Northdonning Heedwell

Bellevistat

Gretchen Whitney High School
Cerritos, California
United States of America

20th Annual International Space Settlement Design Competition
Proposing Team Data 2013

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(we request that participants be at least 15 years old, and not older than 19)

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Erik Wang	[12] (18)	Catherine Chiou	[11] (15)
Justin Ho	[12] (17)	Melissa Su	[10] (15)
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Jina Yoon	[11] (16)	Jeremy Wang	[12] (18)
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Names of two adult advisors currently expecting to attend the Finalist Competition:

Patty Cordova Eric Gutierrez

I understand that if our Team qualifies for the International Space Settlement Design Finalist Competition Aug. 2-5, we will pay for our own travel to/from Nassau Bay, Texas, USA.

Patty Cordova 4-22-13
Responsible Teacher/Advisor Signature Date

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1.0 Executive Summary

Ralph Waldo Emerson once famously stated, “Unless you try to do something beyond what you have already mastered, you will never grow.” Man first walked on the Moon more than sixty years ago, and one of our most significant achievements since then was the first large-scale space settlement community in Earth orbit, Alexandriat. In 2033, however, Alexandriat has been spread too thin; it is time to expand, to pursue mastery rather than simply proficiency.

Northdonning Heedwell is proud to present our proposal for the Foundation’s second settlement, Bellevistat. Designed specifically to address overloaded processes on Alexandriat, Bellevistat will provide the latest in large-scale refining, manufacturing, and mass production technologies to fully utilize its unique position between Earth and the Moon. With a focus on both breadth and depth in its position as an industrial production settlement, Bellevistat will incorporate efficient production pathways for every major manufacturing process, while its port systems will facilitate rapid loading and unloading of goods to maximize output.

Bellevistat must both excel and be versatile in any position, including future usage and novel production processes. The modular construction of its facilities will allow for ease of addition and expansion to accommodate new types of manufacturing; Bellevistat is designed to be a dynamic, constantly upgrading system designed to meet every requirement the Foundation requires in terms of large-scale industry.

Even with its focus on manufacturing and production, Bellevistat will nonetheless provide a consistently high quality of life for its 11,500 residents. The settlement will accommodate multiple gravity zones in addition to multiple atmospheric pressures to allow citizens to feel what it is like to be in space without experiencing the negative effects of zero-gravity. Bellevistat will also provide infrastructure to fully support its population’s comfort and security, employing state-of-the-art food production systems to provide a healthy and varying diet for its residents, complete with seafood and meat. Security on the settlement will also be managed by the latest in machine learning and automated response systems, with many custom-designed robots created to ensure the settlement’s safety even in case of simultaneous multiple failures. Algorithmic advances will also ensure that Bellevistat’s security will only grow more efficient as time passes and more data is collected.

Residents happy to wake up on Bellevistat will be the most productive as was evidenced by the recent and precipitous development of silicon buckystructures, and this mindset will continue to make the settlement a highly desired place to work, play, and sleep.

Bellevistat is, at heart, an ever-evolving system, using existing technologies to pioneer new ones. Using a constellation naming scheme, Bellevistat is designed to keep us all seeking advancements in technology for mankind. Rapid technological advancement coupled with cutting-edge technologies equip the settlement to succeed in any circumstance, and it is thus with pride that Northdonning Heedwell presents to the Foundation Bellevistat, the pioneer settlement.

Structures
(will be sent as an amendment)

Operations

3.0 Operations

3.1 Materials

Raw materials used in the construction of Bellevistat will primarily come from the Moon because of the abundance of silicon and aluminum on the surface of the Moon. These minerals can be fabricated in the preliminary construction stages into the various materials that will be used in the other stages of Bellevistat. The Moon is a convenient place to obtain minerals for the settlement because of the availability of highly useful elements such as silicon, aluminum, calcium, iron, magnesium, and titanium, so we make use of the lowered cost of obtaining minerals from the Moon to construct Bellevistat. The materials not readily available on the Moon will be imported from Earth. Robots mining the materials from the Moon will shuttle the materials back to the settlement through periodic rocket launches. Although we will strive to use materials as soon as possible after they are transported to Bellevistat, storage facilities will be installed near docks while they are waiting to be processed. Low density materials will save fuel costs when materials must come from Earth, and we use a sparing amount of denser materials such as zirconium and chromium.

Table 3.1 Materials/Equipment for Construction

Material (Purpose)	Composition	Amount (kg)	Source
Silicon Nitride (Insulation)	Silicon	53,000	Moon
	Nitrogen		Earth
Silica Nanofoam (Insulation)	Silicon	1,200	Moon
	Oxygen		Moon
7068 and 7079 Aluminum (Hull)	Aluminum	523,000	Moon
	Zinc		Earth
	Copper		Earth
	Magnesium		Moon
	Trace Metals: Zirconium, Iron, Manganese, Chromium, Titanium		Moon when available, else Earth
Carbon Nanotubes (Hull)	Carbon	1,100	Earth, fabricated on Bellevistat
Self-Healing Material (Hull, Airlocks)	Chitosan complex	267,000	Earth
	Diarylbibenzofuranone linker		Synthesized on Bellevistat
	Oxetane		Synthesized on Bellevistat
Anorthite Glass (Windows)	Silicon	50,000	Moon
	Oxygen		Moon
	Aluminum		Moon
	Magnesium		Moon
	Calcium		Moon
	Boron		Earth

3.2 Infrastructure

3.2.1 Atmosphere

Maintaining and controlling atmospheric conditions are essential considerations for survival and successful material production on Bellevistat. Typical residential areas will have an atmospheric pressure of 1.0 atm with approximately the same composition as that on Earth to avoid any negative effects of a different atmosphere on residents and crew members. Residential areas requiring lower pressures (0.8 and 0.6 atm) will have a reduced amount of nitrogen while maintaining the same amount of oxygen. Note that this configuration is still safe for regular operations because the partial pressure of oxygen is still the same; reaction rate is governed by the absolute partial pressure of oxygen, not its fraction relative to other gasses (an implication of chemical equilibrium and rate laws).

Gas exchange and other aspects of maintaining a livable atmosphere will be managed by GEMS (Gas Exchange and Maintenance System). GEMS will ensure a relative humidity of 50% as well as a comfortable living temperature of 21°C. GEMS itself will be a distributed system with a number of independent modules placed around the settlement which typically operate at about 70% capacity with the ability to ramp up atmosphere maintenance in case of failure of other modules.

Table 3.2.1 Atmosphere Composition

Gas	Percent	Volume (m^3)
Nitrogen	78%	242780000
Oxygen	21%	65634000
Other Gases (CO_2, H_2O)	<1%	3125430

3.2.2 Food Production

Our food production system, named Orion after the hunter constellation, will rely on a dynaponics system for growing our produce in addition to a coupled system for growing a variety of seafood for our residents. Dynaponics is a variant of aeroponics chosen for its many advantages over other types of food production. In addition to significant water and nutrient savings over more traditional methods such as geoponics, dynaponics also reduces chance of contracting disease by avoiding direct plant-to-plant contact because plants are suspended in air. This suspension allows nutrients and water to be absorbed directly through plant roots which is many times more efficient that through a separate medium, resulting in healthier and thus more enjoyable produce. An additional advantage of having the plants suspended in air is the ability to increase the plant density because of the lowered chance of plant disease contraction. In this regard, dynaponics is much like aeroponics with one additional optimization - aeroponics was previously hampered by the high energy required to generate the high pressures to spray water over the plant roots. Dynaponics has solved this issue by blowing pressurized air on the water to create the mist required for effective plant growth, which requires significantly less power when considering the high amount of food required by the colony.

Table 3.2.2 Food Production

Source	Amount (kg/year)
Dynaponics	4,264,000
Seafood	2,236,000
In-Vitro Meat	572,000
Total	7,072,000
Required	5,636,800
Storage	1,435,200

3.2.2.1 Growth

Depending on size, plants will be grown in shelves with varying dimensions with plants grouped roughly by space required. The plants will be suspended over tanks of enriched water so that the spray from the water will provide nutrients, and various types of seafood will be cultivated in the water tanks. We will grow a variety of produce with an emphasis on nutrition, taste, and speed of growth; while dynaponics places little restriction on the types of plants grown we avoid extremely large plants to conserve space and nutrient resources. The Mediterranean diet we will provide for residents will include: legumes (beans, lentils, nuts), unrefined cereal (oats, wheat), fruit (berries, grapes), and vegetables (carrots, peppers, broccoli) as produce grown from Orion's dynaponics farm. Staggering the planting and harvest of plants will ensure that fresh produce is available to residents throughout their stay on Bellevistat.

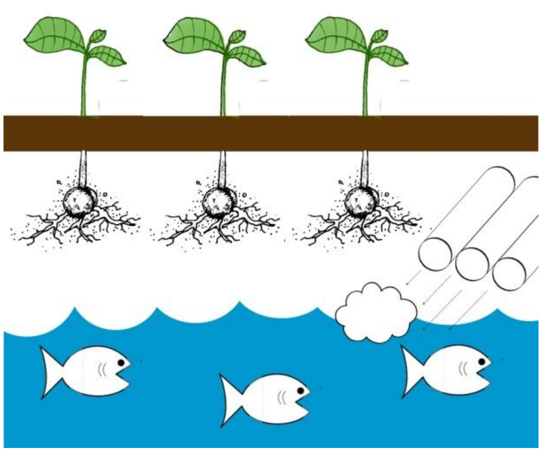


Figure 3.2.2.1 Dynaponics Schematic

3.2.2.1.1 Seafood

Because nutrient-rich water is readily available in the Orion system as a result of dynaponics, it is a relatively easy process to cultivate fish and seafood for Bellevistat's residents in the water tanks underneath the plants. We have chosen a variety of freshwater seafood with an emphasis on sustainability and nutrition, including freshwater oysters, salmon, and seaweed. The seafood grown in Orion will help provide variety in food choice for residents as well as additional nutrients not available from plants such as protein and omega-3 fatty acids.

3.2.2.1.2 Nut Milk/Other Dairy-Related Products

While milk and milk-related products are typically in constant demand on Earth, cultivating cows for such products is relatively resource expensive and wasteful. Because of this, Orion will utilize the peanuts, almonds, and soybeans produced from dynaponics to create milk substitutes: peanut milk, almond milk, and soymilk, respectively. These products have the advantage of not having to grow and care for cows as well as having additional nutrients besides those found in normal milk. Nut milk contains significantly less fat and cholesterol than cow milk and so will provide the benefits of milk without many of its drawbacks. It is also possible to produce other milk-related products such as yogurt and cheese from nut milk, making it an effective alternative to animal milk.

3.2.2.1.3 In-Vitro Meat

Although we will avoid having actual livestock on Bellevistat, it is still possible to produce meat for our residents through an in-vitro process. By cultivating different animal muscle stem cells, we can grow meat relatively quickly in Orion's bioreactors. Our quantity of meat produced will be more limited due to the more expensive meat production process but will still be sufficient to make sure residents obtain enough essential amino acids and protein.

3.2.2.2 Harvest/Processing/Storage

Harvesting our produce will be completely automated by our harvesting robots. Since plants will be mostly suspended on shelves harvesting produce will be relatively easy: robots merely need to pull out the shelf, harvest the plant, and push the shelf back in. The robots will have clippers to trim off needed parts of plants and moldable piezoelectric fabric to gather produce according to the different plant specifications; a machine learning system will be in place so that the robots become more efficient at harvesting as time goes on.

Orion's food processing facilities will be equipped to handle all the various types of produce and seafood grown on Bellevistat; nuts will be shelled and inedible parts of vegetables will be cut away and recycled for energy and nutrients. Because of the staggered growth of food in Orion, fresh produce and live seafood will be provided for residents whenever possible, improving food quality and decreasing processing costs.

However, a portion of food will still be stored on Bellevistat. Approximately 20% of food if not eaten immediately will be vacuum-sealed and refrigerated for future consumption. Food will be rotated out on a regular basis so that fresh food will always be available in case of emergency. Storage units will be placed around the settlement and will hold enough food for relatively comfortable living for two weeks for the residents that they cover.

3.2.2.3 Delivery/Selling

After the food has been processed, the fresh produce will then be delivered by robot to various markets and distribution centers around Bellevistat using the Hydra transportation system (see 3.2.7). Dining halls and markets will be managed by human chefs and automated food distributors to provide Bellevistat residents with the widest possible range of options in food.

3.2.3 Electricity Production

Table 3.2.3.1 Electric Power

Priority	Type	Electric Output (kW)	Number	Location
Primary	Solar	1,300,000	2 Solar panel fields	One on each end of Bellevistat
Secondary	Travelling Wave Reactor	340,000 – 1,230,000 (Depending on need)	5 small reactors	Spread throughout Bellevistat

Solar power is the most preferable source of energy for our settlement due to its renewable nature Bellevistat's relatively close proximity to the sun. Recent developments making use of the unique properties of the newly discovered silicon buckystructures in combination with existing quantum dot solar cell technologies has allowed for solar panels efficient enough to be the primary power source for living and production on Bellevistat.

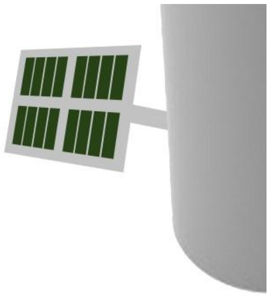


Figure 3.2.3 Solar Panels

These solar cells primarily make use of silicon's properties of tunable band gaps to capture different wavelengths of light. The panels are engineered with multiple layers of silicon sheets with slightly different impurities to cover the majority of wavelengths available from the Sun, using tuned quantum dot sheets to capture most of the remaining light. This tandem-cell system has been shown to approach the theoretical maximum solar cell efficiency (86%) with an efficiency of approximately 81%, which suffices for Bellevistat's requirements.

Our secondary source of electricity will be a network of five nano-travelling wave reactors distributed throughout the station (25m x 25m x 5m). These reactors are notable for their minimal use of uranium-235 to start a reaction in a uranium-238 core. This reaction wave slowly travels through the core (hence the name travelling wave); current limitations require us to replace the core around once every one hundred years given a typical requirement of 26% of a reactor's full operating power output. The relatively small amount of waste is ejected towards the Sun. The low-maintenance and low-waste aspect of travelling wave reactors make them an excellent secondary power source, and the parallel reactors ensure continuous power generation even in event of failure of some reactors and/or solar panel damage/failure.

Table 3.2.3.2 Power Allocation

Purpose	**Power (kW / year)**
Residential	40,000
Commercial	45,000
Manufacturing	550,000
Lighting	10,000
Utilities	90,000
Agriculture	100,000
Communications	50,000
Transportation	60,000
Automations	120,000
Climate Control	80,000
Total	**1,145,000**

Table 3.2.4 Water Usage/Production

Purpose	**Amount (kiloL/year)**
Human Consumption	1,259,000
Atmosphere	500,000
Agriculture	550,000
Manufacturing	600,000
Total	2,909,000

3.2.4 Water Management

Water is both costly to obtain and essential for life and production on Bellevistat, so every precaution will be taken to ensure minimal waste and efficient distribution around the settlement. It is estimated that every person will consume approximately 300 liters of water daily. With about 11,000 residents (and 500 transients) on the station 3.45 million liters of water will be used every day, leading to approximately 5 million liters of water in circulation at any time with an additional 10 million liters of water stored for emergency situations for human use. See Table 3.2.4 for a more comprehensive water consumption list.

