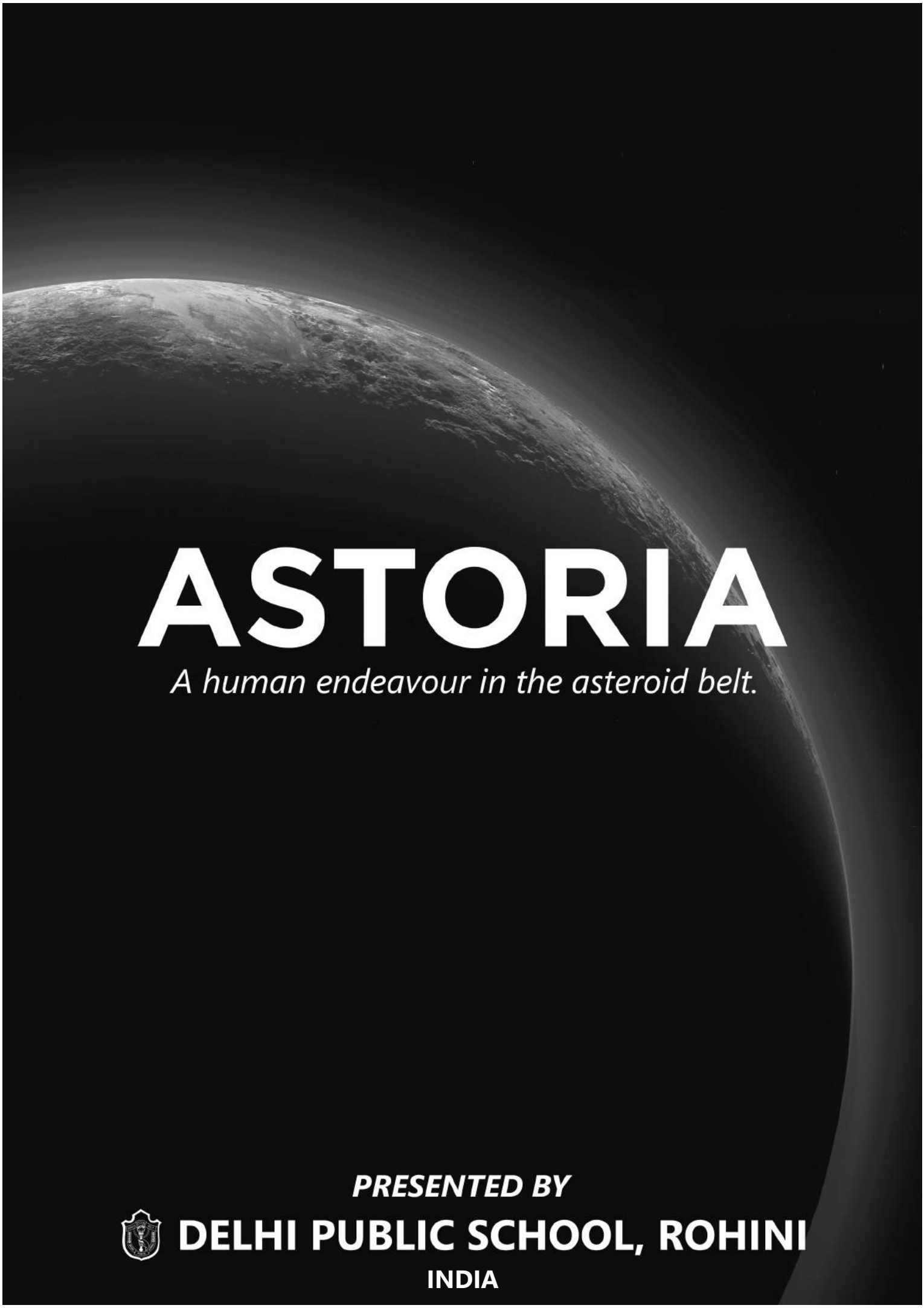
ASTORIA
A human endeavour in the asteroid belt.
PRESENTED BY
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Competition: (we advise that participants be at least 14 years old, and not older than 19)

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MEHUL ARORA	[9](14)	**KUNAL JAIN**	[9](15)
ROHIT AGRAWAL	[12](17)	**HRITIK AGGARWAL**	[10](15)
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SHIVAM BANSAL	[11](16)	**SARANSH KALRA**	[11](16)

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

GAURAV CHAUDHRY **UMA CHAUDHRY**

I understand that if our Team qualifies for the Asian Regional Space Settlement Design Finalist Competition January 2016, we will be expected to finance our own travel to / from Om Shanti Retreat Center, Manesar and share the cost of boarding / lodging during the competition.

Responsible Teacher / Advisor Signature

23.11.2015
Date

EXECUTIVE SUMMARY

"So how do you plan on saving the world?" – *Cooper*
"We're not meant to save the world, we're meant to leave it." – *Brand*

Interstellar

1.1 EXECUTIVE SUMMARY

Astoria is the orbital settlement that this project describes. Astoria provides a home and societal structure for 16,000 individuals. It has been designed and conceptualized as part of a network of space settlements by the Foundation Society. Astoria is located in the asteroid belt.

However, unprecedented in such an approach, Astoria is designed to provide a home, and not merely a house, to the residents. It is designed with all amenities of societal culture in mind and provides all the necessary factors that convert a group to a crowd. It enables not homo sapiens, but humanity, to live on the settlement.

Astoria takes the form of a four torus system surrounding a central cylinder. Pseudogravity is provided by rotating the entire structure about its central axis; the central cylinder is left non-rotating.

Habitation is provided in the two central tori. The top torus is used for agriculture whereas the bottom torus is used for industrial purposes.

The central cylinder has provisions for docking, maintenance, repair and overhaul and microgravity recreation. A 0g industrial center is also located here. A LFTR molten reactor is also a part of the central cylinder which will provide energy for all industrial purposes.

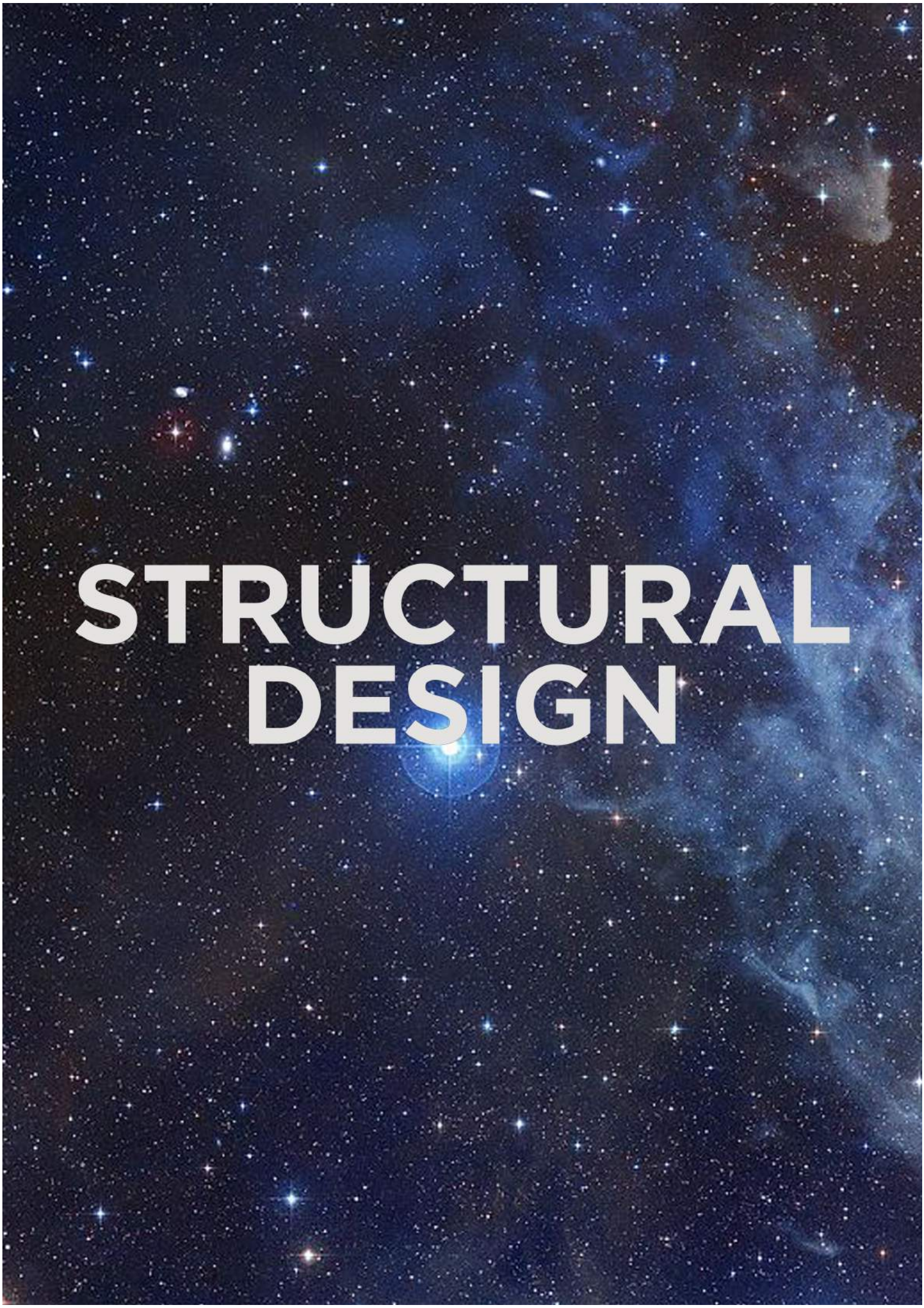
Along with the main structure are 5 secondary settlements each with their unique purpose. They are Kepler (for scientific research), Zuse (for technological developments), Spaceside (for rest and retirement), Quark (for innovation and administration) and Promenade (for family and recreation). These will enhance the timeline of services for Astoria's mining operations.

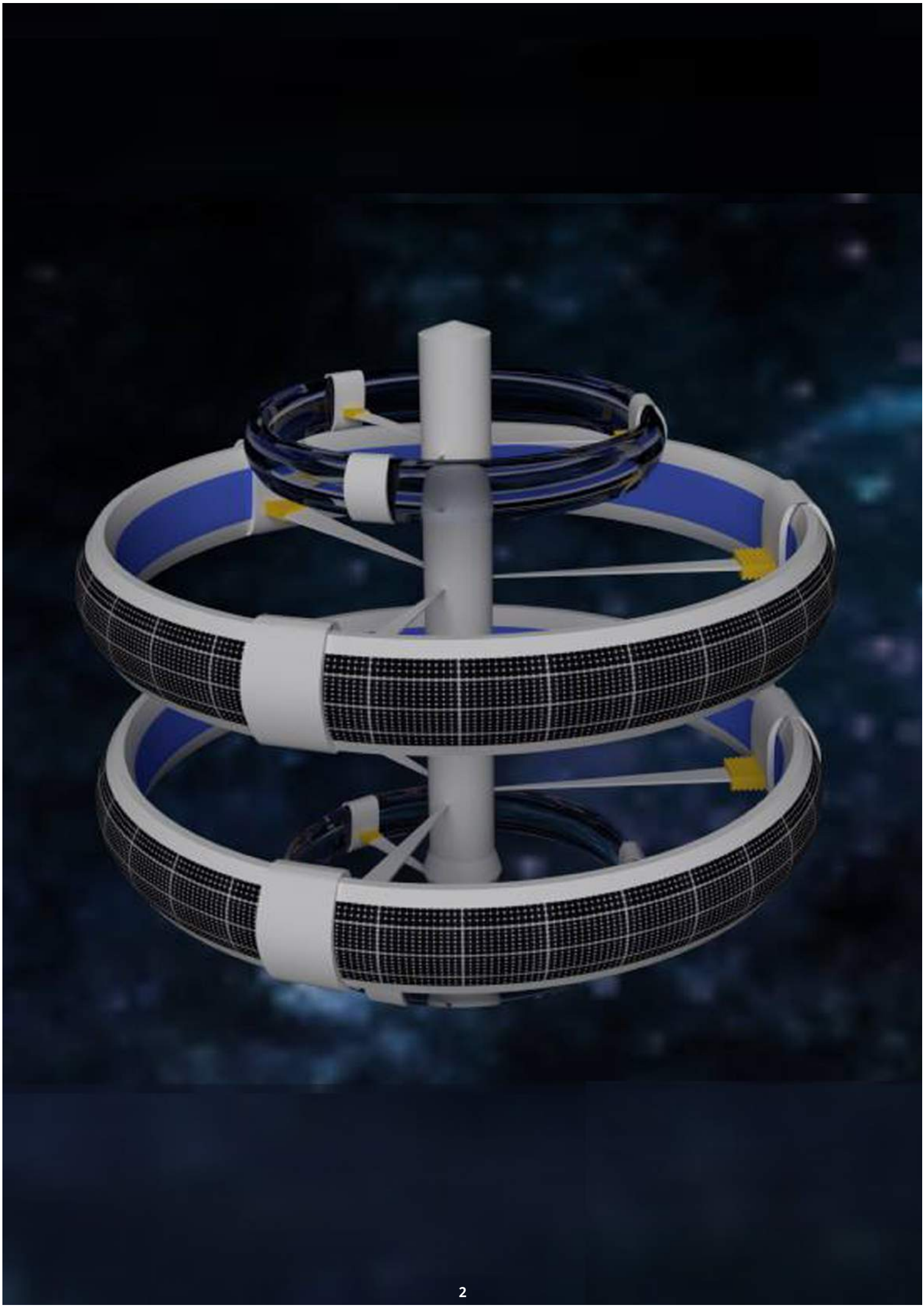
Astoria's primary occupation will be mining on asteroids. This will be done with the help of asteroid mining modules and the Asteroid Capture Module (ASCAMO). These will carry out on-board and off-board mining operations.

A series of machines will be responsible for conducting automation tasks. Robots will be used in all spheres of the settlement including, but not limited to, construction, MRO, transportation and lifestyle enhancement. These will be dedicated to reduce the wastage of valuable human capital is less intellectual tasks.

Scientific and technological research will also be a source of revenue for Astoria, with researchers trading new finding with the people of Earth. Powerful computational machinery will be used to process raw data from scientific equipment like telescopes and particle accelerators.

Astoria, to say the least, is a moonshot. It requires a lot of funding, but given proper planning, it can prove to be a milestone for the human race. It is a space settlement certainly not a first and definitely not the last. It is just another step in the inherent lust of human species to explore the unexplored realms of space and time.


STRUCTURAL
DESIGN



2.1 EXTERNAL CONFIGURATION

Astoria has a well planned structural organization to provide all comforts of life and leisure to its inhabitants. The structure of Astoria is designed to accommodate a maximum of 18,000 residents including 16,000 long term residents. The hull of Astoria will comprise of (a) a central cylinder for energy generation, docking, industrial purposes, etc. and (b) a four torus system including 2 residential tori, one agricultural torus and one industrial torus. Additionally, the main structure of Astoria will be supplemented with five secondary settlements housing one fourth of Astoria's population.

THE CENTRAL CYLINDER

The central cylinder is the pivot component of Astoria. It provides stability to the structure and will also be used for energy generation, docking, industrial purposes and transportation. The cylinder has chamfered edges to remove straight edges from the structure and reduce stress on the structure.

DOCKING STATION

At one end of the central cylinder will be the docking station for shuttles, secondary settlements and incoming spacecrafts. Since the central cylinder is a non-rotating sector, docking here would be the easiest. The docking station is capable of holding upto 10 small shuttles, 6 large spacecrafts and 1 secondary settlement using protruding hangars. There are special provisions for docking the asteroid capture modules.

MRO CENTER

To provide crucial overhaul services to passing spacecrafts, Astoria will have an extensive MRO center dedicated to the maintenance and repair of these spacecrafts. Services like damage analysis, damage repair, refuelling and *space tug* will be provided to restore these disabled. Vessels can also pitstop at Astoria for refuelling, procuring materials for in-situ utilisation as well as rest and recreation of passengers of the vessel.

CONTINGENCY MODULES

Located at the base of the residential tori, the contingency modules will be used to house and evacuate residents of the settlement incase of an emergency. Each module is well stocked with food, water and other prerequisites for human life. The modules are pressurized, but no artificial gravity. Each module can support a population of 100 people, albeit in discomfort, for a journey of atleast 1 astronomical unit.

INDUSTRIAL MODULE

Industrial processing is an essential activity aboard Astoria. Therefore, an industrial module is located in the central cylinder dedicated to microgravity manufacturing. This is a part of the Astoria Industrial Center which also comprises the Industrial Torus. Together, these will be responsible for manufacturing of goods for usage on Astoria and export to other settlements.

MICROGRAVITY RECREATION

To provide enhanced recreation to residents, especially minors, a vast expanse of microgravity recreation opportunities will be incorporated in the settlement. The Microgravity Recreation Center will be located in the central cylinder as a pressurized unit. Several specially designed sports and games will be played here.

NUCLEAR POWER STATION

At the other end of the central cylinder will be a nuclear power station which will be used to generate a majority of power for Astoria's industrial and operational purposes. It will include a molten salt reactor – Liquid Fluoride Thorium Reactor (LTFR) – to produce energy from nuclear fission. Incase of any nuclear calamity, there will be provisions to automatically detach the nuclear power station from the central cylinder to preserve the safety of Astoria.

