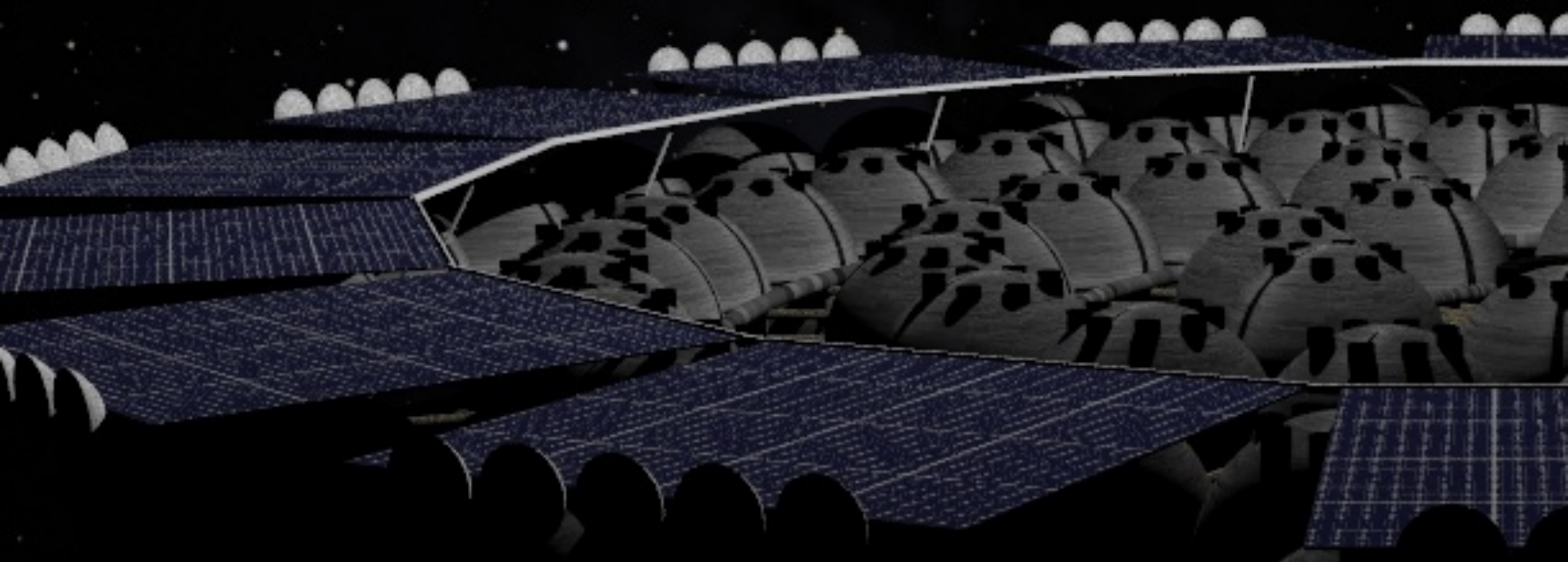
Aynah
Space Settlement



Trinity Christian Academy
Lexington, KY, USA

31 March 2012

19th Annual International Space Settlement Design Competition
Proposing Team Data 2012

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

Caleb Voss	[12] (17)	Jonathan Sekela	[10] (16)
Paul Rockaway	[12] (18)	Dana Brooks	[9] (15)
Joshua Miller	[12] (18)	John Burgess	[9] (15)
Sam Davidson	[11] (16)	Clay Leistensnider	[9] (15)
Andrew Brooks	[10] (16)		[ ] ( )
Jake Adams	[10] (16)		[ ] ( )

Names of two adult advisors currently expecting to attend the Finalist Competition:
Jayne Everson
Carl Voss

I understand that if our Team qualifies for the International Space Settlement Design Finalist Competition July 27 - 30, we will be expected to finance our own travel to/from Nassau Bay,

Jayne Everson BV — 3/29/12

Responsible Teacher/Advisor Signature — Date


1
Executive
Summary

1 Executive Summary

Faithful these past 117 years to the efforts of space pioneering, Northdonning Heedwell believes it is time, once again, for the Foundation Society to call upon its valued partner for the contracting of their latest intended settlement. It is with the utmost respect of your achievements and the greatest pride of our past successes together that Northdonning Heedwell formally submits its candidacy in your contract search and asks to join the Foundation Society in its newest enterprise. We present to you our proposal—our vision—for the Aynah Space Settlement.

The design incorporates both safety and freedom for residents, both efficiency and diligence of automated systems, and both aesthetics and functionality of features. Here are some primary highlights of the settlement:

- Residents live in twelve cylindrical communities around the perimeter of the structure at 0.7 times Earth gravity; this makes up part of a disk rotating at 1 rpm
- The interior of this disk and the entirety of a second, non-rotating disk are populated with partial- and zero-gravity spherical manufacturing facilities
- The two disks are connected by a central hub at which ships may dock and through which traffic intending to switch disks is directed
- Every part of the settlement is encased in a dual-layer hull of radiation-mitigating reardonium plating, filled with 0.5 m of water
- Construction requires minimal oversight or initial investment, as a small envoy of robots will bootstrap a several-generation successive system of manufacturing and assembly automation
- The settlement will be established in a six-hour period orbit 6,385 km above the terminator of Mercury, giving optimal launch windows for surface launches
- Each residential cylinder operates a self-contained system of Earth-like atmospheric control, NFT hydroponics, and zero-waste vitrification furnaces
- Extensive solar panel arrays capitalize on the increased intensity of the Sun's radiation and provide power for the settlement and on-board reardonium manufacture
- The transportation system is composed of trains performing circuits around the structure and elevators shuttling to the central hub
- Communities are laid out in a hexagonal terrace pattern, creating an intriguing and comfortably open cityscape while also maximizing housing density
- Children are exposed to full Earth gravity everyday by attending school on a train coursing around the settlement 16 m/s faster than the ordinary rotation
- Common functions and chores are performed by teams of helpful and ever eager household and public robots
- From contract to completion, the construction of the settlement is expected to take 16 years, consuming a budget of $1.1355 trillion.

We believe our design most effectively addresses the requirements asked of our services, providing innovative and productive solutions to the hazards of space. The Foundation Society will be able to easily conduct large-scale, lucrative reardonium manufacturing processes with our proposed vision of Aynah. We thank you for your consideration.

2

Structural Design

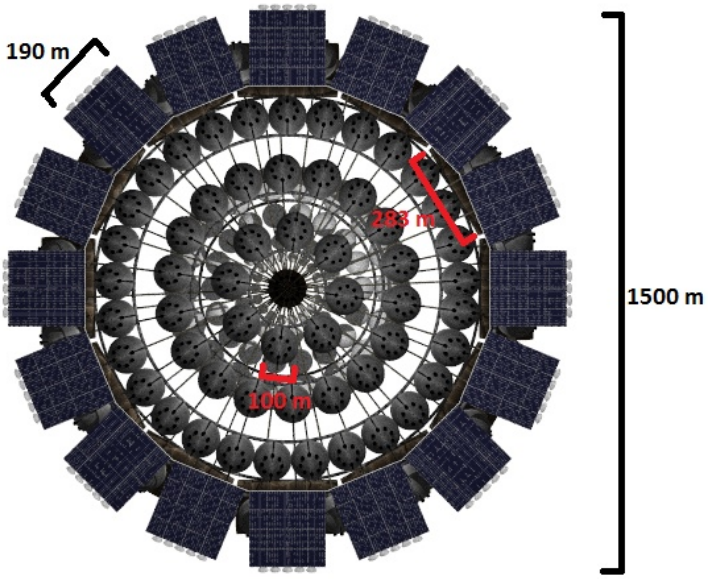
2 Structural Design

Aynah, the Foundation Society's newest space station, will be designed and equipped to provide the utmost comfort to its 14,000 full-time residents and up to 200 short-term visitors. As a satellite of Mercury, Aynah will provide natural views of her governing body and many facilities for refining and manufacturing reardonium.

