

PRESENTED BY NORTHDONNING HEEDWELL  
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18th Annual International Space Settlement Design Competition  
Proposing Team Data 2011

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

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Names of two adult advisors currently expecting to attend the Finalist Competition:

Justin Sumpter Kevin Rucks

I understand that if our Team qualifies for the International Space Settlement Design Finalist Competition  
July 29 - August 1, we will be expected to finance our own travel to / from Nassau Bay, Texas, USA.

Kevin S. Rucks  
Responsible Teacher / Advisor Signature

3/13/11  
Date



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# EXECUTIVE SUMMARY



DON'T TELL ME THAT MAN DOESN'T BELONG OUT THERE.  
MAN BELONGS WHEREVER HE WANTS TO GO-  
AND HE'LL DO PLENTY WELL WHEN HE GETS THERE.  
-WERNER VON BRAUN

### 1.0 Executive Summary

As we look to the stars, a great many people come to mind. The inventors, the investors, and the captains of industry that have made technology, society, and the commercialization of space what it is today. Andrew Carnegie, one of these noble individuals, a giant of US industry and a rags-to-riches entrepreneur, is a prime example of what Astoria stands to be. Much like the investments that Carnegie was known for, Astoria shows foresight toward the expansion of a vast economic empire. Astoria will be the proverbial Atlas in the Golden Age of space exploration; bearing the Foundation Society on its shoulders as they continue their endeavors in colonizing the farthest reaches of the solar system.

Louis Sullivan, the “father of skyscrapers,” was known for his work in shaping and crafting the canonical silhouettes present in today’s cities and skylines. Astoria must act as a defining example of the ideal space settlement, just as Sullivan’s towers defined the architecture of today. Astoria strives to achieve this feat through its material independence, utilizing resources harvested from its host asteroid, 253 Mathilde. The backbone of Astoria integrates the settlement directly with Mathilde, allowing Astoria to interact freely with mining camps spread across Mathilde’s surface. Astoria pays tribute to Sullivan’s contributions to modern architecture through its docking facility, the Sullivan Tower, envisioned as a massive spire with facilities for docking and maintenance, boasting the capacity to handle large numbers of ships and support large import and export operations. Addressing the concerns of space debris, Astoria’s hull employs replaceable, recyclable ballistic foam tiles, safeguarding the station from the ever-present hazards of the Asteroid Belt.

Isambard Kingdom Brunel, a leading British civil engineer, revolutionized public transport and modern engineering with his work on bridges and steamships. Just as Brunel connected England through his rail and bridge networks, Astoria’s operations infrastructure bridges the gap between its remote location and the rest of mankind. Cyclopods solve community networking problems that have plagued space settlements in the past, allowing residents to traverse the span of the torus in as little as fifteen minutes without compromising traffic flow. A major component of Astoria’s safety considerations resides in its ability to detach from Mathilde in the face of imminent danger, avoiding incoming objects by anchoring with another point on the asteroid’s surface.

Frank Lloyd Wright, famous architect and interior designer, is recognized as the greatest architect of all time. Astoria’s architectural design parallels that of even Wright’s, providing residents with grand, flowing community designs and catering to a variety of tastes. Residents will always have access to natural views of space and agricultural sectors, giving them a glimpse of the wild beauty that is the Asteroid Belt, while providing a gentle reminder of their Earthen roots. The “Progressive Locomotive Aiding Youth” train will aid developing children aboard Astoria with a supplemental centripetal force, resolving an issue previously encountered in low-gravity environments. Recreation areas and transient homes ensure that even those aboard Astoria for intermittent durations will enjoy their stay.

Northdonning Heedwell acknowledges the asteroid belt as a formidable opponent in the conquest of space. In a perpetual battle against micrometeoroid invaders, Astoria’s hull will rely heavily on fleets of robotic service craft. The Crowe Repair Platform will serve as an integral part of the settlement, continually refreshing Astoria’s outermost defenses in this never-ending ordeal. Henry Ford’s implementation of the assembly line was lauded for its versatility, enabled through the concept of interchangeable parts. Astoria’s Modubots were designed under this paradigm, utilizing a variety of exchangeable function-specific modules and allowing tailored outfitting on a per-task basis.

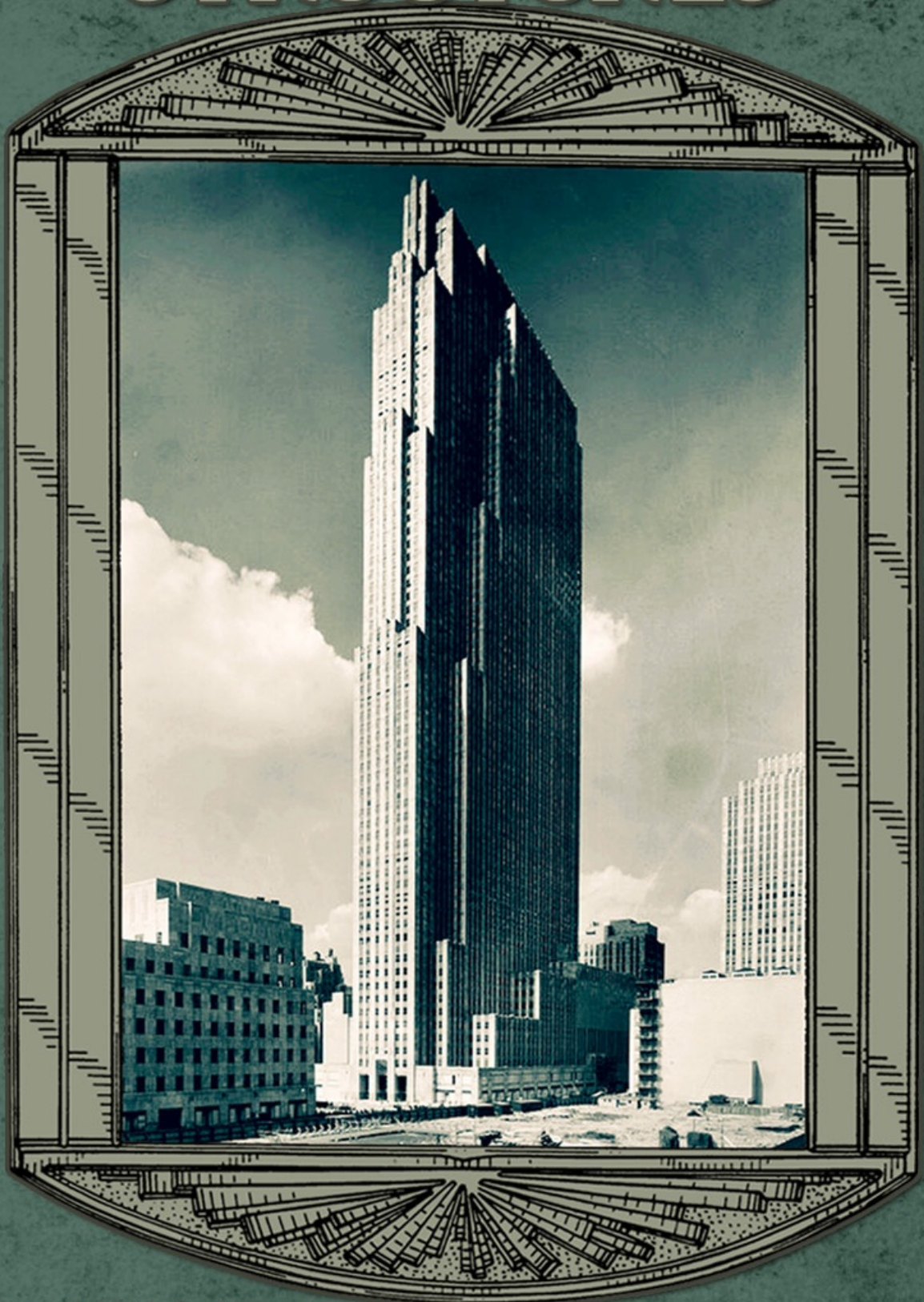
Astoria’s mining will bring in large volumes of LOX and LH2 for the refueling of craft, making Astoria the primary staging ground for expeditions to the outer reaches of the solar system. Astoria will build from the ground up in only 23 years, with life support and artificial gravity being implemented in 20 years. Profits from Astoria’s manufacturing will take mere decades to turn into a full-profit venture.

John D. Rockefeller aggressively ran his company, Standard Oil, to become the richest man alive. Astoria draws inspiration from Rockefeller’s enormous success through its own aggressive mining operations and extensive manufacturing operations. Prefabricated mining stations and processing centers will be assembled on the Carnegie Plate before being distributed over the surface of Mathilde by a Modubot space-tug team, allowing for materials to begin streaming into processing centers as soon as possible. Top of the line rest and relaxation facilities ensure that every visiting crew will be privy to a variety of entertainment and recreational opportunities.

Northdonning Heedwell aims to make Astoria the progenitor to a vast commercial venture in the outer reaches of the solar system.



# STRUCTURES



BE AS A TOWER FIRMLY SET;  
SHAKES NOT ITS TOP FOR  
ANY BLAST THAT BLOWS  
-DANTE ALIGHIERI

## 2.0 Structural Design

Astoria's design will focus on continued progress, providing a familiar and comforting home to 6000 permanent residents, 5000 semi-term occupants, and 500 transient visitors with consideration being taken for population growth. Lunar glass windows located on the residential side of the torus will provide Astoria's residents with natural views of space while protecting them from cosmic radiation. Alaskol will provide materials required for window construction.

### 2.1 Exterior Design

The Carnegie Industrial plate will rest on Astoria's legs, be connected to the Sullivan Tower, and interface directly with the Residential Torus as the main transit hub for Astoria. The interior of the Carnegie Industrial plate will be the site of Astoria's thorium power plant and the host of many processing and manufacturing facilities. Additionally, the top and bottom surfaces of the Carnegie Industrial plate will be suitable areas for construction, as businesses will no doubt seek opportunities to establish themselves in the asteroid belt.

The Sullivan Tower will be Astoria's main docking complex. Once completed, it will have an enormous docking capability of twenty ships at a time.

### Major Components Chart

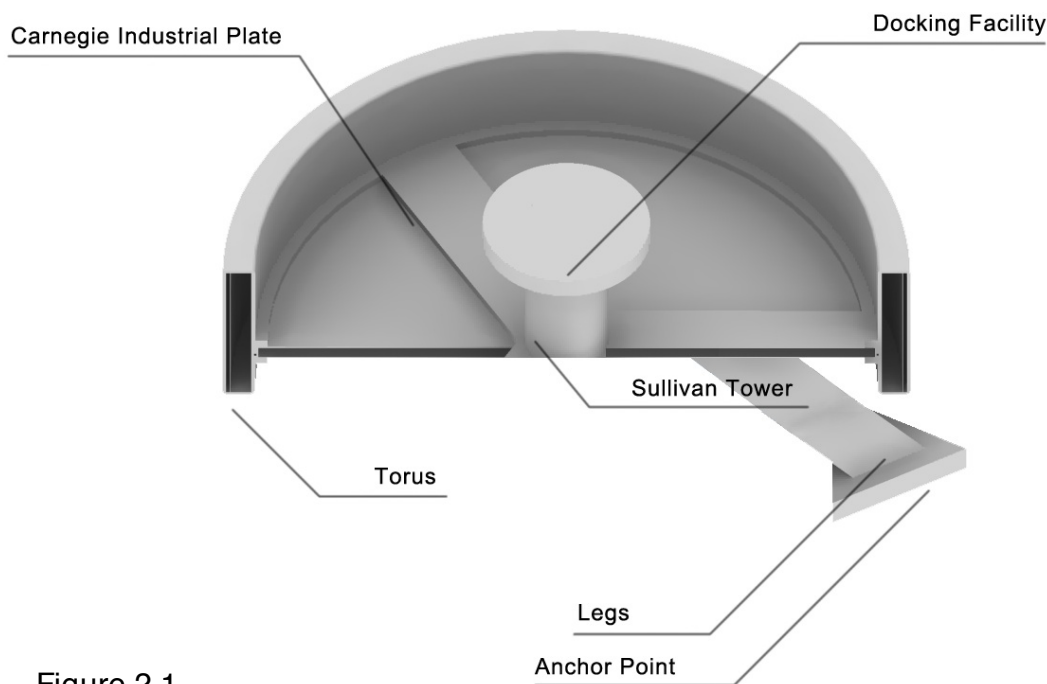


Figure 2.1



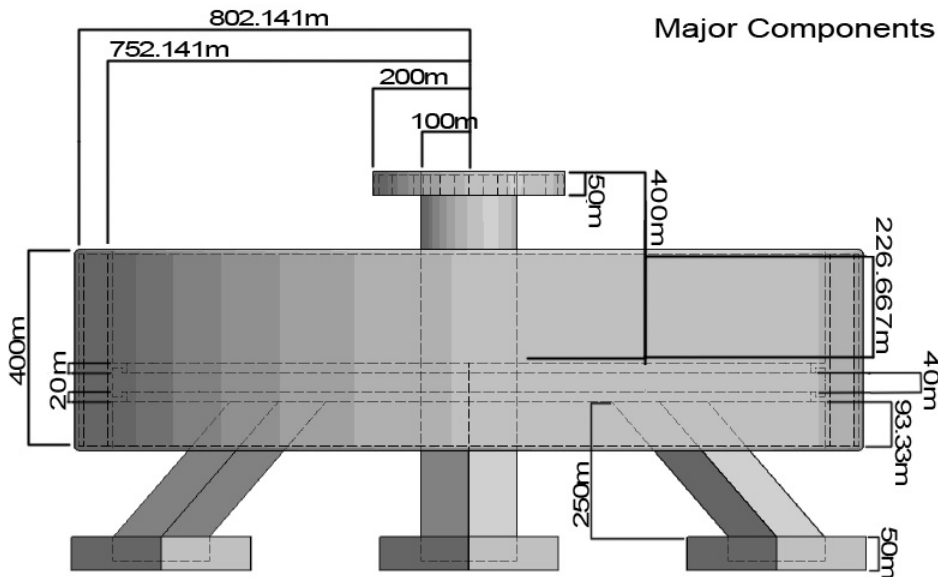
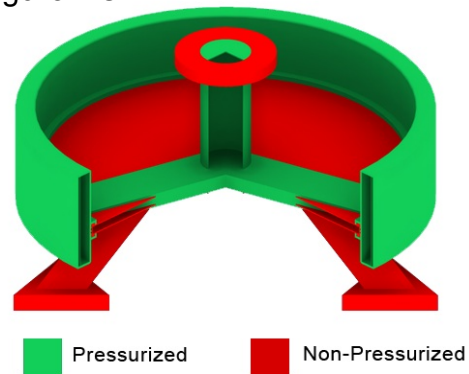


Figure 2.2

Pressurized and  
non-Pressurized Volumes

Figure 2.3



Pressurized Non-Pressurized

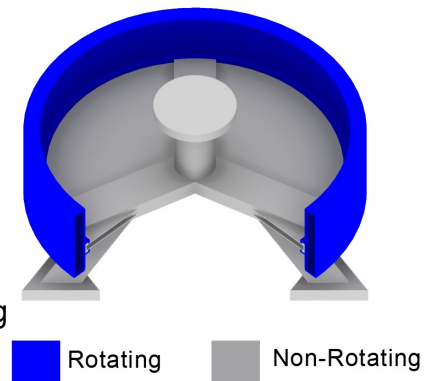
### 2.1.1 Enclosed Volumes

The volume of industrial plate is 53,014,376 m<sup>3</sup>. The volume of residential torus is 101,364,224 m<sup>3</sup>. The design is made to withstand internal pressures of 11psi, conserving costs on gases without significantly increasing structural costs or sacrificing human comfort.

### 2.1.2 Artificial Gravity

The torus of the station will be the only rotating component and will do so at a rate of 0.883 RPM. At this rate, the centripetal force acting on residents inside will have a measure of 0.7 g and the torus will have a tangential velocity of 74 m/s.

Figure 2.4  
Rotating and Non Rotating

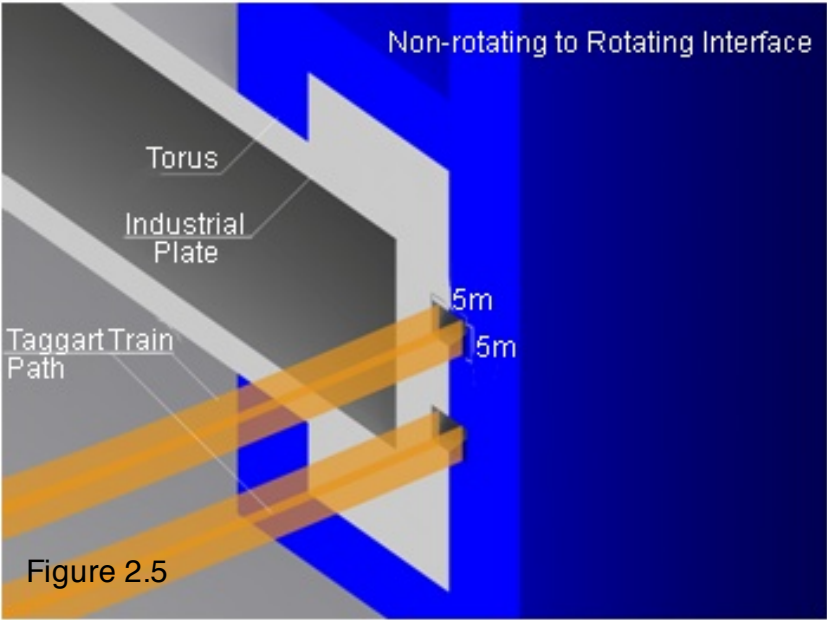


Rotating Non-Rotating



**2.1.3 Interfaces Between Rotating and Non-Rotating Structures**

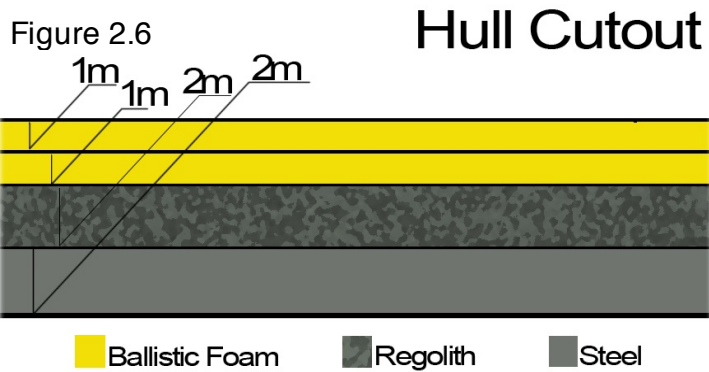
As an interface between the industrial plate and torus, four acceleration train stations will be located uniformly on the border of the torus and the Industrial plate. Trains will operate on an electromagnetic track that will run every two hours. The trains will be able to accelerate to the speed of the torus from the non-rotating industrial plate, providing a gravity gradient spanning 0g to 0.7g. Once cargo and passengers have unloaded from one of the twelve Taggart Acceleration trains, the train will break from the rotating torus and decelerate to match the industrial plate's tangential velocity of zero m/s.



**2.1.4 Radiation and Debris Protection**

**Materials Required for Hull Table 2.1**

Material	Amount Required	Uses within Astoria
Steel	8394335 m³	Pressure seal and kinetic protection against major impacts
Regolith	8394335 m³	Radiation Protection
Ceramic-polymer foam	8394335 m³	Outer hull, replaceable tiles for kinetic dampening



### 2.1.5 Isolation of Volumes

In the event of a loss of pressure, bulkheads concealed within the ceiling of the torus will utilize its centripetal force to deploy. The bulkheads will be sealed secure within a dock nested in the torus’ “ground” level. To aid the bulkheads in pressure relief and sealing, an array of support columns will be placed along the length of the bulkhead “dock,” distributing stress due to pressure on the bulkhead across multiple sections. Seals will be located between agriculture and residential sectors, successfully quarantining the effected sectors with minimal unnecessary isolation.