3.2.4.1 Water Treatment

In transport, water will be constantly monitored by Libra, our automated water management nanoparticle system. Libra, named after the constellation of balance and justice, is at heart a chemical reactor and detector designed to find and remove particles in water that are harmful to living systems and machinery. Modeled after the human body's immune system, Libra's central system manufactures a set of all-purpose iron and copper-based nanoparticles that are deposited into water after the water has been used which are designed to seek and precipitate foreign particles out of the water. Before the water reaches the central water management system, the nanoparticles (attached to particles) are filtered out of the water using magnetic resonance and are then analyzed by Libra's main computing unit. If a harmful chemical/pathogen is found, Libra engineers specific nanoparticles for that chemical/pathogen and that specific water pathway and stores the information for later use, much like the body's B

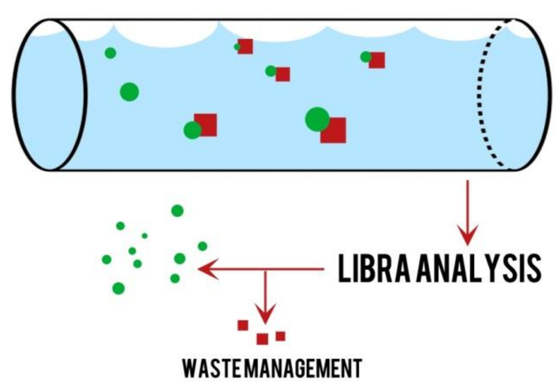


Figure 3.2.4.1 Libra Water Flow

cells and plasma cells. Using this method of machine learning, Libra is able to generate specific treatments for every major waterway, conserving a large amount of effort for the central water processing unit while still remaining robust enough to handle never-before-seen antigens. Constantly learning and adjusting, Libra eliminates most of the work needed to purify water for use again on Bellevistat; the central water processing unit merely needs to serve as a final safety before water is reused in the system by running the water through several final filters to remove large particles and a UV sterilizer.

3.4.2.2 Water Storage

Pure water will be stored in various places around Bellevistat in case of an emergency. To fulfill our need of approximately 10 million liters of water as backup, we will use ten 1 million liter containers distributed throughout the station (10 x 10 x 10m each) to hold water. Reverse osmosis ultra-purified water is used because it is guaranteed to be usable for all purposes and because its purity is easily verified through pure water's resistivity (182 kΩ·m) which only decreases as more substances are present in the water and is very sensitive to changes in water composition - concentrations in parts per trillion result in very noticeable deviations from the normal resistivity.

3.2.5 Household and Industrial Solid Waste Management

Supporting a large community of people as well as large-scale industrial processes demands a waste management system that is capable of handling even the most toxic of wastes by decomposing molecules down to their atomic components. Whereas with water management we use a nanoparticle colloid in the liquid phase, solid waste requires a slightly different approach because of the dependence on surface area.

3.2.5.1 Waste Treatment

Solid waste is almost never able to be quickly decomposed unless it has a high surface area to volume ratio, so waste disposal bots are fitted with powerful garbage pulverizers to grind trash to a powder en route to a waste treatment facility.

Our two waste treatment facilities utilize novel breakthroughs in previous plasma gasification methods to achieve lower power consumption and faster waste processing. Plasma gasification is characterized by running an electric arc through solid waste, dissociating the chemical bonds in waste and reducing molecules to their atoms, rendering all waste to a basic form that is more easily handled. The products of this plasma gasification process include slag, heat, and a mixture of gases deemed synthetic gas which is burned to offset power costs for running electricity. Our first major improvement was using copper-zirconium alloy electrodes infused with specially engineered tungsten nanoparticles, allowing us to use a much lower voltage than usual to provide the same amount of current through the system; we also recover heat freed from the molecular bonds for use in powering the plasma arc. Use of argon in the plasma chamber also slightly reduces the voltage required for gasification because of its greater number of electrons compared to other inert gases such as neon or steam. Because no extra oxygen is available to react, no phenols or complex hydrocarbons are formed. The water used in the process will pick up any leftover toxins and heavy metals and is purified through Libra (see 3.2.4.1) before being used again. The waste removed from the water will be either reused or ejected from the space settlement depending on its toxicity. Plasma gasification of waste is ecologically clean and self-sustaining in terms of power, making it ideal for use on Bellevistat.

Table 3.2.4 Waste Production

Source	**Amount (metric ton/year)**
Households	330,000,000
Manufacturing	460,000,000
Libra	110,000,000
Other	90,000,000
Total	990,000,000

3.2.6 Internal and External Communications

3.2.6.1 Internal Communications

Ensuring internal communications with very high uptimes is a major priority in enabling effective production processes and the safety of Bellevistat's residents. It is for this reason that we have chosen a distributed peer-to-peer network as our primary pathway of communication within Bellevistat named Volans after the Flying Fish constellation. This massively parallel system is embedded in nearly every electronic device needing to communicate with other devices, including computers, robots, and equipment. As adjacent devices communicate with radio waves, they relay and receive signals from other devices as well; each device functions as both a client and a server. Volans will also involve several main servers placed on each cylindrical module of the settlement to provide stronger performance guarantees in case of failure of larger areas of devices - with these servers in place a signal has a worst-case maximum of approximately 10 device "hops" before arriving at any destination. The servers also collect non-intrusive data about signals they relay so that adjustments can later be made to increase the efficiency of the system overall. Volans is a robust and powerful internal communications system for Bellevistat, promising extremely low latency in addition to virtually zero probability of complete system failure.

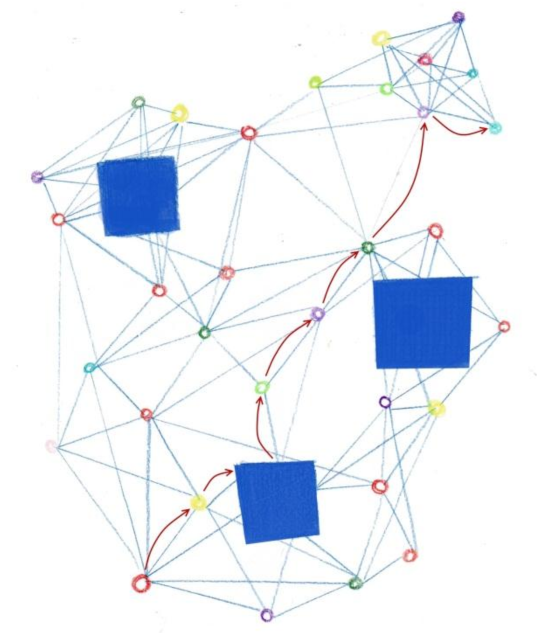


Figure 3.2.6.1 Schematic of Volans With One Possible Pathway Shown

3.2.6.2 External Communications

External communications between Bellevistat and Earth will be maintained through an infrared laser optic communication system for increased capacity and heightened security, backed by a more traditional radio wave system because it is readily available from the Volans system (see 3.2.6.1) and because it is more backwards-compatible with existing Earth infrastructure.

Because of the ever-growing amounts of data that must be transmitted between Earth and the settlement we implement an infrared free-space optical system to ensure low latency and near-lossless data transfer. Made possible because of the relatively short distance between Bellevistat and Earth, this type of communication fully utilizes the superior data capacity of infrared photons and the properties of coherent light. The laser aiming is taken care of by an advanced computerized system taking into account various factors that may affect the quality of the signal such as atmospheric interference and noisy environment. Several receiving stations placed around Earth will allow for constant contact between the settlement and Earth and will be optimized to minimize signal-to-noise ratio by using high-gain photon detectors. Before leaving the station, the photon beam will pass through a N-slit interferometer which will prevent possible tampering with the laser.

Our secondary method of communication with Earth will be through the existing radio wave-based system Volans. The main servers in Volans can easily be fitted with more powerful radio wave transmitters/receivers able to reach the Earth's atmosphere and thus utilize existing Earth infrastructure to communicate with Earth. While not able to send as much data as the infrared laser system, this radio wave system will have the advantage of having a theoretically greater uptime, convenience, and lower power cost.

3.2.7 Internal Transportation

Bellevistat's transportation system is named Hydra after the dragon constellation to denote its ability to transport people and cargo large distances quickly. Multiple extremely low resistance solenoids composed of copper wire with silver nanoparticles will run underneath the track, which will be installed around Bellevistat. Entrances to the track will contain fiberglass platforms embedded with magnetic nanoparticles that will allow users to conveniently gain access to Hydra. Specially fitted platforms made of the same material are also available for transportation robot use. Once a user activates the track, the solenoids' circuits will be activated and the solenoids will be able to detect the user by detecting a changing magnetic flux. A simple

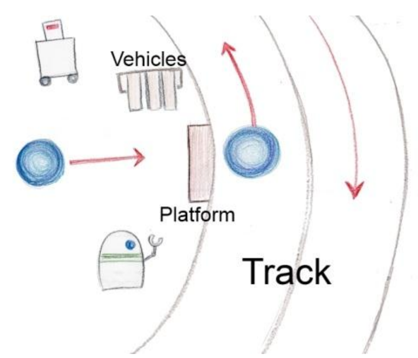


Figure 3.2.7.1 Passenger/Cargo Flow for Hydra

transformer circuit will allow solenoids in front of the user to change polarity to attract the user's vehicle to pull him/her forward, while the magnetic field produced from solenoids underneath and behind the user will repel the user so that the vehicle floats above the track, reducing friction. While the circuits themselves are simple to implement, the issue with multiple users having separate stops will be managed through Hydra's computerized system, which opens and closes gates and slows vehicles to allow residents/robots to stop where they need to. After the initial cost of installing the track and the solenoids, Hydra is remarkably power-efficient because of the low-resistance solenoids and because eddy currents from the solenoids as a vehicle passes can be used to recharge the system. Hydra will be able to transport goods of up to 50 metric tons (which can be increased by increasing the surface area of the bottom vehicle) and up to 15 m in its shortest dimension at maximum speeds approaching 40 m/s, although residents will be limited to a lower speed. There will be two circular tracks on each module of Bellevistat for a total of 6 tracks upon completion; each will run straight along the cylinder wall to create a ring around the cylinder. Each track is 15m wide. (Also see 7.0.2.3)

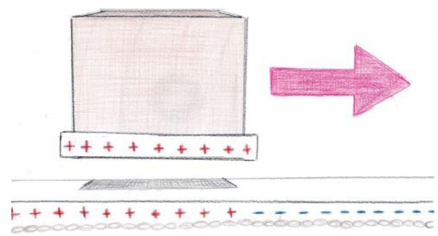


Figure 3.2.7.2 Schematic of Magnetic Track in Hydra

3.2.8 Day/Night Cycle

The day/night cycle on Bellevistat will be implemented through quantum dot LED screens on the ceiling of Bellevistat (the inner cylinder). These LEDs, chosen for their extremely high power-to-light efficiency and their flexibility, will be able to accurately simulate an Earth day/night cycle for residents on the settlement complete with Sun and Moon. We will use a 24-hour cycle with day/night times adjusted to be synchronized with Greenwich Mean Time to allow residents to adjust quickly and feel more comfortable on Bellevistat.

3.3 Machines/Equipment for Settlement Construction

Bellevistat is built as a semi-modular system with its three cylinders as modules. Because each module is designed to be self-contained, construction will involve beginning with a smaller module base which houses basic functionality and provides the capability to expand to a complete module and the remainder of the required modules.

3.3.1 Base Module and Construction

The base module is a bare-bones satellite designed specifically for functionality and utility while the rest of the settlement is being constructed. Parts pre-made on Earth will be installed immediately upon arrival to allow basic manufacturing to take place. It contains facilities for robot repair and production with a focus on automated manufacturing, fabrication, and settlement construction while being managed by stations on Earth. The machinery available on the base will be focused on rapid deployment of construction robots and installation of pre-manufactured parts from Earth. Upon arrival in space, our Heavy Mover bots (see 5.1.1.1) will immediately be deployed to construct the main hull of the settlement to avoid space debris and possible damage, with Finesse Bots (see 5.1.1.2) traveling close

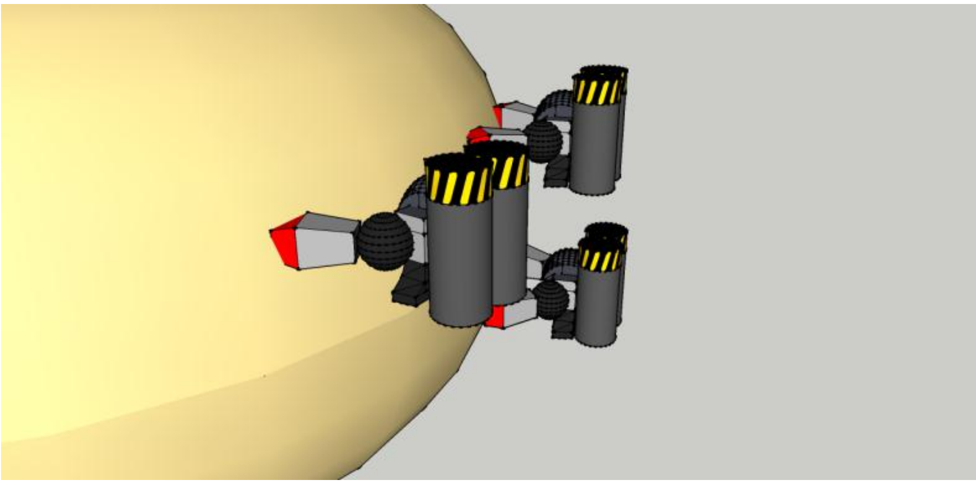


Figure 3.3.1 Mover Bot Pushing Load

behind to attach parts. Each Mover bot is able to carry a single payload from Earth at a time (6m diameter by 24m length).

3.4 Paper Provisions

3.4.1 Raw Material Sources

The primary source of the raw materials for making paper will be bamboo (*Bambusa oldhamii*, the Giant Timber Bamboo). This choice of bamboo over alternative sources of cellulose was based on a number of significant advantages including a fast growth rate (approaching 100 cm per day) and a mature height tall enough to be efficient for paper production. This type of bamboo is also simple to integrate into pre-existing structures for dynaponics production because of its relatively small surface space and nutrient requirements. In addition, the shoots of this type of bamboo can be used as a source of food. Other sources of pulp to be used in producing paper include recycled paper, residues from Orion (see 3.2.2), waste from food consumption, and textile wastes.

3.4.2 Production Process

Due to a limited amount of space and material resources on Bellevistat, efficiency in the paper production process is critical. The two production facilities themselves will be constrained to 10m x 15m x 10m, and are designated to produce paper for either commercial (offices, packaging) or residential (hygiene, food preparation, personal expression) use. Fiber will be extracted from our various fiber sources using a chemical mixture, and the resulting pulp will be pressed into paper. The entire paper production process will be automated and is estimated to use approximately 90% of the raw material mass, a significant improvement over other methods of producing paper by introducing a process that makes use of lignin, resulting in a paper that is slightly less white - estimated brightness is 84 compared to approximately 95 for normal paper on the ISO scale - but much more efficient to produce. Normal brightness paper will also be produced from the facility at a much smaller volume for consumer-specific usage. The waste of this high-yield production is relatively easily converted to fuel through bacterial breakdown and burned to reduce energy usage. The production facility itself is engineered to handle bamboo fiber most efficiently but will also be able to handle alternative fiber sources, including the ones discussed in 3.4.1 (recycled paper, residues from Orion, waste from food consumption, and textile wastes).