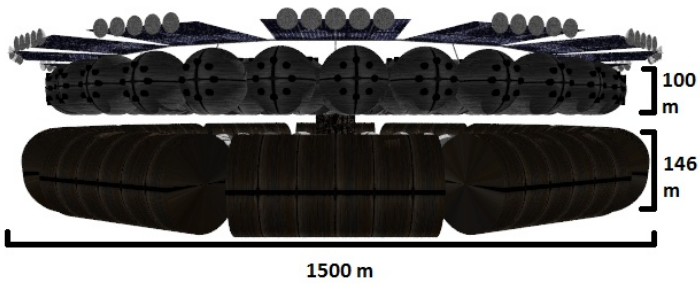
2.1 External Configuration

2.1.1 Basic Structure

The basic structure of Aynah will be two large, sun-facing disks, populated by both spherical and cylindrical components. The disk farther from the Sun will be rotating and is composed of a beaded toroidal section around the outside and spheres of varying sizes toward the center. The nearer disk is non-rotating and is composed entirely of equal-sized spheres. The non-rotating disk is called the "0-g disk," and the rotating one the "partial-gravity disk." Each "bead" of the outer torus on the partial-gravity disk will be a cylinder, 283 m long with a radius of 73 m lying on its longer side; these will be referred to as "residential cylinders." The beaded torus and sphere networks are held together by an external framework around which railroads will run, and through which elevators will run. The spheres nearer to the center of the partial-gravity disk and those on the 0-g disk are designated for manufacturing processes. The manufacturing spheres on the partial-gravity disk have varying gravity depending on their distance from the center. It is expected that a



Settlement Overview: Top-down



Settlement Overview: Side

more extensive 0-g space than partial-gravity space will be required by manufacturing processes, hence an entire disk is designated for the former, while only part of a disk for the latter. All elevators radiate from a central hub connecting the two disks. Cargo and personnel intended to be transported to the residential cylinders must enter the settlement through this non-rotating hub.

The beaded torus design for the residential area provides considerable advantages over other station designs that provide gravity in the form of centrifugal force, such as the dumbbell, cylinder, Bernal Sphere and Stanford Torus:

1. The Torus structure allows easy transportation between different areas with gravity, unlike the Dumbbell
2. It has a reasonable down surface area to volume of atmosphere ratio, unlike the cylinder or sphere
3. The structure can be manufactured in parts, unlike the Stanford Torus
4. It has constant gravity when stationary anywhere on the Torus, unlike the Bernal Sphere
5. Each Capsule can be easily isolated in case of emergency, unlike all other single volume structures

2.1.2 Design Features

The pressurized habitation cylinders on the torus will all be self-sustainable areas, each of which will produce food for its own residents. Each cylinder will also have a hanging garden that will provide a needed earthy and organic feeling. A day/night cycle will be maintained in the habitation capsules to create a more earth-like environment. There will be a total of 12 residential cylinders arranged in a ring with a radius of 600 m. The rotation of the ring will provide 0.7 g at the level of the residents' homes inside the cylinders. The ring of residential capsules will be connected to a central hub by a number of elevators. Also attached to the rotating residential ring will be several concentric rings of manufacturing spheres arranged around the central hub and ranging in radius from 50 m to 15 m. These partial-gravity manufacturing areas will have artificial gravity ranging from 0 to 0.5 g, depending on location, and they will be used for processes that are more easily performed in some small amount of gravity. The central hub will provide some docks for shipments of materials that will go strait to the residential capsules. Attached to the central hub will be several rings of zero-gravity manufacturing spheres, each will have a radius of 50 m and will be customizable by the company who purchases the use of it. There will be 91 of these spheres each having several of its own docks for easy importation and exportation of reardonium and its derivatives. The rings of zero-gravity manufacturing will be placed between the residential capsules and the sun to provide extra shielding. Also included in the design of Aynah, will be 16 solar panel arrays each 190 m by 190 m arranged in a ring resting on the outermost zero-gravity manufacturing spheres.

2.1.3 Construction Materials

The primary structural material used during the construction process of Aynah will be reardonium, mined, cured, and processed into parts by the initial fleet of robots which arrive at Mercury. However, as this process will take some time to initiate, the underlying structure will be initially built out of the Duriron steel alloy, to be later reinforced as reardonium supplies increase. Connective portions of the structure, such as the train tubes, will be made of titanium and reardonium for increased strength and durability. The shield for the entire settlement and for the second generation robots built on-site will require reardonium also. Furthermore, the settlement's shield will be filled with water, another resource obtainable from Mercury. All cables used in the construction of the settlement will be reinforced with carbon nanotubes. Sources of atmospheric gases and other assorted elements for smaller uses, like robot circuitry, ferrofluids, &c. will also be extracted from the Mercurial surface. Since the large and general structures will be built during the first stages of construction, there is ample time to analyze the state of available resources and request shipments of special-purpose materials from Earth or other settlements before detailed work begins.

Construction Materials Properties		
Material	**Use**	**Properties**
Invar Steel	-Underlying structure before reardonium is added	-Strong, excellent malleability for forming components before reardonium plating
Titanium Alloy	-Initial robots, connective structures	-Extremely strong and durable, chemically inert
Reardonium	-Structural integrity, plating, robots, shielding	-Miracle metal, variety of properties depending on curing process
Nanotubes	-Cables, tethers	-Strong down to molecular level, heat resistant, made arbitrarily long
“Detail” materials	-Circuitry, misc.	-Items and resources need for initial construction and first robots

2.1.4 Artificial Gravity

The rotation of the partial gravity disk around the central node will provide the effects of gravity to the residents within and to certain manufacturing processes that require it. Studies have shown that high rotation rates, over two to three rotations per minute, produce negative results on the human body, including nausea, disorientation, claustrophobia, and dizziness. Aynah will have a relatively slow rotation period of 1.02 rotations per minute. This will produce 0.7 times Earth gravity in residential areas and reduce the negative effects of producing gravity via centrifugal force. Manufacturing spheres closer to the central hub have lesser artificial gravity. Lower gravity will also make the construction of internal structures easier and facilitate crop growth. There will be multiple small thrusting engines arrayed around the perimeter of the disk that will be

used to maintain its rotation speed over long periods of time or produce thrust to combat any wobbling motions that might begin to occur. The thrusters will be fired automatically by referencing gyroscopes placed throughout the torus. The zero-gravity disk does not rotate and, therefore, has no artificial gravity. It, too, will have small thrusters to maintain its static position.

2.1.5 Interfaces between Rotating and Non-rotating Sections

The central hub itself is composed of a non-rotating section, coplanar with the zero-gravity disk, and a rotating section, coplanar with the partial-gravity disk. Elevators arriving from the partial-gravity disk connect directly to the rotating section, while those arriving from the zero-gravity disk connect to the non-rotating section. The rotating section is directly open to the non-rotating section by a large portal in its circular face. Cargo and personnel may freely pass through it. The seam along the shared surface of these two sections is filled with ferrofluid lubricant that is held in place by electromagnets. These same electromagnets hold the rotating and non-rotating sections tightly together so as to maintain internal pressure, while the ferrofluid lubricant prevents the surfaces from actually rubbing together.