Each of the 10 major bulkheads span the length of each zoned area specified in section 2.2, and are comprised of a 0.25m layer of steel, a 0.25m layer of iron, and another 0.25m layer of steel. The bulkheads will be manufactured in accordance with the curvature of the torus to ensure airtight containment of precious volumes.

Residents in the immediate area of the emergency will have twenty minutes to move to another section of the station. Medical services and systems will be on standby to receive those affected by the contingency.

Once the section is sealed and specialized hull-repair Modubots seal the pressure breach, Modubot recovery crews will restore the affected area and air reserves kept in the industrial plate will be moved to replace lost gases.

### 2.2 Down Surfaces

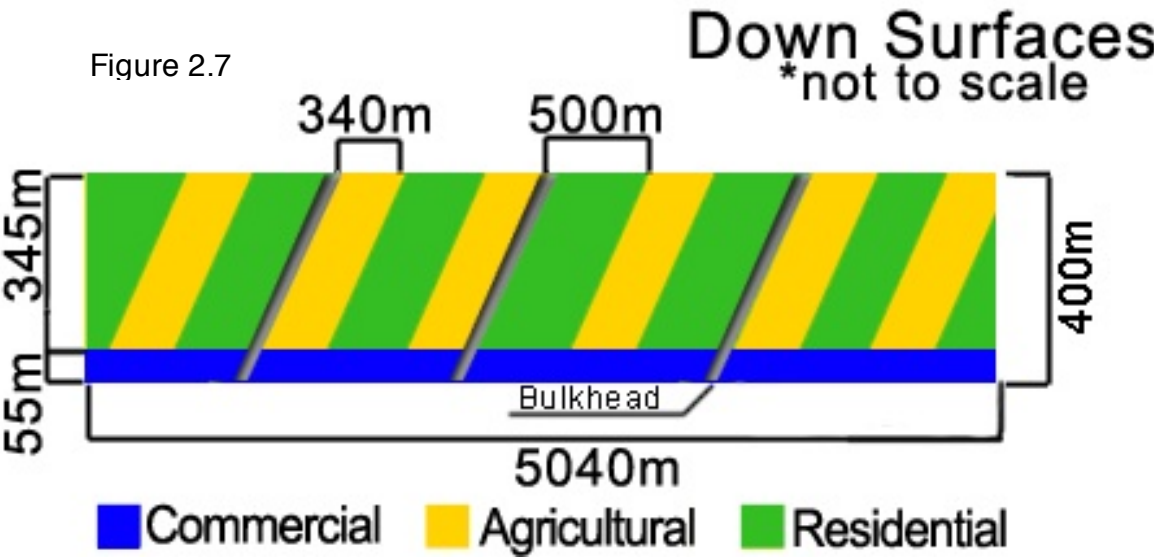


Table 2.2  
Main Level Down Surfaces

Zone	Down Surface Area	Percentage Allocation of level
Residential	1006000 m <sup>2</sup>	49.9%
Commercial	280475 m <sup>2</sup>	13.9%
Agriculture	730800 m <sup>2</sup>	36.25%
Total space required	2014775 m <sup>2</sup>	99.9%
Total space available	2016000 m <sup>2</sup>	100%



Astoria's down surfaces are arranged into 13 sections. The commercial sector of Astoria runs along the side of the asteroid facing the station, and residential and agricultural sectors are split into 12 patterned groups running at an angle of 60 degrees to the commercial sector.

Communities are patterns this way to provide better overall natural views to residents. Astoria's Torus has a 50m ceiling and a 10m basement to provide for maintenance and additional agricultural space. Three large bulkheads rest in Astoria's ceiling and are pulled down in the event of a pressure breach.

Zone	Down Surface Area	Percent Allocation
Utilities	600000 m <sup>2</sup>	27.4%
Maintenance	1257265 m <sup>2</sup>	42.5%
Agriculture	330,000 m <sup>2</sup>	15.1%
Total space available	2186548 m <sup>2</sup>	100%

### 2.3 Construction Sequence

Table 2.4

#	Construction Phase	Description	Materials	Time
1	Morgan	Titanium anchor points will be installed onto the surface of 253 Mathilde on its axis of rotation to form an equilateral triangle.	Steel, Regolith	January 2074 - July 2077
2	Stanford	400m legs will be attached to the anchors to support the combined weight of the industrial plate and Sullivan Tower	Carbon Steel, Regolith	September 2077 - December 2080
3	Flagler	Construction of the industrial plate will begin atop the newly installed support spokes.	Steel, Regolith	February 2081 - March 2086
4	Vanderbilt	The Sullivan Tower will be constructed on the center of the Industrial plate.	Titanium, Steel, Regolith	May 2086 - July 2090
5	Galt	The Residential torus will be constructed on the side of the industrial plate. When completed, the torus will utilize an electromagnetic tether to begin rotation and artificial gravity will be applied.	Titanium, Steel, Regolith, Ceramic Foam	September 2090 - December 2095
6	Rearden	The elevators of the Graham Bell Tower will be completed, doubling Astoria's ship docking capacity. Another anchor point located two kilometers from Astoria's location will be built, providing a relocation	Titanium, Steel, Regolith	February 2096 - February 2097



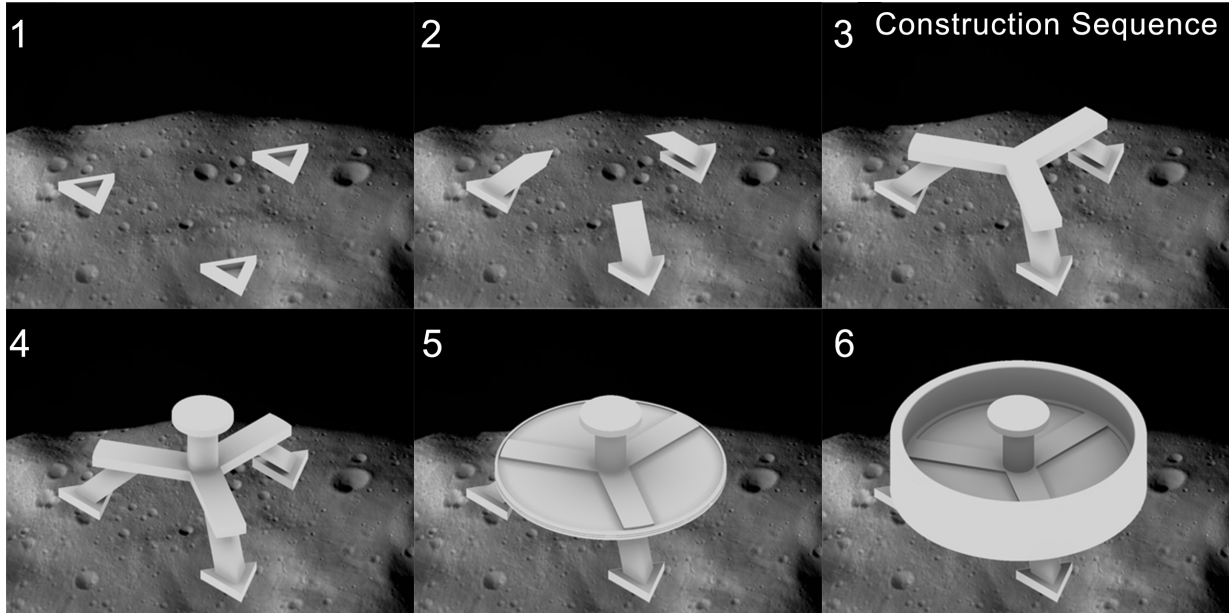


Figure 2.8

### 2.3.1 Initiation of Rotation

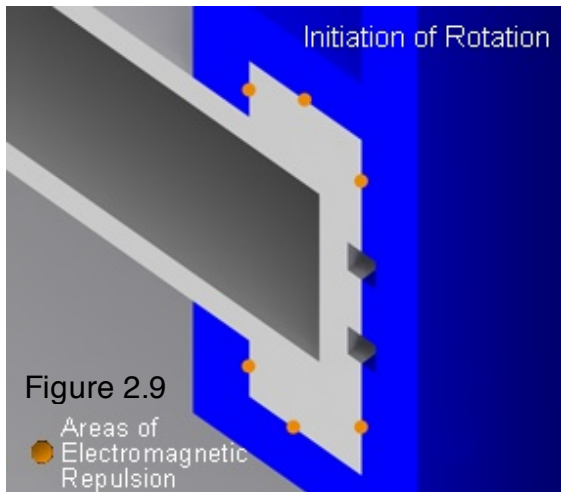


Figure 2.9

Areas of  
Electromagnetic  
Repulsion

Astoria's torus will begin rotating as soon as it is completed, utilizing the Torus' electromagnetic tether with the industrial plate to produce torque through electromagnetic induction.

### 2.3.2 Use of Materials from Asteroids in Interior Construction

In order to construct buildings inside Astoria's torus, Overhead Telescoping Cranes (5.1.1) will be used. Prefabricated structures will be winched down by the cranes and secured to Astoria's base by teams of Modubots outfitted with construction tools.

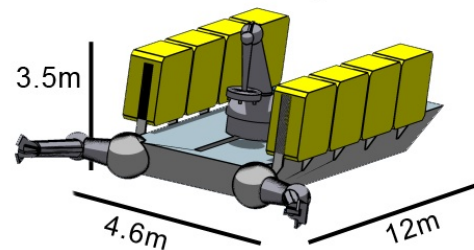
Materials used in Astoria's internal construction include carbon steel, titanium, and regolith for mooncrete.

## 2.4 Debris Impact Protection and Mitigation

The Crowe Repair Platform will be deployed at sites of significant damage along Astoria's hull. Each platform will house 12 tiles in its frame. Its two forward arms will be able to manipulate and remove foam tiles along Astoria's hull, and a 4m boom places and seals tiles into the hull. The Crowe Repair Platform is able to act via remote or direct human control and has a capacity of three crewmen.

**Figure 2.10** demonstrates damage to the outermost layer of the hull and its immediate repair. The ballistic foam tiles cover the outer two meters of Astoria's hull, split into two overlapping layers of tile with dimensions 2m x 2m x 1m (see Figure 2.11). To facilitate repair of damaged sections of tile below the outermost layer, the large boom and forward arms are able to remove tiles on the hull without damaging

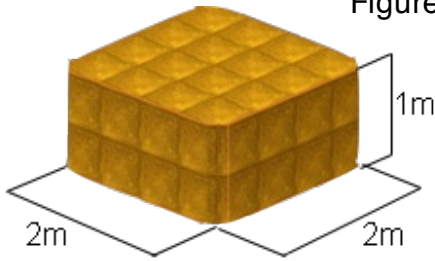
Figure 2.10 Crowe Repair Platform



other components. Once damaged tiles are removed, new tiles are moved in to replace them via jointed rails on the sides of the repair platform and the platform's boom.

#### 2.4.1 Minor Impact Shielding

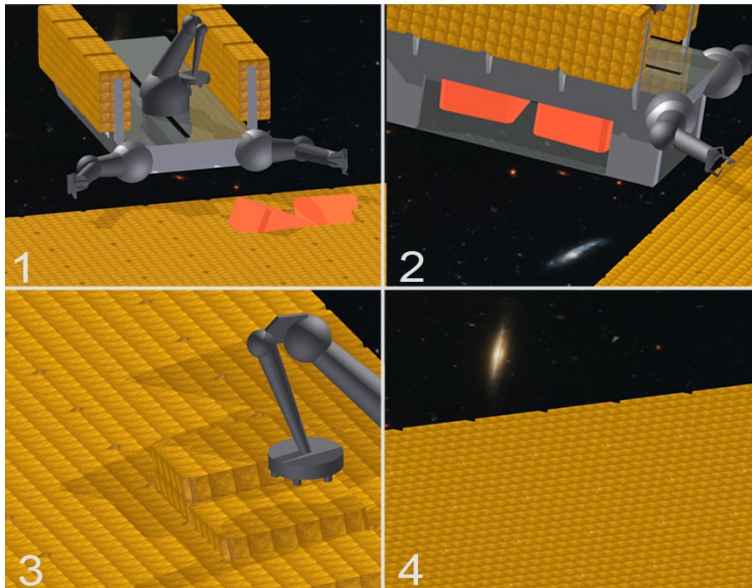
Figure 2.11 Foam



In order to protect the structural integrity of Astoria, ballistic foam tiles composed of ceramic-polymer composites will be employed to stop high velocity impacts by small objects. These tiles have a cellular structure that is built to absorb energy from harmful projectiles up to three inches in diameter, dissipating the energy and preventing it from being transferred beyond the impacted layer to the integral layers of the hull.

#### 2.4.2 Major Impact Shielding

Figure 2.12 Hull Repair



### 2.5 Mining Infrastructure

Mining settlements across Astoria's host asteroid will provide harvested resources and materials to assist in the construction of Astoria and decrease construction time and costs. Direct access to mineral deposits will provide the station with a constant stream of materials vital for all systems aboard. The combined effort of mining bases across the surface of Mathilde will not only support Astoria's initial population, but will also support Astoria's expansion, including its own population growth, new station components and volumes, and new business enterprises seeking to take advantage of Astoria's abundance of resources.

#### 2.5.1 Material Processing

Mined materials will be processed on Mathilde through simple refining and manufacturing centers in order to build Astoria's first components. Once the Carnegie Plate is complete, more expansive industrial facilities will be able to take in raw material.

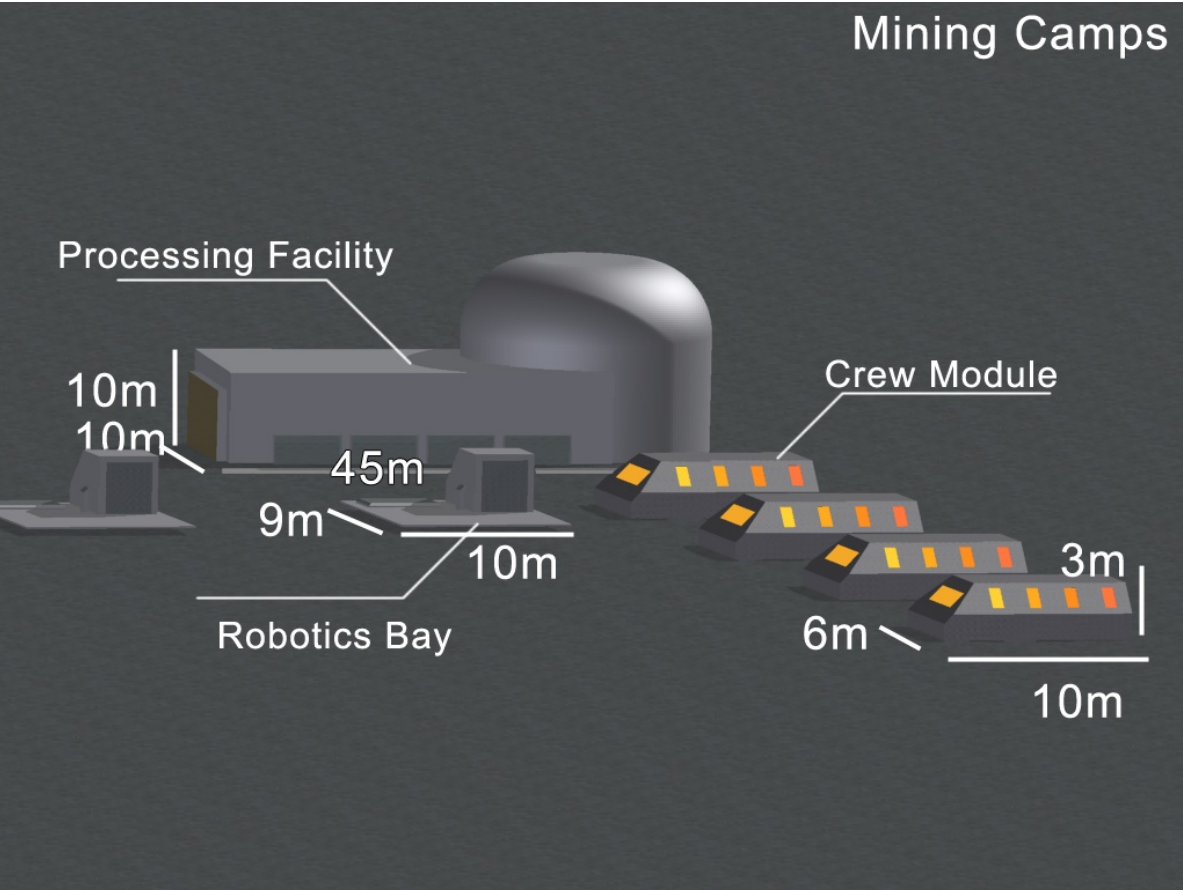


Utilization of 253 Mathilde’s resources will provide the basis for a majority of Astoria’s infrastructure and commodities. The amount of water on 253 Mathilde means that water will be easily attainable and hydrogen fuel can be manufactured.

2.5.2 Human Habitation

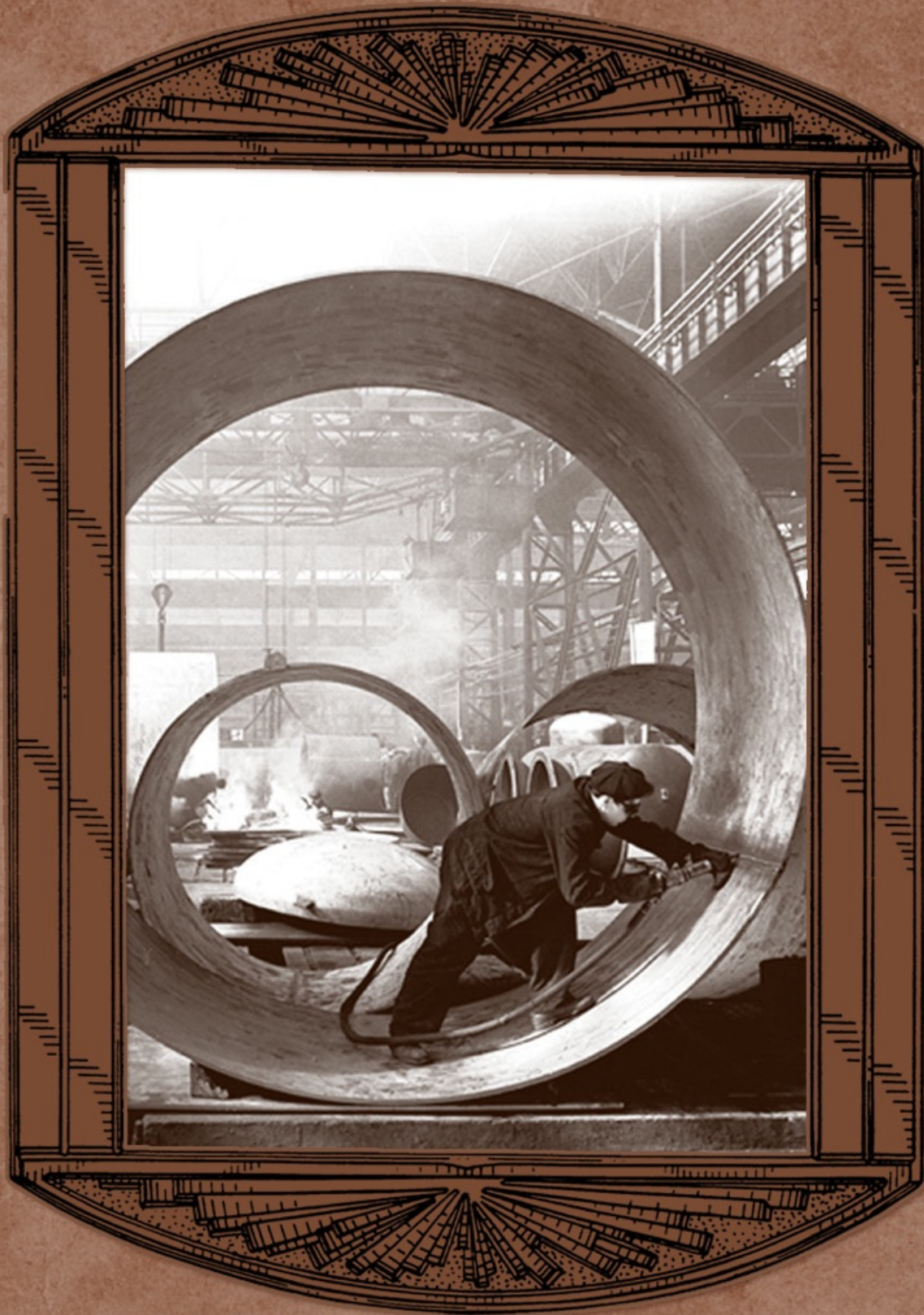
Mining camps will receive power through arrays of hydrogen fuel cells. These prefabricated camps will be manufactured inside the Carnegie Industrial plate, and shipped out via Astoria’s legs. Each camp is constructed mainly of materials mined from Astoria’s host asteroid. Mining camps include a crew quarters module, a robotics bay module, and a loading and processing center module.