THE RESIDENTIAL TORI

The 2 Residential Hybrid Tori (RTs) will serve as the main residential area of Astoria. The RTs provide all conditions that are ideally suited for human survival on Earth. These will be rotating, pressurized chambers. The inner surface of the RTs will have windows to allow sunlight inside the settlement and the outer surface of the RTs will be covered with specially designed rotating solar panels. These will be optimized to always face the

sun so that the light rays fall perpendicularly on the panels, increasing output. The inner surface of the RTs will have windows which will provide views of outer space of the residents. The tori will be connected to the central cylinder with the help of three spokes. The spokes help rotate the residential tori to generate artificial gravity.

The shape of the RTs is unique. A hybrid structure, created by taking an elliptic torus and flattening the outer surface, will be used to provide more residential surface area. However, the flattening will not result in sharp edges in the structure and will not compromise with the structural stability.

THE AGRICULTURAL TORUS

Growth of most kinds of crops will be carried out using scientific cropping techniques on the agricultural torus. This will be a rotating and pressuring hull component. This torus will have the ability of rotate at variable rates in order to increase the yield according to the crops being cultivated. The default rate of rotation will be 0.4g as studies indicate this value might be ideally suited for plant growth and might increase rate of flow of water through the plant. However, according to real tests on Astoria, this value can also be altered.

The walls of the agricultural torus will be made of high tensile strength glass. This will enable the inflow of more amounts of sunlight and thus increase the rate of photosynthesis. However, at certain intervals the glass will be shuttered so as to provide the crops with rest during the dark.

A mixture of Earth soil and Nafion will be used in the agricultural beds of the the torus. Nafion is known for its high water permeability and resistance to chemical attacks. This mixture will be used to mimic the purpose of soil on Astoria. For growing some crops hydroponics will be used, which is a method of growing plants in mineral nutrient solution in water, without soil.

A sophisticated drip irrigation system and an aquaponics system will also be used to minimize wastage of water. Water will be dripped, in regular intervals, onto plant root zones through a network of pipes and valves. This removes the need to level the land and lessens soil erosion.

THE INDUSTRIAL TORUS

The industrial torus will be a part of the Astoria Industrial Center along with the industrial hub on the central cylindrical hub. This will be a pressurized and rotating sector. The speed of rotation of this torus can be increased or decreased according to the demands of the manufacturing activities taking place and 0.9g will be the default value. Along with the Industrial Module in the central cylinder, this will be a part of the Astoria Industrial Center. Unlike the industrial module which specializes in 0g manufacturing, the torus will be used for macrogravity manufacturing.

THE INDUSTRIAL TORUS

Astoria will need to have provisions for artificial gravity, because the the absence of gravity can result in rapid muscle atrophy and bone decalcification. The illusion of gravity on Astoria is provided by rotating the RTs. Centripetal acceleration causes the residents to perceive a sensation of gravity. To ensure conditions as close as possible to that of Earth, the artificial gravity on Astoria should be 9.81 m/s^2.

$$g' = \frac{R \times (\frac{\pi \times rpm}{30})^2}{9.81}$$

where R = radius from center of rotation in meters
rpm = revolutions per minute
π = 3.14159; and
g' = fraction of Earth's gravity experienced

Putting g' = 1 and R = 1273m, the desired rotation speed of Astoria is calculated to be 0.8382 revolutions per minute for residential tori of Astoria.

Though rotation will put extra stress of the settlement's structure, the impact is relatively modest in comparison to the existing stress on the structure to hold itself. Moreover, this is preferable by far to a microgravity environment. Similar calculations will be used to determine the desired angular velocity on the secondary settlements.

The torque for rotation will be provided by the nuclear fission reactor. The tori will be rotated with the help of spokes attaching the central cylinder to the tori. Ball bearings will be used which roll along with the outer structure which moderates friction amid them. Lubricants like Perfluoropolyether (PFPE) will also be used in the rotation mechanism to reduce the energy lost as heat.

Table 1: Dimensions and statistics of structural components

THE CENTRAL CYLINDER	Radius	0.1 km
	Height	2 km
	Volume	0.141 km^3
	Angular Velocity	0 rpm
	Artificial Gravity	0g
	Pressure	0 atm
THE RESIDENTIAL TORI	Radius	1.273 km
	Width	0.3 km
	Vertical Clearance	0.2 km
	Land Area (x2)	4.799 km^2
	Volume (x2)	2.02 km^3
	Population	16000 people
	Population Density	3334.02 people per sq. km
	Area per Person	300 m^2 per person
	Angular Velocity	0.8382 rpm
	Artificial Gravity	1g (9.81 m/s^2)
	Pressure	1 atm (101325 Pa)
THE AGRICULTURAL TORUS	Radius	0.637 km
	Width	0.2 km
	Vertical Clearance	0.1 km
	Land Area	0.8 km^2
	Angular Velocity	0.749 rmp (default), variable
	Artificial Gravity	0.4g (default), variable
	Pressure	1 atm (101325 Pa)
THE INDUSTRIAL TORUS	Radius	0.637 km
	Width	0.2 km
	Vertical Clearance	0.1 km
	Land Area	0.8 km^2
	Angular Velocity	1.124 rpm (default), variable
	Artificial Gravity	0.9g (default), variable
	Pressure	0.5 atm, variable

2.2 INTERNAL CONFIGURATION

The following diagrammatic representations of Astoria's residential land distribution shows the distribution of various amenities in the residential area. Industrial and agricultural facilities will be allocated minimal land percentage because they have dedicated tori and modules for themselves. There will also a significant proportion of land that will be reserved for future development. The residential area will also have plenty of institutional and commercial opportunities for the residents.

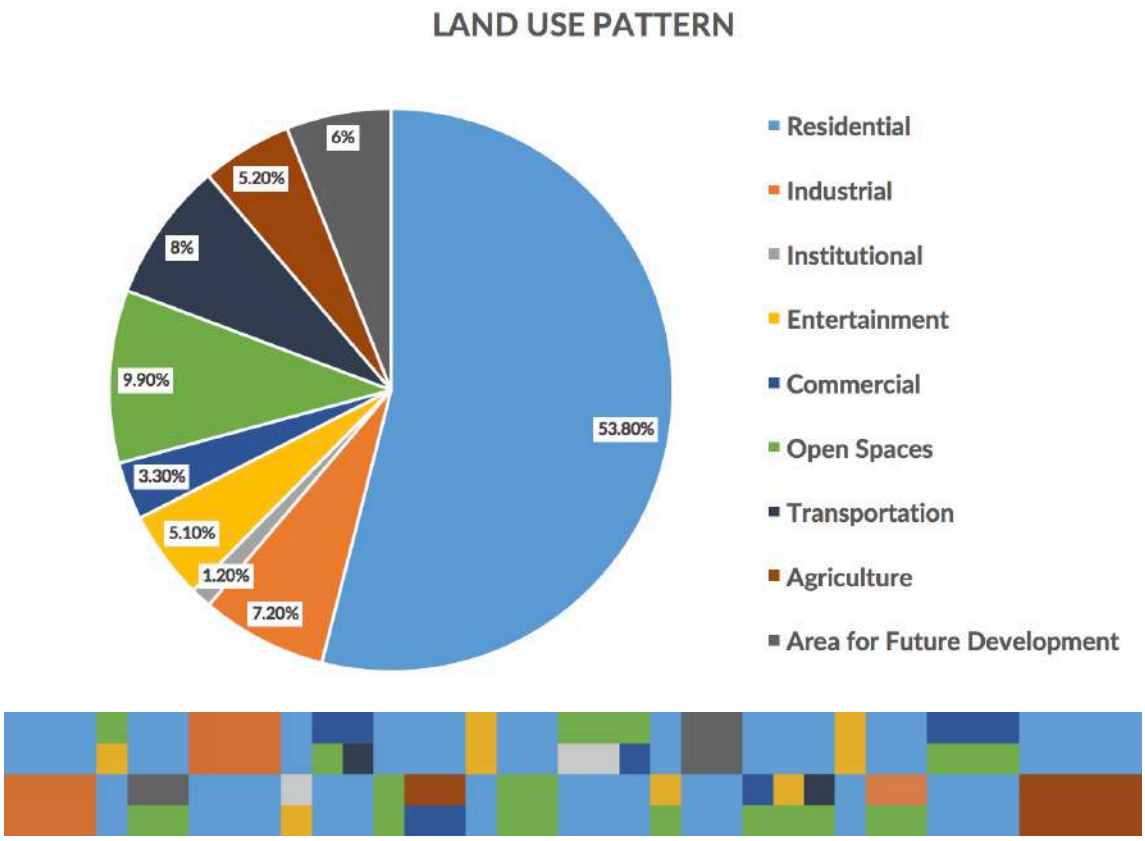


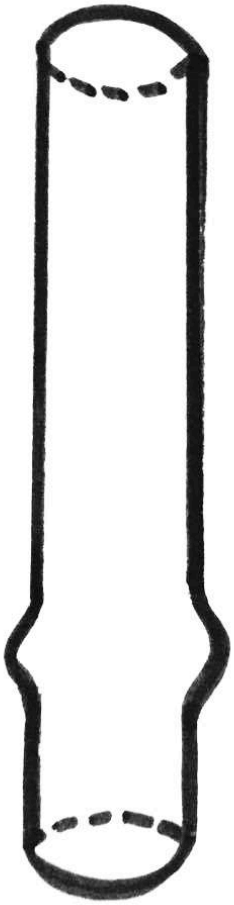
Figure 2: Pie chart depicting percentage allocation of residential land

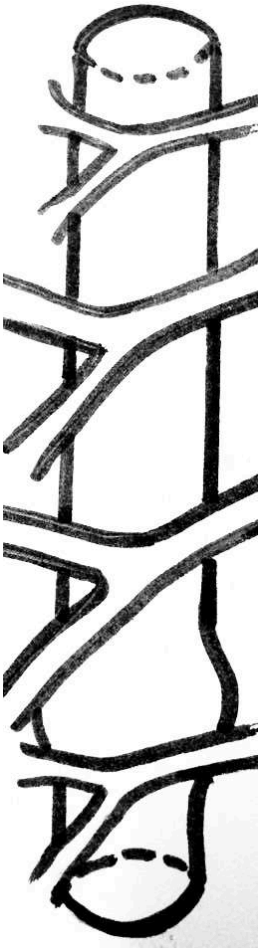
Figure 3: Map showing layout of Astoria's residential land

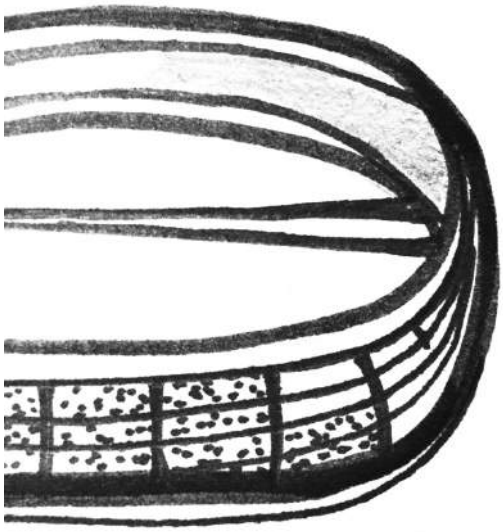
2.3 CONSTRUCTION PROCESS

Building a settlement in the asteroid belt is difficult. However, with the vast network of settlements of the Foundation Society, construction of Astoria will receive valuable support from other inner solar system settlements like Aresam. Moreover, in the first five year of construction of Astoria, its orbit will be synchronised with that of Aresam. As a result a lot of valuable construction materials can be obtained from the Martian settlement. The central cylinder will be the first hull component to be constructed which will be deployed pre-fabricated from Aresam. This will be followed by construction of the four tori and the secondary settlements. The construction of Astoria is estimated to be completed in a mere ten years due to advanced construction machinery and process automation.

Since construction costs are significantly reduced at low gravity and pressure, construction will mostly take place at microgravity and at pressure values lower than 0.5 atm. As a result, rotation of tori of Astoria will only begin once a majority of construction has been completed. In the second phase of construction, the rudimentary asteroid mining apparatus will be deployed. This will allow mining of useful materials that will be used in the construction of Astoria.







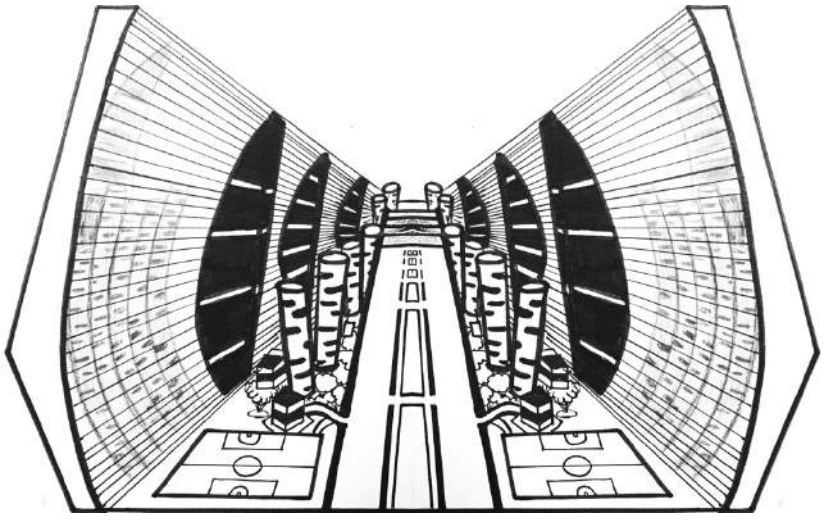


Figure 4, 5, 6 (top row): Construction of central cylinder and spokes
Figure 7 (bottom left): Installation of solar panels
Figure 8 (bottom right): Completed construction of residential tori

2.4 ASTEROID SHEILDING AND DAMAGE REPAIR

Being situated in the asteroid belt makes Astoria prone to asteroid damage. Therefore, the settlement will incorporate a robust set of asteroid defence mechanisms to avoid and repair damage.

TRAJECTORY MAPPING

Using advanced computational mechanism and asteroid imagery, the trajectory of each known object that is a part of the asteroid belt will be mapped. This will be used to calculate and determine the safest trajectory for the settlement that also provides ample access to asteroid mining opportunities.

ASTEROID DEFLECTING SYSTEM

Many of the incoming dangers can be detected upto 1 hour in advance. Astoria will use laser emitting satellites to push small, yet potentially dangerous, objects away from the settlement. Instead of using one giant laser to blast an asteroid away, several small lasers will act as rocket thrusters to push away the object. Upon detecting an impending disaster, laser equipped satellites will be launched to deflect the asteroids away. Even the small deflections will be enough to prevent collision with the settlement and secondary settlement.

ASTEROID STORM SHEILDING

Astoria will often be subjected to storms of small asteroids which may damage the more fragile components of Astoria like windows and docked vehicles. In such a scenario, all docked vehicles will be internalized to avoid damage. To shield the glass of the RTs and agricultural torus, shutters will be used to cover the windows with a graphene based shell.

PROPULSION SYSTEM

In some cases, deflecting the asteroids might not be sufficient to ensure the safety of the settlement and its residents. For these cases, Astoria has provisions to relocate the settlement by 2 kilometres to become clear of the path of the object. Such manoeuvres are achieved by propulsion systems that are a part of Astoria. Hydrogen powered propellers located on the central cylinder of Astoria will be used to move Astoria. Considering ample supply of fuel available to the settlement and time taken to regain stability in new orbit, this manoeuvres should be easily possible every 14 Earth days.

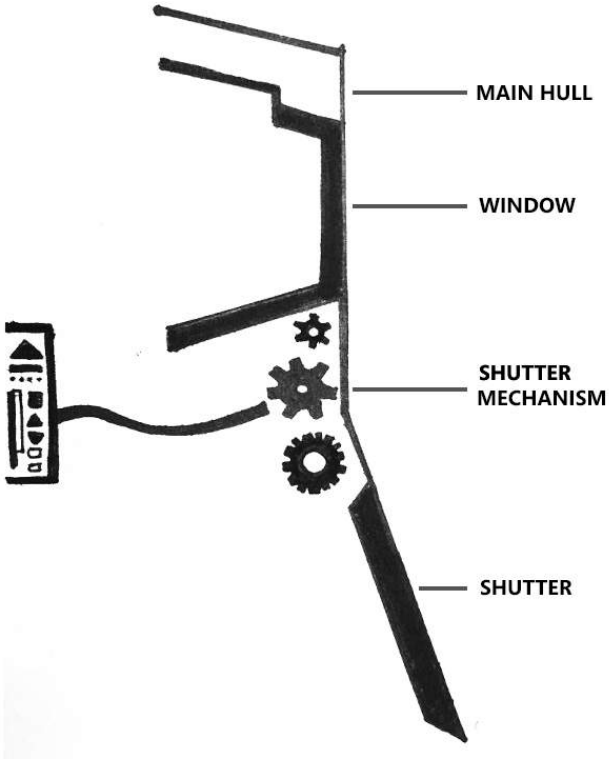


Figure 9: Design of window shutter mechanism

REPAIR MECHANISM

Due to frequent impact of small particles, a robust repair and maintenance mechanism will be adopted on Astoria. Human labour will obviously be incompetent in this regard. The basic principle behind the self-repair mechanism on Astoria will be the regulation of various components to combat the stress. Decreasing in the elasticity of the material at a one place in the structure to avoid further stress on its functioning caused by the damage. This would increase the time available to repair the structure.

