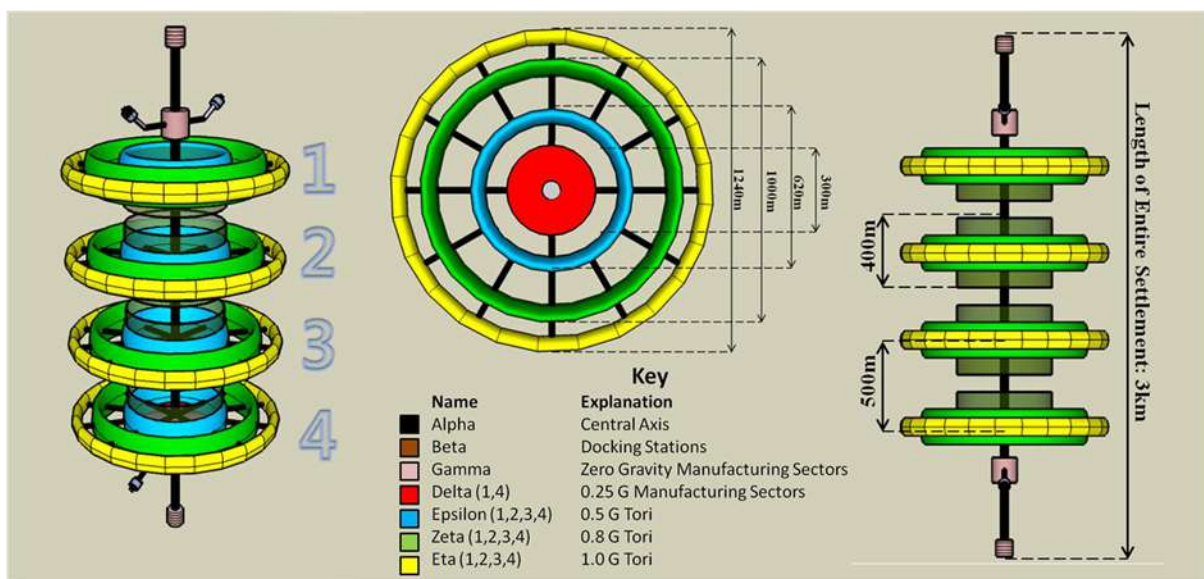


Figure 2.1.1: Settlement Overview

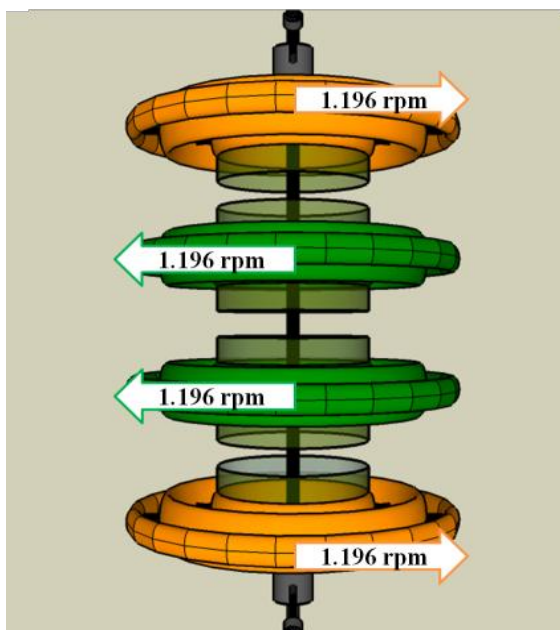


Figure 2.1.2: Direction of Tori Rotation

On the Belvestat Settlement, tiers 1 and 4 (colored orange) will rotate in a clockwise direction at a rate of 1.196 rpm. This angular velocity will create environments with 1.00g, 0.80g, and 0.50g centripetal accelerations for the outermost, middle, and innermost tori, respectively. Tiers 2 and 3 (colored green) will rotate counterclockwise at 1.196 rpm to counter the opposing directional force of tiers 1 and 4 and effectively prevent the central axis from spinning out of control.

Such settlement structure enables the four tiers of tori to be rotated not by small yet costly rocket propulsion units only, but also by a much cheaper alternative, a motor-like spin mechanism initiated about the central axis. To prevent excess stress from compromising the settlement's structural integrity near the central axis, the rotation of the settlement will be initiated through first firing up the small rocket propulsion units that are distributed throughout the outer perimeter of the two outermost tori of all four

tiers. Once the angular velocity has been established to the necessary 1.196rpm for each tier, the angular velocity will be maintained by the aforementioned motor-like spin mechanism. Since the mechanism is electrically powered, the rotational power output can be fine-tuned to consistently maintain the ideal angular velocity. The central axis, 0g manufacturing sections and various port facilities remain as non-rotating sections.

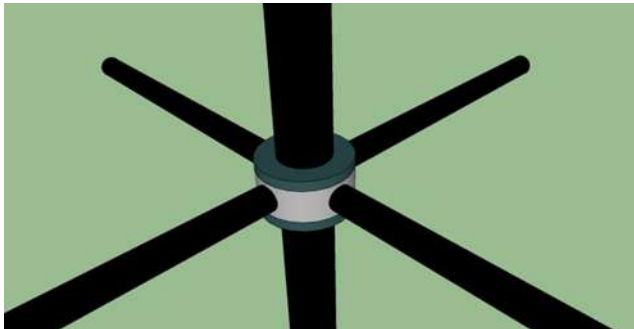


Figure 2.1.3: Motor Close-up

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

To accommodate the various environmental needs of Bellevistat's settlers, Bellevistat will not only have three different levels of gravity, but also three different atmospheric pressures. The possible combinations allow for 9 unique gravity-atmospheric pressure pair environments. The three different levels of atmospheric pressures available in Bellevistat will be 1.00 atm, 0.80 atm, and 0.60 atm. All three tori of tier 1 will have 0.60 atm pressure, all 6 tori of tiers 2 and 3 will have 1.00 atm pressure, and all three tori of tier 4 will have 0.80 atm pressure. Detailed specifics of the Bellevistat Settlement's environments will be further explored in the Human Factors section.

Bellevistat will mostly draw its energy from the 8 solar panels located on the two sides of the innermost tori. While most solar panels are cylindrically shaped, the solar panels on the top and bottom tiers facing the two docking stations of the settlement will be shaped like a large concave disk to maximize the solar energy yield when one of the settlement's poles directly face the sun. The solar panels have been physically attached to the settlement instead of being carried by a nearby satellite to inhibit complete isolation of the settlement's power source. Despite the fact that such allocation will not provide the most energy output to the settlement, the benefit of being able to quickly reach and fix the settlement's power source in case of solar panel malfunction greatly outweigh the allocation's relatively minute cost.

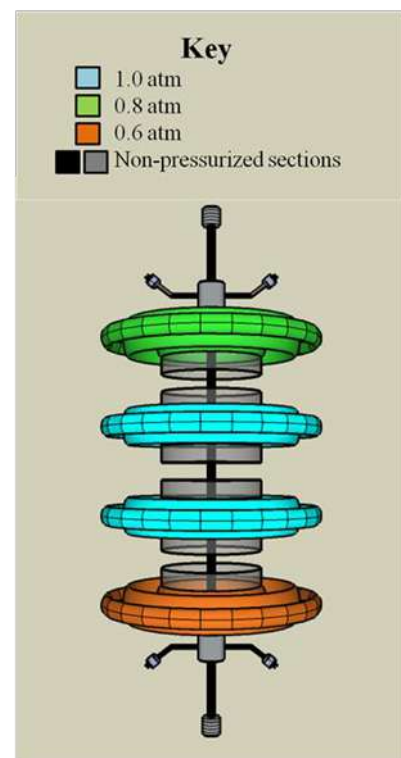
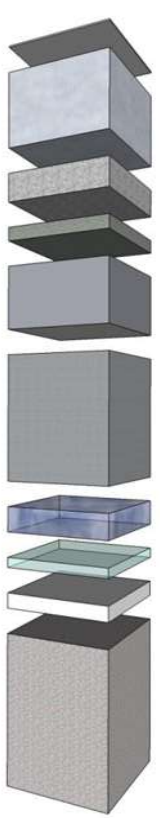


Figure 2.1.4: Atmospheric Pressure

2.1.2 - Hull Components

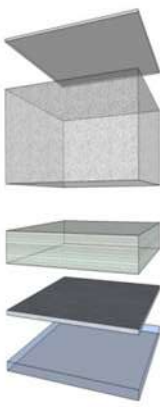
Due to the settlement's placement at the L4 Lagrange point, frequent impact by debris as well as harmful exposure to radiation are both factors which the following hull components will reduce the impact of for the settlers. Most components are placed in order to minimize radiation exposure of the settlers, while three meters of polyethylene foam is placed to reduce impact damage to the rest of the hull components. The following list of materials used for hull components are in order from exterior to the interior side of the settlement.

Bellevistat's main hull will be composed of Raguard to shield the settlement from high-energy cosmic radiation, aluminum 7075-T6 alloy to prevent the settlement from overheating on the side of the settlement facing the Sun, polyurethane to give the settlement resistance to structural stress, borated polyethylene to further protect the settlement from low-energy radiation, and titanium 6.6.2 alloy and 18Ni2400 maraging steel for further structural support. Then the settlement will be further protected by layers of silica aerogel for thermal insulation, liquid water to abate temperature fluctuations, buckystructures to prevent the escaping of the settlement's atmospheric gasses in case of a hull breach, and lastly a layer of Lunar Regolith to give an earth-like surface on which the settlement will be established.



Materials (From Outside)	Usage	Properties	Thickness
Raguard	Primary radiation shielding	High-energy radiation protection	1.00 x 10 ⁻⁴ m
Aluminum	Thermal protection, structural support	Efficient heat dissipation, structural rigidity	1.50 m
Polyurethane	Structural support	Efficient dissipation of structural stress	0.570 m
Borated Polyethylene	Secondary radiation shielding	Low-energy radiation protection	0.270 m
Titanium 6.6.2 Alloy	Structural support	High resistance to structural failure	1.25 m
18Ni2400 Maraging steel	Structural support	High resistance to structural failure	2.50 m
Silica Aerogel	Thermal insulation	Very low thermal conductivity	0.500 m
Liquid Water	Secondary thermal protection, tertiary radiation shielding	High specific heat – prevention of temperature fluctuations	0.200 m
Buckystructures	Gas leak prevention	Flexible, high tensile stress resistance	0.300 m
Lunar Regolith	A firm ground for the settlement's building structures and large botanical root structures	Earth-like surface – serves as the bedrock of Bellevistat Settlement	3.00 m

Figure 2.1.5, Table 2.1.1: Hull Components - Wall



Materials (From Outside)	Usage	Properties	Thickness
Raguard-Titanium Dioxide Compound	Primary radiation shielding	High-energy radiation protection	1.00 x 10 ⁻³ m
Clear Polyurethane	Structural support	Efficient dissipation of structural stress	1.00 m
Silicon Dioxide	Structural support, secondary radiation shielding	Low-energy radiation protection, structural rigidity	0.350 m
Mesh of Titanium 6.6.2 Alloy	Supplementary structural support	High tensile stress resistance	5x10 ⁻³ m
High-impact Acrylic Plastic	Structural support, thermal insulation	High resistance to structural failure, low thermal conductivity	0.100 m

Figure 2.1.6, Table 2.1.2: Hull Components - Window

Settlers of Bellevistat will have natural views of the Earth and the Moon through protective windows. The reinforcements on the windows will include of a thin coating of Raguard-titanium dioxide compound to lessen the harmful effects of cosmic radiation, a clear polyurethane surface to give rigidity to the surface of the settlement's windows, and a silicon dioxide layering to maximize visibility while minimally compromising the structural integrity and the radiation protection abilities of the settlement. The windows will also be meshed with titanium 6.6.2 alloy and a layer of high impact acrylic plastic to further enhance the window's structural integrity and thermal insulation abilities.

2.2 Percentage Allocation

Compartments	Specialization	Each 1.00g Tori		Each 0.80g Tori		Each 0.50g Tori	
		Surface Area (m ²)	Percent Allocation (%)	Surface Area (m ²)	Percent Allocation (%)	Surface Area (m ²)	Percent Allocation (%)
Agricultural	In Vitro Food Production	24,595	6.38%	23,019	7.53%	10,480	5.23%
	Plant Growing	59,444	15.42%	47,567	15.56%	23,724	11.84%
	Food Processing	39,437	10.23%	31,885	10.43%	15,288	7.63%
	Sub Total	123,464	32.03%	102,475	33.52%	49,492	24.70%
Residential	Residences	46,800.	12.14%	33,077	10.82%	12,884	6.43%
	Hospitals	18,697	4.85%	13,818	4.52%	6,512	3.25%
	Hotels	7,440	1.93%	4,800.	1.57%	1,743	0.87%
	Commercial Buildings	74,902	19.43%	57,594	18.84%	28,513	14.23%
	Recreational Space	35,658	9.25%	26,443	8.65%	42,227	21.08%
	Schools	18,619	4.83%	13,512	4.42%	6,111	3.05%
	Sub Total	202,125	52.43%	149,247	48.82%	98,002	48.91%
Operational	Storage	16,654	4.32%	12,809	4.19%	49,929	23.92%
	Transportation	20,200	5.24%	15,683	5.13%	11,682	5.83%
	Scientific Research	28,643	7.43%	29,592	9.68%	36,328	18.13%
	Waste Management	11,064	2.87%	8,713	2.85%	4,869	2.43%
	Sub Total	59,910.	15.54%	53,981	17.66%	52,878	26.39%
TOTAL	-	385499	100%	305703	100%	200373	100%

Table 2.2.1: Dimensions of Down Surfaces per Tori

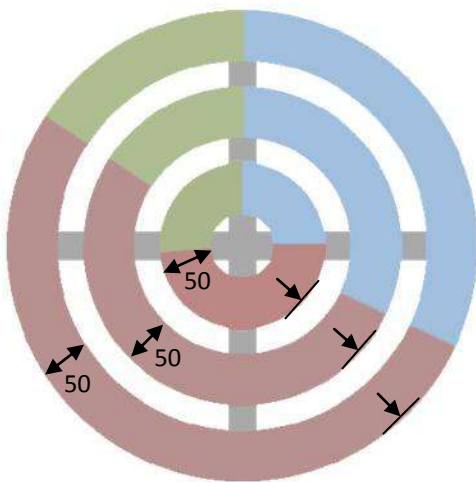


Figure 2.2.1: Map of Surface Area Allocation

Red - residential; Blue - agricultural;

Green – operational

↘ arrows indicate direction of down surface







↔ arrows indicate vertical clearance in meters

To minimize the impacts of a potential catastrophe, Bellevistat's habitable volumes will have percentage allocations that are close to uniform throughout the settlement. Such redundancies would minimally compromise the functioning of Bellevistat if a sector was not able to function properly.

Our settlement's large area allows for people to have plenty of room for their daily activities. After taking into account each individual resident's spatial needs, 1336320m² was calculated to be enough area for all 11,500 residents. Assuming that 7% of both extremities of the settlement's torus width is not utilized, the arc length of the bottom torus times the entire torus' circumference gives us an estimate that we have ample space to provide for our Bellevistat Settlers. The above figure shows each of the 3 different kinds of tori (1.00g, 0.80g, and 0.50g).

While there are residential areas available in the 0.5 0.50g area, these areas do not contain permanent housing for the settlers to live in due to the environment's low gravity. Details of human habitation on Bellevistat will be further explored in the Human Factors section

2.3 Construction Sequence

		
<p>1. Construct the central axis</p>	<p>2. Attach docking station, enabling transport ships to supply construction materials</p>	<p>3. Construct the main spokes and the rotational mechanism around the central axis.</p>
		
<p>4. Construct the innermost tori. Layer the internal surface with lunar regolith.</p>	<p>5. Attach solar panels to supply power to the settlement.</p>	<p>6. Extend the main spokes</p>

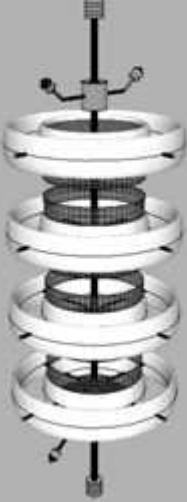
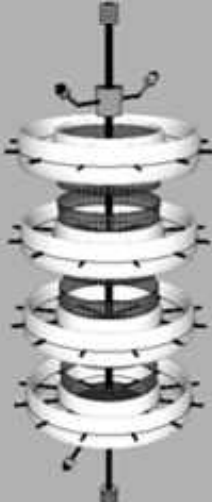

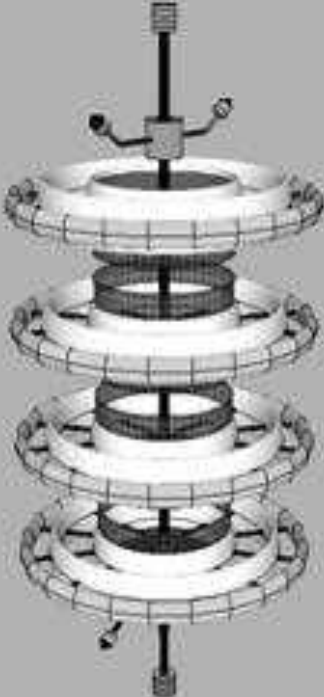
		
<p>7. Construct the second ring of tori on each tier. Like the inner ring, the internal surface is covered with lunar regolith.</p>	<p>8. Construct all minor spokes, which brings the total number of spokes to 12, including the main spokes. The minor spokes connect the 3 tori, but are not connected to the central axis.</p>	<p>9. Construct the outer tori and layer the internal surfaces with lunar regolith. Add pressurized atmosphere to all 12 tori.</p>
		
<p>10. Rotation of the settlement to generate artificial gravity is initiated by small rocket propulsion units and then maintained by electromagnetic motors. The central axis remains static relative to the rotating tori.</p>		

Table 2.3.1: Construction Sequences

2.4 Buckystructure Production

The settlement located at the L4 Lagrange point can easily access lunar silica for use in buckystructure production. Buckystructures similar to carbon nanotubes will be integrated into the hull for insulation and radiation shielding as well as reinforcing other structures. Because of the high demand for its extraordinary tensile properties and strength, an investment in buckystructure production is predicted to generate significant revenue. For that reason, buckystructure manufacturing will be an important industry on the settlement.