2.1.6 Pressure

Pressure will be maintained at 0.8 atmospheres throughout most of the habitable areas of Aynah. This is a supremely habitable pressure, and several mountainous areas on Earth have significant populations living comfortably in 0.8 atmospheres. The docking stations will have pressure varying whenever the structure opens up to release or receive space craft. Before the volume is opened to space, air is vacuumed out to be stored for later re-pressurization. The 0-g spheres and partial-gravity spheres will also have the ability to lower the pressure of the entire environment, in order to ease industrial processes that may required low or no pressure.

2.1.7 Emergency Precautions

The structure of Aynah itself will lend itself very easily to safety. Each of the twelve residential cylinders is connected to the other portions of the settlement by rail and by elevator. The pressure of each is maintained separately, so in the case of a large hull breach in any one of the cylinders, that single cylinder, holding only 8.3 percent of the population, is significantly affected. Also, in the case of a severe emergency with little to no notice, such as a very large debris impact, nuclear detonation, or biological warfare, each capsule can be released from the Torus itself, and be flung into space for distant isolation. The likelihood of such a disaster is very small, but precautions will be taken nonetheless. The capsules will also include an airlock and parts to build a solar panel, powerful communications equipment, and large provisions of preserved food.

2.2 Internal Layout

2.2.1 Residential Cylinder Layout

Each cylinder will have houses laid out in in hexagonal terraces, creating artificial mountains and valleys each 5 terrace levels deep/tall. Scattered on and in the terraces will be a variety of houses of differing designs, and interspersed among these communities will be businesses, stores, and offices. In each cylinder, above the houses there will be hanging gardens and recreational park areas. Beneath the terraces lie all of the agricultural, environmental, water, and waste management systems.

2.2.2 Zero-gravity and Partial-gravity Area Layout

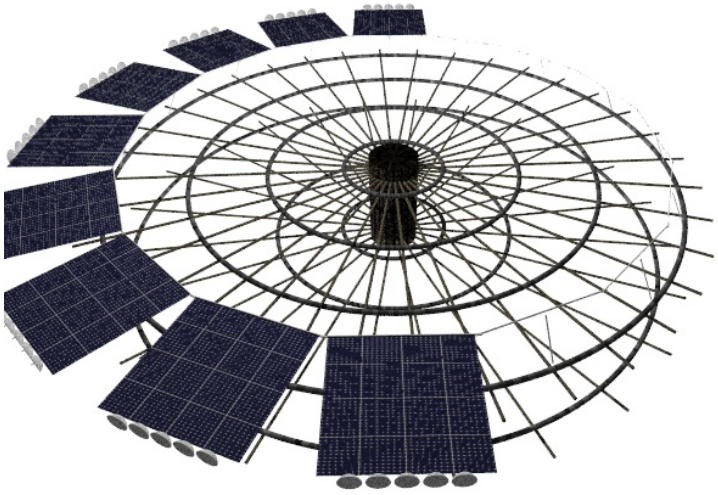
The central hub at the center of the rotating torus simply provides a transportation hub between the living areas and zero-gravity areas. It is largely automated, and personnel never leave their elevator car. There are 91 separate 0-g capsules, in which various industrial and scientific processes can be performed.

2.3 Construction Sequence

2.3.1 Pre-Construction Procedures

Prior to construction, the construction robots themselves and initial solar panels must be built in Earth orbit. In the initial stages, all the starter robots and 15 people to supervise the construction will be launched for travel to Mercury. These robots will deploy small, self-contained mining infrastructures onto the Mercurial surface and basic 0-g factories in orbit to begin the mining and reardonium part manufacturing processes for eventual use in the settlement's stucture.
Time for completion: 3 years

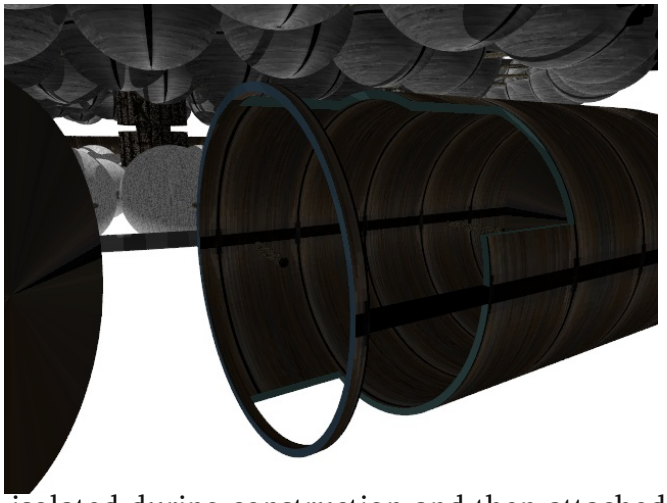
2.3.2 Construction Phase 1



In Mercury's orbit, the settlement construction will begin by building the framework of the two disks. The underlying structure will be initial manufactured out of steel, but as reardonium parts are finished, they will be used to reinforced the structure. Basic assembly robots transport and attach parts to the

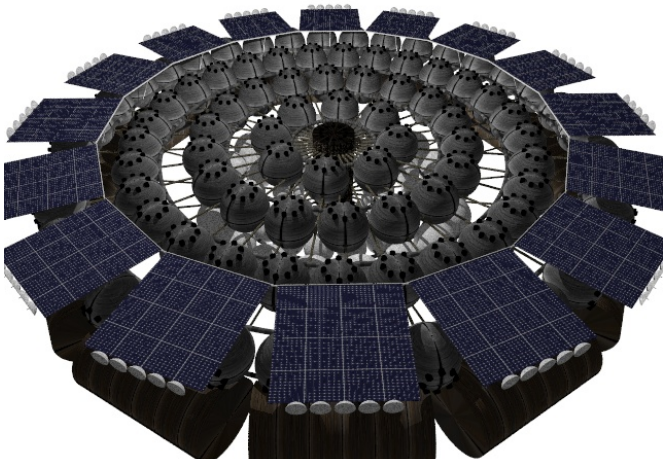
structure, and the TuRTLes (Transport Rail Tube Layer) will progress around the settlement, building the tubes that contain the train systems. The central hub and elevators tubes will also be constructed in this phase. Finally, all remaining solar panels will be assembled in order to harness more energy for faster construction purposes.
Time For Completion: 2 Years

2.3.3 Construction Phase 2



Once the framework of the structure is complete, the CEB (Capsule Exterior Builder) will begin construction of the outside of the residential cylinders and manufacturing spheres including the double hulled radiation protection that will eventually be filled with water. To make the fabrication easier and to reduce dense transportation traffic, these pieces will be isolated during construction and then attached to the main structure once they are complete.
Time for Completion: 4 Years

2.3.4 Construction Phase 3



In Mercurial orbit, all the parts of the settlement will be united. The cylinders and spheres will be securely fashioned to the rest of the framework. The rail and elevator transportation system will be completed, and internal and external finishing work will begin. Construction of the internal terrace infrastructure, hanging gardens, and operations facilities will commence.
Time for Completion: 2 Years