Upon damage, a swarm of robots will be deployed. These will move across the exterior of the settlement by magnetically attaching themselves to the hull. They will be able to screw, unscrew, seal, reinforce and latch various components of Astoria.

These robots will reinforce the damaged parts. They might also be supported by repair robots from the inside of the hull, incase of bumps and dents. Incase there is damage to the glass in the windows of Astoria, shutters will immediately swing into positions to prevent adverse effects. Thereupon, the glass pane will be replaced from the inside. Since the hull of Astoria will be mostly tiled, incase of severe damage, the entire composite can be replaced after vacuum locking the area using shutters.

2.5 SECONDARY SETTLEMENTS - STRUCTURE

Astoria will also be accompanied with 5 secondary settlements to suburbanised Astoria each one serving a specific and vital purpose and improve timeline of services for asteroid mining. Each settlement will be capable of launching and docking asteroid mining units. This implies that mining modules can return to Astoria and be processed in a shorter duration of time. These secondary settlements are Kepler (for scientific research), Zuse (for technological developments), Spaceside (for rest and retirement), Quark (for innovation and administration) and Promenade (for family and recreation).

STRUCTURE OF SECONDARY SETTLEMENTS

The general structure of secondary settlements will consist of a central hub and three protruding arms. The ends of the arms will be pressurised and rotating residential hubs whereas the central hub will be used for microgravity activities. The spokes will be used to rotate the residential hubs and inturn, create artificial gravity. The central cylinder will be used for docking and also for conducting microgravity research. Three isolated residential hubs, although can house a smaller fraction of people, serves the purpose of separating the population based on specialisation and area of research. Internal transportation lines can be used to quickly get from one hub to another.

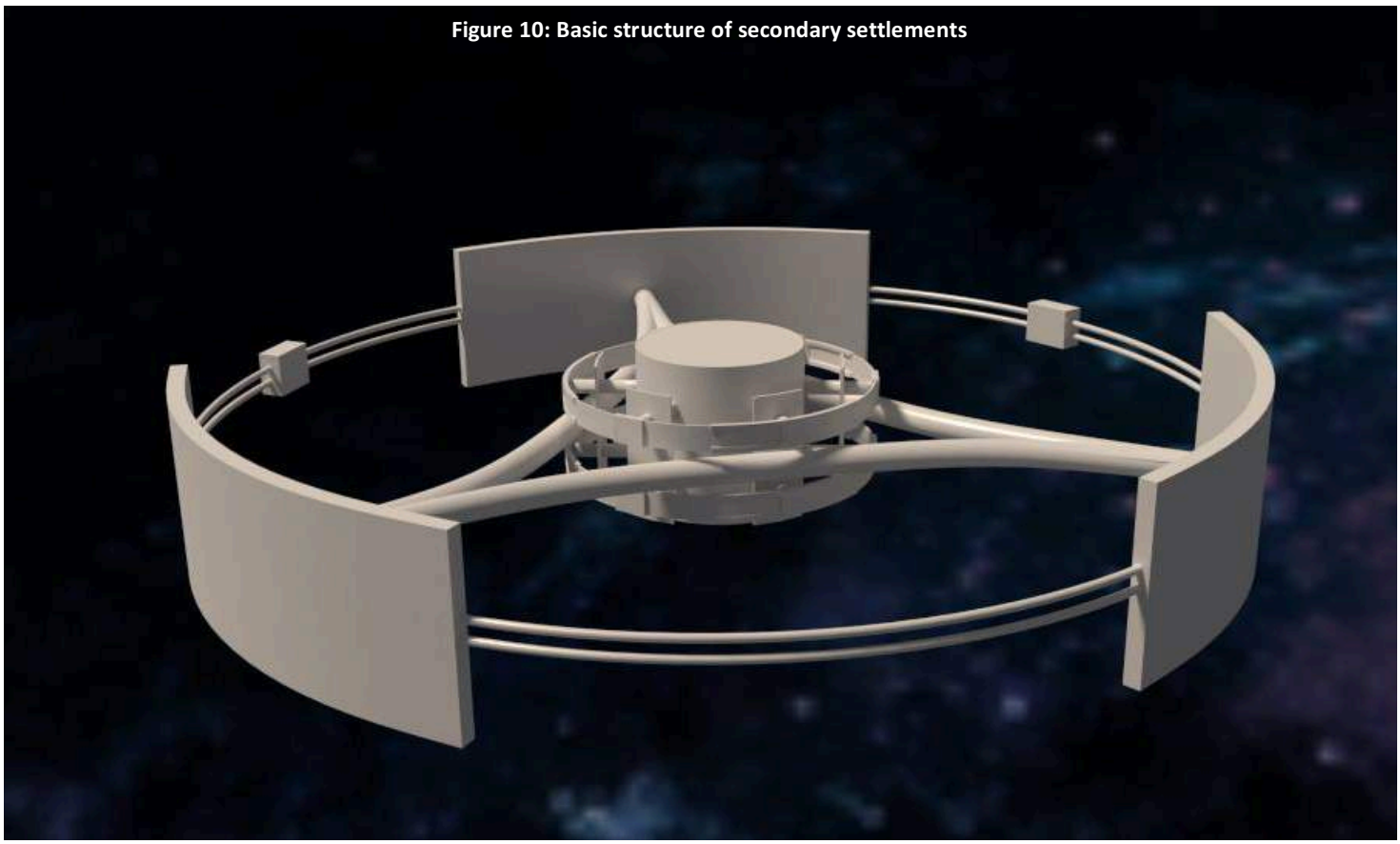


Figure 10: Basic structure of secondary settlements

Table 2: Dimensions and statistics of secondary settlements

Name	KEPLER	ZUSE	QUARK	SPACESIDE	PROMENADE
Basic Purpose	Scientific Research	Technological Development	Innovation and Administration	Rest and Retirement	Family and Recreation
Floor Width (km)	0.2	0.2	0.2	0.2	0.2
Vertical Clearance (km)	0.2	0.2	0.2	0.2	0.2
Radius (km)	1.2	1.2	1.2	1.2	1.3
Area (km^2)	0.50	0.50	0.50	0.50	0.54
Population	1000	1000	700	600	1200
Population Density	2000.00	2000.00	1400.00	1200.00	2205.89
Velocity of Rotation	0.863 rpm	0.863 rpm	0.863 rpm	0.863 rpm	0.829 rpm
Gravity	1g	1g	1g	1g	1g
Distance from Astoria	1 AU	1 AU	0.5 AU	0.5 AU	0.1 AU

OPERATIONS & INFRASTRUCTURE

3.1 ORBITAL LOCATION AND MATERIALS

Determining the location of Astoria and its secondary settlements settlements is key. During the construction, the period of revolution of Astoria will coincide with that of Mars so as to obtain useful materials and machines for construction from the Aresam settlement. Astoria will be located at a mean distance of 2.2 astronomical units (329 million kilometres) from the Sun in a region of low spatial density of asteroids. Being nearer to Earth and other settlements will hasten the process of construction of Astoria.

However, five years into the construction, Astoria will be relocated to a mean distance of 2.77 astronomical units (414 million kilometres) from the Sun in a region of high spatial density of asteroids, which is the orbital distance of dwarf planet Ceres. It will be located at a Lagrangian point of Ceres. Lagrangian points are positions in an orbital configuration of two large bodies where a small object affected only by gravity can maintain a stable position relative to the two large bodies. Such a location ensures that Astoria can have a stable orbit despite attractive pull from the Sun and Ceres. This region is also home to many valuable asteroids as listed in Table 11.

A variety of materials will be used aboard Astoria for construction, industrial and automation purposes. Alloys and hybridized materials will be used to provide a suitable blend of strength and lightness.

Table 3: Raw materials for construction

MATERIAL	YOUNG'S MODULUS	USED IN CONSTRUCTION
Carbyne	32,400 GPa	• main hull components of Astoria and secondary settlements • space shuttles • asteroid mining installments
Diamond	1,210 GPa	• main hull components of Astoria and secondary settlements • windows and glass panels • Industrial manufacturing and processing
Graphene	1,050 GPa	• main hull components of Astoria and secondary settlements • windows and glass panels • computer chips and components
Single Walled Carbon Nanotubes	940 GPa	• main hull components of Astoria and secondary settlements • asteroid mining installments
Osmium	562 GPa	• industrial manufacturing and processing • automation and manufacturing machinery
Silicon Carbide	450 GPa	• industrial manufacturing and processing • nuclear fuel particles and cladding • electric and lighting systems
Carbon Fibers	448 GPa	• construction of transportation system • construction of automation and manufacturing machinery
High Speed Steel	5.25 GPa	• Structural reinforcement • Industrial and cutting tools
Polyethylene Terephthalate	2.7 GPa	• radiation shielding • spacesuits

Alongside, Wurtzite boron nitride (w-BN) will also be used in industrial processes. With its extreme hardness and polycrystalline structure w-BN can forged with cutting tools.

To make the windows in Astoria, special multi-layered tempered glass will be used. Astoria's glass comprises of six distinct layers out of which one layer will comprise of transparent luminescent solar concentrator (TLSC).

TLSC panels use organic salts that absorb specific wavelengths of ultraviolet and infrared light, which then luminesce as another wavelength. These are guided to the edge of plastic, where thin strips of conventional photovoltaic solar cell convert it into electricity. This serves the dual purpose of harnessing solar energy and also preventing infrared rays from entering and heating the settlement.

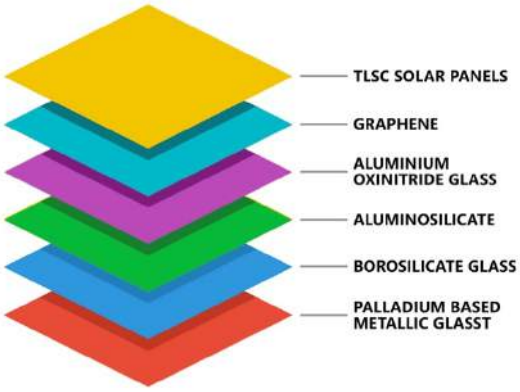


Figure 11: Six layered glass for windows of Astoria

The aforementioned materials as well as a set of other materials will also be used for various industrial, maintenance and agricultural processes. Their sources, amounts and uses are enlisted in table ###.

Table 4: Types, amount and sources of raw materials

MATERIAL	VOLUME REQD.	SOURCE	USE
Carbyne	2,000,000 tonnes	C-Type Asteroids	Construction
Diamond	1,000 tonnes		
Graphene	2,000,000 tonnes		
Carbon Nanotubes	2,000,000 tonnes		
Carbon Fibers	1,000,000 tonnes		
Osmium	500 tonnes	M-Type Asteroids	Industrial
Silicon Carbide	400 tonnes	S and C-Type Asteroids	
Aluminium Oxinitride Glass	400 tonnes	M-Type Asteroids	Windows
Palladium based Metallic Glass	400 tonnes		
Borosilicate Glass	400 tonnes	M and S-Type Asteroids	
Aluminosilicate	400 tonnes		
UHMWPE Fibers	1000 tonnes	C-Type Asteroids	Radiation Shielding
HDPE Fibers	1000 tonnes		
Polyethylene Terephthalate	500 tonnes		
Titanium	1000 tonnes	M-Type Asteroids	Industrial
Tungsten	100 tonnes		
Vectran	100 tonnes	C-Type Asteroids	Construction
Teflon	75 tonnes	C-Type Asteroids	Spacesuits
Kevlar	75 tonnes		
Titanium Carbide	100 tonnes	M and S-Type Asteroids	Industrial
High Speed Steel	1,000,000 tonnes	M and C-Type Asteroids	

3.2 LIFE SUPPORT AND BASIC INFRASTRUCTURE

Astoria will be equipped with all basic infrastructure necessary to sustain a specie and a community. A dynamic system comprising of machinery and manual labour will ensure everything from the climate control system to the waste management system works smoothly. To provide a living experience identical to Earth even trivial aspects such as controlling the day night cycle and public transport will be explored in detail.

ATMOSPHERE COMPOSITION

To maintain life processes, the humans require an atmosphere of acceptable composition and pressure. In the residential area of Astoria, a consistent pressure of 101325 Pa will be maintained. The atmosphere of the Astoria will comprise of a partial pressure of oxygen equal to 170 mmHg which is sufficient to provide ideal partial pressure within the alveoli of the lungs for good respiration. This is also the level that exists at sea level on Earth.

The atmosphere of Astoria will also have a partial pressure of 200 mmHg of nitrogen. Nitrogen constitutes almost 80% of Earth's atmosphere. Being an inert gas, the presence of nitrogen in Astoria's atmosphere is desirable since it would prevent an unusual form of decompression from occurring in the body's chambers, while providing a greater safety margin during either accidental pressure drops. Some organisms also require nitrogen for regular growth and fixed nitrogen is essential in the growth of leguminous plants.

The level of carbon dioxide on Astoria will be maintained below the OSHA standard i.e. pCO_2 (partial pressure of carbon dioxide) should be less than 0.4 kPa (3 mm Hg). At the same time the carbon dioxide levels will be high enough to permit maximum rates of photosynthesis by crop plants. Based on analysis of human needs, it is observed that 22°C and a relative humidity of 40% will also be maintained on Astoria.

CLIMATE CONTROL

To save energy and enable a less cumbersome lifestyle, seasons on Astoria will be kept constant. It is observed that 22°C and a relative humidity of 40% are ideal for human physiological and psychological functioning. This will also eliminate any maladies that arise due to change in season and enables a pleasant climate all the time.

However, due to its location and orbit, the settlement will not be able to attain these conditions naturally. Therefore, a series of artificial climate control measures will be adopted. Temperature can be increased and decreased using thermal induction from the nuclear station and vapour-compression refrigeration respectively. Humidity can be controlled using a network of which can humidify or dehumidify the environment using sieves of appropriate pore diameters. To meet personal needs, each home will be equipped with a network of smart thermostats which learn and adapt to the needs of the resident.

POWER GENERATION

Astoria will employee three sources of power generation – nuclear fission, solar power and hydrogen combustion. Nuclear fission will be used to meet the industrial and operational demands of Astoria like mineral processing and artificial gravity generation. Having abundant reception of sunlight, Astoria will use solar panels located along the outer rim of the residential tori to meet residential and a fraction of industrial demands of energy. Hydrogen combustion will power launch vehicles that are a part of Astoria and asteroid dodging.

SOLAR ENERGY

Concentrator Photovoltaic (CPV) Technology will be used to generate electricity from sunlight aboard Astoria. CPV technology uses lenses and curved mirrors to focus sunlight onto small, but highly efficient, multi-junction (MJ) solar cells and are most efficient of all available solar energy. Moreover, Photon Enhanced Thermionic Emission (PETE) scheme will be used, which involves a wide-bandgap semiconductor absorber under CPV solar panels. Herein electrons are first promoted to the conduction band by photon absorption and subsequently emitted into vacuum by thermal excitation. This is a novel approach to increase the efficiency of the solar panels.

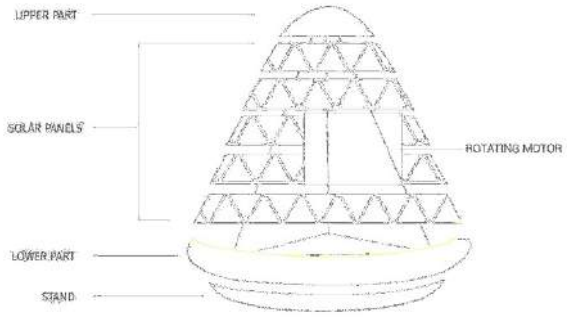


Figure 12: Design of rotating solar panels

Silicon and other metals required to manufacture these solar panels will be obtained from mining of silicate (S-type) and metal-rich (M-type) asteroids.

NUCLEAR FISSION

Astoria, being a center for various industrial processes, requires a lot of power which cannot solely be achieved with the help of solar energy. To provide energy for rotating the tori of Astoria and industrial processes, nuclear fission will be used. Specifically, the molten salt reactor – Liquid Fluoride Thorium Reactor (LTFR) – will be used for nuclear power generation in the settlement. This is inherently safer, leak resistant and produces less long lived waste.