Figure 2.13





# OPERATIONS



ANY SUFFICIENTLY ADVANCED TECHNOLOGY  
IS INDISTINGUISHABLE FROM MAGIC.

-ARTHUR C. CLARKE

### 3.0 Operations and Infrastructure

Station operations on Astoria will create a safe and healthy environment for the residents while providing necessary and efficient infrastructure systems for all of station’s industrial functions and processes.

#### 3.1 Location and Materials Sources

Astoria will be located on the asteroid 253 Mathilde and will utilize materials from the asteroid in construction.

##### 3.1.1 Station Location

The station will be located on the asteroid 253 Mathilde, a C-Type asteroid located in the main belt, approximately 2.5 AU away from the Sun. 253 Mathilde shows evidence of hydrated materials, useful for fuels and water; abundant silicates, to create aerogel, and a layer of regolith, useful for shielding and mining.

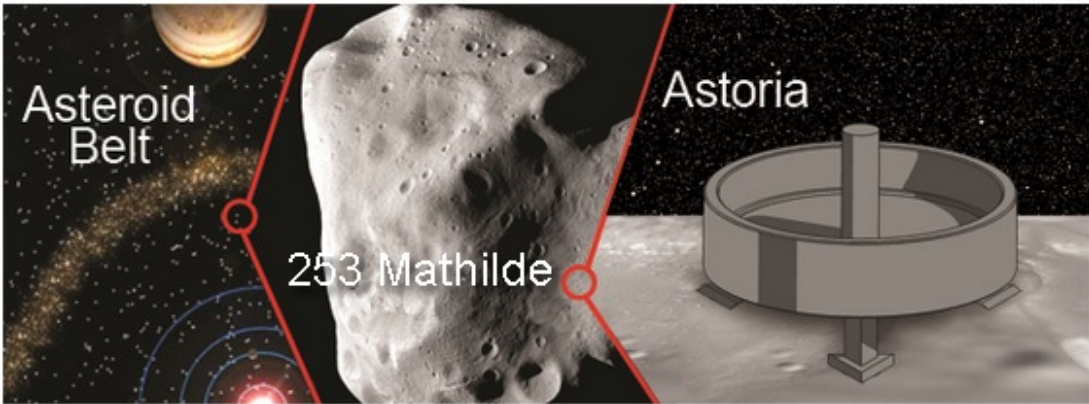


Figure 3.1 Location

3.1.2 Construction Materials and Equipment      Table 3.1

Material	Purpose	Amount (m³)	Source
*Thorium	Power supply	0.15	Aresam
Steel	water system, power system, Cyclopods	5,000,000	Mathilde; refine
PVDC plastic (Polyvinylidene chloride)	pipes, food storage	10,000	Earth
ABS plastic	meat printer exteriors and some interior components	20,000	Earth
Plastic Wires	Wires	15,000	Mathilde
Silica aerogel	food storage	1,000	Mathilde; manufacture
Titanium Oxide	catalyst for water purification	4,000	Earth
Aluminum	waste system, trains, bikes	250,000	M-type asteroids
Polycarbonate	Cyclopods,dynaponic tanks, apiary walls, interior windows	150,000	Earth
Polychloroprene Rubber	bike tires	2,000	Earth
OLEDs	lights	45,000	Earth
Carbon Nanotubes	Wire grid in Thorium Reactor	375	Mathilde

\*amount of Thorium always needed for continual power production



### 3.1.3 Means of Material Transport

Materials on Astoria will be transported through a series of pressurized tubes which use jet streams of air to propel the materials. The tubes will run along with the station’s infrastructure, hidden from view. Modutugs will be used to move ore from orbiting bodies and other mining sites to Astoria. Vehicles will transport material in cargo containers to the Eiffel Elevators located in the legs of the settlement, where they will be transported to the industrial plate.

### 3.1.4 Mining Target

The mining target will be the station’s location, 253 Mathilde, which will be mined for its hydrated materials (a rarity on C-type asteroids), silicates, and regolith. Mathilde has a mass of  $1.03 \times 10^{14}$  metric tonnes and a volume of  $7.7 \times 10^{13}$  cubic meters. The asteroid completes its orbit every 4.31 Earth years, and lies between the orbits of Jupiter and Mars, providing for easy access to Aresam. When the asteroid’s ore has been depleted, mining processes will be continued on another suitable asteroid.

## 3.2 Community Infrastructure

Station operations will allow life-support systems to function efficiently and keep the environment healthy for residents.

### 3.2.1 Atmosphere

The atmospheric pressure on Astoria will be 11 PSI to conserve on materials and the humidity will be 30% and the temperature 26 Degrees Celsius. The atmosphere will be monitored and maintained using small sensors in the ceiling (detailed in section 5.2.1) and a filtration system.

Table 3.2 Atmosphere

Gas	% of Atmosphere	Volume
Nitrogen	70.20%	71,157,685.25 m <sup>3</sup>
Oxygen	22.00%	22,300,129.28 m <sup>3</sup>
Argon	7.30%	7,399,588.352 m <sup>3</sup>
Hydrogen	0.25%	253,410.56 m <sup>3</sup>
Carbon dioxide	0.25%	253,410.56 m <sup>3</sup>
Total Residential Volume:		101,364,224.56 m <sup>3</sup>

### 3.2.2 Food Production

Figure 3.2 Dynaponics



A total of 1060800 m<sup>2</sup> will be allocated to agricultural facilities, split evenly between the first and second levels of the torus, allowing for viewing of crops and also maximum use of land area (Figure 3.2). The facilities will be capable of providing crops for 12,000 people, in addition to a surplus for use in the event of contingency (see Table 3.3).

Dynaponics will be used to grow produce on Astoria. Dynaponics uses air pumped through a shallow reservoir solution to spray roots. This reduces energy costs while reducing root rot, water consumption and crop diseases, and also increasing the rate at which plants can absorb

nutrients and water, compared to traditional farming and methods such as hydroponics. Produce will be harvested, processed and packaged by an automated system (see section 5.2.1)

In bioprinters, live cloned cell solution will be printed with a non-toxic supportive gel medium to give it a 3D structure. This cellular tissue will be the basic meat, which will then be stimulated with an electric current to flex the proteins and mimic muscle use, to provide a proper texture. During this process, nutrients such as fats and vitamins may be added or removed to create any desired final product. Products such as beef, chicken, fish, and pork can be produced in this way.



Produce will undergo a pressure-assisted thermal sterilization process, which will maintain food quality and safety, before being subsequently stored in silica aerogel crates, which are made from mined minerals on Astoria. Produce can be delivered fresh, refrigerated, or frozen by demand. Meat will be packaged in vacuum sealed containers and refrigerated or frozen. All food will be stored in the basement underneath neighborhood distribution centers, based on average demand for the area. Food will be purchased from and delivered to neighborhood distribution centers. All distribution centers are interconnected so as to ensure all food supplies are available to consumers. which utilizes a series of pressurized tubes that will transport goods between manufacturing facilities, storage, and the consumers at the kiosks.

Table 3.3 Food Production

Product	Grams/person/day	*Total kg produced/year	Total kg contingency per year
Grains	400	1679000	1679000
Fruits	350	1469125	1469125
Vegetables/Legumes	450	1888875	1888875
Meat Products	175	734562.5	734562.5
<b>TOTAL</b>	<b>1375</b>	<b>5771562.5</b>	<b>5771562.5</b>

\*Assuming population of 11500 people

Contingency amounts assume normal consumption of an at-capacity population for 12 months. This will give ample time for dynaponic systems and meat printers to come back online and begin to produce new crops. Contingency foods will be freeze dried or frozen, based on type, and stored in silica aerogel crate. An additional total of 1505625kg will be produced yearly to provide visiting ships with supplies of food.

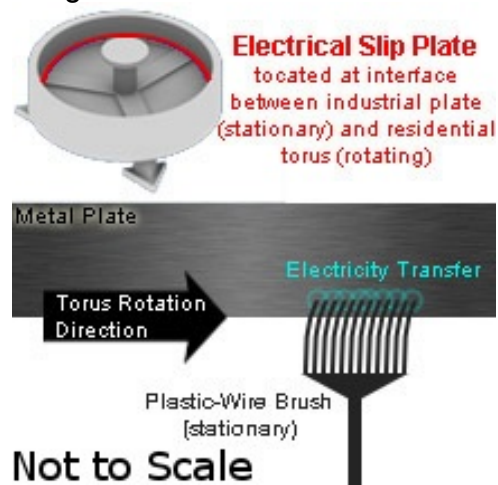
### 3.2.3 Power

Power on Astoria will be produced by a Thorium nuclear reactor in the industrial plate with a grid infrastructure comprised of carbon-nanotubes, efficient conductors which will limit collateral damage in the event of system failure. The carbon-nanotubes will be cheaply made from Carbon gathered from Mathilde, and Thorium will be imported from Aresam. A (Th-232) Thorium reactor will be used over a conventional Uranium- or Plutonium-based reactor to minimize reactive waste and offer more control over the reaction, as a Thorium reactor cannot undergo fission or sustain a reaction without external assistance. To facilitate the high volume of power being produced, a SMES (Super Magnetic Energy Storage) system will be used to allow power at peak production times to be reserved for peak consumption times. In case of system failure, a backup array of batteries will be utilized until the problem can be alleviated. A total of 2,000,000 kW will be produced. Table 3.4 Power Allocation

Uses	Allocation
Residential	25,000 kW
Industrial	1,500,000 kW
Agricultural	50 kW
Life-support	5,000 kW
<b>Total</b>	<b>1,530,050 kW</b>

Electricity will be distributed through the station via two methods-- Witricity and a system of plastic wires. Witricity is wireless conduction of electricity, which allows for power to be sent throughout the residential torus without large masses of infrastructure-- just strategically placed antennas. Plastic wires contain fibers of copper microns thick in a polymer medium and are 80% lighter than metal wires, conserving expensive materials without a sacrifice in

Figure 3.3



efficiency. Plastic wires carry electricity from power generation in the industrial plate into the residential torus using an electrical slip disc (see figure 3.3). The total power consumption of Astoria will be 1,530,050 kW.

### 3.2.4 Water

Figure 3.4



For residential water treatment, Astoria will use a natural water system which utilizes an Aerobic process, UV lights, and conventional filters for purification. The system will be modularized by floor, as opposed to a centralized system, to reduce the possibility of station-wide failure. The systems will be readily linkable to a shared floor-reservoir for this purpose. The halls of each floor will feature a glass-bottom floor pond serving both a practical and aesthetic purpose. Waste water from buildings will first be filtered for visible solid and liquid wastes, and then forwarded to the ponds for natural purification from bacteria and plant-life. After this water is forwarded to a housing tank where it will be filtered again and treated with UV light to ensure it is pure before being forwarded to the reservoir. Special microbial fuel cells will be placed in the soil of the ponds to help produce electricity to power water systems.

The industrial water system of Astoria will use a dual water treatment system that utilizes electrochemical oxidation and photocatalysis. It will be contained in a centralized system separate from the residential system, to avoid any chance of contamination and for stronger treatment of the industrial waste water. The purification method uses two types of electrodes, one for each method: an electrochemical electrode to create an electric current and another to fire UV light at a titanium oxide catalyst which in turn oxidizes the pollutants. The electric current from the electrochemical electrode helps boost the efficiency of the photocatalysis method in keeping it from reverting from the oxidized state. The water is then filtered until it is clean enough to be reintroduced into industrial processes. Astoria's water system will require 1,500,000 liters of water.

Purpose	Amount
Industrial	800,000 liters
Residential	250,000 liters
Reserve (residential torus)	350,000 liters
Agricultural	82,000 liters
<b>Total</b>	<b>1,500,000 liters</b>

Table 3.5 Water Allocation

### 3.2.5 Waste

Station waste will be treated with the Thermal Conversion Process (TCP). The process will use heat, water and pressure to transform organic and inorganic wastes into oils, gases, and carbons. The TCP will be used due to its approximately 85% energy efficiency and ability to generate a portion of its own energy. Additionally, the TCP will produce no uncontrollable emissions or secondary hazardous waste streams. The industrial plate and residential torus will each have their own identical system.

Once separated from recyclable waste (which is processed in the industrial torus), waste will arrive at the treatment facility by means of a sewer system centralized in the basement or trash chutes from residential areas. From there, the waste will be fed into a hydro-pulper, where it will be homogenized and blended with water. The mixture will then be pumped under pressure through heat exchangers to a

first stage reactor, where it will be heated to the desired temperature. Next, the processed material will enter a flash vessel where water will be vaporized and re-used within the system. Steam will exit through the top of the vessel, the solid material component will be removed from the bottom, and the remaining organic liquid will continue through the process. The vaporized organic mixture will travel through heat exchangers and will pass to a cooker, where it will be pressurized and the temperature will be increased. The organic mixture is reformed into fuel gas and light oil, and non-volatile organic compounds. Fuel gas will leave the reactor, pass through a heat exchanger and then through a condenser where it will be cooled. The cooled fuel gas and oil mixture will then separate. The fuel gases, oil, and carbon will then be sorted and sent to their respective storage areas.

Source	Approximate Amount of Waste Processed (tonnes/year)
Residential	7,700
Industrial	4,500
Agricultural	550
Total	12,050

Table 3.6 Waste Processing

### 3.2.6 Communications

The main communication hubs of Astoria will be located on the top and bottom of the Sullivan Tower, with smaller sub-hubs on the residential torus. These hubs will form the primary method of communication with external facilities, including existing settlements. These hubs will make use of laser transmitters to exchange messages with five relay satellites in orbit around Mathilde.

Table 3.7 Communication Devices

Type of Device	Number of devices needed	Location of devices
Personal Devices (user chooses style, see 5.3.4)	12,000	On persons
Fiber optics backbone (see 5.3.4)	1	Throughout Astoria
M.A.N. network (see 5.3.4)	1	Throughout Astoria
Communication satellites	5	In proximity of station

### 3.2.7 Transportation

Transportation on Astoria includes three types-- bicycles, Cyclopods, and a train. The bicycles are checked out from stations throughout Astoria. A user may use the bicycle to get to their destination, or may use the bike within a Cyclopod unit. The biker approaches a fully automated Cyclopod center and they ride into a locking station, where their bike is enclosed in a pod. The pod then begins to move with the continued pedaling of the user. The Cyclopod path allows for little friction and greater aerodynamics, allowing for a maximum speed of 30km/h while also reducing street level traffic, decreasing travel time. The user may choose to have their movements amplified by the Cyclopod, or, in the case of children or the disabled, may have a fully automated Cyclopod. If the user desires, from there they can request to board the train from their Cyclopod. The pod will automatically speed up without an increase in effort required from the user and will catch up to the train's speed, where it will enter the side of a train cabin and attach to the train, using the train's power to continue traveling. To exit the system, the user requests to leave the train, uses a Cyclopod to reach a



Figure 3.5 Bike

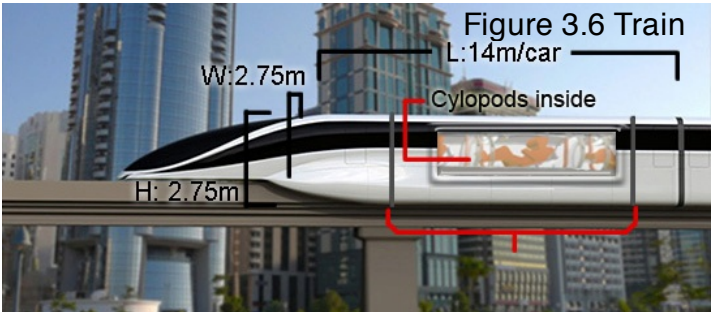


Figure 3.6 Train



Figure 3.7 Cyclopod



slower speed, and exits the Cyclopod via a Cyclopod station, and may check the bike back in at a bike station.

Should an emergency arrive requiring ambulances, a multi-person pod similar to Cyclopods (the Emergen-C railway, see 4.1.3), but entirely automated, arrives by Cyclopod paths with priority access to the pathways.

For route information, see section 4.1.1

Table 3.8 Vehicles

Vehicle	# of Vehicles	Capacity (persons)	Dimensions
Cyclopods	4,500	1-4	4.5 m x 1.25 m (up to 4 Bikes each)
Bicycles	7,000	1	2 m x 0.5 m
Electric Trains	1	1000	14 m x 2.75 m x 2.75m (6 Cyclopods per Car )

### 3.2.8 Day/Night Cycle

The Day/Night cycle on Astoria will be a 24 hour cycle and make use of an OLED screen covering the entire ceiling of the station, producing synthetic sunlight, which will vary in intensity as time progresses throughout the day. The amount of sunlight during the day will be modeled after that of Earth to replicate the seasons and provide an environment akin to Earth's sunlight for the population. The day and night will each be 10 hours long, with two light transition periods, each 2 hours long.

Table 3.9 Day/Night Schedule

Phase	Length	Time Frame
Day	10 Hours	5a.m. - 7 a.m.
Day to Night Transition	2 Hours	5 p.m. - 7 p.m.
Night	10 Hours	7 p.m. - 5 a.m.
Night to Day Transition	2 Hours	5 a.m. - 7 a.m.

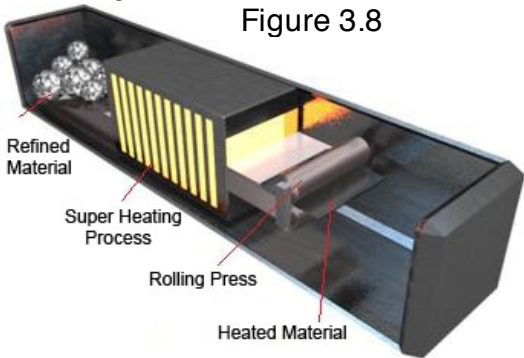
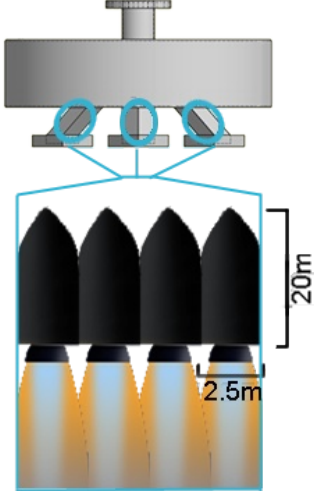


Figure 3.8

### 3.3 Construction Machinery

Raw materials for the construction of Astoria will be transferred from the mines to Hot-Boxes in the space surrounding the station during construction. The raw materials will enter one

Figure 3.9 Propulsion



end of the box, and will be superheated to allow for manipulation of the material's shape. Hotboxes will have a special preset design for forming the desired piece. Accompanying the Hotboxes will be a fleet of Modubots designed to maneuver in space for the construction period. Grip-Modubots (see 5.1.2) will handle the super heated material from the Hotboxes and bend it further if necessary into the desired shapes for the station's infrastructure. The pieces will then be welded into place with Weld-Modubots.