Table 3.4 Paper Production

Fiber Source	**Amount of Paper Made (kg/year)**
Bambusa Oldhamii	310,000
Used Paper	90,000
Orion Residues	15,000
Waste from Food Consumption	10,000
Textile Waste	7,000

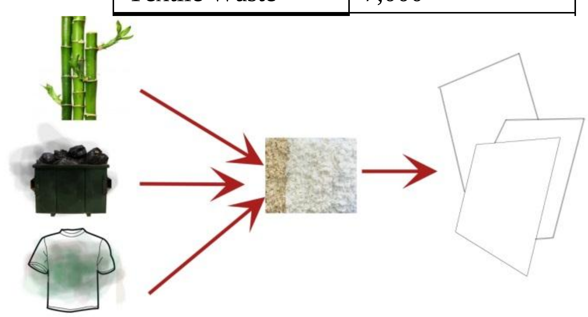


Figure 3.4.2 Manufacturing Flow

3.5 Repair Services for Visiting Ships

Repair facilities on Bellevistat will be in constant demand due to the nature of space travel and the large amount of debris present in space. To accommodate this need, adaptations to our previous design for our loading/unloading dock will be required. Instead of large robots with more powerful arms for cargo we will use Caelum robots designed to repair damage in spaceship hulls using more precise welding and hammering tools in tandem with our Finesse bots. Our docking system will use our computerized system for ship alignment to make sure ships can find their way into the dock; braking will be facilitated by shock cords in the dock that attach to ships as they enter the port so that the ships will stay in a relatively fixed position as the Caelum and Finesse robots repair the visiting ship. (See 7.0.3)

Humans

4.0 HUMAN FACTORS

Bellevistat is not only designed to provide settlers with the beautiful views of space, Bellevistat also ensures maximum comfort on the settlement by accounting for the people's needs. With the modern innovative technologies, residents of Bellevistat can enjoy a new, exciting lifestyle.

Figure 4.0.1.2.1

Molecular Gastronomy

4.0.1 Comfortable Living

By accommodating colonists with housing, food, entertainment, and professional amenities, settlers can enjoy new experiences without sacrificing the comforts of Earth.

4.0.1.2 Access to Fine Foods

Bellevistat's restaurants will allow residents to enjoy the finest foods of each culture. Experienced and professional chefs will cook be able to cook home-style dishes as well as unique entrees using molecular gastronomy.

4.0.1.2.1 Molecular Gastronomy Chefs will study the chemical aspects of food, so residents can experience food made with science and technology. With molecular gastronomy meals offered at fine dining restaurants, residents can fully appreciate the flavors and textures of each dish. Using various techniques such as food pairing and spherification, chefs can cater tasty and enticing dishes to appeal to the colonists' palate. (*See Figure 4.0.1.2.1.)*

4.0.1.2.2 Convenience Food

For those on the rush, freshly made take-out food is available at convenience restaurants. For familiarity and comfort, colonists can eat at food chains contracted from Earth such as McDonald's and Panda Express.

4.0.2 Natural Sunlight and Views of Earth and Moon With viewing ports and observatories, the colonists will have multiple opportunities for natural sunlight and views of space.

4.0.2.1 Viewing Ports At viewing ports, people will be able to view natural sunlight through 2x5 meter windows.

4.0.2.2 Telescopium Observatory Observatories will provide a relaxing and serene atmosphere in which people can enjoy views of space. Stocked with the top-notched astronomical equipment, the Telescopium will allow citizens to gaze at the wondrous views of the Earth, the Moon, constellations, and space with ease. Two large adjustable telescopes located at each end of the observatory will allow more people to view space. (*See Figure 4.0.2.3).*

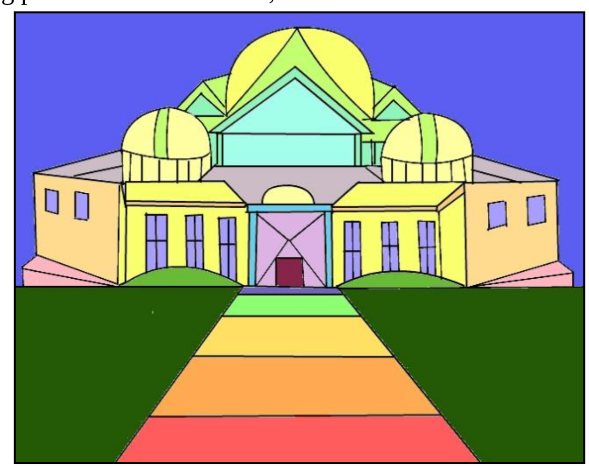
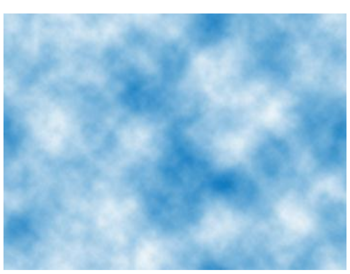


Figure 4.0.2.2 Telescopium Observatory

4.0.3 Artificial Lighting The colony will utilize artificial lighting using LED and quantum dots to illuminate the colony. Roads and pathways will be lit with quantum dots along the perimeters for easy navigation at night.

4.0.4 Day-Night Cycle Bellevistat's day-night cycle will be based on GMT, with 24 hours in a day and 7 days per week.

Figure 4.0.4.1 Skies



4.0.4.1 Skies

Ceilings and upper walls will be lined with quantum dots and LED screens to simulate the Earth-like scenes and environment including skies and mountains. The skies will change accordingly to the day-night cycle. *(See Figure 4.0.4.1)*

4.0.5 Gravity and Pressure

Within our structure, our colony will be separated into three sectors –Cygnus, Musca, and Pavo- which each contain residences and commercial facilities. Each unit sector will consist of different pressures and gravity.

4.0.5.1 Gravity

Because children need at least 3 hours per Earth day of 1g, most of our family residences will be located in the 1 g Cygnus sector. On the other hand, since adults prefer living at 0.8 g, our condos will mainly be located in the Musca sector with 0.8g. The Pavo sector will accommodate more apartments at 0.5g. At each sector, Bellevistat will allocate several of each type of residences for colonists.

4.0.5.2 Pressure Colonists can find different pressures in each sector. At Cygnus, 1.0 atm will be used, and 0.8 atm is used the Musca sector. Bellevistat will employ a pressure of 0.6 atm in the Pavo sector. *(See 3.2.1)*

4.0.5.2.1 Sports Complex At the each sector, sports complex will offer traditional sports as well as low gravity sports in basketball, tennis, football, and soccer along with unique sports such as outdoor ice skating, underwater hockey, and Quidditch. Trampolines are available, so residents, especially those at 0.5 g, can enjoy jumping at higher heights.

Table 4.1.1 Variety and Quantity of Facilities Buildings	Quantity	Floor Area/ unit (m^2)	Total Floor Area (m^2)
City Hall	1	5000	5000
Visitor Center	1	2500	2500
Justice Building	1	2200	2200
Public Safety Department	2	1200	2400
Fitness Center	3	700	2100
Sports Complex	3	2500	7500
Weather Park	3	9000	27000
Bank	3	750	2250
Hotel	2	6500	13000
Clinic	3	850	2550
Hospital	3	9000	27000
Personal Health Center/ Spa	2	950	1900
Religious Facility	3	2200	6600
Market	3	2800	8400
Large Restaurant	3	1800	5400
Small Restaurant	9	750	6750
Fine Dining	3	1100	3300
Convenience Food	3	600	1800
Convenience Store	3	600	1800
Mall	1	15000	15000
Star Galaxy Arcade	3	700	2100
Circinus Theater	3	3300	9900
Leo E-Book Station	3	600	1800
School	2	6000	12000
University	1	20000	20000
Telescopium Observatory	3	1500	4500
Museum Horologium	1	10000	10000
Research Facilities/ Laboratories	3	5000	15000
Office Buildings	6	8500	51000
Industrial District (Warehouse, backups)	1	12500	12500
Computer/ Robot Repair Center	2	5500	11000
Water/ Waste Management	1	5000	5000
Manufacturing Center	1	6500	6500

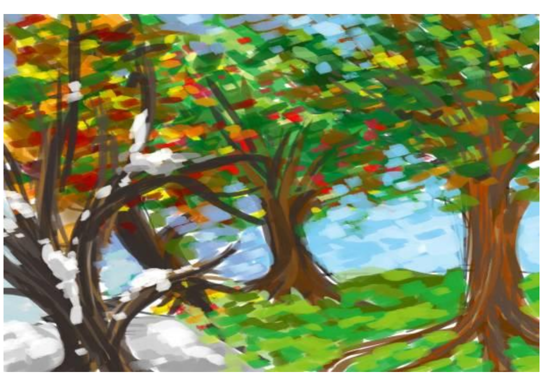


Figure 4.1.1.4 Weather Park

4.1 MODERN COMMUNITIES

4.1.1 Facilities An array of facilities throughout the residential and commercial regions of Bellevistat will provide colonists with comfortable modern communities. (*See Table 4.1.1.)*

4.1.1.1 Circinus Theater

Bellevistat will offer theaters featuring world-class performances including Cirque du Soleil. Residents can relax and enjoy live entertainment such as concerts and theatrical plays as well as films in 2D, 3D, and 4D.

4.1.1.2 Fitness Center

At the fitness center, residents can maintain healthy lifestyles by exercising with a variety of equipment. Employees and trainers will ensure that the machines are used correctly and efficiently, especially at different gravities. Dance and fitness instructors will teach and train colonists in areas regarding flexibility, strength, and endurance.

4.1.1.3 Leo E-Book Station

To fulfill the colonists' desire for reading entertainment, Bellevistat offers several e-book stations, which contain several tablets, each with an assortment of books ranging from fictional adventurous stories and fairytales to nonfictional biographies and historical accounts. Each station is modeled after the traditional modern living room with many couches and sofa seats to ensure a comfortable and serene atmosphere.

4.1.1.4 Weather Parks Weather parts will simulate the weathers of the different seasons found on Earth. They will provide long lines of sight to mitigate psychological factors such as claustrophobia. Not only will the people be able to experience the different climates, they can enjoy the sweet scent of spring and even the taste of the white powdery winter snow. *(See Figure 4.11.4)*

Figure 4.1.1.5 Museum Horologium

4.1.1.5 Museum Horologium
Our museum will feature exhibits of how the universe and Earth have formed and changed such as the Big Bang Theory. Bellevistat's museum will hold several exhibits about constellations, galaxies, the planets, and more. Museum Horologium will also provide many interactive and hands-on activities to ensure that kids and adults of all ages will learn and enjoy the exhibits. The museum is designed to be an addition to the Telescopium Observatory, so that residents can become more knowledgeable about space. *(See Figure 4.1.1.5)*

4.1.2 Consumables
To ensure healthy diets of the residents, Bellevistat promotes Mediterranean style foods. Bellevistat will use dynaponics (*See 3.2.2 Food Production)* to farm and harvest foods that have been selectively chosen based on their high nutritional content and taste. In-vitro production will be used to produce meat. Food will be distributed through supermarkets, convenience stores, and restaurants and the calculations have been made to certify enough food for visitors and in cases of emergencies. (*See Table 4.1.2)*

4.1.2.1 Kale
A nutritional powerhouse, kale is a tasty nutrient dense food with many health benefits such as protection against various cancers and Alzheimer. Abundant in antioxidants and phytochemicals, kale has been found to have protective effects against breast, cervical, and colon cancer. With a high sulfur and sulforaphane content, kale helps to detoxify the body and maintain a healthy liver. High in Vitamin A, C, and K, kale is not only great for eye and skin health, but it also helps to build bones and high in protein and fiber.

4.1.2.2 Goji Berries
Goji berries contain powerful antioxidants that help prevent diseases such as cancer and heart disease. They can slow down the human aging process by minimizing damages in cells and DNA in the body. Goji berries also contain a high concentration of vitamin A, which helps to boost the immune system, protect vision, and prevent heart disease.

4.1.2.3 Bamboo Shoots
A great addition to meals, especially Asian cuisines, bamboo shoots contain high fiber content, aiding in digestion. Naturally low in calories, bamboo can help aid in losing excess weight. Also high in potassium, bamboo shoots helps regulate blood levels. They also contain antioxidants, which help fight cancer.

4.1.2.4 Dairy Products
Bellevistat will offer dairy products such as milk and yogurt using substitutes such as peanuts, almonds, and soy. *(See 3.2.2.1.2 Nut, Milk, Dairy Products)*

4.1.3 Water and Consumer Goods
Water, paper, and fabric are essential goods needed in everyday life in the colony, which will be available to businesses and homes. Paper and fabric will both be reused and recycle to minimize waste. (*Refer to Table 4.1.3)*

4.1.4 Community Layout
The colony is divided into 3 sectors: Cygnus, Musca, and Pavo. Each sector will contain commercial and residential buildings. 4.8% of the land is allocated to roads and paths for pedestrians. *(See 4.0.5.1 Gravity and Figure 4.1.4)*

Table 4.1.2
Variety and Quantity of Consumables

Food	kg/ person/ day	kg/ person/ yr	kg/ colony/ yr
Brown Rice	0.15	54.75	629625
Soy	0.13	47.45	545675
Wheat	0.15	54.75	629625
Barley	0.2	73	839500
Oats	0.13	47.45	545675
Nuts	0.02	7.3	83950
Sweet Potato	0.13	47.45	545675
Kale	0.15	54.75	629625
Spinach	0.07	25.55	293825
Broccoli	0.05	18.25	209875
Squash	0.05	18.25	209875
Brussel Sprouts	0.05	18.25	209875
Bamboo Shoots	0.03	10.95	125925
Onion	0.05	18.25	209875
Mushroom	0.08	29.2	335800
Carrots	0.05	18.25	209875
Olives	0.04	14.6	167900
Bell Peppers	0.05	18.25	209875
Goji Berries	0.03	10.95	125925
Blueberries	0.07	25.55	293825
Cantaloupe	0.1	36.5	419750
Tomato	0.1	36.5	419750
Pineapple	0.05	18.25	209875
Tilapia	0.1	36.5	419750
Salmon	0.1	36.5	419750
Chicken	0.15	54.75	629625
Lamb	0.05	18.25	209875
Pork	0.1	36.5	419750

4.2 RESIDENCES
Bellevistat offers an assortment of comfortable housings including apartments, condos, and family houses. Residents may select from two different exterior and interior designs for each type of residence.

4.2.1 Types of Residences Houses in Bellevistat will be built using carbon nanotubes and nanobots. This will allow for a sturdy yet flexible structure, since nanobots will allow the homes to reduce or accommodate additional rooms, if needed for the changing demographics.

Table 4.1.3 Variety and Quantity of Consumer Goods

Water and Consumer Goods	Consumption/ Capita	Total Consumption	Sources	Method of Distribution
Water/ year	127750 L	1469125000 L	Imported from Earth and Moon	Distributed to homes and businesses using a pipe system.
Paper/ year	135 kg	1552500 kg	Manufactured from bamboo.	Distributed by Hydra and robots to businesses and homes.
Fabric/ year	30 kg	345000 kg	Fabric will be manufactured at Bellevistat.	Fabric made in factories will be used to make furniture, shoes, and clothes, which will be transported to stores and homes by Hydra and robots.

4.2.1.1 Family Houses

Belleveistat's family houses are deigned to allow families to live comfortably. With a spacious living room and a playroom, these houses are child friendly. These houses include an office, three bedrooms, two bathrooms, a kitchen, and a dining room. For a more luxurious stay, parents can stay in the master bedroom, which includes a large master bathroom and a walk-in closet.

Table 4.2.1 Quantity and Area of Residences

Residential Homes	Max Occupancy	Quantity	Floor Area/ Unit (m^2)	Floor Area/ Unit (ft^2)	Total Floor Area (ft^2)
Apartment Complex	20	600	98	1050	630000
2-Story Condominiums	8	1250	88	950	1187500
Family Houses	6	1000	111	1200	1200000

*For each type of home, there are equal amounts of each design.