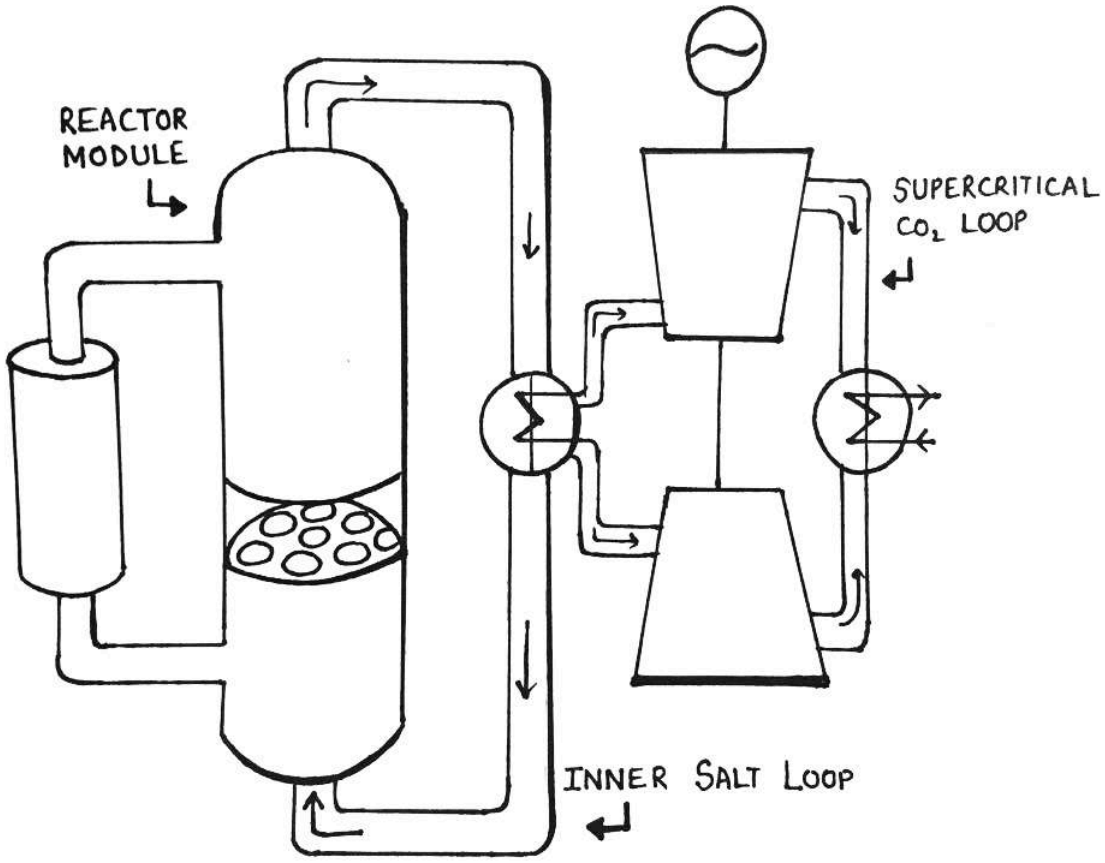


Figure 13: Design of Liquid Fluoride Thorium Reactor (LFTR)

HYDROGEN COMBUSTION

Hydrogen Internal Combustion Engines will be used in the ASCAMO, the shuttles and the asteroid dodging mechanism of Astoria. Having a high calorific value, hydrogen combustion will serve as the ideal fuel source for short distance space travel. Liquid hydrogen will be obtained from the electrolysis of water into water and hydrogen. Liquid hydrogen will also be compact and consume less space. the Using hydrogen combustion is essential because electrical energy cannot provide reaction forces which is required to navigate objects in space.

STORAGE OF ENERGY

To store extra energy produced for to power the main settlement, spaceships, secondary settlements or asteroid mining operations, metallized xenon difluoride will be used in solid fuel cell. The battery is capable of storing 1 kilojoule of energy per gram. Xenon difluoride crystals compressed to a dense state inside a diamond vice make for an ultra-dense battery. Under the extreme pressure conditions, the substance is *metallized* and its atoms are pushed closer to a new stable state.

Table 5: Allocation of energy use

PURPOSE	KILOWATTS USED (kW)	PERCENTAGE
Residential	128,000	14.05%
Entertainment	18,000	1.97%
Transportation	45,000	4.94%
Industrial	162,000	17.79%
Operational	120,000	13.17%
Mining	200,000	21.96%
Agriculture	37,500	4.11%
Commercial	50,000	5.49%
Backup	150,000	16.47%
Total	910,500	100%

COMMUNICATION

To facilitate data transfer and communication within the settlement, a series of optical fibers and Powerline adapters will be used. Free-Space Optical communication (FSO) will be used by Astoria to connect with secondary settlements as well as Earth. A centralised communication interface will be provided to all residents of Astoria as part of the Astoria Visor.

INTERNAL TRANSPORTATION

Internal transportation on Astoria will comprise of a network of auto rickshaws, bicycles and a mass rapid transport system. Bicycles will be used by residents for travelling to nearby places, such as houses of friends and shopping complexes and also as a means of exercise. Self driving auto rickshaws, will be used by differently abled and elderly population. The rapid transport system will be used a means of public transport and comparatively long distance commute.

For daily commute of residents, Astoria will have an advanced rapid transport system. It will be a part of an elevated system to save ground space. Trains will run in circular paths covered the circumference of the residential torus in both directions. The trains will have a high frequency, however at the cost of low capacity of each train. Each train will have 1 compartment that is capable of seating 20 people and a standing area for an additional 20 people. The trains will be self-driving to reduce the risk of accidents and increase efficiency.

Another network of operational trains will be used on Astoria which will be only be used by authorized personnel. This will allow access to the Astoria Industrial Center, agricultural torus, nuclear power plant, docking station, etc. Transportation will be carried through the spokes and through the central cylinder.

The tracks will be a magnetic levitation (maglev) line along evacuated (vacuum) tubes whereas the trains will be pressurized capsules. Using linear induction motors and air compressors, the train will create an air cushion upon which it will move. The maglev technology will also levitate the train. The combination of these two technologies will eliminate friction as well as air resistance and enable the train to speeds of upto 8,000 kilometers per hour.

EXTERNAL TRANSPORTATION

Astoria will also be equipped with a fleet of 100 shuttles to enable commute to and from secondary settlements. These non-rotating, pressurized vessels will be used for the conveyance of man and kind in a to and fro journey of up to 1 astronomical unit. It will be well stocked with not only with fuel but also with food and fluids in the form of meal replacement beverages. Solar panels and stored energy will serve the power needs of the shuttles. Plants on board the modules will be responsible for atmosphere sustenance and oxygen replenishment.

Each shuttle will be capable of housing 50 people. Passengers will be required to sit on strap on seats and beds optimized for microgravity conditions. Complete 0g exposure will be limited to 3 hours in one Earth day.

Ample entertainment and community activities will be available to all the passengers to avoid creating a monotonous environment. The shuttles will be capable of docking at the docking stations of the main and secondary settlements.

The shuttles will be capable of navigating themselves, but will still be accompanies with a crew of 3 pilots to take control incase of an unforeseen emergency. Moreover, the trajectory taken by the shuttles in its journey will be in the shape of an arch to provide atleast slight amounts of centrifugal force and subsequently artificial gravity.

WATER MANAGEMENT

Astoria is a self sustaining system. Therefore, all the water aboard the settlement must be recycled. The water conservation methods are concentrated around the three Rs - reduce, reuse and recycle. Moreover, water can also be obtained from mining of C-type asteroids and other objects in the asteroid belt such as Ceres.

REDUCE AND REUSE

A broad set of conservative activities will be performed on Astoria to minimize the water that needs to be recycled. This will involve using equipment specifically designed to minimize the wastage of water. These will consist of:

- Drip irrigation will be used in the agricultural torus to minimize usage of water, yet providing sufficient water to the plants at ideal periods.
- Proximity sensing taps and other bathroom equipment will be installed.
- Water from air conditioning units will be pure and will be used for other purposes.
- An extensive aquaponics system will be incorporated which will reuse water after irrigation.
- A greywater system will divert water from daily menial works like washing hands to other uses, say for example flushing the toilet.
- The users will be provided with a Water Pinch Analysis Report to make them realize the amount of water they are wasting so that they can take necessary action against it.

RECYCLE

Water, in all forms sweat, sewage and greywater will be recycled in the water purification system. By using vapour compression distillation, it is estimated upto 91% of liquid fed into the water purification system can be recycled. The process will mimic the water cycle on Earth and use the space vacuum to lower the boiling point of water. More specifically, evaporation of more or less viscous fluids will be conducted for the purpose of removing the liquid phase in order to produce a concentrate of the contents of solid material. The residue is removed and the condensed pure water is sent back to the water cycle.

Detergent contamination in water, from laundry and cleansing, can be treated using zinc oxide nanoparticles. Zinc oxide nanoparticles create a catalytic reaction in the presence of sunlight, which hastens the process of photochemical mineralization of detergent contamination.

WASTE MANAGEMENT

In order to be truly self sustaining, Astoria needs to employ a robust waste management system. Therefore, all waste will be segregated using a series of advanced processes followed by individually teating each kind of waste.

WASTE GASIFICATION: Waste gasification is a process of converting garbage into fuel and electricity without incinerating it. This technique uses a multiple high-temperature processes - including subjecting garbage to plasma arcs - to break down organic materials into syngas. This process can convert waste into more useful products.

INDUCTION SORTING: In induction sorting, waste material is sent along a conveyor belt with a series of sensors underneath. These sensors locate different types of metal which are then separated by a system of fast air jets which are linked to the sensors.

NEAR INFRARED SENSORS (NIR): When materials are illuminated they mostly reflect light in the near infrared wavelength spectrum. The NIR sensor can distinguish between different materials based on the way they reflect light which can be used to segregate the materials.

After segregation, liquid waste, solid waste, e-waste, etc. will be recycled using specific techniques to reduce pollution and increase efficiency.

DAY NIGHT CYCLES

For psychological stability in life aboard Astoria, provisions need to be made for an accurate day night cycle. Due to its high angular velocity, one part of Astoria will experience a day night change every 30 seconds. To solve this problem, illumination will be produced artificially on Astoria using a network of light emitting diodes (LEDs). In one half of Astoria, polarization filters will be activated in the windows to not allow light from entering and thus create a dark environment. At the same time, in the other half of Astoria, artificial lighting will be used to provide 12-hour illumination. LEDs will be used for this purpose because they are energy efficient and also dimmable.

FOOD PRODUCTION

Food production activities will be centred in the agricultural torus. Automated machines such as tractors, mowers, planters, cultivators and harvesters will be used to grow crops. A wide variety of crops will be grown to provide a balanced diet to the citizens. Food will be rationed for families depending upon the number of people part of the family. The weekly food stock will be delivered to each house via an automatic door to door delivery system.

Storage units will be established to store excess crop production for future use. The walls of the storage units will be made of metals that will be coated with conjoined aluminium spheres. The spheres will be hollow and will contain gas. These spheres will function as excellent insulators to prevent stored food from rotting due excess heat. This will thus provide us with thermal protection for the grains. To curb the growth of insects and pests, high frequency sound radiators will be used. The high frequency sound radiators will scare the pests away with the help of sound waves inaudible to humans. These storage units will be scattered evenly across Astoria to provide a better timeline for delivery of food.

Table 6: Crop production on Astoria

CROP CATERGORY	PERCENTAGE	CROP	PERCENTAGE
1 FOOD CROPS	73.41%		
1.1 Food Grains	65.53%		
1.1 a) Cereals	53.08%	Wheat	20.79%
		Rice	17.00%
		Maize	7.66%
		Other Cereals	7.63%
1.1 b) Pulses	12.45%	Gram	4.05%
		Other Pulses	8.40%
1.2 Sugar	2.29%	Sugarcane	2.29%
1.3 Condiments and Spices	1.55%	Other Condiments and Spices	1.55%
1.4 Fruits and Vegetables	4.04%		
1.4 a) Fresh Fruits	1.51%	Mangoes	0.58%
		Citrus Fruits	0.17%
		Other Fruits	0.76%
1.4 b) Dry Fruits	0.30%	Cashew Nuts	0.21%
		Other Dry Fruits	0.09%
1.5 c) Vegetables	2.23%	Potato	0.63%
		Onion	0.20%
		Other Vegetables	1.40%
2 NON-FOOD CROPS	26.59%		
2.1 Oil Seeds	20.07%	Groundnut	3.79%
		Mustard	3.28%
		Other Oil Seeds	13.00%
2.2 Fibers	5.29%	Cotton	4.56%
		Other Fibers	0.73%
2.3 Dyes	0.02%	Other Dyes	0.02%
2.4 Other Non-Food Crops	1.21%	Other Non-Food Crops	1.21%

3.3 CONSTRUCTION MACHINERY

Figure 14, 15, 16, 17: Design of construction machinery

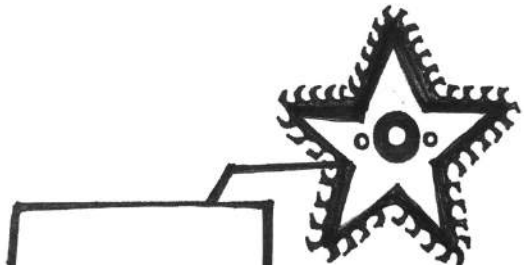
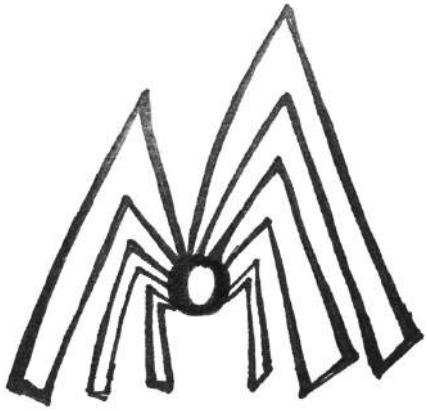
	THE CUTTER will be use a special star shaped cutting blade to cut structural components during the construction of Astoria. It will move across the hull of the settlement to cut and parts. The special shape of the blade will also enable precise cuts at the small scale.
	THE ORBITOR will also be used for cutting components for the structure. It will rest itself on the central fulcrum while the central rod rotates. In this process, the blades on the end pieces will cut perfect circles for the structure of Astoria.
	THE SPIDER will consist of six legs, three inner legs and three outer legs. Incase something has to be lifted, the three outer legs will provide support by positioning themselves outside the while the three inner legs attach the part to be lifted. Upon lifting, the three legs will move the part to another location.
	THE IMPACTER will be used to make precise holes in the hull of Astoria. These holes will be used to fit other material parts on the settlement. It will use an impact drilling and exert an additional force perpendicular to the structural surface.

Table 7: Design and specification of construction machinery

3.4 PROPULSION SYSTEM

Astoria's location in the asteroid belt makes it vulnerable to asteroids. Due to their high kinetic energy, an asteroid impact can be ruinous. Therefore Astoria will have use advanced techniques to deflect. However in some cases, deflecting the asteroids might not be sufficient or possible to ensure the safety of the settlement and its residents. For these cases, Astoria has provisions to relocate the settlement by 2 kilometres to become clear of the path of the asteroid.

Such manoeuvres are achieved by propulsion systems that are a part of Astoria. Hydrogen powered propellers located on the central cylinder of Astoria will be used to move Astoria. These will be located at the top and bottom of the central cylinder. The propellers will use water as a working fluid which will be accelerated out of the nozzle and pushed towards the back which in turn will make the entire settlement move in front due to Newton's third law.

However, to accelerate the immensely heavy settlement, a large force is required. there are two possible ways to produce high thrust. One way to increase the force is to make the engine flow rate as high as possible. Another way to produce high thrust is to make the exit velocity much greater than the incoming velocity. Both these processes together will responsible for generating sufficient force to move Astoria.

Considering ample supply of fuel available to the Astoria and the inertia due to large mass of the settlement, this manoeuvre could be easily possible every 14 Earth days. Secondary settlements will also be equipped with such a system.

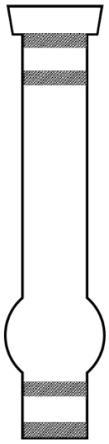


Figure 18: Striped part shows the location of propulsion engines on central cylinder

3.3 SECONDARY SETTLEMENTS - SERVICES

Astoria will be accompanied with five secondary settlements to improve the timeline of services. Each secondary settlement will be designed with a particular purpose in mind. Each secondary settlement will have a population and equipment which will serve the purpose of the settlement. The settlement will borrow all necessary structural and functional cues from the main settlement.

KEPLER

Kepler will be used for conducting research on various scientific domains. It has been named after German astronomer Johannes Kepler who made significant contributions towards quantitatively describing planetary motion.

Research on Kepler will be funded by the revenue produced by Astoria and any significant discoveries will be used inturn to generate revenue by outsourcing the findings. The main areas of focus for research on Astoria will be dark matter and dark energy, medical sciences, microgravity research and space sciences. Kepler will be equipped with advanced equipment such as optical and radio telescopes, particle detectors, electron microscopes, etc.

SPACE RESEARCH

To lay the foundation for upcoming settlements, Kepler will be equipped with an advanced department dedicated towards space research. A network of high power telescopes on Astoria will serve the vital purposes of searching for extra-terrestrial life and detecting Earth-like habitable planet. The location of Kepler, and Astoria in general, in the asteroid belt will enable a better view of intergalactic locations which cannot easily seen by Earth bound telescopes.

MEDICAL RESEARCH

The department for medical research will dedicate its efforts towards observing the physical and psychological effects of prolonged exposure of humans to microgravity. The department will be have electron microscopes. The department will also try to discover cures for certain diseases and develop medicines towards them.

MICROGRAVITY RESEARCH

Kepler will have a special Zero-Gravity Facility (ZGF) in the central cylinder due to the absence of rotation. The ZGF will provide researchers with microgravity environment that will be used to conduct research. It will

be used to observe the changing behaviour of different states of matter as well as other physical objects in a microgravity environment.

DARK MATTER AND ENERGY RESEARCH

A group of scientists on Kepler will try to use the advanced equipment to study and get a better sense of dark matter and dark energy. It is speculated 70% of the universe is composed of dark energy and 25% is composed of dark matter. Yet very little is known about these making them intrinsically mysterious. The researchers will try to detect dark matter, figure out how and why it exists and answer many unsolved mysteries regarding the same.

ZUSE

Zuse will be used for conducting research related to technology. It has been named after Konrad Zuse, a German computer pioneer who made valuable contributions to field of computer science and created the world's first Turing complete computer.