### 3.4 Settlement Relocation

To propel Astoria from Mathilde in case of emergency, Astoria will utilize a two stage process. First, the station legs will detach from Mathilde, followed by the activation of 150 Liquid CosmoLOX engines evenly

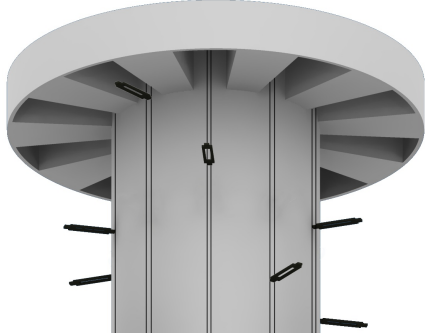


distributed about the leg bases, generating a total of 62,597 MN of thrust. Astoria will accelerate away from Mathilde at  $0.014 \text{ m/s}^2$  over 345 seconds, consuming  $5.88 \times 10^6 \text{ kg}$  of liquid fuel in the process and moving the mile needed within the given time frame. The boosters will use liquid hydrogen and oxygen fuel produced by the settlement from materials mined from Mathilde.

**3.5 Ore Reception from Foreign Facilities**

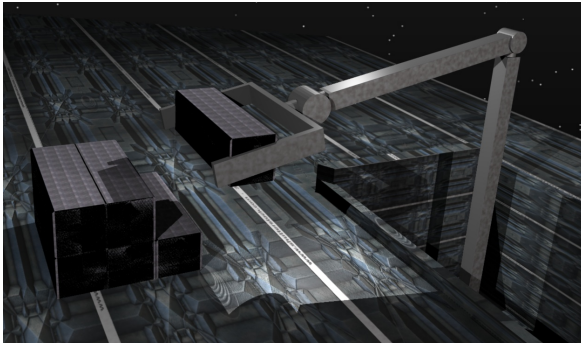
Operations on Astoria will provide the infrastructure necessary for receiving and handling ore from the asteroid and from other surrounding locations.

Figure 3.11 Port Facilities



will facilitate ease of access between incoming materials and material-processing centers, reducing overall transfer times.

Figure 3.10 Ore Handling



**3.5.1 Port Facilities**

The port facilities of Astoria are on are on the top and sides of the Sullivan Tower and on the top surface of the industrial plate. The docking facility on the industrial plate surface will be the location for accepting ore from other mining stations. This

**3.5.2 Ore Handling Processes**

Ore sent to Astoria will be shipped to the top surface of the industrial plate. The materials will be unloaded by robots that will bring the materials inside the plate to be refined. After refining the materials will be shipped to where they are needed the most.



# HUMAN FACTORS



COMING TOGETHER IS A BEGINNING;  
KEEPING TOGETHER IS PROGRESS;  
WORKING TOGETHER IS SUCCESS.  
-HENRY FORD



## 4.0 Human Factors

On Astoria, it will be vital to keep the humans A.H.H. “Alive, Healthy, and Happy,” whilst they pioneer to the desolate midst of the solar system. By designing and continuously innovating new technologies, the pioneers will be able to sustain an oasis in the middle of vast nothingness by replicating precious traits original to Earth.

### 4.0.1 Natural Views

Due to the perpendicular orientation of the torus comparatively to the asteroid, the natural views for the residences facing the asteroid will be disorientating. To counteract this, the side facing the asteroid will not have access to the natural views of space and will be the commercial area. The roof of the station will be composed of OLED lights and will paint an image of a natural Earthen sky. The side facing space will have natural view of space by a lunar glass for the residents to gaze at.

### 4.0.2 Transit Routes

To prevent head turning, all routes and paths will be in a straight line -- opposed to curves -- so the resident does not have to crane their neck.

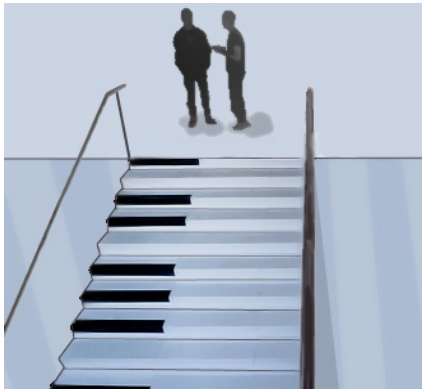


Figure 4.2 Piano Stairs

Due to the small size of the station relative to a standard city, walking will be encouraged as a primary source of transportation. To encourage walking, stairs will be electronically rigged to produce aesthetic sounds to make walking up stairs an enjoyable task. The theme of the stairs will be interchangeable over time for variety to entertain the residents. The sounds of the stairs could be a piano one week, a woodwind instrument the next, or be themed for the spring season with the sound would be birds chirping.

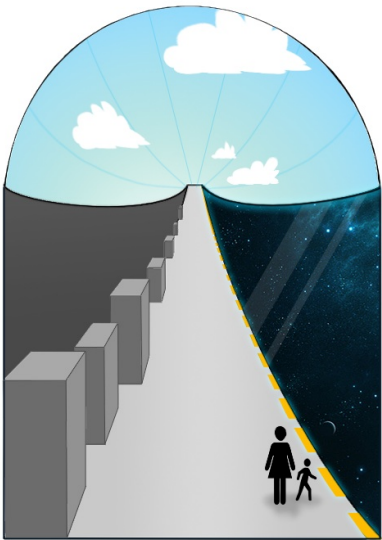
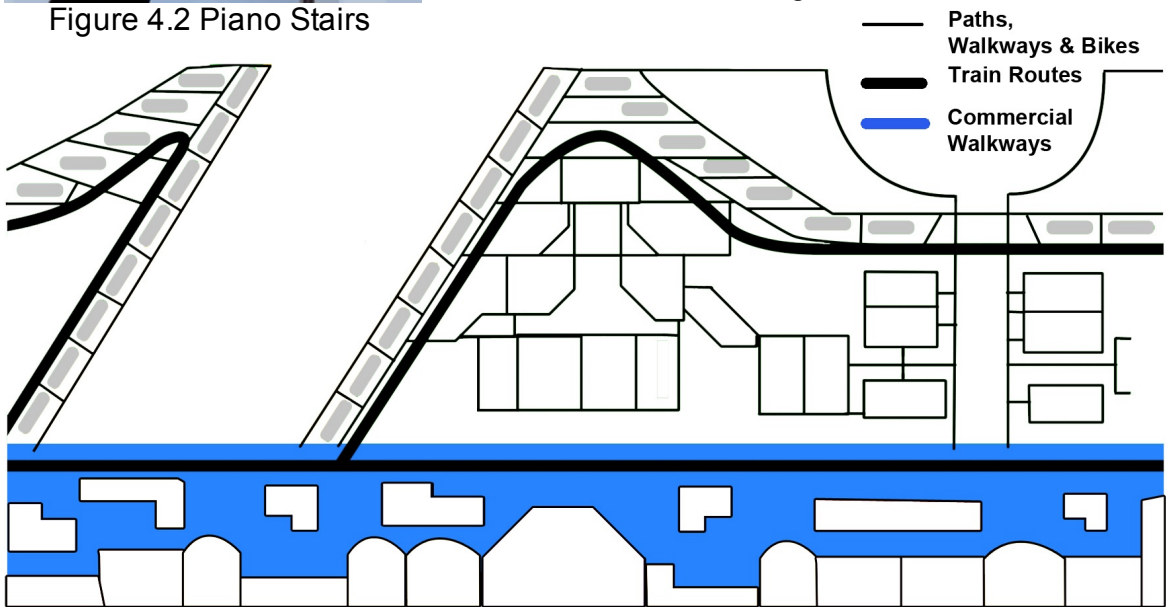


Figure 4.1 Natural Views

Figure 4.3 Transit Routes



Bicycles and Cyclopods (see section 3.2.7) will provide an excellent secondary choice for traveling to a given location. They are able to access the bottom floor of the residential area, are an excellent source of exercise and can transport the user to their destination.

**Emergen-C Railway**

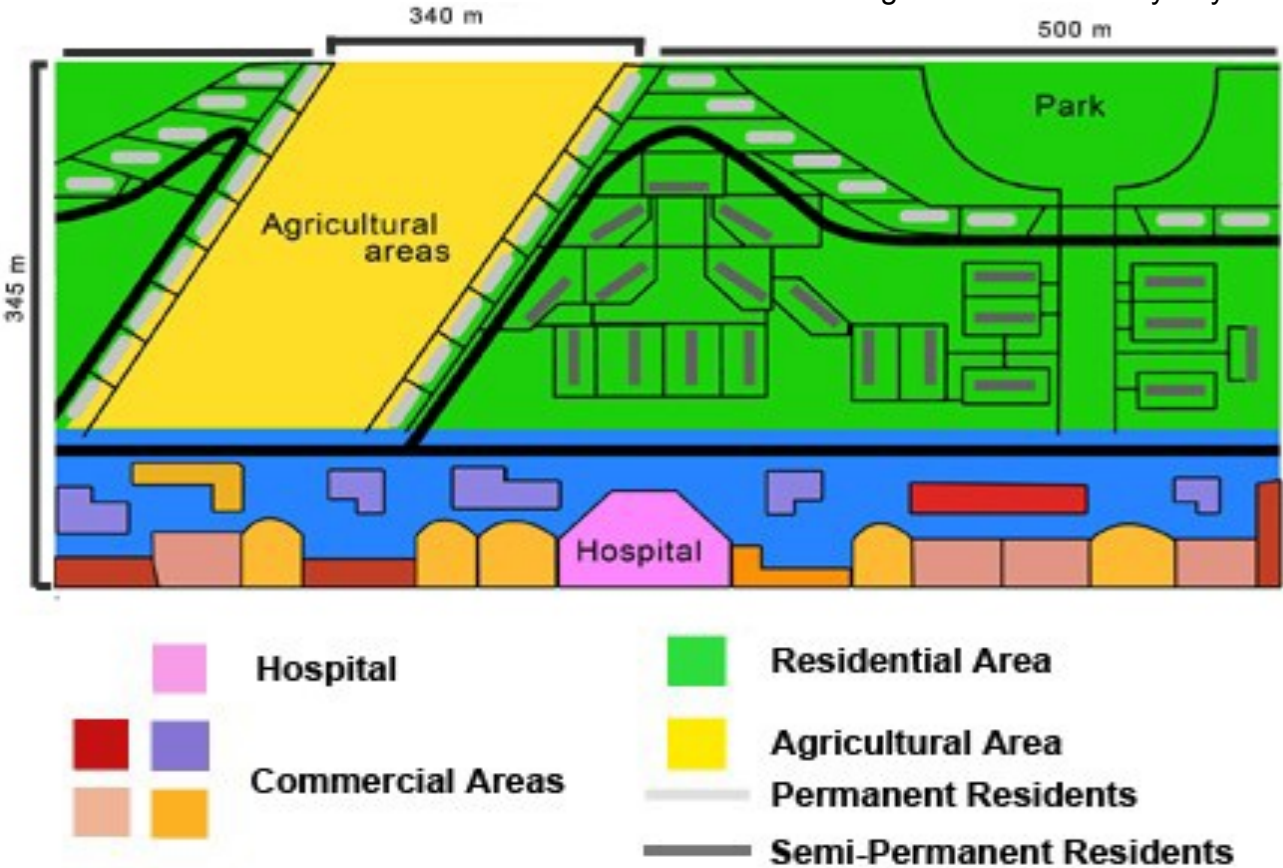
Cyclopods will be capable of engaging an emergency mode where the Cyclopod becomes fully automated and takes the most direct path on any type of path to a hospital or contingency area in the event of evacuation.

**4.1 Community Design**

Community layout will be divided by themes that complement one another. The themes of the residential area will be evenly divided between Exhibit Earth and the Prosperous Twenties. Exhibit Earth is inspired by Astor's patronage to the arts and provides an artistic reminder of the diverse cultures of home. The Prosperous Twenties is inspired in accordance to the time period in which John Jacob Astor's luxurious lifestyle thrived in American society. The commercial area of the station will be Manhattan Street, inspired by Astor's subtle growth in wealth of investments in Manhattan. The layout is designed for efficient transportation, and will ultimately give the residences the warm comfort of their home on Earth. These designs allow distinction between areas.

**4.1.1 Community Layout**

Figure 4.4 Community Layout





The parallelogram orientation of the residential and agricultural areas will give natural views to the permanent residential homes. The agricultural areas between the residences will serve as a distinct border between neighborhoods.

Table 4.1 Space Allocation

Space Use	Surface area required, m <sup>2</sup> /person	Estimated height, m
<b>Residential</b>	49	3
<b>Business</b>		
-Shops	2.3	4
-Offices	1	4
<b>Public and semi-public</b>		
-Schools	1	3.8
-Hospital	.3	5
-Assembly	1.5	10
<b>Recreation and entertainment</b>	1	3
<b>Public open space</b>	10	50
<b>Transportation</b>	12*	6
<b>Storage</b>	5	3.2
<b>Miscellaneous</b>	2.9	3.8
<b>Agricultural space</b>		
-Plant growth areas	44	15
-Food processing, collection, storage, etc.	4	15
-Drying Areas	8	15
<b>Total:</b>	142 m <sup>2</sup> /person	

\*4.5% of the station's down surface area will be dedicated to roads and paths.

#### 4.1.2 Consumer Goods and Distribution

There will be two hospitals on Astoria equally placed apart to provide optimum access in case of an emergency from any point on the station.

Astoria will provide a plentiful variety of foods for the wide demographic of people on the station. Residents will be given a warm reminder of their home though a variety of different foods, such as Italian, Hispanic, Japanese, Vegan and many more. Astoria will use synthetic meat as a substitute in cultural dishes. Synthetic meat will be created by taking proteins from Earth and cultivating them to a larger output and healthier form. Residents of Astoria will consume a large number of Calories in the morning, and taper off their caloric intake throughout the rest of the day.

Table 4.2 Nutrition

Demographic	Calories	Calories	Calories	Calories	Calories
	Breakfast	Lunch	Dinner	Snacks	One day's total
<b>Women</b>	798	698	598	106	2200
<b>Men</b>	1182	1032	882	104	3200
<b>Children</b>	745	655	565	105	2070

Major materials such as toiletries, clothing, food, and medicinal supplies will be produced on Astoria as well as on Earth. Medicinal supplies, like herbs such as chamomile, aloe, and ginger, along with other compounds needed for medicinal purposes, will be produced by Astoria's agricultural facilities. Those which cannot be supplied by the station will be shipped from Earth.



Category	Source	Amount Produced	Description
Toiletries	Earth	2,025,704 items	soap, toothbrushes, hairbrushes, makeup, toothpaste and personal hygiene products.
Clothing	Earth	3,375,463 products	shirts, pants, jackets, socks, undergarments and spacesuits
Food	Astoria	183,575 kg	meats, vegetables, fruits, grains and legumes
Medical Supplies	Earth and Astoria	655,926 products	Prescription and over the counter medications, herbal remedies, hospital supplies

Table 4.3 Consumables

On Astoria, residents will maintain their food supply through a neighborhood Distribution Center. All orders can be specified and placed remotely by calling up the Distribution Center via interface ring, or the center can be visited in person by the resident. The entrance of the Distribution Center will serve as a reception area for receiving calls and greeting customers; this area will also be used for product pickup and placing orders. The back of the store will stock all food supplies. The Distribution Center will prepare and package orders in about half an hour. After this time, the goods will be delivered to the resident's doorstep or be available for pickup.

#### 4.1.3 Residential Services

For entertainment, residents on the station will be provided with in Zero-G games and activities, which can produce any number of games from human pong to basketball depending on the preference of the resident. Zero-G entertainment includes interactive holograms of museums, streamed live concerts, movies, malls, and other forms of casual entertaining events as well.

Taking into consideration the professions on Astoria, there will be education programs to assist residents in their careers or career training, present opportunities for relaxation, provide athletic courses, and offer up the chance to take creative courses. "Progressive Locomotive Aiding Youth," (PLAY) will provide education daily for four hours to all children and teenagers in grade school. Classes focusing on subjects that will train future engineers and workers will also be provided for children and teenagers aboard PLAY.

#### 4.1.4 Parks

There will be a focus on making exercise fun for all residents in the station to motivate exercise. Psychological studies have proved entertainment in exercise motivates persons to work out. The parks will incorporate opportunities for exercise for both children and adults. Each park will have a jungle gym with a different combination of monkey bars, cargo netting to climb, balance beams, obstacle courses, and other various forms of entertainment. Once every two months, the parks will be rearranged automatically to provide variety. The focus will be to exercise the neck, the arms, and the legs since those are the areas of the body that experience the most loss in bone mass. There will be tracks and trails for runners, walkers, and bicyclist to use. Parks will also have basic exercise equipment for adults in the parks to use; such as stair machines, pull-up bars, balance platforms, and sit-up areas.

Figure 4.5 Park



## 4.2 Residential Design

Residents on Astoria will be able to live a pioneering life in space while also always being comforted by the familiarity of home.

### 4.2.1 Residences

**Population Table 4.4**

Nominal Population	Total Population	Expected Inflation Rate at Maximum 20%
Married Adults	3,450	4,140
Single Men	4,255	5,106
Single Women	3,105	3,726
Children (under 18)	690	828
Women	4,830	5,796
Men	5,980	7,176
Total population	11,500	13,800

**Housing Table 4.5**

Demographic Focus	Room Space	# of Buildings	Stories	Persons per floor	sq.ft per floor	total sq.ft
Transient	500 ft <sup>2</sup>	3.5*	5	32	20,700 ft <sup>2</sup>	64687.5 ft <sup>2</sup>
Semi-Permanent	800 ft <sup>2</sup>	125	5	8 singles, couples, or families	7900 ft <sup>2</sup>	1987500 ft <sup>2</sup>
Permanent	1100 ft <sup>2</sup>	375	4	4 singles, couples, or families	5900 ft <sup>2</sup>	2212500 ft <sup>2</sup>

\*To accommodate for the amount of transients, the last building will only be 3 stories

Each resident will be able to choose their housing style based on personal preference. Permanent residents will be given priority, followed by semi-permanent and transient, respectively. Every residence home will have mobile walls so the resident can design their room as they wish to meet their desired customizability.

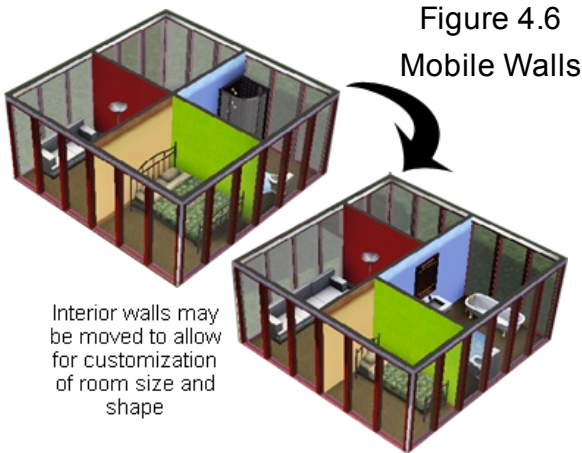
#### Neighborhoods

The residential area will be divided between the themes: Exhibit Earth and the Prosperous Twenties. And the commercial area of the station will be Manhattan Street. Communities will include glass bottom floors ponds (see section 3.2.4) outside of each apartment building to provide calming aesthetics -- yet its true purpose is for water management.