The process of buckystructure production requires a very specific environment. Our production sites will utilize the laser ablation technique, which has a high 70% production yield. Each unit will consist of a high-temperature chamber into which a pulsed laser vaporizes a silicon target. Buckystructure nanotubes will develop on the cooler surfaces of the chamber as the vaporized silicon condenses. The temperature can be adjusted to monitor the diameter of the nanotubes.

To generate mass quantities of buckystructures efficiently, there will be 150 units for production in both Gamma and Delta, the 0g and 0.25g manufacturing sectors, taking up a total of 50,000 sq ft under a 26 ft ceiling height in both of these facilities. Delta's unique 0.25 g environment will maximize efficiency by minimizing the energy required for production processes while still giving the production site enough centripetal acceleration for the materials to aggregate into a certain direction. To meet Bellevistat's Business Operational needs, Delta, the 0.25g manufacturing sector has been designed with additional features such as an extra storage area, a smaller version of Gamma's 0g manufacturing sector, and 1.0g and 0.8g processing and testing sites. Because Delta's radius from the Central Axis is only 190 meters while its maximum centripetal acceleration 1.0g, Delta will spin at a faster rate than the rest of the settlement - at a rate of 2.169 rpm.

The Delta buckystructure manufacturing sectors are located between the spokes of tiers 1 and 4 and the concave solar panels. This location enables Delta to be rotated independently of the rest of the settlement, which is essential for Delta sectors' complete functionality. In addition, Delta's close proximity to the concave solar panel as well as other solar panels ensures that Delta will have access to more than just the required 1 MW of continuous electrical power. Furthermore, Delta manufacturing sectors' advantageous location of being near the torii of tiers 1 and 4, the ports, as well as the 0-G manufacturing sector Gamma, enables the movement of materials between various facilities of Bellevistat to be easily carried out by Pelton, the settlement's main transport robot. Movement of parts within Delta will be also done through the usage of specialized Pelton units that are equipped with tools specified for transporting buckystructure-related materials.

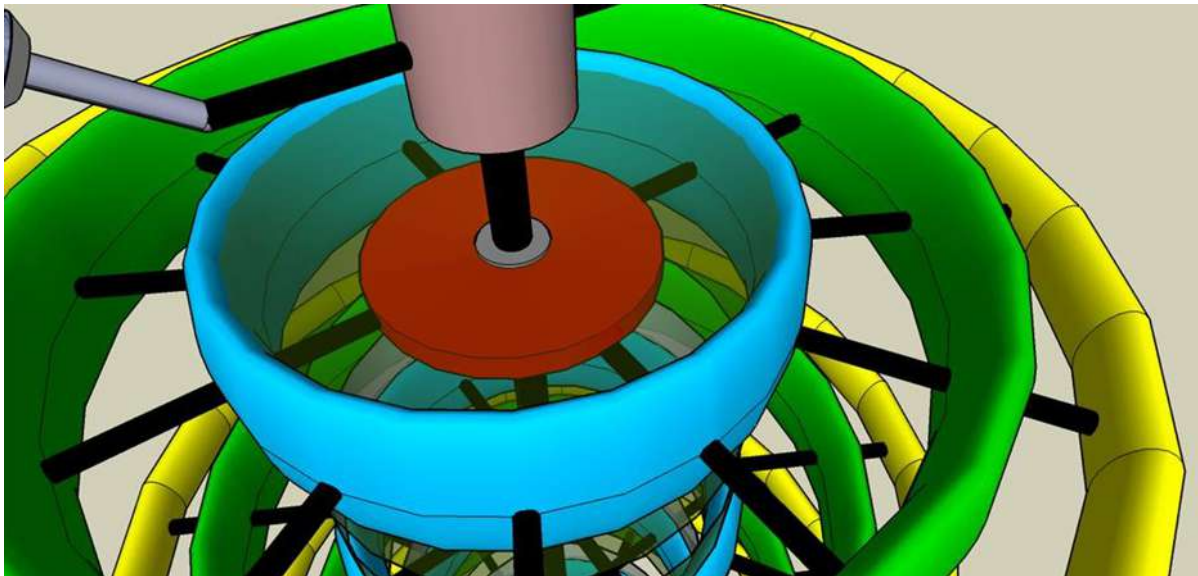


Figure 2.4.1 Buckystructure Production Facility (Red)

2.5 Port Facilities

The ports are located on the very top and bottom of the central axis. The axis is the only section of the settlement that does not rotate, thus making it the ideal location for ports. On each port, there are 3 docking stations of different sizes. The largest of the 3 is connected to the main settlement via the extension of the central axis. Two arms branch out of the central axis in a perpendicular angle, and then bend 45 degrees away from the center of the settlement to provide maximum maneuverability for spaceships.

The location where the three branches meet is Gamma, the Zero Gravity Manufacturing sector. This allocation of Gamma enables lunar materials and other resources to not travel far before being processed for usage in the settlement. Furthermore, a portion of Gamma is dedicated to accommodate incoming and outgoing travelers and guests of the settlement, and thus acts as a centralized hub for these individuals before coming in to the main settlement or going out to the docking stations.

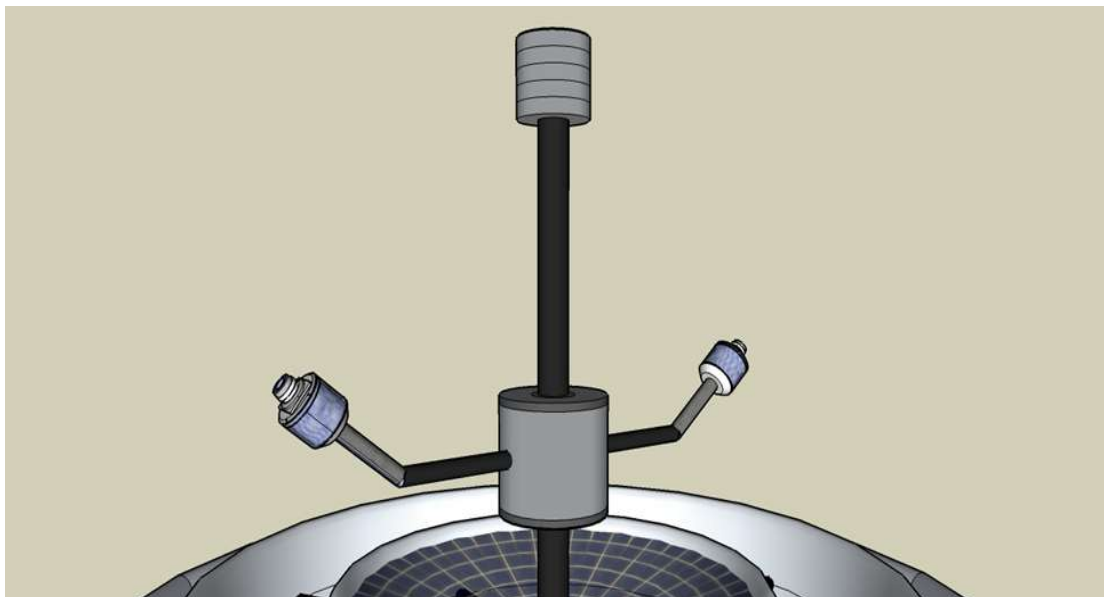


Figure 2.5.1: Docking Stations

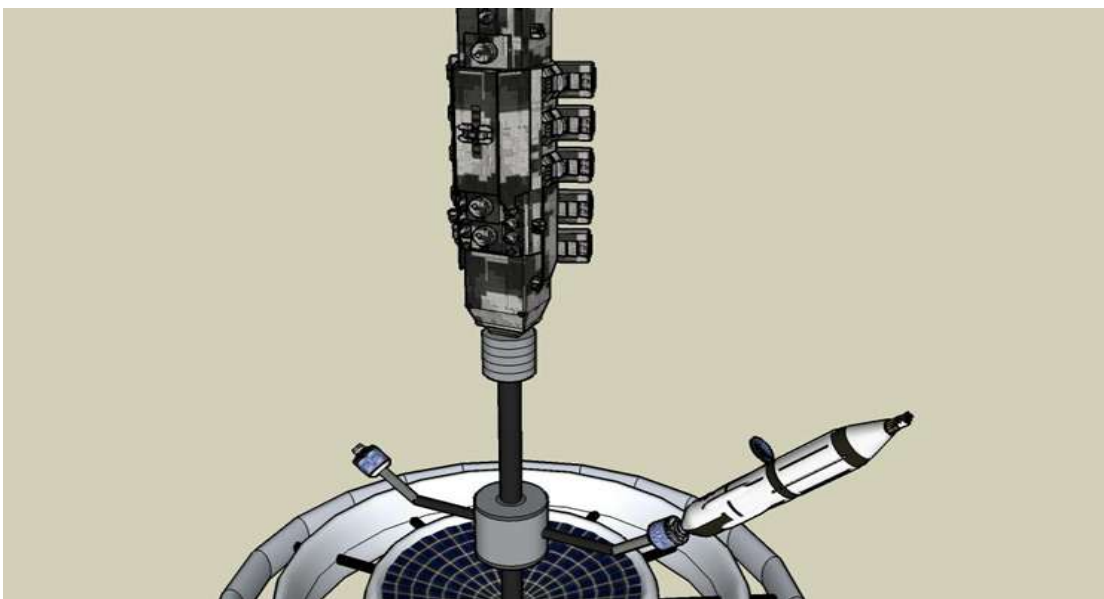
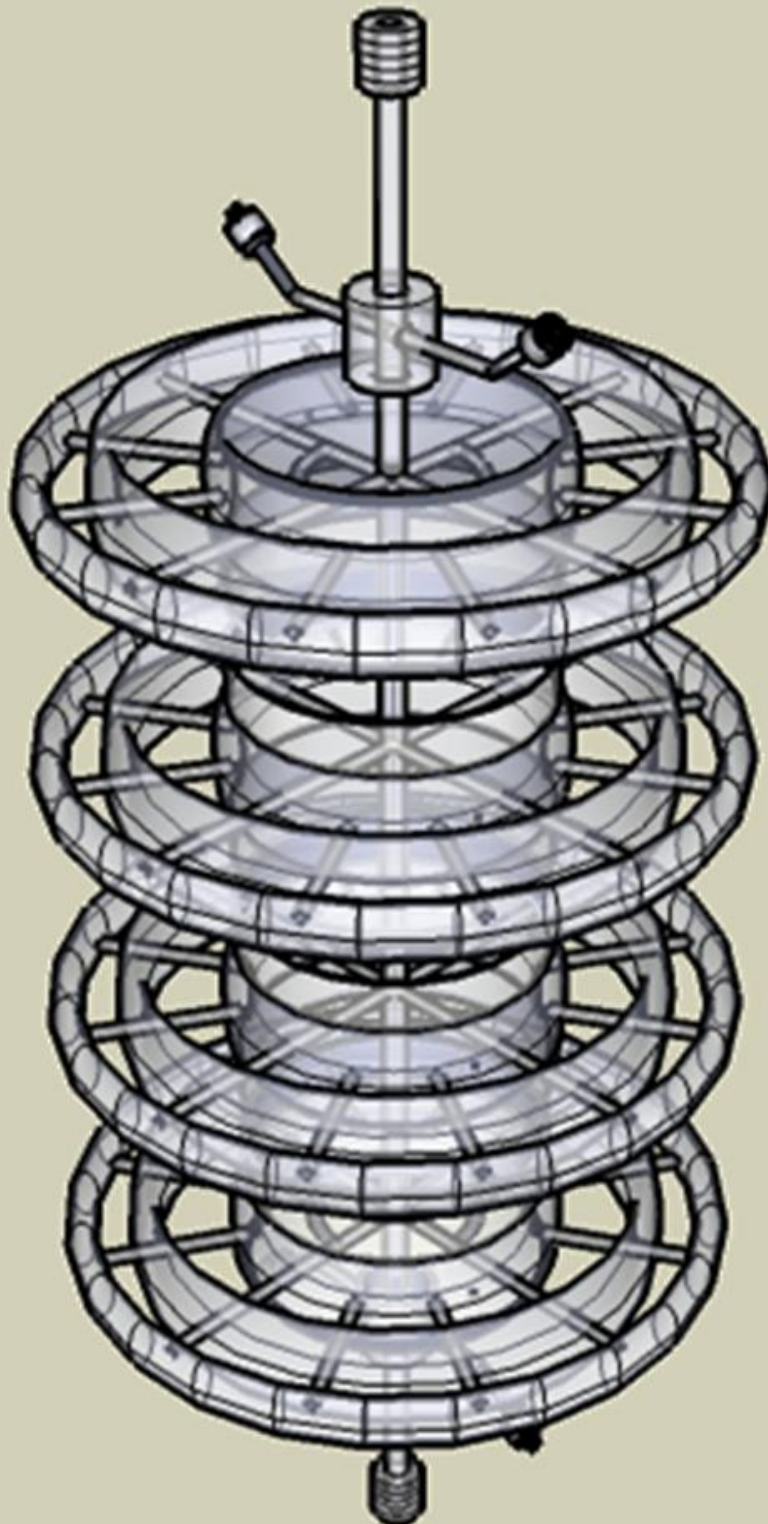


Figure 2.5.2: Docking Stations with Ships in Port

3.0 OPERATIONS AND INFRASTRUCTURE



SECTION 3: Operations and Infrastructure

3.1.1 Orbital Location and Specifications

Bellevistat will orbit around the Earth-Moon L4 Lagrangian point, approximately 380,000 kilometers from both the Moon and the Earth and 60 degrees in front of the Moon's orbital path around the Earth. This location was chosen due to its orbital stability, especially in comparison to the L1, L2, and L3 points. Furthermore, the location will complement the location of Alexandriat on the L5 Lagrangian point.

3.1.2 Sources and Transportation of Construction Materials and Equipment

Material	Amount	Source	Transportation	Storage
Lunar Regolith	2.75×10^5 kg	Moon	Nadir	Alpha
Buckystructures	7.50×10^6 kg	Moon	Nadir	Alpha
Silica Aerogel	3.85×10^3 kg	Moon	Nadir	Alpha
Water	5.00×10^6 L	Alexandriat & Earth	Whitman	Alpha
18Ni2400 Maraging Steel	4.42×10^7 kg	Asteroids, Earth, Moon	Bauer, Nadir	Alpha
Titanium 6.6.2 Alloy	6.91×10^7 kg	Asteroids, Earth, Moon	Bauer, Nadir	Alpha
Borated Polyethylene	3.30×10^4 kg	Alexandriat, Earth	Bauer, Nadir	Alpha
Polyurethane	2.45×10^4 kg	Earth	Bauer	Alpha
Aluminium 7075-T6 Alloy	8.12×10^6 kg	Asteroids, Earth, Moon	Bauer, Nadir	Alpha
Robots	20,000 Units	Alexandriat, Earth	Bauer, Nadir	Alpha
Electronics	5.33×10^4 kg	Alexandriat, Earth	Bauer, Nadir	Alpha
Solar Panels	1.50×10^6 m ²	Alexandriat, Earth	Bauer, Nadir	Alpha
Fission Fragment Reactors	4 Units	Alexandriat, Earth	Bauer, Nadir	Alpha
Carbon Nanotubes	1.28×10^6 kg	Alexandriat, Earth	Bauer, Nadir	Alpha
Raguard	7.81×10^3 kg	Earth	Bauer	Alpha
Atmospheric Gases	8.24×10^{11} L	Earth	Whitman	Alpha

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

3.2.1 Atmosphere, Climate, and Weather Control

Season	Months	Temperature	Humidity	Daytime
Spring	March - May	20 °C	50%	12 hrs.
Summer	June - August	25 °C	70%	14 hrs.
Autumn	September - November	20 °C	50%	12 hrs.
Winter	December - February	15 °C	30%	10 hrs.

Table 3.2.1: Seasonal Variations on Belvestat

Atmospheric composition on Belvestat will resemble that of Earth, but trace gases will be removed to reduce costs. Because the atmospheric pressure will be different throughout the settlement, atmospheric composition will vary.

HEPA filters as well as ultraviolet and ozone treatment will purify and decontaminate the air throughout its circulation. In addition, spectrometry and spectrophotometry will detect pollutants,

which will be removed using activated charcoal and combustion burners. Polymer “sponges” will absorb excess carbon dioxide, which will then undergo the Bosch reaction. Oxygen can be generated through the electrolysis of water, and chemical oxygen generators will produce oxygen quickly in emergency situations.

Belvestat will also experience four distinct seasons marked by changes in temperature, humidity, and day length. Weather such as rain or snow will be simulated in “weather parks” around residential areas.