Zuse will have a population of highly qualified computer scientists and mathematicians and a cluster of quantum computers. These quantum computers will be used for various purposes such as cracking cryptographic hashes, outsourcing computation power to Earth, solving complex mathematical problems, trajectory mapping, planet detection, etc. By outsourcing this data, Zuse can become a major source of income for the settlement. Research on artificial intelligence (AI) will also be conducted on Zuse. Computer scientists will be involved in advancement of AI that will be used for various automation tasks at homes and in industries. Computation equipment for automatic machinery used in mining will also be developed on Zuse.

Since Zuse will have a major population of computer scientists, it will also be involved in the development and production of various consumer electronic items such as computers, laptops and mobiles. Scientists here will also be involved in developing efficient methods for live-time data transfer techniques with Earth which would be very beneficial for Astoria.

QUARK

Quark will be used for a series of innovative and administrative purposes. Scientists and innovators will work at this secondary settlement and will focus on creating new technologies. It will also be home to the Astoria Senate where all administrative decisions will be taken.

SUPERCONDUCTOR RESEARCH

Major unsolved questions of theoretical condensed matter physics will be answered using advanced equipment to research superconductivity of various materials on Quark. Researchers will try to develop a better understanding of the characteristics of the physical properties of existing compounds and synthesize new materials that can be used in superconductors. Developing an advanced superconductor technology can be instrumental in the development of powerful computational facilities.

INNOVATION LAB

Hundreds of scientists and researchers will work in the innovation lab and consistently brainstorm on how to find simple solutions to every problems. They will aim to create new and unique gadgets that will make the lives of residents of Astoria easier. Monthly hackathons will be organised for the entire population of Astoria.

VIRTUAL REALITY THEATRE

Quark will be home to a robust and well equipped virtual reality theatre. The theatre itself will be spherical in shape. Herein, the viewers will be provided with a pair of virtual reality glasses. The lens of these glasses will be made of tinted glass with OLED panels for each eye. The glasses will have a camera facing the eyes of the viewer to track his or her eye movement and provide him or her with a seamless experience. A new environment will be imposed on the screen of the viewer to provide him or her with an enhanced perceptual experience.

The theatre will also have an impressive hologram machine as a part that will be used to project holograms of diagrams, illustrations and sketches. It can be used for enhanced educational involvement of children by proving high definition visualisation.

NANOTECHNOLOGY

A nanotechnology lab will be present on Quark and will be used to conduct research on and develop nanotechnology in domains such as medicine and information technology. This lab would work in collaboration with many other labs for which nanotechnology could be useful such as pharmaceutical labs and radiation labs.

THE ASTORIA SENATE

The government of Astoria will be based on Quark and all legislative and executive decisions will be taken here. The government will make laws, define ordinances, regulate business and will have ultimate authority on Astoria over long-term decisions.

The government will be composed of three branches, much like a democratic government (a) the legislature (b) the executive; and (c) the judiciary. Each of these branch will have a different role to play in Astoria's governance.

The legislature will deal with the making of laws. It provides a long-term vision for the settlement and will work with the residents of Astoria to adapt to changing conditions and sentiments. It is of the utmost importance that government responds to the will of the people, which is the function that the legislative branch serves. The legislature will be centred at Quark but will have local office in the main settlement as well as other secondary settlements. It will be composed of 20 members drawn from districts within Astoria. However, taking advantage of the small population of Astoria, all citizens will be able to vote for the passing of laws made by the legislature. Citizens will also be able to suggest changes that could be made into laws directly to the law makers.

The executive will implement the laws passed by the legislative branch. The executive will also maintain diplomatic relations with Earth and other space settlements to regulate import and export of goods and services. The executive will also have the authority to make emergency decisions for the settlements. The president will be elected by the people for a tenure of 4 years. He or she will then appoint the Secretary of Finance, Secretary of Operations, Secretary of Internal Affairs and the Secretary of External Affairs. The executive will also appoint ambassadors of Astoria to Earth and other settlements. The executive will be headquartered in Quark.

The purpose of the judiciary will be the enforcement of the laws and treatment of criminals. It will have direct authority over the police force. Both the residential tori and each secondary settlement will have their own judiciaries. The core of the judicial system will be a group of five judges who preside over trials, hold hearings, and hold the legislature and executive accountable. The judges will be selected for ten-year terms and cannot be re-elected.

PROMENADE

Promenade will serve the purpose of housing families with children in the age group 5 to 15. Therefore a large population of Promenade will include students who live with their parents.

The main focus of Promenade will be skill building of the students while guaranteeing them a healthy and comfortable lifestyle. This secondary settlement will include three schools for the students where they can choose to study subjects of their choice. Most of the education will be computer based along with one on one guidance to resolve doubts and administer progress. There will also be an academy which would teach the students the basic techniques of mining and metallurgy.

There will be several sources of entertainment for minors on Promenade such as sports complexes, movie theatres and amusement parks. There will be a shopping complex and an advanced hospital to deal with medical emergencies. Thus Promenade will focus on the holistic development of students so that they can grow to become responsible citizens.

SPACESIDE

Spaceside will be used mainly to house senior citizens of the settlement. It will house a population from 55 years of age. It will provide a comfortable and stress free lifestyle to such senior citizens. Spaceside will have arrangements for several community lifestyle solutions to reduce boredom and loneliness amongst them. This will foster a sense of belongings in the elderly population.

Spaceside will feature a best-in-class medical unit that will specialise the maladies of aging. This secondary settlement will also be located nearest to Astoria, at a distance of 0.1 AU, to provide quick access to the main settlement in case of medical emergencies.

Homes in Spaceside will be equipped with artificial intelligence systems to maximise comfort and ease for the citizens. Comfortable beds, ideal temperatures and a high level of automation will improve the lives of these senior citizens. In community halls, the senior citizens will be able to spend their time in a pleasant company. Here, they will be called to play cards, chess and other board games. There will be activities such as yoga and meditation to help them relax and a variety of other sports to provide them with some exercise. This blend of clean air, community living and comfort is the perfect lifestyle for a senior citizen.


HUMAN FACTORS

4.1 COMMUNITY DESIGN

To provide recreation and foster a sense of belonging and community spirit in residents of Astoria, a wide range of community activities will be organized. Such amenities will be evenly distributed across Astoria and the secondary settlements to enhance accessibility. Multiple sources of entertainment will prevent the residents from being sucked into a monotonous lifestyle.

MOVIE THEATRES: There will be movie theatres which will showcase the latest movies and films from production studios on the settlement as well as from Earth. The 4 movie theatres will be capable of seating 200 people.

RESTAURANTS: Many restaurants and fast food joints will invite people to eat savoury dishes every once in a while. More than 100 restaurants will be located in malls and shops across the main settlement and secondary settlements.

SHOPPING COMPLEXES: Flamboyant malls and shopping centres will be an ideal destination for purchasing garments, gadgets and other accessories. They will also be equipped with a food court featuring a myriad of restaurants. 6 of shopping complexes will be distributed across the main settlement.

PARKS and OPEN SPACES: Lush green parks distributed in plenty across the settlement will be ideal place for families and individuals to have picnics and hang out. They will be calm and peaceful environments to enjoy a few hours in the laps of nature.

AMUSEMENT PARKS: A couple of amusement parks will be a part of main settlement Astoria and one on the Promenade secondary settlement. These will be equipped with rides like roller coasters, horror houses and Ferris wheels. Even though these attractions will be low rise ones, they will serve the purpose of providing an entertaining weekend getaway for families.

SPORTS COMPLEXES: Around 50 sports clubs and gyms will be a part of Astoria. People will be able to work out and play various sports such as football, basketball and tennis in these clubs. Gymnasiums will provide residents the opportunity to pump some iron using equipment such as treadmills, weights and joggers.

MICROGRAVITY RECREATION: Part of the central cylinder and then secondary settlements of Astoria will be a microgravity recreation center. Here, several games and sports specifically designed to be played in microgravity conditions will be played such as Galactic Football, Galactic Basketball and UltimateFIGHT!.

Table 7: Number and dimensions of public places

	NUMBER	CAPACITY (avg.)	AREA
CITY HALL	4	500	10,000 sq. ft.
MOVIE THEATRES	8	200	5,000 sq. ft.
RESTAURANTS	100	30	500 sq. ft.
SHOPPING COMPLEXES	6	2000	20,000 sq. ft.
OPEN SPACES	150	-	30,000 sq. ft.
AMUSEMENT PARKS	2	4000	80,000 sq. ft.
SPORTS COMPLEXES	10	1000	40,000 sq. ft.
GYMS	40	75	500 sq. ft.
HOSPITALS and CLINICS	75	50	1,000 sq. ft.
SCHOOLS	15	300	7,500 sq. ft.
MICRGRAVITY RECREATION	1	250	-

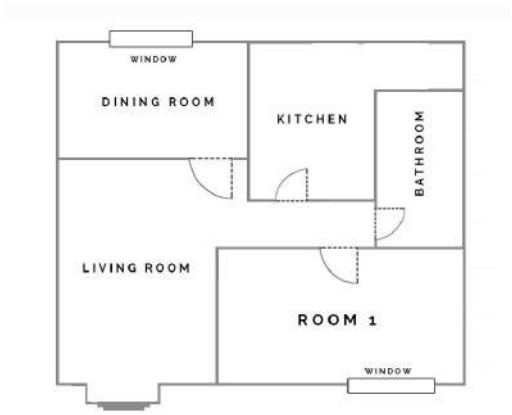
Other modern amenities like consumer goods and consumables will also be made available to the residents of Astoria. Malls and shopping complexes will have various outlets for purchase of cloths, gadgets and accessories. Consumables such as vegetables, fruits and bread will be distributed via a ration system and also be available for purchase. Each house will receive its rationed food, depending upon number of people in the family, on the Sunday of each week via an automatic door to door delivery system. This food will be sourced from the agricultural torus.

4.2 RESIDENTIAL DESIGN

Houses on Astoria will be of four sizes. Houses will have a common urban design scheme in order to achieve consistency. They will go from 1000 sq. feet to 2000 sq. feet. Most houses will occur as a 2 floor bungalow. The 2000 sq. ft. houses will be a duplex and will be owned by a single family. All houses will be fully furnished with instant move-in designs.

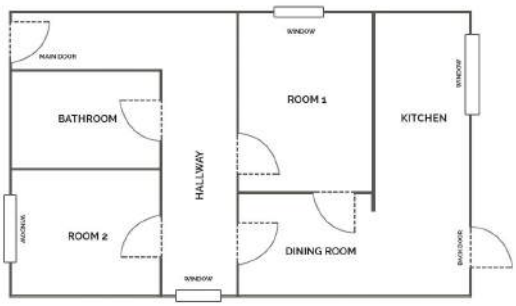
Figure 19, 20, 21: Interior floor plan of four home designs

SIZE: 1000 sq. ft.
NUMBER OF ROOMS: 1
SIZE OF FAMILY: 1 Person
TOTAL NUMBER: ###



SIZE: 1400 sq. ft.
NUMBER OF ROOMS: 2
SIZE OF FAMILY: 2
TOTAL NUMBER: ###

Duplex Version
SIZE: 1600 sq. ft.
NUMBER OF ROOMS: 4
SIZE OF FAMILY: 4
TOTAL NUMBER: ###



SIZE: 2000 sq. ft.
NUMBER OF ROOMS: 3
SIZE OF FAMILY: 3
TOTAL NUMBER: ###

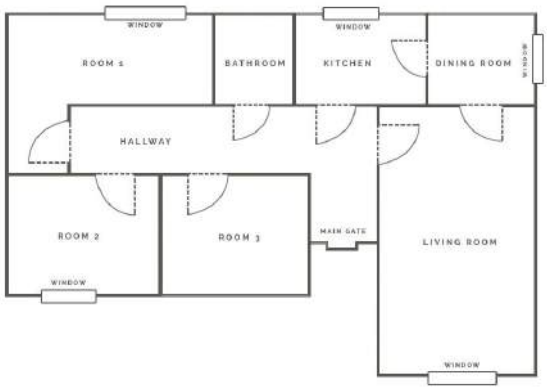


Table 8: Size, dimensions and floor plans of four home designs

4.3 SAFE ACCESS

The absence of gravity in many components such as the industrial module and microgravity recreation center will make these components difficult to access. Though a large extent of process automation will be used, there might arise several occasions that demand human access in these areas. Access to these areas as well as outer space will happen with the help of specially designed equipment. These comprise of suits, tethers, chains and airlocks.

MAGNETIC BOOTS: Magnetic boots will help people walk across the microgravity module.

MANEUVERING UNIT: A maneuvering unit will be a part of these suits which will squirt a propellant fluid to create a reaction force to help people navigate by altering linear and angular momentum.

HANDRAILS: Machinery and walls of the microgravity area will be laden with handrails which can be grabbed by workers in order to pull themselves. These can also be used as a support to rest on while inspecting parts of the microgravity module.

TETHER CHAINS: A tether chain will be used by people to easily access the microgravity modules. These tethers will be made of snake hinges which will enable it to rotate a complete 360°. With the push of a button, the hinge mechanism can be blocked so that the tether is taut and the person can stay stationary. This will help is precise movement through the microgravity module.

SPACESUITS

To enable a vast variety of extravehicular activity (EVA), spacesuits will be available on Astoria for authorized personnel. The spacesuit will be heavily insulated with layers of fabric (made of Neoprene, Gore-Tex and Dacron) and reflective outer layers (made of Mylar and white fabric) to reflect sunlight. Multiple layers of durable fabrics such as Dacron and Kevlar will prevent the suit from collisions with micrometeoroids and tearing.

An Integrated Thermal Micrometeoroid Garment (ITMG) will be used for the outer layer of covering. It will insulate the suit occupant and prevent heat loss, shield the occupant from harmful solar radiation and protect the occupant from micrometeoroids and other orbital debris, which could puncture the suit and depressurize it. The spacesuits will also have a nitrogen based cooling system to remove excess heat from the suit (generated from strenuous activities) which may result in fogging of helmet and severe dehydration which will be used for EVAs in extremely warm conditions.

The outermost layer of the suit will comprise of a white Ortho-Fabric, made with a blend of Gore-Tex, Kevlar, and Nomex. It will be capable of withstanding temperatures from −200°C to 150°C. The outer layer provides both micrometeoroid and thermal protection, by reflecting most of the sun's thermal radiation.

The thermal radiation protection layer will comprise of layers of aluminized PET film (Mylar), nonwoven Dacron to provide provide thermal spacing, followed by two layers of high density polyethylene (HDPE) and Beta cloth marquisette laminate each. The outermost layer of PTFE Teflon-coated filament Beta cloth is non-flammable and provides useful abrasion protection from extremities of the space environment. The HDPE layer, containing an appreciable quantity of hydrogen, reduces primary and secondary radiation to a great extent.

Figure 22: Snake hinge design for tethers

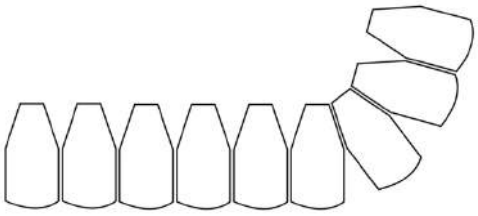


Table 9: Estimates of the spacesuit

Mass	127 kilograms in vacuum
Thickness	4.7 cm (9 layers)
Atmosphere	0.3 atm of pure Oxygen
Volume	0.153 m^3 (unoccupied)
Cost	$0.8 million per suit

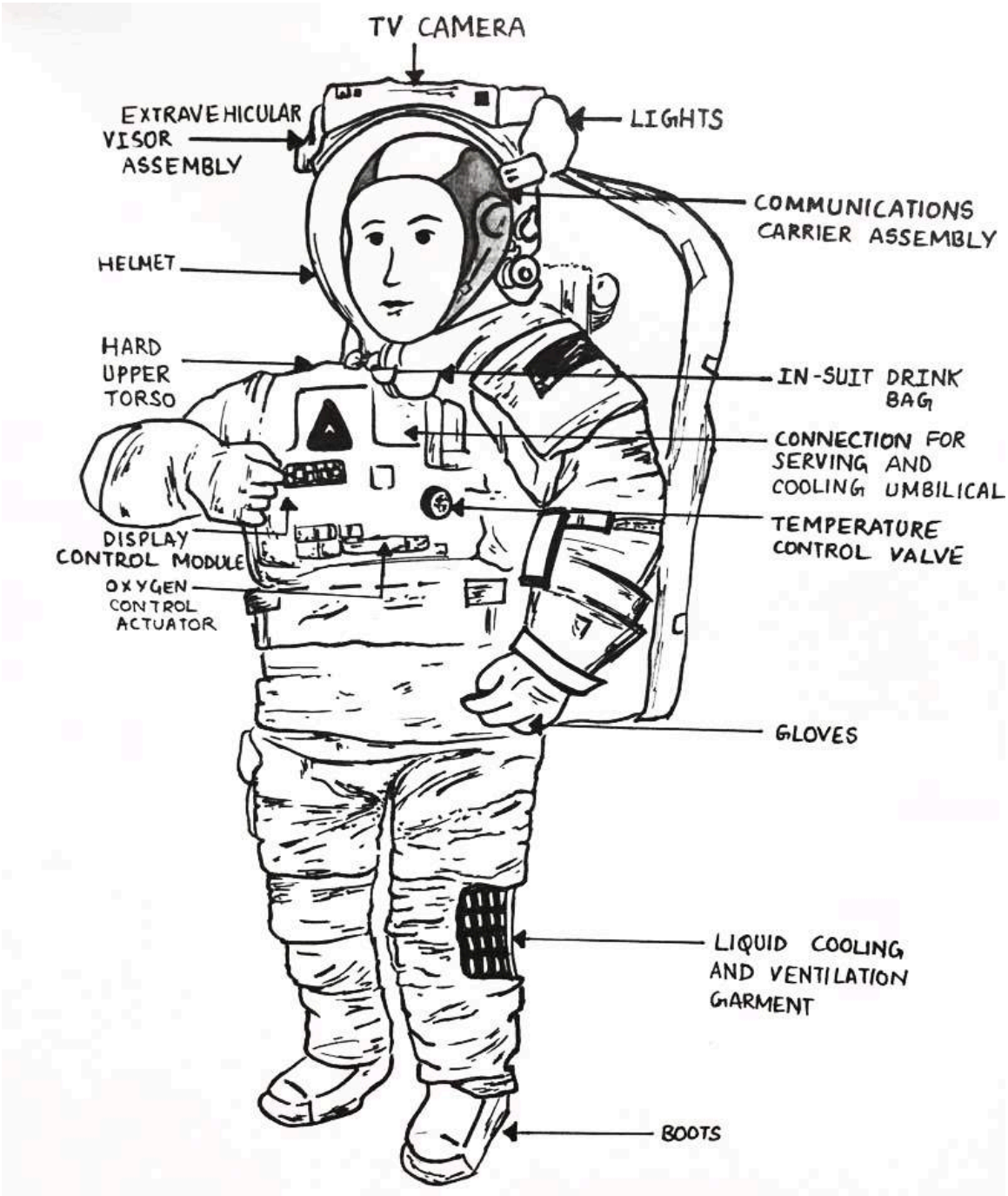


Figure 23: Design of spacesuit

AIRLOCKS

To allow the passage of man and machine between pressurised and non-pressurised units, a series of airlocks will be used on the settlement. Airlocks on Astoria will be a combination of pressure bubble and pressure sink airlock technology. This two-compartment airlock arrangement allows personnel to suit up before changing the pressurised compound while at the same time, one on the modules is sealed from the adjacent and connected areas. This compound airlock is also designed to minimize the wastage of pressure or gas, which is desirable.