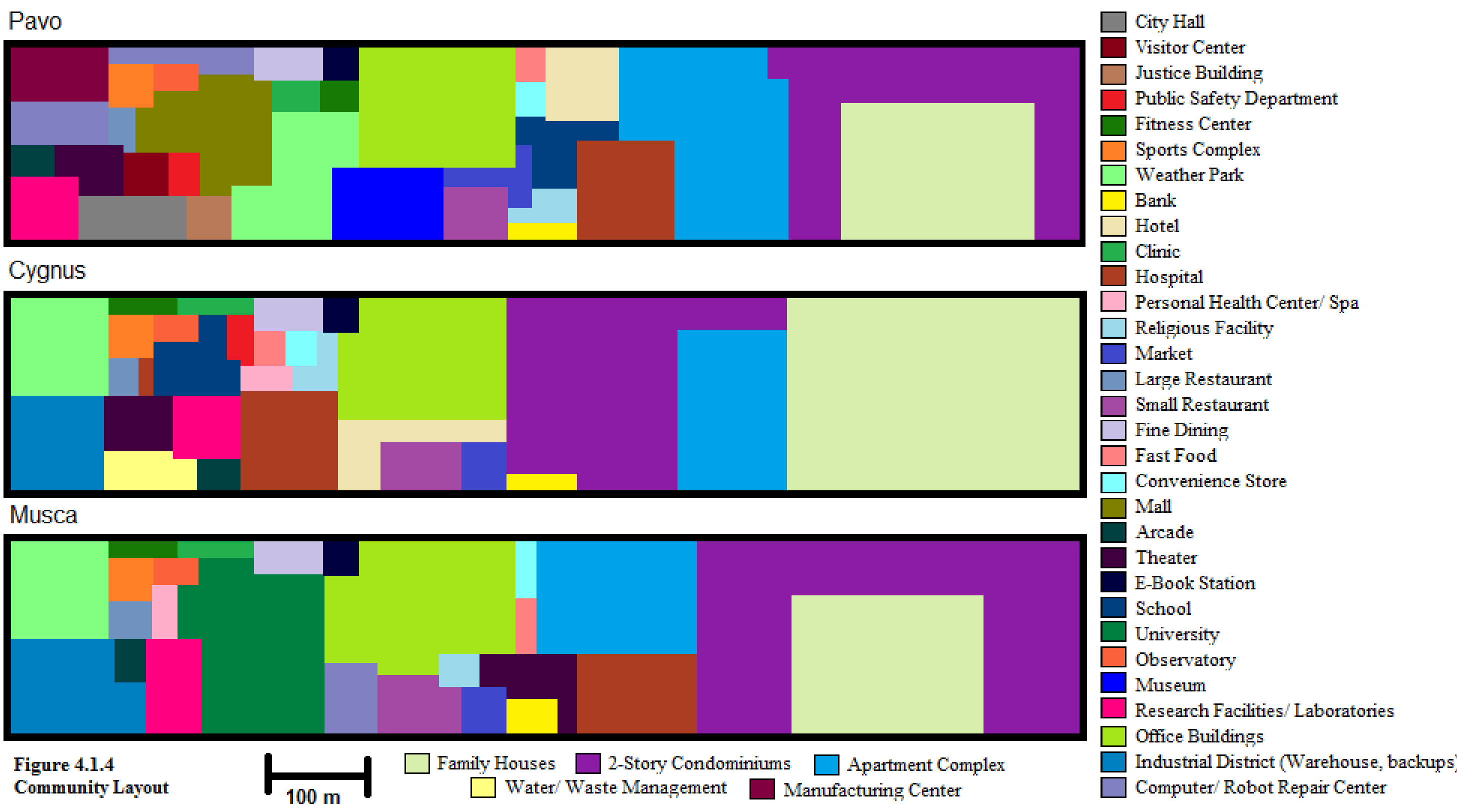


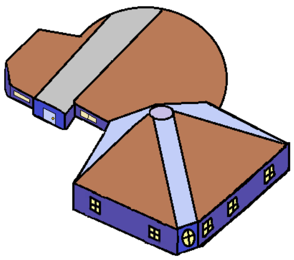
Figure 4.1.4 Community Layout

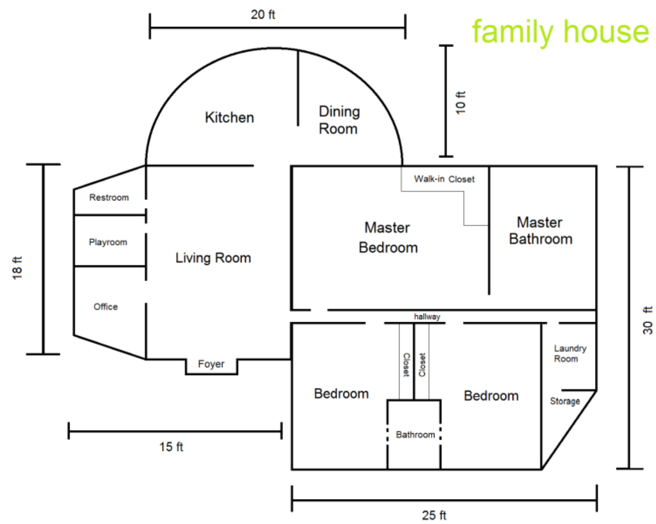
4.2.1.2 Two-Story Condominiums

For those who would rather own their property, Bellevistat offers 2-story condominiums. The two stories in the same condominium will have the same floor plans. The condominiums include a living room, two bedrooms, two bathrooms, one laundry room, an entertainment area, a kitchen, and a dining room. While one condo includes a patio for people who enjoy the outdoors, the other contains an office room for residents who need a quiet space to work. Stairs are located at the sides of the building.

4.2.1.3 Five-Star Apartment Complexes

To accommodate a variety of people, five-story apartments are available. Each apartment complex contains two apartment rooms on each of the five floors. Each of the 3 different rooms can hold 1, 2, or 3 people. Each apartment contains a living room, at least one bedroom and bathroom, a kitchen, and a dining room. While apartments are compact, they are designed to be flexible; sliding walls can adjust the size of each room to the residents' requests. At each end of the apartment complex, a glass elevator will transport people and allow them to see the community.





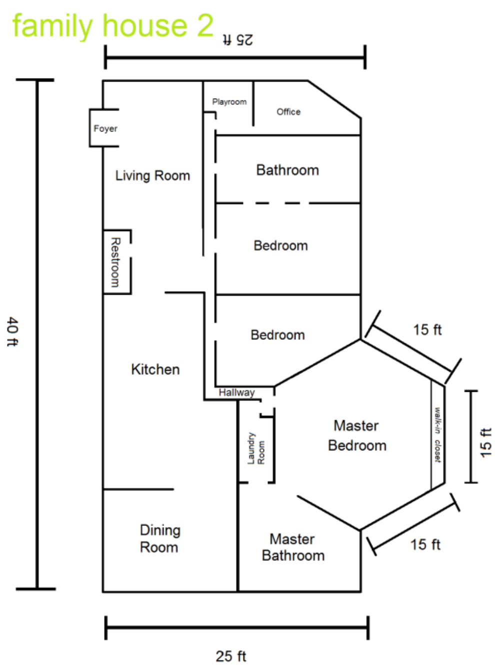
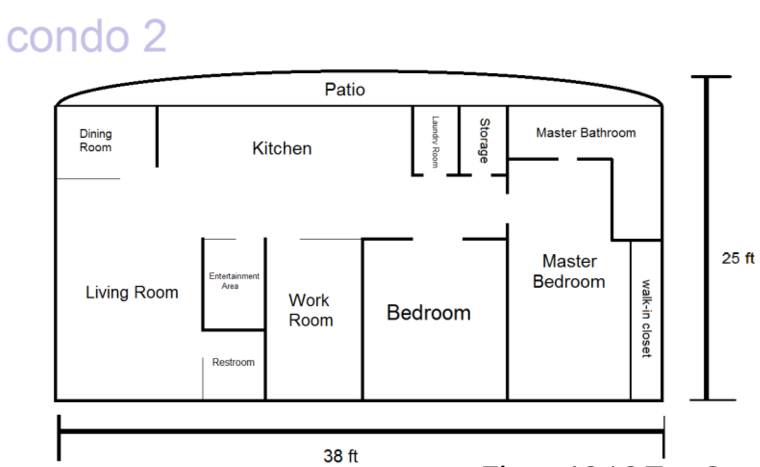


Figure 4.2.1.1 Family Houses



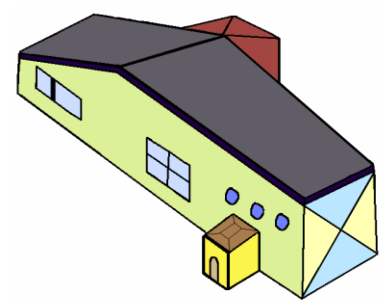
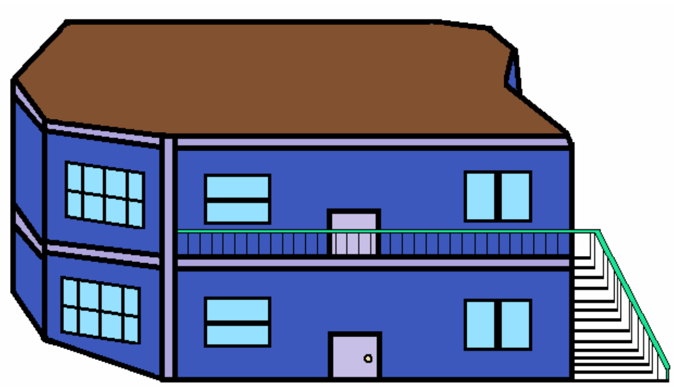
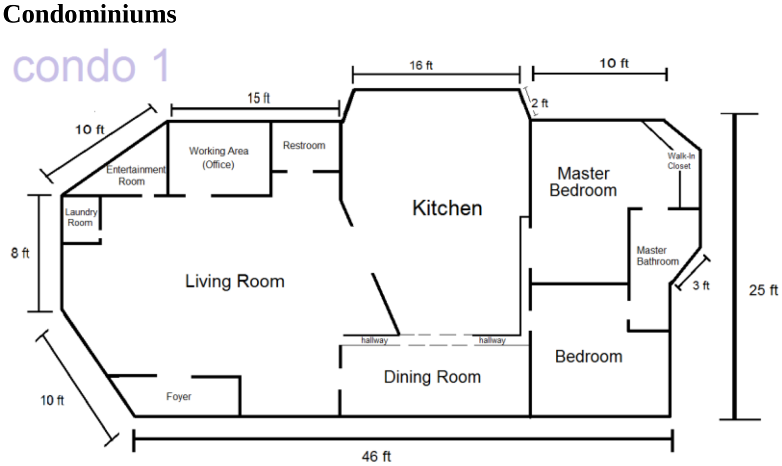
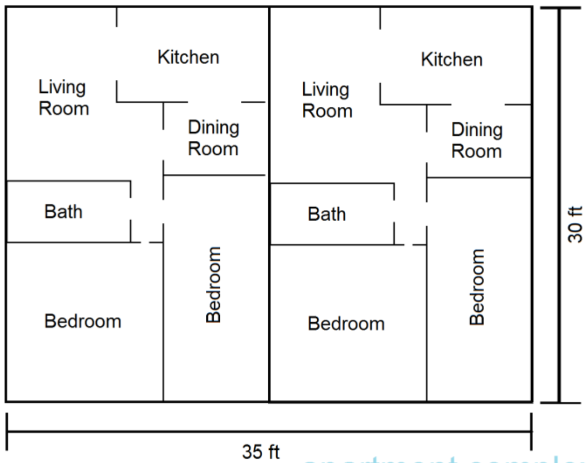


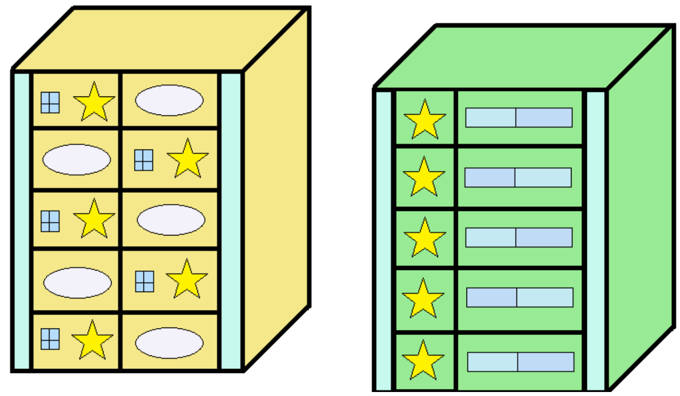
Figure 4.2.1.2 Two-Story Condominiums







apartment complex 1



apartment complex 2

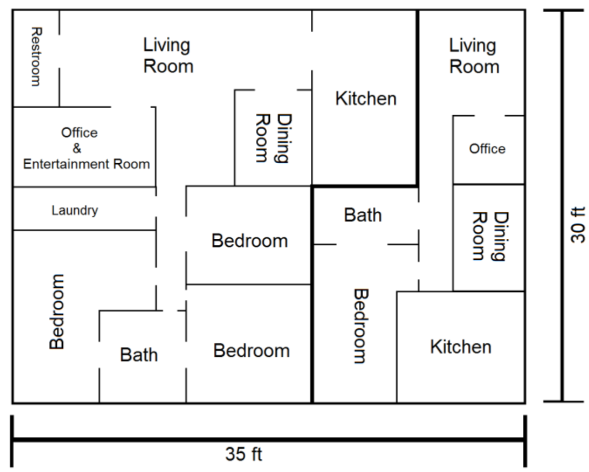


Figure 4.2.1.3 Five-Star Apartment Complexes

4.2.2 Furniture, Appliances, and Personal Items

All furniture and appliances will be manufactured in Bellevistat using various available materials. Clothing and shoes will be manufactured using fabric. *(See Table 4.1.3 and Table 4.2.2)*

4.3 DEVICES AND TRANSPORTATION

4.3.1 Vehicles

4.3.1.1 Tachyon Bike

This Tachyon bicycle is designed for a variety of speeds. Made out of a mixture of graphene and Kevlar, its rigid structure allows for it to be sturdy, yet lightweight. The bike is also readily foldable, able to fit inside a briefcase.

Figure 4.3.1.1 Tachyon Bike

4.3.1.2 Hydra Bellevistat will utilize a magnetic conveyance system called Hydra in order to transport people and distribute various goods throughout the commercial and residential areas at each sector. Recommended for long distances, Hydra provides a safe, efficient, and convenient way of traveling. *(See 3.2.7)*

4.3.2 Devices and Systems for Safe Access

4.3.2.1 Nitrile Shoes Rubber nitrile is a substance often used as a substitute for regular rubber and is very flexible and resilient.

The Nitrile Shoes are specially designed to prevent slipping. A layer of corroborated nitrile will be applied to the bottom of the shoes. *(See Figure 4.3.2.1)*

4.3.2.2 Tether System A safety tether system will attach users to surfaces. The tether will be made out of 35 m long carbon nanotubes. This will allow stability for users while working in space, such as repairing exterior surfaces.

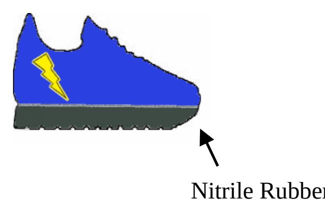


Figure 4.3.2.1 Nitrile Shoes

Table 4.2.2 Quantities and Sources of Furniture and Appliances

Item	Source	Apt 1	Apt 2	Condo	Family
Stoves	Stainless steel, manufactured	10	10	1	1
Refrigerators	Stainless steel, manufactured	10	10	1	1
Tables	Bamboo, manufactured	10	20	2	3
Chairs	Bamboo, manufactured	20	30	4	7
Sinks	Ceramics, manufactured from silica	20	25	3	3
Showers	Ceramics, manufactured from silica	10	15	2	3
Toilets	Ceramics, manufactured from silica	10	15	2	3
Television	Glass, manufactured from silica	10	10	1	1

Figure 4.3.3.1 Spacesuit

4.3.3 Spacesuits Spacesuits will be stored in airlocks.

4.3.3.1 Spacesuit Design The ZX-1 Spacesuit will be a lightweight suit to enable quick mobility on exterior surfaces of the colony. It will be composed of layers such as Nylon tricot, spandex, and Dacron. These lightweight yet very strong materials will protect from space radiation, space dust and extreme cold. *(See Figure 4.3.3.1)*

4.3.3.1.1 Life Support Pack The Life Support Pack, worn on the back, will monitor heart rate and body pressure and provide oxygen to the individual. Canisters of lithium hydroxide will be used to absorb the CO_2- to prevent fatal CO_2 buildup.