2.3.5 Construction Phase 4

The volumes intended to contain habitable space will then be filled with air comparable to that on Earth, and automated hydroponics

systems activated. The partial-gravity disk will begin rotation by using the thrusting sections arrayed around the perimeter. Also, in the hanging gardens, vegetation will be planted. The station will begin preparing itself for arriving residents.
Time for Completion: 3 Years

2.3.6 Construction Phase 5

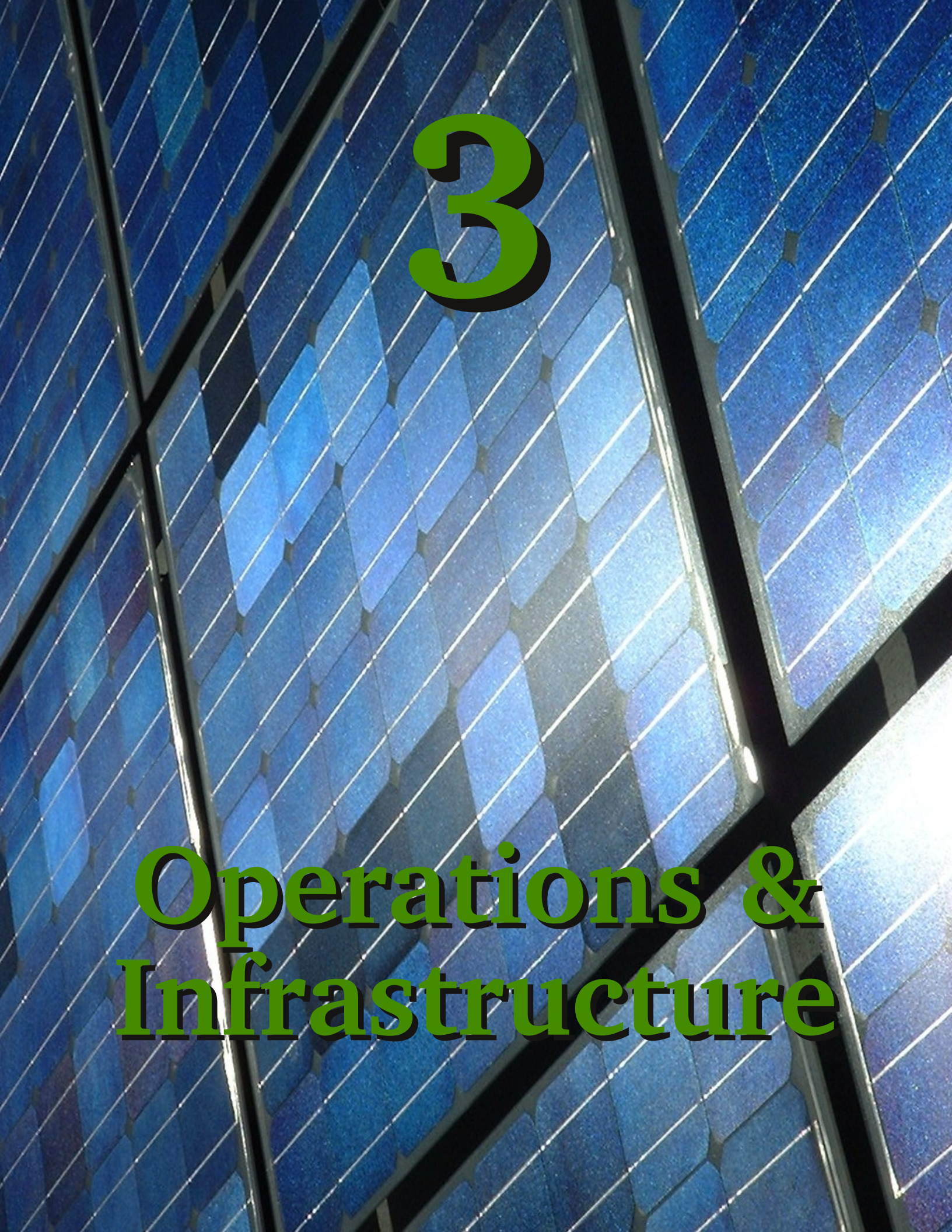
The first wave of residents, consisting mainly of engineers, laborer, and medical staff, will begin transportation to Aynah. Upon arrival, they will finish any necessary manual construction. Final quality checking of all systems and facilities will also occur at this time. They station will be ready for human habitation, and the full population will arrive over the next four years.
Time for Completion: 2 Years

2.4 Reardonium Refining

Aynah will provide approximately 47,500,000 m^3 of 0-g volume for refining in the zero-gravity disk and production operations as well as 523,600 m^3 of 0.5-g, 179,600 m^3 of 0.35-g, 47,700 m^3 of 0.225-g, and 14,100 m^3 of 0.15-g environment in the partial-gravity disk. Each of the zero-gravity and partial-gravity manufacturing spheres will be individually configurable to have anywhere from 0 to 20 psi by the use of air-storage tanks and large vacuum pumps.

2.5 Radiation Shielding

Aynah will be specifically designed to shield the inhabitants from dangerous levels of radiation. Between the residential cylinders and the Sun will be a ring of manufacturing spheres as well as a ring of solar panels. All hulls of both these spheres and the residential cylinders are double-layered, each composed of 0.1 m of reardonium, a material that shields from radiation very efficiently. Additionally, the entire settlement will have a half of a meter of water between the two layers of its hull. The water will be partitioned into many different sectors and circulated around the capsules to keep the water evenly heated and to continue to protect from radiation poisoning even if the hull is breached temporarily in one place.



3

Operations & Infrastructure

3 Operations and Infrastructure

The operation of Aynah, both during construction and normal operation, is described below, including its location, the internal processes of primary subsystems that are involved in residents' daily lives, the conducting of mining and construction, and the means by which Astoria evades dangerous oncoming asteroids.

3.1 Initial Operations

The first processes of the developing settlement are its establishment Mercury orbit and the formation of construction material supply lines from the surface.

3.1.1 Orbital Location

Aynah will be in a polar orbit around Mercury at an altitude of 6,385 km to create a six hour period. This provides a balance between proximity to mining bases, reducing transport times between the settlement and the surface and decent length of optimal launch windows for meeting up with the settlement after the least transit time. With the high volume of traffic between the Aynah and the surface regarding mining and refining operations, minimizing travel distances and fuel costs is of high priority. All water for the settlement will be harvested form the icy regions close to the poles.

3.1.2 Materials Sources

Any waste needing disposal during construction will be recycled in initial vitrification centers (the process is fully described in 3.2.5), one product of which is nitrogen gas. As this is not enough for the atmosphere of the entire settlement, tankers from Earth will bring supplementary nitrogen. Since much of Mercury is composed of silicates, a decomposition process due to Sebolt et al.[1] involving a small amount of fluorine, which can be recycled, will extract oxygen gas from the silicates. Carbon harvested from an asteroid by Bellevistat will be shipped to Mercury where Aynah's manufacturing centers, which will be operational very early on in construction, will combine it with the abundant iron found on Mercury's surface for the steel supply during construction of the settlement and for incorporation into products after construction is complete. Mining vessels capable of harvesting both the iron and the silicates will shuttle ore from mining sites to hubs that launch cargo ships back to Aynah on a daily basis providing a steady supply of construction materials and oxygen. Meanwhile, ice-drilling vessels will bus large blocks of ice from regions, suggested to contain it by high reflectivity, to Aynah's water storage tanks. Additionally, the cooler temperatures on Mercury's dark side are conducive to the formation of hydrated minerals, from which water can easily be extracted.