Astoria will contain many innovative features that give remind one of home as well as giving the wonders of space. Cork flooring is easily replaceable as well as being simple to maintain.

Transients will be placed in standard-sized apartments to save space. Each room will be pre-furnished for the convenience of a quick move-in and move-out for the resident. See 4.5.1 for images of the Transient living areas.

Semi-permanent residences will consist of either pre-furnished or manually designed apartments, per resident request. This will allow for a custom interior design, while still facilitating easy move-ins and move-outs.



**Figure 4.6**  
**Mobile Walls**

## Semi-Permanent Residences Homes

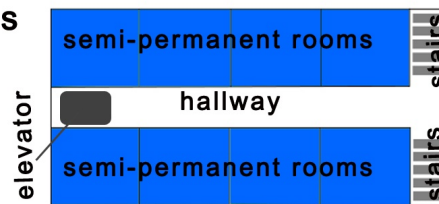
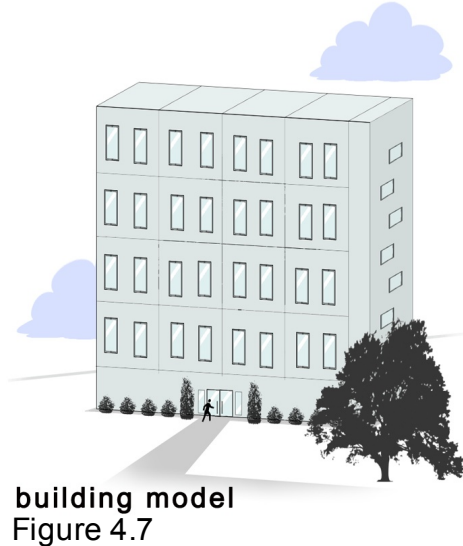


Figure 4.8 apartment floor

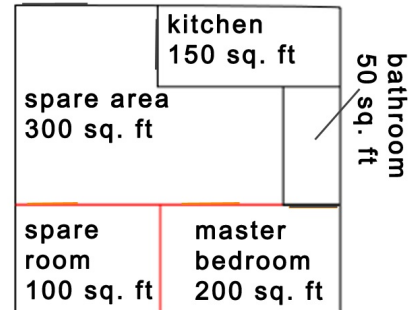


Figure 4.9 floor plan 800 sq. ft

Permanent residences will be comprised of single family penthouses and moderately sized apartments.

## Permanent Residence Homes

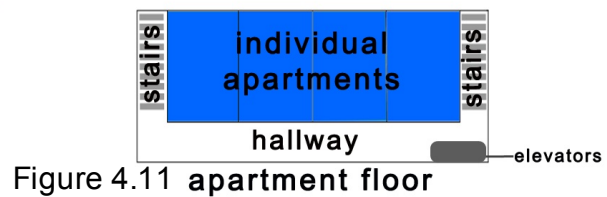
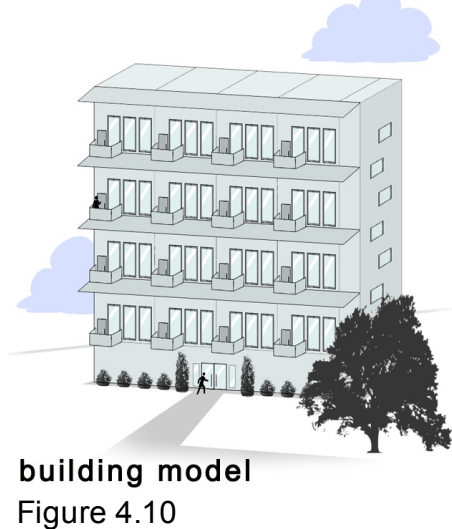
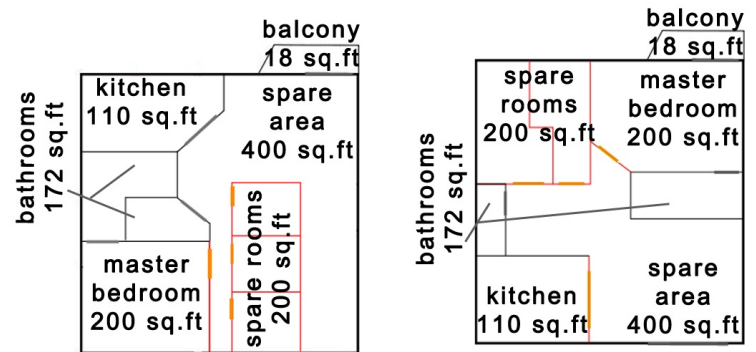


Figure 4.11 apartment floor



floor plan A 1,100 sq.ft

Figure 4.12

floor plan B 1,100 sq.ft

Figure 4.13



**4.2.2 Materials Sources**

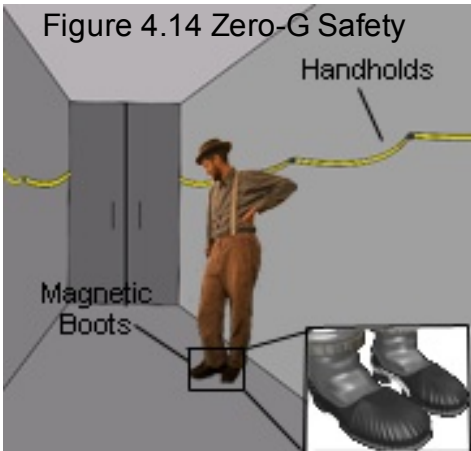
Goods that will be brought from Earth are fabrics and various flooring. Such flooring consists of cork, hardwood and carpets. Most furnishings will come from Earth, since materials needed to make such furniture are not wide available on Astoria -- with the exception of bamboo furniture.

**4.2.3 Residential Technologies**

Every residence will live in a computerized home that will accommodate for the residences needs. Sensors on the floors will also be featured in buildings that can turn lights on when someone enters a room and may also be used for games, but may also be manually turned off. The computerized home will also moderate air currents so there will never be a complaint of air temperature ever again. Bots will help out with house work and do dull tasks or repairs faults. (See 5.1.2 for more details)

Table 4.6 Furnishing

Furniture	Quantity (Pieces)
Bed	9,775
Couches	9,085
Shower/Bath	9,085
Toilet	9,775
Sink	9,085



that monitor vitals. In the event that a resident is in need of emergency medical aid, assistance will be dispatched immediately.

**4.3 Zero-G Accommodations**

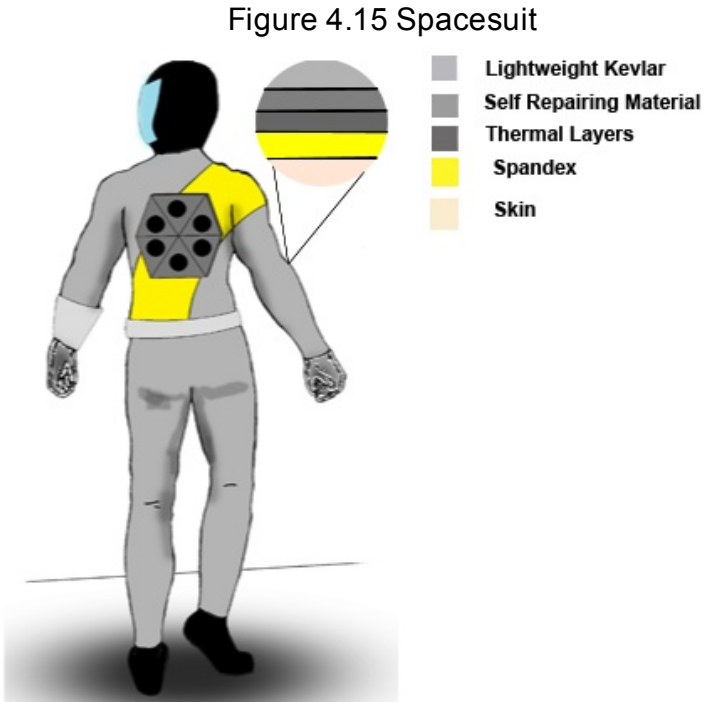
Zero-G safety is an utmost priority on Astoria to tend to the residences. With innovative technology, Spacesuits and Airlock Systems defend the colonists from the dangers they could potentially face.

**4.3.1 Zero-G Safety**

Zero-G Safety will focus mainly on ropes, tethers, and magnetic boots used by industrial workers to transport them from one point to another in Zero-G safely. The magnetic boots will have the option of being turned on and off depending on the situation of the wearer. Health in Zero-G will be monitored using implanted chips on the back of the hand

**4.3.2 Spacesuits**

The space suit will be a mechanical counter pressure suit composed of four layers that will completely cover the wearer except for the head, hands and feet. The first layer will be composed of spandex, which will allow the wearer to move with flexibility while performing tasks. The next layers will be compressed thermal material used to protect the wearer from the dangerous temperatures in space. The third layer will be a self repairing material thick enough to mitigate possible debris damage, while the final layer of the suit will be lightweight Kevlar used as the primary user protection. Donning and doffing will take place in the airlocks. The helmet of the space suit will have an



attachable screen that will cover the face and be used for any memos, tasks lists, or guidelines to assist the wearer. A utility belt secured around the waist will hold any tools or necessities needed by the wearer. An armband will be worn on the left arm and used for communication purposes. A jet pack system controlled by the user via the screen/helmet will be worn on the back and used for transportation. In the event that the user is rendered unconscious, the jet pack will automatically pilot the user to safety. Any additional protection or equipment, such as tools being carried, will be able to be added or removed depending on the tasks to be carried out by the wearer.

### 4.3.3 Airlock Design

External exploits will be regulated through air locks. The main chamber houses the control booth, as well as suit storage. Settlers will enter and exit the station through a revolving decontamination chamber.

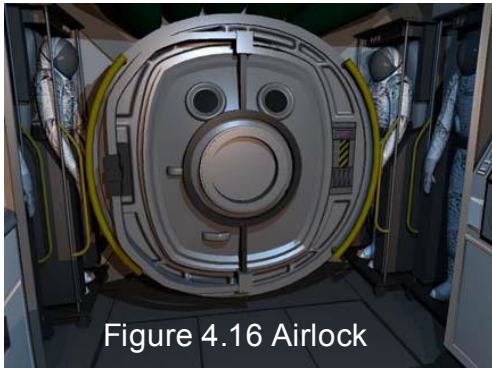


Figure 4.16 Airlock

When entering the station, colonists will undergo decontamination before exiting to the main chamber at 2 psi per minute. In the main chamber, colonists may doff and store their space suit. The air lock containment chamber has a maximum capacity of 30 colonists and will be cleaned after every 30 colonists go through the airlock. Magnets will attract colonists' accumulated small metal dust from all sides with and finally create a vacuum to catch any stray non-charged particles.

Colonists will prepare leaving pressurized areas to non-pressurized areas when they put on their suit 30 minutes before leaving for work. The suit will slowly decrease the pressure of the suit to accustom the user. Upon reaching the airlock the colonists will enter the chamber to exit at 0.5 psi per minute. The exit chamber has a maximum capacity of 30 colonists.

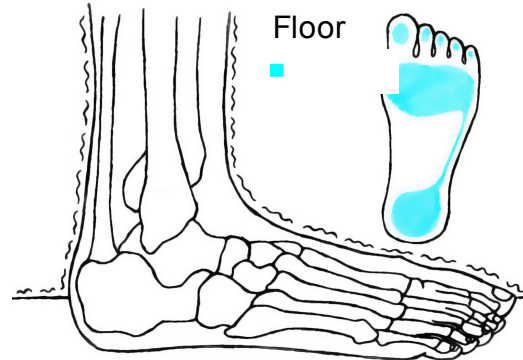
## 4.4 Gravity Accommodations

Adults prefer living in less than 1G, but because children require time spent in 1G for proper bone development they will receive gravitational therapy while in school.

### 4.4.1 Adults

Humans living under less gravity than Earth's often experience a loss in bone and muscle mass. By giving optional small vibrating floor pads, that vibrate at minuscule levels, to the residents of the station, they will be able to receive exercise to the muscles while going on with their daily routines. This happens because putting pressure on the bones, causing them to produce more bone cells, which cuts down the amount of time it takes to counteract the effects of microG, which typically takes two hours of exercise. To prevent loss of mass in bones, Calcium will be supplemented in dietary consumables.

Figure 4.17 Vibrating



#### 4.4.2 Children

To provide children with their daily 1g, Astoria will combine school in the process of gravity therapy. A train on the border of the commercial and agricultural/residential area will travel at a speed of 55 km/h, 1.05 rpm around and in the same direction as the torus, increasing perceived gravity due to higher rotations per minute. Named the Progressive Locomotive Aiding Youth (PLAY), the train will be a school running for a normal school day; 8:00 a.m. - 12:00 p.m. Combining education with the necessary gravity simulation, PLAY takes the focus off of gravity therapy and transforms it into a healthy educational experience.

PLAY floor plan      Figure 4.18



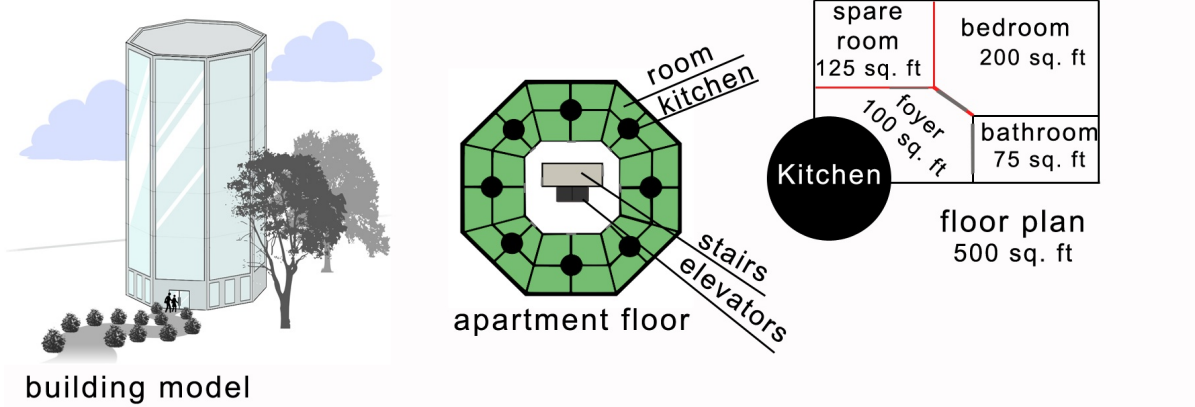
### 4.5 Transient Residents

Transients will have job opportunities in industry and research, and will be thoroughly immersed in the Astorian culture through recreational activities that bring the community together.

#### 4.5.1 Housing

Transients will be placed in apartments with other transient residents where four residences they will have separate rooms and share one large kitchen. In doing so, Astoria is able to save space.

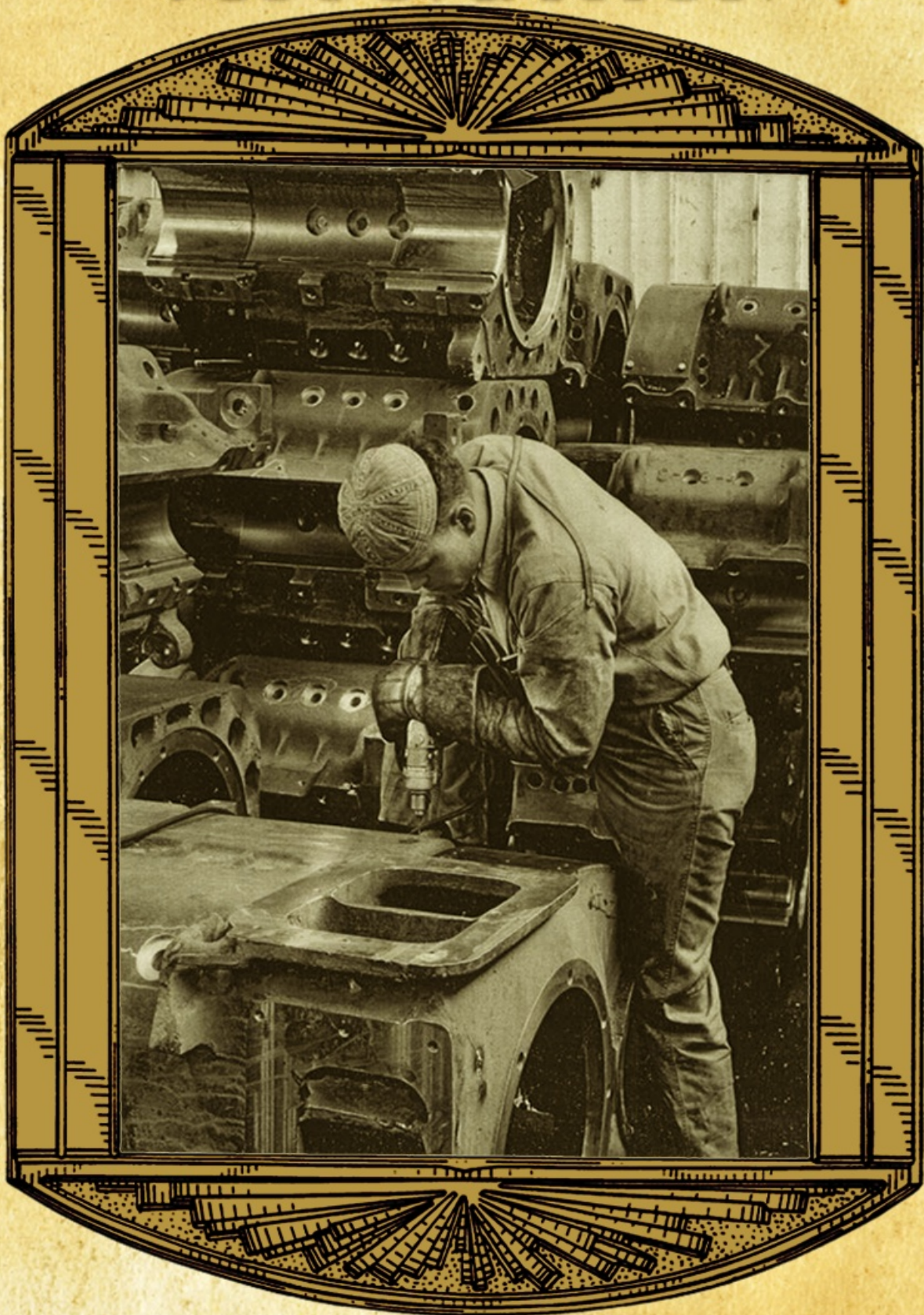
Transient Residences Homes      Figure 4.18



Each room will come pre-furnished to facilitate quick move-ins and move-outs. Residents may choose from different interior designs based on their neighborhood theme as well as a choice of Earth culture styles. Furniture will come in easily interchangeable styles and colors for residents.



# AUTOMATION



THE ABILITY TO CONVERT IDEAS TO THINGS  
IS THE SECRET TO OUTWARD SUCCESS.  
-HENRY WARD BEECHER



## 5.0 Automation

Automation will give Astoria the infrastructure necessary to promote healthy living and efficient production.

