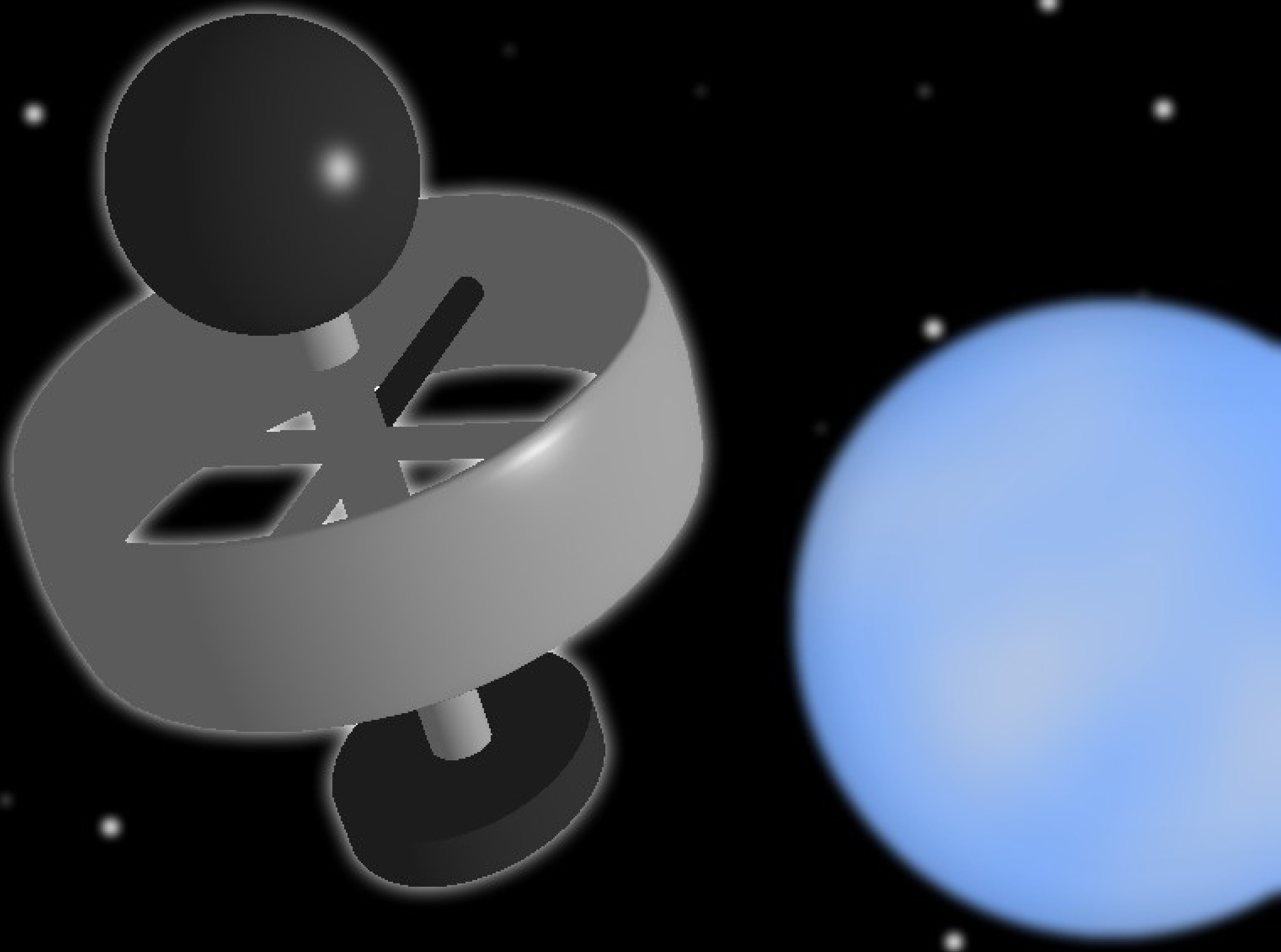
NORTHDONNING HEEDWELL



ASTORIA

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UNIVERSITY HIGH SCHOOL ISSDC

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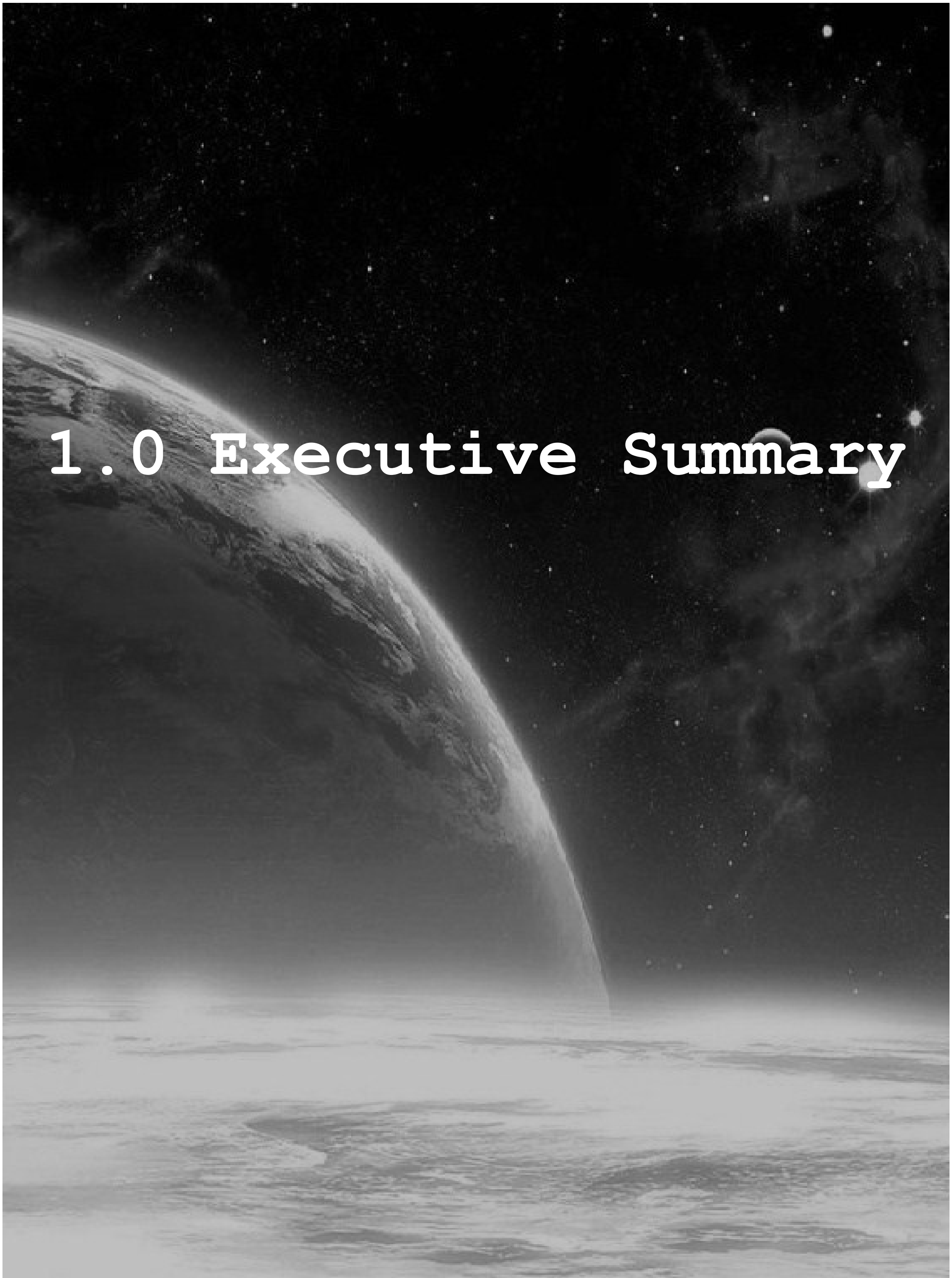
Jasmin Kung	Jiho Park	Steven Huang	Sherwin Tang	Jaron Kong
Kevin Chung	Tiffany Huang	Alex Zivkovic		

1.0 Executive Summary



SECTION 1.0: EXECUTIVE SUMMARY

Space: a challenge, a frontier, an enigma. For centuries, the very existence of outer space has intrigued the human race and prompted scientists around the world to fund countless research projects, aiming to delve into the mysteries of this seemingly endless universe. We have established ourselves throughout space, on the moon, and recently, even on the hostile red planet, Mars. Now, in 2071, we at *Northdonning Heedwell*, present ***Astoria***, a mining gem in the asteroid belt that continues the tradition of challenging new boundaries.

Astoria's advanced design aims to create a suitable, comfortable environment for its residents while maintaining smooth operations among the settlement, other Earth-based settlements, and Earth itself:

- A separate *manufacturing sphere*, ***Pei***, operating both pressurized and non-pressurized sector, will handle all heavy manufacturing, including the refinement of raw materials.
- The *port facility, **Saarinen***, will be the hub for the traffic of spacecraft entering and leaving the settlement, providing extensive facilities equipped with the newest, most advanced technology to aid damaged ships.
- Extensive *community designs*, with particular emphasis on integrating a large population of semi-term residents, will guarantee residents superior comfort and living quality.
- Innovative *robotic technology* will be implemented to improve the lives of residents and provided automated assistance to the maintenance of the settlement at large.

Upon its completion, Astoria will have the capability of housing up to 6,000 permanent residents, 5,000 semi-term residents, along with a large transient population in its torus, ***Wright***. Along with the basic elements that accompany a commercial settlement, Astoria will be equipped with novel mining technology, aimed at tackling the large-scale mining and refining of raw materials from nearby asteroids. Detailed emergency and contingency plans will be implemented throughout the Astoria system to ensure the safety and well-being of the residents.

Construction will begin on Astoria as soon as approval has been granted. It is projected that Foundation Society members will be able to move to the settlement starting in March of 2097. All businesses, industries, and commercial ventures can begin operation around August of 2097. Full population is expected to be attained at a date no later than May of 2100.

Although designed to be a mining outpost and communication point in the asteroid belt, Astoria is also a center for scientific research, for superior outer space living, for technological advancement. While the mining operations parallel that of the sparkling city-in-space, Bellevistat, Astoria offers the alternate experience of living in the smaller, quaint little-town-in-space environment. We at *Northdonning Heedwell* are proud to present ***Astoria***, an engineering success at the edge of the human frontier.

2.0 Structural Design

SECTION 2.0: STRUCTURE

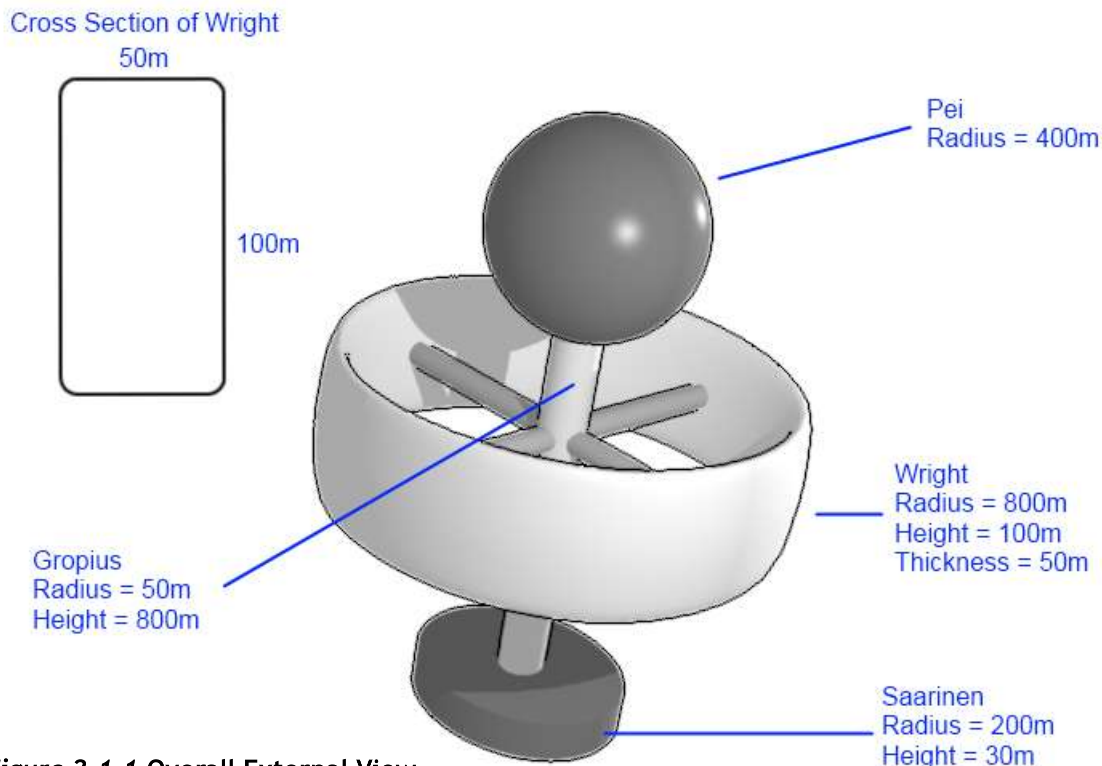


Figure 2.1.1 **Overall External View**

2.1.1 Exterior Design

Astoria will be made up of a single pressurized torus structure, *Wright*, rotating around a central axis, *Gropius*. Divided into four sectors, *Wright* will serve as the main residential area for the colonists, as well as provide space for agricultural operations and light manufacturing activities. The torus will be maintained at .9 earth gravity with a rotation rate of 1 rpm. *Wright* will be connected to the axis by four spokes. Each spoke will double as a passageway between the torus and the central axis.

At the top of the central axis will be the manufacturing sphere, *Pei*. The sphere will contain both pressurized and non-pressurized sections, all operating in zero gravity. *Pei* will mainly handle the heavy manufacturing processes, such as the refinement of raw materials.

Connected to the bottom of the central axis will be a port facility, *Saarinen*. Through this port, spacecraft will be able to travel to and from Earth and other colonies, important because of the large transient population. The port will also be essential in accepting spacecraft carrying the raw mined materials from Ceres. *Saarinen* will also double as an observation deck, providing colonists with natural views of outer space.

The central axis, *Gropius*, will hold the central control system for Astoria as well as provide a means of transportation between *Wright, Pei,* and *Saarinen. Gropius* will also provide storage space and a temporary pressurized residential area for emergencies.

To protect against radiation and debris penetration and maintain a safe living environment, Astoria features a multilayer hull that guards against various particles. More details may be found in Section 2.4.1.

Sections:	Dimensions:	Total Surface Area:	Total Volume:
Gropius Central Axis	Radius = 50 m Height = 800 m	267035 m^2	6283185 m^3
Wright Pressurized Rotating Torus	Radius = 800 m Height = 100 m Thickness = 50 m	1507964 m^2	25132741 m^3
Pei Manufacturing Sphere	Radius = 400 m	2010619 m^2	268082573 m^3
Saarinen Spaceport	Radius = 200 m Height = 30 m	289026 m^2	3769911 m^3

2.1.2 Artificial Gravity and Rotation Rate

In order to maintain comfortable and natural living conditions for human habitation, the residential torus must provide gravity. An artificially produced gravity of 0.9G will be maintained on the torus at all times. This will be achieved by a constant rotation of *Wright* around the central axis at a fixed velocity. A gravity limited to 0.9G will significantly lower structural maintenance costs.

With a radius of 800 meters, the torus will only have to rotate at 1 rpm, or a 60 second period, in order to maintain a gravity of 0.9G. This rotation rate is slow enough to greatly minimize the effects of the Coriolis effect. The calculations are below:

Centripetal acceleration due to rotation: $a_c = \frac{v_t^2}{r}$

Translational velocity of torus: $v_t = \frac{2\pi r}{p}$

a_c = centripetal acceleration

v_t = translational velocity

r = radius

p = period of rotation

Combining the two formulas, we get: $a_c = \frac{4\pi^2 r}{p^2}$

By plugging the values in, we get: $a_c = \frac{4\pi^2(800\,m)}{60\,s^2} = 8.77\frac{m}{s^2} \times \frac{1G}{9.8\frac{m}{s^2}} = .90\,G$

Gropius, *Pei*, and *Saarinen* will not rotate and therefore will not produce centripetal acceleration, as there is no need for gravity in these volumes.

2.1.3 Pressurized and Non-Pressurized Sections.

Astoria will have both pressurized and non-pressurized volumes. *Wright* will be pressurized to accommodate human residency, except for some manufacturing facilities. Half of *Pei* will be pressurized and half will not, to allow for manufacturing processes in both environments. *Gropius* and the four spokes will be used mainly for transportation and need not be pressurized, except for the emergency residential area within the central axis. All pressurized areas will be maintained at a constant pressure of 13.5 psi.

2.1.4 Volume Isolation

In case of an emergency such as a hull breach, Astoria will be able to isolate each of its eleven structures in any combination at any given time. Each of the four sectors of *Wright*, as well as the four spokes that connect each to the *Gropius*, may be isolated. *Gropius*, *Pei*, and *Saarinen* may also be isolated from each other and the spokes. All sections will be separated by airlocks, for a total of fourteen airlocks.

2.2.1 *Wright*

Wright will be split into four sectors, with each sector holding its own residential community. Each residential community will have its own manufacturing and agricultural operations. The following table shows the percentage allocations for operations in a single sector:

Section (1 sector)	DA (Down Area)	Percent of total DA
RESIDENTIAL NEIGHBORHOOD		
Residential	50265 m^2	10%
Hospitals/Health Research	2513 m^2	0.5%
Schools	75398 m^2	15%
Recreation/ Open space	125663 m^2	25%
AGRICULTURAL/FOOD PRODUCTION/WASTE PROCESSING		
Agricultural	70371 m^2	14%
Livestock	50265 m^2	10%
Processing, Drying, Storing	30159 m^2	6%
Waste and recycling	25132 m^2	5%
MANUFACTURING		
Non-pressurized	10053 m^2	2%
Pressurized	40212 m^2	8%
MISCELLANEOUS		
Electrical distribution	1005 m^2	0.2%
Communications	50 m^2	0.01%
Entrances to Communities	251 m^2	0.05%
Miscellaneous	30159 m^2	6%
TOTALS*	502654 m^2	100%

Table 2.2.1 **Residential Torus Allocations** *Calculations are approximate. Totals may not add up completely due to rounding error.

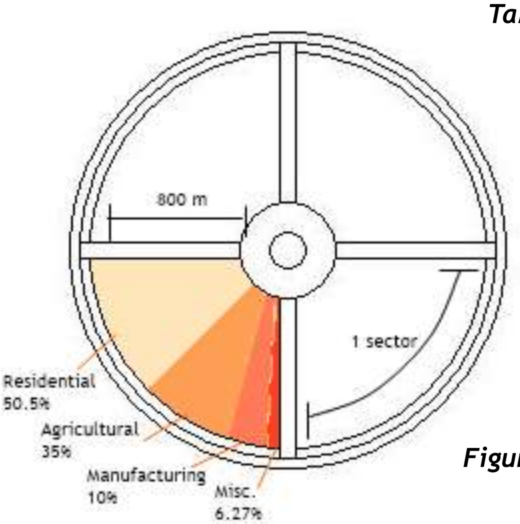


Figure 2.2.1: **Torus Allocations**

Each sector of *Wright* operates as a single community. The sectors are separated by airlocks so emergencies in one sector will not affect the others.

Sectors will begin operations one-by-one, although to ease energy costs artificial gravity production will not begin until the interiors of all sectors are finished.

Each sector will have access to two spokes, which increases the chances that colonist my successfully flee to the central axis in case of emergency.

2.2.2 *Gropius*

Gropius will hold the main control system for Astoria. The central axis also contains an emergency residential area, and large amounts of storage space. The axis will also be used for transportation between *Wright, Saarinen,* and *Pei*. The lack of gravity within the axis means heavy cargo may be moved with minimal energy. Percentage allocations for functions of *Gropius* are detailed in the figures below. As there technically no "down surface," allocations are given in volume.