4.3.3.1.2 Headgear The headgear consists of a helmet and communications cap. The helmet is made of clear, impact-resistant, polycarbonate plastic. It will be tinted to protect the resident's eyes from the sun and treated with an anti-fog compound to maximize clarity. A purge valve will remove CO_2. The fabric communication cap will contain microphones and earphones for convenient hands-free communication.

4.3.3.1.3 EVA Gloves EVA gloves will allow the user to easily pick up objects. Heaters at the fingertips will prevent hands from freezing.

4.3.4 Airlocks

Airlocks will be located throughout the colony and at each entrance of Cygnus, Musca, and Pavo in order to allow people to adjust to the differences of gravity. Each airlock will be 3.3 m wide, 2.3 m long, and have radius of 2.8 m. Each airlock can allow two people to enter and exit.

4.3.4.1 Airlock at Cygnus

In the airlock at Cygnus, the airlock will consist of two volumes: the first volume will reduce the pressure from 1.0 atm to 0.8 atm and the second from 0.8 atm to 0.3 atm. Two airlocks are used so that people can gradually adjust to the changes in pressure. (See Figure 4.3.4.1)

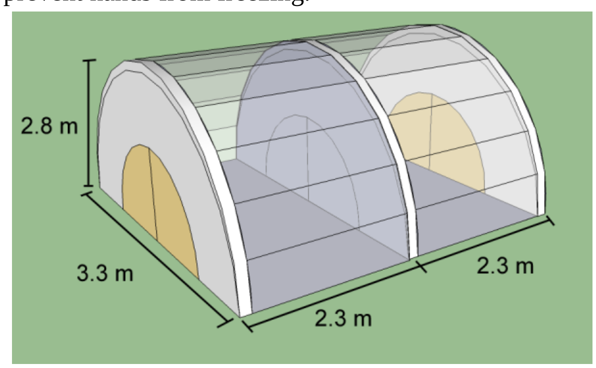


Figure 4.3.4.1 Airlock at Cygnus

4.3.4.2 Airlock at Musca and Pavo

At Musca, the one airlock will reduce the pressure from 0.8 atm to 0.3 atm; at Pavo, the airlock will reduce the pressure from 0.6 atm to 0.3 atm. (See Figure 4.3.4.2)

4.3.4.1 Procedure

At the airlock at Cygnus, the first airlock will provide bedding and food, since two people will stay overnight to adjust to the pressure drops. While they don the spacesuits (if necessary), pure oxygen is introduced into the airlock. When a light flashes, the two people have the signal to enter the second airlock. After they experience the depressurization process in the second airlock, the people will be checked for safety. Doors are will quickly seal the airlock to prevent debris from spreading.

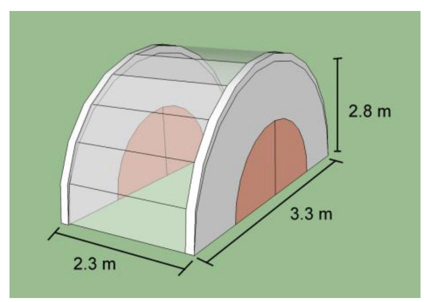


Figure 4.3.4.2 Airlock at Musca and Pavo

4.4 TRANSIENT POPULATION

To integrate the transient population into the population, Bellevistat will utilize community features to ensure harmony among the people.

4.4.1 Social Attributes

In the community, social skills are deemed very important for the colony to be successful. Bellevistat will encourage social activities and mingling.

4.4.1.1 Tours

Permanent settlers will join volunteer committees to give tours to the visitors. They will introduce the different lifestyles found on the colony to allow visitors to adapt quickly and easily. By encouraging permanent residents to interact with the transients, Bellevistat will be able to reduce the feelings of the temporary residents as outsiders and intruders.

4.4.1.2 Community Activities
Bellevistat will employ committees in each neighborhood, where the leaders are voted by residents in the respective communities. These committees are mainly responsible for arranging bi-monthly neighborhood bonding activities, especially between visitors and the permanent population. In addition, each committee will resolve minor conflicts in the community and is in charge of organizing tours for new residents and visitors.

4.4.1.3 Holidays
To encourage interactions among settlers, the importance of holidays will be emphasized in the colony. While various cultural holidays such as New Year's will be celebrated, another new holiday will be held twice a year. This bi-annual holiday called International Day will promote a stronger community. On this day, citizens will become more aware of the different cultures by enjoying traditional customs and performances such as throwing Holi powder, flying Japanese koi-shaped kites, and being entertained by traditional Chinese lion dancers. While settlers are encouraged to taste foods of other cuisines, restaurants are encouraged to decorate to a cultural theme.

Figure 4.4.1.3.1 Tanabata

4.4.1.3.1 Tanabata
In accordance with the theme of constellations on Bellevistat, one of the holidays celebrated on Bellevistat is Tanabata, which is the Japanese star festival. Colonists will learn about the folklore in which two stars are separated by the Milky Way. On this day, people can write wishes and hang them on bamboo stalks. Residents can even attend the Museum Horologium and Telescopium Observatory for free. *(See Figure 4.4.1.3.1)*

4.4.2 Community Features
Throughout the community, many places such as weather parks and theaters allow residents to feel welcome and implemented into the community. In addition, Bellevistat will offer schools and jobs to enforce hospitality to the permanent residents, in order to create live social experiences and remove unfriendly and antisocial feelings.

4.4.2.1 Schools
In addition to the traditional subjects taught at school such as math, science, and the humanities, children are taught the value of good communication, etiquette, and social skills from a very young age. By emphasizing hospitality from a young age, Bellevistat will help short-term residents feel welcome and integrated in the community.

4.4.2.2 Training
At the university, adults are suggested to take a 1-week long course on communication and social skills before obtaining jobs. With this system, the value of hospitality will be part of the culture of Bellevistat.

4.5 VISITOR CENTER
Upon arrival, settlers will be directed to the visitor center, where they will see a "Welcome to Bellevistat" sign *(Figure 4.5)* at the visitor center and will watch a welcome video highlighting all the comfortable and fun attributes at Bellevistat. In addition, they will receive a welcome package including a map of the colony, tickets to the Museum Horologium and Telescopium Observatory, and more. During idle times, kids can play at playground, while adults can relax at cafés and lounges. Before leaving Bellevistat, colonists will be directed to the departure area of the Visitor Center. There, souvenir shops are available where people can purchase their own Bellevistat keychain and pens or even plushies of various planets and constellations, while they wait for their transportation. *(See Figure 4.5)*

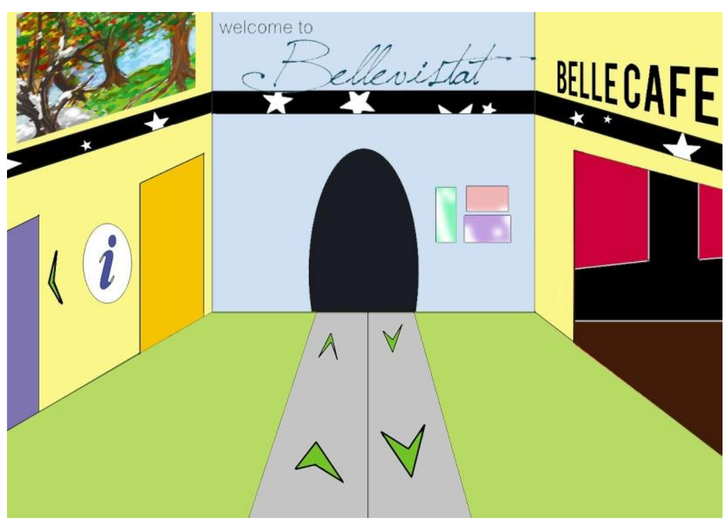


Figure 4.5 Visitor Center

Automations

5.1 Automation for Construction

5.1.1 Automation for Construction of Settlement

Bellevistat will be constructed from large pre-fabricated parts. All the wiring and electrical components are done on earth. Robots will merely connect the parts together. Two types of robots will be used. One will have heavy duty moving power, and the other will weld and bolt parts together. The robots can recharge its batteries at a separate nuclear generator that will be put in orbit in the vicinity and will later serve as the settlement's main energy source. As a backup power source, these robots also feature a series of graphene batteries that will take in ambient heat from the sun and convert this into electricity. While this will not provide the power necessary to work on the settlement, it would provide the power necessary for these robots to find a safe berth or dock in case of an emergency. These robots will be constructed of a single chassis and feature two different motor systems, one for the heavy duty move system, the other for the work that requires lower power and more finesse. This alternative drive system will possess a modular charging component in order to allow for either robot system to charge from the mobile charging station.

5.1.1.1 Heavy Mover

This robot will feature a different set of thrust systems because in moving large parts, this robot requires more power in order to counteract the momentum of the heavier components of the station. In addition, the more developed series of thrust systems allow for easier maneuvering while in space. These robots will later be repurposed for use in maintenance of the exterior and in facilitating the docking of ships. These large automations will be 3 meters by 2 meters by 2 meters approximately.

The software architecture of this robot features two different modes. One for the initial construction of the settlement and the other for after the settlement has been completed. This architecture allows for the robot to switch quickly between the two modes after completing its task rather than have to return to Earth to be reprogrammed. *(See Figure 5.1.1 Heavy Mover)*

5.1.1.2 Finesse Bot

This robot features a lighter thrust system that is more developed for more fine points of work such as welding and bolting. This robot will be mainly responsible for fabricating together many of the pieces of the station. In order to do this, the robot will possess a variety of tools at its disposal allowing for it to complete a variety of jobs at the same time using a series of servo motors operating various arms and appendages to increase efficiency. This robot will later be repurposed for assistance in interior construction and maintenance. Slightly smaller than the heavy mover due to a smaller drive system, the finesse bot will be 2.5 meters by 2 meters by 2 meters.

Because the job of this robot will not be much different from its initial job during the construction of the station, this robot will not feature the dual software systems that the Heavy Mover uses. This robot will feature system that is programed to be very simple reducing the amount of memory and processing power needed. This will reduce the chance of a critical error occurring because it would be cheapest to reduce the amount of errors that may occur rather than produce extra facilities to repair robots. *(See Figure 5.1.1 Finesse Bot)*

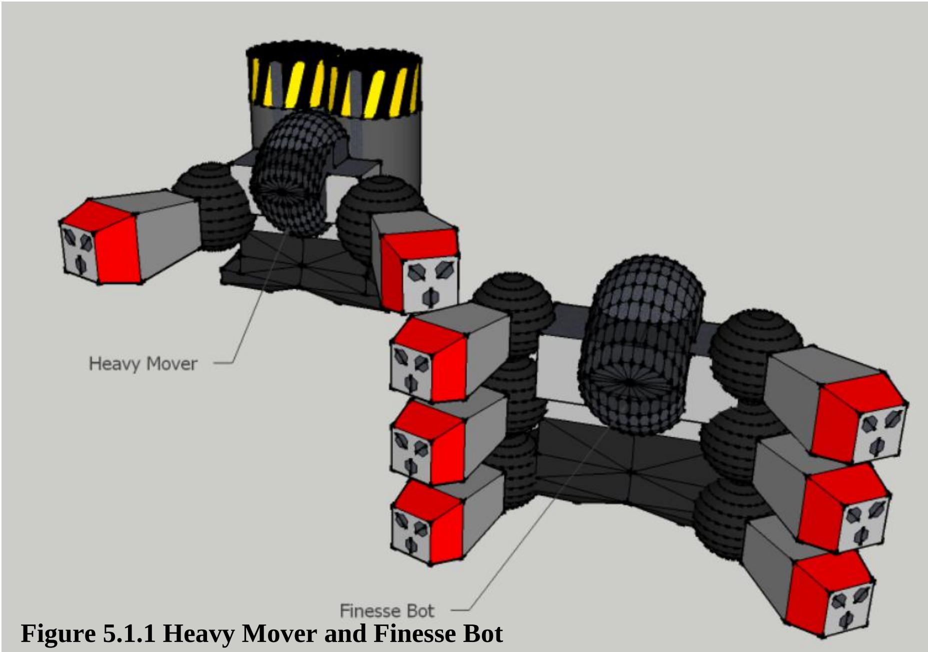


Figure 5.1.1 Heavy Mover and Finesse Bot

5.1.2 Automation for Construction of Interior

All large structures such as buildings will be constructed with prefabricated parts by the same construction robots, with the addition of a smaller type of robot that can fit in tighter spaces, which will later double as a general repair bot for the settlement. The repurposed construction bots, the Heavy Mover and Finesse Bot will primarily assemble the larger buildings first before the station begins to rotate because the two robot's drive systems function in zero-g environments. Air will be supplied through chemical reactions.

5.1.2 Tiny Bot

A robot built to work in small areas, this robot will be designed with an extremely modular chassis allowing for there to be a wide range of different attachments to fulfill the duties that are required of this robot. The modular attachment system will consist of a set for the interior design of residential portions, interior design of industrial areas and the maintenance and repair of space station's main facilities. The use of legs will make it easy for these robots to travel up and down walls and across ceilings making access easier for these robots. These robots will be controlled by and programmed by programming hubs in the space station itself allowing for robots to quickly be repurposed in case of emergency. This robot will be of a significantly smaller scale that the other two robots at just 1 meter by 0.5 meters by 0.5 meters.
(See Figure 5.1.2 Tiny Bot)

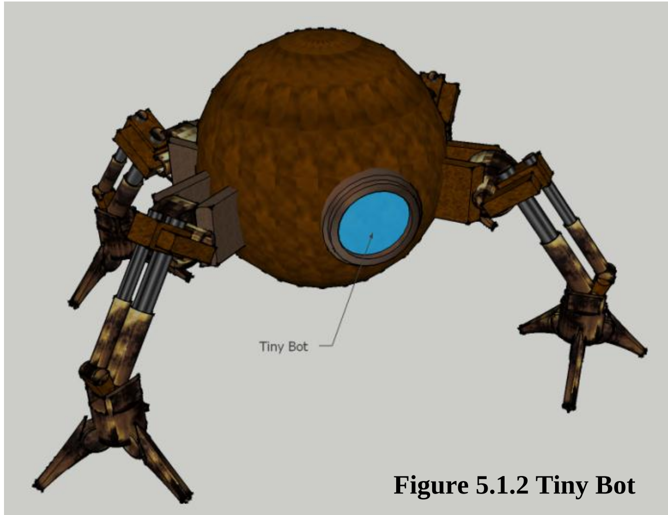


Figure 5.1.2 Tiny Bot

5.2 Automation for Maintenance, Safety, and Repair

5.2.1 Automation for Maintenance and Repair of Structure

Due to the completely modular nature of the structure, we will be using the Finesse Bot to detach and reattach portions of the station for easy quick fixes. More delicate repairs on certain components can be made back on the surface of Earth after the section has been removed from the station. This maintenance and repair function will be further assisted by the modular structure of the entire station allowing for easy use of interchangeable parts as well as not needing a large supply of specific parts in case of an issue. *(See Table 5.2)*

Table 5.2.1 Automation for Maintenance, Safety, and Repair

Robot Name	Dimensions (m)	Use
Finesse Bot	2.5 x 2 x 2	Versatile, multipurpose repair robot
Heavy Mover	3 x 2 x 2	Exterior maintenance, cargo transporter
MediBot	2.5 x 1 x 1	Medical transport for the injured
SafetyBot	.75 x .5 x .5	Incapacitation of human criminals
FireBot	1.5 x 1 x 1.5	Extinguishing local fires
TinyBot	1 x .5 x .5	Repair and maintenance for hard-to-reach locations