4.4 CHILDREN'S ENTERTAINMENT

To cater to the entertainment needs of children, a wide variety of recreational spots will be planned. They will be located on the main settlement as well as on the Promenade secondary settlement. Children will have a lot of microgravity and 1g recreation opportunities to explore. Many of the microgravity recreation opportunities are located in the microgravity recreation center in the central cylinder.

MACROGRAVITY RECREATION

- Amusement parks equipped with horror houses, Ferris wheels and rollercoasters will provide an excellent weekend getaway to children as well as adults.
- A variety of studios in malls and shopping complexes will provide children an arena to play games like paintball, bowling and laser tag.
- Children will be able to play multiplayer games including first person shooters and role playing games with their friends over a network connection.
- Parks and picnic spots will give children a breath of fresh air and also a healthy break.
- Movie theatres will also play movies catering to the interests of children.

MICROGRAVITY RECREATION

GALACTIC SOCCER: Galactic Soccer is played in a zero gravity environment. It is a 5-a-side game played inside a sphere using magnetic shoes. Both the teams' main motive is to put the football inside the goal of the opposite team, which are at diametrically opposite ends of the sphere. The ball will be equipped with tri-axial-accelerometer which will measure the force and thus determine the propulsion speed and trajectory of the ball.

GALACTIC PAINTBALL: Galactic paintball, just like Galactic football, is played in a zero gravity environment. It is a 6-a-side game played inside a sphere using magnetic shoes, just like Galactic football. The main motive of the game is to eliminate the other team by shooting them with their paintball guns. Each person can be shot maximum two times. The team that gets eliminated first loses.

ultimateCHESS: ultimateCHESS is a version of 3D chess will be available for the residents of Astoria to play. The players will us voice command to move the pieces. It will be played with the help of the a pair of virtual reality glasses. The pieces will move as the player commands and animations will be made every time the players take each others' pieces. Tournament will be held for interested participants every week. Apart from the tournaments, players will be able to play friendly matches with each other.

ultimateFIGHT!: ultimateFIGHT! is the perfect platform for children to display their fighting skills. The players will be put in a microgravity environment and will have a face-off with their opponent. They will show their martial art skills against each other. Equipment such as a light-air propeller to help players navigate around the space and magnetic boots to run around will be provided. All players will wear a specially designed suit which will enable them to deliver high speed punches and attacks. Players will be given necessary protective equipment to protect them from injury. The duration of each match will be 10 minutes. Every weekend, a tournament will be held between residents of Astoria.

To not hamper with the growth needs of minors, a daily time limit on access to microgravity components of Astoria will be mandated. Children must spend at least 8 hours every day in macrogravity environments. This limit might be relaxed or tightened as studies are conducted on the effects of exposure to low levels of gravity. In addition, children below 3 years of age are not allowed to access microgravity regions. A similar limit of atleast 5 hours will be in mandated for adults. It will be ensured that even workers of Astoria do not cross this limit.

4.5 HOME DESIGNS

Astoria is being built to provide all comforts on life to its residents as the central focus. The residents of Astoria will live in uniformly designed and urban homes. The furniture in these house will be prefabricated and yet sufficiently customizable to give residents a homely feel.

CONSTRUCTION MATERIAL

PET, silicone and araldite will be the the most appropriate materials to build the foundation and outline of the houses. These are thermosetting plastics which makes them ideal for construction. They are lightweight and easy to transport. These can also be easily manufactured using materials easily available on asteroids.

LIGHTING

Keeping conservation of energy as priority, techniques to minimize use of electricity for domestic consumption will be adopted. To achieve this, setting a bright LED light in a central place of the house and placing mirrors at apt angles wherever the light is needed can result in significant amounts of energy conservation. This will also reduce dangers induced by inferior quality of wiring.

INTERIOR DESIGN

All houses will have a minimal number of walls to avoid wastage materials. The furniture will be made of lightweight materials. Storage units will be shared with a neighbourhood of about 10 houses, to conserve spatial resources.

MAINTENANCE OF TEMPERATURE

Regulation of in-room temperature will be done using smart thermostats which will monitor a person's body temperature and sweat levels to set the temperature to an ideal level. These will automate the entire HVAC (Heating, Ventilation and Air Conditioning) process. It will learn a user's habits to set the temperature accordingly. It can also be programmed to cool or heat the room while a person is en route to his house.

Figure 24: Design of smart thermostat

HOME AUTOMATION

Automation will be extensively used in homes in the main settlements and secondary settlements of Astoria. Many different types of robots will be used in homes to reduce the effort done by humans, especially senior citizens. This will enable more efficiency in home and household activities and increased quality of life for old and elderly persons. This will include centralized lighting control, HVAC (Heating, Ventilation and Air Conditioning), centralized security systems and energy management devices. The concept of internet of things will be tied in closely with the functioning of Astoria. Control of entertainment systems, planting and watering, pet feeding, light control, etc. will be passed onto domestic robots.

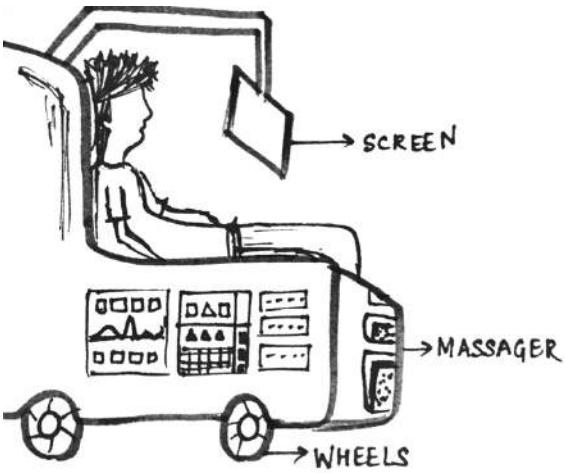


Figure 25: Design of smart chair

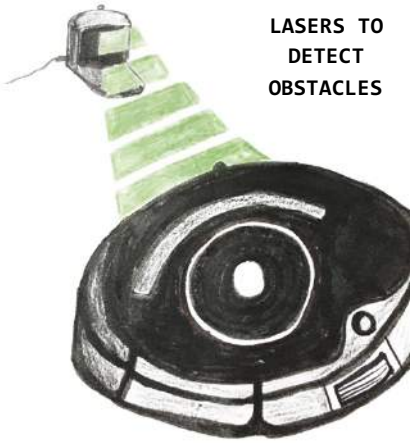


Figure 26: Design of vacuum cleaner


AUTOMATION
DESIGN

5.1 AUTOMATION OF CONSTRUTION PROCESSES

The construction demands of Astoria make the use of a manual labour force for construction unreasonable. Therefore, advanced automation technologies will be used for the construction of Astoria. These will be optimized to function in 0g conditions. Automation can help significantly bring down the cost of construction and reduce the time taken for completion. The low tolerance for error also makes the use of automation a promising technique.

DRILLING AND FASTENING: Manual drilling machines require sophisticated jigs. However, robots can use a vision system to drill and fasten holes at desired locations and with a high precision in measurement. Moreover, this can be achieved by robots in a single pass, which is far more effective than manual labour.

WELDING AND LAYERING: Astoria will use many composite parts for construction. Therefore, the use of automation will allow for more precise measurements such as cutting layers accurately to the micron and welding parts with low margin for error.

SMALL SCALE CONSTRUCTION: Many parts of the structure require the precise fitting of several small scale components. Human labour cannot possibly match the level of precision that can be obtained by automation in these small scale and often hard to reach locations.

5.2 FACILITY AUTOMATION

Because of the inherent qualities of precision and cost effectiveness of automation techniques several scopes of the settlement other than construction will also use advanced machines to operate. Such automation will be used to conduct repairs of Astoria and incoming spacecrafts and protecting the settlement from harmful radiations.

AUTOMATION OF MAINTANANCE AND REPAIR

Astoria will be equipped with an extensive MRO center dedicated to the maintenance and repair of disabled or damaged vessels in the vicinity of Astoria. Services like damage analysis, damage repair, refuelling and *space tug* will be provided to these vessels. Incase of an such an event, an MRO satellite will be deployed from Astoria. It will use trajectory mapping and hydrogen propellers to find its way to the vessel. Herein automated construction machinery as used in Astoria will be used to restore the vessel. Incase of the satellite in unable to restore the vessel, a *space tug* facility will be used to pull it to the main MRO center on Astoria. Vessels can also pitstop at Astoria for refuelling, procuring materials for in-situ utilisation as well as rest and recreation of passengers of the vessel. The entire MRO Center in the central cylinder is automated and robotic arms and other machines are used to repair vessels that are brought in. Advanced technology like ultrasonics and x-ray analysis will be used for quality assurance.

CONTIGENCY PLANS

Despite the extensive asteroid shielding capabilities of Astoria and other necessary security measures adopted by the settlement, a situation might arise in which the settlement needs to be evacuated. The Contingency Modules are located in the central cylinder at the base of the the RTs. Similar modules are located in the secondary settlements. Each module is capable of housing 100 residents albeit in discomfort. They are not intended for refuge and not long term residency. Each module will be capable of housing 100 people, albeit in discomfort.

The modules will use solar panels and stored energy from power reactors to navigate to the nearest Foundation Society's settlement. The modules will have sufficient fuel to make a journey of atleast 1 astronomical unit. Water and food will also be available in sufficient quantities to support this journey. Food will be in the form of meal replacement beverages which will contain of all necessary nutrients. Plants on board the modules will be responsible for atmosphere sustenance and oxygen replenishment.

Moreover, the central cylinder will also have arrangements to isolate the nuclear power reactor incase of any malfunction or radioactive leak. This will prevent the need to abandon the entire settlement instead of just one component. The extensive network of batteries and solar energy will suffice to meet the energy requirements of the settlements for atleast two Earth months. In this while, help can approach Astoria from Earth and other inner solar system settlements of the Foundation Society.

RADIATION SHEILDING

In the absence of an atmosphere, Astoria must have measures to shield residents from harmful radiations of the Sun. Exposure to radiation for extended periods of time can lead to vomiting, fatigue, low blood counts and

harmful diseases such as cancer and cataract. Exposure to a slow drizzle of cosmic rays can penetrate flesh and damage tissue at the microscopic level of astronauts. These precautions will also secure the settlement from harmful effects of solar flares and ensure uninterrupted activity despite the anomalies of space.

To prevent such adverse ill-effects, several preventive measures will be adopted by the settlement. Hydrogen is known to absorb and disperse radiation. Materials such as polyethylene which contain high hydrogen contents, can reduce primary and secondary radiation to a great extent and will be used to reinforce the structure of Astoria.

Moreover, an invisible magnetic ion shield will be set up creating a magnetic bubble to surround Astoria. This will be done with the help of two magnetospheres which will be located at two diametrically opposite ends of the residential tori. In the event of an incoming solar wind or an approaching cloud of energetic particles from a solar flare or coronal mass ejection (CME), the magnetospheres will be powered on, creating a strong magnetic field around the settlement. A magnetic field can deflect the paths of certain particles around the void encapsulated by the magnetic field. Thus, for Astoria, the magnetic field will have sufficient deflecting strength to redirect harmful energetic particles away from the structure.

AUTORISED DATA ACCESS

Since all of operational tasks of Astoria will be automated, unauthorized access to core computational infrastructure can prove to be ruinous. Therefore, all possible security methods will be adopted to secure the access of crucial data to authorized personnel only. There will be two types of authentications on various devices. The first is biometric authentication, such as fingerprints, hand geometry, earlobe geometry, retina and iris patterns, voice waves, and keystroke dynamics. These will be powered by the Astoria Visor The second one is cryptographic hashing of passwords which will be using the most secure cryptographic hashing algorithm at that time. Constant research at Zuse will be focussed towards developing more secure hashing algorithms.

5.3 HABITABILITY AND COMMUNITY AUTOMATION

To enable quick and easy communication between the residents of Astoria, a centralized communication system will be adopted. This will consist of advanced networking techniques and a vast array of smart devices to use to connect to this network. This will include devices such as laptops, smartphones, smartwatches and a head mounted display called the Astoria Visor.

ASTORIA VISOR

Each resident of Astoria will be given a smart visor, a wearable ubiquitous computer. The visors will be an optical head mounted display (OHMD) which will use a liquid crystal on silicon (LCoS), field-sequential color system, LED illuminated display. It will also comprise of a camera capable of taking high quality photographs and recording high definition video which will facilitate gesture recognition, bone conduction speaker and wireless connectivity. All visors will be a part of an interconnected network and serve to notify citizens of all kinds of announcement. They will enable communication by allowing people to call each other. Moreover, by using iris scanning, the visors can serve as a means of biometric verification and in-turn payment authentication. The visor can also be used to replace the smartphone by providing navigation tools and a web browser.