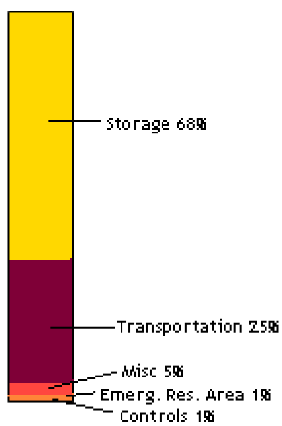


***Figure 2.2.2:* Central Axis Allocations**

Section	Volume	Percent Volume
Storage	4272565 m^3	68%
Transportation	1570796 m^3	25%
Control Systems	62831 m^3	1%
Emergency Residential Area	62831 m^3	1%
Miscellaneous	314159 m^3	5%
TOTALS:	6283185 m^3	100%

***Table 2.2.2:* Central Axis Allocations**

2.2.3 *Pei*

Pei will handle heavy manufacturing duties in both pressurized and unpressurized environments. The lack of gravity will greatly lower manufacturing costs by reducing the energy and effort to move large objects. The sphere will be the main refinery for raw ore mined from Ceres. The sphere's location on the central axis mean cargo, such as ore, may move directly from the port to the sphere.

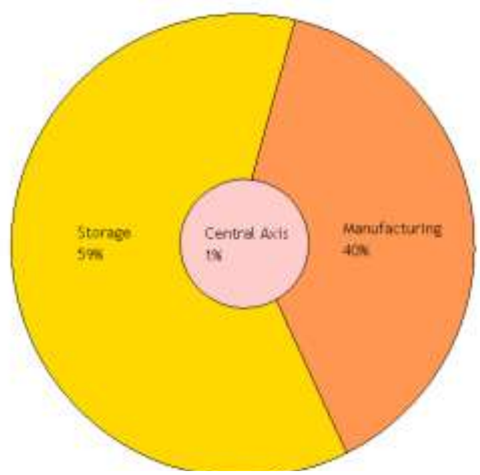


Figure 2.2.4: Manufacturing Sphere Allocations

Sections	Volume	Percent Volume
Manufacturing	107233029 m^3	40%
Storage	158168718 m^3	59%
Central Axis	2680825 m^3	1%
Totals:	268082573 m^3	100%

Table 2.2.4: Manufacturing Sphere Allocations

2.2.4 *Saarinen*

Saarinen will handle the docking and unloading of spacecraft as well as launch and loading operations. *Saarinen* will have a pressurized area to accommodate human travelers, which also functions as as an observational deck for colonists to view outer space.

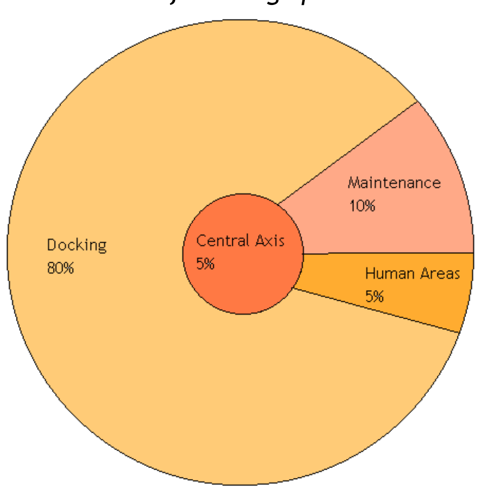


***Figure 2.2.4:* Spaceport Allocations**

Sections	Volume	Percent Volume
Docking	3015928 m^3	80%
Maintenance	376991 m^3	10%
Human Areas	188495 m^3	5%
Central Axis	188495 m^3	5%
Totals	3769911 m^3	100%

Table 2.2.4: **Spaceport Allocations**

2.3 Construction

The construction of a space settlement is a difficult and time-consuming process. As such, we have devised a rough time-line for the construction of the settlement in order to ensure maximum efficiency and to maintain a timely schedule.

	
Step 1: *Gropius* is constructed. The fusion reactors begin producing power for basic operations. *Estimated time: 3 years*	Step 2: *Saarinen* is constructed and begins operations, docking ships bearing materials from other settlements. *Estimated time: 2 years*
	
Step 3: *Pei* is constructed, and begins some manufacturing operations. Relevant areas are pressurized. *Estimated time: 4 years*	Step 4: The four spokes are constructed. *Estimated time: 2 years*

	
Step 5: *Wright* is constructed and pressurized. *Estimated time:* 5 years	Step 6: The interior of the torus is constructed, one sector at a time. *Estimated time: 3 years*

Step 7: Finalization
Rotation of the torus begins and artificial gravity is produced. Colonists begin populating Astoria, and *Pei* and *Saarinen* become fully operational. *Estimated time: 1 year*

Total estimated construction time: 20 years

2.4.1 – Hull Components

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

Materials/Amount	Usage	Property
Raguard-0.04m	Radiation Protection (Overall)	Has a diverse application through its ability to be coated. It provides X-ray radiation shielding
Depleted Uranium-0.01m	Radiation Protection (Beta)	Blocks beta particle penetration by a factor of 1/2 every 0.2 centimeters. In total, beta particle penetration is reduced to 1/32 of the original amount
Polyethylene Foam-1m	Protection (Secondary Particles), Shock Absorption	Light weight property and high H concentration act as radiation protection against secondary particles. The Foam structure allows the material to absorb shocks
Aluminum Alloy (6061-T6)-3m	Radiation Protection (Secondary Particles), Structure Support	Light weight material lowers second particle showers. It is easily welded, yields structural support, and has good ductility

Polyethylene Foam-1m	Secondary Shock Absorption Layer	Same as PF used earlier
Silica Aerogel-1m	Thermal Protection	As a lightest solid, the block contains air bubbles inside that serve as an outstanding infrared radiation shield material
Polyethylene Foam-1m	Tertiary Shock Absorption Layer	Same as PF used earlier
Steel Alloy (18KhGNMFR)-2m	Structural Support	Very high tensile strength. The abundance of Iron on Ceres makes producing this material on the settlement very feasible and cost-efficient
11% Chromium Stainless Steel-0.5m	A dividing layer between the inner layer of the settlement and the outer shielding layer	a very low oxidation level due to the iron's reaction with chromium
Regolith-5m	A firm ground for the settlement's building structures and large botanical root structures	Found in nearby asteroids, they contain lots of mineral materials and are abundant throughout the asteroid belt
Packed Soil (Decomposed Wood)-2m	primary type of ground used to give the settlement a more earth-like atmosphere	Reduces any leftover radiation that still penetrates all the layers of shield
Total Thickness-16.55m		
Approximate volume-3,129,266,044m^3		

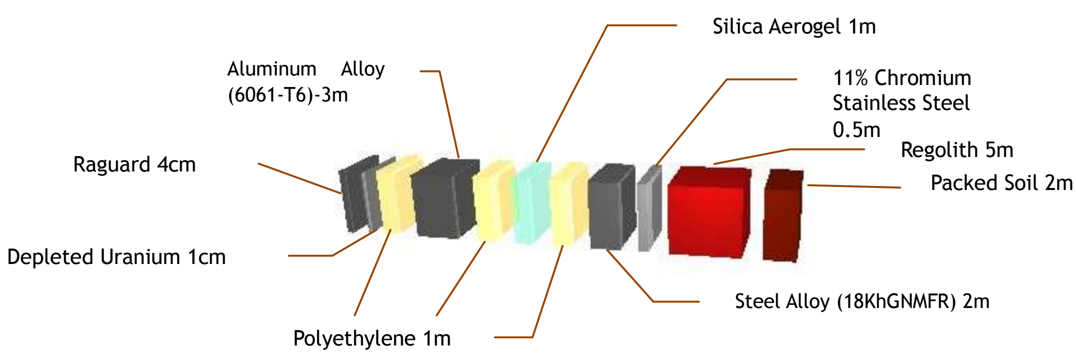


Figure 2.4.1 **Hull Component Layering**

2.4.2 – Damage Repair System

The damage repairing work will be done by robots designed to replenish all the layers of the damaged wall. Due to the numerous layering of the shielding layer, it is necessary that the robot must repair the walls with minimal incision. The repairing robot will check for any external and internal damages every 12 hours. The damage check is accomplished using ultrasound imaging to peer through all layers and assess for damage. If damage were to be detected (which would only occur in rare circumstances), the repairing system will send out two teams of wall repair robots; one dedicated for internal wall maintenance, and the other dedicated for the external wall maintenance. The two teams will align themselves on the nearest place close to the impact zone and dig through the walls in order to fix for the damage from the most internal area of the wall. Each of the external wall maintenance robots has four legs for structural durability and has numerous tools at its disposal in order to able quick repairing of the walls. The internal maintenance robot is similarly structured as the external counterpart, but is smaller in size and is more developed to fix the inner layers of the wall.

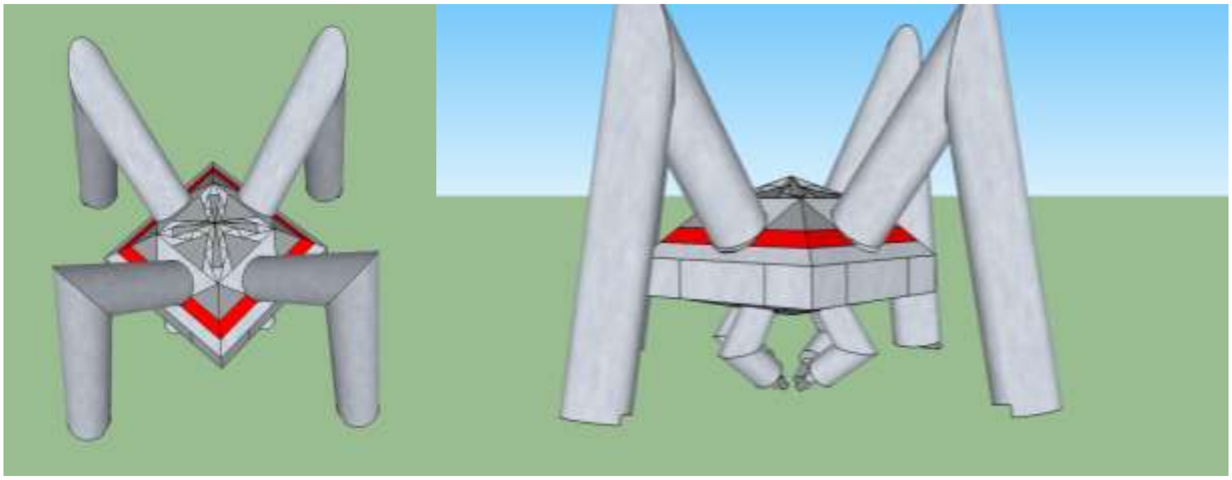


Figure 2.4.2 **The External Wall Maintenance Robots – Aerial View (Right), Horizontal View (Left)**

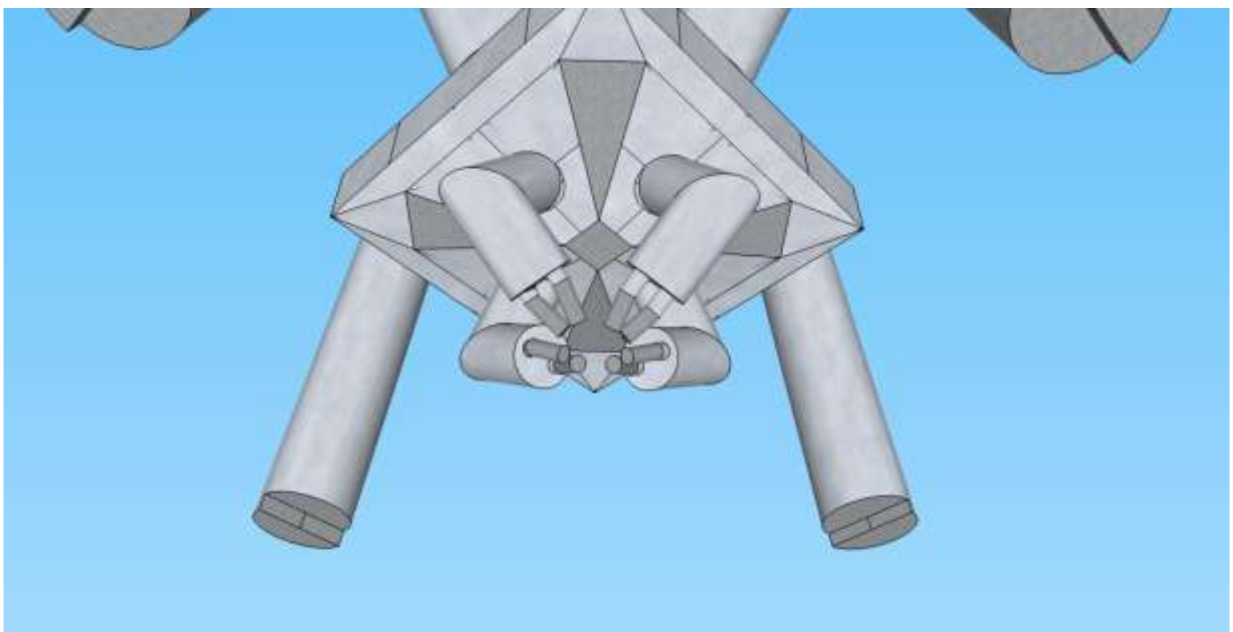


Figure 2.4.3 **The "Arms" of the Robot Used for Holding tools (Common for both Internal and External Wall Maintenance Robots)**

For larger items that may be detected only hours in advance, the colony may make a combination of evasive maneuvers and have robots prepared to make repairs immediately after collision.

2.5 – Mining House

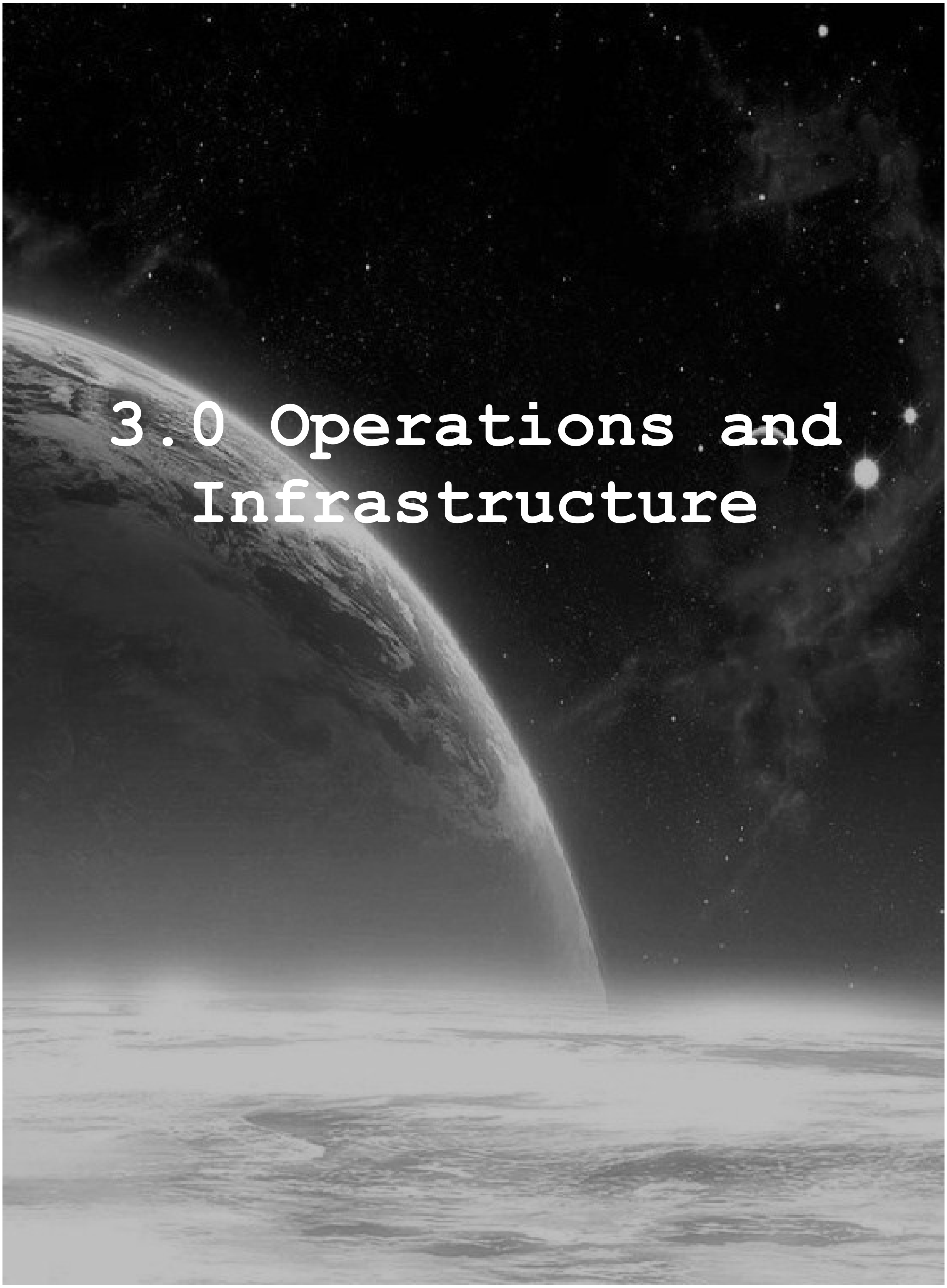
Figure 2.5.1 **The Internal Structure of the Mining House**

The mining settlement will be stationed underneath the Cererean crust in order to be shielded from minor asteroid impacts as well as low-energy radiation. The outer cylinder has an internal radius of 10m and a height of 20m. The outer cylinder is coated with one millimeter of gold, a meter of regolith, 50 centimeters of silica Aerogel, 99 centimeters of memory foam, and nine millimeters of titanium alloy, designed to significantly reduce the amount of harmful radiation such as cosmic rays and ionized solar winds.

Four horizontal beams and the beam underneath the inner cylinder are composed of a titanium alloy that will provide a structural support for the inner cylinder. The elongated beam above the inner cylinder is a transport passageway for the settlers to enter and exit the mining house. All six of these beams have hallowed centers that allow wirings and gas pipes to run through. The five structural beams measure four meters in length while the elongated passageway measures 15 meters in length. This allows for airlock spaces to be built within the passageway. Besides the beams, vacuum takes up the space between the internal and external cylinders, allowing the internal structures to retain heat more easily.

The inner cylinder is where the settlers will spend most of their time inside. The inner cylinder has a meter thick wall composed of nylon, iron, and concrete that closely resembles the basic components of numerous building materials. The inner cylinder’s internal dimensions measure five meters in radius and ten meters in height, allowing enough space for 10 crew members to stay for a sojourn, during which they will fix and edit mining programs to run optimally. The inner cylinder has an air conditioning system that will control the atmospheric conditions inside the mining house to be suitable for the crew members. The inner cylinder has a section of its wall composed of numerous computer systems that will allow the crew members to control the mining operation. In case there is an emergency such as solar flares where they are forced to stay in the mining house, there are packs of freeze- dried foods and water that will allow the crew members to stay in the mining house for up to a month. The rest of the inner cylinder’s space is dedicated for placement of essential household objects such as toilets, beds, and tables.

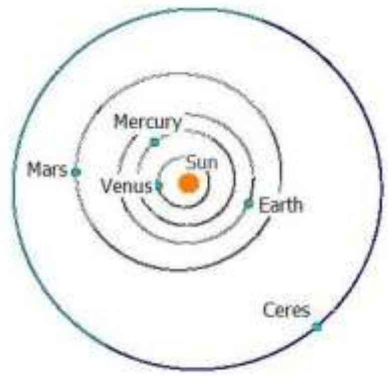
3.0 Operations and Infrastructure



SECTION 3: OPERATIONS & INFRASTRUCTURE

To ensure the best facilities for the residents of Astoria, Northdonning Heedwell will take into account the operations of all systems. It is our highest priority to ensure that the settlement runs smoothly, allowing residents to live comfortably and safely.