Humidifiers and chemical dehumidifiers will maintain desired humidity levels throughout Belvestat, while central temperature control consisting of a network of heat sinks and sources connected with buckystructure coolant tubes will maintain thermal and temperature settings.

0.6 atm	Percentage	Pressure (atm)	Weight (kg)	Volume (m ³)
Nitrogen	62.0%	0.372	4.12 x 10 ⁷	3.29 x 10 ⁷
Oxygen	37.3%	0.224	2.59 x 10 ⁷	1.98 x 10 ⁷
Carbon Dioxide	0.700%	0.700	6.71 x 10 ⁵	3.71 x 10 ⁵

0.8 atm	Percentage	Pressure (atm)	Weight (kg)	Volume (m ³)
Nitrogen	71.5%	0.572	8.38 x 10 ⁷	6.70 x 10 ⁷
Oxygen	28.0%	0.224	3.44 x 10 ⁷	2.63 x 10 ⁷
Carbon Dioxide	0.500%	0.00394	8.48 x 10 ⁵	4.69 x 10 ⁵

1.0 atm	Percentage	Pressure (atm)	Weight (kg)	Volume (m ³)
Nitrogen	77.2%	0.772	5.67 x 10 ⁷	4.53 x 10 ⁷
Oxygen	22.4%	0.224	1.73 x 10 ⁷	1.32 x 10 ⁷
Carbon Dioxide	0.400%	0.00394	4.25 x 10 ⁵	2.35 x 10 ⁵

Table 3.2.2: Atmospheric Composition and Requirements on Various Areas of Belvestat

3.2.2 Food Production and Distribution

Belvestat will use conveyor-belt aquaponics technology, a novel combination of hydroponics and aquaculture, for the production and harvest of fruits, vegetables, grains, and fish. Aquaponics bypasses the limitations of its component systems and additionally possesses the advantages of both systems. Most fruits, vegetables, and grains will grow on trays floating on circular nutrient water tanks containing high-protein fish and crustaceans. By the end of each cycle around the water tank, crops in the tray will be planted, grown, and ready for automated harvest. Meanwhile, fish and crustaceans in the water will be grown and harvested, with effluents in the water serving as fertilizer for the crops above. Other crops will grow in porous vermiculite trays in rotating cylinder carts that periodically dip into a water-based nutrient trough.

Automated robots will conduct the management of these systems, and regular inspections will provide quality control. 24-hour LED lights at specific wavelengths will optimize crop growth and harvesting efficiency. Furthermore, in vitro meat will provide proteins and variety to the settlers’ diets.

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

Table 3.2.3: Trade Study of Food Production Methods

Harvesting will be fully automated, with harvesting robots programmed to detect ripeness by size, color, and chemical factors with stereovision “eyes” and chemical “noses”. In addition, these robots can also detect diseases in crops. Similar robots will harvest high-protein fish and crustaceans. Harvested food will then be transported by conveyor belts to a central processing plant.

Fresh food and beverages for immediate distribution to restaurants and grocery stores will be packaged in reusable biopolymer containers. Surplus food will be freeze-dried, vacuum-sealed, and sent to central storage units. Surplus food will provide

an 8-week supply in emergency scenarios.

Robots will handle delivery of the food to grocery stores and restaurants, which will distribute the food as needed and sell food to people individually. The amount of food that a person can buy will be limited to minimize food waste, although people will be allowed to make a request for additional food if necessary.

3.2.3 Electrical Power Generation

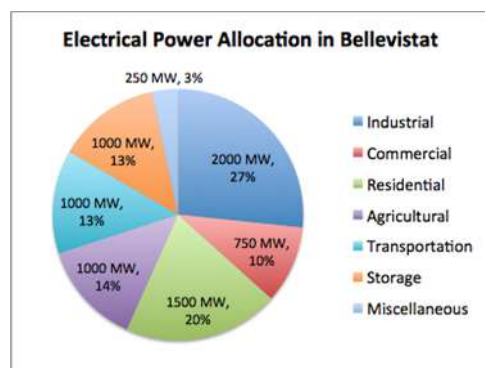


Figure 3.2.1: Electrical Power Allocation

Primary electrical power generation for Bellevistat will be provided by high-efficiency solar panels with photovoltaic cells based on graphene and buckystructure technology that will cover approximately 1,700,000 square meters and generate 5,000 megawatts of power. Secondary electrical power generation will come from four fission fragment reactors that will produce 2,500 megawatts of power. Tertiary electric power generation will come from the combustion of biogas derived from anaerobic digestion (refer to 3.2.5).

Excess electrical power will be stored in high-density batteries and capacitors based on molten salt, carbon nanowires, and buckystructure technology. These batteries will be located throughout Bellevistat will have a total power capacity of 10 gigawatts and maintain an emergency power supply for up to 6 months. Buckystructure wires will provide AC electricity throughout Bellevistat.

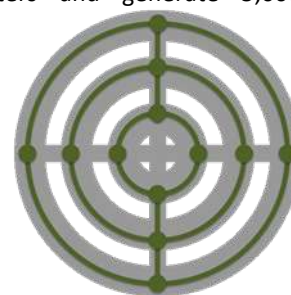


Figure 3.2.2: Map of Electrical Power Lines and Storage Stations

3.2.4 Water Management and Recycling

Bellevistat’s water filtration system will filter water condensate as well as liquid and solid wastes in three stages. Initially, screen filters will filter out solid debris. Secondly, nanofiltration will remove chemicals as well as kill 99.99% of biological contaminants. Finally, reverse osmosis filters with activated carbon will effectively remove any remaining chemical and biological contaminants. Water will additionally be purified with UV and ozone treatment, while iodine and fluoride will be added for public health purposes.

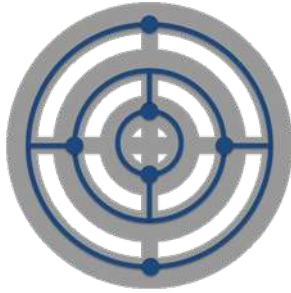


Figure 3.2.3: Map of Main Water Lines and Storage Stations

250 liters of water will be allotted per capita per day, and a total of 2,500,000 liters of water will be circulated through Bellevistat to serve human, agricultural, industrial, and other uses. Another 2,500,000 liters of water will be stored for emergency purposes in tanks made from graphene and carbon nanotubes.

3.2.5 Household and Industrial Waste Management and Recycling

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

3.2.6 Internal and External Communications Systems

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

Table 3.2.4: Trade Study of Communication Systems

Internal communication on Bellevistat will consist of public and personal communications, in addition to peer-to-peer information sharing. A centralized intercom system will make general announcements to residents of specified areas around Bellevistat. Individuals will be able to communicate using portable tablet devices, using voice-over IP. Finally, the intranet system will carry out data transfer for file and information sharing through fiber optic cables, in addition to wireless systems.

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



Figure 3.2.4: Map of Tram Lines and Stations

3.2.7 Internal Transportation Systems

To enhance health, walking will be the primary means of transportation in Bellevistat. Moving walkways will be placed along the entire length of each torus for convenience. Pod-based trams will run through each of the concentric tori, providing inter-torus and intra-torus travel. The tram will also run through Bellevistat's tiers with buckystructure cables to provide transit and transport between levels. Furthermore, buckystructure bicycles will be provided for both transportation and recreation. For the transportation of goods, equipment, and heavy machinery, an additional tram system will travel throughout the settlement. These trams will be reinforced with buckystructures to handle large loads.

3.2.8 Day/Night Cycle Provisions

To emulate conditions on Earth, Bellevistat will follow day/night cycles that change according to the season (refer to 3.2.1) in residential areas. LED lights simulating sunlight will slowly turn on during “sunrise”, and gradually dim during “sunset”. In addition, electrochromism-based smart glass on the exterior walls of each torus will automatically adjust the amount of incoming solar radiation to match day/night cycles.

3.2.9 Required Quantities of Operations Resources and Equipment

Resource/Equipment	Required Quantity	Resource/Equipment	Required Quantity
Gas – Nitrogen	1.45×10^{11} L	Water – Human	1,000,000 L/Day
Gas – Oxygen	5.93×10^{10} L	Water – Agricultural, Industrial	1,250,000 L/Day
Gas – Carbon Dioxide	1.09×10^9 L	Water – Other	250,000 L/Day
Gas – Emergency	2.50×10^5 L	Water – Emergency	2,500,000 L/Day
Food – Vegetables, Grains, Fruits	20,000 kg/Day	Waste – Liquid	1,000,000 L/Day
Food – Meat, Seafood	6,000 kg/Day	Waste – Solid	2,000,000 kg/Day
Food – Emergency	100,000 kg	Communications Devices	15,000 Units
Power – Primary, Secondary, Tertiary	8000 MW/Day	Internal Transport – Trams	20 Trams
Power – Emergency	10 GW	Internal Transport – Bicycles	12,000 Units

Table 3.2.5: Required Quantities of Operations Resources and Equipment

3.3 Construction Machinery

Automated robots will carry out the construction of Bellevistat to significantly reduce human labor, provide efficiency, and enhance stability.

Construction robots will be modular and covered in buckystructures that have thermal insulating qualities to protect from solar flares. They will also be versatile; the robots will have the ability to extend “working arms” in order to reach difficult areas of construction. Furthermore, only the highest-level authorities will be able to control the construction robots, reducing the risk of security breaches and malfunctions.

Multiple robots will be utilized throughout the structure and will also work together. The main construction robots (Wingers) will build the exterior of the settlement and the internal construction robots (Edison) will complete the interior. During construction, transportation bots (Nadir, Whitman, and Bauer) will be continuously delivering materials to the robots that require them. When there is a minor structural lapse with one of the buildings, such as a breach in the wall, Perry will apply buckystructures that will immediately fix the defect. Finally, Slater will be in charge of designing settlements while working with Barnes (large internal construction) to rearrange furniture. All construction robots use advanced 3-D printing technologies for constructing individual parts. Individual parts will be integrated together with welding and/or adhesions with a buckystructure-based polymer glue.

Name/Type	Description	Dimensions (L x W x H)	Quantity
Winger (Main Construction, External Construction)	Modular robots that can interchange different parts for different necessary processes. Height can be adjusted to necessary length. They are also huge robots which can connect different sections of structures together, useful for early, large-scale construction of the settlement structure.	1.5 m x 2.5m x 3 m (extendable to 5 m)	350

Nadir (Transport between Bellevistat and Alexandriat, Moon)	Mainly transports construction materials and equipment. Made out of titanium steel alloy and will be able to carry up to 500 kg of material. Nadir will be a short-range transportation system.	Maximum Payload: 30 m x 30 m	40
Bauer (Transport between Bellevistat and Earth, asteroids)	Also mainly transports construction materials and equipment; however, it is a long-range system. While it can also have variable storage sizes, it is generally larger than Bauer.	Maximum Payload: 6 m x 24 m	40
Whitman (Transport of gases and liquids)	Similar to Nadir and Bauer, Whitman transports any gases and liquids between Bellevistat, Alexandriat, the Moon, the Earth, and asteroids. This is because it can set temperature and pressures.	Maximum Payload: 50 m x 10 m	40
Perry (External Repair)	With a layer of buckystructure to protect them from space debris and solar flares, Perry is able to maintain the external structure. In addition, Perrys also patrol the area around the docking bays, maintaining the shuttles that pass through.	1 m x 1 m x 3.5 m	150
Edison (Small Internal Repair)	Miniature robots are able to navigate the infrastructure and temporarily fix water, gas, and electrical failures. They are able to mark structural failures for future repairs.	4 cm x 2 cm x 1 cm	5000
Barnes (Internal Construction and Repair)	Repair robots are refitted from main construction robots. They are used to construct buildings, set up the different floor plans and put in gas, water, and electricity fixtures.	1.75 m x 1.5 m x 2 m	250
Pelton (Unloading)	Pelton will unload material such as ores and shipping containers outside the settlement at docking bays. Located inside every docking bay, they help the processing and transportation throughout the settlement.	2.75 m x 5 m x 2 m	75
Slater (Intra-settlement Transport)	Slater is capable of transporting materials within the settlement, moving large objects otherwise difficult to carry.	4 m x 2 m x 1 m	35

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

3.4 Paper Production and Machinery

Paper on Bellevistat will comprise of a composite of hemp fibers and buckystructures, which will keep it strong and cheap. The hemp will be grown in the aquaponics system (refer to 3.2.2), and will be genetically modified to enhance growth, strengthen fibers, and remove THC. In addition, chemical pulping as opposed to mechanical pulping will be utilized due to its self-sustainability and ability to produce strong paper. Harvested hemp will be transported to a central paper production facility, where it will first be cooked to remove lignin and separate it into cellulose fibers. The lignin will be used as a fuel source to sustain this process, and buckystructure microfibers will be added to the remaining pulp. Other chemical additives such as chalk and kaolinite will be added to meet desired requirements. Furthermore, specific pulp drying, pressing, smoothing, and cutting processes can vary to produce certain qualities for the final paper product.

To minimize energy and resource consumption used for paper production, all paper products will be recycled. Automated robots will specifically sort out disposed paper products (refer to 3.2.5). These paper

	Corn	Pampas	Hemp	Bamboo	Kelp	Buckystructures
Growth	3	1	3	4	5	3
Cost	4	3	3	2	2	2
Processing	2	4	4	2	2	4
Efficiency	4	3	5	3	1	3
Strength	2	4	2	4	1	5
Total	15	15	17	15	11	17

products will be de-inked using supercritical carbon dioxide, then reconverted to pulp with water, mechanical action, and other chemicals. The resulting pulp can once more be used to create paper products.

Table 3.4.1: Trade Study of Paper Components

Facilities	Process
Hemp Harvesting	Hemp grown in aquaponics system and automatically harvested with robots that shear the hemp.
Hemp Processing and Paper Production	Sheared hemp converted into pulp with chemicals, cellulose fibers extracted, and chemical additives added.
Final Paper Processing and Customization	Pulp dried, smoothed, pressed, and cut according to customer requirements and specifications.
Paper Recycling	Recycled paper deinked and reconverted to pulp with chemicals and mechanical action.

Table 3.4.2: Description of Paper Production Facilities in Bellevistat

3.5 Repair Services for Visiting Ships

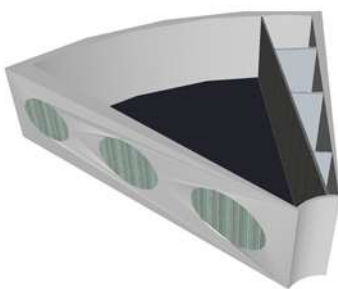


Figure 3.5.1: Repair Docks

Bellevistat will contain docks exclusively devoted to repair services for visiting ships. When visiting ships arrive at unloading/loading docks, nanorobots will visually and physically inspect the surface and interior of ships for any damage during spaceflight. Furthermore, flight recorder data will be retrieved automatically and inspected to discover any anomalies and damage. If any damage is detected, ships will be transferred to the repair dock. There, automated robots will take the necessary steps to effectively repair damaged ships. Depending on the type and extent of damage, the repair process will take between 30 minutes to 12 hours.

Repair docks will differ from unloading/loading docks in various ways. First, the repair docks will contain two levels (floor and subfloor), in contrast to other docks, which will contain three or five levels. Furthermore, repair docks will uniquely possess compartments and subcompartments to store robots, supplies, and quarantine units. Lastly, repair docks will be larger than their unloading/loading counterparts in order to enclose the entire ship, rather than parts of the ship.

4.0 HUMAN FACTORS

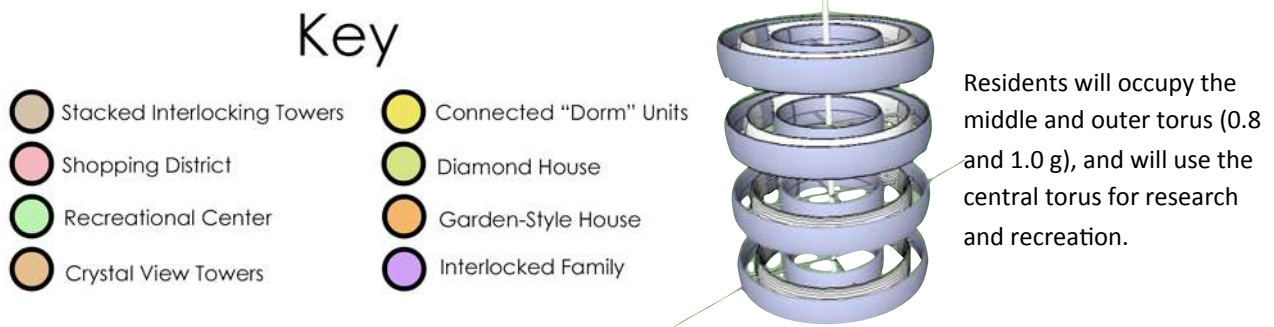


Section 4: Human Factors

4.1.1 Community Design



Figure 4.1.1 Community Layout



The settlement design will feature a repeating pattern as pictured above. The settlement will be in diagonal rows to maximize lines of sight. The settlement will alternate between high-density housing and more rural housing designs, thus allowing residents to have wide variety of housing plans. Roads will take up 6% of the settlement, with parks taking up 30% of land.