3.2 Community and Utility Infrastructure

Aynah's habitation cylinders are designed to support a high quality of living for the more than 14,000 residents, providing them necessary and desirable utilities and services. The environment must be self-sustainable, efficiently operated, clean, and, most importantly, it must be an enjoyable place to live.

3.2.1 Atmosphere, Climate, and Weather

The atmosphere on the settlement, whose composition is listed in the table on the right, will be kept free of pollutants, allergens, and particulates by a circulation and filtration system with ion fans and vents placed strategically around the cylinder to prevent stagnation. Outdoor breezes can be created as weather effects in this manner. The outdoor plants, especially those in the suspended gardens in the upper region of each residential cylinder, will require precipitation. Instead of introducing particulates into the air to seed clouds, the ceiling of the cylinder will have a system of ultra-fine mist sprinklers that periodically create a cooling humidity fog which descends on the plants. This system will also be used to control humidity levels and even regulate temperatures.

Atmospheric Composition		
Gas	% Volume	Mass (kg)
Nitrogen	76.00%	35,237,200
Oxygen	22.00%	11,653,700
Water Vapor	1.00%	3,199,760

The filtration system will monitor the O_2 level, as well as the levels of unwanted gases. Fractional distillation processes will remove and contain the unwanted and possibly distribute them to manufacturing centers if they are in any way useful. Reserve O_2 tanks will always be on hand in every cylinder in case of the need for quick recovery from a partial depressurization. If O_2 levels are low, a robot is dispatched to the mercurial surface to collect silicates, which will undergo the same fluorine decomposition process used during settlement construction. If needed, the filtration system can also heat and cool the air, especially to match moderate Earth-like day and night temperature differences.

The ceiling of each cylinder will be composed of stacked, transparent, organic LEDs varying across a wide spectrum. This ceiling will display a sun as seen from Earth crossing the sky once in every 25-hour “day” on the settlement, including realistic and varied sunsets and sunrises, as well as cloud formations. The advantage of the wide spectrum here is the ability to generate vivid, authentic light actually resembling that of the Earth sky, rather than simulate it by composing merely red, green, and blue light. Included in this spectrum is infrared and mild ultraviolet light so that the cylinder is heated through natural processes during the day and the residents can receive necessary and healthy doses of the light required to generate vitamin D.

3.2.2 Food Production

Food Provision	
Growing	All crops will be grown in an NFT hydroponics systems in every residential cylinder. There will be no livestock; all meat will be produced *in vitro*.
Harvesting	The harvesting processes for both crops and meat will be entirely automated.
Processing	Growing facilities will be kept clean and free from harmful bacteria, and all crops are washed before reaching the residents.
Packaging	Residents will enjoy the ability to order fresh, unpackaged food harvested the same day to be delivered directly to them. Other food is packaged for short-term storage, with the exception of the emergency stores and supplies for ships, which are prepared for long-term storage.
Storing	Storage facilities for food not currently in a store are located just beneath the terraces in every cylinder and have cryogenic functions for perishables.
Delivering	Food is automatically delivered to stores where residents may choose to go to pick it up themselves, or residents may place ordered to have it delivered to the home, workplace, &c.

Crop production operations on Aynah will take beneath the terraces of the living spaces. The system will consist of stacked levels of nutrient-film-technique hydroponics with organic LED lighting tailored to the specific wavelengths best utilized by the plants. Hydroponics allows for much denser crop placement and higher crop yield. Hydroponics facilities such as this one are more conducive to full automation, from the planting, to the maintenance, to the harvesting. Being fully automated allows the levels to be only as high as the crop, and therefore greatly increases space availability. A wide variety of crops are naturally suitable for hydroponic growth, and those that are not will be substituted with counterparts that have been genetically altered through selective breeding to accommodate them to the hydroponic environment. Each residential cylinder will have a complete set of crops so that they can maintain a full complement of nutritional sources locally. Should the cylinders become isolated from one another for any reason, each will be self-sustainable.

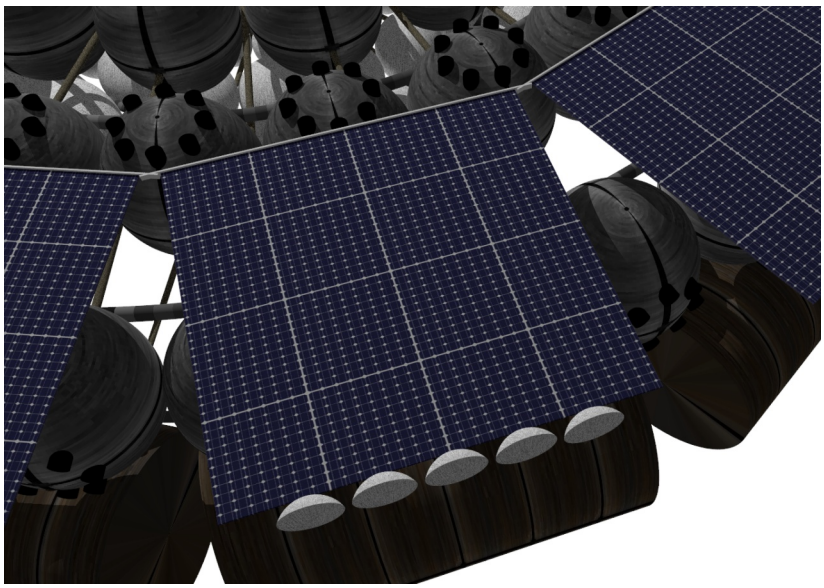
NFT Hydroponics

Primary Crop Production						
Crop	g/capita/day	g/m²/season	Season days	m²/capita	m²/cylinder	Total m²
Wheat	1000	856	120	135	163,125	1,957,500
Rice	600	1327	100	45	54,375	652,500
Corn	400	1133	70	25	30,208	362,496
Vegetables	1200	3805	90	27	32,625	391,500
Total	3200	N/A	N/A	232	280,333	3,363,996

Instead of maintaining livestock on the settlement, Aynah will have *in vitro* meat production systems. Rather than raise an entire animal, only to utilize part of it, genetically engineered cell systems can be grown into fully formed meat products using very little space. There will be no need for field space, a feed supply, or oversight of livestock herds. The fully automated system can produce 1200 grams of meat from every cubic meter per day.

The food production facilities will always have a capacity greater than what is needed for normal settlement function. (These same storage facilities also contain vital emergency equipment and supplies of disposable essentials in case of contingency.) Advance cryogenic packaging systems will store away an excess quantity of food capable of sustaining the settlement for six weeks should the production systems be disrupted. When functionality is returned, the system can then run at maximum capacity to return the food stores to normal levels as quickly as possible. Portions of the cryogenically packaged food will be stored near the ship docking areas for quick loading of rations.

3.2.3 Electrical Power Generation



Solar Panels on Aynah

Since Aynah will always be within a mere 70,000,000 km from the Sun, the insolation ranges from 6290 W/m^2 to 14500 W/m^2, averaging about eight times that near Earth, making solar panels a very efficient means of harvesting energy. The primary solar arrays will be on the front (solar-facing) side of the outermost zero-gravity manufacturing spheres, in sixteen segments. Their combined area will be 577600 m^2, which produces 2.9 GW, many times the settlement's standard operating power excluding reardonium processes, even during the aphelion. All solar panels are layers of high-end material at the theoretical limit of operating efficiency. Together, the combined layers work with an 80% efficiency at utilizing solar energy, making their location between residential cylinders and the Sun logical for assisting in radiation protection. Some of the power from each solar array segment is conducted into a power network spanning all of the zero-gravity manufacturing spheres. This network is secure from small attacks since the power can easily be routed through a different path should one of the conduits be compromised.