3.1.1: Orbital Diagram



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3.1: Orbital Specifications and Materials

3.1.1: Orbital Locations and Specifications

Astoria will be situated in an orbit close to the dwarf planet, 1 Ceres, at an inclination of 10.59 ^{O} to the Ecliptic and 9.20 ^{O} to the Invariable Plane, between 2.54 AU (Perihelion) and 2.99 AU (Aphelion). After careful consideration, 1 Ceres was chosen as an appropriate location for Astoria. Firstly, 1 Ceres is dwarf planet rich in iron silicates, allowing for easy mining. In addition, there is a large amount of water locked up in minerals, allowing the production of water. Finally, 1 Ceres itself can be used as a shield to avoid larger pieces of debris.

3.1.2: Sources and Transportation for Construction Materials and Equipment

Listed below are materials used for the construction and operations of Astoria. Once acquired, raw materials will generally be processed on Ceres or Astoria before use, except in the case of construction materials. Construction materials will be processed before settlement construction and any excess will be stored as repair material. Northdonning Heedwell has ensured that a majority of raw materials will come from our site location, 1 Ceres, to minimize costs and stimulate production.

Table 3.1.1 Settlement Construction

Processed Material	**Source of raw material**	**Transportation**
6061-T6 Aluminum Alloy	Bellevistat	Commerical Spacecraft
Steel Alloy Grade 18KhGNMFR	Bellevistat, 1 Ceres	AstMin Mothership
Radiation Protection		
Depleted Uranium	Earth	Commercial Spacecraft
Raguard	Earth	Commercial Spacecraft
Polyethylene Foam	Alexandriat	Commercial Spacecraft
Silica Aerogel	1 Ceres	AstMin Mothership
Regolith	1 Ceres	AstMin Mothership
Operations		
Uranium 235/238	Earth	Commercial Spacecraft
Electronics	Earth	Commercial Spacecraft
Water	1 Ceres	AstMin Mothership
Hydrazine	Earth	Commercial Spacecraft
LOX (O_2)	1 Ceres	AstMin Mothership
LH2 (H_2)	1 Ceres	AstMin Mothership

3.2: Settlement Infrastructure

3.2.1 Atmosphere, Climate, and Weather Control

In order to best replicate Earth-like conditions on Astoria, its atmospheric composition and its pressure shall be similar to that of Earth's. Pressurized air will be provided throughout Astoria. Trace elements such as methane, argon, neon, etc. have been excluded from the atmosphere to reduce both cost and complications resulting from a highly diverse atmosphere. Atmospheric composition will be maintained constant through the use of the Bosch reaction: CO_2 (g) + $2H_2$ (g) $\rightarrow$ C (s) + 2 H_2O (g). The water would be allocated for electrolysis to regenerate oxygen (to replenish the atmosphere) and for human and industrial purposes in Astoria.

Astoria will also have four "seasons" marked by moderate changes in the temperature of the colony to replicate Earth-like environment. The seasons will be in three month cycles. The seasons will also be marked with changes in humidity, as well as changes in temperature. To further replicate Earth conditions, rain shall be formed by collecting water vapor on condensation plates above the communities and deposited in special storage containers, and hidden sprinklers located throughout Astoria will spray the water during appropriate times of the season.

Table 3.2.1 Atmospheric Composition and Qualities

Component	Percentage	Pressure (kPa)	Volume (m^3)	Weight (in kg)
Nitrogen (N_2)	52.363	53.043	471,267,000	589,555.017
Oxygen (O_2)	45.265	44.685	407,385,000	582,153.165
Carbon Dioxide (CO_2)	0.795	0.787	7,155,000	14,145.435
Water Vapor (H_2O)	0.201	1.969	1,809,000	2,170.8

3.2.2 Food Production

Meat will be a necessity for the diet of the residents of Astoria. Animals will be kept in normal gravity in order to ensure a normal growing process. When the animals are ready to be consumed, they will be processed by machines.

Table 3.2.2 **Animals**

Animal	Advantages
Cattle *(Bos taurus)*	-Produces milk and dairy products as well as meat -Leaves grass roots intact for easy regrowing when grazing
Japanese quail *(Coturnix japonica)*	-Eggs show no adverse effects due to low gravity -Small and easy to maintain
Goat *(Capra aegagrus hircus)*	-Produces milk as well -Thick hair can be used for commercial manufacture - Needs relatively small grazing area

Trout *(Oncorhynchus mykiss)*	-Thrives in ponds/lakes

Table 3.2.3 **Plants**

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

Plants will be grown on aeroponic tiers and harvested by machines. Aeroponics was chosen, because it allows for maximized plant growth, without the soil needed for traditional methods, or the large amount of water from other growing methods, such as hydroponics. Instead, nutrient-filled mist will be used to "water" the plants, while lighting will be provided be sodium vapor lamps. This allows for a controlled environment, without disease or pests. Growth will be completely automated, with regular inspections to ensure no problems.

Figure 3.2.1 **Food Storage Grid**

After harvesting, surplus food will be freeze-dried and vacuum-packed for storage. Food sufficient for 9 months will be stored in the central axis, while food sufficient for 3 months will be stored in community centers and the industrial section. All other food will be made available for stores and restaurants to distribute, using the mag-lev system described in 3.2.7. To minimize food waste, people can only purchase a limited amount of feed. If larger amounts of food are needed, people can apply for this at their community center. In addition, food on sale for over 3 days will be freeze-dried and vacuum-packed for storage.

Figure 3.2.2 **Aeroponic Tiers**

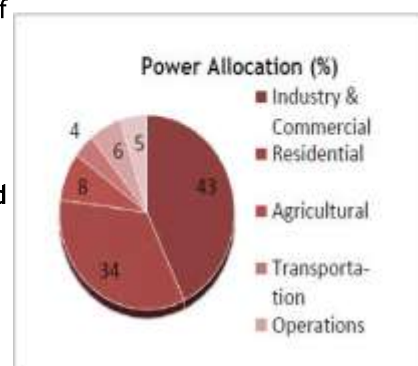


Figure 3.2.3 **Power Allocation**

3.2.3 Electrical Power Generation, Distribution, and Allocation

Electric power on Astoria will primarily be generated with two SSTAR (Small, Sealed, Transportable, Autonomous Reactor) units that can each generate 100 megawatts for a total power generation of 200 megawatts. Uranium-235 and Uranium-238 will power the reactor through fission. The fuel will be converted into Plutonium-239, making the reactor self-sustaining. Secondary power generation will be provided through one TWR (Traveling Wave Reactor) unit that can generate 50 megawatts for use as backup in case any one of the SSTAR units fails. It will also use Uraniuam-238 as fuel and convert it into Plutonium-239, making it self-sustaining as well. Excess power from both the SSTAR and TWR units will be stored in lithium nanowire batteries, chosen because of their extremely high power density, that will be distributed around Astoria and provide up to 18 months of power in case both types of reactors fail.

Figure 3.2.4 **Water Storage Tanks**

3.2.4 Water Management

The water usage of a resident in Astoria per day will average around 10.76 L. With a community of 25,000 residents, the settlement will maintain 540,000 liters of water, taking into account food production, atmosphere, etc. Water will be stored in 54 water tanks that can hold 10,000 liters, located throughout the settlement. 6 tanks will be located in each residential sector, for a total of 24 tanks (240,000 liters). 15 tanks (150,000 liters) will be located in the central axis and industrial sector, while 5 tanks (50,000 liters) will be located in the port.

3.2.5 Household and Industrial Solid Waste Management

All household and industrial solid waste disposed of in Astoria will first be screened for any recyclable materials, then recyclable materials will be divided into their respective categories, processed into its raw form, and sent back to the industrial sector for reuse, to minimize the total waste produced by Astoria. The remaining materials able to undergo anaerobic digestion processed by microorganisms into biogas, waste water, and digestate. Waste water will undergo further treatment and processing for recycling (and future use for human and industrial purposes), while digestate will be used as a soil conditioner. The biogas will be further processed with amine gas treating (to remove hydrogen sulfide and carbon dioxide), and the Bosch reaction (to convert hydrogen and carbon dioxide to carbon and water). Remaining waste shall be disposed of by plasma arc waste disposal, resulting in syngas and slag (used as a soil conditioner). Despite the high energy usage of plasma arc waste disposal, the resulting syngas will produce enough energy to cover the energy used.

3.2.6 Internal and External Communication Systems

Internal Communications:

Internal communication on Astoria will mainly be based on the Intranet system of Astoria, due to the problems of distance on rapid Internet communication between other colonies and Earth. Mass communication, for uses such as emergencies and announcements, will be provided by an intercom system with intercom units strategically located throughout the colony to ensure access to all citizens. The intercom system will be able to take announcements from control stations operated by authorized personnel. All citizens will be able to connect with each other using voice over IP (VoIP) networks for voice communication, provided by wireless networks. Data will be handled by an efficient network of fiber optics, ensuring fast transfer speeds.

External Communications:

External communication on Astoria will take place using a system of lasers for high transfer rates and long-range communication without the utilization of excess energy. Laser communication also prevents solar flare-caused interference that is typically seen in other communication systems. Furthermore, laser communication is able to perform under high capacities and is able to handle large data packages that the colonies demand. Astoria will be part of a network of Earth and other developed colonies, and is transferred using an efficient system that duplicates data packages, divides them into smaller packages, and then sends them on different routes to ensure the fidelity of the data. In the case of failure of the laser communication system, backup radio systems will be able to transmit data, albeit at a slower rate.

3.2.7 Internal Transportation Systems

Internal transportation on Astoria will be subdivided into two categories: human transportation, and cargo transportation. Human transportation will mainly be based on walking, to ensure that citizens receive a sufficient amount of exercise per day to negate the effects on lower gravity on skeletal systems. Wheelchairs and bicycles will also be provided for those are unable to walk due to debilitating illness or age. Long distance travel will be provided through a maglev rail network that will circle around the colony on an elevated track. Emergency human transport will be located under the main level and consist of maglev pods that will quickly transport people. Cargo transportation will also be exclusively located under the main level and will consist of

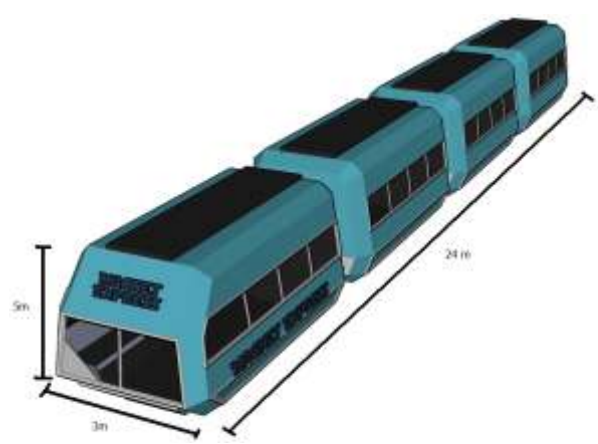


Figure 3.2.7 **Freight Subway System**

heavy-duty maglev transportation systems that are capable of transporting large and heavy goods from the industrial sectors to anywhere in the settlement

3.2.8 Day/Night Cycle

In order to keep residents psychologically healthy, the day and night cycles in Astoria will emulate Earth's 24-hour cycle. Sheets of OLED screens will be spread out above the colony across the sky. The OLED panels will brighten and dim as it mimics Earth's day and night cycle. The panels require little energy and will closely resemble the natural light of Earth.

3.3 Settlement Construction and Machinery

Figure 3.3.1 **Hull Assembler**

3.3.1: Hull Assembly

A skeletal structure will first be constructed, in order to provide a base for the settlement. Construction robots will then assemble the exterior of the settlement, using interlocking sections. Each robot can carry a variety of sections, like window pieces. Furthermore, each section will have barcodes, allowing robots to identify and place each one in the appropriate location.

The interior of the hull will also be constructed by robots. To ensure sufficient insulation and redundancy, the radiation protection will be assembled in a series of staggered layers. Furthermore, gaps in between each layer will be filled with insulation, to provide further redundancy.

3.3.2: Interior Building Assembly

The exterior of buildings will be constructed using interlocking panels. This allows for quick and stable assembly of any structure, as well as easy replacement of damaged sections. Panels will first be used to construct walls, then interlocked to form buildings. Horizontal panels will be used to provide floors and ceilings. Gaps between each panel can either be filled for insulation, or used to accommodate for electrical and other wiring. Finally, a team of specialized robots will assemble the final interior of the building. For example, one robot each for power, water, flooring, and other specialized functions, depending on the building (e.g. equipment for the entertainment complex). Furthermore, each robot can be called for repairs when they are required.

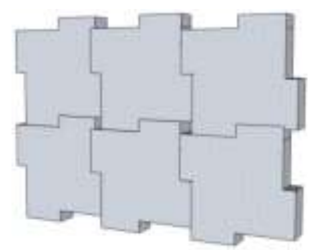


Figure 3.3.2: **Interlocking Panels**

3.4 Emergency Propulsion System on Astoria

Due to Astoria's location in the Asteroid Belt, collisions with objects of various sizes are inevitable. Although the hull of Astoria is specifically designed to withstand impacts with micrometeorites and other medium-sized objects, an impact with a large body will be devastating to Astoria and its citizens. Astoria thus will have an emergency propulsion system to circumvent such impacts with large objects, using a coordinated system of monopropellant and bipropellant liquid rockets located throughout the exterior of Astoria. The monopropellant rockets will use liquid hydrazine (N_2H_4) as both fuel and propellant. In order to generate thrust, liquid hydrazine contained in titanium spheroid fuel tanks with an ethylene-propylene bladder will be pushed out by pressurized helium or nitrogen into a decomposition chamber. This decomposition chamber contains a catalyst consisting of granular alumina coated with molybdenum nitride, which will initiate decomposition of hydrazine on contact. Hydrazine rapidly decomposes into gases in the exothermic reactions, $3N_2H_4 \rightarrow 4NH_3 + N_2$, $N_2H_4 \rightarrow N_2 + 2H_2$, and $4NH_3 + N_2H_4 \rightarrow 3N_2 + 8H_2$, which causes the decomposition chamber to heat up to 1000 C° instantaneously. Firing duration varies depending on the required distance to circumvent impact, but lasts from a few milliseconds to at most 10 seconds. In cases where the monopropellant rockets are insufficient to travel the required distance to prevent impact, or in cases of hydrazine depletion or monopropellant rocket failure, bipropellant liquid rockets fueled by liquid oxygen (LOX) and liquid hydrogen (LH2) will be employed.

Table 3.5.1 Emergency Propulsion Systems on Astoria					
Type	**Fuel(s)**	**Effective Exhaust Velocity (km/s)**	**Thrust (N)**	**Firing Duration (seconds)**	**Maximum Delta-v (km/s)**
Monopropellant Rocket	Hydrazine (N_2H_4)	2	1000	0.005-5	3
Bipropellant Liquid Rocket	LOX (O_2) LH2 (H_2)	3.5	10,000	100-600	9

3.5: Mining Locations and Ore Handling Processes

3.5.1: Ore Handling Processes

To facilitate mining and minimize costs, a mining base will be constructed on Ceres. Using this base as a center of operations, AstMin (7.1.1) will be sent out to collect raw materials from Ceres' surface. Once they have finished collecting and sorting materials, the AstMin will return to the base, where the materials will be refined under high temperature and pressure. Then, the materials will be transported to Astoria for use.

In the case of any AstMin breaking down, several AstMin will be held on standby. Broken AstMin will be retrieved from their location, then technicians living in the mining base will proceed to repair them.

Figure 3.5.1 **AstMin**

3.5.2: Alternative Mining Location

Although 1 Ceres will provide the majority of on-site materials for mining, in the event that Ceres is unavailable, the asteroid 12279 Laon will be used as a substitute. As Ceres is an interloper in the Gefion family asteroids, there are an abundant number of asteroids that can also serve. However, due to Laon's orbital characteristics, which are relatively close to Ceres', Laon was deemed the best asteroid to mine from in the vicinity. If materials cannot be mined from Ceres, spaceships carrying AstMin' s will proceed to Laon. There, the AstMin will mine materials from Laon's surface, then return to Astoria via the spaceships. Once the materials have been deposited in the settlement, they will be carefully refined under high temperature and pressure conditions in the industrial section.

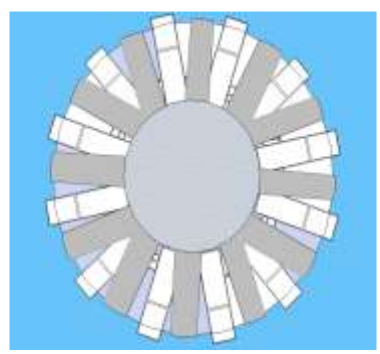


Figure 3.5.2 **Port Facilities**

4.0 Human Factors

SECTION 4.0: HUMAN FACTORS

A SANCTUARY WHERE EARTHLY COMFORTS FUSE WITH OUTERSPACE EXHILARATION, Astoria guarantees an elevated living experience, reminding inhabitants of their native homeland while providing the exotic experience of living in the stars. We at Northdonning Heedwell are committed to creating the highest levels of quality and comfort for our residents.

*4.1.*1 Community Designs and Amenities

Aimed at providing a secure, adaptable living space for residents, Astoria replicates many of Earth's most desired amenities and services. Communities are designed to include shopping facilities, offices, schools and entertainment district, mirroring the style of life typical to earth communities.

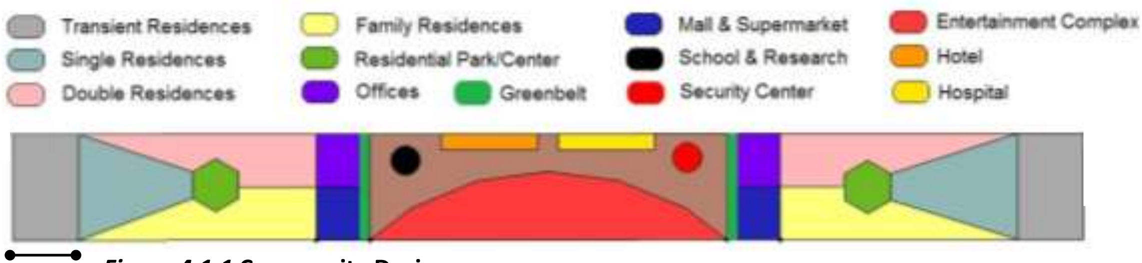


Figure 4.1.1 **Community Design**

Paralleling classic shopping malls on Earth, the splendid three-story Astoria Plaza and Astoria mall contain a myriad of retail stores, offering everything from designer apparel and outer space collectibles to typical home goods and practical electronics. The malls will also include a variety of fine dining opportunities to satisfy the hunger of busy shoppers.

The entertainment district is merged with the business zone, which consists of two 5-story office buildings. Seurat Tower is primarily dedicated to large corporations, banks, and courtrooms. The bank will be located on the first floor of Seurat Tower, with the security deposit on the very top floor. A few courtrooms will be located on the 4th floor, and the remaining two floors will house the settlement's largest corporations. Smaller businesses will be located in Cassatt Offices. The Astoria General Hospital, Astoria Security Headquarters, and John Jacob Astor School will also be in this business district.

The 4-winged Renoir Entertainment Complex (REC) is the main facility for exercise and entertainment. The south and east wings of the building are dedicated to exercise facilities, providing residents with access to various indoor courts and a well-equipped fitness center. The north wing will be dedicated to the intellectually-inclined, with the Van Gogh performance hall, the Astoria Natural History Museum and the Degas Public Library. Performances at Van Gogh Hall include various plays, musicals, concerts, and dance showcases. The west wing of the REC consists of a variety of high-tech arcade games, including laser tag and virtual-reality gaming consoles. The west wing will also have 3 large theaters for movie screening.

Residential buildings will be congregated at the edges of the community. Recreational parks will run through the sides of the central district with a green belt stretching from one side of the settlement to the other, providing residents with an unobstructed 100 m line of sight.

About 2% of the community will be designated for extensive paths and roads. These paths guarantee access to almost all parts of the community. Additional spacing between residential buildings provides opportunities for expansion should the population of our settlement increase.

4.1.2 Major Consumables

Table 4.1.1 details the annual quantities of major consumables for residents and transients. The amounts of certain items, such as paper, clothing, shoes, may vary based upon annual conditions. Consumables will be available for purchase in supermarkets and stores around the community.