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

4.1.2 Psychological Effects

Table 4.1.1 Psychological Effects

Psychological Problem	Effects	Solution
Coriolis Effect	In a settlement where gravity is generated by a centrifugal force, the speed of the rotation can cause people's heads to spin and their vision to blur	<ul style="list-style-type: none"> - Create long diagonal lines of sight - Along streets, ~ 350 meter line of sight - Diagonal-grid pattern - No abrupt turns <ul style="list-style-type: none"> - 30° angle turns are mitigated by transept streets
Solipsism	When the environment becomes too artificial or controlled, people no longer believe that they exist in reality; the present world seems to be a dream because events are either too predictable or the landscape is too artificial	<ul style="list-style-type: none"> - Long lines of sight, so that people view a landscape that is large and not controlled (large parks) - Prominently display plants and parks into the design to show things that grow and change over time - Horizon is lighted to appear larger
Cultural Blending	Bellevistat will be an international settlement; in order to make everyone comfortable, the settlements must satisfy various cultural trends	<ul style="list-style-type: none"> - Three different community areas (Rural, Suburban, Urban) that closely match the three defined communities that many psychologists believe people prefer - <i>People will be matched to a community based on their preference and psychological test results)</i>
	Individualistic and Isolationistic (Rural) People within this community are independent and self-sufficient; they prefer a private living environment rather than a more social living environment in which basic facilities are shared	<ul style="list-style-type: none"> - Live in individual houses - Have their own garden to grow plants, crops, etc. - Diamond building - Housing plans C
	Heterogenistic , Mutualistic and Symbiotic (Suburban) People within this community believe in harmony and cooperation; each community is created with variety and many distinct elements are included in the community	<ul style="list-style-type: none"> - People within this community believe in harmony and cooperation and like to share basic facilities - Community gardens and shared buildings plans - "Dorm" building, shared living spaces - Housing plans B
	Homogenistic and Hierarchal (Urban) Everyone within this community shares similar beliefs and are of the same ethnicity; the community is divided into individual sections (housing in one section, industrial facilities in another, recreational facilities in another, etc.)	<ul style="list-style-type: none"> - The urban area places housing in certain blocks and businesses in the others - Tower Design - People with different jobs live on different floors so that they live near people with similar beliefs as them - Housing plans A
Sensory Deprivation and Anhemia	The enclosed environment of the space settlement and limited resources can have long-term effects on mind-body connections	<ul style="list-style-type: none"> - Try to maximize space and create illusions of space on the settlement by having large windows in residences and utilizing creative housing methods similar to those in Japan
Isolation	Initial settlers are prone to feelings of remoteness due to the settlements physical distance of earth	<ul style="list-style-type: none"> - Close-knit communities divided by personal interest or ethnicity to encourage interaction among settlers

4.1.3 Consumables

Table 4.1.3 provides expected yearly figures of consumables. The figures are susceptible to change in relation to demographic changes and the needs of Belvestat's residents. These products will be mass produced on the settlement as well as imported from Earth and should be regularly available in general stores located on Belvestat.

Table 4.1.2 Distribution of Consumables

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

* Figures may vary. Figures are estimate

** R - Residential (11000) ; T - Transient (500)

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

The settlement will provide all kitchen appliances and furniture upon purchasing a home in Belvestat. Everything will be furnished with default options but residents may select upgrades before arriving that will meet residents when they arrive. Food and nondurable goods will be provided at supermarkets near residential areas.

4.2.1 Demographic Trends

*Transient population has already been factored in. Model based on assumption that the targeted population on the settlement will be 11,000 with a transient population of 500.

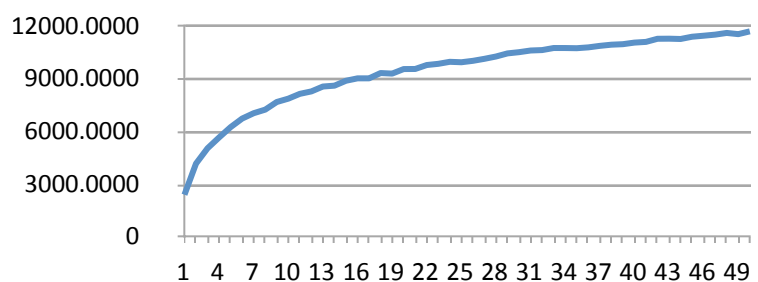
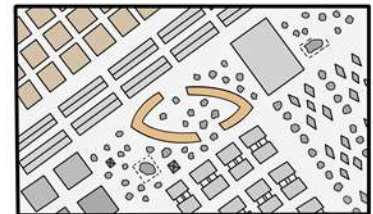
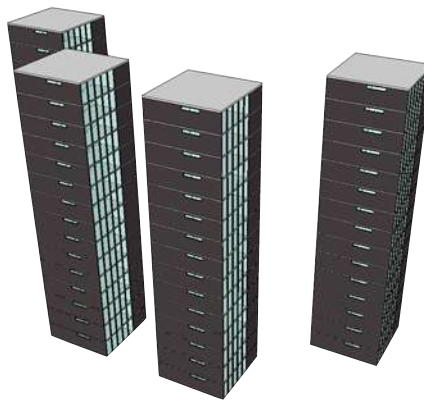
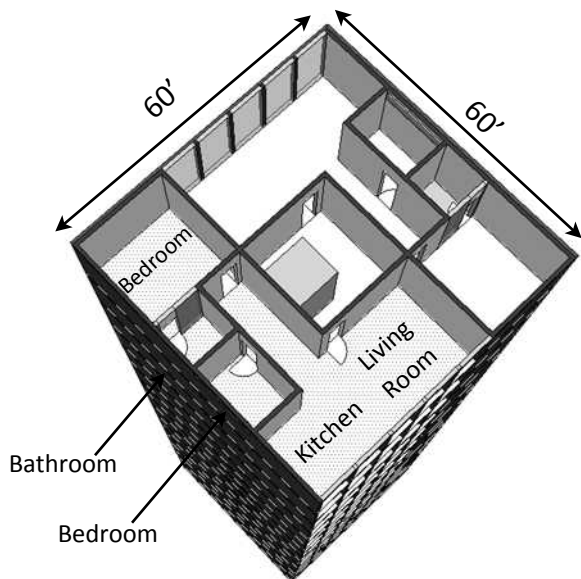


Table 4.2.1 Demographic Changes (year 0-17)

4.2.2 Housing Designs

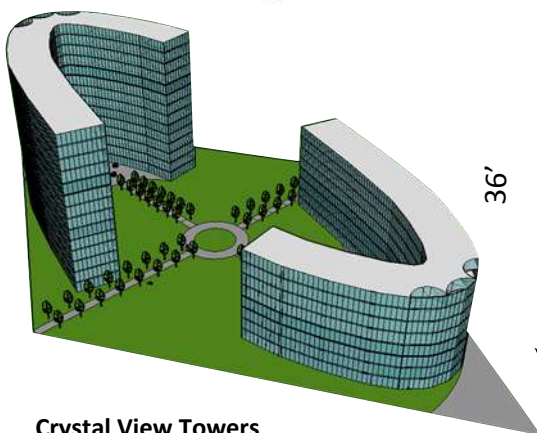
House Type	Residency Type	Average Square Feet	Number of Buildings	Number of People Per Building	Number of People Housed
Stacked Interlocking Towers	Single, Couples, Family	1400	60	120	7200
Crystal View Towers	Singles, Couples, Family	1152	8	405	3240
Garden-style House	Singles, Couples, Transient	?	100	3	300
Connected "Dorm" Units	Singles, Couples, Transient	2000 (400 of individual space)	40	24	960
Diamond House	Couples, Family	2200	240	3	720
Interlocked Family	Family	?	100	8	800
				563	13,220

4.2.2A Housing Designs - Single/Couple Living Spaces



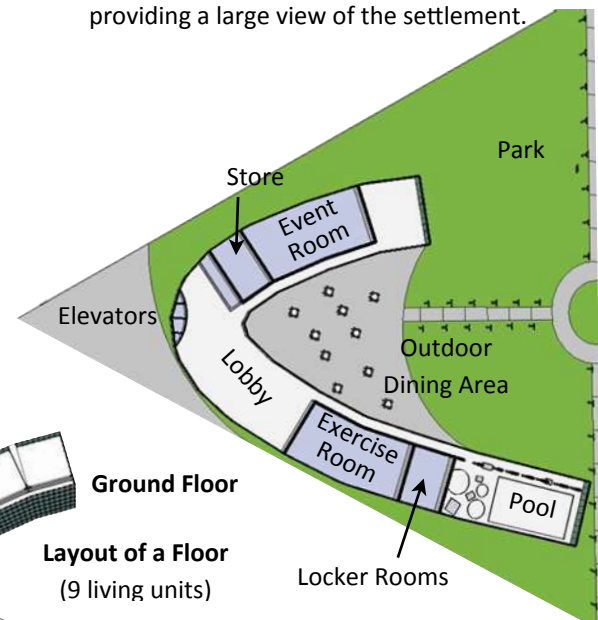
Stacked Interlocking Towers

These towers feature a central elevator and two "interlocked" houses per level. This residency is ideal for urban singles, couples, and growing families and features two bedrooms and one large bathroom. The two different apartments (one in beige and the other in blue) interlock together on one floor. These houses feature large windows to provide maximum light into the home, thereby reducing energy requirements and providing a large view of the settlement.



Crystal View Towers

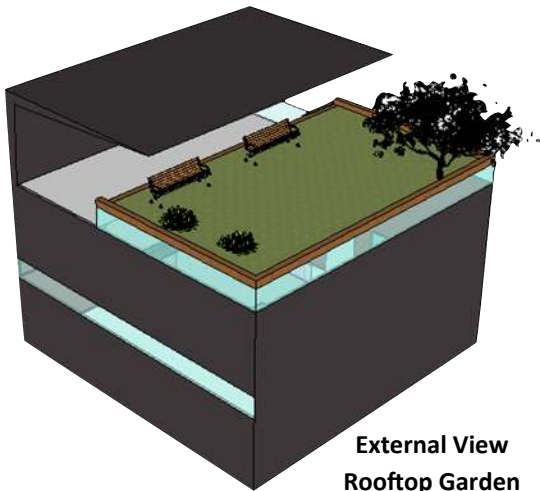
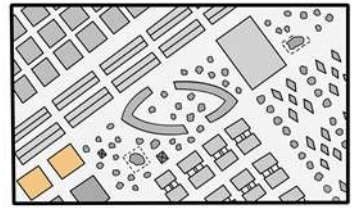
These large towers are at the center of each community, serving as the heart of the urban centers. Each floor is prefabricated and can be stacked on top of each other with cranes and welded with robots, thus reducing the costs of construction.



Ground Floor

Layout of a Floor
(9 living units)

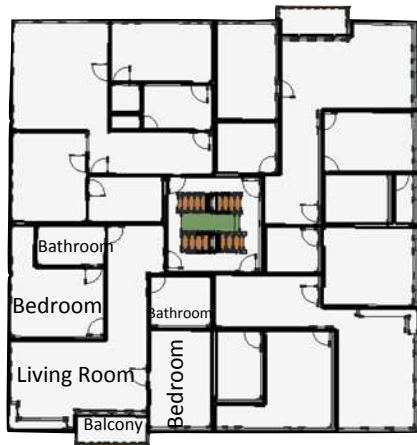
4.2.2B Housing Designs - Communal Living Spaces



Garden Home Design

This housing design provides two bedrooms for up to 4 residents. The communal second floor has a kitchen, living room, and dining area, while the third floor provides a natural garden and communal bonding space. This settlement is ideal for new settlers to become adjusted to the artificial life of a settlement while still having earth-like gardens and living with other people.

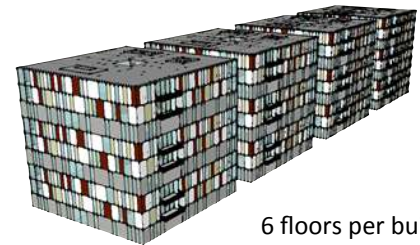
Individual Floor (4 locked living spaces)



Communal Floor



*Each person/couple gets 2000 feet of space:
1600 communal, 400 private.*



6 floors per building
(3 individual, 3 communal)

Connected "Dorm" Units

This housing plan emphasizes communal spaces. It is ideal for single people and young families. Residents share a communal floor with 4 to 8 other people, while each person or couple has an individual second floor living space that is accessed through a locked door. *The building alternates between a communal floor and an individual living area, providing room for up to 24 people in one building.*



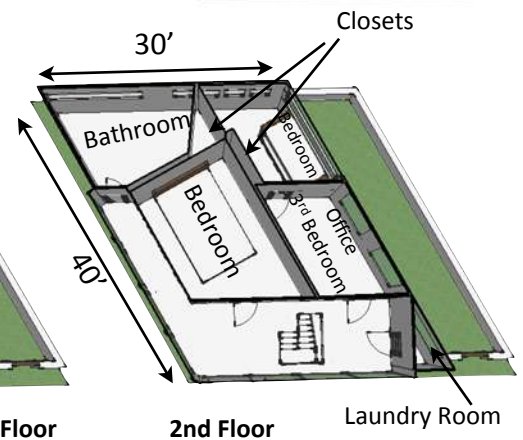
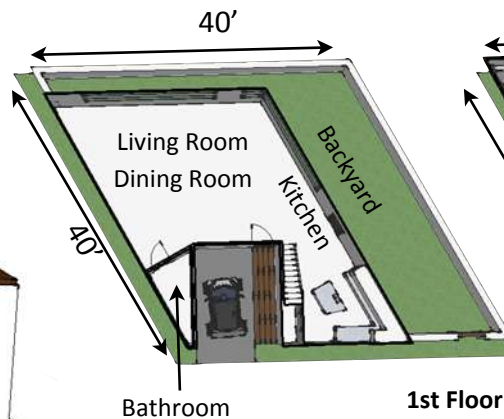
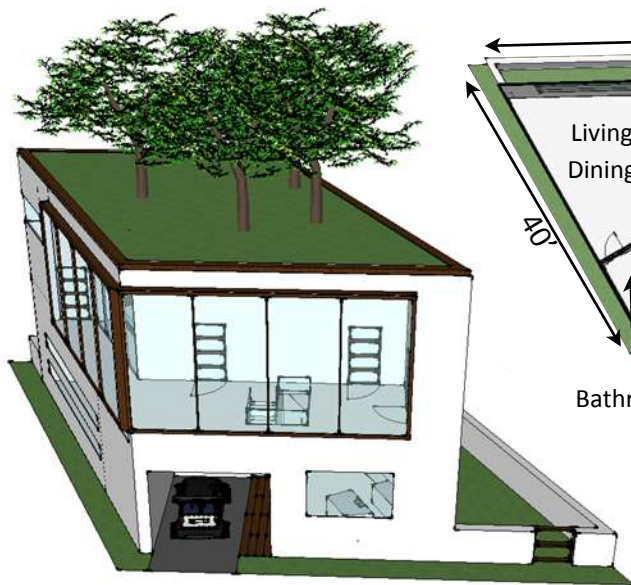
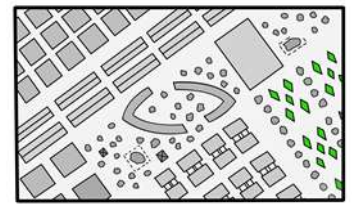
Communal Floor (Transient Housing)

Contains standard floor amenities

- TV, game tables, couches
- Floor mats and children's toys
- One on every level

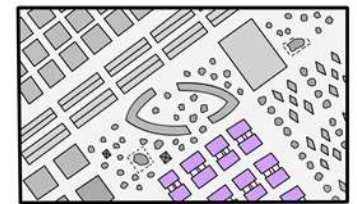
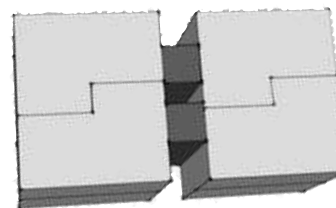
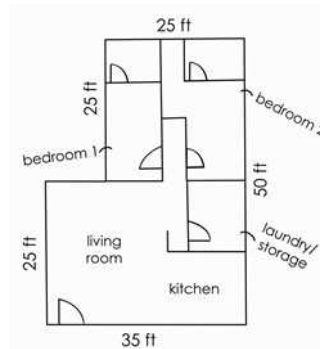
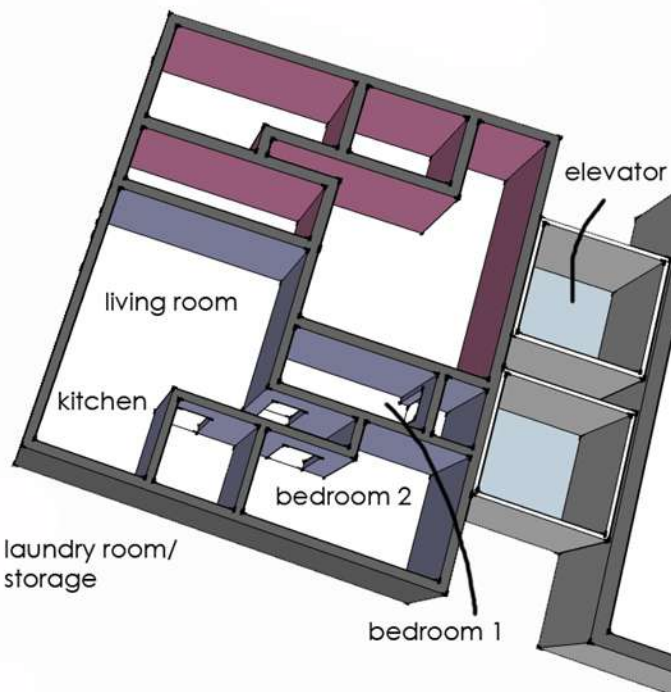


4.2.2C Housing Designs - Family Living Spaces



Diamond Houses

These individual homes are ideal for families, featuring our largest home size (1400 ft²). These houses line the park areas, emphasizing the rural, individualistic theme that many of our residents desire.