Additionally, the remaining power from the solar arrays is conducted to the

central hub, where four independent transformer systems balance the energy loads between sectors of rotation disk, containing the partial-gravity spheres and residential cylinders. This way, if one of the four systems goes offline, only one fourth of the rotation part of the settlement will lose power, and only momentarily until the other systems can compensate. Buffer systems throughout the electrical network always hold enough power to maintain critical settlement functions for fifteen minutes—the time needed for robots to replace parts anywhere in the system. Some energy is used to quickly charge robots that routinely make physical contact with the settlement. While these robots do have solar-power capabilities of their own, for fuel-efficiency reasons, they do not carry large enough arrays to sustain their systems indefinitely; were they to not return to the settlement, they would have to go through alternating periods of charging and operation. The settlement can also charge the long-term energy storage systems of docking ships. A small quantity of power produced by the plasma glassification process of the waste management systems is also introduced into the power grid.

Non-Reardonium Power Allocation	
Use	**Power (MW)**
Living Space	22.8
Personal Devices	8.5
Transportation	2.5
Food Production	11.4
Other Infrastructure	15
General Industry	74
Quantum Cascade Laser	80
Total	214.2

All energy not required for use on the settlement is devoted to the quantum cascade laser array that is tethered to the central node of the settlement. The primary function of the laser array as a communication device is discussed in section 3.2.6, but the laser serves the additional purpose of transmitting optical power in mass quantities to a network of relay satellites with similar arrays. In this manner, Aynah can sell the easily obtained excess solar energy to other space settlements and to Earth, where the insolation is much less, since recent developments in high-end laser technology can produce beams which do not spread significantly over long distances.

3.2.4 Water Management

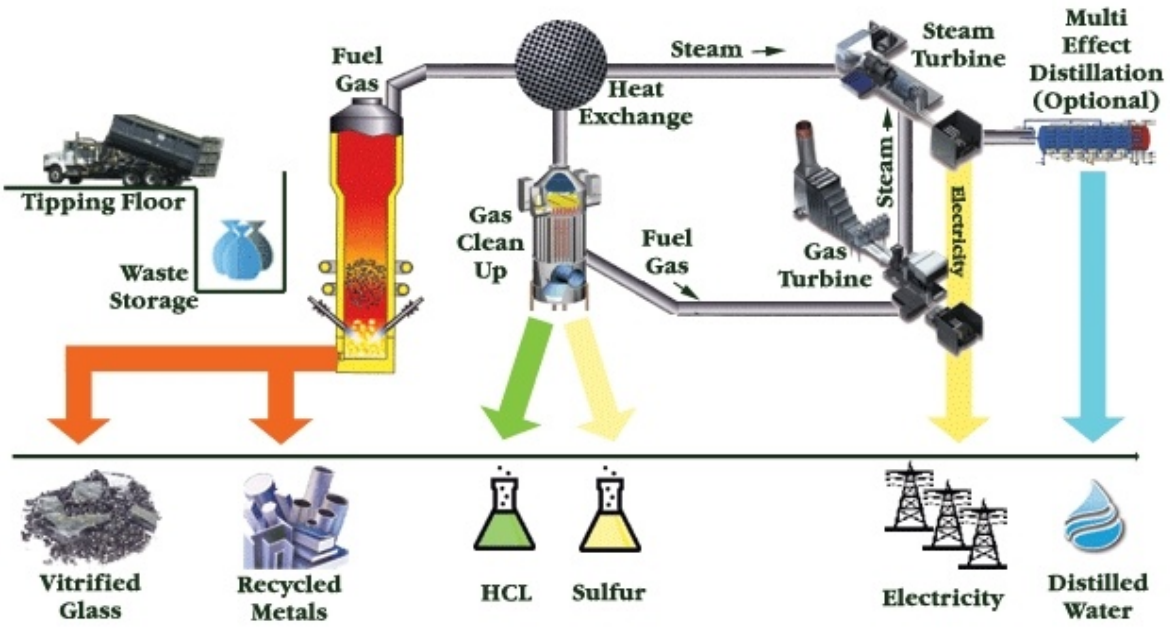
Aynah's water and waste management systems will be able to recover nearly all of the water at the end of the settlement's water cycle. After the initial supply of water is gathered, very little additional water will need to be added to the system. The total initial water supply will need to be around 12,583,289 L for internal use and 2,898,500 L for the 0.5 m water shield encasing the entire settlement. Each residential cylinder has an entirely self-contained water system with its own purification and circulation system, whereas the manufacturing areas have centralized purification systems, and their water supply is transferred between spheres through pipes in the train tubes. The water shield is compartmentalized into narrow rings running around the cylinders and spheres of the settlement from the sun side to the dark side and back again. Each compartment is individually circulated so that the heat built up on the sun side is distributed throughout

the shield for even heating. The water in the shield does not need purification. The water treatment processes for the manufacturing and residential systems are similar; however, the manufacturing system is not as comprehensive. Manufacturing-grade water is only sedimented and filtered since industrial uses do not often depend on sterilized or perfectly pure water. It is important, then, that the industrial water supply not be mixed with the residential systems. Residential water is additionally irradiated to kill bacteria, filtered more thoroughly, chemically treated, and distilled. Chemical additives for health reasons like those on Earth, such as chlorine, fluoride, etc., are then re-introduced to the supply. A small quantity of water may be separated from the residential supply, before the chemical additive stage, and be subjected to even further purification to meet medical and laboratory standards. The largest consumer of the internal water supply is the hydroponics system in each cylinder, using a total of 9,883,200 L/hr. There, the water is enriched further with minerals suiting the needs of the specific crops being grown. Large reservoirs of residential-grade water are maintained in the central hub and at all zero-gravity docking stations to refill visiting ships' water supplies.

Water Usage Allocation	
Purpose	**Rate (L/hr)**
Environment/vegetation	87,839
Industrial Use	335,860
Household/Personal Use	179,175
Hydroponics Systems	9,883,200
Total	10,486,074

3.2.5 Household and Industrial Solid Waster Management

Any and all waste, industrial or household, is processed via the same method: vitrification. Manufacturing areas send their waste via cargo train to centralized waste management centers in designated spheres, while each residential cylinder maintains its own management center. Specifically, Aynah utilizes a plasma glassification process, a high-level waste recycling system that produces zero waste. The three-day process begins with a 4000 °C plasma gasifier furnace with very little oxygen. The gas produced consists mainly of carbon monoxide, hydrogen, and nitrogen, will other elements suspended in it. Harmful toxins will not form at such high temperatures. A heat exchange cools the exiting gas while boiling water to power steam turbines. The gas is then scrubbed to remove hydrochloric acid for commercial use and hydrogen sulfide for fertilizer in the hydroponics facilities. Finally this gas can be used to power a gas turbine. All substances not suspended in the gas exiting the plasma gasifier are liquified and separated into individual recycled metals while the rest becomes vitrified glass during cooling. [2] This glass has a wide variety of commercial and industrial applications, being a strong, durable material. Aynah also provides waste recycling services for visiting spacecraft.