Table 4.1.1 Major Consumables (per year)

Consumable	Amount (R)**	Amount (T)**
Food	1,756,562 kg/yr	20,961 kg/yr
Water	43,201,400 kg/yr	1,963,700 kg/yr
Oxygen	2,107,875 kg/yr	23,953 kg/yr
Hygiene Products	481,800 kg/yr	5,475 kg/yr
Pharmaceuticals	40,150 kg/yr	456 kg/yr
Paper Products*	100,980 kg/yr	1,148 kg/yr
Clothing*	4415 articles/yr	100 articles/yr
Shoes*	3000 pairs/yr	100 pairs/yr
Electronics	27,000 items/yr	600 items/yr
Kitchen Appliances	1631 items/yr	20 items/yr
Furniture	65,000 items/yr	1594 items/yr
Research Materials	5,500 items/yr	50 items/yr

*** Figures may vary. Figures are estimate**
**** R - Residential; T - Transient**

4.2.1 Residential Floorplans

Astoria will offer residences in 3 basic types: single, double and family. These residences will have various floorplans. Single residences will range from 900 to 1200 sq. ft. Double residences will have 1200 to 1600 sq. ft., and the largest family residences will range from 1600 to 2000 sq.ft. Each community will have 4 sections of singles residences, 2 sections of double residences, and 2 sections of family residences. Each individual section will consist of 3 or 4 residential complexes. These sections will be evenly distributed through the community to simulate the diversity on earth. For residents who prefer to live in single family houses, custom housing will also be available upon request.

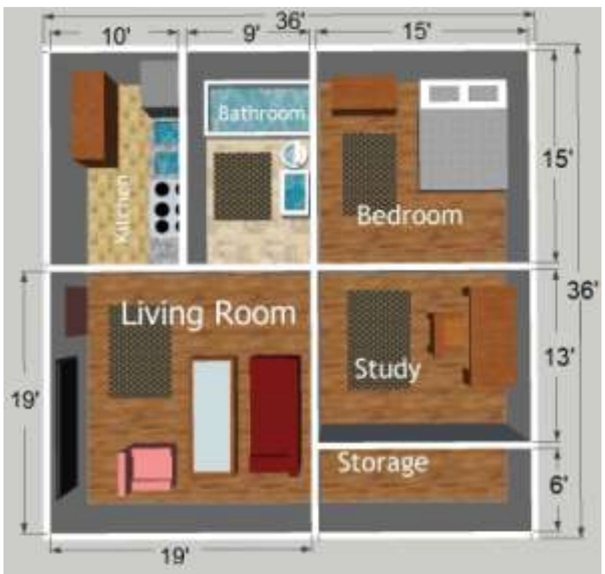


Figure 4.2.1 **Single Residence (1200 sq.ft) ↑**

Figure 4.2.2 **Double Residence (1600 sq.ft) ↓**

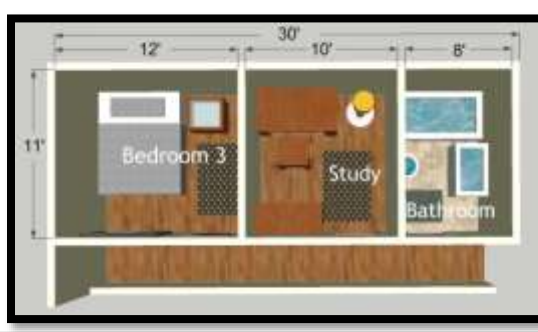


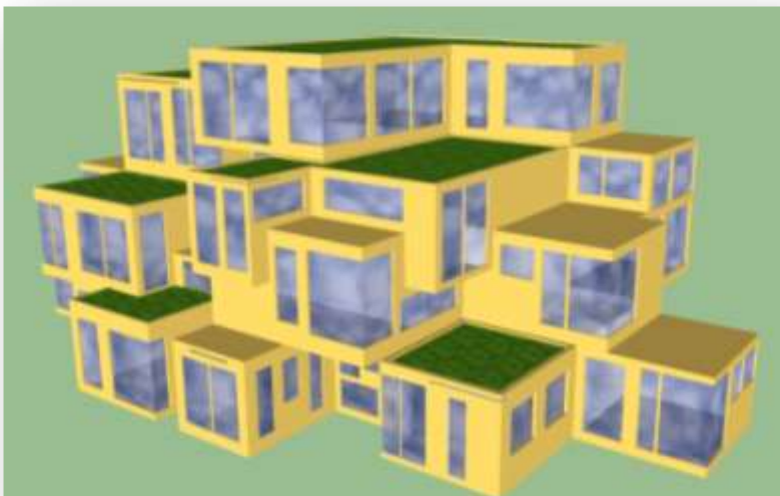
Figure 4.2.3 **Family Residence (1700 sq.ft) First floor↑ and second floor →**

← *Figure 4.2.4* **Single Residence (900 sq. ft.)**

4.2.2 Exterior Design

The exterior configurations of residential complexes will display the clean, sweeping lines and asymmetric characteristics of modern architecture. These residences may also resemble the designs of 20th century architects, such as those of Frank Gehry, Le Corbusier, and Frank Lloyd Wright.

Figure 4.2.5 **Exterior of Residential complex (Concept 2) ↓**



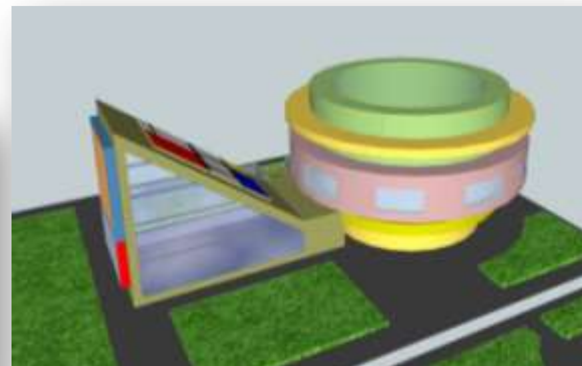


Figure 4.2.6 **Exterior of Residential Complex (Concept 2) ↑**

4.2.3 Furniture

For residents who prefer to create an outer space atmosphere in their homes, Astoria will offer unique futuristic furniture designs. For the more traditional residents, Astoria will also provide typical earth-like furniture. Furniture will be supplied by typical Earth furniture stores, such as IKEA. In addition, Astoria Furniture Company will be the supplier of furniture from our Space Furniture line.

4.3.1 Human Travel in Microgravity Areas

Figure 4.3.1 **Magnetic Foot rail**

Astoria will implement many security measures to ensure human safety in microgravity areas. When working outside the space settlement, humans and robots will be attached to cable harnesses (tethers) to prevent them from drifting away. Humans must communicate with the space settlement at least twice every hour to relay their status to the settlement's control crew. Humans participating in exterior maintenance work will be in spacesuits at all times and under all circumstances. Foot rails will be placed on all accessible exterior areas of the settlement as another safety measure and to serve as a visual map for workers on the exterior of the settlement. Workers will be asked to wear special magnetic footwear to prevent detachment from these magnetic rails. Maintenance robots will also be magnetically attached to these rail lines. Most maintenance work will be conducted by robots.

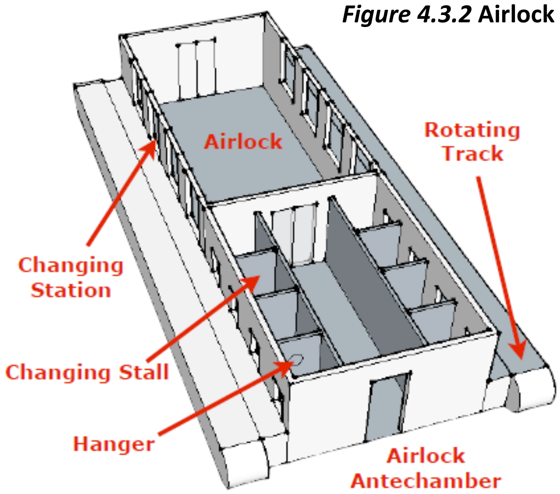


Figure 4.3.2 **Airlock**

*4.3.*2 Airlock Design

Spacewalkers will enter the Airlock Antechamber Changing Room. The first steps in donning the spacesuit will occur here. Lining the Airlock Antechamber are two rotating tracks. In each changing stall, there is a keypad in which the spacewalkers will type in their customized pin numbers. This activates the rotating track and brings the spacewalker's personal Spacesuit Storage Bin (SSB). The SSB arrives at the room, with only the drawers appearing in the window of the changing stall. Once the contents of the first two drawers are removed, the SSB moves to the next room and awaits the spacewalker at his or her corresponding changing station. The first room, the antechamber, contains eight changing stations and is depressurized to 70 kilopascals. After the first stages of the spacesuit donning procedure, spacewalkers enter the airlock. The remaining portion of the spacesuit is put on. Robots check the spacesuit for accurate donning, and once this is completed, the airlock is depressurized to 30 kilopascals. Once all air is removed, the suit is checked for leaks. If the suits pass inspection, then the exterior hatch is opened.

*4.3.*3 Spacesuit Design

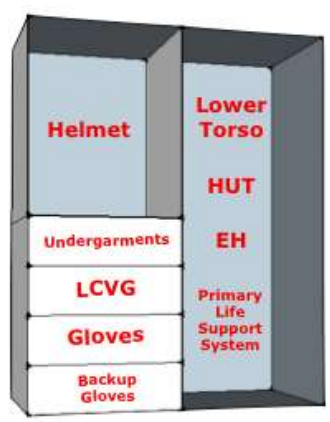


Figure 4.3.3 **Suit Storage Device**

Materials
Mylar, Nylon, Urethane-coated Nylon, Neoprene-coated Nylon, Nylon Tricot, Spandex, Dacron, Gortex, Kevlar, Nomex

Donning Procedure
1. Enter the Airlock Antechamber Changing Room and select a changing stall. Once all of the spacewalkers enter the room, it will be depressurized to 70 kilopascals.
2. In the stall, enter pin number to obtain customized spacesuit. The rotating track will bring the stored suit to the changing room with only the drawers accessible through the window. Remove the contents of the first two drawers.
3. Once removed, the box will leave and head to the assigned changing station in the airlock, with the entire box appearing in the window. Here, the helmet will be automatically rubbed with an anti-fog mixture and the in-suit drinking bag will be filled.
4. Begin pre-breathing 100% oxygen from the tube located in the stall for at least thirty minutes.
5. Put on the Urine Collection Device (m) or Disposable Absorption and Containment Trunks (f).
6. Put on the Liquid Cooling and Ventilation Garment (LCVG).
7. Leave the changing stall and enter the airlock. Proceed to the assigned changing station indicated by the automated response in the changing stall. Awaiting at the station is the remainder of the spacesuit.
8. Remove the helmet. Ensure that the helmet has been cleaned with anti-fog mixture by checking the color of the indicator strip located in its upper right hand corner.
9. Ensure that the in-suit drinking bag has been filled. Attach this to the HUT, which is hanging above the changing station. Additionally, attach the Electrical Harness (EH) to the Hard Upper Torso (HUT).
10. Put on the Lower Torso. Check to ensure that the joints function properly.
11. Enter the HUT, located above the station.

12. Attach the Primary Life Support System to the back of the HUT and connect to the cooling tubes of the LCVG for distribution throughout the body and the EH for power.
13.A robot locks the closure rings between the Lower Torso and the HUT.
14. Put on inner gloves and attach the helmet to the suit (this triggers airflow to begin).
15.Put on firmer outer gloves and attach to the suit.
16. Ensure that the built-in communications system of the helmet is working properly.
17. Robots will assess the functionality of the EH and Primary Life Support System.
18. Once the systems of the suit are checked, the air pressure of the airlock is reduced to 29 kilopascals and oxygen flow into the airlock is cut off.
19. Leaks in the suit are assessed by in-suit monitors. Any problems are alerted to both the spacewalker and the control center.

Doffing Procedure

1. Enter the airlock and proceed to the changing station. Once the pressure is increased to 70 kilopascals, an alarm will sound.
2. Ensure that oxygen flow into the airlock has begun as indicated by the screen.
3. Remove the outer gloves and store in the suit-storage top drawer at your station.
4. Remove the helmet and place the helmet in its compartment.
5. Remove inner gloves and store in the glove compartment.
6. A robot unlocks the closer rings between the Lower Torso and the HUT.
7. The Primary Life Support System is unattached from the EH and the LCVG.
8. Remove the Primary Life Support System from the back of the HUT and hang in the bin.
9. Detach the EH from the HUT and place in the storage bin.
10. Hook the HUT on the hanger located on the wall. Once secured, the hanger will pull the HUT upwards. Slip out of the HUT.
11. Remove the in-suit drinking bag from the HUT.
12. The HUT is further pulled upwards and is hung above the changing station.
13. Remove the Lower Torso and hang in the bin.
14. Exit the airlock and proceed to the Airlock Antechamber Changing Room.
15. Enter the assigned changing stall and remove the LCVG. Store this in the lowest drawer of the storage box.
16. Remove the Urine Collection Device or Disposable Absorption and Containment Trunks and place in the bin of the changing room.
17. Receive medical examination in the changing room.

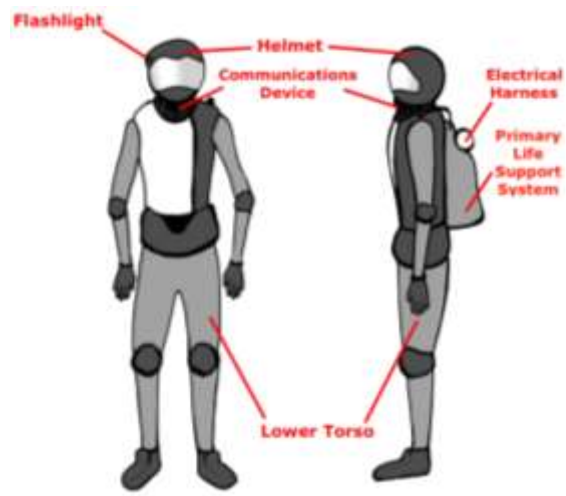


Figure 4.3.4 **Spacesuit Design**

4.4 Means for Children to spend time in 1g

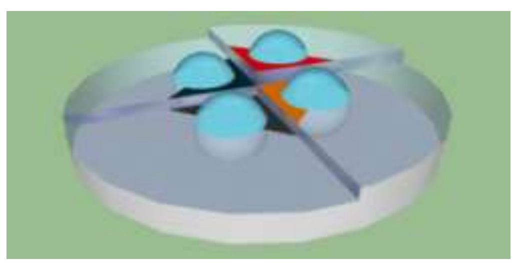


Figure 4.4.1 **Rotating Classroom Building**

In order to promote healthy development of children through their growing years, Astoria will provide means for children to spend time in a 1g environment on a daily basis. All classrooms will be on a rotating platform that produces a 1g environment while the children are in school. Furthermore, children will also have the option of "biking" on a human-powered centrifuge that would also expose them to a 1g environment.

4.5 Semi-term Residences

These five story buildings have four inhabitable floors. The primary floor is a common area available to any of the inhabitants of the semi-term residencies. Each of the top floors houses eight distinct homes that has two bedrooms, one bathroom, and a separate room that functions as both a kitchen and dining room. All of the residents that inhabit these buildings are living on Astoria for only six to thirty-six months, therefore they have limited time to adapt to the space settlement. These buildings feature small homes; emphasizing the use of communal areas to enhance integration into Astorian society. The first floor of the building has several living room areas that encourage socialization, as well as a small gym for exercise. Families are especially encouraged to meet in this area so that their children can socialize with other semi-term residents as well as meet local children so that they can learn how to adapt to their new schools and social groups.

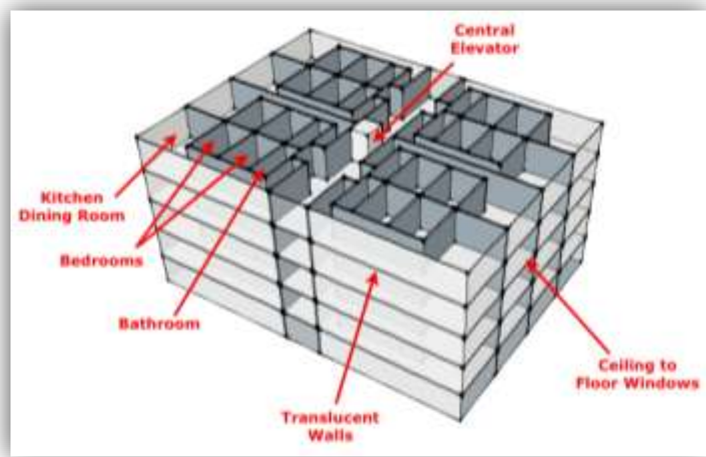


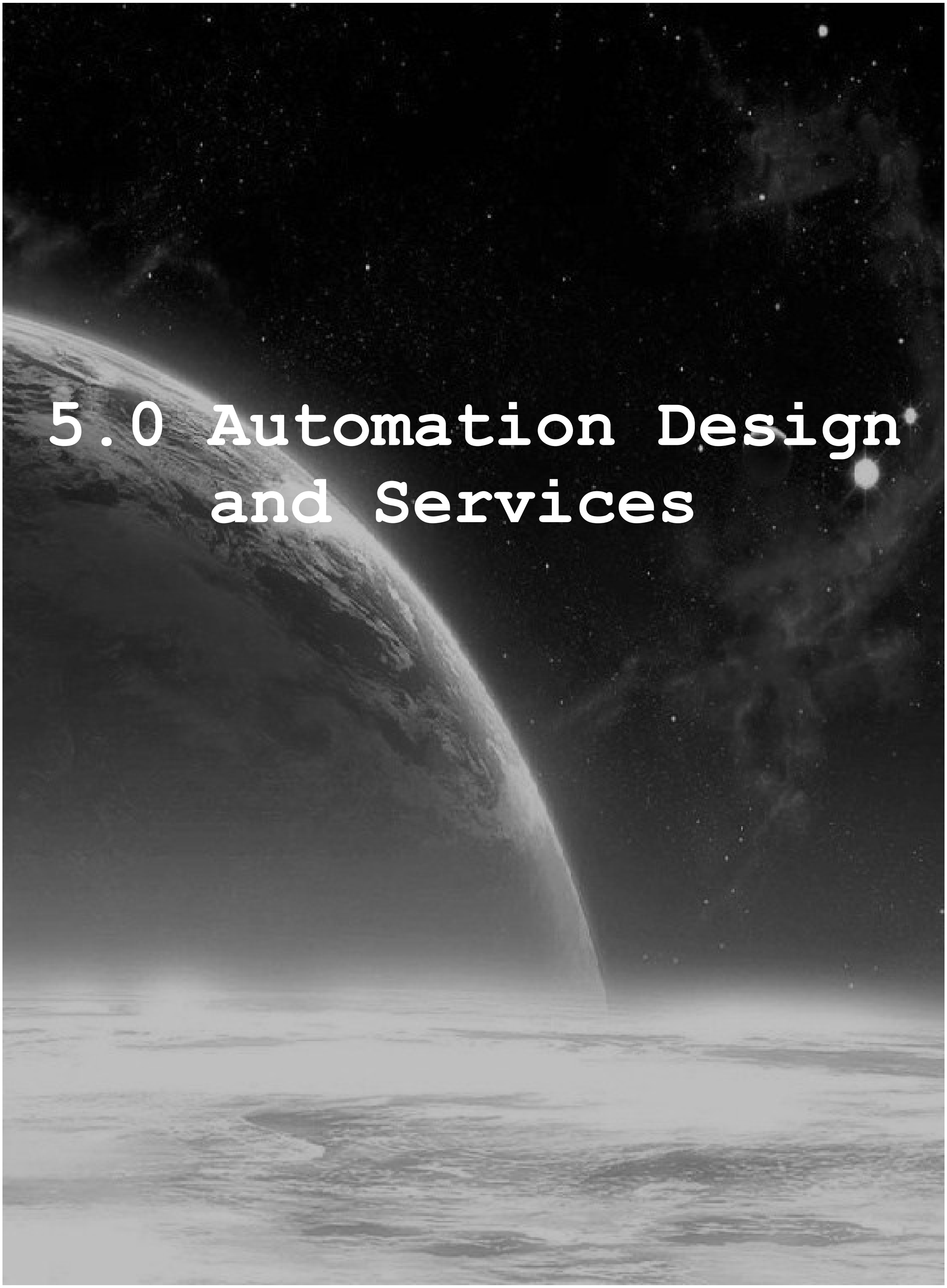
Figure 4.5.1 **Semi-term residence**

The "walls" lining the long-side of the building are made from a thick, canvas fabric that connects to the frame of the building. This translucent material filters light from the rest of the settlements into the homes, thereby decreasing the light requirements for the semi-term residency buildings during the "daytime". Along the shorter end of the building, the homes feature the kitchen/dining room. Because this room is frequently used by the residents, ceiling to floor windows will be installed, thus offering residents a view of the settlement.