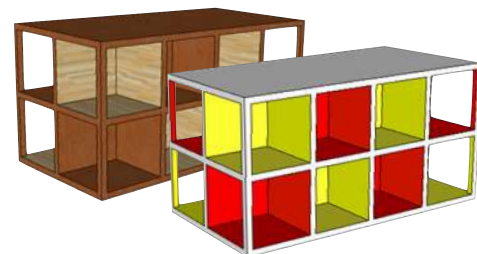
"Interlocking" Houses

Two "locked" houses connected to two others with two elevators between "locked" blocks for easy access between floors. Sections can be stacked on top of each other to conserve space, so you can increase the height with population growth.

4.2.3 Furniture

Furniture will be purchased from Earth in disassembled units. Residents will be able to select their furniture before arriving at Bellevistat from catalogues and these will be assembled in their homes upon their arrival. Later furniture demands can either be purchased from the colony's furniture store (featuring locally crafted furniture as well as Earth-manufactured pieces available upon request).

All furniture will conserve space, with collapsible portions, fold-outs, or multiple purposes.



Storage unit and small table
(2 different color themes)

Collapsible tables



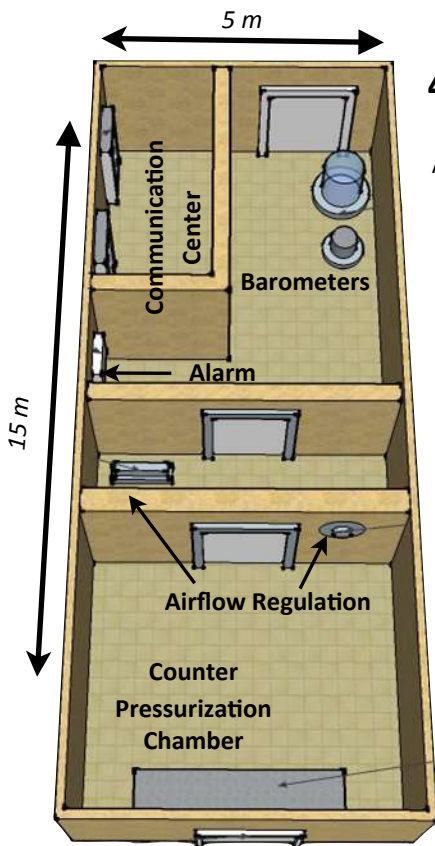


Figure 4.3.2 Airlock Entrance Chamber

4.3.1 Airlock Safety System

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

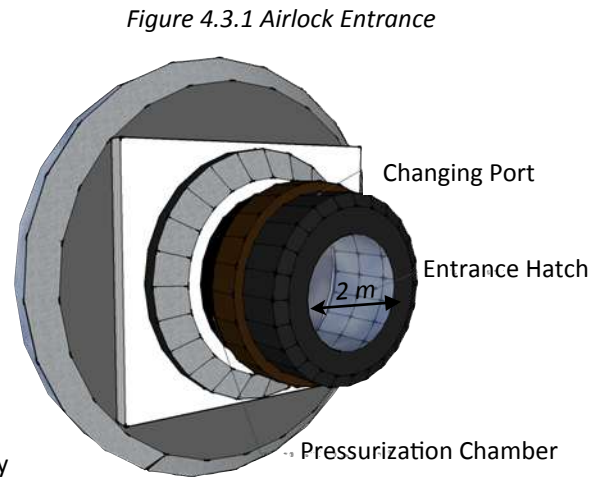


Figure 4.3.1 Airlock Entrance

4.3.2 Spacesuit Designs

The suits primarily used for inspection and repairs on the exterior of the settlement will be designed with mechanical pressurization. Unlike traditional gas pressurization, mechanical counter pressure suits adhere to the body of the wearer and do not inhibit the wearer's mobility. The suits will be made with elastic memory fabrics that physically compress the wearer's body in response to the wearer's movements and the pressure provided by the compressive fabrics will be used to maintain functional pressure conditions for the wearer. Aside from increased mobility, mechanical counter pressure suits provide several additional advantages over gas-pressurized suit: 1) The reduced weight and size of the suit allows wearers to work longer durations of time in depressurized environments 2) In low-gravity environments, wearers will have an easier time maintaining balance

Various safety devices will also be incorporated in the suit. Wearers will be required to carry patches of **elastic bandages** with them while they work. In the event of a partial tear in the suit, wearers can easily prevent the loss of pressure by sealing the tear with the bandages. The suits will use smaller, closer fitting gas-pressurized helmet that regulate oxygen supply. A network of conductive nanowires and biosensors superimposed on the suit will allow the wearer to **generate fiber-optic displays on the visor of the helmet by voice command**. These displays would provide information about the wearer's oxygen intake and energy level.

Additionally, **Kevlar** and **Mylar** materials will line the exterior of the suit to protect wearers from radiation. A thin layer of aerogel in the suit will provide insulation and maintain a consistent body temperature. Lastly, each suit will contain an emergency communication device that enables the wearer to contact rescue personnel on the settlement if any part of the suit is not working properly.

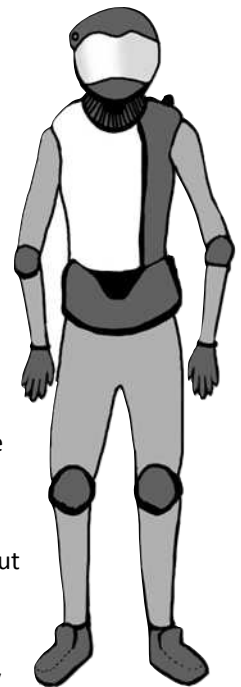


Figure 4.3.3. Spacesuit elastic design



Figure 4.3.4. Magnetic footwear will be used to provide additional safety if a power failure were to occur.

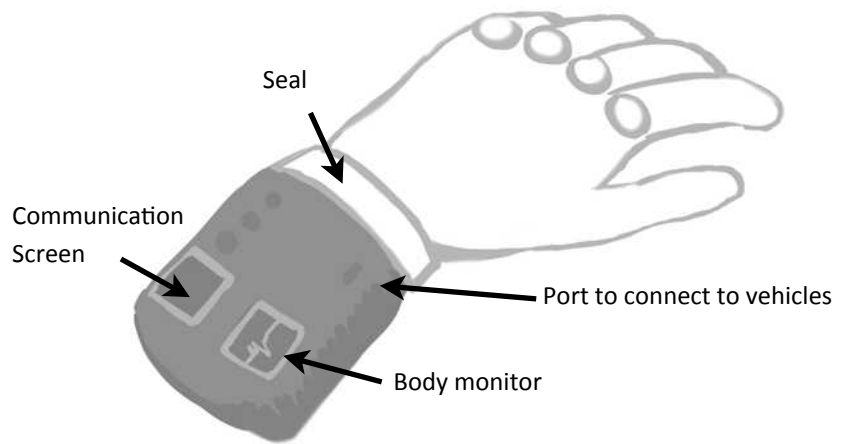


Figure 4.3.5 Wrist Modules will provide communication, task lists, and a monitor for body functions.

4.3.3 Morphing Transport System

The Morphing Transport System

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

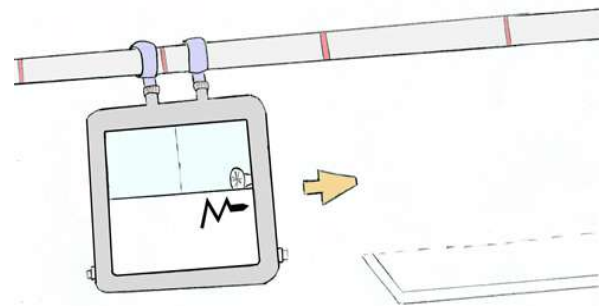


Figure 4.3.6 Boxes attached to hanging rail approaching designated platform

“Morphing”

- After reaching designated platform, storage box is “unscrewed”
- Human transport boxes are attached to special magnetic “wheels”
- Used for outer-settlement transportation and repair work
- Cars can be locally or remotely driven
- This “tube” system allows for transfer in and out of artificial-gravity volumes with ease

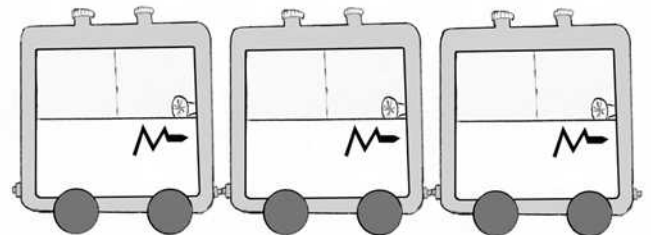


Figure 4.3.7 Interconnected boxes with magnetic wheels attached

4.3.4 Spoke Transportation System

Within the spokes *between* torii and to the axis, there will be half cylinder elevator transportation devices. One of the half cylinders will go up, while the other will go down. There will be many spokes simply for traveling between with no structural purpose so that there will be readily available transportation options for all residents.

Each elevator system will be able to accommodate up to 8 people at one time. Transportation will move slowly due to change in gravity and each person will be seated to help the adjustment

4.3.5 Other Safety Devices

Humans will wear tethers when repairing the outside of the settlement and must communicate with the settlement at least twice every hour.



Figure 4.3.8 Axial Transport System

4.4.1 Community Living for Temporary Visitors

Visitors and temporary residents will live within community housing alongside permanent residents. Single visitors will be encouraged to live in housing designs depicted in 4.2.2B because they emphasize communal living spaces. Because permanent residents often see others as outsiders, placing them inside of the home, living alongside permanent residents will make the residents feel more comfortable with them and help the outsiders and visitors become more accustomed to settlement lifestyle.

4.4.2 Community Layout

In the center of each settlement's community layout (see 4.1.1), there is a recreation center and a park. this central area has an emphasis on the natural and communal, thus it is an ideal *gathering place* for residents to bond, providing a calm (and earth-like) location for new residents to meet current residents.

4.4.3 Pre-Settlement Social Program

To accustom visitors to settlement life, there will participate in the pre-settlement program that all residents go through before arriving at the settlement. This will familiarize newcomers to settlement practices and connect new temporary residents with one another. This program will be briefer than the one for permanent residents, lasting only one week, as oppose to three weeks for permanent residents. They will be trained in saving water and will become familiar with the automation used on the settlement. Additionally, residents will live in groups during the program (created from the results of personality tests) and the members of these groups will become their future neighbors.

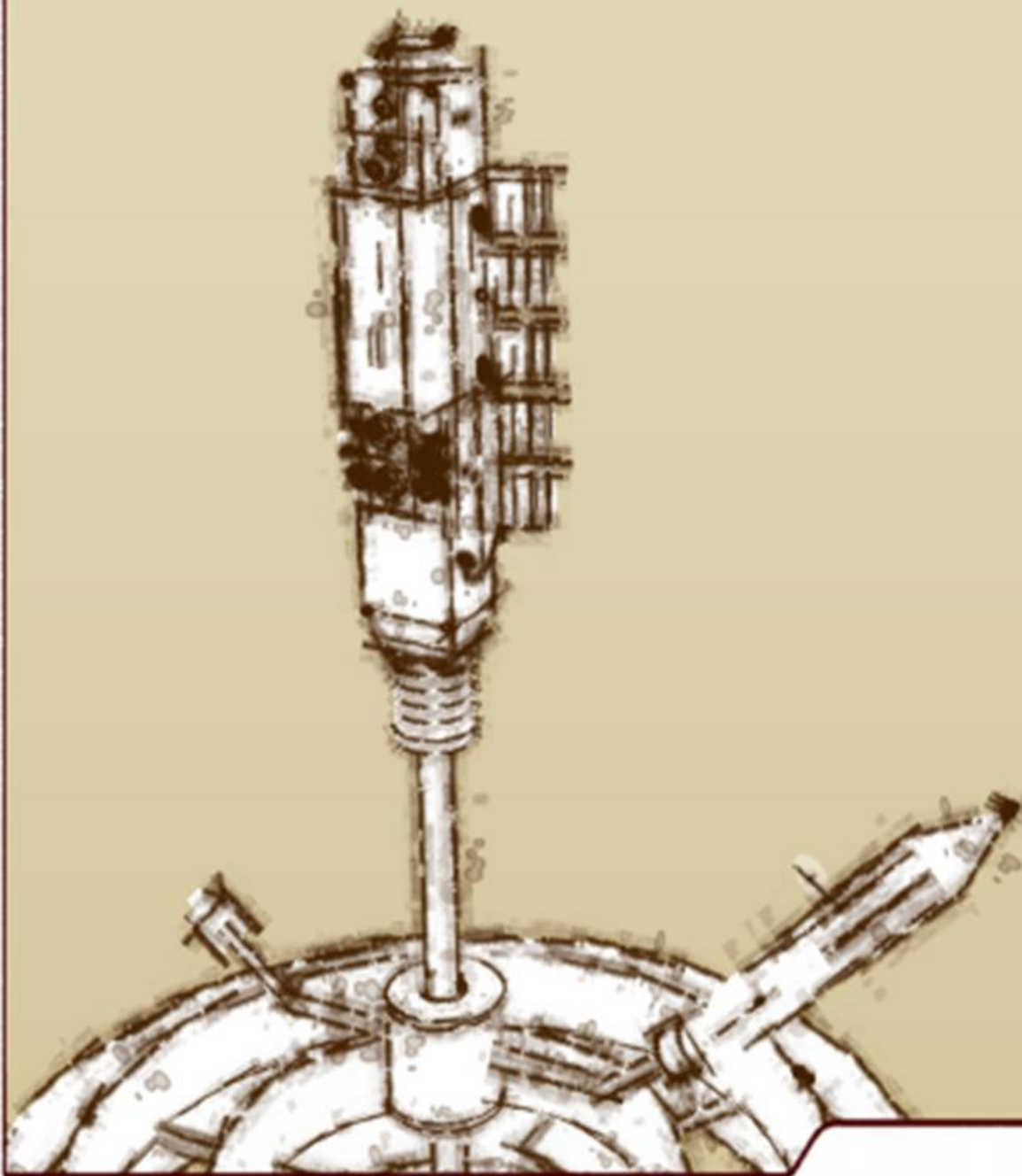
4.5 Dock

The dock will provide a large natural view of the earth provided through large panels. There will be waiting areas with large seating and televisions.



Figure 4.5.1 Natural views of the Earth are available at each dock along with amenities such as waiting areas, cafes, and plant life.

S.O. AUTOMATION DESIGN



SECTION 5 : Automation

Automation is an integral part of any settlement, and on Belvestat, it will play a large role in productivity, manufacturing, construction, transportation, maintenance, and more. We want settlers on Belvestat to live comfortably and productively while not needing to worry about menial tasks.

Name	Description	Specifications	Quantities
Servers	Central hub of all internet-connected devices, due to the settlement being cloud-based. This allows any information to be accessed at any time, all around the settlement.	WiFi network is built into infrastructure, coverage through entire settlement, Solid State Drives with 750 Exabytes, 75 Petaflops, automatically compress data	One main server system of 300 networked servers, one backup server (5 exabytes)
Kane (Personal Tablet/Phone)	The main personal device for residents, it is able to connect to the WiFi and cloud storage system, rendering the use of hard drives obsolete. It can call other phones through WiFi too, and has a built-in RFID chip. Flexible for convenience.	25GHz octo-core processors, 512GB DDR4 RAM, speakers, projector, wifi connectivity	Issued at certain age for every citizen
Magnitude (Personal Device)	The home computer, with the lowest priority for backing up. Has gaming/rendering capabilities for entertainment.	100GHz Octo-core, 1TB DDR4, speakers, projector, wifi	1 for every 3 people in a household
Business Device	Loaded with business applications, intra-company communications, and contains more processing power than the Magnitude home computers.	200GHz Octo-core processor, 3TB of DDR4 RAM, speakers, 2TB GDDR4 RAM, projector, projected keyboard, battery for mobility (tablet), wifi	1 per businessman
Router Points	Server/WiFi relay points will be added into the infrastructure to maintain optimal connection throughout the settlement.	802.11n triple band wifi connection	2 on every level, perpendicular in terms of every level
Relay Point	Satellite close to the settlement that will relay data between Earth and settlement	Between Earth and relay point: W-band radio frequency at 110Ghz Between relay point and settlement: Ku band radio frequency at 18Ghz	1 orbiting around Earth at a speed to keep up with settlement

Table 5.0.1: Robot Overview

5.1 Construction

(For a table, please refer to the one provided in section 3.3.)

Construction of Belvestat will be done by automated robots to significantly reduce human labor, and provide efficiency and stability. In addition to productivity, construction will be economically resourceful and systematic.

Construction robots will be modular and covered in buckystructures that have thermal insulating qualities to protect from solar flares. They will also be



Figure 5.1.1 – Edison, the infrastructure repair and construction robot.

efficacious and versatile; the robots will have the ability to extend “working arms” in order to reach difficult areas of construction. Only the higher-tiered users, as explained later, will be able to control robots so that security breaches and malfunctions will be a rare problem.