Vitrification Flow Chart

3.2.6 Internal and External Communication Systems

Aynah's external robots, both those in orbit and those on the surface, are exposed to intense solar radiation that makes it difficult to receive signals without using large antennae and high-power transmission devices. As such, large communication relays, buoys in space or towers on the surface, localize the logistical concerns of the large antennae and power supply. Since the Sun emits less intense light at the longer wavelengths of radio waves, communication is is received most easily if sent on these long wavelengths, and this requires very large antennae to produce strong signals. The relays can emit these kinds of signals and have very sensitive directional receiving antennae to pick up the feeble signals of the surrounding robots or ships. High-temperature superconductor filters serve to allow for many simultaneous communication channels to be utilized without suffering the effects of signal loss. This way, these robots do not need to use large antennae or have large power supplies and can still engage in communication with each other by sending it through the relays. Aynah itself has transmission and receiving antennae just like the buoys for local external communication.

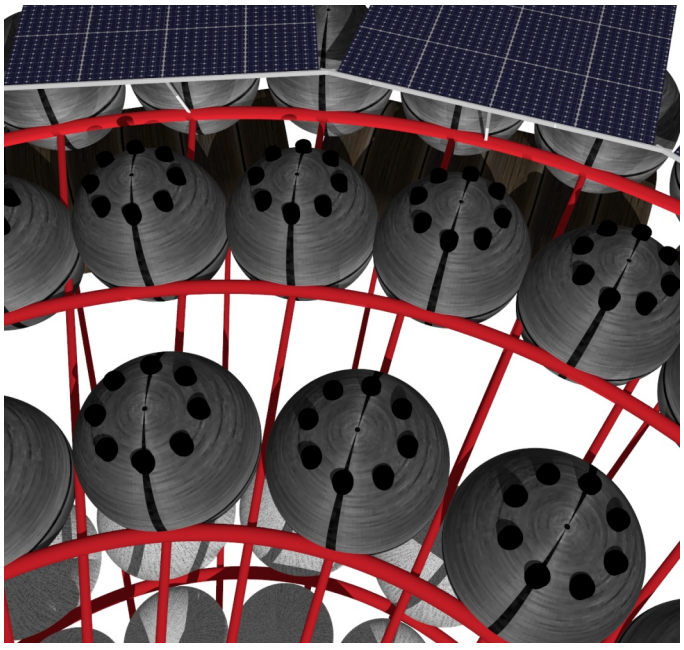
Internally, all communication is routed through a two-stage system involving both wired and wireless components. All hand-held electronics and portable computational devices, as well as internal robots and machinery engage, in wireless communication with router nodes in each home, distributed throughout the residential community, and in the manufacturing centers. These nodes are all wired together in a mesh network using high-temperature superconducting cables that do not need to be cooled. These cables can preserve quantum entanglement, so quantum encryption keys can be

established between nodes. The nodes themselves each have a small portion of the settlements' internet cache so there are no centralized servers.

Communication over long distances with Earth or other settlements occurs via the quantum cascade laser array tethered to the central hub of Aynah. Quantum cascade lasers can alter their emission frequency through a wide variety of ranges so massive amounts of data can be sent concurrently on different wavelengths as needed. There is a corresponding receiving array that can pick up data coming from other quantum cascade lasers or ordinary radio communication from other satellites. Aynah maintains a cache of Earth's internet so that residents feel informed and socially connected to Earth. This cache is periodically updated. Because the cascade laser requires so much power, it is not economical to leave it on all the time, so an energy buffer is used to power it on short intervals to perform transmission dumps to the satellites. There are six primary communication satellites that Aynah directly interacts with: one in Earth orbit, Mars orbit, and one at each of the L4 and L5 Earth-Sun and Mars-Sun libration points. This way, there will certainly always be more than one satellite not on the other side of the Sun. From there, communication is relayed between these satellites to reach Earth and other settlements. Aynah's and the satellites' communication capabilities can also engage in the establishment and secure relay of quantum encryption keys for the transfer of sensitive information.

3.2.7 Internal Transportation Systems

Each residential community is only 283 m by 73 m, so there is no need for horizontal transport, although residents may wish to use bicycles. There are corridors on each terrace level that cut through the hills to reduce the need to continually go up and down while traversing the cylinder. There will be stairs, escalators, and elevators to facilitate the changing of terrace levels. The only vehicular transport within a residential cylinder are automated, electrically powered cargo carriers that distribute and deliver food, products, and other resources to various locations throughout the community.



Train and Elevator System

Inter-cylinder and inter-sphere transportation to move residents and cargo between residential cylinders and manufacturing spheres occurs in train tubes that run a course around the settlement at varied radii and elevators that extend radially from the central hub to the spheres and cylinders. The elevators in the partial-gravity disk operate

on a standard cable system, but all elevators have their own motors for movement through zero- or near-zero-gravity areas. The trains are magnetically levitated by high-temperature superconductors, eliminating the need for cryogenic cooling of the track. One train tube runs immediately above the residential cylinders, with stations at each, accessed through the hanging gardens. This tube contains one large track for the school trains discussed in 4.4, two medium tracks for cargo, and four small tracks for human transport. The elevators also make contact with the residential cylinders at these stations. The remaining train tubes focus on cargo transport in the manufacturing areas, so they have four cargo tracks and one personnel track.

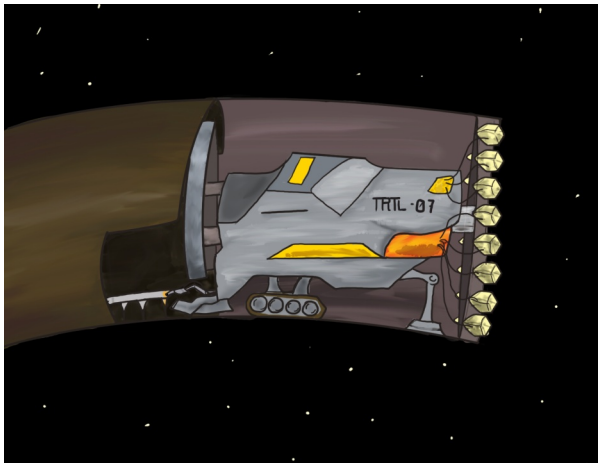
3.2.8 Day and Night Cycle Provisions

In order to create Earth-length days and nights on Aynah, each the arching ceiling of each residential cylinder will be covered in a screen of organic LEDs of a wide variety of wavelengths, rather than the less-than-realistic red-green-blue displays on ordinary electronic devices. These LEDs will be transparent and stacked to greatly reduce pixel gap and increase vibrancy. A full spectrum of authentic colors can be produced by this screen instead of relying on the illusion of primary color combinations produced by red-green-blue displays. These organic LEDs can not only paint a realistic sky, complete with clouds, but they can also perfectly reproduce the composition of visible, infrared, and ultraviolet light emitted by the Sun. For health reasons, however, the ultraviolet radiation will be limited. This realistic Sun traces across the sky every day, from beautiful, dynamic, and varying renderings of sunrises to sunsets. The hanging gardens above the residents do not completely obstruct the view of the top of the sky, but they do provide residents with welcomed shade which progresses along the community. At night the LEDs turn off completely except for the few required to paint the stars as seen from Aynah's current position around Mercury. Temperatures and humidity decrease during the night, giving residents comfortable and relaxing evenings.