Few families would choose to relocate their families for such a short time span, so the semi-term residencies reflect the projected composition of the semi-term residents (mostly single workers or couples). Families that do move into the settlement for six to thirty-six months can either choose to live in another area or select the family pack which includes built-in collapsible bunk beds to free up space in the rooms when not in use. Semi-term families will be placed in buildings with other families, while singles and couples will also be grouped in the same building.

These buildings will be situated near the edges of the community and will be surrounded by the permanent residencies. Living in proximity to permanent residents, the semi-term residents will be able to learn how to adapt to life on the settlement. Simple daily tasks such as shopping and going to work will easily be learned by the guidance of their neighbors. Semi-term residents that have been on the settlement for several months are encouraged to assist new residents on their transition into Astorian life.

5.0 Automation Design and Services



SECTION 5.0: AUTOMATION

Maintaining a space settlement with the depth and complexity of Astoria is a difficult task. Thus, we at Northdonning Heedwell will be using automated systems to help mitigate the task of running a space settlement. Through the use of innovative and creative technology, Astoria takes humanity to the limits of technological advancement.

5.0.1 Types and Numbers of Computers

Name	Description	Specifications	Number
Chell (Personal Device)	This is the basic computer for residents, a pocket-sized device that contains a projector, videocamera, mike for voice commands, and can interface with the Wheatley for boosts in power	50 GHz, 2 TB RAM, 5 PB SSD, 24 hr battery life	12000
CAKE (Business Computers)	These computers are used for more intense business work, and have increased processing power for complex simulations and rendering	100 GHz, 4 TB RAM, 100 PB SSD	6000
GLaDOS (Server)	The GLaDOS is the workhorse of the space settlement, and multiple will be at each server station throughout the settlement, controlling everything from environmental control to security to robot mining.	500 ExB, 100 petaflops	200
Wheatley (Personal Computer)	The Wheatley is a combination home computer/movie player/gaming system. Working in conjunction with Chell, it boosts computing power and can run VR simulations.	100 GHz, 4 TB RAM, 60 PB SSD	5000

Table 5.0.1 **Types and Numbers of Computers**

5.0.2 User Hierarchy in System

Type of User	Description	Number
Network Administrator	The top administrator, these top citizens have full access to the computer mainframe. Together, they overview the maintenance of the entire settlement.	5
Database Administrator	A database administrator is able to change access levels for other users and has full access to servers.	10
Communication and Operations Administrator	Communication and Operations Administrators make sure all of Astoria's automated robotics are working at maximum efficiency. They are also in charge of earthbound communication and interaction between community leaders.	10
System Developer and Technicians	System Developers and Technicians design the next generation of Astoria's computers. They also police Astoria's wireless network and help maximize efficiency.	200
Advanced User	Advanced Users help basic users with daily tasks. They can call for robots to accomplish tasks for the community. They are also able to reserve robots at certain times to arrange specialized events for the community.	10 Per Community
Basic User	Basic Users have access to personalized accounts. They can do basic tasks such as surfing the web, writing a report, or producing art.	20000+

Table 5.0.2 **User Hierarchy in System**

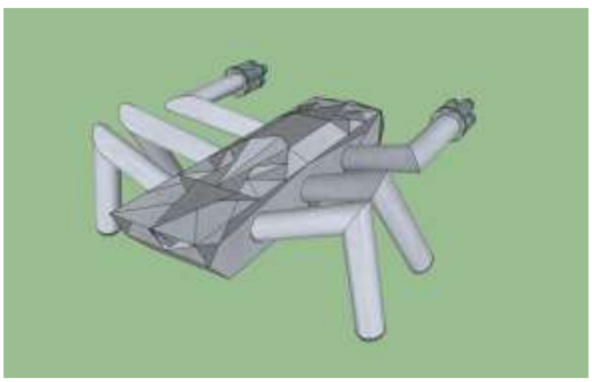
5.1 Automation for Construction

The innovative design of Astoria's construction robots provides efficient transport and use of materials. All construction can proceed at accelerated paces, unknown to man on Earth. Automated robotic workers allow full utilization of all resources and provides for fast, cost efficient, and fastidious development of the space settlement. The robots available for construction and repair on Astoria are extremely complex and versatile. Through the use of the omnitool and the visearm, construction and repair robots are extremely efficient and low maintenance. Multiple classes of robots keep the machines small and available at any time for use.

An omnitool is an innovative robotic arm developed by the people of Northdonning Heedwell. With multiple tools such as drills, saws, hammers, and magnetic clamps, the omnitool makes Astoria's robots capable of doing nearly anything. By simply switching out a tool and replacing it with another, the omnitool is a perfect example of the creativity and innovation that went into designing Astoria.

A visearm is a simple yet pioneering addition to construction robots in Astoria. Basically a large arm designed to hold on to anything too large or awkward for use, the visearm gives construction robots more mobility and capabilities previously unheard of.

5.1.1 Types of Construction Robots



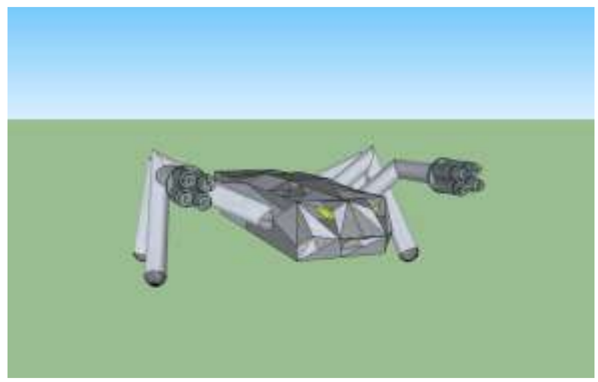


Figure 5.1.1 **Construction robot (back view, side view)**

Robot Type	Description	Dimensions
External Structural Repair	Designed to work outside in a vacuum. Default equipment in the omnitool contains caulking gun, laser cutter, riveter, welder, soldering arm, with spaces for extra specialized parts.	H: 2 m L: 1 m W: 1 m
Internal Structural Repair	Designed to be more delicate, repairing furniture or internal structure. Equipped with a vacuum, screwdriver, impact driver, manipulating hand, and equipment scanner.	H: 1 m L: .5 m W: .5 m
Electrical Repair	Robot to repair electrical connections throughout the settlement. Carries voltmeter, wiring, solder, sprayable insulation, and is able to scan rooms to compare to blueprints of the settlement and identify where wiring should go.	H: .1 m L: 1 m W: .1 m
Construction	These robots are larger than the external and internal repair robots, and are designed to carry large pieces of building materials to a construction site. Equipped with all the arms of the repair robots and large graspers to carry cargo.	H: 2 m L: 5 m W: 1 m

Table 5.1.1 **Types of Construction Robots**

For convenience, construction robots are preprogrammed with instructions for the creation of furniture. A built in camera will allow the robot to identify parts based on sight and, by following the preprogrammed instructions, allows the robot to build furniture on-site, quickly and efficiently.

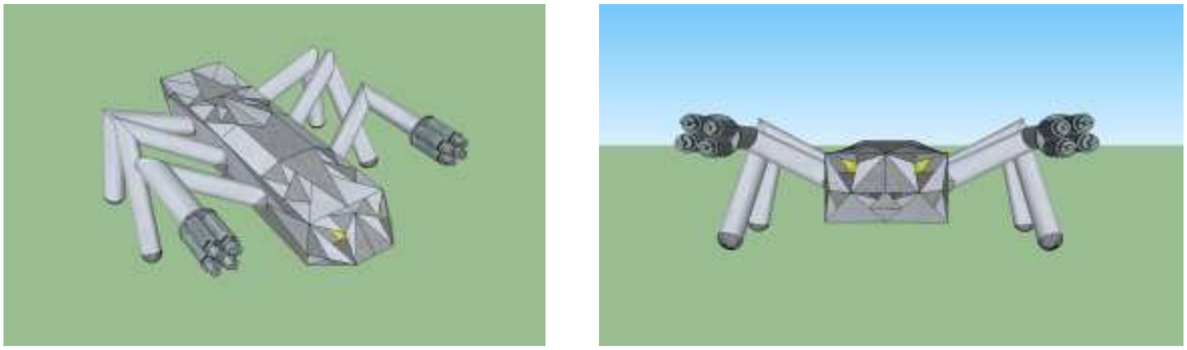


Figure 5.1.2 **Construction bot (top view, front view)**

5.2 Automation for Maintenance, Emergency Repairs, and Security Systems

Astoria's state of the art computer mainframe, combined with the efficiency of Astoria's automation systems provide, guarantees of Astoria's safety and efficiency at all times. Investors in Astoria can sleep easy knowing their investments are protected 24/7 by an automation system unequaled in the known universe.

5.2.1 Emergency measures

Emergency type	Security Measures
Solar Flare	Humans will not be allowed to leave the settlement. All unnecessary external activity will be paused Robots will be covered in radiation protection made from aerogel and depleted uranium Fiber-optic cables will be used for command and communication
Fire	Gas detectors will identify what class of fire Class A: Sprinklers will turn off Class B, C, D, and K: CO_2 extinguishers until humans in area are evacuated. When evacuation is finished, O_2 is shut off, and bicarbonate dust is scattered in the area
Atmosphere loss	Spacesuits will be provided in the affected areas Atmosphere regulation will be controlled by computer as evacuation procedures are carried out
Hull damage	External repair bots will be sent outside to survey damage and fix if necessary. In case of serious damage, sections can be cordoned off and quarantined.
Computer server failure	Multiple backups for redundancy, in different physical locations Saved full data sent to Earth.
Rogue personnel	Security bots and cameras identify, isolate, and remove suspects

Disease	Quarantines will go into effect Pharmabots will provide early warning signs of diseases and will be able to isolate most sources of contamination early.

5.2.2 Security

Astoria will use state-of-the-art 256-bit encryption to secure all records and protect from any hacking. In addition, the settlement will have multiple servers, each with their own security systems, and for an attack to succeed, the hacker will have to break in to all servers simultaneously. Should this happen, a security breach will still be set off, for through quantum entanglement, a listener who breaks into the system will be caught due to a change in the molecule's quantum state.

For physical server security, access to the station will rely on a simultaneous palm, face, and iris scan during voice recognition of a pass-code. This high degree of redundancy should eliminate most biometric avoidance techniques such as, a voice recording, the removal of a finger, or the removal of an eyeball. Safety is high on the Astoria's long list of priorities.

To make sure everybody working with Astoria's computer system has a legitimate purpose, employees will be required to state their purpose several hours beforehand in order to access the computer mainframe. All maintenance procedures and non-life threatening procedures must be approved by a supervisor within 12 hours of request. To ensure emergency procedures can be enacted, the chief administrators will be able to override security procedures by gathering the override codes of several administrating officers. This prevents a single person from doing anything destructive to Astoria but also allows for quick and safe enactment of emergency procedures to prevent loss of life during disasters.

Lastly, once the scan has been completed, security cameras inside record the user's face continuously as he works, checking against the database in his previous work and noting any differences in habits.

Assuming personnel passes all security measures, he or she will be granted access to the central computing mainframe of one of Astoria's servers. From the central computing mainframe, robots can be programmed to accomplish tasks necessary for Astoria.

5.3 Automation for Enhanced Livability

Astoria's versatile arrays of automated devices provide residents safe, enjoyable, and efficient environments to do business, work, and live in. As a result, residents of Astoria are both extremely productive and extremely satisfied allowing for the development of a vastly improved social order, free of many of the problems that plague society on Earth.

5.3.1 Entertainment

Because we at Northdonning Heedwell believe that everybody living on Astoria should have all the entertainment they want to encourage a sense of family contentment, we provide several automated conveniences designed to make resident life easier and more enjoyable.

For at home entertainment, we provide personal devices to all residents. Light, aesthetic, and fast, the **Chell** is equipped with a holographic projector, voice recognition and video camera for ease of use. We also offer a virtual reality simulator built into the home computer, for those days when you just don't want to be you.

Another entertainment offered by Astoria is the pet-simulator. An optional addition, the pet-simulator robot changes forms through a complicated series of movable parts. It can the form of any animal found at the local zoo and also helps with chores. The pet-simulator checks for intruders, scans for things that need to be repaired with cameras, and, thanks to the ingenious addition of a built in vacuum, can clean the house while owners are away.

To increase efficiency and productivity in the working environment, we send automatic cleaning robots to keep the working sections of Astoria white and shiny. Upgraded computers and personal cubicles with virtual windows provide for personalization and allow employees to feel at ease while working.

Daily chores for at home residents are far diminished thanks to automated robots designed to help at home. A NewsBot, optionally imported into residences by the request of inhabitants, updates news daily to keep residents aware of whats important in their society. The cleaning robot takes care of residencies by taking objects on the ground, figuring out what it is through the help of a laser chip, and storing the object in the proper location. A cooking bot can be requested for free by any resident of Astoria. Offering over twenty dishes of every flavor, the cooking bot pulls freshly cooked food out from one of many cafeterias and delivers the hot dish to residents. A Pharmabot helps the sick and impaired with their daily medical needs. Not only does it keep track of blood pressure, body temperature, heart rate, height, and weight through several microsensors swallowed in a pill once a month, it also monitors consumption of nutriens and medicine. The Pharmabot can also detect when a resident is sick and in need of medical attention. It can message resident telling them what they have and when to go to a doctor. The Pharmabot can also hold medicines such as cough medicine and aspirin and automatically refills when supplies run low.

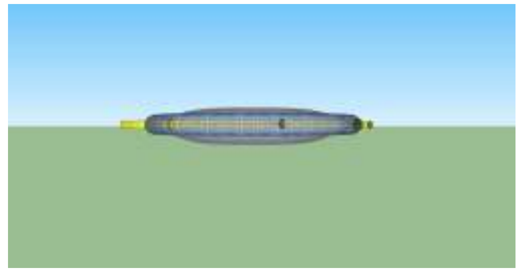


Figure 5.3.1 **Pharmabot (side view)**

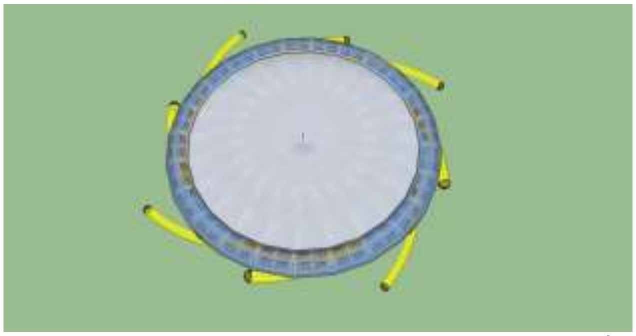


Figure 5.3.2 **Pharmabot (top view)**

Since the people of Astoria need exercise, we provide complimentary exercise bots in several gyms located around each community. The exercise bot requests information on the health of a resident and, when the resident wants to work out, provides a grueling workout designed around the resident to strengthen the body.

5.3.2 Networking

The Intranet system enables citizens to access the entire Internet of Astoria, other colonies, and the Earth without any lag-time problems associated with the distance between Astoria and Earth. Astoria will maintain large servers that will be able to establish a cache of all websites on the Internet, which will be continuously updated, to simulate the real-time capabilities of the Internet. All parts of Astoria will be connected through a network of compact fiber-optic cables that will allow efficient data transfer and is able to function under high data loads, especially in industrial sectors. A network of wired and wireless routers will be systematically located throughout Astoria to ensure that all parts of Astoria are connected. (see following page for networking diagram).

5.4 Automation for Mining and Other Operations on Asteroids

Astoria's state of the art mining system alleviates all the difficulties associated with deep space mining. Thanks to both the ingenuity of Astoria's leaders and the support of Northdonning Heedwell, the entire asteroid can be mined at ease efficiently and safely.

Figure 5.4.2 **Omnitool**

Figure 5.4.1 **Mining robot**

Mining robots are all slight variations of the 'spider' robot design. The 'spider' is a mining robot frame. Installed are feet and arms, allowing for movement and versatility. Legs are equipped with specialized 'feet' for rooting the robot into place during operations. The specialized 'feet' also allow for the robot to walk along the side of an asteroid with no fear of falling off. Arms are equipped with omnitools allowing the robots to do anything required for the operation. The "hands" and "feet" can be switched out with differently specialized appendages depending on the materials being mined and the mission the spider is carrying out. The "back" will store the ore within, and carry it back to the unloading stations.

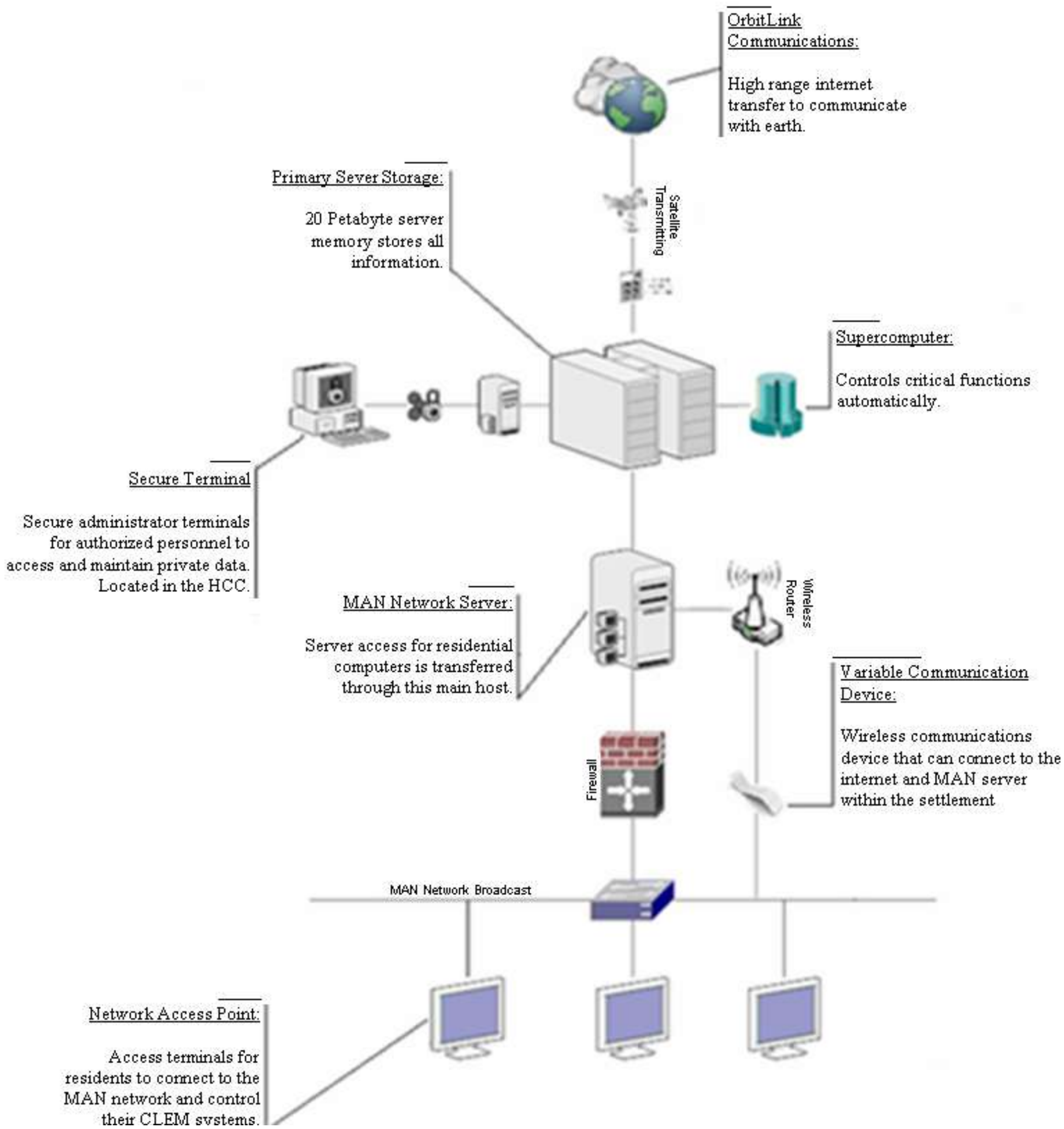
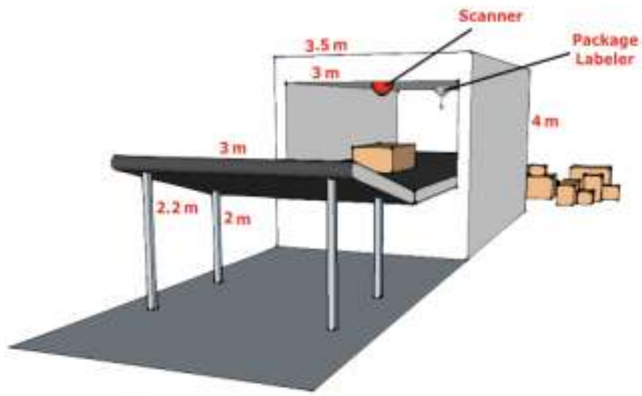


Figure 5.3.3 **Networking**

5.5 Automation for Unloading Ore

Without an unloading system, mined ore would be useless, so we at Northdonning Heedwell have developed an automated unloading system to sort, refine, and distribute ore to where it is needed.