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

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

5.2 Automation for Maintenance, Repair, and Safety

On Bellevistat, we have put great thought into determining the most effective ways to combat against any emergency situations as well as systems and robots for the settlement’s upkeep.

Contingency plans are essential to the protection and security of the Bellevistat. To respond to fires, the settlement will deploy brominated flame retardants when sensors are tripped, detecting the air composition. Regular sprinklers will be used for minor flames that are easily contained.

Crime will be handled by using Star-Burns in security checkpoints, where any suspicions will lead to further investigation. Star-Burns can apprehend criminals by either chasing them down or tazing them.

In the event of flooding, the quarantine system will be deployed in necessary areas and the residents will be evacuated from the systems that are shut down. Sodium polyacrylate will be used to absorb liquids, and robots will dispose of the leftover polyacrylate.

Server or power failure will be dealt with backup generators, and important data will automatically be backed up nightly during downtimes by sending critical data to Earth. Fission fragment reactors and biogas will provide backup energy sources.

For debris impact damaging the settlement, the quarantine walls will be used to section off the breached sections, and the residents inside will be evacuated as quickly as possible. External repair robots will then work to use buckystructure fabrics to patch up any areas that were breached temporarily, until the robots can implement more permanent and sturdy repairs.

Solar flares will be handled with preemptive measures, as all robots that will be working externally with buckystructures, while all buildings and structures will be outfitted with this material as well. This unique buckystructure has the combined effects of the space-tolerant shielding and the thermal insulation variants by having alternating layers of each “fabric”.

Gas leaks will be detected by sensors that are installed in every room, monitoring the concentration of gases. Once gases reach dangerous levels, residents will be quickly evacuated and the sections will be quarantined. For electricity problems, water leaks, and other utility problems, micro-internal Edison repair bots will travel around the infrastructure and when it locates the problem, will apply a temporary buckystructure patch and tag the location for further investigation.

Epidemics on a large scale will be handled with quarantining infected sections. Nurse bots that are coated with hypoallergenic materials will treat patients in quarantined areas while preventing the spread of disease.

5.3 Automation for Productivity, Livability, and Convenience

Residents living on Belvestat will have convenient access to several robots that will contribute to their ease of living on the settlement and will help with typical menial tasks such as cooking, cleaning, business work, and nursing. In addition to these amenity bots, entertainment and a secure environment will be provided for everyone to ensure a pleasurable living experience on Belvestat.

Name / Type	Description	Dimensions (L x W x H)	Quantity
Bennett (Cook)	Bennett prepares meals for civilians, delivers the food, and cleans the dishes.	1 m x 1 m x 1.5 m	One per household
Duncan (Cleaning)	Duncan cleans the house and operates on a daily schedule. Duncans will have built-in cleaning materials. Comes with flexible and extendable arm to be able to get into small, tight spaces.	1 m x 1 m x 1.5 m	One per three households
Laybourne (Nurse)	Hypoallergenic coating for antibacterial prevention. It can only dispense the amount of drugs necessary and prescribed in order to prevent substance abuse. They have a first-aid kit that is accessible to anyone, and can administer quick first aid	.5 m x .5 m x 1.5 m	1 nurse per 50 people
Chang (Work Assistant)	Chang bots runs errands for businesses and can print out, staple, and deliver papers for employees.	.5 m x .5 m x 1.25 m	3 per office building floor
Star-Burns (Police)	Whenever a crime is reported, Star-Burns police robots are sent out to apprehend robots. They use tasers to stop criminals, are extremely fast, and can communicate with other robots and security systems around the settlement.	.5 m x .25 m x 2 m	1 per 100 people

Table 5.3.1: Productivity Robots

5.3.1 Automation for Routine Tasks

Seeking to minimize the time-inefficient processes that people go through during their everyday lives, we have come up with novel solutions in the form of robots to save time.

For residents who think it is a hassle to cook meals every day, Bennett cooking bots will be easily accessible and will allow people to customize a meal from available ingredients. Bennett will be able to effectively cook multiple meals at a time in a quick paced manner and deliver the food to the residents. In addition, Bennett can create individual meal plans for residents with dietary restrictions personal preferences. Not only will it cook meals, but Bennett will also clean and dry dishes, to maximize its practicality.

Furthermore, maintaining a clean environment at all times will not be a concern for residents. Duncan cleaning robots will be plentiful throughout residential and business complexes, and will operate on a daily schedule. Duncans will have built in cleaning systems and will greatly reduce manual labor for the civilians.

In the case of illnesses, Laybourne nurse bots will be immediately provided for assistance. Laybournes will be programmed to give patients just the right amount of medication they need, and never over/underdose. Because Laybourne will be constantly near infectious patients, we will prevent cross-contamination by sterilizing Laybourne after every checkup, and anti-bacterial coating on every Laybourne. They will carry generic medication such as acetaminophen and a first aid kit for minor problems. It is important to note that these nurse bots will not replace doctors, and patients with severe health issues will be taken to a professional doctor.

Chang is a multipurpose work assistant robot that will have to ability to perform basic tabs such as stapling and taping as well as more advanced errands including printing and faxing. Business administrators will be able to access and use Chang bots. A certain amount will be allocated to each building.

5.3.2 Automation and Systems for Entertainment

Kane entertainment devices will be generously distributed throughout Belvestat and will include entertainment and productivity apps. Internet connection will be available at all times so the internet can be browsed and support entertainment media such as music, video, and games. A projector built into the devices will allow the screen to be projected onto any flat surface. In addition, communication will be utilized through Kane; it can be a personal phone in addition to an entertainment tablet.



Figure 5.3.1 – The flexible Kane tablet, shown in both its normal and flexible configurations. 22 cm x 16 cm x .25

One Magnitude, a home computer, will be provided for every 3 people and has the same entertainment capabilities as Kanes. What makes Magnitude unique from Kane is that these home computers will be able to program when they want to schedule their cleaning and cooking robots to serve them. Also, Magnitude has a larger memory capacity for more apps and data. Because the information Magnitude processes will be more critical than the information stored within Kane, data stored from Magnitude will have priority when information is backed up to Earth.

5.3.3 - Server and Network on Belvestat

All data will be stored on centralized servers for users, essentially creating a cloud computing system. Users will connect to this network through Wi-Fi access points built into the infrastructure with 802.11n triple band wifi connection. Accessing these servers will ensure the fastest speeds possible, because the servers will be outfitted with Solid State Drives with 750 Exabytes, 75 Petaflops, and will automatically compress data. Having all the data stored on these servers will allow for devices without local hard drives, considerably reducing the form factor and price, while increasing speed and reliability with less moving parts when compared with hard drives. Users can be inherit multiple user levels.

User Level	Permissions	Number
Admins	Access to everything except political / confidential partitions	5
Technician	Access to essential partitions to run essential settlement tasks (electricity, water, etc)	100
Security	Access to security features such as quarantine walls and cameras	250
Politicians	Access to confidential or time-sensitive information	250
Business	Access to encrypted partitions and private networks	2,500
Basic Users	Access to partitions users can buy at different pricing plans	8,395

Table 5.3.2: Network User Allowances

Security within the network will be handled by restricting access to certain servers, depending on the users' level of access. For the basic user and business partitions, passwords will be required to access the servers. The remainder of the positions will also require an RFID chip that will be inserted into their personal devices to identify individuals. If this personal device is to be stolen or lost, its can be tracked within the settlement. In addition to the RFID, only specific computers in certain locations will be able to access the higher partitions. These locations will be heavily guarded with security cameras and Star-Burns police robots; entrance into these buildings will require a retina scan.

There will be another server on the settlement as a backup that contains all the necessary information and programs to run the systems necessary for basic survival. Further backups will be consistently synced to Earth.

Another useful advantage of having the Wi-Fi network is all devices that are connected to the network are automatically connected with each other. This allows for efficient data transfer between devices, allowing for phone calls, text messages, large file transfers, and other necessary communication aspects.

For internet connections with Earth, Relaypoint (satellite) close to settlement. Connection between Earth and relay point uses W-band radio frequency at 110Ghz frequency. Connection between satellite and settlement uses Ku-band radio frequency at 18GHz. Average speeds are 15 MBps download and 5MBps upload, with 100ms ping times. However, speeds will vary greatly based on traffic and usage. There will be four access points on Earth spread out equally that will connect with the relay point. The relay point will connect with the closest available access point and switch points as the Earth orbits to ensure maximum connection speed and strength at all times.

5.4 - Shipment and Unloading of Ores

All ores from the Moon will arrive on Belvestat through shuttles that contain shipping containers, 4.572 meters by 18.288 meters (or 15 feet by 60 feet) large. In automating the transport and delivery process, each shuttle will first dock at a five-layer port complex. Within the complex are three storage levels and two processing levels; due to the zero-gravity nature of this complex, the unloading Pelton robots will cling onto and maneuver itself around the complex as well as the transport area located within the complex and settlement. Each port will have 8 docks, and each dock will have a Pelton which immediately quarantines supplies as needed, links up the shuttle to a fuel supply for refueling, and removes the cargo, while any available external repair Winger robots will clean and maintain the shuttles as needed.

As each shuttle arrives to dock, they will be guided to an open dock by a radio transmission system. Pelton will be able to remove the ores and supplies from the incoming shuttles, and move the shipping containers into the central transport area. Before being sent off for further transport, each container will be labeled by Pelton with a QR code indicating its weight, origin, date and time of entrance, destination, and other necessary information. This allows the process to be further automated and simpler to follow.

Once the shipping containers are moved into the central transport area, their contents will be scanned and recorded, and all the containers will be put in a queue to be transported back to the settlement, mostly depending on the time it was delivered. However, any quarantined materials will have priority and either be immediately sent out of or into the settlement. While containers are in queue and waiting to be transported, they will wait in one of the three storage levels, moving downwards as they move up the queue. These storage levels will have pressures and temperatures from 10°C to 30°C, and a pressure from 0.5 bar to 2 bar.

Eventually, the containers will be sent to a within the central axis of the settlement structure, where it feeds into a zero-gravity tube which is called "The Tube". Each container will be pushed down the tube, propelling it downwards. Along the Tube, the QR code on the container are scanned; scanners are located just before the entrance into each torus level within the structure. Because of this placement, when the sensor scans a container that needs to be transported into the corresponding level, it activates a mechanism where a triangular platform protrudes and allows the container to deflect and enter the spoke of the torus closest to its destination. From there, a conveyer belt system located within the spokes of each torus delivers the shipments further along to its destinations, with each container of ore being sent to its designated refining facility.

5.5 - Port and Docking System

When ships are 750 kilometers away from their destination, they will start communicating with ports on how they will be directed there. The ships will be put into a queue and assisted to certain locations that are respective to their sizes, as different ships be allocated to different ports. Because Pelton is the robot in charge of unloading, it is versatile and will be able to perform unloading tasks for all types of ships, and will adapt to special exceptions for different robots. To ensure safe delivery of all materials, constant communication between the ships and ports will be enforced through radio.

Nadir and Bauer, with the help of Pelton, will unload cargo and deposit the goods into a transport system held in the central axis, called "The Tube," as mentioned in 5.4. Whitman will store gases and liquids into containers at a previously specified size, pressure, and temperature. Once the containers are properly sorted, they will subsequently be shipped through The Tube to their specified destinations. This system will be automated for general packages, but there will be availability for manual or re-programmed unloading processes for special deliveries.

E.O. SCHEDULING AND COSTS



SECTION 6 : Scheduling and Costs

6.1 Construction Schedule

Years After 15 May 2033	Workers	Robots	Approximate Cost (USD)	0	1	2	3	4
Initial Development Phase								
Research & development	200	N/A	\$67,000,000					
Approval by Foundation Society	N/A	N/A						
Location of construction site	20	N/A						
Robot & subsystem development	250	N/A						
Command and communications system development	150	N/A						
Initial Construction Phase								
Alpha central axis constructed	50	200	\$13,570,000,000					
Beta docking stations constructed	80	170						
Beta docking stations commence operation	30	20						
Main Construction Phase								
Gamma 0-G manufacturing sectors constructed	30	80	\$52,245,000,000					
Delta 0.25-G manufacturing sectors constructed	40	130						
Manufacturing sectors commence operation	50	20						
Motor modules of 4 tiers constructed	30	70						
4 spokes constructed about each of the 4 motor modules	40	170						
Epsilon 0.5-G tori constructed on each tier	60	220						
Construction of internal structures	70	200						
Solar panels installed and become operational	30	80						
Extension of main spokes	40	170						
Zeta 0.8-G tori constructed on each tier	70	250						
8 minor spokes for each tier constructed	50	180						
Eta 1.0-g tori constructed on each tier	70	260						
Atmospheric pressure established	N/A	30						
Angular velocity of settlement established	N/A	N/A						
Final Development Phase								
Settlement interior examination and fixes	80	120	\$7,500,000					
Final system tests and fixes	30	N/A						
Habitation Phase								
Foundation Society welcomed	N/A	N/A						
All other colonists welcomed	N/A	N/A						
Full population established	N/A	N/A						

Years After 15 May 2033													
Initial Development Phase													
Research & development													
Approval by Foundation Society													
Location of construction site													
Robot & subsystem development													
Command and communications system development													
Initial Construction Phase													
Alpha central axis constructed													
Beta docking stations constructed													
Beta docking stations commence operation													
Main Construction Phase													
<i>Gamma</i> 0-G manufacturing sectors constructed													
<i>Delta</i> 0.25-G manufacturing sectors constructed													
Manufacturing sectors commence operation													
Motor modules of 4 tiers constructed													
4 spokes constructed about each of the 4 motor modules													
<i>Epsilon</i> 0.5-G tori constructed on each tier													
Construction of internal structures													
Solar panels installed and become operational													
Extension of main spokes													
<i>Zeta</i> 0.8-G tori constructed on each tier													
8 minor spokes for each tier constructed													
<i>Eta</i> 1.0-G tori constructed on each tier													
Atmospheric pressure established													
Angular velocity of settlement established													
Final Development Phase													
Settlement interior examination and fixes													
Final system tests and fixes													
Habitation Phase													
Foundation Society welcomed													
All other colonists welcomed													
Full population established													

Table 6.1.1 Construction and Habitation Schedule

6.2 Costs

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

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

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

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

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

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

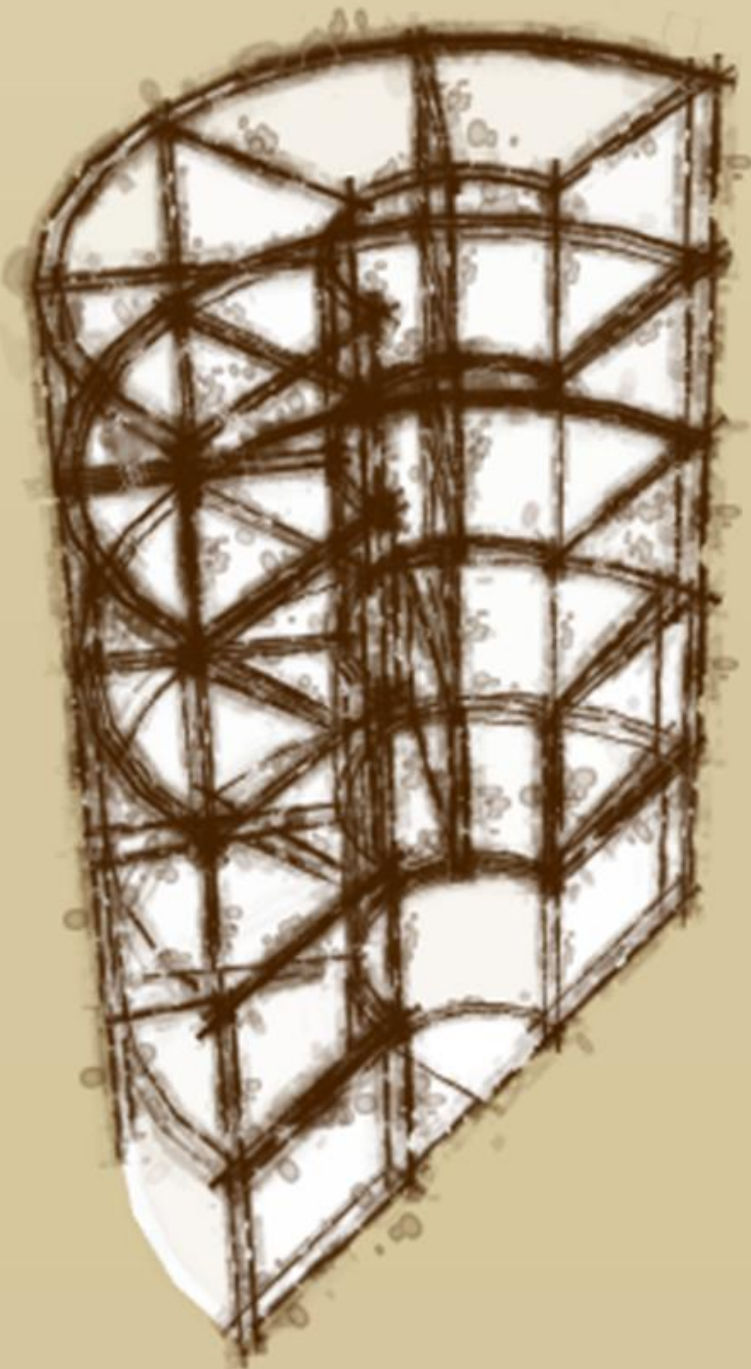
6.2.7: Construction	Cost	Quantity	Total Cost	Annual Upkeep
Winger (Main Construction)	\$500,000	350	\$175,000,000	\$25,000,000
Perry (External Repair)	\$350,000	150	\$52,500,000	\$7,500,000
Edison (Small Int. Infrastructure Repair)	\$1,100	5,000	\$5,500,000	\$1,000,000
Barnes (Internal Construction)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

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

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

Amount of Time to Break Even
$145196237680 + 7824954000x = 14246666667x$
$145196237680 = 6421712667x$
$x = 22.61020466$
23 years to break even

7.0 BUSINESS DEVELOPMENT



SECTION 7 : Business Development

Bellevistat will host various commercial and industrial ventures. Besides from handling extraterrestrial materials with a port, transportation system, and processing area, Bellevistat will generate income in a variety of innovative ways. Bellevistat's basic design will also be flexible enough to add compatible business types with little configuration change.