5.2.2 Automation for Safety Functions (including backup systems and contingency plans)

5.2.2.1 MediBots

We have medical transport robots (MediBots) to quickly travel to locations of emergency situations and retrieve injured people. These robots include a suite of sensors that help assess and diagnose the condition of a person that is injured or otherwise incapacitated. These robots will defer action to human doctors in order to prevent a person from receiving the wrong treatment but the preliminary diagnosis will help doctors a lot. These medical transport robots however, are programmed to prefer emergency medical care though which includes but is not limited to CPR, setting broken bones and stemming the bleeding from lacerations. *(See Figure 5.2.2.1)*

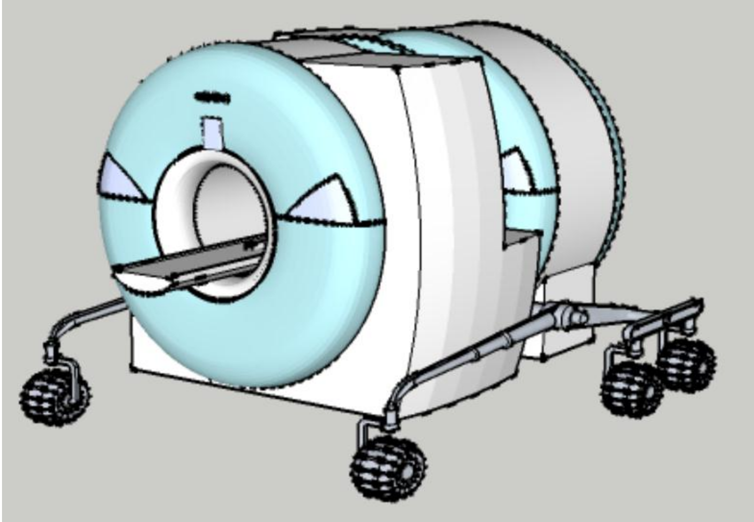


Figure 5.2.2.1 MediBot

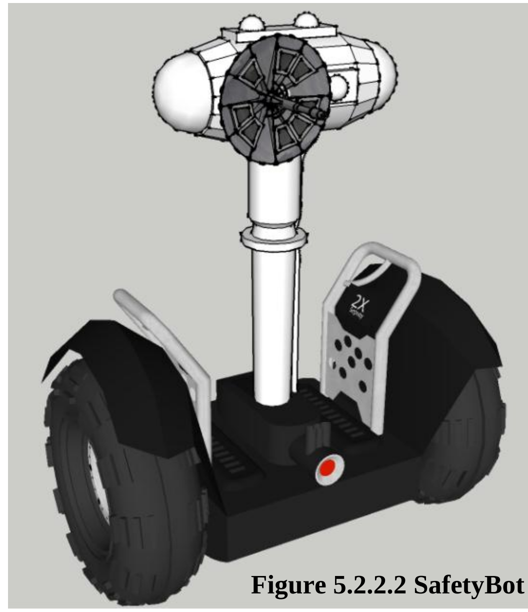


Figure 5.2.2.2 SafetyBot

5.2.2.2 SafetyBots

In case of criminal activity, we have security robots (SafetyBots) equipped with tasers and lasers for non-lethal incapacitation. These security robots will be put on a two-wheeled transport system to allow for quick maneuverability in narrow corridors as well as be fairly small and inconspicuous in order to not alarm residents. All security robot action will be supervised remotely by a law enforcement operator for complex decision making in addition to confirming the correct suspects and preventing the robots from hurting innocent bystanders. *(See Figure 5.2.2.2)*

5.2.2.3 Emergency Hull Breaches

For emergency external repairs, we will quickly dispatch specially outfitted Heavy Movers to the damaged location to cover the area with multiple layers of bucky structure sheets to seal any depressurized regions. Finesse Bots will quickly move in to weld in the sheets in order to fully seal off the area. After the damage has been assessed, more specific repairs can start taking place, starting from a more permanent solution to the external issues to internal electronic systems that would be most likely disrupted by the entrance of electromagnetic radiation through the breach. All interior robots making repairs are sufficiently shielded from electromagnetic radiation due to a conductive bucky structure layer that acts as a Faraday cage.

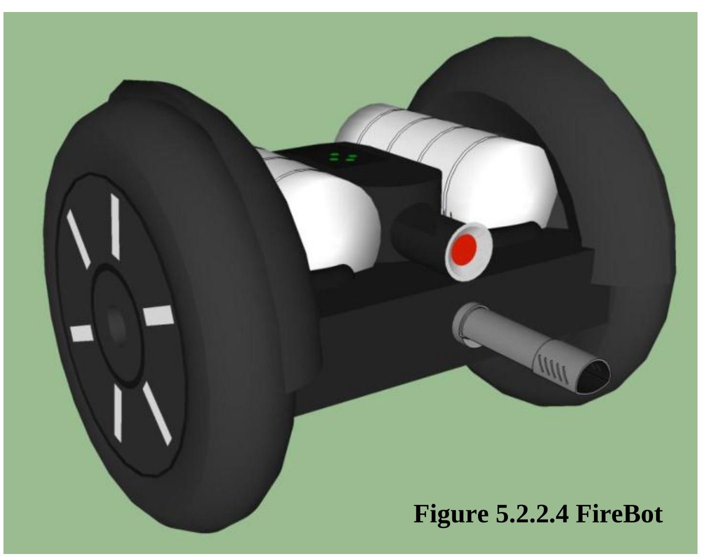


Figure 5.2.2.4 FireBot

5.2.2.4 Fires

In the case of fire, there are automated sprinkler systems to quickly put out any small fires. For larger fires caused by explosions, we have specially fitted fire extinguishing robots (FireBots) that use high pressure nozzles to put out fires in hard to reach places. These robots will be accompanied by MediBots in case of burns or injuries due to smoke inhalation. Because of the modular structure of the components of the station, individual sections can be sealed off and the oxygen can be vented in order to quickly extinguish fires.

Evacuation orders are also quickly sent, so in the case that the fire cannot be contained; the area can be quickly sealed off without risking lives and deoxygenated. *(See Figure 5.2.2.4)*

5.2.3 Access of Critical Data and Functions for Authorized Personnel

Everyone is given a specific clearance level. Most people are given free access to intranet networks and earth connectivity to communicate with other people and businesses as they please. Homeowners are given access to their house functions and are the only ones who can access them; however, access to settlement infrastructure is limited to officials and technicians. Use of retinal scanners from the glass technology and fingerprint readings from interface devices are used to verify clearance and any access to internal infrastructure networks, communications, or other resources are logged for security purposes.

5.3 Automation for Livability and Work Efficiency

5.3.1 Automations for Livability

All residents can use the settlement's version of AR (augmented reality) glasses. It is recommended that residents use this service as it facilitates many operations in the settlement. The retinal scan function is useful for speeding security procedures, as it provides a method of unique identification that cannot easily be forged, and can also identify a few health problems such as high blood pressure or diabetes. It has connectivity capabilities and many utilities which can be used for anything from navigating the settlement to accessing earth's internet.

Residences will have a large automation component to reduce much of the manual labor needed for everyday life. Many functions such as controlling the temperature, turning on and off appliances, and even heating up pre-made meals can be accomplished through a touchpad or any other device with connectivity. Sensors in the house can also measure and regulate water and electricity consumption. Residents can adjust these settings to their liking.

A novelty option for a robotic pet is offered to residents. There are two main models, DOG and CAT, which residents may choose from. These pets can play games with its owner, and can have personalities installed to broaden interactions with residents. Besides entertainment values, the robotic pets can perform tasks such as cleaning, carrying objects, and eating trash, which gives them extra utility that could be desired by residents. *(See Figure 5.3.1)*

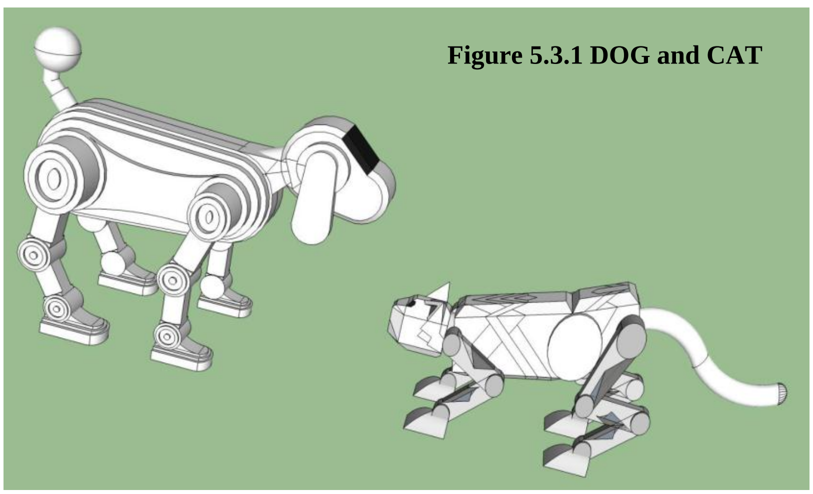


Figure 5.3.1 DOG and CAT

5.3.2 Automations for Work

For convenient transportation and quick commutes, the settlement has a network of maglev trains which all residents are free to use. The network of trains travels through all the major sectors of the settlement, so there are no inconvenient locations to travel to in the settlement. An added bonus of the maglev trains is that they are also an energy efficient and pollution-free form of transportation.

There is an automated delivery and tracking system for packages, which makes use of the maglev trains and also individual robotic couriers. At any time, residents can see the status and location of any packages or deliveries that they are waiting for. They may also instruct the robotic courier to deliver the package to their current location, wherever that may be in the settlement.

The ZX-1 Spacesuit is used for maintenance and other work outside of the settlement. It is made of sturdy and insulated material to protect and keep warm those who are using it. Every spacesuit is also equipped with a tether to prevent workers from drifting away, magnetic boots to anchor them to the settlement when necessary, a robotic arm to aid in manual labor, and a harpoon in case the tether is broken and the worker has no other way to return to the settlement. *(See 4.3.3 Spacesuits)*

Finesse Movers can be requested for personal use to move large amounts of and/or heavy objects. Residents may order services like this whenever they need to through intranet connectivity.

5.3.3 Automations for Environment

The settlement will have various weather parks for the enjoyment of the residents. There are designated areas where weather conditions cycle through weather of rain, snow, windy, sunny, and mist.

There will be service terminals located throughout the settlement that people can use to order services and give their opinions on the living conditions in the area. It also collects air samples during different times of the day and analyzes it for factors such as temperature, pollutants, and humidity. These terminals can receive user input through the wireless network, and will notify settlement officials of any potential problems that could pose a risk to or otherwise annoy residents.

5.3.4 Communications and Networks

There are three networks on the settlement. One is regular internet connectivity and communication with earth which is facilitated by special earth-oriented transmitters and receivers on the settlement's exterior. Everyone on the settlement is allowed to use these resources. Another is a settlement intranet in which the people of the settlement are allowed to communicate with each other and order private and public services. The final network is a wide range space network that coordinates space traffic and emergency situations. Each network has its own servers to process data. Only settlement operators and incoming ships are allowed to access the third network.

Specific computing systems that people may encounter include their own set of AR glasses, which can hold up to 56 GB of data with 2 GB of RAM. However, these glasses are designed to access the settlement's computing services to aid in its many functions through a wireless connection. It has 50 Mb/s download speed and 25 Mb/s upload speed.

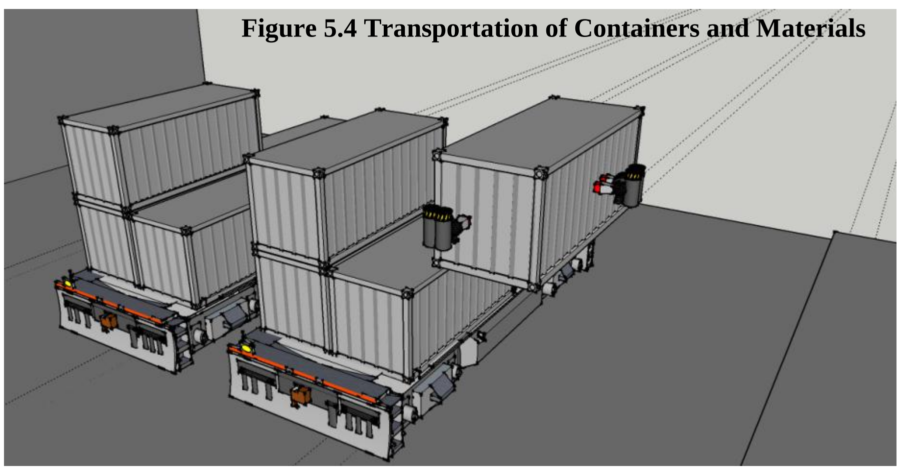
As many functions of the home will be automated, as stated in 5.3.1, each house will have its own processor, data storage, and connectivity capabilities. These resources will also be available for personal use if needed. Each house will have 50 TB of data storage and 250 GB of RAM, though part of that will be set aside for routine functions throughout the house.

Servers for connectivity will use quantum processors to handle the large influx of data. They can handle up to 100 Tb/s of data, and each network will have its own dedicated servers.

5.4 Automations for Ore Processing

5.4.1 Automation for Transportation of Containers and Materials from Ships

Figure 5.4 Transportation of Containers and Materials



Ships will be arriving with standardized shipping containers full of ore from mining operation as well as supplies in similar containers. These containers will be removed by Heavy Movers and placed onto large carts that will transport the ore to be automatically sorted and processed. Other supplies will also be placed on carts but these carts will be sent towards other sorting centers. This separation of industry with residential and commercial sectors will make it easier for residents to receive their supplies rather than have the supplies congested with other industrial sectors. *(See Figure 5.4)*

5.4.2 Automation for Transportation of Containers to Refining Facilities

The transportation of containers will first be placed upon carts that will have to clear an airlock system first. These carts are designed to follow a series of rails that allow quick, unimpeded movement to and from refining facilities. These carts will safely move these ores between facilities for different ores as Heavy Movers will have already sorted the containers during the unloading process.

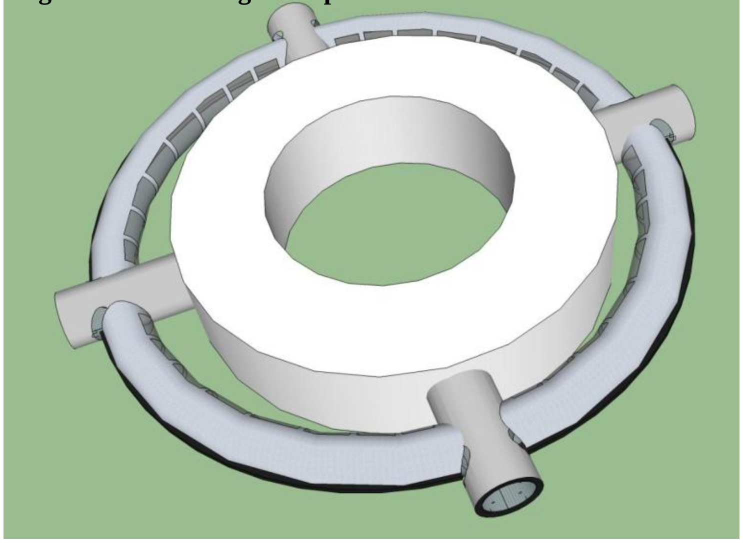
5.4.3 Automation for Unloading Containers in Zero G and Vacuum

Each shipping container that is removed from a ship will be equipped with an infrared emitter. This emitter will remain unique for the shipping containers until it has been processed through the docking facilities upon when it will be removed and reused. Combined with a series of infrared sensors, the computer can map the position of each shipping container in a 3D grid system. This will allow for a central computer to accurately track each container as it is unloaded and then direct the Heavy Mover to the correct position where the container will be placed.