Figure 5.5.1 **Ore Unloading System**



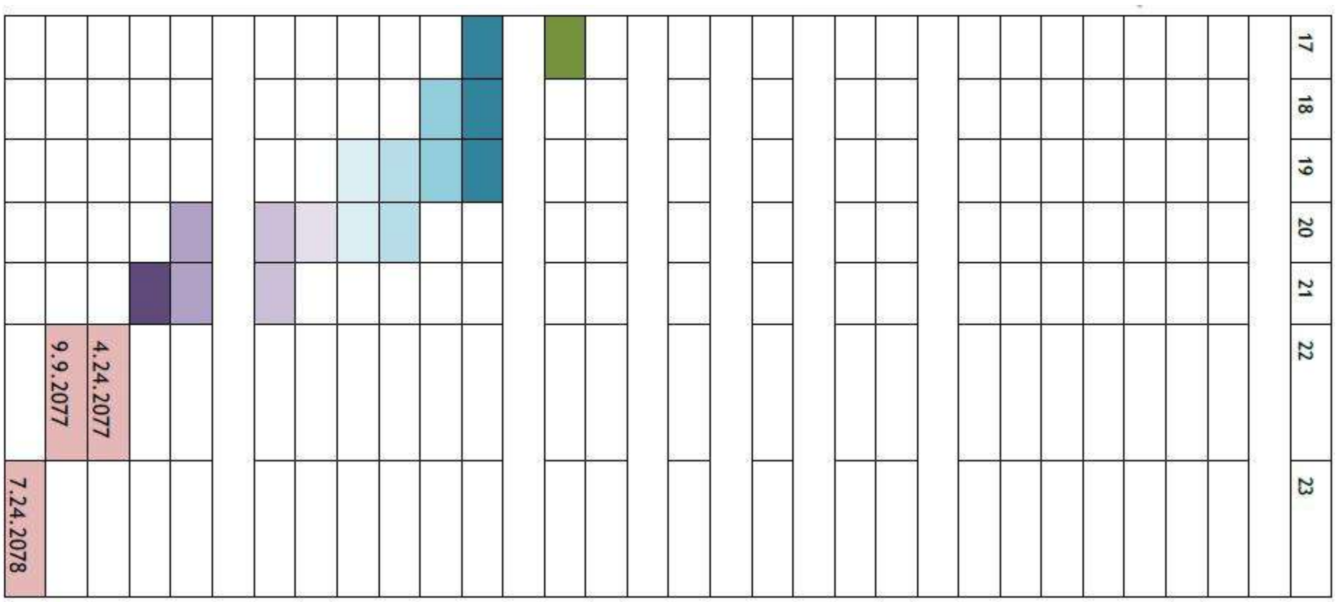
After a mining robot has filled itself with ore, it will load onto ships which will bring the robots to the colony. The unloading system will take the prepackaged loads from the robots, and will label the cases with the types of materials they contain within. The quality of ore will be determined by scanning robots that have specialized cameras installed. After the quality has been determined, the ore will be sent to one of several refineries conveniently located around Astoria. After ore has been refined and is ready for use, it will be sent to one of several holding stations around Astoria. Administrators, construction workers, and citizens around Astoria will be able to request ore for use at any time.

6.0 Schedule and Cost

SECTION 6: COSTS AND SCHEDULING

6.1: Scheduling

Years after 7 May 2055	Workers	Approx. Cost (USD)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Phase 1		40,349,688,750																
Research & development	200																	
Approval by Foundation Society	N/A			Dec. 2056														
Robot & subsystem development	250																	
Central Command system set up	150																	
Communications systems set up	50																	
Hawking satellite set up	80																	
Central Axis constructed	200																	
Phase 2		13,449,896,250																
Pascal port facility constructed	200																	
Ports commence operation	50																	
Phase 3		26,899,979,250																
Graff sphere constructed	250																	
Phase 4		13,449,896,250																
Spokes for tori are assembled	80																	
Phase 5		26,899,979,250																
Watson and *Crick* constructed	150																	
Watson & *Crick* operations begin	50																	
Phase 6		40,349,688,750																
Gauss constructed	150																	
Interior finishing in *Gauss*	Robotic																	
Interior finishing in *Watson*	Robotic																	
Interior finishing in *Crick*	Robotic																	
Establishment of atmosphere	N/A																	
Transportation set up	80																	
Phase 7		26,899,979,250																
Debugging and final system tests	50																	
Commencement of rotation	N/A																	
Foundation Society moves in	N/A																	
All other colonists welcomed	N/A																	
Full population established	N/A																	



6.2 Costs

6.2.1: Technology	Cost	Quantity	Total Cost	Annual Upkeep
PC	$800.00	5,000	$4,000,000.00	$200,000.00
Astar Server	$20,000.00	30	$600,000.00	$30,000.00
Storage (Tech)	$45,000.00	10	$450,000.00	$13,500.00
Cake Business Computer	$2,000.00	2,500	$5,000,000.00	$250,000.00
System Management PC	$3,000.00	50	$150,000.00	$7,500.00
Network (Components)	$1,750,000.00	1	$1,750,000.00	$87,500.00
Cleaning Robots	$450.00	12,500	$5,625,000.00	$281,250.00
Chell Personal Device	$1,500.00	15,000	$22,500,000.00	$2,250,000.00
Security Devices	$5,000.00	200	$1,000,000.00	$500,000.00
Security Robots	$10,000.00	5,000	$50,000,000.00	$6,000,000.00
Settlement Construction Robot	$350,000.00	3,000	$1,050,000,000.00	$84,000,000.00
Exterior Finishing Robot	$400,000.00	6,000	$2,400,000,000.00	$96,000,000.00
Interior Construction Robot	$400,000.00	9,000	$3,600,000,000.00	$84,000,000.00
Omnitool	$2,000.00	150,000	$300,000,000.00	$21,000,000.00
Pharma Robot	$15,000.00	2,000	$30,000,000.00	$2,100,000.00
GlaDOS Central Computer	$16,500,000.00	1	$16,500,000.00	$2,475,000.00
Supercomputer	$2,500,000.00	20	$50,000,000.00	$6,000,000.00
Docking Facility	$26,700,000.00	5	$133,500,000.00	$9,345,000.00
SSTAR	$3,000,000.00	2	$6,000,000.00	$682,000.00
Traveling Wave Reactor	$2,500,000.00	1	$2,500,000.00	$578,000.00
AstMin	$500,000.00	25	$12,500,000.00	$1,854,100.00
Radio Telescope	$30,000.00	5	$150,000.00	$75,000.00
Optical Telescope	$4,000.00	11	$44,000.00	$22,000.00
Development			$320,000.00	
TOTAL COST			$7,692,589,000.00	$317,750,850.00

6.2.2: Transportation	Cost	Quantity	Total Cost	Annual Upkeep
Cargo Subway	$75,000,000.00	2	$150,000,000.00	$15,000,000.00
Magnetic Rail Network	$3,000,000.00	10	$30,000,000.00	$3,600,000.00
Bicycles	$50.00	5,000	$250,000.00	$25,000.00
TOTAL COST			$180,250,000.00	$18,625,000.00

6.2.3: Annual Wages	Wages	Number Employed	Total Cost
Technician/Engineer	$165,000.00	1,300	$214,500,000.00
Worker (Average)	$85,000.00	16,100	$1,368,500,000.00
Government Official	$120,000.00	650	$78,000,000.00
Researcher	$120,000.00	1,500	$180,000,000.00
Teacher	$35,000.00	30	$1,050,000.00
Security Personnel	$57,500.00	200	$11,500,000.00
Planner*	$200,000.00	60	$12,000,000.00
TOTAL WAGES			$1,865,550,000.00

*Planners paid sum of $200,000 each during construction

6.2.4: Communications	Cost	Quantity	Total Cost	Annual Upkeep
Fiber Optic Cables	$15.00	375,000	$5,625,000.00	$112,500.00
Lasers	$6,000.00	15	$90,000.00	$4,500.00
Intercom	$5,000.00	1	$5,000.00	$350.00
Wireless LAN	$550.00	250	$137,500.00	$6,875.00
Radio Satellite	$1,005,000.00	4	$4,020,000.00	$4,000.00
Development			$1,500,000.00	
TOTAL COST			$11,377,500.00	$128,225.00

6.2.5: Materials	Cost	Quantity	Total Cost	Annual Upkeep
Nitrogen (m^3)	$60.00	471,267,000	$28,276,020,000.00	$0.00
Oxygen (m^3)	$0.30	407,385,000	$122,215,500.00	$0.00
Carbon Dioxide (m^3)	$0.01	7,155,000	$71,550.00	$0.00
Water (m^3)	$15.00	540	$8,100.00	$810.00
Demron Cloth (m^2)	$300.00	25,000,000	$7,500,000,000.00	$300,000,000.00
Silica Aerogel (m^2)	$6.00	1,250,000,000	$7,500,000,000.00	$300,000,000.00
Polyethylene Foam (m^3)	$324.00	75,000,000	$24,300,000,000.00	$972,000,000.00
6061-T6 Aluminum Alloy (kg)	$12.70	1,000,000,000	$12,700,000,000.00	$508,000,000.00
Steel Alloy Grade 18KhGNMFR (kg)	$15.64	750,000,000	$11,730,000,000.00	$462,000,000.00
Uraniuam 235/238 (kg)	$69.76	300,000	$20,928,000.00	$5,840,000.00
Raguard (m^2)	$350.00	12,500,000	$4,375,000,000.00	$246,000,000.00
Ring Motor	$100.00	2	$200.00	$1,000.00
Steel Cargo Box	$125.00	350,000	$43,750,000.00	$2,500,000.00
TOTAL COST			$96,567,993,350.00	$2,796,341,810.00

6.2.6: Landscaping	Cost	Quantity	Total Cost	Annual Upkeep
Trees	$10.00	10,000	$100,000.00	$2,000.00
Grass (m^2)	$8.00	250,000	$2,000,000.00	$2,000.00
TOTAL COST			$2,100,000.00	$4,000.00

6.2.7: Housing	Cost	Quantity	Total Cost	Annual Upkeep
Single Residence	$200,000.00	3,000	$600,000,000.00	$420,000,000.00
Double Residence	$275,000.00	2,000	$550,000,000.00	$390,823,529.00
Family Residence	$350,000.00	1,000	$350,000,000.00	$263,666,666.00
School	$800,000.00	4	$3,200,000.00	$1,877,333.00
Park	$750,000.00	4	$3,000,000.00	$1,788,000.00
Hospital	$11,000,000.00	4	$44,000,000.00	$27,500,000.00
Community Center	$1,350,000.00	4	$5,400,000.00	$2,457,000.00
Office	$2,540,000.00	8	$20,320,000.00	$5,410,550.00
Library	$1,850,000.00	1	$1,850,000.00	$928,000.00
Entertainment Center	$15,000,000.00	4	$60,000,000.00	$12,000,000.00
Hotel	$19,906,500.00	4	$79,626,000.00	$15,925,200.00
Development			$100,000,000.00	
TOTAL COST			$1,817,396,000.00	$1,142,376,278.00

6.2.8: Totals

Construction Costs	Total Cost	Annual Costs	Total Costs
Technology	$150,000.00	Technology	$317,750,850.00
Transportation	$7,692,589,000.00	Transportation	$18,625,000.00
Wages (planners only)	$12,000,000.00	Wages	$1,865,550,000.00
Communication	$11,377,500.00	Communication	$128,225.00
Material	$96,567,993,350.00	Material	$2,796,341,810.00
Landscape	$2,100,000.00	Landscape	$4,000.00
Housing	$1,817,396,000.00	Housing	$1,142,376,278.00
Transportation Costs	$108,793,542,496.00		
		TOTAL	$6,140,776,163.00
TOTAL	$214,897,148,346.00		

Annual Revenue	Total Income
Tourism	$1,188,353,186.00
Recreation	$826,504,945.00
Net Trade Revenue	$8,014,747,651.00
Manufacturing	$10,210,092,511.00
Private Contracting and Advertising	$1,963,241,375.00
TOTAL	$22,202,939,668.00

Amount of Time to Break Even

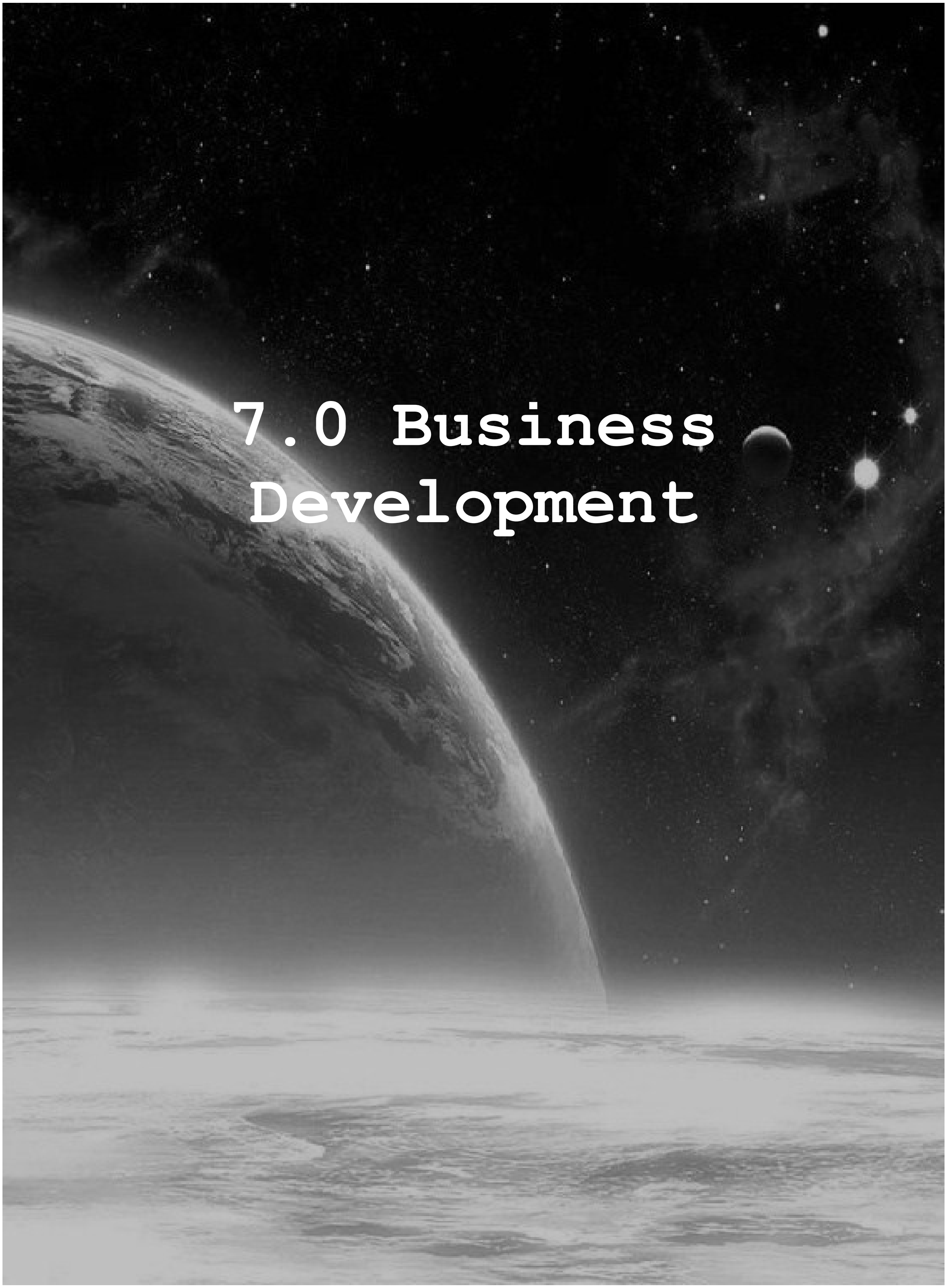
214,897,148,346.00 + 6,140,776,163x = 22,202,939,668x

214,897,148,346 = 16062163505x

X = 13.30979

13 years to break even

7.0 Business Development



SECTION 7: BUSINESS

7.1.1 Mining and Refining Operations

AstMin, Astoria's asteroid miners, will be composed of titanium imported from both Earth and other previously established space settlements. The lightness and durability of titanium will make it an ideal material in the environment the AstMin drones will be working in. AstMin will contain a main body, an ellipsoid with polar radius 0.5 meters and equatorial radii of 1.25 meters and 0.5 meters, that will be split into two major compartments. AstMin will travel on asteroid surfaces with four protruding legs.

A drill extending from the front will drill into the asteroid surface until materials are detected by a sensor that will recognize materials by comparing them to a catalogue of known materials. Once materials are detected, a shovel-like mechanism will fill the first compartment of the main body with the material. Another sensor will more carefully sift out unnecessary material such as rock and deposit it back onto the asteroid surface. Unknown materials not in the sensor's catalogue will be placed in a small quarantine compartment that will be sealed once filled. The rest of the known materials will be transported to the second compartment, where they will be crushed into a powder to optimize storage space for maximum efficiency. After the second compartment is filled, the first compartment will empty the remaining materials and the AstMin will return to the transport spacecraft.