7.1.1 Port for Receiving Lunar and Asteroid Materials

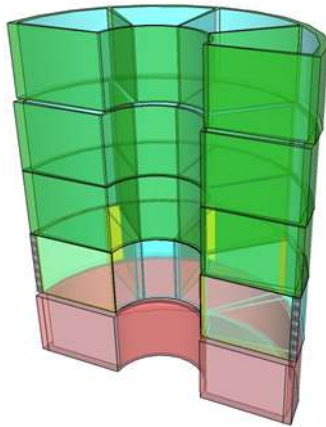


Figure 7.1.1: Port Complex

There will be three types of ports on the settlement – one for raw material transportation, one for passengers and other cargo, and one for repairing space shuttles. One of each port will be on each side of the settlement, for a total of three ports per side, or six total ports. The raw material port will be a five-layer complex that facilitates transportation and storage. The layers will be designated the subfloor, main floor, and storage floors I, II, and III, in ascending order.

Running through the center of the complex will be a cylindrical transport area. Because the entire complex is in zero gravity, cargo-carrying transport robots will be able to freely move throughout the cylindrical area and from floor to floor. They will latch onto whatever raw materials need to be moved, then transport them to the appropriate floor.

The main floor will consist of eight different compartments, each of which will hold one ship. Sensors will detect incoming space shuttles, then guide them to vacant compartments via radio waves. A gate will open and allow the space shuttles to dock; space shuttles will land in the interior of the compartment. If all eight compartments are full, the space shuttles will be directed to the other raw material port on the opposite side of the settlement.

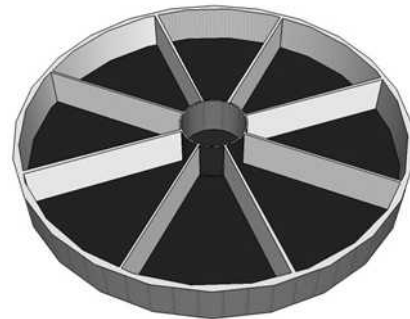


Figure 7.1.2: Main Floor of Port

7.1.2 Storage between Delivery & Use and Transferring Raw Materials

After the raw material space shuttles arrive at the port, they will unload. All ores that arrive will be contained in standard shipping containers that are 4.572 meters square by 18.288 meters long (15 feet square by 60 feet long). Any unpackaged raw materials will be placed into standard shipping containers later on, after they have been moved to their appropriate storage floor. After the shuttles have been unloaded, they will move to the repair ports to undergo maintenance.

The top three floors of the raw material port complex will be storage areas. The bottommost floor (I) will have a pressure of 0.5 bar, the middle floor (II) will have a pressure of 1 bar, and the topmost floor (III) will have a pressure of 2 bars. Each floor will have eight compartments. These compartments will have different temperatures, from 10°C to 30°C in 5°C increments, then back down to 10°C.

The transport robots in the inner cylindrical area will deposit cargo in the appropriate floor and compartment. Any unpackaged materials will then be placed in standard shipping containers. They will be moved into the compartment to await further transport. Once a specific package is to be transported either back to the settlement or to a space shuttle, it will be sent to the inner cylindrical area and moved via the transport robots. The top of the cylindrical area will be connected to the rest of the settlement via the internal transportation system, and will be a hub for all incoming or outgoing raw materials. Please see the side view of the settlement for the specific route that will be taken.

7.1.3 Separate Port Facilities for Passengers and Cargo

The last two ports will be passenger ports. They will consist of a subfloor, a main floor, and one storage floor for cargo. The docking and cargo transporting systems in the passenger ports will be the same as those in the raw material ports. Most non-bulk cargo that arrives will be contained in standard shipping containers that are 4.572 meters square by 18.288 meters long (15 feet square by 60 feet long), and will be moved to the storage floor, which will be in zero gravity at room temperature.

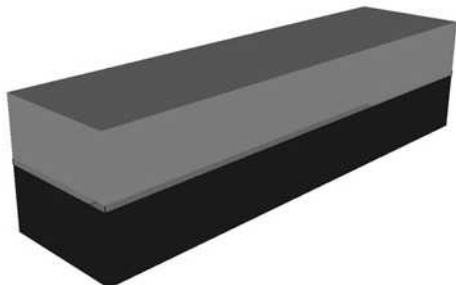


Figure 7.1.3: Standard Shipping Container

Along the sides of the cylindrical area, there will also be hand rails. Personnel entering or leaving space shuttles will use the hand rails to move up or down the floors. The top of the cylindrical area will again be connected to the rest of the settlement via the internal transportation system, and will be a hub for all incoming or outgoing personnel and cargo. Please see the side view of the settlement for the specific route that will be taken.

7.2.1 Production of Goods Manufactured from Extraterrestrial Materials

Extraterrestrial materials, which will be either harvested or transported from other settlements, will arrive at the settlement's port, described in section 7.1.1. The materials will be stored in the three storage layers of the port. When they are ready to be processed, they will be transported to the industrial sector of the settlement, which will be located beneath the buckystructure manufacturing sector (which is directly beneath the port). The materials will be unpacked from the standard shipping containers, then will be refined, analyzed, and processed as needed.

7.2.2 Material Processing

After being unpackaged, materials will undergo refining and analysis. Different refining processes will be used, depending on the type of material being processed. Processing will occur in the outermost layer of the industrial sector, in three different sections. In the smallest section, gases will be liquefied under high pressures and low temperatures. They will then be refined as though they were liquids.

Liquids will undergo three processes – distillation, fractionation, and solvent extraction. Distillation will occur first to separate the liquids based on volatility. Continuous distillation will be utilized to maximize the efficiency of handling a large volume of liquid. Fractionation will occur using Liebig condensers to separate the liquid by composition through a gradient. Finally, solvent extraction will separate any remaining mixtures by their relative solubilities. Water and an organic solvent will be used for the solvent extraction process.

Solid refining will consist of many different processes, depending on the material in question. Solids will be processed in the largest section of the outermost layer of the industrial sector. Chemical reactions, such as hydrolysis, will be used to purify a variety of solids. Crystals will undergo refining via zone melting, in which a molten area of a crystal is moved along the crystal's length. Organic materials will be refined using pyrolysis and thermochemical decomposition. Finally, metals and raw ores will undergo extractive metallurgy, smelting, and calcination for extraction and purification through thermal decomposition and phase transition.

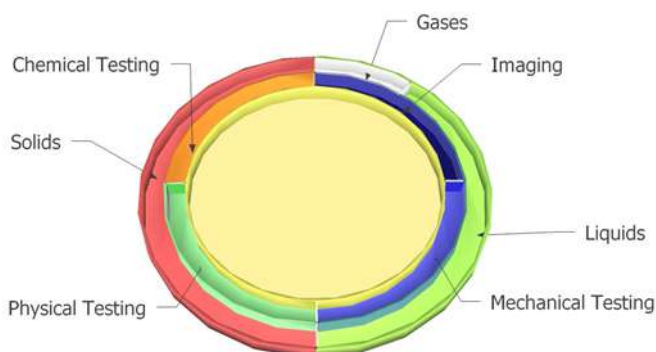


Figure 7.2.1: Industrial Sector Allocations

7.2.3 Material Analysis

After processing and refinement, the extraterrestrial materials will be fully analyzed for their properties and potential uses. The analysis will be conducted by robots in the layer right inside of the refining layer in the manufacturing sector of the settlement. There will be four parts to the analysis process – imaging, mechanical testing, physical testing, and chemical testing.

The analysis will begin with imaging. A scanning electron microscope will be used first to image the sample, simultaneously retrieving information regarding its surface topography and composition. Transmission electron microscopy will then be used to create images with higher resolutions. Tilt series will also be collected by taking multiple images of a sample, creating a three-dimensional image. Finally, x-ray crystallography will determine the atomic structure of crystals, as well as their chemical bonds and entropy.

7.2.4 Material Testing

After imaging, materials will undergo mechanical testing to determine their mechanical properties. Compressive strength, tensile strength, and yield strength will be measured first. Next, the density of the material will be determined. A hydrometer will measure the density of liquids, and a dasymeter will that of gases. Solids will have their masses and volumes measured to determine their density. Stress will be applied to the materials in multiple cycles to find their fatigue limit, and the materials will be bent or pounded to find their plasticity.

After mechanical testing, materials will undergo physical testing. An external magnetic field will be

applied to the materials to determine their diamagnetism. For nonmetals, the Lanvegin theory of diamagnetism will be used. Afterwards, materials will be tested for electrical and thermal conductivity by applying an electric current and heat through the materials, respectively.

Finally, materials will be subject to chemical testing.

Through a predetermined set of chemical reactions, the corrosion resistance of the materials will be determined. Simultaneously, the reactivity of those materials will be measured, and any flammability will be recorded as well. After chemical testing, the materials will have undergone the complete process of analysis.

The thorough analysis of the materials after they have been refined will determine how they should be best put to use and what products they should be manufactured into. The analysis will be completed three times for each material, and the results will be recorded and stored in a material information database. Recognized materials will not undergo the above analysis; only foreign, unknown materials will be analyzed.

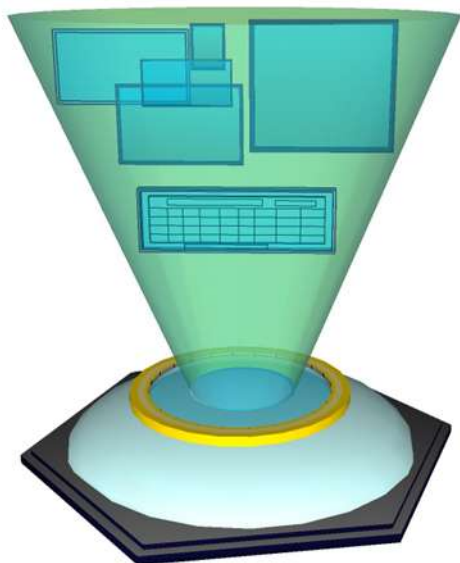


Figure 7.2.2: Material Information Database

7.2.5 Operations in Various Gravities

The manufacturing sector will be underneath the buckystructure production sector, which is directly below the port. After materials have been refined (and analyzed, if needed), they will be stored in separate compartments. When a product needs to be manufactured, a robot will determine the properties that are most important for that product.

For example, a table in a residential building will need to have a high tensile strength and low reactivity, but will not need corrosion resistance or electrical conductivity. The robot will input the properties required by the material into the material information database, which is described in section 7.2.2. The database will then match up the product to the materials that will help the product best serve its purpose.

Operations that require different gravities will take place in different parts of the manufacturing sector. At the middle of the sector will be processes requiring zero g, and outside of that will be processes requiring at least 0.2 g. If a process does not require a specific gravity level, it will occur in either zero g or 1 g.

After products have been manufactured via an array of different machines operating in different pressures and temperatures, they will be stored in another storage compartment. From there, they will be delivered to the settlement when needed, to be placed in either the commercial or residential areas.

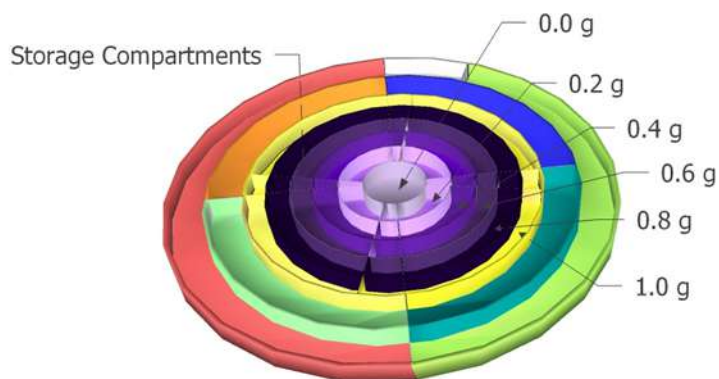


Figure 7.2.3: Industrial Sector Gravity Levels

7.2.6 Accommodations for Other Companies and Interplanetary Trade

Manufacturing will encompass a wide variety of products. Other companies from outside of Bellevistat will be welcome to conduct business within the settlement. To accommodate these companies, the Foundation Society will lease space for manufacturing facilities. This space will consist of any currently unused space within the manufacturing sector of the settlement, and other companies can lease up to a third of the total manufacturing facility space at any given time.

Products created at Bellevistat will be used for various purposes, including exportation, provisioning for visiting ships, and internal use or consumption. Products for exportation will be transported from the manufacturing areas to the passenger and cargo ports. They will then move to their destinations via the designated shuttles. Products to provision visiting ships will undergo a similar process, but they will be moved to the repair ports for refueling, maintaining, and provisioning the space shuttles as needed. The products for internal use and consumption will be moved from the manufacturing sector to the residential areas, where they will be put into the commercial centers or residential areas.

The manufacturing areas at Bellevistat will accommodate the future assembly of large interplanetary ships that will promote interplanetary trade. Space will be set aside for the future expansion of manufacturing areas so that such ships can be assembled and utilized.

7.3.1 Repair and Restoration of Ships in Specialized Docks

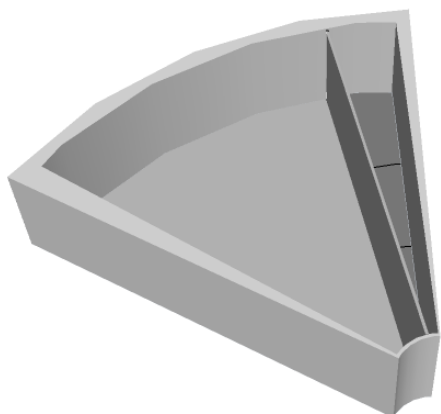


Figure 7.3.1: Repair Port Compartment

Space shuttles will enter the repair port after unloading their raw materials and cargo at the raw material port or passenger port. The two repair ports will be structured similar to the raw material ports, except that they will only contain the bottom two layers – the subfloor and the main floor. The main floor will be again divided into eight separate compartments, each of which will hold one shuttle.

Besides each compartment will be a small storage compartment that will contain four sections. The innermost and smallest section in the storage compartment will be for any foreign debris that needs to be immediately quarantined on entrance. The second smallest section will have cleaning supplies that the automated robots – stored in the second largest section – will use. The largest section will contain liquid fuel for the space

shuttles. All necessary supply and robot replacements or fuel restocking will come from the settlement via the inner cylindrical area. Quarantined debris will also be sent back to the settlement for identification and research.

After a space shuttle enters a compartment, it will be maintained and repaired by the automated robots adjacent to that compartment. They will clean it of foreign debris, use electrostatic plates to remove any cosmic dust, make any necessary repairs, and refuel the shuttle. The robots will then place the cleaning supplies back into their appropriate section, then move themselves to their own section in the adjacent compartment.

The floor of the main compartment will then descend, and the space shuttle will be placed on the subfloor, which will act as a shuttle storage area with a capacity of sixteen shuttles, to hold one ingoing and one outgoing shuttle for each of the eight compartments above. The platform will then ascend back to the main floor and await the next shuttle.

When a shuttle is needed by the settlement, the outgoing shuttle will undergo a similar process. The floor of a vacant compartment will descend and bring the outgoing shuttle to the main floor. The automated robots will thoroughly inspect the shuttle and ensure that it is ready for departure. The gate to the compartment will then open, the shuttle will take off, and the robots will return to the adjacent compartment.

7.3.2 Space Tugs

Space tugs will operate from Bellevistat. A fleet of ten space tugs will always be available for use, and five tugs at a time can be docked. Space tugs will be at each of the three types of docks – passenger and cargo, raw material transport, and repair docks. One space tug will be at each dock, except for the second passenger and cargo dock, which will hold a vacancy for a space tug to dock in the case of an emergency that requires such action.

Space tugs will be used for transferring payloads quickly, or for acting as an intermediary transport vehicle between mining shuttles and the raw material ports. Space tugs will also be used in emergency situations to facilitate the safe return of other space shuttles to their intended ports, or to the repair ports if needed.

7.3.3 Future Port Expansions

Future port expansion will be accommodated at Bellevistat. An increase in numbers and sizes of visiting ships requiring services is expected. As such, each port has a ship storage area (the subfloor) with a capacity of sixteen ships, even though the main floor only holds eight incoming or outgoing ships. Additional ships that are visiting the settlement can thus be stored until further notice.