5.5 Docks

Each dock will have several platforms large enough to contain one ship that will dock to a facility. Each facility will feature an airlock for the crew while the cargo will be offloading in a zero gravity environment in order to make it easier to drop off

Figure 5.5.1 Docking of Ships



5.5.1 Docking of Ships

Multiple docks on the surface of the station, each has an entrance which is like underground parking. Each "parking spot" is a modular service platform, with different capabilities depending on the type of ship and its purpose. Each platform has refueling capabilities, simple scanners to detect maintenance issues for ships, and service terminals to communicate with the settlement and order services.
(See Figure 5.5.1)

5.5.2 Docking Aids for Different Types of Ships

Specific platforms for different types of ships may have additional capabilities. Docks for transport ships have an automated unloading system which transports its material to its intended destination in the settlement. There are also emergency docks close to the port entrance that are equipped with robots for heavy duty repair for damaged ships and emergency medical aid, as well as speedy transportation to medical facilities.

Schedule and Cost

6.0 Schedule and Cost

6.1 Settlement Construction Schedule

Table 6.1 Construction Schedule

	Schedule	2033		2034		2035		2036		2037		2038		2039		2040		2041		2042		2043		2044		2045	
	Preparation phase																										
E	Base module hull parts pre-assembly (12 months)	■	■																								
E	Refining and manufacturing facility construction (14 months)	■	■	■																							
E	Main hull pre-assembly (17 months)	■	■	■																							
E	Main port pre-assembly (14 months)	■	■	■																							
E	Robot assembly and programming (6 months)		■																								
E	Construction of ports (8 months)	■	■																								
E	Fuel/material transport and storage facility construction (5 months)		■																								
B	Launch and installation of base module in orbit (12 months)			■	■	■																					
	Construction phase I																										
B	Lunar base launch and setup (3 months)					■																					
B	Refining facility installation (3 months)					■																					
B	Manufacturing facility installation (3 months)					■																					
B	Assembly of hull of first Bellevistat module (6 months)						■																				
B	Expansion of refining and manufacturing facilities to Bellevistat standard (12 months)							■	■																		
	Construction Phase II																										
B	Production of construction robots (12 months)									■	■																
B	Assembly and installation of settlement communities (12 months)											■	■														
B	Assembly and installation of infrastructure for human living (12 months)											■	■														
B	Assembly and installation of human receiving ports (6 months)											■															
E	Importing of atmosphere gases (102 months)										■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
B	Beginning of settlement rotation (6 months)												■														
	Construction Phase III																										
B	Human move-in (12 months)													■	■												
B	Large-scale manufacturing processes (84 months)													■	■	■	■	■	■	■	■	■	■	■	■	■	■
B	Launch and assembly of second module hull (12 months)													■	■												
B	Assembly of second module manufacturing facilities (12 months)													■	■												

B	Assembly of robots and infrastructure (16 months)
B	Assembly and installation of human receiving ports (6 months)
B	Beginning of second module rotation (6 months)
	Construction Phase IV
B	Second human move-in (12 months)
B	Second module manufacturing processes (60 months)
B	Launch and assembly of third module hull (8 months)
B	Assembly of third module manufacturing facilities (8 months)
B	Assembly of robots and infrastructure (12 months)
B	Assembly and installation of human receiving and cargo ports (9 months)
B	Beginning of third module rotation (6 months)
	Construction Phase V
	Third human move-in (12 months)
	Third module manufacturing processes (48 months)
	Large-scale mining processes (42 months)
	Final testing and ramp-up of all industrial processes (12 months)
	Settlement finishing and process testing (12 months)

E –Processes on Earth; B –Processes on Bellevistat

6.1.1 Construction Phases

Preparation Phase: The first parts for the preliminary module will be pre-assembled and launched.

Construction Phase I: The base module will install the first Bellevistat module's hull and manufacturing facilities.

Construction Phase II: Infrastructure and residential facilities will be constructed.

Construction Phase III: At this point, the first residents will move in. The second module is constructed.

Construction Phase IV: The second group of residents move in, and the third module is constructed.

Construction Phase V: The third group of residents move in, and construction of Bellevistat ends

6.2 Cost of Construction

Table 6.2.1 Cost of Labor During Construction

Jobs	Annual Salary (In thousands)	Number of Years	People	Construction Phases	Total (In Millions)
Foreman	$175	13	10	0-5	$22.75
Robotic Technicians	$145	13	95	0-5	$179.1
Electricians	$120	7	280	3-5	$235
Pilots	$135-210	13	60	0-5	$117
Construction Engineer	$120	2	180	0	$43.2
Mechanical Engineer	$120	3	250	0	$90

Chemical Engineer	$130	3	100	0	$39
Electrical Engineer	$120	2	210	0	$50.4
Software Engineer	$110	4	190	0, 1	$83.6
Subtotal: $860 million					

Table 6.2.2 Cost of Operations (During Construction)				
Operation	**Cost/ year**	**Number of Missions/ year**	**Years in Operation**	**Total Cost**
Cargo Transportation	$64,350,000	2	13	$1,673,100,000
Passenger Transportation	$5,720,000	2	13	$148,720,000
Manufacturing	$83,000	N/A	9	$747,000
Production	$2,576,000	N/A	6	$15,456,000
Mining	$8,000,000	N/A	3	$24,000,000
Subtotal: $1.86 billion				

Table 6.2.3 Cost of Equipment			
Equipment	**Cost/ Unit**	**Amount**	**Total**
Mobile Headquarters	$43 Billion	1	$43 Billion
Robotic Support Ships	$18 Billion	3	$54 Billion
Subtotal: *$97 Billion*			

Table 6.2.4 Cost of Construction Materials			
Materials	**Amount (kg)**	**Cost/kg**	**Total**
Silicon Nitride	53,000	$350	$18,550,000
Silica Nanofoam	1,200	$800	$960,000
7068 and 7079 Aluminum	523,000	$10	$5,230,000
Carbon Nanotubes	1,100	$900	$990,000
Self-Healing Material	267,000	$25	$6,675,000
Anorthite Glass	50,000	$16	$800,000
Subtotal: $33.2 Million			

Table 6.2.5 Raw Materials			
Material	Cost/kg (Cost/L for gases)	Amount (kg; L for gases)	Total Cost
Nitrogen	$0.04	357 billion L	$14.3 billion
Oxygen	$0.14	98 billion L	$13.72 billion
Carbon Dioxide	$0.20	800 million L	$0.16 billion
Copper	$14.20	49,000 kg	$695,800
Water	$0.10	4,825,000 kg	$482,500
Subtotal: $28.2 billion			

Table 6.2.6 Cost of Robots			
Type	Cost/ Unit	Total Units	Total (in Millions)
Heavy Mover	$420,000	270	113.4
Finesse Bot	$310,000	300	93
MediBot	$270,000	120	32.4
SafetyBot	$280,000	140	39.2

FireBot	$120,000	150	18
TinyBot	$80,000	210	16.8
Nanobots	$30,000	940	28.2
Subtotal: $341million			

Table 6.2.7 Cost of Systems and Computers				
Computers	Memory	Cost/ Unit	Number of Units	Total Cost (in millions)
GEMS Processing System	500 GB	$1,400,000	10	$14.0
Robot Control Unit	9 TB	$500,000	19	$9.5
Electrical Power Control System	700 GB	$400,000	21	$8.4
Libra Control Module	8 TB	$700,000	35	$24.5
Waste Control Module	500 GB	$1,600,000	8	$12.8
Volans Unit	40 TB	$900,000	72	$64.8
Hydra Unit	1 TB	$1,100,000	55	$60.5
Day/Night Cycle Control System	4 TB	$3,000,000	3	$9.0
Manufacturing Central Computing System	50 TB	$5,000,000	3	$15.0
Subtotal: $218 million				

Table 6.2.8 Income	
Source of Income	Yearly Income
Refining Exports	$7 billion
Manufacturing Exports	$14 billion
Tourism	$4 billion
Subtotal: $25 billion	

Table 6.2.9 Operating Costs	
Operation	Cost
Atmosphere Maintenance	$5 billion
Robot Maintenance	$1.3 billion
Miscellaneous Materials	$1.9 billion
Research and Development	$0.8 billion
Mining	$1.1 billion
Subtotal: $9.0 billion	

TOTAL COST OF CONSTRUCTION

$161.68 BILLION

ANNUAL REVENUE

$25 BILLION

YEARS TO COVER CONSTRUCTION COSTS

6.47 YEARS

Business

7.0 Business Development

7.0.1 Ports for Lunar and Asteroid Materials Bellevistat will have 2 major ports to receive lunar and asteroid materials located on opposite sides of the cylinder in the center so the gravity generated by the station will not affect cargo loading and unloading.

7.0.1.1 Standard Shipping Container Receiving Shipping containers will arrive through our standard ports fitted to accommodate up to 20 standard size containers; as the ports are located in zero gravity zones our robots will be able to easily handle weights of 100 metric tons, reaching an approximate limit of 1000 metric tons.

7.0.1.2 Ore Storage Ore will be stored in our automated storage facilities between arrival and use in our refineries. Each facility, which is connected to each cargo port, will be able to house a volume equivalent to 100 standard size containers while raw materials are being refined.

7.0.1.3 Cargo Transport to Storage Because ports will be immediately adjacent to storage facilities, automated cranes will be able to relatively easily transport containers from port to storage by attaching them to carrier robots, which will convey cargo by means of a track.

7.0.1.4 Non-Standard Cargo Cargo not arriving in standard shipping containers will be shock corded to provide a standard interface for our port cranes and carrier robots as well as keeping cargo together for ease of transport. Cargo not arriving in standard containers will be placed in a separate and smaller area of our storage facilities, each large enough to hold the equivalent volume of 5 standard size shipping containers while cargo is waiting to be processed.

7.0.1.5 Preprocessed Cargo and Passengers Preprocessed cargo will utilize smaller ports connected to manufacturing and fabrication facilities for ease of transport and use. Human passengers will be received in small ports on the sides of Bellevistat so that they will be able to experience gravity after the ship has docked; the ports will directly guide passengers to visitor reception areas (see 4.5).

7.0.2 Production

7.0.2.1 Metal Extraction Ore extraction will take place as soon as possible after ore arrives through the main cargo receiving ports. Treatment for extraction will depend on how concentrated the required material is in the ore.

7.0.2.1.1 High Concentration Extraction Materials with high concentrations in the raw ore will be separated using low energy methods such as density separation. After being crushed, ore will be suspended in a high-linkage polymerized glycerin for its viscosity and will be centrifuged to separate the ore's components, which will be individually extracted and sent for additional refining if necessary.

7.0.2.1.2 Low Concentration Extraction Materials with low original concentrations will be subject to more intensive methods of refining. Metal leaching and subsequent electrowinning will be used for metals where convenient as a low-cost, high-yield method of metal extraction. Metals with higher reduction potentials will be directly melted and electrolyzed to extract the metal, although this method will only be used in special cases where the unoxidized metal is required.

7.0.2.2 Variable Gravity Refining For processes requiring operations in different gravity conditions, a separate refining facility will be located farther away from the center of Bellevistat's cylinder to provide additional services for metal purification. Care will be taken to separate processes to ensure as little unnecessary transport as possible.

7.0.2.3 Manufacturing Expansion and Construction The manufacturing and fabrication facilities on Bellevistat will be full-featured, allowing customers and settlement to produce complex pieces efficiently and quickly through readily available manufacturing processes including casting, molding, machining, joining, and rapid manufacturing usig laser technologies. Bellevistat's individual manufacturing units will be modular and will be connected to a main computing unit for each manufacturing facility. This design allows relatively easy additions to the manufacturing processes available on Bellevistat by enforcing that each unit be largely independent. Each unit will also be required to meet a specific physical and application programming interface so that integration into Bellevistat's systems will be seamless.

7.0.2.4 Product Delivery Products fabricated on Bellevistat will be delivered throughout the settlement through robot carriers using the Hydra transportation system (see 3.2.7). Additional tracks for Hydra will be in place so that cargo robots are able to access ports for product export and ship provisioning on the top and bottom of Bellevistat's cylinder. Hydra will also allow robots to deliver goods for internal use by having tracks run throughout the settlement.

7.0.3 Repair and Restoration of Space Vehicles

7.0.3.1 Repair Docks Repair docks will be provided on Bellevistat via an extension of the normal cargo ports. The ports can accommodate ships fitting dimensions 200m x 200m x 50m, although the walls are not permanently attached to each other to allow larger ships to receive repairs. After being tugged into the dock, the ships will be shock corded so that they stay in place relative to the port, allowing smaller ships to safely dock and repair as well.

7.0.3.2 Port Expansion Repair docks are fashioned so that adding additional space after constructing the main hull involves removing a wall from the previous dock, allowing for relatively easy expansion space-wise. Different ships will be recorded and procedures for repair for various types of ships will be stored in databases on Bellevistat so that we can accommodate the specification of a variety of ships. Ships arriving on Bellevistat will be required to comply with standard docking interfaces for robot and shock cord attachment to expedite repair, although repair is still able to take place at a slower pace without the interface.

7.0.3.3 Safety Precautions Repair facilities on Bellevistat typically operate in a zero-gravity and zero-atmosphere environment, eliminating hazards such as fire. The docks will typically be separated from the main settlement in such a way that an explosion of any sort will damage the dock without affecting the settlement's structural integrity. In a severe emergency, dock modules are able to be ejected from the settlement.

Appendix

8.0 Appendix

Appendix A Operational Scenario

A.1 Hull Breach

Since the hull breach occurs at an interface between two livable areas we will not have to deal with rapid atmosphere loss to the space vacuum, although the atmospheric pressure cannot be guaranteed to be the same. Hull repair will involve rapid response to the changing atmospheric pressure through our Finesse Bots and specially outfitted Heavy Movers (see 5.2.2.3). Silicon buckystructures will be used as a preliminary blockage of air flow, with metal replacement later. Air pressure restoration will be managed by our GEMS system (see 3.2.1) which will pump air from one side to the other.

A.2 Internal Explosion

The immediate danger from the explosion can be avoided by rapid evacuation of all residents near the explosion and subsequent isolation of the explosion area through airlock. Fire response will be handled through FireBots (see 5.2.2.4). If isolation of the area is possible a GEMS module will generate strong winds in the area while filtering air to quickly remove toxic gas. If isolation of the area is not possible vacuum-fitted robots will swarm the area and filter air until the concentration of the gas is below a safe threshold.