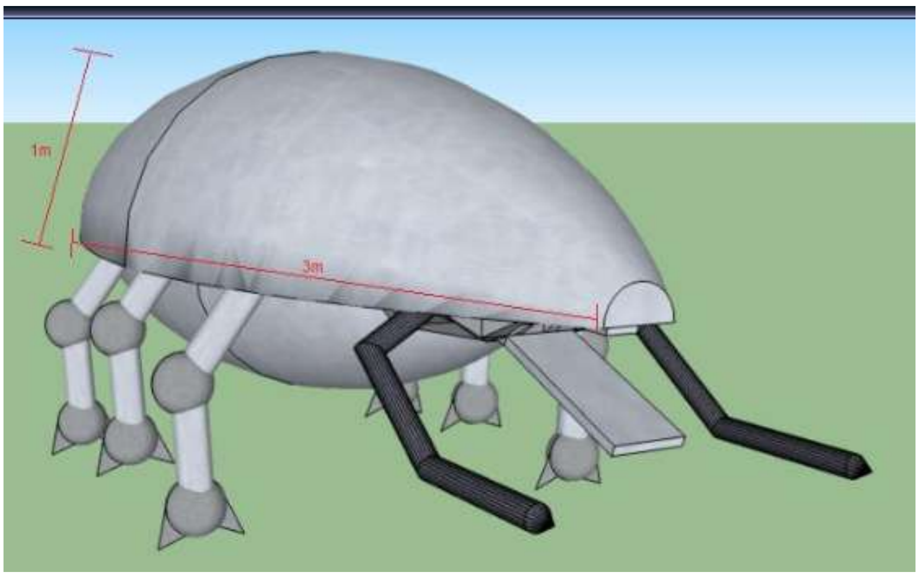


Figure 7.1.1 **AstMin**

Every five AstMin will be assigned to a transport spacecraft, which will transport the AstMin to the asteroid surface. After the AstMin finish their harvesting operations, they will deposit the contents of the second compartment into the spacecraft. The AstMin will then return to their harvesting locations while the spacecraft returns to Astoria to empty its payload in a dock. The transport spacecraft will then return to the asteroid in time for the AstMin to again unload their materials. Only when the asteroid has been depleted of its required materials or the AstMin are no longer necessary will the AstMin return with the transport spacecraft to the settlement.

The materials at the dock will be transported into the central port. Every week the materials in the central port will be taken into the settlement via robots. Materials will be delivered to the industrial center in the settlement, where they will be refined and stored until needed for processing and distribution.

7.1.2 Docking System and Port Facilities

Twelve individual docks will be connected to a central port. Each dock will have a capacity of one spacecraft. An airlock will be at the end of each dock to account for pressure differences between outer space and the ports. Once a spacecraft approaches the port, radio waves will be sent out to guide the spacecraft to one of the unoccupied docks. They will then pass through the airlock and land in the dock, where they will be cleaned.

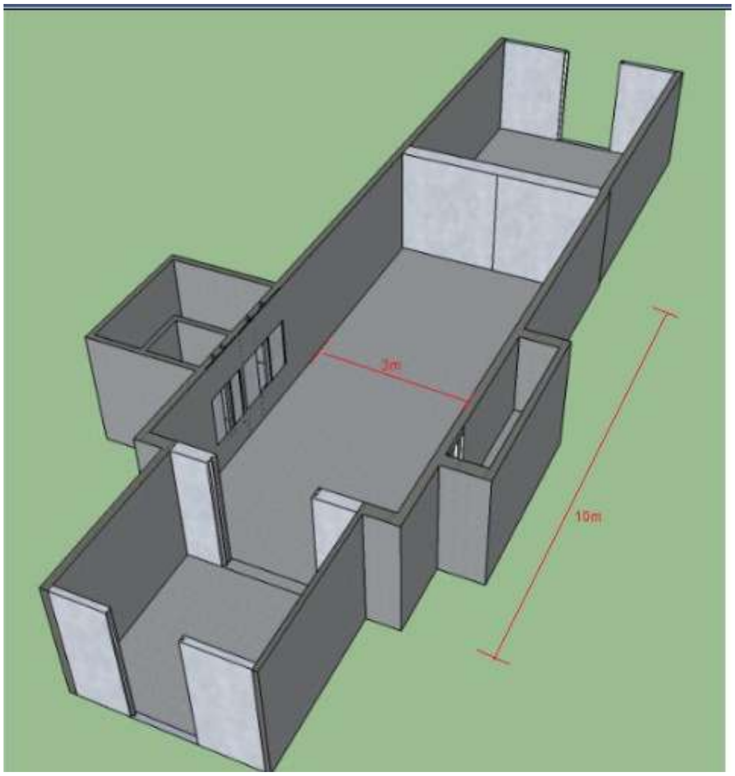


Figure 7.1.2 Dock

Five cleaning robots will enter the landing room equipped with an apparatus similar to a lint roller that will have a metal handle wrapped with adhesive paper that will remove foreign particles, such as those from dust contamination, from the exterior of the spacecraft. Each side of the craft will be cleaned by two robots while the fifth swabs the front end. The adhesive paper will be replaced after the robots return to the robot storage compartment. Each cleaning will take roughly two minutes to complete. Afterwards, another group of five robots will remove remaining particles with charged plates through the principal of electrostatic charge for roughly two minutes. Spacecraft will then be covered with a biodegradable plastic film that will temporarily shield against foreign particles until it is replaced by another film at its destination port. The film will be manufactured in the industrial center and transported to the port in large rolls that will be stored in and dispensed by one robot per dock.

After the cleaning process, three maintenance robots will detect and fix any problems. Robots will then unload the spacecraft, storing any quarantined items in a separate compartment to be transported to scientific labs where they will be investigated. Remaining materials will be shipped down to the central port to be transported to the industrial center of the settlement to companies such as QZK Industry, which will receive all asteroid mining products. Aircraft will then be stored in a separate compartment in the port, where they will be refueled with LOX and LH2 as explained in 7.2.2 and prepare for their next departure. The spacecraft crew will then enter an R&R center.

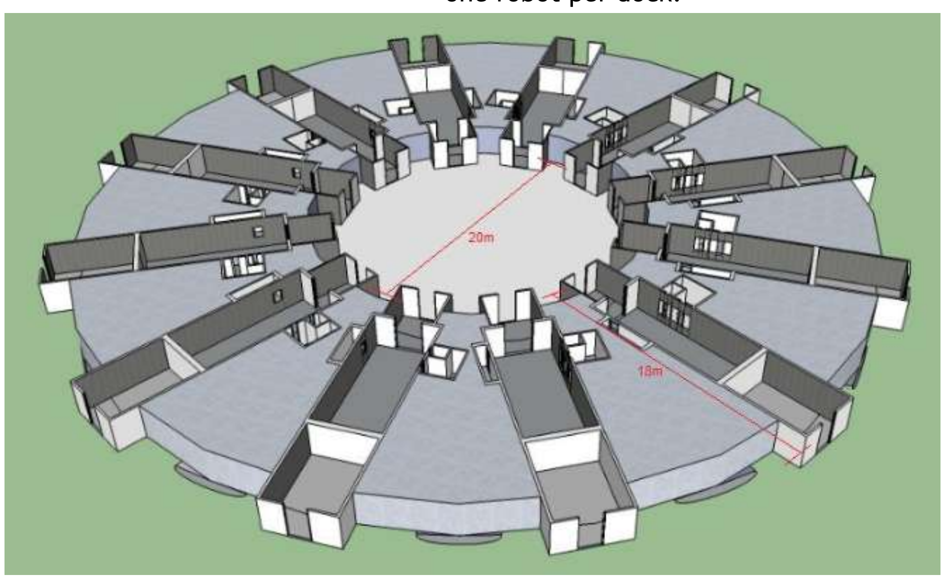


Figure 7.1.3 **Central Port**

7.2.1 Crewmember Provisions and Facilities

Five hundred square miles of excess aeroponic agriculture will be allocated to the needs of visiting spacecraft crew. The produce, mainly fruits, vegetables, wheat, corn, and soybeans, will be cleaned and freeze-dried, then stored. They will be distributed in biodegradable bags.

The crew R&R centers will be the same as the entertainment centers within the communities, where crewmembers can indulge in movies, sports, and other activities. One entertainment center will be outside of each central port. Fifty double rooms in two buildings will be allocated to each central port, where crewmembers will be able to stay until their next departure.

Crewmembers will be able to stay in the entertainment centers for as long as they desire, and will go to food distribution centers for their meals. They will also have access to the central port if they need to supply their spacecraft or check the progress of its repairs. Shops including souvenirs and tools will also be open to the crewmembers all day.

7.2.2 Spacecraft Repair and Refueling Systems

Spacecraft will be automatically repaired on entrance to the docks by the maintenance robots. However, spacecraft that are severely damaged will be transported to the central port for major repairs. Three individual rooms will be allocated for this purpose, each with its own crew of five robots. The crewmembers of the damaged spacecraft will be immediately removed and sent to a nearby medical center, also included in the central port. The robots will then proceed to scan the spacecraft and conduct necessary repairs. Once the spacecraft is again functional, it will be transported to the spacecraft storage center until it is further needed or until the crewmembers have recovered sufficiently.

Other, less damaged spacecraft will have necessary adjustments made within the docking area while simultaneously being cleaned of foreign particles, as explained in 7.1.2. After the entire process, they will be refueled with LOX and LH2. Two containers of 150 cubic feet for each fuel will be in each central port. Once a container of fuel is empty after about three of four weeks, containers of oxygen or hydrogen gas will be transported to the industrial center where the cryogenic process will begin. The other tank of liquid fuel will be used during the three-day cryogenic cycle. After the cycle has been completed, the empty container from the oxygen or hydrogen gas will be transported back to the industrial center for the next cryogenic cycle. After the spacecraft have had minor repairs in the docking area, they will move to the central port where they will be refueled by one of twelve robots directly from the large containers of fuel. Although the process may require longer periods of time than inserting an already made container of fuel, it will account for the differences in spacecraft fueling systems among the spacecraft from other settlements.

7.2.3 Rescue Operations

A Space Tug will be available to assist disabled vessels. Fueled by LOX and LH2, the Space Tug will rely on two main thrusters positioned near the back of the craft. Two smaller thrusters will accompany it for more specific directing or for more launching power. Two other pushing thrusters located in the bottom front of the Space Tug will help the craft

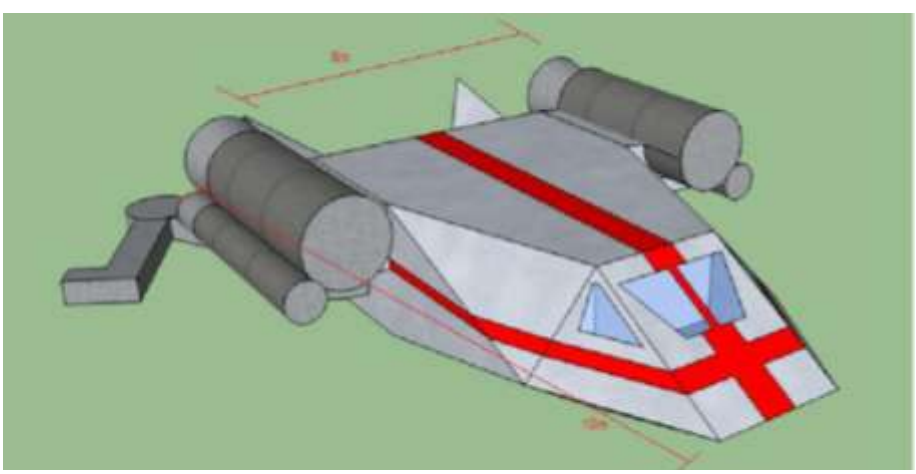


Figure 7.2.1 **Space Tug Front View**

maneuver more efficiently. These two thrusters will be protected by two flaps that will close upon arrival to ensure smooth landing. A linear docking mechanism at the end of the Space Tug will enable disabled vehicles to latch onto the Space Tug for transport back to the settlement. Two clamps on the side of the Space Tug will attach onto the disabled vehicle to secure it for the passage back to the settlement. The Space Tug will have a capacity of twenty people, and will initially contain five to rescue the disabled vehicle. Standard supplies including one month's worth of food, oxygen, and water as well as various tools and spacesuits will be included on the Space Tug. One Space Tug will be on standby at each central port, fully prepared to leave at all hours once a crew is available.

A fully provisioned ship at each central port will be ready to leave in twenty-four hours to assist asteroid miners. It will have the general shape of the asteroid miner mother ship, except it will have a capacity of ten vehicles and have ten months' worth of consumables as well as greater amounts of tools and spacesuits available. It, too, will be run on LOX and LH2, and will rely on four main thrusters and two emergency thrusters at the back of the ship. Ten crewmembers will be allocated to this ship, and the ship will be maintained on a weekly basis to prepare for emergency rescues. Once a distress signal is received from the asteroid miners, the ten crewmembers will be notified and will leave in twenty-four hours on the rescue ship.

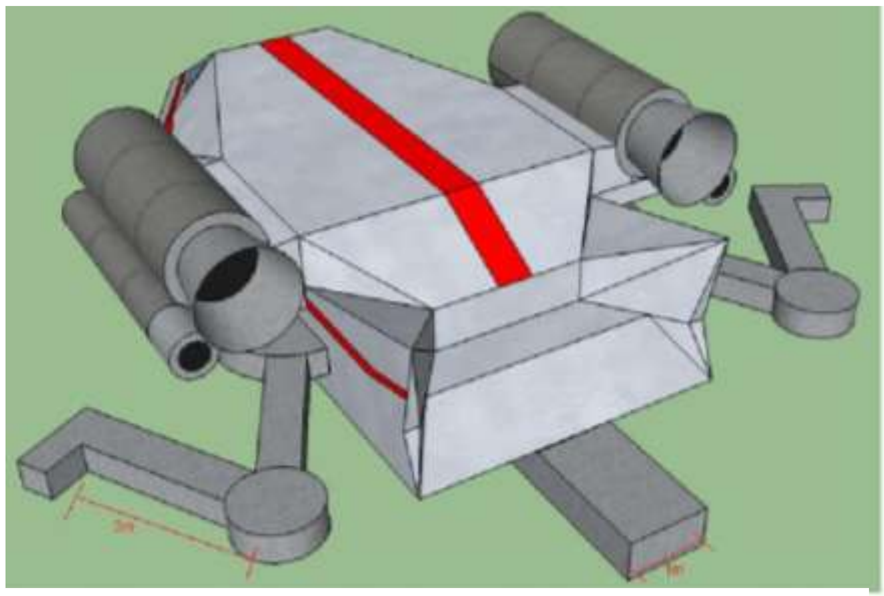


Figure 7.2.2 **Space Tug Back View**

7.3.1 Sensing and Imaging Research

Four radio telescopes 109.5 degrees apart around the settlement will provide a source of sensing and imaging research. Each one will have a diameter of 150 meters. They will be located fifty meters from the settlement to provide an overall view of the space around Astoria. Laser communication relay will control the position of the radio telescopes from the settlement in order to direct them or move them in the case of an incoming asteroid. Regular vibrations caused by activities on the settlement will be measured and recorded. These vibrations will be inputted into the telescopes to disregard them. Other vibrations will be avoided through the laser relay from the settlement, which will keep the radio telescope in place.

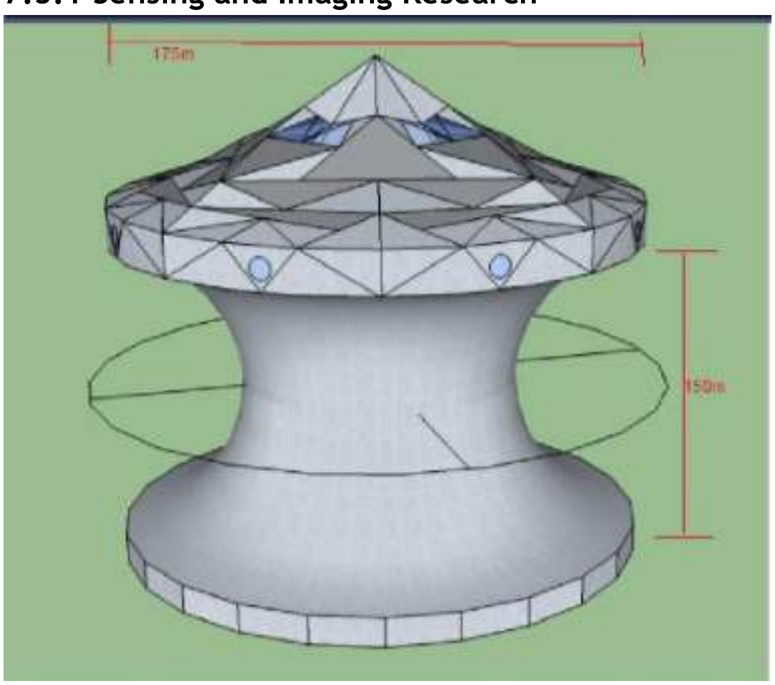


Figure 7.3.1 **Radio Telescope**

Two optical telescopes near each radio telescope will provide a closer view of objects in space. They will have a diameter of six meters, and will be stationed on the radio telescopes. A signal will allow them to detach from the radio telescope for more specific viewing. The controlling and vibration-preventing mechanisms associated with the eight optical telescopes will be the same as those for the radio telescopes.

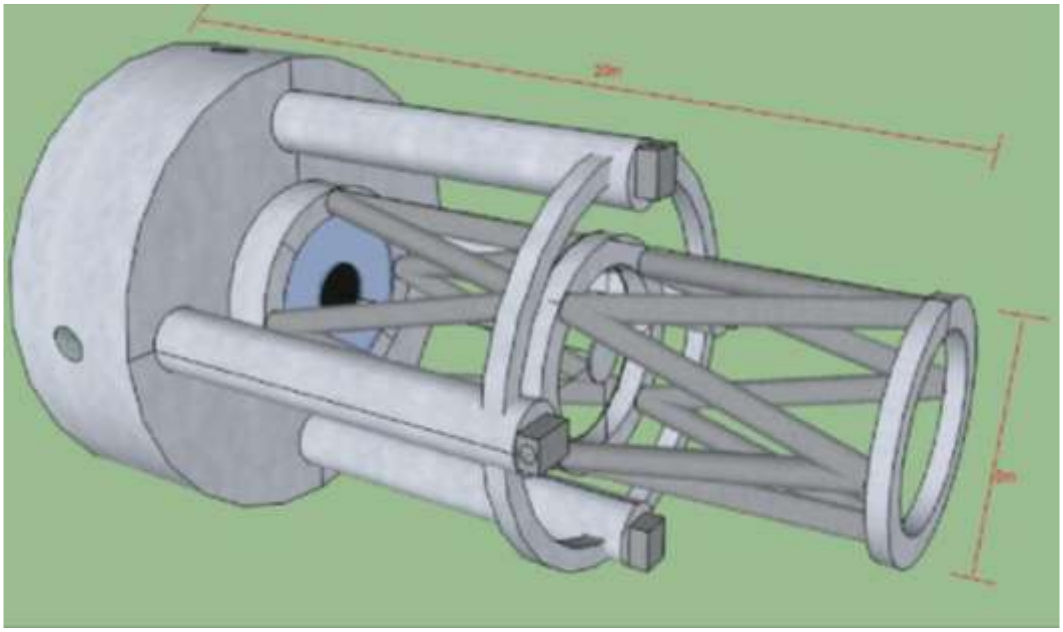


Figure 7.3.2 **Optical Telescope**

All twelve telescopes' images will be relayed to a sensing and imaging research center that will analyze the readings. Images will also be sent to two smaller imaging centers in the event that the central one malfunctions or is destroyed. These imaging centers will be located in the industrial section. They will also have a storage compartment for an extra radio telescope and three extra optical telescopes should a telescope need to be replaced.

7.3.2 Earth Communications

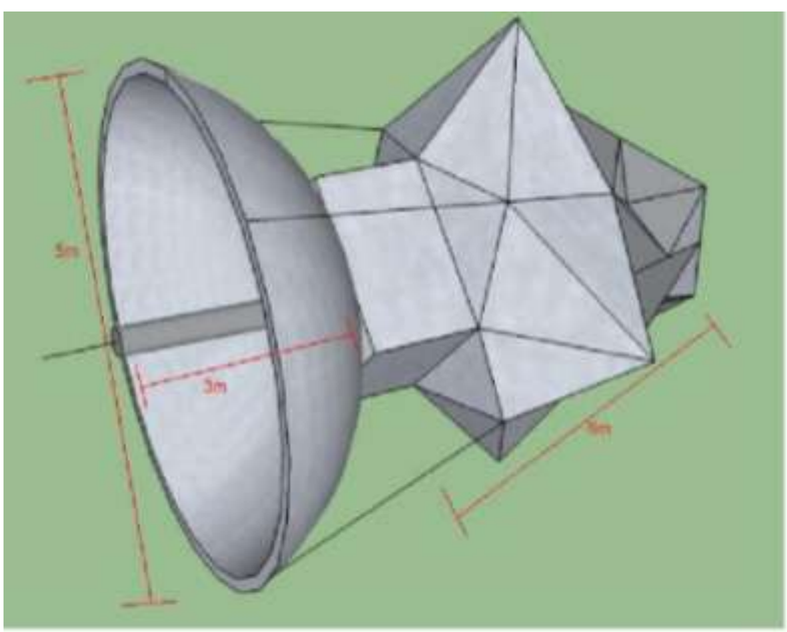


Figure 7.3.3 **Radio Satellite**

Communication with Earth will involve lasers specialized for long range communication. A network including Astoria, Earth, and other settlements in space will allow for quick and efficient communication. Email technology will also be utilized for communication. In the event of a laser malfunction or destruction, radio satellite systems will be ready to act as backups until the lasers are functional again. Although radio satellites are less efficient than laser communication, they provide a reliable source of information relay. Multiple radio satellites placed around Astoria will further increase the radio satellite reliability and stability.