### 5.1 Automation of Construction Processes

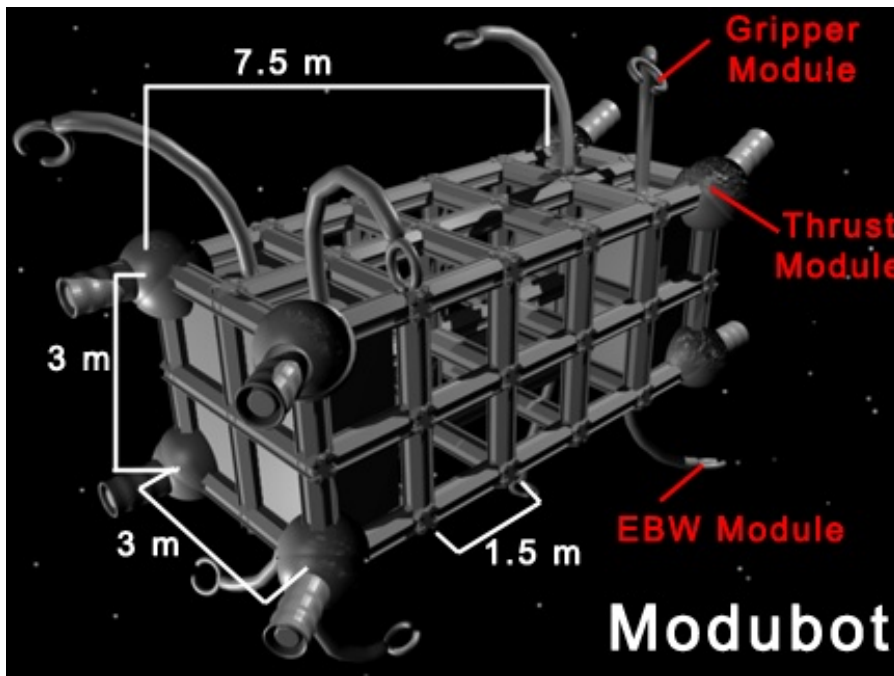
The construction process of Astoria will be facilitated by automation to ensure efficiency and safety in near-zero G surface mining and construction.

#### 5.1.1 Transportation of Materials and Equipment

The initial construction dispatch of equipment, early engineering teams, and materials will be carried out with prefabricated mining bases that will be propelled by an array of Modubots with temporarily modified fuel tanks. The initial team will be supported by a spaceship grade life support system and basic radio communication to control robots remotely and remain in contact with other stations near Earth.

#### 5.1.2 Exterior Construction

Upon arrival to Mathilde the prefabricated mining units will be positioned near the construction site and at strategic mining positions. The mining of resources will commence immediately after installation and will be mostly autonomous. The array of Slivers, mining at an approximate rate of 500 kg/sec will be connected to the OPU by means of a bucket container pipeline. The materials and parts used for the station will be manufactured at the OPU and stored in Stocky. Meanwhile the Automated Anchor system will commence preparation for the large structure. The Modubot will be the main construction robot during



the construction process. The Modubot will have many benefits as it will adapt for each step of the construction process by changing its modules. Once construction is complete, Modubots will be outfitted with thrust modules to become Modubot tug-teams, Astoria's on-site ferries. The Crowe Repair Platform will be used to install the foam outer layer of the torus. All of these automated systems will be overseen by the central command center on Astoria where engineers on site will supervise progress and make any necessary repairs.

Figure 5.1

Automation	Purpose	Construction sequence/Location	Number	Dimensions W x H x D
Slivers	Mining and excavating raw material	All construction/on Mathilde	100	8 m x 4 m x 8 m
Screw Conveyor Pipeline	Transporting raw material	All construction/on Mathilde	20	2 m x 2 m x 300 m
OPU Ore Process Units	Portable Multipurpose Refinery	All construction/on Mathilde	20	10 m x 5m x 20 m
Stocky	Modular and tugable storage material	All construction/on Mathilde	20	10 m x 10 m x 30 m
Anchor	Drill and build anchor deep in the asteroid.	Only step one/ on Mathilde	30	30 m x 10m
Modubot	Propulsion and central control of and anchor for modules	All steps/ in Space	300	3 m x 3 m x 7.5 m
EBW Module	Electron beam welding arm for Modubot	All steps/ on Modubot	600	1.25 m x 1.25 m x 3 m
Gripper Module	Manipulates and secures building components. Can exchange gripper with different tool bits.	All steps/ on Modubot	1000	1.25 m x 1.25 m x 3 m
Structural Anchor Module	Uses large customized gripper to attach to completed structure	All steps/ on Modubot	300	1.25 m x 1.25 m x 3 m
Crowe Platform	Crowe Repair Platform	Final hull foam installation	50	4.6 m x 3.5 m x 12 m

Table 5.1 Exterior Construction Robots

### 5.1.3 Interior Construction

The interior construction process will begin upon completion of the Carnegie Plate where it will be streamlined by use of centralized Building Block assembly line. The Building Blocks will be 4.5m x 4.5m x 8m at most and will make up the structure of different rooms for each floor. The walls, wiring, plumbing, and windows will all be installed in the assembly line and built into the Building Block. These Building Blocks will be stored on the Carnegie Plate until the completion of the Residential Torus upon which they will be transferred to the residential Torus through the transitional train interface. On the Residential Torus floor the layer bot will prepare the necessary roads, wiring, plumbing, and lighting to accommodate infrastructure. The Building Blocks will be placed by the Overhead Telescoping Crane which works both with or without gravity. The Maskobot, which attaches to the Crane, will secure the building blocks to one another and will complete the external finishing of each building. The Base Bot will install all the basement facilities.

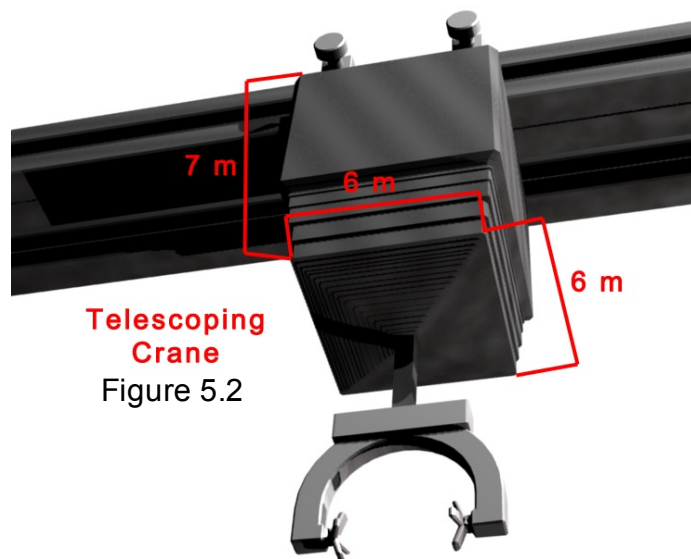


Figure 5.2





Robot	Purpose	Number	Construction Phase/Location	Dimensions W x H x D
Building Assembly Line	Manufactures building block units using assembly line	1	Industrial Plate	N/A
Overhead Telescoping Crane	Places building units	36	Torus	6 m x 7 m x 6 m
Layer Bot	Wiring, piping, station lighting	200	Torus	6 m x 2 m x 4.5
Maskobot	Secures building blocks to floor and other units, Beautifies raw façade with tiles.	36	Torus	2 m x 1 m x 2 m
Smart Waiter	Multipurpose item placement, removal, assembly, and repair	5000	Buildings	.75 m x 2 m x .75 m
Base Bot	Basement facilities assembly	160	Basement	3 m x 3 m x 3 m

Table 5.2 Interior Construction Robots

## 5.2 Facility Automation

### 5.2.1 Automation of Settlement Operations

All of the following functions will be monitored by the critical life support systems Table 5.3

Automated	Location	Function
Atmosphere	Torus	Monitoring, adjustment of atmospheric components using scrubbers and sensor arrays built into buildings
Agriculture	Torus	Growth maintenance, pollination, harvesting, packaging. Done by "Plantationer" (see 5.3.1)
TUBES	Torus	Moves goods, supplies, robots within basement
Power	Industrial Plate	Distributes power between torus and power storage.
Water Monitor/Distributor	Torus	Distributes water between storage, cleaning, and locations of usage. (see pipe repair 5.2.2)
Waste Management	Torus and Industrial Plate	Monitors waste system for problems (i.e. blockages, temperature control), controls the process of waste
Cyclopod Traffic Controller	Torus	Controls flow of cyclopod traffic based on real-time traffic data.

### 5.2.2 Interior Repair and Maintenance Table 5.4

Type of Maintenance	Example of Damage	Automation Used	Methods Used
Structural Integrity	Building Instability	Built in stress and movement sensors will monitor Building Block to ensure	In case of instability building may be reinstalled with Crane and new Building Blocks
Piper	Pipes burst, cracked pipes	Swarm of Piper Bots	The small piper bots connect together to create a mesh traveling like snakes and mending leaks by welding
Minor Interior Work	Broken Furniture, Cracked Floor Tiles/Boards	Smart Waiter	Removes broken items to be recycled or repaired. Brings back new one.
Minor Robot Repair	Damaged robots	Robots are transitioned to	Robots are brought to robot repair facility in

### 5.2.3 Exterior Repair and Maintenance Table 5.5

Type of Repair	Example of Damage	Automation Used	Methods Used
Minor Repair of Settlement Exterior	Micrometeorite damage to exterior foam layer	Crowe Repair Platform	Two forward arms remove damaged tiles from hull. Replacement tiles are attached into place by a 4 m boom.
Major Repair of Settlement Exterior	Hull damage deeper than foam layer other significant structural damage	Modubot	An original construction Modubot will be used to repair large scale damage.

### 5.2.4 Methods for Solar Flare Protection

External robots and mining facilities will be engineered to be least affected by Solar Flares. Upon receiving information regarding an oncoming solar event most nonessential robots will be placed on hold in a lower radiation area such as on the Carnegie Plate engulfed by the Torus or by the wall of a crater on Mathilde. The mining bases will be placed in predetermined locations such as inside craters to reduce how affected they are by solar events. Certain robots non critical robots may shut during the solar event to try to reduce the chances of damage. Other critical robots such as Modubots or Crowe Repair platforms will be fitted with electromagnetic shielding in the form of large blocks of metal nanofoam that will protect all the electronics onboard.

### 5.2.5 Security

A heart rate monitor will constitute the first basic security system, by analyzing signatures in the unique heartbeat of each individual requesting access. The heartbeat signature will be compared to a database of acceptable users, in order to determine whether access is granted or denied. A pressure level map of the feet will serve as the second basic security system. The unique pressure signature applied by the soles of the individuals feet, known as plantar pressure, will be analyzed and, once again, compared to a database of acceptable users. This pressure map will be produced by a device embedded in the floor. Like a unique fingerprint, this isobaric level map of the soles of the feet are unique to each individual. Weight Distributing Analysis (WDA) analyzes weight distribution over the soles of the user's feet, as well as the size and shape of the user's feet Thus, this allows security system to identify the person accessing an area or a room. In cases of high security, the subject will have to pass a third security system in addition to the two basic systems described previously. A saliva sample swabbed from the inside of the mouth will provide a DNA analysis to give an absolute identity confirmation.

Table 5.6 Security Levels

Security Level	Personnel	Locations	Method
1	Everyone	Public	Ring
2	Residents	Housing and their work place	Heartbeat signature, WDA
3	Maintenance/Engineers	Public and Industrialized zone, Manufacturing Areas	Heartbeat signature, Fingerprint
4	Office Workers	Offices of Working Station	Heartbeat signature, Password, WDA, Iris scan
4	Computer Monitors and Tech support	Control Station	Heartbeat signature, Codeword, WDA, Iris scan
5	Station Administrator	Administrative HQ	Heartbeat signature, Passphrases, WDA, Iris scan, Group authentication with more than one person accepting



### 5.2.6 Contingencies Table 5.7

Contingency	Automation	Description
Fire	Built in fire extinguisher	All Building Blocks will have built in plumbing with fire extinguishers built into the structure.
Injured Citizen	Ambulance Cyclopod	Smart Waiter equipped with medic load out will tend to the patients needs while an automated two-passenger Cyclopod Ambulance arrives with paramedic staff to bring citizen to hospital
Hull puncture and Meteorite shower	Modubot and Crowe Repair Platforms	Bulkheads are released to partition volumes. Repair robots inflate barriers into the breach and patch up structure quickly.
Server Crash	Redundant backup system	Independent server nodes will complement each other during regular usage but act as backups if some nodes happen to fail.
Epidemic Outbreak	Smart Waiter	Medical bots will be put on standby to receive patients affected by outbreak.
Loss of rotation	Emergency rotation control	Systems will calculate best decelerations and ensure that if rotation has to come to a full stop, transition interfaces between residential and industrial torus will be lined up

## 5.3 Habitability and Community

### 5.3.1 Community Automation

#### Delivery of Food and Robots

A series of magnetic tubes called “Tubular Underground Bypass for Essential Services” or TUBES will be placed throughout the torus, connecting the growing areas to the processing areas, and then the processing areas to the building or areas. These tubes will serve and connect the numerous neighborhood distribution centers.

Table 5.8 Community Automation

Automation	Purpose	Dimensions W x H x D	Quantity
Sir Wiper	Keeps vertical surfaces (i.e. walls) free of dust and debris.	.5m x .25 m x .5m	500
Pleco	Cleans and maintains the surface floor of the station.	.25 m x .25 m x .025 m	800
Pond Bot	Cleans and maintains water maintenance ponds	.2m x .1 m x .2 m	3000
Restaumatic	Automated restaurant food services	3 m x 3 m x 4 m	75
Plantationer	Pollination, Harvest, Tending to, processing of crops	340 m x 1 m x 3 m	12



5.3.2 Workplace Automation

In the work place the Thinking Cap, an advance Brain-Computer Interface, will be used to streamline workflow and provide workers with a more efficient means of controlling computing resources. Offices will be fully immersive, to ensure high productivity and ease of communication.

Assistance Technicians are specially trained technicians who monitor all robots and help solve problems that AI may not solve. Technicians are equipped with Thinking Caps and use them to remotely control robots efficiently and intuitively. When an issue arises the Technician is made aware of the problem and given data on the issue at hand. With human ingenuity the person will solve the conflict and the robotic system will use the human data to improve its algorithms and operation.

Figure 5.3 Immersive Office



Table 5.9 Workplace Automation

Thinking Cap	Helps train robots without being present beside it. Hyper mobile computing for robotic interfacing.
Immersive Cubicle	Uses large screen to display data and provide best mood for working without distractions.
Automated Cleaning System	Cleanse and maintains the working place and offices'

5.3.3 Residential Automation

Table 5.10 Residential Automation

Automation	Method	Quantity
House Manifest	Attends the well-being of the house and it's residents. Can be controlled by residents.	One per house
Housing Bathroom Cleaning System	Bathroom seals itself and water jets clean all the	One per house
Smart Waiter	Multipurpose organizational robot	One per house
Miniature Restaumatic	Prepares food in the home	One per house

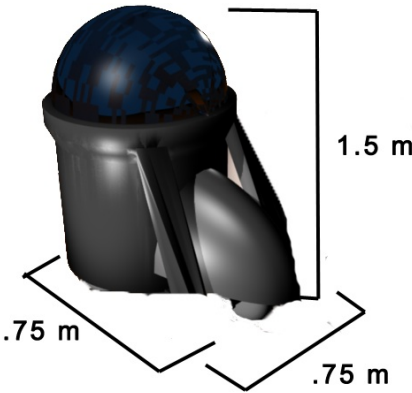


Figure 5.4 Bathroom Cleaning System

### 5.3.4 Computing and Networking

Using the communication support satellites, Astoria will always be reachable and connected. Two types of long distance communication will be used, S band radio signals for critical communications complemented by laser based free space optical communication for high bandwidth communication. To provide a real-time like experience for Astoria's citizens, common websites, movies, and information will be cached on Astoria. This will ensure a seamless experience with external communications.

Internal communications will consist of a hardwired fiber-optic backbone that will connect the 24 data-center nodes within the residential Torus. This backbone will also link the hundreds of wireless transmitters built into the Building Block units enabling the residential Torus to be blanketed by a high bitrate, low latency, MIMO enabled wireless network. This Metropolitan Area Network (MAN) will connect all portable devices within the Torus.

The Cloud-9 Centralized Computing System will be Astoria's life and blood. This centralized computing system with distributed server nodes will provide Astoria with most of its processing power. The Cloud-9 system will be remotely accessed by users on any device which has been authenticated. All users will wear a RING with personalized style that will be their portable computing device and authentication. The RING will monitor vital health signs, location using a mesh of ultrasound beacons, link up local interface devices such as, text input, screens, virtual retinal displays, time of flight cameras etc.

The interface ring will use an open protocol to connect to any device developed making the interface ring a user's intermediate connection between the Cloud-9 and their devices. Standard devices will be issued to all such as the DigiSlate and the Virtual Retinal Display (in contact or glasses form) for permanent residents. Other device will be left for 3<sup>rd</sup> parties to develop as specific niches and needs may arise to develop devices such as tabletop touch screens or interactive wristwatches.

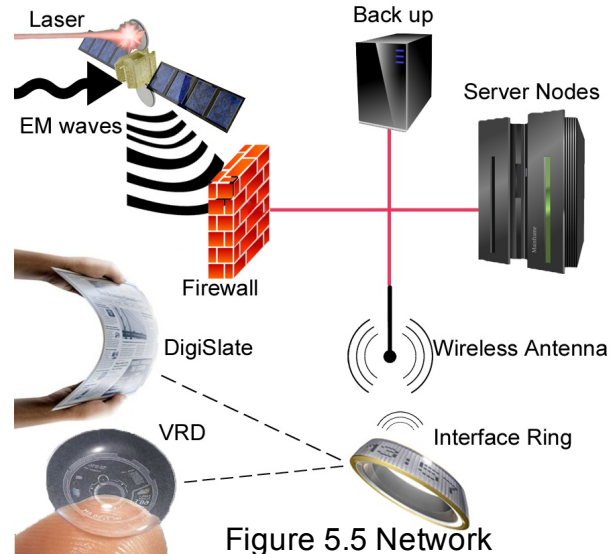


Figure 5.5 Network

## 5.4 Adaptation for Environment

In the asteroid belt, Astoria and all her members will be forced to deal with conditions like asteroid dust, and nearly non-existent gravity. Dust destroys equipment. Nearly nonexistent gravity means that our robots especially will need to be equipped for Astoria's rocky domain.

### 5.4.1 Methods of Adjustment

Procedure for dust removal for robots and powered suits

To reduce Astoria's dust exposure from ships and containers that will dock dust removal will take place before they approach the station based on dust filth level. Before they approach the station, we will have Modubots fitted with special electromagnetic units that will fly out to a ship and attract the dust off of the ship's surface using directional electromagnets. The collected dust will be cleaned off.

#### 5.4.2 Robot Component Design

The Sliver bots and other robots will have a system of meter long rod anchors in order to stay put on the asteroid. These rods will be driven into the surface if it is strong enough and will be used by the anchored Sliver bot to slowly move forward while it slides on its anchors. The anchors will then be moved forward one at a time and re-anchored with a hydraulic activated blast into the surface. Regolith will be closely monitored or removed to ensure that the anchors will always work. The Sliver bot will use a covered bucket-wheel excavator that will feed the material into a screw conveyor pipeline. The screw conveyor pipeline enables bulk transportation of material in near zero gravity.

### 5.5 Material Unloading

Operations on Astoria will provide the infrastructure necessary for receiving and handling ore from the asteroid and from other surrounding locations.

#### 5.5.1 Shipping Specification

The Carnegie Plate industrial docking facilities were designed for maximum flexibility to accommodate all forms of shipments. Although ore accepted in standard containers will be preferred from a logistics stand point Astoria will also be able to accommodate bulk shipments. Bulk shipments will be dealt with by placing the bulk ships into a centrifuge similar to rotary car dumpers on earth. Cargo bay doors will be opened and standard container will be attached to and cover the bay. The ship will be spun to cause the bulk material to transfer into the container which will close when full before stopping the centrifuge. From that point on the standard containers will be dealt with identically from both bulk and container ships.