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Whitney High School 2009 Columbiat Proposal

Whitney High School 2010 Aresam Proposal

Appendix C Compliance Matrix

2 STRUCTURAL DESIGN

	Requirement	Location in Proposal	Page
2.0.0	Provide a safe and pleasant environment for residents and a transient population of 500 visitors		
2.0.1	Enable residents to have natural views of Earth and the Moon		
2.1.0	Identify large enclosed volumes and their uses		
2.1.1	Show dimensions of major structural components and design features		
2.1.2	Identify construction materials for major hull components		
2.1.3	Specify volumes where artificial gravity will be supplied		
2.1.4	Means for initiating and sustaining artificial gravity		
2.1.5	Structural interface(s) between rotating and nonrotating sections		
2.1.6	Design must show capability to isolate at minimum any five separate habitable volumes in case of a depressurization or other emergencies		
2.1 Min Req	Overall exterior view of settlement, with major visible features showing rotating and non-rotating sections, pressurized and non-pressurized sections, and indicating functions inside volumes		
2.2.0	Specify percentage allocation and dimensions of interior "down surfaces"		
2.2.1	Drawings labeled to show residential, industrial, commercial, agricultural, and other uses		
2.2 Min Req	Overall map or layout of interior land areas, showing usage of those areas		
2.3.0	Describe the process required to construct the settlement, by showing the sequence of major components assembled		
2.3.1	Specify when artificial gravity will be applied		
2.3.2	Describe a construction technique for interior structures making use of minimally refined lunar materials		
2.3 Min Req	Drawing(s) showing at least ten intermediate steps of settlement assembly		
2.4	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		
2.4 Min Req	Show locations on overall structural drawing of buckystructures production facilities, and means for moving parts between those facilities		
2.5	Port facilities must accommodate various sizes, configurations, and purposes of visiting ships		

2.5 Min Req	Drawing(s) of dock configuration(s), including ships in port		

3 OPERATIONS

	Requirement	Location in Proposal	Page
3.0	Describe facilities and infrastructure necessary for building and operating the Bellevistat space settlement and its communities	3.2 Infrastructure	7
3.1.0	Identify sources of materials and equipment to be used in construction	3.1 Materials	7
3.1.1	Identify means for transporting those materials to the Bellevistat construction location, and storage between arrival and use	3.1 Materials	7
3.1 Min Req	Table identifying types, amounts, and sources of construction materials	Table 3.1 Materials/Equipment for Construction	7
3.2.0	Elements of basic infrastructure	3.2.1 Atmosphere 3.2.2 Food Production 3.2.4 Water Management 3.2.5 Household and Industrial Solid Waste Management 3.2.6 Internal and External Communications 3.2.7 Internal Transportation 3.2.8 Day/Night Cycle	7-13
3.2.1	Identify air composition, pressure, humidity, thermal control, and quantity	3.2.1 Atmosphere	7-8
3.2.2	Include growing, harvesting, storing, packaging, delivering, and selling	3.2.2 Food Production 3.2.2.1 Growth 3.2.2.1.1 Seafood 3.2.2.1.2 Nut Milk/Other Dairy-Related Products 3.2.2.1.3 In-Vitro Meat 3.2.2.2 Harvest/Processing/Storage 3.2.2.3 Delivery/Selling	8-9
3.2.3	Specify kilowatts distributed to habitable areas for electrical power	Table 3.2.3.1 Electric Power	9
3.2.4	Specify recycling and/or disposal required water quantity and storage facilities	3.2.4 Water Management 3.2.4.1 Water Treatment 3.4.2.2 Water Storage	10-11
3.2.5	Specify recycling and/or disposal of household and industrial solid waste management	3.2.5 Household and Industrial Solid Waste Management 3.2.5.1 Waste Treatment	11
3.2.6	Specify devices and central equipment for internal and external communications systems	3.2.6 Internal and External Communications 3.2.6.1 Internal Communications 3.2.6.2 External Communications	11-12
3.2.7	Show routes and vehicles, with dimensions, of internal transportation systems	3.2.7 Internal Transportation	12-13
3.2.8	Specify schedule and mechanisms/ operations for providing day/night cycles	3.2.8 Day/Night Cycle	13
3.2.9	Define storage facilities required to protect against interruption in production of food or commodities	3.2.2.2 Harvest/Processing/Storage	9

3.2 Min Req	Chart(s) or table(s) specifying quantities required of air, food, power (for residents), water, waste handling, communications devices, and internal transport vehicles	Table 3.2.1 Atmosphere Composition Table 3.2.2 Food Production Table 3.2.3.1 Electric Power Table 3.2.3.2 Power Allocation Table 3.2.4 Water Usage/Production Table 3.2.4 Waste Production Table 6.2.7 Cost of Systems and Computers	8-13
3.3.0	Show conceptual designs of primary machines and equipment employed for constructing the settlement, especially for assembling exterior hull and interior buildings / structures	Figure 3.3.1 Mover Bot Pushing Load	13
3.3.1	Describe materials, components, and/or subassemblies delivered to the machines, and how the machines convert delivered supplies into completed settlement structures	3.3 Machines/Equipment for Settlement Construction 3.3.1 Base Module and Construction	13
3.3 Min Req	Drawing(s) of primary construction machinery, showing how it shapes and/or manipulates raw materials or structural components into finished form	Figure 3.3.1 Mover Bot Pushing Load	13
3.4	Show process(es) for providing paper (or equivalent) products in Bellevistat, including recycling	3.4 Paper Provisions 3.4.1 Raw Material Sources 3.4.2 Production Process	14
3.4 Min Req	Chart or table listing raw materials source(s) and facilities for paper (or equivalent) production processes.	Table 3.4 Paper Production Figure 3.4.2 Manufacturing Flow	14
3.5	Provide repair services for visiting ships	3.5 Repair Services for Visiting Ships	14
3.5 Min Req	Show how docks for ship repair differ from unloading/loading docks	3.5 Repair Services for Visiting Ships	14

4 HUMAN ENGINEERING

	Requirement	Location in Proposal	Page
4.0.0	Quality of life	4.0 Human Factors 4.0.1 Comfortable Living	16
4.0.1	Natural sunlight, and views of Earth and Moon	4.0.2 Natural Sunlight and Views of Earth and Moon 4.0.2.1 Viewing Ports 4.0.2.2 Telescopium Observatory	16
4.0.2	Provide options for residential areas in 1g, 0.8g, and 0.5g; and with 1.0, 0.8, and 0.6 times Earth sea level atmospheric pressure	4.0.5 Gravity and Pressure 4.0.5.1 Gravity 4.0.5.2 Pressure	16
4.1.0	Provide services that families could expect in comfortable modern communities (e.g., housing, entertainment, medical, parks and recreation)	4.1 Modern Communities 4.1.1 Facilities Table 4.1.1 Variety and Quantity of Facilities	17
4.1.1	Variety and quantity of consumer goods	4.1.3 Water and Consumer Goods Table 4.1.3 Variety and Quantity of Consumer Goods	18
4.1.2	Areas designed with open space and long lines of sight	4.1.1.4 Weather Parks	17
4.1.3	List major types of consumables and quantities	Table 4.1.2 Variety and Quantity of Consumables 4.1.2 Consumables	18

4.1.4	Depict or specify means of distributing consumables (including food)	4.1.2 Consumables Table 4.1.3 Variety and Quantity of Consumer Goods	18
4.1 Min Req	Map(s) and/or illustration(s) depicting community design and locations of amenities, with a distance scale; identify percentage of land area allocated to roads and paths	Figure 4.1.4 Community Layout 4.1.4 Community Layout	18, 19
4.2.0	Provide designs of typical condominium or apartment residences, clearly showing room sizes	4.2 Residences Table 4.2.1 Quantity and Area of Residences Figure 4.2.1.2 Two-Story Condominiums Figure 4.2.1.3 Five-Star Apartment Complexes	18-20
4.2.1	Identify source(s), and/or manufacture of furniture items, appliances, and personal items (e.g. clothing and shoes)	4.2.2 Furniture, Appliances, and Personal Items Table 4.2.2 Quantities and Sources of Furniture and Appliances	21
4.2 Min Req	External drawing and interior floor plan of at least six home designs, the area (in sq.ft.) for each residence design, and the number required of each design	Table 4.2.1 Quantity and Area of Residences Figure 4.2.1.1 Family Houses Figure 4.2.1.2 Two-Story Condominiums Figure 4.2.1.3 Five-Star Apartment Complexes	19-21
4.3.0	Provide designs of systems/ devices/ vehicles intended for outside of gravity and pressurized volumes will emphasize safety	4.3 Devices and Transportation 4.1.1 Tachyon Bike 4.3.1.2 Hydra Figure 4.3.1.1 Tachyon Bike 4.3.2 Devices and Systems for Safe Access	21
4.3.1	Show safety systems to enable human inspection and repair of exterior surfaces of rotating volumes	4.3.2 Devices and Systems for Safe Access 4.3.2.1 Nitrile Shoes Figure 4.3.2.1 Nitrile Shoes 4.3.2.2 Tether System	21
4.3.2	Show features required for spacesuits enabling work outside or pressurized volumes	4.3.3 Spacesuits 4.3.3.1 Spacesuit Design 4.3.3.1.1 Life Support Pack 4.3.3.1.2 Headgear 4.3.3.1.3 EVA gloves	22
4.3.3	Show airlock designs for exiting/entering habitable areas from unpressurized volumes	4.3.4 Airlocks 4.3.4.1 Airlock at Cygnus 4.3.4.2 Airlock at Musca and Pavo 4.3.4.1 Procedure Figure 4.3.4.1 Airlock at Cygnus Figure 4.3.4.2 Airlock at Musca and Pavo	22
4.3 Min Req	Drawings showing spacesuit, airlock, and exterior mobility device designs	Figure 4.3.2.1 Nitrile Shoes Figure 4.3.3.1 Spacesuit Figure 4.3.4.1 Airlock at Cygnus Figure 4.3.4.2 Airlock at Musca and Pavo	21-22
4.4	Describe community attributes intended to enable short-term residents to feel welcome and integrated into the settlement's community life	4.4 Transient Population 4.4.1 Social Attributes 4.4.1.1 Tours 4.4.1.2 Community Activities 4.4.1.3 Holidays 4.4.1.3.1 Tanabata 4.4.2.1 Schools 4.4.2.2 Training	22-23
4.4 Min Req	Describe at least one physical and one social community feature intended to involve non-permanent residents in social structures of the settlement	4.4.1.1 Tours 4.4.1.2 Community Activities 4.4.1.3 Holidays 4.4.1.3.1 Tanabata Figure 4.4.1.3.1 Tanabata	22-23

		4.4.2 Community Features 4.4.2.1 Schools 4.4.2.2 Training	
4.5	Create pleasant and efficient areas for passenger arrival and departure	4.5 Visitor Center	23
4.5 Min Req	Illustration of the passenger experience when arriving at Bellevistat	Figure 4.5 Visitor Center	23

5 AUTOMATIONS

	Requirement	Location in Proposal	Page
5.0.0	Specify numbers and types of computing and information processing devices, multi-function personal electronic tools, servers, network devices, and robots required for Bellevistat's facility, community, and business operations	Table 5.2.1	26
5.0.1	Describe types and capacities of data storage media, data security, and user access to computer networks	5.3.4 Communications and Networks	29
5.0.2	Show robot designs, clearly indicating their dimensions and illustrating how they perform their tasks	Figure 5.1.1 Heavy Mover and Finesse Bot Figure 5.1.2 Tiny Bot Figure 5.2.2.1 MediBot Figure 5.2.2.2 SafetyBot Figure 5.2.2.4 FireBot Table 5.2.1 Automation for Maintenance, Safety, and Repair	25-27
5.1.0	Describe use of automation for construction	5.1 Automation for Construction	25
5.1.1	Consider automation for transportation and delivery of materials and equipment, assembly of the settlement, interior finishing, and manufacture of furniture and appliances	5.1 Automation for Construction	25
5.1 Min Req	Drawings showing automated construction and assembly devices-both for exterior and interior applications -and illustrating how they operate	5.1 Automation for Construction	25
5.2.0	Specify automation systems for settlement maintenance, repair, and safety functions, including back-up systems and contingency plans	5.2 Automation for Maintenance, Safety, and Repair	26
5.2.1	Robots required for emergency external repairs must survive and accomplish tasks during solar flare activity	5.2.2.3 Emergency Hull Breaches	27
5.2.2	Describe means for authorized personnel to access critical data and command computing and robot systems	5.2.3 Access of Critical Data and Functions for Authorized Personnel	28
5.2.3	Include descriptions of security measures to assure that only authorized personnel have access, and only for authorized purposes	5.2.3 Access of Critical Data and Functions for Authorized Personnel	28
5.2 Min Req	Chart or table listing anticipated automation requirements for operation of the settlement, and identifying particular systems and robots to meet each automation need	Table 5.2.1 Automation for Maintenance, Safety, and Repair	26
5.3.0	Describe automation devices to enhance livability in the community, productivity in work environments, and convenience in	5.3.1 Automations for Livability	28

	residences		
5.3.1	Emphasize use of automation to perform maintenance and routine tasks, and reduce requirements for manual labor	5.3.1 Automations for Livability	28
5.3.2	Provide for privacy of personal data and control of systems in private spaces	5.3.2 Automations for Work	28
5.3.3	Describe devices for personal delivery of internal and external communications services, entertainment, information, computing, and robot resources	5.3.3 Automations for Environment 5.3.4 Communications and Networks	29
5.3 Min Req	Drawings of robots and computing systems that people will encounter in Bellevistat, and diagram(s) of network(s) and bandwidth requirements to enable connectivity	5.3.1 Automations for Livability	28
5.4	Automate unloading of shipping containers from ships, transfer of containers to refining facilities, and unloading of containers in zero g and vacuum	5.4.1 Automation for Transportation of Containers and Materials from Ships	29
5.4 Min Req	Drawings of automation systems to deliver ore to refining processes	Figure 5.4 Transportation of Containers and Materials	29
5.5.0	Automate final docking of ships in the various port facilities	5.5 Docks 5.5.1 Docking of Ships Figure 5.5.1 Docking of Ships	30
5.5.1	Show differences in docking procedures for different types of docks	5.5.2 Docking Aids for Different Types of Ships	30
5.5 Min Req	Show automated docking aids for at least two different types of ships	5.5.2 Docking Aids for Different Types of Ships	30

6 SCHEDULE AND COST

	Requirement	Location in Proposal	Page
6.0.**0**	Schedule for completion and occupation of Bellevistat within 13 years	6.0 Schedule and Cost	33
6.0.1	Costs for design through construction phrases of schedule	Table 6.2.2 Cost of Operations (During Construction)	33
6.1.0	Describe contractor tasks from the time of contract (15 May 2033) until customer assumes responsibility for operations of the completed settlement	6.1.1 Construction Phases	33
6.1.1	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.	Table 6.1 Construction Schedule	32
6.1 Min Req	Durations and completion dates of major design, construction, and occupation tasks, depicted in a list, chart, or drawing	Table 6.1 Construction Schedule	32
6.2	Estimate numbers of employees working during each phase of design and construction in the justification for contract costs	Table 6.2.1 Cost of Labor During Construction	33
6.2 Min Req	Chart(s) or table(s) listing separate costs associated with different phases of construction, and clearly showing total costs that will be billed to the Foundation Society	6.2 Cost of Construction	33

7 BUSINESS DEVELOPMENT

	Requirement	Location in Proposal	Page
7.0	Port for receiving lunar and asteroid materials	7.0.1 Ports for Lunar and Asteroid Materials	37
7.0	Ores will arrive in standard shipping containers	7.0.1.1 Standard Shipping Container Receiving	37
7.0	Ore arrives in batches but is delivered for continuous processes, so must be stored between delivery and use	7.0.1.2 Ore Storage	37
7.0	Provide method(s) and route(s) for transferring raw materials to processing facilities	7.0.1.3 Cargo Transport to Storage	37
7.0	Most non-bulk cargo will arrive in standard shipping containers	7.0.1.4 Non-Standard Cargo	37
7.0	Provide separate port facilities for passengers, and cargo other than raw materials	7.0.1.5 Preprocessed Cargo and Passengers	37
7.0	Production of goods manufactured from extraterrestrial materials	7.0.2.1 Metal Extraction	37
7.0	Materials require processing varying from minimal to refining for extraction of metals and rare earth elements	7.0.2.1.1 High Concentration Extraction 7.0.2.1.2 Low Concentration Extraction	37
7.0	Many processes require operations in both zero g and at least 0.2 g	7.0.2.2 Variable Gravity Refining	37
7.0	Manufacturing will encompass a wide variety of products; the Foundation Society will welcome companies to lease space for manufacturing facilities	7.0.2.3 Manufacturing Expansion and Construction	37
7.0	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	7.0.2.4 Product Delivery	37
7.0	Allow for future expansion of manufacturing areas, to eventually include assembly of large interplanetary ships	7.0.2.3 Manufacturing Expansion and Construction	37
7.0	Repair and restoration of ships and other space infrastructure elements	7.0.3 Repair and Restoration of Space Vehicles	38
7.0	Repair docks are required to accommodate different types and sizes of ships	7.0.3.1 Repair Docks	38
7.0	Allow for future port expansion, both for increasing numbers and sizes of visiting ships requiring services	7.0.3.2 Port Expansion	38
7.0	Provide safety procedures in the event a visiting ship develops a hazardous situation	7.0.3.3 Safety Precautions	38