APPENDIX A: Operational Scenario

Chase Anderson, a 38 year old resident of Astoria, and his wife, Natasha Anderson, 35 year old resident of Astoria, have two children: Clement and Sandra (10 years old, and 4 years old, respectively). Both children are at their regular stages of development. The family lives on the northside of the Residential Sector, and has been living comfortably in Astoria for 3 years. Chase is an employee of QZK Industries, and is an analyst who identifies nearby asteroids suitable for mining operations to sustain Astoria. Natasha is also an employee at QZK Industries, and is an engineer who repairs malfunctioning mining robots that operate on asteroid surfaces. Both work from 9:00 am to 5:00 pm five days a week, with weekends and select holidays off. Clement is a 4th grade student who attends John Jacob Astor School, while Sandra attends a daycare located within the school. Regular school hours are from 8:30 am to 2:30 pm, while regular daycare hours are from 8:30 am to 5:30 pm. Sandra also has mild asthma, and her doctor has prescribed an inhaler for asthma medication twice a day.

The Anderson family's day begins at 7:00 am as they all wake up, and prepare for the day. They perform their regular hygienic functions, such as brushing their teeth and showering, and also dress. They proceed to eat oatmeal with fruits at 7:15 am, while Chase and Natasha review the daily news with their electronic device, which are wirelessly connected to Astoria's Intranet and Internet System. While eating breakfast, Sandra surreptitiously spills a large amount of oatmeal on the floor, which the Cleaning Robot hastily cleans to create an immaculate floor. The family finishes their light breakfast at 7:27 am, and leaves from the front door by 7:30 am. Chase and Natasha walk with their children to John Jacob Astor School, which is approximately a 20-minute walk from the northside of the Residential Sector. Chase and Natasha drop their children off, and then proceed to QZK Industries Headquarters, located at their heart of the Industrial Sector. They walk from John Jacob Astor School to the Maglev Station (a 7 minute walk), where they take a train to the Industrial Sector, a ride that takes 10 minutes. They arrive at their destination, QZK Industries Headquarters, at approximately 8:57 am, and separate to proceed to their respective workplaces.

Clement begins his regular studies at John Jacob Astor School, which includes a curriculum of math, English, writing, history, science, physical education, and a foreign language (Latin). His class takes a snack break from 10:00 am to 10:30 am, where Clement consumes carrot sticks while also socializing with his friends. Human teachers mainly instruct the students, while some robots are employed to assist human instructors with the daily curriculum. Lunchtime is from 12:00 pm to 12:40 pm, where he consumes macaroni and cheese and participates in a game of basketball with various classmates at the nearby park. While participating in an intense game of basketball, he trips and suffers from a minor scrape. An adult supervisor quickly notices the incident and refers Clement to the Health Robot, which swiftly sprays an antiseptic solution and bandages it. Clement then continues his studies until 2:30 pm, and then he walks to the Astoria Library (a 5 minute walk), where he finishes his homework with his friends until 5:35 pm, when his parents pick him up. Clement makes use of the Intranet and Internet systems in order to complete his homework and study for tomorrow's test.

Sandra is in a very supportive environment at the daycare located in John Jacob Astor School. There she spends her time immersed in an educational environment, learning basic mathematical skills and improving her English speaking and writing skills. At the daycare Sandra also learns invaluable social skills by associating herself with her fellow classmates at the daycare. Robot caretakers supervise the children and also assist them in their activities. At approximately 10:20 am Sandra consumes a banana, and then later at 11:40 am eats Chicken Noodle Soup with Whole Wheat Bread. Sandra takes a nap from 12:30 pm to 3:00 pm and then continues her activities until 5:30 pm, when Chase and Natasha pick her up.

Chase begins his work at the Asteroid Discovery Department at QZK Industries by first receiving a brief of the latest activities in his group at 9:00 am, and the brief lasts about 15 minutes. At 9:16 am, Chase detects a nearby asteroid that is targeted as a potential candidate for mining by his computer. He analyzes the exterior features of the asteroid and soon determines that the asteroid requires further examination of the interior features and composition. Chase requests to send a Mining Research Craft (MRC) to the potential candidate asteroid in order to determine its interior features and composition, which is accepted at 10:04 am. At 10:11 am the MRC is sent to the asteroid, a journey that takes approximately 30 minutes. During this time Chase updates his team manager on his findings and receives further instructions. At 10:40 am the MRC arrives at the candidate asteroid, which is now named A-CFM-19524 for technical purposes. The MRC proceeds with experiments, which is being manually controlled by Chase. Wit the experiments it is determined that A-CFM-19524 contains desirable minerals such as iron ore, rare earth metals, and some aluminum and titanium. With the experiments over at about 12:34 pm, Chase orders the MRC to come back to Astoria, and now the A-CFM-19524 project is deferred to the Asteroid Mining Department. At about 12:41 pm he takes his lunch break, which will last until to about 1:20 pm.

Natasha begins her work at the Asteroid Machinery Department at QZK Industries at about 8:58 am, and quickly proceeds to continue her previous work on repairing a malfunctioning motor of an Asteroid Harvesting Craft (AHC). She and her coworkers determine that a new motor is required, and use the Intranet to order one; unfortunately, the inventory at Astoria is empty, and a motor must be imported from Aresam. Although the order for the new motor is processed relatively quickly, the motor for the malfunctioning AHC will arrive tomorrow at the earliest, so Natasha continues her other work. At 9:53 am, she receives a report of a broken AHC on A-CFM-15729, and is ordered to repair it remotely using an Asteroid Repair Craft (ARC). She sends the ARC to A-CFM-15729 at 10:04 am, but since the journey will take approximately two hours, she heads to a monthly meeting discussing new updates and new methods discovered to repair leaking fluid leaks in microgravity. The meeting lasts from 10:10 am to 12:10 pm, and Natasha also presents a report on a novel repair method for micrometeorite impacts. At 12:15 pm she takes her lunch break, which will last until 1:30 pm.

Natasha and Chase meet up at the main lobby of QZK Industries Headquarters at 12:22 pm, and both head towards the cafeteria located there. Natasha dines on a tofu burger, while Chase consumes a chicken vegetable salad. At the heart of the Industrial Sector is a shopping mall, which Chase and Natasha both go to after they finish lunch, at approximately 12:47 pm. The walk from QZK Industries Headquarters to the shopping mall is approximately 3 minutes. Chase enters Hamilton Press Books, and purchases a copy of <u>Going Rogue</u> by Sarah Palin (a very well-known figure at Astoria), while Natasha buys Vera Wang shoes from Cadbury's. They also drop by at the pharmacy to pick up the prescription for their daughter's asthma medication at 1:03 pm. Chase and Natasha also purchase a Robotic Dog from the Pet Emporium as a surprise for Clement, because it happens to be his eleventh birthday today. Chase and Natasha leave from the shopping mall at 1:15 pm, and arrive at QZK Industries Headquarters at approximately 1:18 pm after engaging in a brisk walk.

Chase begins his work activities at 1:23 pm, and monitors nearby asteroids to identify more potential candidates for mining. After an hour of monitoring, Chase fails to identify any new potential asteroids, and decides to explore a previously unmonitored area of the asteroid belt for new potential candidate asteroids for mining. Chase sends an Asteroid Exploration Vehicle (AEV) towards the unexplored region at 2:37 pm, and manually guides it towards the unexplored region. Chase discovers 574 newly discovered asteroids, and after some analysis, determines that approximately 117 of these asteroids are candidates for further analysis and exploration. At 3:30 pm, Chase attends a group meeting in order to announce and discuss his newly found results with his coworkers and discuss future steps. The meeting lasts until 4:55 pm, and at 4:57 pm Chase finishes up his remaining work and heads toward home.

Natasha resumes her work activities at 1:28 pm, and with the ARC now arrived at A-CFM-15729, she proceeds to remotely control the broken AHC on A-CFM-15729. Using the ARC's multiple onboard cameras, she has determined that the AHC is stuck on a patch of very soft regolith on A-CFM-15729. Natasha confers with her coworkers on how to solve the problem, and determines that the ARC must physically tow the AHC back to solid ground by using a makeshift chain. Using the method that she and her coworkers developed, Natasha successfully gets the AHC back to solid ground, at about 3:48 pm. With the AHC now functioning normally, she sends the ARC back to Astoria, at about 3:59 pm. From 4:00 pm to 4:56 pm, Natasha works with her coworkers on a malfunctioning Asteroid Transport Craft (ATC), which is suffered from a devastating impact with a micrometeorite and subsequently had an engine explosion. After an hour of repair on the ATC, it is determined that it is irreparable and is sent to the Scrap Metal Processing Center, with its metal content to be recycled for future use. At 4:59 pm Natasha finishes her work and heads toward home.

Chase and Natasha once again meet at the lobby of QZK Industries Headquarters at 5:01 pm, and head towards the Maglev Station, which is nearby. Following a 10 minute train ride and an 8 minute walk from the Maglev Station, they arrive at a neighborhood grocery store, where they pick up a bottle of non-fat milk, and other groceries for dinner. They finish grocery shopping at about 5:28 pm, and they quickly walk to John Jacob Astor School, which is close to the grocery store. There, they pick up Sandra from the daycare located within the school. Following a 5 minute walk to the Astoria Library to pick up Clement, the entire family walks home, and arrives at the northern side of the Residential Sector at about 5:43 pm. At home, Natasha notices a leak under the sink while she is washing the vegetables to be used for today's dinner. Natasha notifies Chase, who promptly calls for a Repair Robot to repair the sink. Within 5 minutes, the Repair Robot arrives at their house and automatically repairs the sink leak by 6:07 pm. With the sink now fixed, Chase and Natasha start to prepare dinner, which for today will be chicken pot pie with salad. Dinner is served at 6:30 pm and goes on until 7:15 pm, during which the family celebrates Clement's birthday, and reveals his birthday present. For dessert, they eat a chocolate satin cake that Chase and Natasha picked up from the bakery yesterday.

After finishing their dinner, the family decides to further celebrate Clement's birthday by watching a 3D movie at the Entertainment Sector. They walk together to the Entertainment Sector, which is strategically located next to the Residential Sector, and watch a family appropriate movie from 7:30 to 9:38. They are awed by the graphics and three-dimensional quality. Following a very long and tiring day, the whole family showers and heads to sleep, awaiting another day at Astoria tomorrow.

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APPENDIX C: Compliance Matrix

Requirement	Subsection	Page
1.0 ***Executive Summary***	**N/A**	**1**
2.0 ***Structural Design*** -Provide residence for 6,000 long-term residents, 5,000 semi-term residents, and up to 500 transient residents	**N/A**	**2**
2.1 ***Exterior*** -Identify large enclosed volumes and major structural components. -Show dimensions of major hull components. -Specify construction materials for major hull components and design features. -Specify where artificial gravity will be supplied. -Show interfaces between rotating and non-rotating sections. -Rationalize rotation rate and artificial gravity. -Specify means for debris/radiation protection. -Show capability to isolate at least two of ten separate volumes. -Identify pressurized/unpressurized volumes. -Identify rotating/non-rotating sections. -Indicate functions of each volume.	**2.1.1** **2.1.2** **2.1.3** **2.1.4**	**2** **3** **4**
2.2 ***Interior*** -Specify allocation of down area. -Show drawings with dimensions of residential, industrial, commercial, agricultural, and other sections. Provide overall map of layout. -Show orientation of down area and vertical clearance in each area.	**2.2.1** **2.2.2** **2.2.3** **2.2.4**	**4** **5**
2.3 ***Construction*** -Describe construction process and show at least 6 steps of assembly. -Specify when and how artificial gravity will be initiated. -Describe use of materials from asteroids for construction.	**2.3**	**6** **7**
2.4 ***Shielding and Damage Repair*** -Details shielding and repair methods for frequent impact by particles -Describe means for reducing damage from larger objects	**2.4**	**8** **9**
2.5 ***Asteroid Mining Camp*** -Describes the mining camp infrastructure on Ceres -Describe human inhabitation of the mining facility on Ceres	**2.5**	**10**
3.0 ***Operations & Infrastructure*** -Describe facilities necessary for building and operating the community, including business and accommodating vehicles.	**N/A**	**11**
3.1 ***Orbit and Materials*** -Recommend an orbital location (altitude and inclination) for Astoria and provide rationale. -Identify sources of materials/equipment for construction/operations. -Identify means of transport for materials to Astoria -Specify mining target	**3.1.1** **3.1.2**	**11**
3.2 ***Infrastructure*** -Identify air composition, pressure, and quantity, and describe climate	**3.2.1** **3.2.2**	**12** **13**

control. -Describe food production: growing, harvesting, storing, packaging, delivering, selling. -Describe how power will be generated (specify kW), distribution, & allocation. -Describe water management (quantity and storage facilities). -Describe household and industrial solid waste management (recycling, disposal). -Describe internal/external communication devices & central equipment. -Describe internal transport systems (routes, vehicles, dimensions). -Describe day/night cycle provisions (schedules and mechanisms). -Define storage facilities in case of interruption in food or commodities for up to ten months.	**3.2.3 3.2.4 3.2.5 3.2.6 3.2.7 3.2.8**	**14 15**
3.3 *Construction Equipment* -Show designs of machines for settlement construction, especially hull and interior buildings and structures. -Describe necessary materials and how machines create the structures.	**3.3.1 3.3.2**	**15**
3.4 *Propulsion System* -Describe emergency propulsion system to move Astoria when threatened with impact • Describe thrust, acceleration, and fuel requirements	**3.4**	**15 16**
3.5 *Mining* -Describe ore handling processes -Indicate and provide rationale for an alternative mining location	**3.5.1 3.5.2**	**16**
4.0 *Human Factors* -Have natural sunlight and views of space outside -Ensure that facilities enable mobility with a minimum of excess motion.	**N/A**	**17**
4.1 *Services & Consumables* -Provide services expected from comfortable modern communities. -Ensure that public areas have long lines of sight. -List major categories of consumables and quantities. -Depict and specify means of distributing consumables to residents. -Provide maps/illustrations of communities with locations of amenities and distance scale. -Identify percentage of land area allocated to roads and paths.	**4.1.1 4.1.2**	**17 18**
4.2 *Residences* -Provide designs of typical homes, clearly showing room sizes. Homes must be between 900 and 2000 square feet. -Identify sources and/or manufacture of furniture items and appliances. -Provide external drawing and interior floor plan of at least 4 home designs, the area (in sq. feet) of each design, and the number of each required.	**4.2.1 4.2.2 4.2.3**	**18 19**
4.3 *Access* -Provide means for safe access to any location in parts of settlement with low-gravity, inside settlement or on exterior surfaces. -Show spacesuit designs with stowage and donning/doffing procedures. -Show airlock designs for entering/exiting unpressurized volumes.	**4.3.1 4.3.2 4.3.3**	**19 20 21**

4.4 ***Means for Children to spend time in 1g environment*** -Describe how to provide exposure to 1g to children on a daily basis -Provide drawing(s) of means for children to spend time in 1g	**4.4**	**21**
4.5 ***Instant Move-in Home Designs*** -Describe how semi-term occupants can integrate into the community -Provide drawing(s) of instant move-in home designs	**4.5**	**22**
5.0 ***Automation*** -Specify number and types of computers, servers, software, network devices, and robots required for facility, community, & business operations. -Include types and capacities of data storage media, collection, distribution, and user access to computer networks in computer system descriptions. -Show robot designs, clearly indicating dimensions and illustrating how they perform their tasks.	**5.0.1** **5.0.2**	**23**
5.1 ***Construction*** -Describe automation for construction (transportation/delivery of materials, assembly, interior finishing). -Provide drawings showing automated construction and assembly devices for interior/exterior applications and show how they operate.	**5.1**	**24** **25**
5.2 ***Maintenance*** -Specify systems for maintenance, repair, and safety, including backup systems and contingency plans for failures. -Provide solar flare protection for emergency robots. -Describe means for authorized personnel to access critical data and command computer/robot systems; include security measures to assure that only authorized personnel have access -Provide chart with anticipated automation requirements and systems or robots to meet each need.	**5.2.1** **5.2.2**	**25** **26**
5.3 ***Livability*** -Specify automation to enhance livability, productivity, and convenience. -Emphasize automation for routine tasks, and reduce manual labor. -Provide for privacy and control of private systems. -Describe devices for personal delivery of internal and external communications services, entertainment, information, computing, and robot resources. -Provide drawings of robots/computers on settlement, and diagrams of networks and bandwidth requirements for connectivity.	**5.3.1** **5.3.2**	**26** **27** **28**
5.4 ***Mining*** -Describe robot adaptations to cope with difficulties of mining(nonexistent gravity, areas with thick layers of dust) -Provide drawings of robot components that enable drilling, shoveling, loading, transporting, etc. on zero-g surfaces	**5.4**	**27** **28**
5.5 ***Unloading Ore*** -Describe automated system for ore unloading -Specify whether ore will be accepted in bulk or in containers -Show how ore moves from ship to refinery	**5.5**	**29**

6.0 *Schedule and Cost* -Provide a schedule with costs through the construction phases of the	N/A	30
6.1 *Schedule* -Describe tasks from time of contract award (8 May, 2071) until customer assumes responsibility for settlement operations. -Show dates when Foundation Society members may move into settlement and when entire initial population will be established.	N/A	30 31
6.2 *Costs* -Specify costs associated with design in US dollars without inflation. -Estimate numbers of employees per phase of construction. -Provide charts/tables with separate costs per phase of construction.	N/A	31 32 33
7.0 *Business Development* -Design of settlement should be able to add compatible business types and various industrial and commercial venues easily.	N/A	34
7.1 Mining, Refining, and Docking Systems -Describe equipment required to conduct harvesting operations -Describe refining capabilities on the settlement -Describe commodities for imports and exports -Describe port facilities to receive incoming raw materials -Describe methods to prevent dust from entering Astoria	7.1.1 7.1.2	34 35
7.2 Crew Facilities, Spacecraft Operations, and Rescue System - Describe excess agricultural production, storage, and processing -Provide suitable facilities for visiting spacecraft crews -Provide a repair depot for maintenance and repair of space vessels - Provide fueling services for spacecraft traffic using port facilities; show fuel production and storage facilities for at least 40,000 cubic feet of LOX and 110,000 cubic feet of LH2, replenished monthly - Describe “Space Tug” services - Describe capability to send rescue operations for asteroid miners requires at least one ship fully provisioned for a mission up to ten months long, ready to leave in 24 hours	7.2.1 7.2.2 7.2.3	36 37
7.3 Sensing and Imaging, Earth Communications -Describe radio telescope with dish diameter 150 meters -Describe optical telescope with mirror diameter of 6 meters -Describe structural isolation from vibration-causing activities on Astoria -Describe data processing and communications capabilities to return data to Earth in real time	7.3.1 7.3.2	37 38
8.0 *Appendices*	N/A	
8.1 *Operational Scenario* -Describe a family’s activities on a typical day of work, school, and play. -Describe how features of Astoria design and operations apply to the family’s daily life, including travel time and distance between destinations, transportation routes and methods of travel, buildings/facilities visited, interactions with other people, duration of each activity, and tools/computers/robots used.	N/A	39 40 41
8.2 *Bibliography*	N/A	42
8.3 *Compliance Matrix* -List requirements in SOW and page where requirement is addressed.	N/A	45