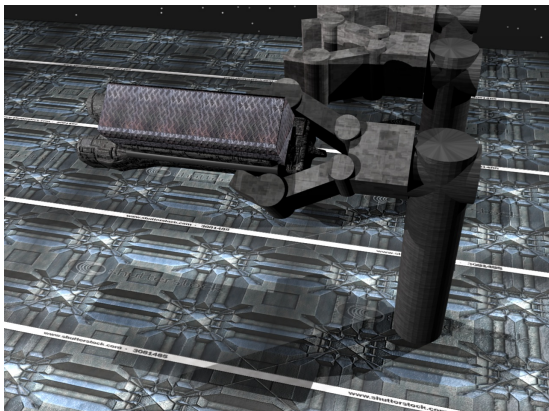


Figure 5.6 Automated unloading

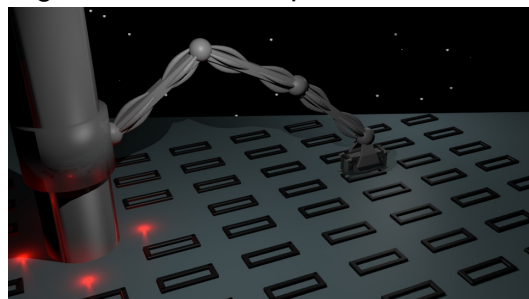
#### 5.5.2 Acceptance of Ore

The Carnegie Plate has numerous external access bay hatches that will accommodate many ships when these are brought to the Plate by the docking elevators. The ore acceptance hatches will open and let two industrial robotic arms to extend out with standard container attachments that will grab the containers and either move them into the plate or secure the containers on the exterior for temporary storage.

#### 5.5.3 Transport of Material

Once ore and other raw material have been accepted they will be transported to the adjacent ore processing facilities within the Carnegie Plate. The amount of transportation necessary for all materials is greatly reduced by the proximity between ore acceptance and the processing facilities. The standard containers will be transported on the inside ceiling of the Carnegie Plate that is fitted with a mesh to enable modular overhead cranes to move the containers to designated areas.

Figure 5.7 Ore Acceptance





# SCHEDULE AND COST



**METHOD IS THE VERY HINGE  
OF BUSINESS AND THERE IS NO METHOD  
WITHOUT PUNCTUALITY.**

**-RICHARD CECIL**

## 6.0 Schedule and Cost

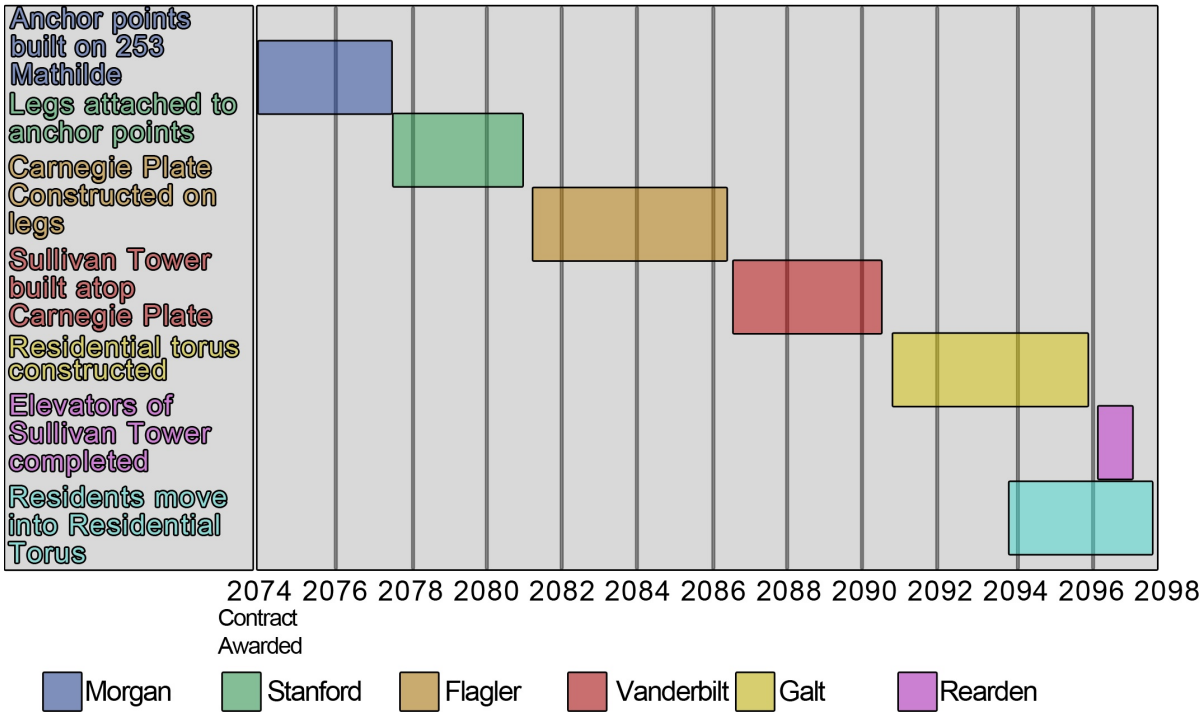
Construction of Astoria will begin on January 2074 (refer to chart 2.3 for a complete construction sequence chart).

### 6.1 Schedule

The first stage of operations in Astoria’s construction will begin with the delivery of mining and processing facilities to 253 Mathilde. These bases will take advantage of Mathilde’s resources to build Astoria’s anchor points, legs, and eventually, the Carnegie Industrial Plate.

Once the Carnegie Plate is completed, work will begin on the Residential torus on the plate’s edge. This torus will initially be connected to the Carnegie Plate via mechanical means to facilitate easy construction, but will initiate and sustain rotation with electromagnetic repulsion once completed in December of 2095. At this point in time, internal construction of communities will be completed and residents will be able to move in.

Figure 6.1 Schedule



### 6.2 Cost

Table 6.1 Structure Cost

Structural Materials	Volume m <sup>3</sup>	Cost per m <sup>3</sup>	Cost
Steel	12,394,335	524.48	6,500,580,820.80
Titanium	8,520,000	1,223.23	10,421,919,600.00
Regolith	8,394,335	10.00	83,943,350.00
Ballistic Foam Tiles	8,394,335	997.29	8,371,586,352.15
Lunar Glass	3,124,000	128.85	402,527,400.00
Totals	40,827,005	N/A	25,780,557,522.95



Table 6.2 Operation Cost

<u>Operations Materials</u>	<u>Volume m<sup>3</sup></u>	<u>Cost per m<sup>3</sup></u>	<u>Cost</u>
Steel	5,000,000	524.48	2,622,400,000.00
PVDC	10,000	990.80	9,908,000.00
ABS Plastic	20,000	620.99	12,419,827.20
Silica Aerogel	1,000	1,631.70	1,631,700.00
Titanium Oxide	4,000	923.23	3,692,920.00
Aluminium	250,000	353.20	88,300,000.00
Polycarbonate	150,000	223.84	33,576,000.00
Polychloroprene Rubber	2,000	3,548.22	7,096,440.00
OLED Components	45,000	3,856.00	173,520,000.00
Thorium	0.50	55,000,000.00	27,500,000.00
Totals	5,482,001	N/A	2,980,044,887.20

Table 6.3 Automation Cost

<u>Automation Costs</u>	<u>Cost</u>
Infrastructure	\$135,000,000.00
Robot Construction	\$7,796,000,000.00
Robot Maintenance	\$2,500,000,000.00
Networking	\$4,500,000.00
Material Processing	\$24,080,000.00
Total	\$10,459,580,000.00

Table 6.5 Human Factors Cost

<u>Human Factors Costs</u>	<u>Cost</u>
Og Infrastructure	24,000,000
Home Furnishings	45,000,000
Amenities	125,000,000
Medical Services	20,000,000
Total	214,000,000

Table 6.4 Infrastructure Cost

<u>Operations Costs</u>	<u>Cost</u>
Transportation infrastructure	\$124,000,000
Agricultural infrastructure	\$2,170,000,000
Electricity	\$1,530,000,000
Waste and Water management	\$650,000,000
Atmosphere control	\$8,500,000
Construction equipment	\$3,500,000,000
Food Processing	\$600,000,000
Reactor	\$3,450,000,000
Communication Infrastructure	\$300,000,000
Total	\$12,032,500,000

Table 6.6 Overall Cost

<u>Overall Costs</u>	<u>Costs</u>
Structural Materials	25,780,557,522.95
Operational Materials	2,980,044,887
Operation Costs	12,032,500,000
Human Factors Costs	3,114,000,000
Automation Costs	10,459,580,000
Total	54,366,682,410





**Table 6.7 Yearly Billing**

Phase	Year	Number of Employees	Cost (USD)	Total Cost (USD)
Morgan	2074	65	9,052,020,000.00	9,052,020,000.00
	2075	70	902,114,450.00	9,954,134,450.00
	2076	80	3,545,576,000.00	13,499,710,450.00
	2077	90	902,114,450.00	14,401,824,900.00
Stanford	2078	120	3,185,834,056.80	17,587,658,956.80
	2079	130	3,185,834,056.80	20,773,493,013.60
	2080	135	4,466,834,056.80	25,240,327,070.40
Flagler	2081	160	3,403,822,390.47	28,644,149,460.87
	2082	170	850,955,597.62	29,495,105,058.49
	2083	175	1,237,753,596.54	30,732,858,655.03
	2084	180	928,315,197.41	31,661,173,852.442
	2085	190	1,392,472,796.11	33,053,646,648.554
	2086	200	1,856,630,394.82	34,910,277,043.37
Vanderbilt	2087	220	1,740,590,995.07	36,650,868,038.44
	2088	245	1,885,640,244.66	38,536,508,283.10
	2089	270	2,610,886,492.61	41,147,394,775.71
	2090	340	725,246,247.95	41,872,641,023.66
Galt	2091	435	2,175,738,743.84	44,048,379,767.50
	2092	675	2,900,984,991.79	46,949,364,759.29
	2093	700	1,015,344,747.13	47,964,709,506.42
	2094	800	1,450,492,495.90	49,415,202,002.31
Rearden	2095	825	1,747,581,320.41	51,162,783,322.72
	2096	840	2,038,844,873.81	53,201,628,196.53
	2097	850	1,165,054,213.61	54,366,682,410.139

### 6.2.1 Justifications of Costs

Astoria's construction costs remain relatively low compared to other stations due to its almost complete reliance on Mathilde for construction and operational resources. Automation resource costs and mining package costs are among the highest constituents in Astoria's Cost.

# BUSINESS DEVELOPMENT



A GOOD ENGINEER THINKS IN REVERSE  
AND ASKS HIMSELF ABOUT THE STYLISTIC  
CONSEQUENCES OF THE COMPONENTS  
AND SYSTEMS HE PROPOSES.  
-HELMUT JAHN



## 7.0 Business Development

### 7.1 Infrastructure for Asteroid Mining Operations

Several prefabricated mining, processing, and robotics facilities will be shipped to Mathilde on the date that Northdonning Heedwell's contract is awarded. These structures will facilitate Astoria's construction.

#### 7.1.1 Harvesting Operations Equipment

Fleets of mining craft will harvest Mathilde's resources with humans available for observation and intervention if necessary.

#### 7.1.2 Processing Facilities

Processing facilities outlined in 2.5.2 will be able to receive Mathilde's regolith and convert it into construction parts for Astoria's construction, significantly reducing construction costs and time required.

#### 7.1.3 Port Facilities

The Sullivan tower is Astoria's main docking complex. The Sullivan Tower's sheer size makes docking a relatively easy experience, with the capability to dock twenty ships at once. Modular docking designs enable an almost unlimited range of ship sizes to dock with Astoria.

#### 7.1.4 Vehicle Dust Decontamination

Magnetic plates on the Sullivan Tower will charge and remove dust from vehicles.



Figure 7.1 Port Facilities

### 7.2 Logistic Services

Astoria will provide a number of logistic services to passing ships, including repairing, refueling, and restocking of materials such as food and medicines. Taking advantage of its location in the Asteroid belt, Astoria will be a popular staging ground for new expeditions.

#### 7.2.1 Agricultural Provisioning

Astoria will have a significant surplus in food thanks to agricultural space being utilized in the residential torus' basement level. This food will be either consumed in the face of an emergency or traded to other settlements. Expeditions planning to depart from Astoria may be provisioned by this stock if the need arises. A large seed bank exists on Astoria in order to supply new settlements with the resources required for agricultural expansion and to aid in agricultural research in space.





### **7.2.2 Recreational Facilities**

Astoria's recreational facilities accommodate a large number of annual transients and passing crews, with 0g activities in the Sullivan Tower and many entertainment establishments in the Residential torus. The PLAY (Progressive Locomotive Aiding Youth) has a number recreational facilities available, providing 1g therapy to visitors while they experience the many enjoyable activities aboard the train, including clubs, restaurants, and a park area.

### **7.2.3 Maintenance Services**

The Sullivan tower is outfitted with the equipment and structures for specialized ship repair, including large repair bays and a fleet of repair craft. Human repair crews will oversee robotic repairs and intervene if necessary.

### **7.2.4 Refueling Services**

Astoria's mining complexes extract and process elements of Mathilde into LH2 and LOX. These fuels are used for movement of Astoria and refueling of visiting craft. These LH2 and LOX reserves are kept in 0g inside the Carnegie industrial plate. Astoria will always have enough LOX to detach from Mathilde once a month with the amount of resources pooling in from the station's mining outposts.

### **7.2.5 Ferry Services**

To ferry and repair ships visiting Astoria, Modubots acting in specialized space-tug-teams will haul disabled or otherwise shutdown spacecraft to repair facilities along the Sullivan Tower's surface.

### **7.2.6 SAR Operations**

Astoria will always have one fully stocked and fueled ship on standby in the Sullivan tower for search and rescue operations. This ship will be stocked with fuel, food, and medical supplies to provide for marooned crews.

## **7.3 Research Opportunities**

Astoria's unique position provides a wealth of research opportunities to scientists everywhere.

### **7.3.1 Edison Telescope**

The Edison telescope is a large radio telescope that orbits 253 Mathilde, staying clear and safe from Astoria's many industrial operations. This telescope will provide an unparalleled view of the cosmos. Operational crews on Astoria observe and correct the Edison telescope's path if it is in danger of collision with an object.

### **7.3.2 Optical Telescope**

The Tombaugh Observatory will be established on the far side of Astoria, built on a suspension plate to reduce vibration interference attributed to mining operations. From this location and from Mathilde's extremely slow rotational period, more precise observations can be attained, and in larger numbers.

### **7.3.3 Real-Time communication**

Astoria's communications relies on a constant stream of cached data from satellites orbiting Earth. In this aspect, Astoria will provide the fastest in real-time data transfer that any outpost in the solar system has ever seen.

# OPERATIONAL SCENARIO



LEARN TO VALUE YOURSELF,  
WHICH MEANS:  
FIGHT FOR YOUR HAPPINESS.

-AYN RAND



### 8.0 Appendices

#### A. Operational Scenario

Consider the Herbert family: Isaac, the family's father, a 38-year old asteroid analyst; Zooey, the mother, a 35-year old robotics repair specialist; Arthur and Dagny, the family's two children. A quaint little family, the four are fortunate enough to have a niche aboard Astoria. The father, Isaac, has been contracted as an analytical specialist for objects in the asteroid belt, taking data from the Tombaugh Observatory to scout out new likely candidates for extraction of ore. Zooey, Isaac's wife and mother of two, is a maintenance specialist for mining and transporting robots that scour the surface for raw materials. Arthur and Dagny are the family's two children. A ten-year old boy and a four-year old girl, these children are at normal developmental levels for their age.

Isaac's day begins with Astoria's skylights turning to a crisp, bright morning. He puts on clothes and dons his interface ring, which connects him with his Virtual Retina Display, a pair of contacts that act as his personal computer and heads-up-display. As he switches on his interface ring and reads through his personal messages, an invitation to coffee from a colleague pops up. He eagerly replies with his acceptance, and before he walks out the door, he gives the sleeping Zooey a good-bye peck. The Herbert family lives about a half-kilometer from Astoria's commercial sector, so Isaac decides to hop in a Cyclopod, many of which make up Astoria's main transportation network. Isaac decides to take a slow, relaxed pace with his Cyclopod and enjoy the scenery. Minutes later, he arrives at a Cyclopod station near *Eris' Café*, a coffee and breakfast establishment that is renowned across the Foundation Society for its supreme culinary creations and robotic culinary experts. As he enters the café, his HUD guides him to his colleague's table. He orders a coffee and some toast from a service bot and discusses his latest finding in the belt, an M-type asteroid with an eccentric rotational period and orbit. Moments later, Isaac's breakfast is brought out by the robotic server. Isaac wastes no time wolfing it down. After spending an hour with his colleague, he notes the time projected in a corner of his vision and heads to his office, located on the exact opposite side of the Residential Torus. The trip doesn't take him long; at his relaxed pace the 2.5 kilometer trek takes about fifteen minutes.

Zooey's day starts out three hours after Isaac's. She wakes up, slips on her interface ring, and wakes up the kids. She prepares breakfast for them both: eggs and sausage for Isaac, orange juice and oatmeal for little Dagny, aided by advanced cooking systems. Thirty minutes later, the children are ready for school and she sends them off in a double -Cyclopod. She gets ready for work herself, putting on her work garment and strapping on her utility belt. Her transit route takes her to the commercial sector as well, where an elevator takes her to one of the twelve Taggart Acceleration trains, Astoria's 0-G to full-G interfaces. As she enters the train, she straps into one of the seats and packs her items into a cubby. The train glides into motion, slowly accelerating in the opposite direction of the Residential torus. Ten minutes later, Zooey is on the Carnegie plate in microgravity, mere meters from her work station. Her interface ring clocks her in as she enters the repair complex, and she floats to her newest project: a mining robot with a malfunctioning sensor array, nothing she's never faced before. She cracks her knuckles and activates her magnetic boots, tethering her to the "floor" of the repair facility.

Arthur and Dagny, once finished with breakfast, are sent off to school in one of Astoria's double-Cyclopods. This Cyclopod has been given directions to arrive at the Progressive Locomotive Aiding Youth(PLAY) train, Astoria's main children's center and recreational facility on rail. This locomotive travels along Astoria's circumference on elevated rail and travels faster than the Residential torus itself to increase its centripetal force. When the children connect with the PLAY train, the centripetal force acting on them will be 1g, promoting healthy development and growth for the children. They spend three hours at the school, receiving their daily exposure to Earth-level gravity. When they are out of class, the two spend four hours at the park playing with other children, moderated by school staff and robotic observational systems to ensure that neither Dagny nor Arthur are put into any danger.