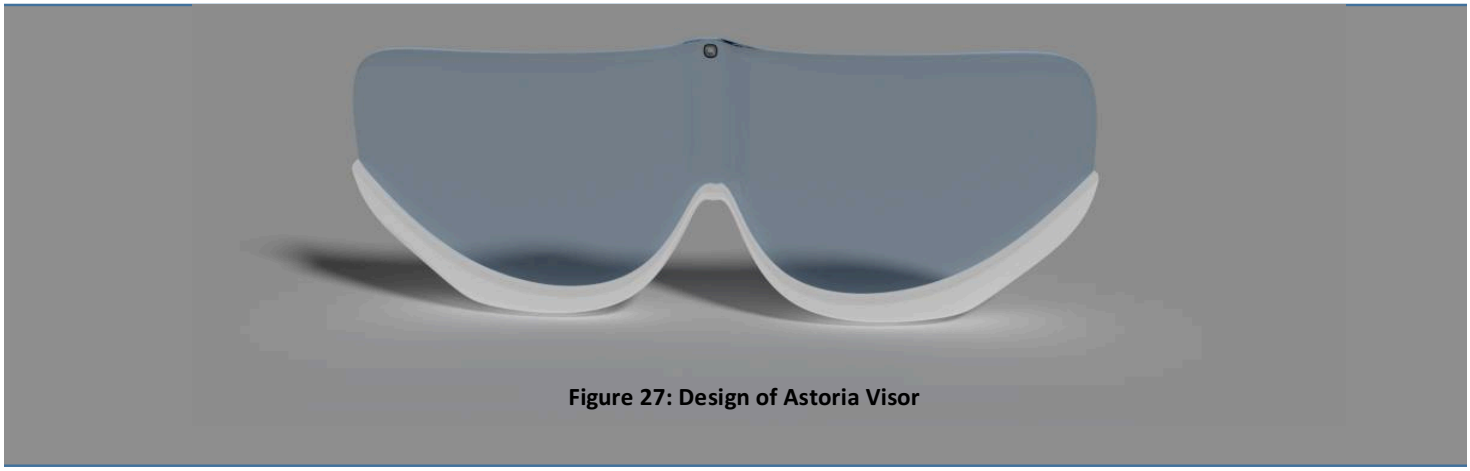


Figure 27: Design of Astoria Visor

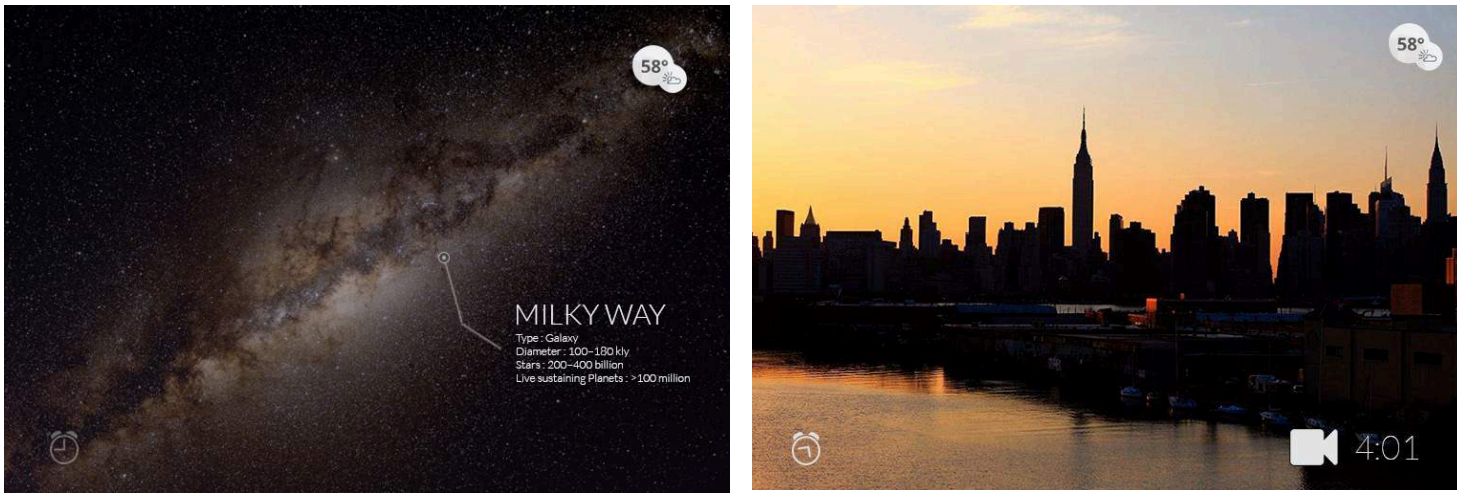


Figure 28: User interface for Astoria Visor

INTERNAL COMMUNICATION

To facilitate data transfer and communication within the settlement, a series of optical fibres and Powerline adapters will be used for networking purposes. Powerline technology uses electric power cables instead of Ethernet cables to create a local network. This allows for a network which does not loose strength as we move farther from the source. It is also much faster and more secure. All kinds of gadgets will be able to connect to this network.

For wide area networking, optical fibres will be used. Fibre-optic communication uses light pulses to enable high speed data transfer. The light forms an electromagnetic carrier wave that is modulated to carry information. For Astoria's purposes multi-mode fibre with bandwidth–distance product of 500 MHz·km should suffice to provide high speed communication for all purposes of the settlement.

5.4 ORE DELIVERY

To prevent abrasive and harmful dust from entering the enclosed units of Astoria, an advanced particle filtration system and enclosed ore unloading mechanism will be adopted. Astoria will also have High-Efficiency Particulate Arrestance (HEPA) filters which will be responsible for clearing dust. Ores will be unloaded in bulk using pressurized sealed tubes which will enter the mining modules though an airlock.

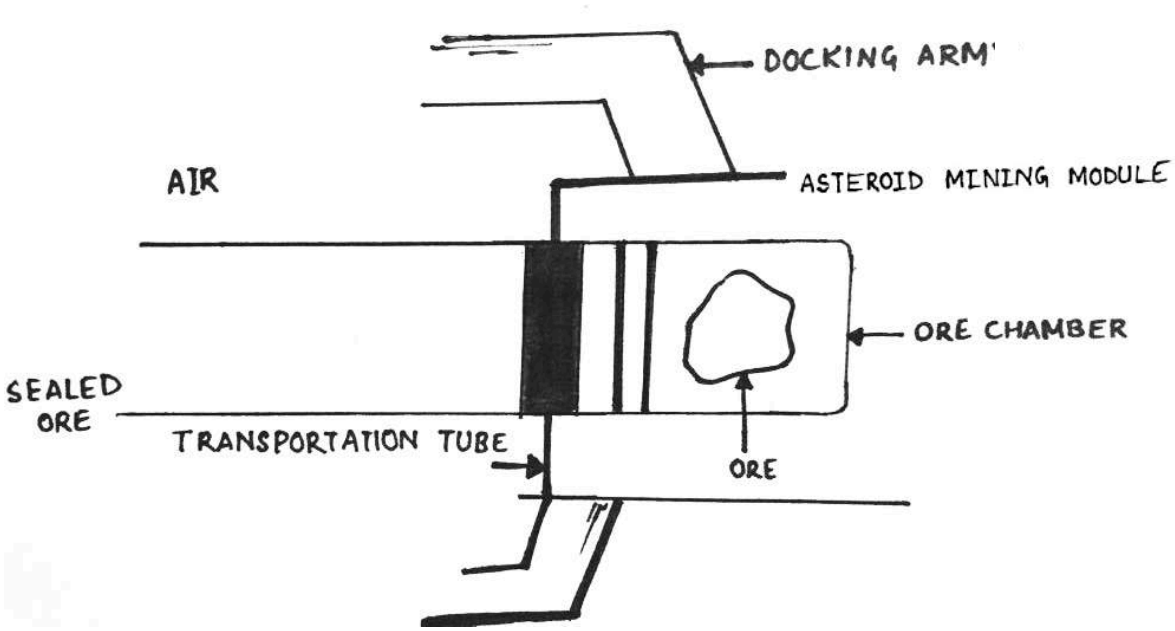


Figure 29: Mechanism for unloading ores from mining modules

The mining modules and ASCAMO will have, at their rear end, an airlock. Unloading of ores will take place on Astoria using a sealed, pressurized tube that will attach to the docked asteroid mining modules and ASCAMO through the airlock at their rear end. Through these sealed tubes, ores will travel through a series of High-Efficiency Particulate Arrestance (HEPA) filters which will remove harmful asteroid dust from the ore. The ore, without harmful dust particles, will reach the Astoria Industrial Center where it will be processed.

Moreover, The Environmental Control System (ECS) will also monitor the dust particle count aboard Astoria. It will include a distributed ventilation system that contains HEPA filter elements to remove suspended particulate matter and protect humidity control and air purification equipment from debris accumulation and biofouling. Air will be re-circulated using fans to prevent accumulation. Furthermore, a quality assurance software will perform periodic audits to ensure that certified-facility cleanliness levels conform to the set requirements. Particle counters will also routinely measure aboard crewed spacecraft.

5.5 EXTERNAL COMMUNICATION

Using physical connections on Astoria to communicate with other settlements and Earth is not viable. Therefore, Free-Space Optical communication (FSO) will be used by Astoria to connect with secondary settlements as well as Earth. This system will use Ultra Violet (UV) light to carry a signal with the help of LEDs. However, only special receivers on Astoria will be able to receive and interpret these signals. Connectivity to Earth can also be enhanced by installing repeater satellites that will prevent the signal from diminishing. Moreover, by varying the breath of the light beam, data can be easily encrypted enhancing security. Further research will be conduced on improving the efficiency of this technology on Zuse.


SCHEDULE
AND COST

6.1 CONSTRUCTION SCHEDULE

It can be estimated that given the contract in 2076, the construction of Astoria can begin by 2110 which is approximately 30 years. Before beginning construction, all cost estimations, fund raising, team recruitments and programming tasks will be completed. However, once the construction begins, with the help of automation and drawing experience from past settlements, the construction will be completed quickly, within a span of 10 years.

Table 10: Predicted timeline of construction

YEAR	PROGRESS
	CONSTRUCTION BEGINS
2110	Hull central cylinder put into orbit
	Construction of ASCAMO and Industrial Module begins
2111	Construction of central cylinder completed
	Construction of ASCAMO and Industrial Module completed
	Construction of nuclear reactor begins
	ASTEROID MINING OPERATIONS COMMENCE
2112	Construction of industrial torus begins
	Construction of residential torus begins
2113	Construction of nuclear reactor completed
	Construction of industrial torus completed
2114	Construction of agricultural torus begins
	Construction of docking station begins
2115	Construction of docking station completed
	ASTORIA MOVES TO NEW ORBITAL LOCATION
2116	Construction of agricultural torus completed
	Agricultural torus pressurised
	Rotation of agricultural torus begins
	Construction of secondary settlements begins
	PHOTOSYNTEHSIS BEGINS
2117	Construction of residential tori completed
	Installation of solar panels begins
2118	Installation of solar panels completed
2119	Rotation of residential tori begins
	Residential tori pressurised
	Construction of secondary settlements completed
2120	Quality assurance and inspection
	PEOPLE BEGIN TO MOVE INTO ASTORIA

6.2 COST ESTIMATES

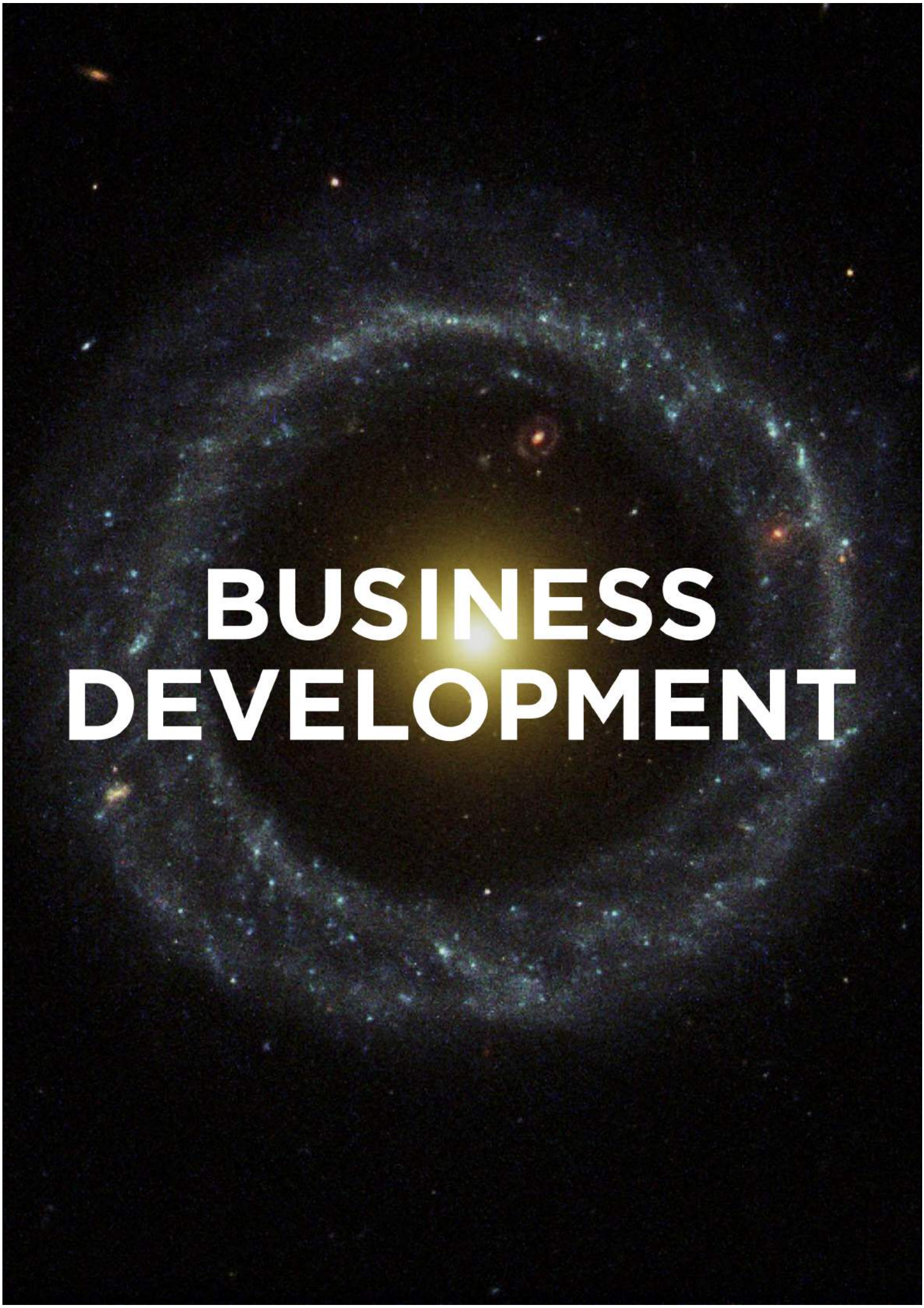
Capital will be gathered for the construction of Astoria by raising funds from countries and businesses interested in investing in extending the outreach of human civilization. The construction of Astoria will require an estimated of slightly north of 400 billion USD (without adjusting for inflation). This money will be raised in the buffer period of 30 years between 2076 and 2110.

Table 11: Estimated cost of construction of Astoria

COMPONENT	TOTAL COST ($)	COMPONENT	TOTAL COST ($)
STRUCTURAL COMPONENTS		**INTERNAL INFRASTRUCTURE**	
Central Cylinder	1,000,000,000	Flooring	10,000,000,000
Residential Torus	2,000,000,000	Residences Spaces	15,000,000,000
Industrial Torus	750,000,000	Commercial Spaces	100,000,000
Agricultural Torus	500,000,000	Institutional Spaces	50,000,000
Docking Station	100,000,000	Entertainment Spaces	1,000,000,000
MRO Center	50,000,000	Open Spaces	10,000,000
Microgravity Module	50,000,000	Trains	5,000,000,000
Contingency Modules	10,000,000,000	Industrial Equipment	75,000,000,000
ASCAMO	500,000,000	**OPERATIONAL COSTS**	
Mining Modules	15,000,000,000	Networking	500,000,000
Magnetospheres	5,000,000	Astoria Visors	10,000,000
Secondary Settlements	75,000,000,000	Automation	10,000,000,000
POWER GENERATION		Farming	25,000,000
Nuclear Reactor	10,000,000,000	Scientific Research	10,000,000,000
Solar Panels	50,000,000,000	Supercomputer Research	10,000,000,000
Batteries	500,000,000	Telescopes	5,000,000,000

STRUCTURAL COMPONENTS	$104,955,000,000
INTERNAL INFRASTRUCTURE	$106,160,000,000
POWER GENERATION	$60,500,000,000
OPERATIONAL COSTS	$35,535,000,000
OTHER MISCELLANEOUS COSTS	$100,000,000,000
TOTAL COST	$407,150,000,000

COMMUNICATION MAINTANCANCE (YEARLY)	$13,000,000,000
OPERATION AND FUNCTIONING (YEARLY)	$10,000,000,000
MINING OPERATIONS (YEARLY)	$17,500,000,000
STRUCTURAL MAINTINANCE (YEARLY)	$12,000,000,000
OTHER CONTINUOUS COSTS	$6,000,000,000
TOTAL COST	$58,000,000,000


BUSINESS
DEVELOPMENT

7.1 ASTEROID MINING OPERATIONS

Astoria is being built as a processing center for asteroid resources to obtain resources for internal operations of the settlement as well as for export to other inner solar system settlements. Therefore, it is essential that Astoria employees a robust mechanism to capture resource rich asteroids for further processing. Astoria will extract minerals chiefly from carbonaceous (C-type) and metal-rich (M-type) asteroids, but during the initial stages of construction, silicate (S-type) asteroids will also be mined. Depending upon the size of the asteroid, either on-board or off-board extraction techniques will be used. The mined resources will be used to fulfil the settlement's own needs and also be traded with other settlements and Earth

For obvious reasons, the mineral extraction process is completely automated. This ensure higher efficiency, avoids putting lives at risk and is does not require creation of human friendly conditions such as artificial gravity on the asteroid.

Table 12: List of valuable asteroids near Astoria

NAME	TYPE	ORBITAL DISTANCE (AU)	VALUE (IN $)
Gyptis	C	2.770	>100 trillion
Lucina	Ch	2.719	>100 trillion
Aurelia	C	2.596	>100 trillion
Hersilia	C	2.741	>100 trillion
Faina	Ch	2.550	>100 trillion
Liguria	C	2.759	>100 trillion
Sapientia	C	2.771	>100 trillion
Arsinoe	Ch	2.595	>100 trillion
Arachne	C	2.624	>100 trillion
Concordia	Ch	2.701	>100 trillion
Una	C	2.728	>100 trillion
Lova	Ch	2.702	>100 trillion
Bavaria	C	2.725	>100 trillion
Melanie	C	2.698	>100 trillion
Russia	C	2.553	>100 trillion
Lotis	C	2.607	>100 trillion
Admete	C	2.739	>100 trillion
Frieden	C	2.787	>100 trillion
Neva	Ch	2.755	>100 trillion
Jacqueline	C	2.605	>100 trillion

ON-BOARD MINING

The Astoria Asteroid Capture Module (ASCAMO) will be used to capture small asteroids (upto a radius of 500 meters) as they approach near Astoria.