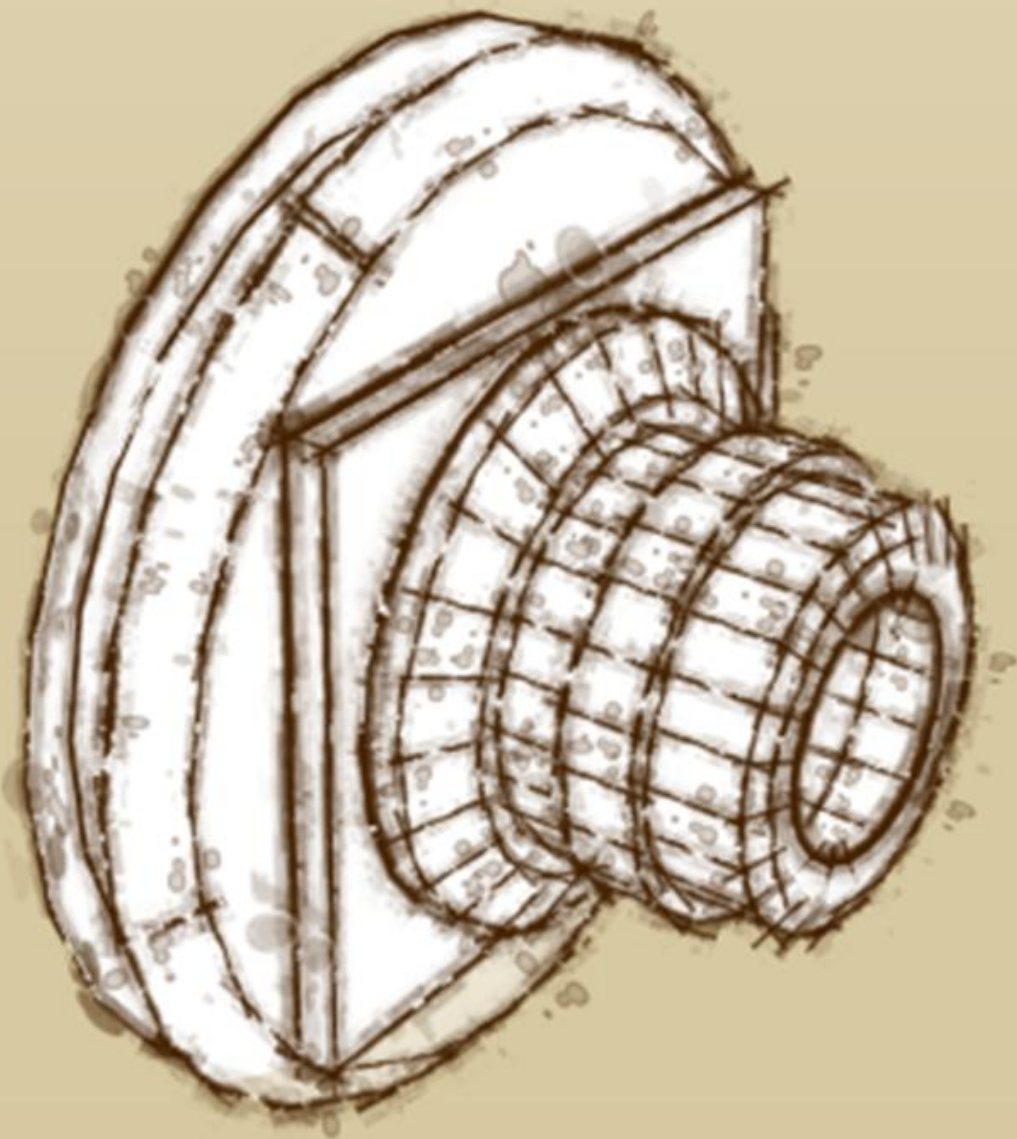
Furthermore, at construction Bellevistat will have a total of six ports – two each for passengers and cargo, raw material transport, and repair. A third port of each type will be created when the need arises, to provide space for more space shuttles of each type.

7.3.4 Safety Procedures

Safety procedures will be provided in the event that a visiting ship develops a hazardous situation. Ships of different sizes and shapes will be accommodated by the generalized method for rescuing ships from such situations. Space tugs will be released from one of the ports to locate missing ships or ships in otherwise dangerous situations. If the ship cannot be salvaged, its contents will be transported by the space tug back to the appropriate port – either the passenger and cargo port, or the raw material port.

In the event that the ship can be restored, two space tugs will be released from the two shuttle repair ports. They will attach to the endangered ship and transport it back to one of the repair ports, where it will undergo maintenance, refueling, and other necessary systems checks. The space tugs will then return to their designated ports, or continue searching for ships in hazardous situations.

E.O. APPENDICES



Section 8: Appendices

8.1.1 Operational Scenario – Hull Breach

Following a hull breach at an interface between two separate habitable volumes containing residential and commercial areas, with a hole equivalent to 6 inches (15 centimeters) diameter in each volume, within 20 milliseconds, pressure sensors located within every corridor and room will detect pressure changes that indicate a hull breach. The sensors will automatically seal shut the doors of both the residential and the commercial areas to prevent further loss of gases.

Within 40 milliseconds, portable oxygen supply masks will drop down from the ceiling for residents in affected areas. Additionally, evacuation pathways will simultaneously light up and direct residents towards safety.

Within 10 seconds, Edison robots will spray a temporary buckystructure-based patch to prevent further loss of gases and initiate repair and the hull breach.

Within 30 seconds, the doors to the commercial and residential areas will open to allow the residents to evacuate to safer and unaffected areas of the settlement.

Within 5 minutes, emergency oxygen generators and air pumps will replace any lost atmospheric gases.

Within 30 minutes, repair robots, such as Barnes and Edison, are now able to inspect affected areas for structural damage to the hull and make appropriate repairs. Furthermore, other robots will identify damage to electrical wiring, water piping, etc. and make appropriate repairs.

Within 36 hours, all structural faults and failures will have been identified and tagged for repair. The future course of action for repair will be determined at this point.

Within 72 hours, Barnes and Edison will have repaired all structural faults and failures. Nanorobots will once more inspect repaired areas and clear it for habitation and industrial use.

8.1.2 Operational Scenario – Internal Explosion

Following a hypothetical internal explosion without a hull breach in a habitable industrial area resulting in a large release of heat and toxic gas, within 10 milliseconds pressure, temperature, and chemical sensors located in every room and section of Belvestat will detect the internal explosion and subsequent heat and chemical release. These sensors will continuously monitor the temperature, gas concentration, and pressure in order to determine the future course of action.

Within 50 milliseconds, portable air purification and oxygen supply masks will drop down from the ceiling for people in affected areas to use. Additionally, evacuation pathways will simultaneously light up and direct residents towards safety.

Within 100 milliseconds, air circulation and purification will then be set to its maximum setting, and activated charcoal and combustion burners will quickly remove the contaminant gases. Central temperature control will also remove excess heat with heat sinks.

Within 30 seconds, nanorobots will address any fires caused by the explosion by spraying fire extinguishants consisting of carbon dioxide, fire-suppressant foams, water, and salts, depending on the type of fire (electrical, chemical, liquids, solids, gases, etc.).

Within 10 minutes, all inhabitants within the affected area will have evacuated into safer areas located in the spokes of each torus. Each safe house within the torus is completely isolated from the exterior environment and will have a self-contained food, water, and air supply for up to 48 hours. All affected areas will be on lockdown and quarantined to isolate fires, damage, and chemical contaminants.

Within 30 minutes, all fires will be extinguished, and all contaminant gases will be removed from the air of affected areas. Repair robots, such as Barnes and Edison, are now able to inspect affected areas for structural damage and make appropriate repairs.

Within 24 hours, all structural faults and failures will have been identified and tagged for repair. The future course of action for repair will be determined at this point.

Within 72 hours, Barnes and Edison will have repaired all structural faults and failures. Nanorobots will once more inspect repaired areas and clear it for habitation and industrial use.

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8.3 Compliance Matrix

Requirements	Subsection	Pages
1.0 Executive Summary	1.0	1
2.0 Structural Design - Belvestat must provide a safe and pleasant living and working environment for a population of 11,000 full-time residents, plus an additional transient population, not to exceed 500 at any time, of business and official visitors, guests of residents, and vacationers. The design must enable residents to have natural views of Earth and the Moon		2-7
2.1 External Configuration - On exterior design drawing(s), identify large enclosed volumes and their uses, and show dimensions of major structural components and design features. - Identify construction materials for major hull components. - Specify volumes where artificial gravity will be supplied, the means for initiating and sustaining it, and structural interface(s) between rotating and non-rotating sections. - The design must show capability to isolate at minimum any five separate habitable volumes in case of a depressurization or other emergency. - Settlement with pressurized and non-pressurized sections - Functions inside each volume (e.g., port, residential areas, and agriculture).	2.1.1 2.1.2 2.1.1 2.1.1 2.1.1 2.1.1, 2.2	2 3-4 2-3 2 3 2, 5
2.2 Internal Arrangement - Specify percentage allocation and dimensions of interior “down surfaces”, with drawings labeled to show residential, industrial, commercial (included under residential), agricultural, and other uses. - Show orientation of “down surfaces” with respect to overall settlement design, and vertical clearance in each area. - Overall map or layout of interior land areas, showing usage of those areas.	2.2 2.2 2.2	5 5 5
2.3 Construction Sequence - Describe the process required to construct the settlement, by showing the sequence in which major components will be assembled. - Specify when artificial gravity will be applied. Describe a construction technique for interior structures making use of minimally refined lunar materials. - Drawing(s) showing at least ten intermediate steps of settlement assembly, and method of initiating rotation for artificial gravity.	2.3 2.3 2.1.1, 2.3	6-7 6-7 2-3, 6-7
2.4 Buckystructure Production - The Foundation Society’s production facility for silicon buckystructures requires 50,000 sq ft (4645 sq meters) with at least a 26 ft (8 meter) ceiling height in 0.25 g, plus a comparable volume with 10 ft (3 meters) in one dimension in zero g, and 1 MW of continuous electrical power. - Show locations on overall structural drawing of buckystructures production facilities, and means for moving parts between those facilities.	2.4 2.4	8 8
2.5 Port Facilities - Port facilities must accommodate various sizes, configurations, and purposes of visiting ships. - Drawing(s) of dock configuration(s), including ships in port.	2.5 2.5	9 9
3.0 Operations and Infrastructure -Describe facilities and infrastructure necessary for building and operating the Belvestat space settlement and its communities.		10-16
3.1 Location and Materials Sources -The settlement will operate in orbit around the Earth-Moon L4 libration point.	-3.1.1	10

-Identify sources of materials and equipment to be used in construction, means for transporting those materials to the Bellevistat construction location, and storage between arrival and use.	-3.1.2	10
-Table identifying types, amounts, and sources of construction materials.	-3.1.2	10
3.2 Community Infrastructure		
-Atmosphere (identify air composition, pressure, humidity, thermal control, and quantity).	-3.2.1	12
-Food production (including growing, harvesting, storing, packaging, delivering, selling).	-3.2.2	11-12
-Electrical power generation (specify kilowatts distributed to habitable areas).	-3.2.3	12
-Water management (specify required water quantity and storage facilities),	-3.2.4	12-13
-Household and industrial solid waste management (specify recycling and/or disposal).	-3.2.5	13
-Internal and external communication systems (specify devices and central equipment).	-3.2.6	13
-Internal transportation systems (show routes and vehicles, with dimensions).	-3.2.7	13
-Day/night cycle provisions (specify schedule and mechanisms/operations for providing it).	-3.2.8	14
-Define storage facilities required to protect against interruption in production of food.	-3.2.2	12
-Chart(s) or table(s) specifying quantities required of air, food, power (for residents), water, waste handling, communications devices, and internal transport vehicles.	-3.2.9	14
3.3 Construction Machinery		
- Show conceptual designs of primary machines and equipment employed for constructing the settlement, especially for assembling exterior hull and interior buildings / structures. Describe materials, components, and/or subassemblies delivered to the machines, and how the machines convert delivered supplies into completed settlement structures.	-3.3, 5.1	14-15, 26
-Drawing(s) of primary construction machinery, showing how it shapes.	-3.3, 5.1	14-15, 26
3.4 Paper Production and Machinery		
-Show processes for providing paper (or equivalent) products in Bellevistat, including recycling.	-3.4	-15-16
-Chart or table listing raw materials source(s) and facilities for paper (or equivalent) production processes	-3.4	-16
3.5 Repair Services for Visiting Ships		
-Bellevistat will provide repair services for visiting ships.	-3.5	-16
-Show how docks for ship repair differ from unloading/loading docks.	-3.5	-16
4.0 Human Factors		
- Provide comfortable living environment		17-25
- Provide residential areas of 1g, 0.8g, and 0.5g and with 1.0, 0.8, and 0.6 times sea level atmospheric pressure	4.1.1	17
4.1 Community Design		
- Provide maps of settlement	4.1.1	17
- Provide a variety of consumables and specify means of distributing them to the people	4.1.3,	19
- Provide a distance scale and identify land area	4.1.1	17
4.2 Housing Designs		
- Design six housing plans to accommodate singles, couples, and families	4.2.2	20-22
- Show external views and floor plans of each residency	4.2.2	20-22
- Identify sources and manufacturing of furniture items	4.2.3	22
4.3 Safety Systems		
- Design systems that enable safe access for humans to all parts of the settlement	4.3.1	23
- Show airlocks and spacesuit stowage procedures to enter/exit habitable areas	4.3.1, 4.3.2	23-24
- Show exterior mobility devices	4.3.3, 4.3.4, 4.3.5	24

4.4 Short-term Residents - Design the community to encourage settlement community interaction - Design a social program to help nonpermanent residents enter the social circles of the settlement	4.4.1, 4.4.2 4.4.3	25 25
4.5 Docking Amenities - Provide a pleasant and efficient area for passenger arrival and departure	4.5	25

5.0 Automation - Table of servers and devices with description	5.0	26-30 26
5.1 Construction - Description of construction robots - Roles of construction bots in settlement - Communication between construction robots	3.3 3.3, 5.1 5.1	14, 15 15, 26 26-27
5.2 Automation for Maintenance, Repair, and Safety - Provide contingency plans - Execute how plans will be utilized	5.2 5.2	27 27
5.3 Automation for Productivity, Livability, and Convenience - Provide robots to ease livability for residents - Table of robots - Descriptions of automation for routine tasks - Privacy and network security	5.3 5.3 5.3.1 5.3.3	28-29 28 28 29-30
5.4 Shipment and Unloading of Ores - Descriptions of shipping containers - Automation of docking and unloading materials - Transportation of materials on site in different environments	5.4 5.4 5.4	30 30 30
5.5 Port and Docking System - Docking systems to accommodate different sized ships - Procedures for handling and docking different ships	5.5 5.5	30 30

6.0 Schedule and Cost - The proposal will include a schedule for completion and occupation of Bellevistat within 13 years, and costs for design through construction phases of the schedule.		31-35
6.1 Construction and Habitation Schedule - Describe contractor tasks from the time of contract award (15 May 2033) until the customer assumes responsibility for operations of the completed settlement. - Show schedule dates when Foundation Society members may begin moving into their new homes, and when the entire original population will be established in the community.	6.1 6.1	31-32 32
6.2 Costs - Specify costs billed per year of Bellevistat design through construction in U.S. dollars - Estimate numbers of employees working during each phase of design and construction in the justification for contract costs.	6.2 6.1, 6.2	33-35 31-35

7.0 Business Development - Bellevistat will host various commercial and industrial ventures, which may change with time. The basic design must be sufficiently flexible to add compatible business types with little configuration change.		36-40
7.1 Port for receiving lunar and asteroid materials -Ores will arrive in standard shipping containers -Ore arrives in batches but is delivered for continuous processes, so must be stored between delivery and use -Provide method(s) and route(s) for transferring raw materials to processing facilities	7.1.1 7.1.2 7.1.3	36 36 37

-Most--but not all--non-bulk cargo will arrive in standard shipping containers	7.1.3	37
-Provide separate port facilities for passengers, and cargo other than raw materials	7.1.3	37
7.2 Production of goods manufactured from extraterrestrial materials		
-Materials require processing varying from minimal to refining for extraction of metals and rare earth elements	7.2.1	37
-Many processes require operations in both zero g and at least 0.2 g	7.2.2, 7.2.5	37, 39
-Manufacturing will encompass a wide variety of products; the Foundation Society will welcome companies to lease space for manufacturing facilities	7.2.1, 7.2.2	37
-Products will be created at Bellevistat for export, provisioning visiting ships, and internal use/consumption; provide delivery paths from manufacturing area(s) to customer acceptance for each market	7.2.2, 7.2.3, 7.2.4	37-38
-Allow for future expansion of manufacturing areas, to eventually include assembly of large interplanetary ships	7.2.6	39
7.3 Repair and restoration of ships and other space infrastructure elements		
-A fleet of 10 space tugs will operate from Bellevistat, of which up to 5 tugs may be docked at any one time	7.3.2	40
-Repair docks are required to accommodate different types and sizes of ships	7.3.1	39-40
-Allow for future port expansion, both for increasing numbers and sizes of visiting ships requiring services	7.3.3	40
-Provide safety procedures in the event a visiting ship develops a hazardous situation	7.3.4	40

8.0 Appendices		
8.1 Operational Scenario		
- Describe in detail processes that will occur during two different emergencies, and how normal functions will be restored after each situation is stabilized:		
A.1 Hull breach at an interface between two separate habitable volumes containing residential and commercial areas, with a hole equivalent to 6 inches (15 centimeters) diameter in each volume.	8.1.1	41
A.2 Internal explosion without a hull breach in a habitable industrial area resulting in a large release of heat and toxic gas	8.1.2	41-42
8.2 Bibliography / References		43-44
8.3 Compliance Matrix		45-48