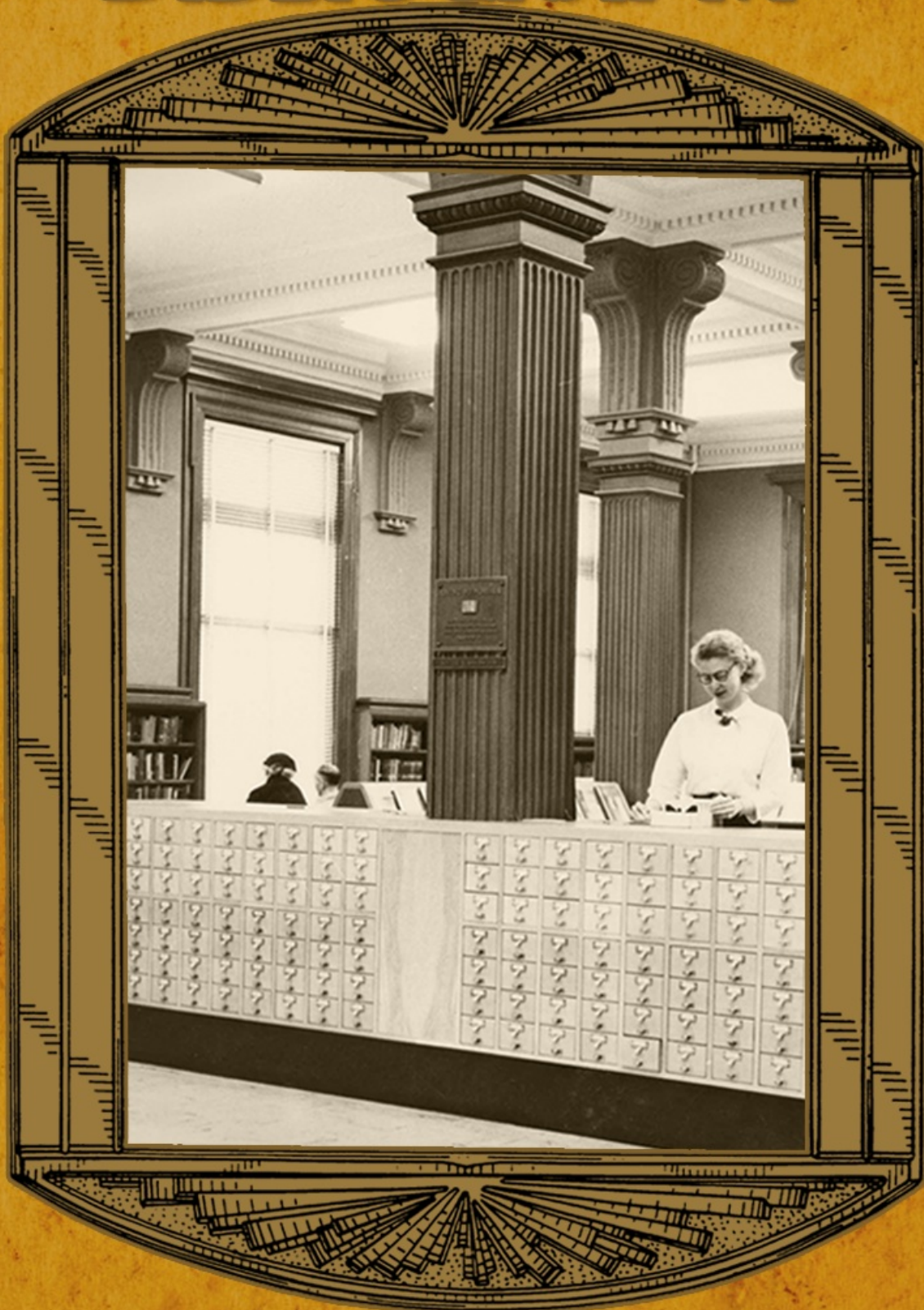


At 5:00pm Astoria time, the lights are low and the Torus' virtual sun is setting, painting the landscape in a deep orange. The family is finally reunited and takes a walk to their shopping district. Isaac takes Arthur to the book store, to purchase a copy of *Micrometeorites with Mike Crowe*. Zooey takes Dagny to a clothing store, where Zooey looks for a new pair of heels for herself. Before the clan leaves, Isaac finds an excuse to evade the family, as he buys Arthur a present for his upcoming birthday: the boy's very own DigiSlate, a wristband and mobile computing device. When Arthur turns eleven, the DigiSlate will keep him connected to a social network consisting of his parents and friends at all times. Zooey takes Dagny to the pharmacy to pick up medicine for a developing cold, stopping by the nearest food distribution center to order a half-gallon of milk. The milk is summoned from storage in Astoria's basement and makes its way through the TUBES system, soon finding itself, as though conjured, in Zooey's hands.

At 7:00pm, the family goes to see a science fiction film, *Space Elevator Deathrace 4: The Perpetual Motion Picture*. As an apology for his terrible selection, Isaac treats the family to ice cream in a café overlooking one of Astoria's many agricultural fields. Once home, Isaac tunes in to the news using his retina display and makes himself comfortable in the family's living room. Zooey walks in to find a leaky faucet in the couple's private restroom, and schedules a utility drone to drop by the very next morning, making sure that the bot's repairs will not interfere with the family's sleep schedule.

As Isaac and Zooey tuck their children into bed, the skylights on Astoria's ceiling have turned to a crystal-clear, starry night. The two parents smile as they look out of their balcony onto the simulated night. Isaac and Zooey look at each other, embrace, and kiss. There's first love, and then there's space love- all in all, just another wonderful day on Astoria.

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I DO NOT THINK THAT THERE IS ANY OTHER  
QUALITY SO ESSENTIAL TO SUCCESS OF ANY  
KIND AS THE QUALITY OF PERSEVERANCE.  
-JOHN D. ROCKEFELER





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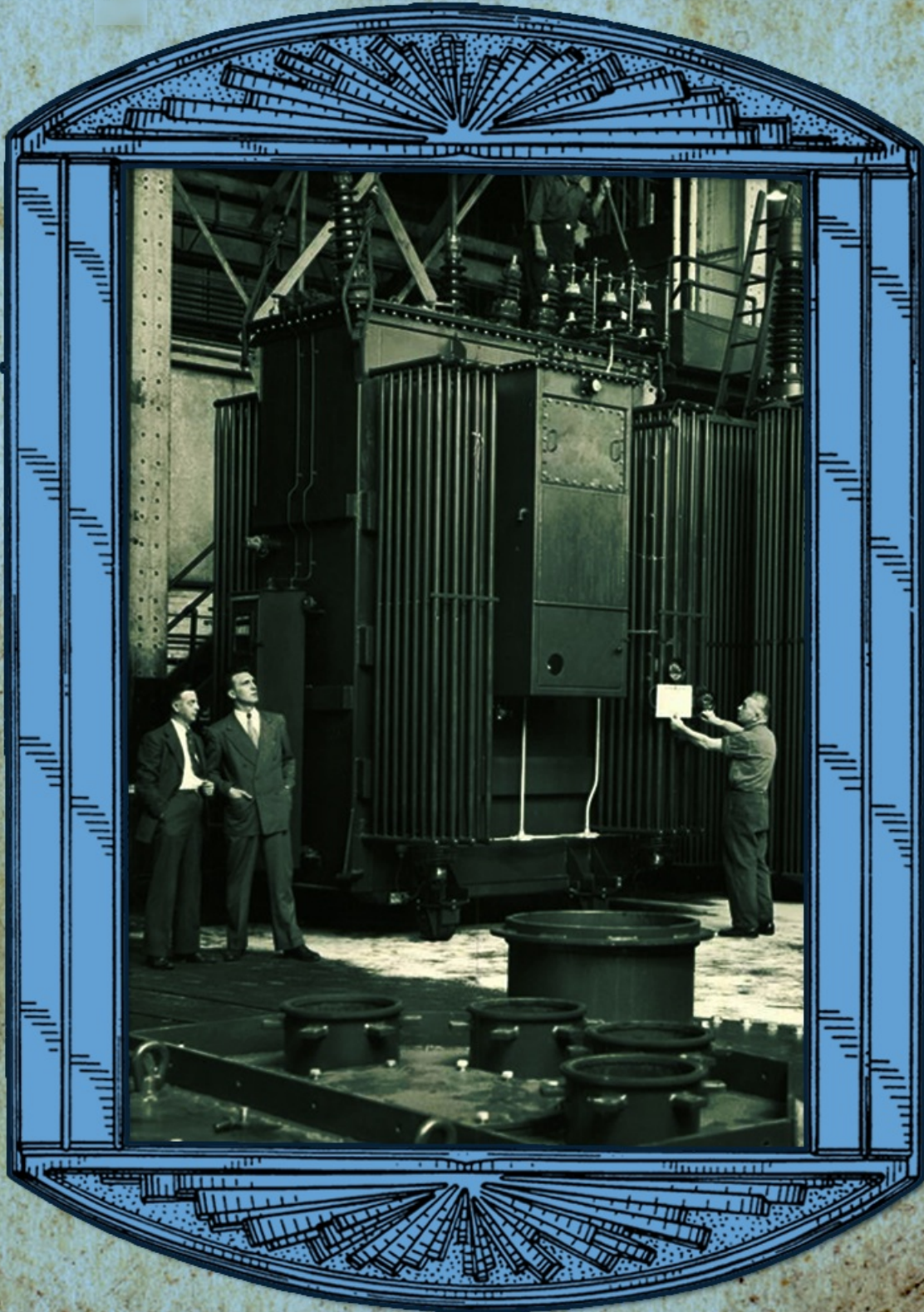
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# COMPLIANCE MATRIX



I BELIEVE THAT THE TRUE ROAD TO  
PREEMINENT SUCCESS IN ANY LINE IS TO  
MAKE YOURSELF THE MASTER OF THAT LINE.  
-ANDREW CARNEGIE



### C. Compliance Matrix

Point	Title	Addressed
1.0	Executive Summary	Summary of Astoria design goals and expected impacts.
2.0	Structural Design	Astoria's design allows for a growing population with an emphasis on natural views.
2.1	Exterior Design	Major settlement components include a zero-g industrial center, a residential torus, and a tower for exterior docking.
2.1.1	Enclosed Volumes	Portions of the Carnegie Plate will be non-pressurized due to benefits in manufacturing. The residential torus will be pressurized to 11 psi.
2.1.2	Artificial Gravity	The residential torus will rotate at 0.883 RPM. The Carnegie Plate will be immobile.
2.1.3	Interfaces Between Rotating and Non-Rotating Structures	Trains operating on electromagnetic rails will act as the interface between the residential torus and Carnegie Plate.
2.1.4	Radiation and Debris Protection	Astoria's hull will make use of regolith gathered from 253 Mathilde to shield residents from radiation, while using ceramic-polymer foam tiles as a safeguard against debris.
2.1.5	Isolation of Volumes	Bulkheads nested within the ceiling of the residential torus will serve to partition volumes in the event of pressure leakage.
2.2	Down Surfaces	The down surface of the residential torus will be sectorized off into 13 parts, split between residential, agricultural, and commercial purposes.
2.3	Construction Sequence	Astoria will be constructed over a 23 years, through 6 major phases.
2.3.1	Initiation of Rotation	Electromagnetic induction will be used to initiate rotation of the residential torus.
2.3.2	Use of Materials from Asteroids in Interior Construction	Interior structures will make use of carbon steel, titanium, and regolith used in mooncrete.
2.4	Debris Impact Protection and Mitigation	Multiple layers of ballistics foam tiles will protect Astoria from minor projectiles, supplemented by an automated tile-replacement system.
2.4.1	Minor Impact Shielding	Multiple layers of ballistics foam tiles will protect Astoria from minor projectiles.
2.4.2	Major Impact Shielding	The Crowe Repair Platform will replace severely damaged foam tiles.
2.5	Mining Infrastructure	Mining outposts will be spread across 253 Mathilde's surface.
2.5.1	Material Processing	Outposts will be equipped with refinement tools, to assist in the initial construction of Astoria.
2.5.2	Human Habitation	"Mining camps" will be fabricated in the Carnegie Plate and provide all the basic necessities for healthy life, with expandable crew modules.
3.0	Operations and Infrastructure	Station operations on Astoria will provide the necessary infrastructure for settlement functionality.
3.1	Location and Materials Sources	The Astoria station will be located on the asteroid 253 Mathilde and will utilize materials from the asteroid in construction.
3.1.1	Station Location	Astoria will be located on the asteroid 253 Mathilde, at an orbital radius of 2.5 AU.
3.1.2	Construction Materials and Equipment	Astoria will be constructed using materials from existing Foundation Society settlements and its host asteroid.
3.1.3	Means of Material Transport	Materials will be transferred from Mathilde's surface to the Carnegie Plate by Eiffel Elevators.
3.1.4	Mining Target	Mathilde was selected for its hydrated materials, silicates, and regolith.

3.2	Community Infrastructure	Station operations will provide a healthy environment for residents.
3.2.1	Atmosphere	The atmospheric pressure on Astoria will be 11 PSI to conserve on materials and the humidity will be 30% and the temperature 26 degrees Celsius.
3.2.2	Food Production	Crops will be produced using dynaponics facilities and harvested with an automated system before being packaged and stored in basement facilities.
3.2.3	Power	A Thorium reactor located in the Carnegie Plate will provide power to Astoria, transferring it to the residential torus by means of an electrical slip disc.
3.2.4	Water	Communities will share water reservoirs, showcasing a portion of the filtration process in ponds sporting full ecosystems.
3.2.5	Waste	Thermal Conversion Process will be used to treat all waste on Astoria.
3.2.6	Communications	Astoria's internal communications will be based on a fiber optic backbone. External communications are handled by several relay satellites.
3.2.7	Transportation	Cyclopods will provide both automated and manual transportation methods to residents of Astoria.
3.2.8	Day/Night Cycle	Astoria will operate on a 24-hour clock.
3.3	Construction Machinery	The bulk of station construction and assembly will be handled by Modubots.
3.4	Settlement Relocation	150 Liquid CosmoLOX engines will propel Astoria to avoid large projectiles.
3.5	Ore Reception from Foreign Facilities	Astoria will provide the infrastructure necessary for receiving and handling ore from the asteroid and from other surrounding locations.
3.5.1	Port Facilities	The Carnegie Plate will accept ore from foreign asteroids and Mathilde
3.5.2	Ore Handling Process	Ore will be unloaded by Modubots outfitted with cargo grip modules and brought to refining facilities
4.0	Human Factors	The aim is to keep the priorities of the residences to be A.H.H. "Alive, Healthy, and Happy."
4.0.1	Natural Views	The station facing the asteroid will not have natural views, but the side facing space will.
4.0.2	Transit Routes	Curves are cut out of paths so residences do not have to crane their neck, and modes of transportation that require exercise are encouraged.
4.1	Community Design	The Astorian community is designed for efficient transportation and themes to bring the warm comfort of Earth to the resident.
4.1.1	Community Layout	The parallelogram orientation of the residential and agricultural areas will give natural views to the permanent residential homes. The agricultural areas between the residences will serve as a distinct border between neighborhoods.
4.1.2	Consumer Goods and Distribution	Astoria will have a variety of goods and food. Food supply will be maintained through a neighborhood Distribution Center.
4.1.3	Residential Services	Recreation and entertainment on Astoria will be available plentifully for the colonists.
4.1.4	Parks	Parks will provide recreation and gravity accommodations.
4.2	Residential Design	Residents on Astoria will be able to live a pioneering life in space while also always being comforted by the familiarity of home.
4.2.1	Residences	Residences will be able to choose their housing style based on personal preference. Permanent residents will be given priority, followed by semi-permanent and transient, respectively.
4.2.2	Materials Source	Furniture sources that can be produced on Astoria will be grown, but

		imports from Earth will supply the rest.
4.2.3	Residential Technologies	Innovative technologies will ease the lives of residences from tedious work.
4.3	Zero-G Accommodations	Zero-G safety is an utmost priority on Astoira to tend to the residences. With innovative technology, Spacesuits and Airlock Systems defend the colonists from the dangers they could potentially face.
4.3.1	Zero-G Safety	Zero-G Safety will focus mainly on ropes, tethers, and magnetic boots used by industrial workers to transport them from one point to another in Zero-G safely.
4.3.2	Spacesuits	The spacesuit provides comfort, safety, and innovative technology for the user.
4.3.3	Airlock Design	External exploits will be regulated through airlocks.
4.4	Gravity Accommodations	Gravity accommodations will be met separately for adults and children.
4.4.1	Adults	There will be the option of a vibration pad or standard exercise to counteract the effects of microG, and Calcium will be supplement in consumables to prevent loss of bone mass.
4.4.2	Children	Children will receive gravitational therapy while in school.
4.5	Transient Residents	Transients will have superb opportunities on Astoria and will be thoroughly immersed in the culture.
4.5.1	Housing	Mobile walls and pre-furnished homes facilitate quick move-ins and move-outs.
5.0	Automation	Astoria will have reduced human labor thanks to the automation of a majority of the stations construction, operation, resident needs, and mining.
5.1	Automation of Construction Processes	The construction process will be facilitated by prefabricated outposts and Zero-G adapted robots.
5.1.1	Transportation of Materials and Equipment	The transportation of materials will be taken care of the by the construction modules modified for long distant space tugging.
5.1.2	Exterior Construction	Local mining materials of material and the construction will help reduce the cost and need for transportation.
5.1.3	Interior Construction	Interior construction will be optimized by an assembly line making building blocks and their installation by an overhead crane.
5.2	Facility Automation	The safe and continued operation of Astoria will be ensured by automated monitoring and repair systems
5.2.1	Automation of Settlement Operations	Life critical life support variables will be constantly monitored and corrected.
5.2.2	Interior Repair and Maintenance	The internal structure will be monitored and repair in case of any damage.
5.2.3	Exterior Repair and Maintenance	Because of the high chances of external damage the external repair will be constantly handled by robot
5.2.4	Methods for Solar Flare Protection	External critical robot will be fitted with electromagnetic shielding.
5.2.5	Security	A comprehensive authentication and
5.2.6	Contingencies	Plans will be at hand incase of possible failures.
5.3	Habitability and Community	Everyday life of humans on Astoria will be simplified and enjoyable thanks to the automated infrastructure at their hand.
5.3.1	Community Automation	Communities will be maintained and kept fully functional by automated services
5.3.2	Workplace Automation	Will make work more efficient
5.3.3	Residential Automation	Living will be easier and far more comfortable
5.3.4	Computing and	A future proof networking infrastructure will provide plenty of



	Networking	bandwidth and processing power for the station to grow.
5.4	Adaptation for Environment	Robots will be designed to withstand environmental hardships.
5.4.1	Methods of Adjustment	Procedures will be implemented to reduce risk.
5.4.2	Robot Component Design	To ensure efficient mining, robots will have Zero-G adaptations.
5.5	Material Unloading	Astoria will have a state of the art shipping and docking facility
5.5.1	Shipping Specification	Material will be accepted in both containers and bulk.
5.5.2	Acceptance of Ore	The shipments will be accommodated into standard containers.
5.5.3	Transport of Material	Materials in the Carnegie plate will be transported by a mesh rail system
6.0	Schedule and Cost	Construction begins in January 2074.
6.1	Schedule	Astoria's construction will take 23 years to complete.
6.2	Cost	Astoria's cost will total \$54,366,682,410.13.
6.3	Justification of Costs	Most of Astoria's construction materials will come from 253 Mathilde.
7.0	Business Development	Astoria economically lucrative
7.1	Infrastructure for Mining	Mining facilities will be shipped to Astoria to begin resource harvesting and ore processing
7.1.1	Harvesting Operations Equipment	Fleets of mining craft will mine Mathilde's resources, with humans available for observation and intervention
7.1.2	Processing Facilities	Processing facilities turn raw materials into construction pieces
7.1.3	Port Facilities	The Sullivan tower houses twenty ships at once when completed
7.1.4	Vehicle dust mitigation	Magnetic plates will charge and remove dust from vehicles
7.2	Logistic Services	Astoria will provide all manner of services for expeditionary forces and developing business ventures.
7.2.1	Agricultural Provisioning	Provisioning services for departing ships will be provided using Astoria's surplus stock.
7.2.2	Recreational Facilities	Recreational facilities include 0g entertainment centers, clubs, parks, and activities.
7.2.3	Maintenance Services	The Sullivan Tower will house multiple repair bays.
7.2.4	Refueling services	LH2 and LOX reserves are kept in the Carnegie Plate.
7.2.5	Ferry Services	Modubot space-tug teams will ferry ships on-site.
7.2.6	SAR Operations	Astoria will always have one fully stocked and fueled ship on standby in the Sullivan tower for search and rescue operations.
7.3	Research Opportunities	Astoria's unique location offers a variety of research opportunities.
7.3.1	Edison Telescope	The Edison telescope will aid in detecting incoming missiles.
7.3.2	Optical Telescope	The Tombaugh Observatory will be built on a suspension plate to reduce interference from mining operations.
7.3.3	Real-Time Communication	Caching services will enable real-time data sending to Earth.