Figure 30: Asteroid Capture Module (ASCAMO)

The ASCAMO will consist of an adjustable capture ring, carbon nanotube clamps and hydrogen propellers. Depending upon the size of the asteroid to be captured, the radius of capture ring can be adjusted. Once the asteroid is within the capture ring, the carbon nanotube clamps will be used to clutch the asteroid. Hydrogen propellers (using liquid hydrogen as fuel) will be used to navigate the ASCAMO and decelerate the asteroid.

The ASCAMO will be deployed from the launch pad hours before the approach of the asteroid to be captured. The ASCAMO will therefore have sufficient time to align itself accurately according to minor deviations in the predicted trajectory of the asteroid to be captured in the final moments. Since asteroids possess high kinetic energy stopping them in a short interval of time is difficult. To solve this problem, once the asteroid to be captured is within the capture ring, the hydrogen propellers will propel the ASCAMO with the asteroid. The carbon nanotube clamps will gradually begin to clutch the asteroid and the ASCAMO will slowly decelerate. This will reduce the rate of change of momentum of the the asteroid (impulse) and consequentially the force required to stop it.

However, in this process, the ASCAMO will detour from the orbit of Astoria and therefore a return mechanism will be required to rendezvous the capture module with the settlement again. Once the asteroid has been completely captured, the return process would initiate. The hydrogen propellers will navigate the ASCAMO along with the asteroids to the docking station at Astoria. Then the asteroid will be transferred to the Astoria Industrial Center for further processing.

OFF-BOARD MINING

Many asteroids however, cannot possibly be captured by Astoria due to their large size and kinetic energy. Therefore, Astoria will also have provisions for offboard mining operations, which will take place on the surface of the asteroid. Specialized mineral extraction modules will be transported to valuable approaching asteroids. Depending upon the kind of asteroid and need for resources, *surface* or *interior* mining units will be deployed. On the occasion of the next approach of the asteroid with Astoria, the asteroid mining modules will return to the settlement and refinement of the collected materials will be carried out at the Astoria Industrial Center.

MOTORIZED OFF-BOARD MINING MODULES (SURFACE)

Motorized units that will specialized in sweeping minerals from the surface of asteroids upto a maximum depth of 0.5 meters will be used for surface mining. Solar panels will power them to move on the asteroid surface and hydrogen propellers will be used for liftoff on completion of the mining operations.

SEDENTARY OFF-BOARD MINING MODULES (INTERIOR)

Sedentary units will establish themselves on the porous craters on the asteroid and conduct interior mining. They will be equipped with powered solar drilling machinery which will enable them to extract minerals from deep layers of the asteroid. Hydrogen propellers will be used for liftoff and return to Astoria after the mining operation has been completed.

DRILLING MACHINERY

The drilling rig of the mining module will comprise of a main arm which will be used to gather rocks comprising of the solar powered drill, a storage compartment to house the extracted rocks and a tripod stabilizer. The drill assembly will be capable for impact drilling and use an Archimedes Screw mechanism to lift the rocks. The pilot hole will be using additional force perpendicular to the rock using the impact driver mechanism. After the rocks have been collected at the top of the drilling rig, gravity of the asteroid will be used assist mass flow into the storage compartment by lifting the drilling rig up. After this transfer, the extraction process will resume.

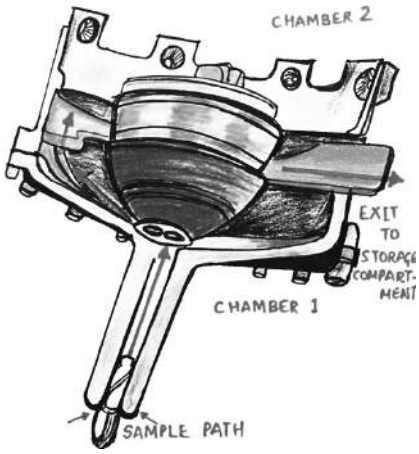


Figure 31: Design of drilling rig

ASTORIA INDUSTRIAL CENTER

Since Astoria is being built with the purpose of asteroid mining, it incorporates a large number of manufacturing capability, which will become useful in any of a number of possible developmental regimes. The industrial torus and the industrial module on the central cylinder of the settlement together comprise the Astoria Industrial Center

The torus will have variable rotation speeds to suit the demands of the industrial activities taking place. The torus can be pressurized or depressurized depending on the same. The industrial module on the central cylinder will be a non-rotating center. It will be used for 0g manufacturing on Astoria. This torus can also be pressurized or depressurized depending upon manufacturing needs. Macrogravity manufacturing will be used mainly for extraction of minerals from captured asteroids while microgravity manufacturing will be used for processing and assembling.

0g manufacturing can be useful because the absence of gravity increases the precision obtained in production. As a result, higher quality crystals and components including semiconductors, shuttle components, power reactor components and other tools can be manufactured while requiring lesser infrastructure.

STRUCTURAL ISOLATION

To prevent industrial activities from or causing disturbance to the residential tori or in extreme causes compromising on the stability of Astoria, the industrial center will be structurally isolated from the rest of the settlement. This will happen with the use of adaptive base isolation technology which is used for preventing structures form seismic waves. Base isolation uses components that decouple a superstructure from its substructures thus protecting the entire settlement's integrity. A tunable isolator will also be used that can adjust its properties based on the industrial activity going on to minimize the transferred vibration. Magnetorheological fluid dampers and isolators with Magnetorheological elastomer will be used for this purpose.

AUTOMATION

In an attempt to automate most of the processes of the settlement, the Astoria Industrial Center will run extensively on a process automation system (PAS) and manufacturing execution system (MES). This will reduce the need to employee humans in microgravity conditions, increase efficiency and bring down costs. Robots will be specialized in molding, carving, reinforcement and other manufacturing tasks.

The entire automation process will be based on an artificial neural network (ANN) that will mimic biological neural networks. It will contain sets of adaptive weights i.e. numerical parameters to tune a learning algorithm. As a result, functions will be performed collectively and in parallel by the units, rather than there being a clear delineation of subtasks to which individual units are assigned. This will bring in higher efficiency in the industrial process by adopting to quality and quantity constraints in imported minerals.

7.2 SERVICES FOR VISITING SPACECRAFTS

Due to its location Astoria can serve as an ideal interplanetary pitstop for several outer solar system missions. Incoming vessels will be able to dock on Astoria for a couple of days for structural reinforcements, refueling, maintenance, etc. In this period, astronauts will be able to benefit from a number of rest and recreation facilities available on the residential torii. All of these will also contribute to the economy of Astoria.

RECREATION FOR CREWS

Once an incoming vessel is docked for maintenance, the entire crew will first be checked for diseases. If all crew members are healthy, they will be transported to the residential torus. They will live in special homes designed for incoming vessels. The crew members will also be able to reap benefits from all the entertainment facilities of the settlement such as amusements parks and open spaces. They will be allowed to enter and try their luck at microgravity entertainment. Moreover, relaxation activities such as massages and yoga will be provided to the crew members to give them their much needed relief from the extended space travel they have been through.

SPACE TUG

If any vessel is disabled in a vicinity of 0.5 AU from Astoria, it can benefit from the MRO facilities offered by the settlement. By issuing a mayday call to the administrative department, they can order a set of dedicated MRO satellites to be deployed to their location. These satellites will able capable of refueling and conducting external repairs. Incase the satellites are unable to fix the damage, the *space tug* facility will be used. Herein, two chains made of snake hinges will initially attach to the disabled vessel with the help of magnetic snake hinges. The magnetic connection will be solidified using a drill that will create a magnetic connection with the vessel. The powerful thruster of the MRO satellite with be able to pull it towards the more equipped MRO Center on the main Astoria settlement. The thrusting mechanism of the disabled vessel can also be used to assist the pulling process.

IN-SITU RESOURCE UTILISATION

In-Situ Resource Utilization (ISRU) is the the collection, processing, storing and use of materials encountered in the course of a space exploration that replaces materials that would otherwise be pre-stocked. Incoming vessels can use Astoria as a pitstop to restock their materials. Certain materials such as some rare elements and carbon based materials which are found in plenty on asteroids are scarce on Earth. Using Astoria as a station for ISRU can help increase the quality of materials available for the spacecraft and reduce the cost of the settlement.

REFUELING SERVICES

Spacecrafts can also dock at Astoria to refuel themselves. Quick nozzles operating on Bernoulli's Principle will be used to quickly refuel the vessel. Astoria will be sufficiently stocked with 1500 cubic meters (52972 cubic feet) of liquid oxygen and 4000 cubic meters (141258 cubic feet) of liquid hydrogen which will be replenished monthly. These will be obtained by the electrolysis of water obtained from C-type asteroids. At low temperature and high pressure, these gases will liquefy to their compact counterparts.

7.3 SCIENTIFIC AND TECHNOLOGICAL RESEARCH

Astoria's outer solar system location can help it in several sensing and imaging research. The secondary settlements Kepler and Zuse will use specially designed equipment to fulfil this requirement. A group of highly qualified scientists and researchers will work towards this cause. The scientific and technological progress made on Astoria will be outsourced to Earth as a means of business development. This, along with Astoria's own funds, will bring in the remuneration for the researchers.

TELESCOPES

To search for extra-terrestrial life and discover more habitable planets in the universe, the Kepler space settlement will be equipped with a powerful radio telescope and optical telescope. The radio will have a dish diameter of 200 meters. It will use a parabolic disk, to reflect radio waves to the subreflector situated close to the prime focus. This will be used to create an image of the universe in frame using emissions from gases. The optical telescope, on the other hand, will have a mirror diameter of 10 meters. It will use mirrors and lenses with long focal length to reflect the light and a tube with length shorter than its focal length. This will use emissions from stars to create an image of the universe in frame. Really large mirrors deform under their own weight so thin, lightweight mirrors and a special technique called active optics will be used in the telescopes on Kepler.

Moreover, the telescopes will use torque rods to rotate freely providing altitude control, detumbling and stabilization. It uses electromagnetic coils to carry out manoeuvres by creating magnetic fields to rotate the telescopes and orient it towards a specific point in space. A computer controlled support system ensures that the mirror keeps its desired orientation at all times to nanometre precision.

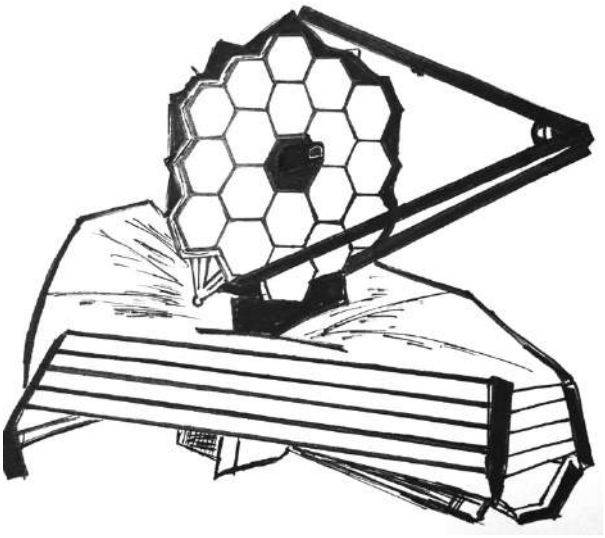


Figure 32: Radio telescope design

COMPUTATIONAL POWER

Due to the presence of quantum computers and a team of computer engineers, Astoria will have a highly qualified technology department. There will be large scale research conducted on computer security and encryption. The computers will use their immense computational power to break hashes. Discoveries and advancements in this regard will be traded with scientists on Earth. The computers will also process large amounts of data that are produced by a scientific equipment, such as a particle accelerator or telescope. Even these findings can be shared with Earth. The researchers will also work towards developing communication technologies that will have the capability to return data to Earth in real time.

APPENDIX A: OPERATIONAL SCENARIO

"Space is big. You just won't believe how vastly, hugely, mind- bogglingly big it is. I mean, you may think it's a long way down the road to the chemist's, but that's just peanuts to space."

Douglas Adams, The Hitchhiker's Guide To The Galaxy

• The universe is interesting, isn't it? It emerged from nothing, and is now *everything*. The universe is expanding, right? So, *everything* is expanding. So there is more of everything everyday. More things to discover, learn and talk about. No wonder humans are curious!

• And then there is time. Or is it spacetime? I will leave story for another day.

• Confining ourselves to space for the moment. It is razzmatazz of fuzz and fury. Adventures and misadventures. Smart machines and dumb people. Infinities and negative infinities. You know, its like a haystack. You know what they say about hay. Make your hay while the Sun shines. And in space there is not just the Sun, there is the Proxima Centauri, μ And, somerandomwigglywogglyname and a whole lot more.

• There is another thing about hay. That it is a lot. They say finding a needle in a haystack is next to impossible, but hey, the needle is there. In this universe we know, we have our own needle. Well, technically, it more like a popsicle stick with four donuts around it. It's Astoria!

• I know, I know, you must have dropped your jaw and waved in enthusiasm. Afterall, Astoria is a symbol. A symbol of human curiosity. A symbol of out of the box thinking. A symbol of humanity. It is something you can legitimately obsess over.

• From the inherent symmetry in rotation of the residential tori to the smudge free glass of the agricultural torus in which you can almost see your reflection, this thing is a marvel. For a quick moment, we dock ourselves and get a glimpse of everything Astoria has to offer in its fast and effortless transportation system. It's a sight to behold.

• But there is some unparalleled beauty in the seeing the Astoria move through space with a 30,000 foot view. How it automatically dodges an asteroid every moment or two. Seeing Astoria is a serene experience, almost like a lullaby. And this kind of makes sense, because the family was who Astoria was designed for. It is not just for asteroid mining and researchers, it is an experience indistinguishable from Earth.

• But then there are people. People who question. *Why did you locate your settlement in this ridiculous location? All the random asteroids and stuff!* To these people Astoria calmly responds.

"Introduce a little anarchy, upset the established order, and everything becomes chaos, I'm an agent of chaos , and you know the thing about chaos? It's fair."

The Joker

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APPENDIX C: COMPLIANCE MATRIX

S. No.	MINIMUM REQUIREMENT	LOCATION	PAGE
1.0	describe the design, development, construction, and operations/maintenance planning for the Astoria space settlement in the asteroid belt	Executive Summary	1
2.1	overall exterior view of the settlement with major visible features, showing rotating and non-rotating sections and indicating functions inside each volume	Figure 1	2
2.2	overall map or layout of interior land areas, showing usage of those areas	2.2 Internal Configuration	6
2.3	drawing(s) showing at least five intermediate steps of settlement assembly, and method of initiating rotation for artificial gravity	2.3 Construction Process	6
2.4	illustrations of shielding and damage repair systems	2.4 Asteroid Shielding and Damage Repair	8
2.5	show a standard design for secondary settlements; suggest how many settlements in which orbital locations will enable improved services to customers	2.5 Secondary Settlements - Structure	9
3.1	table identifying types, amounts and sources of construction material	3.1 Orbital Location and Materials	11
3.2	chart(s) or table(s) specifying quantities required of air, food, power, water, waste handling, communications devices, and internal transport vehicles	3.2 Basic Infrastructure	13
3.3	drawing(s) of primary construction machinery, showing how it shapes and/or manipulates raw materials or structural components into finished form	3.3 Construction Machinery	19
3.4	drawing showing location(s) and approximate dimensions of propulsion system(s), with descriptions of thrust, acceleration, and fuel requirements	3.4 Propulsion System	20
3.5	identify business purpose of each secondary settlement	3.5 Secondary Settlements - Services	21
4.1	map(s) and/or illustration(s) depicting community design and locations of amenities, with a distance scale, and sizes of buildings for services	4.1 Community Design	23
4.2	external drawing area and interior floor plan of at least four home designs, the area for each residence design, and the number required of each design	4.2 Residential Design	24
4.3	drawing(s) showing examples of handrails, tethers, cages, and/or other systems enabling safe human access to any location on or in low-g settlement areas	4.3 Safe Access	25
4.4	drawing(s) of means for children to spend time in 1g	4.4 Children's Entertainment	27
4.5	drawing(s) of "instant move-in" home designs	4.5 Home Designs	27
5.1	drawings showing automated construction and assembly devices — both for exterior and interior applications — and illustrating how they operate	5.1 Automation of Construction Processes	29
5.2	chart or table listing anticipated automation requirements for operation of the settlement, and identifying particular systems and robots to meet each automation need	5.2 Facility Automation	29
5.3	drawings of robots and computing systems that people will encounter in Astoria, and diagram(s) of network(s) and bandwidth requirements to enable connectivity	5.3 Habitability and Community Automation	30

5.4	drawing(s) of automated unloading system(s), clearly showing how ore moves from ship to refinery	5.4 Ore Delivery	31
5.5	define systems enabling communication and data transfer between Astoria and all of its secondary settlements	5.5 External Communication	32
6.1	durations and completion dates of major design, construction, and occupation tasks, depicted in a list, chart, or drawing	6.1 Construction Schedule	33
6.2	chart(s) or table(s) listing separate costs associated with different phases of construction, and clearly showing total costs that will be billed to the Foundation Society	6.2 Cost Estimates	34
7.1	define infrastructure for processing asteroid materials	7.1 Asteroid Mining Operations	35
7.2	define services for remote asteroid mining	7.2 Services for Visiting Spacecrafts	38
7.3	describe sensing and imaging research appropriate to Astoria's outer solar system location	7.3 Scientific and Technological Research	39
8.A	Operational Scenario	Appendix A	(i)
8.B	Bibliography	Appendix B	(ii)
8.C	Compliance Matrix	Appendix C	(iii)