3.3 Construction Machinery and Operations

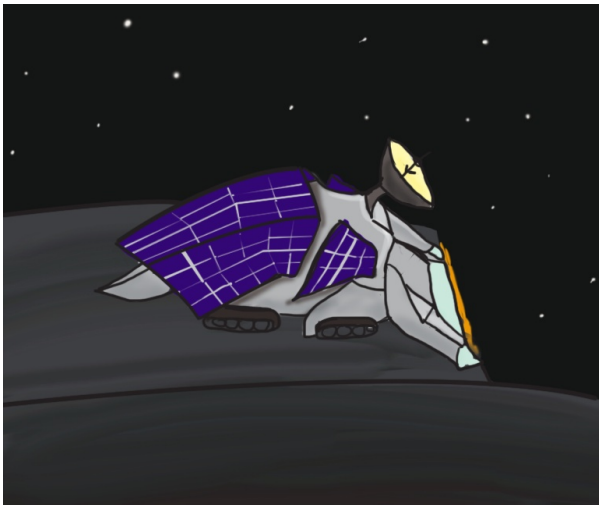
The primary robots and devices used in construction of the major structure of Aynah are the TuRTLe, CEB, RIA, and other modified versions based off of this equipment. For the TuRTLes, stand-alone zero-gravity manufacturing facilities produce titanium, steel, and reardonium segments for the train tubes. The segments consist of circular arcs of different radii designed to be assembled into rings for the entire tube as well as for each individual track tunnel running through the tubes. There will also be gently curving pieces to cover the length of the tubes to form the tracks themselves. Transportation robots will carry the manufactured segments from the production facilities to the TuRTLes. Each TuRTLe is responsible for one track tube and progresses around in a large circle, assembling the rings and building the walls of the tube from the inside. As it moves out of the recently assembled section, it lays the tracks and individual tunnel

walls in its wake. At locations where a residential cylinder or manufacturing sphere is going to be attached, the TuRTLe elaborates on the structure to build a station for the trains.



TuTRLe

At each of these stations on what will become the train tube for the residential area, CEBs begin construction of the residential cylinders. Starting from the tube they lay the first layer of reardonium hull, plates of which are delivered from the Mercurial surface by launch vehicles. After it has begun to spiral down the length of the cylinder under construction, another CEB will being the second pass, construction the second layer of reardonium hull. Once the interior hull is finished, but before the ends of the cylinder are sealed off by general purpose assembly robots move the plates into place, the RIA (Residential Interior Assembler) inserts itself into the cylinder and begins to lay infrastructure for the hydroponics and other utilities facilities as well as for the terraces.



CEB

As segments of both hull layers for the residential cylinders are completed the CEB installs a circulation system for the incoming water, and tankers, which have been amassing water brought up from the surface, pump the area between the hulls full. Once the exterior of the cylinder, shielding and all is completed, tankers with compressed atmosphere pressurize the cylinder so that vegetation can be established. Detail robots enter the cylinder, disassemble the RIA, recycle its parts, initialize the equipment for utilities, and begin construction on homes and businesses.

A similar, though non-residential-targeted complement of robots builds the central hub and lays elevator tubes radially to anchor the train tubes and residential cylinders. A further modified complement of robots designed for the construction of spheres instead of cylinders lays the double hull of the manufacturing spheres. The preexisting manufacturing facilities and factories will be installed into some of these spheres, and yet more will be brought online. The hulls are filled with water, but rather than simply be pressurized, the atmosphere tankers themselves and vacuum pumps are installed into the spheres to allow variable pressure.

By now the partial-gravity disk has begun to rotate, and the manufacturing

facilities have come online. Mining operations bring raw ores for materials other than reardonium to the refineries, and rare or delicate items and resources have arrived on special-purpose shipments from Earth. This supplies are delivered to the detail robots inside the residential cylinders for them to use in the construction of a comfortable and aesthetically pleasure environment for humans. Appliances, accessories, and household robots that residents have pre-ordered are produced and installed into their homes. The first residents have arrived by this time and assist these robots in final initialization and fine tuning of operations.

3.4 Reardonium Manufacturing Solar Panels

The manufacturing operations regarding reardonium on Aynah itself will utilize the excess power generated by the large on-board arrays. Only about 40,000 m^2 of those arrays are required for ordinary settlement operation, so approximately 537,000 m^2 of their total area is allocated for manufacturing processes. Surface operations are powered by local solar panel arrays. Each of the 37 mining bases along the terminator will have its own 265,000 m^2 array. These arrays are vertical and elevated off the ground so that there are fully exposed to the sunlight. This will provide sufficient power for base operations, life-support functions, quick robot recharging, and the inside-out mass driver. All robots and vehicles operating on the surface have their own on-board solar panel arrays, which total to make up the remaining 17,100 m^2 of required paneling, bringing the final total up to 10,360,000 m^2, or 4 square miles. The robots that make frequent stops at the base and especially those which perform heavy lifting will utilize the quick recharging functionality instead of their solar panels as much as possible so that their on-board arrays do not have to be prohibitively large.

3.5 Reardonium Movement Vehicles

Reardonium parts will cure on large platforms resting on the Mercurial surface. For efficient transport of parts across the terrain, those with like curing requirements and schedules will be located on the same platform. Small teams of transportation robots, called HRPRs or Hybrid Reardonium Part Relocators, defined and pictured in 5.5, will lift and move these platforms and thereby relocate many parts simultaneously. These robots will drive on durable treads designed to operate on even the most hostile terrains whenever possible, using electric engines powered by solar panels. However, should the terrain become absolutely unnavigable, high-power ion thrusters will allow the robots and platform to hover just long enough to move to less severe terrain. The sparing use of the ion thrusters allows for very small fuel requirements. As these robots spend significant amounts of time working with platforms which may be on the dark side of Mercury, their energy buffers are very large so that they do not become stranded without solar power. If in rare need of rescue, however, they can be transported by each other.


4
Human
Factors

4 Human Factors

4.1 Community and Neighborhood Design

4.1.1 Housing

Architectural Sample

Residents of Aynah will have a comfortable and modern day-to-day community experience. The residential community is divided into twelve distinct districts, one in each of the twelve residential cylinders. Each district will feature a different cultural theme in architecture, such as residences resembling Victorian Era, Oriental, Occidental, and American styles. These houses will integrated into the ten-leveled terraces for the purposes of space efficiency and allowing long lines of sight throughout the residential capsule. Houses can be packed close together while still maintaining the appearance of large open space. Businesses, such as offices and shops, will be interspersed among the houses. These terraces and the walkways along them are configured in a tessellated hexagonal formation. This hexagonal grid layout is superior

Interior Terrace Layout

to a diamond grid layout because residents will never have to turn street corners sharper than 120°, whereas the diamond pattern makes only half of the corners gentle and sharpens the other half. Above the community will be suspended gardens serving as a park space. Weather-like effects, such as cloud and rain, seemingly emanate from the gardens. The walls and ceiling of the residential cylinder will have a screen of organic LEDs to emulate the same light spectrum experienced by Earthlings and provided both psychological and physiological benefits from authentic light. Throughout the course of the day, a sun-like sprite will progress along this sky screen to provide a realistic circadian rhythm. The sky screen also provides realistic sunset and sunrise events, complete with proper colors, as well as the stars of the Mercurial night sky.

4.1.2 Entertainment

There will be no lack of settlement-provided entertainment aboard Aynah. Firstly, the aforementioned suspended garden parks will provide a valuable source of entertainment and relaxation for the residents of any given capsule. The direct sunlight and abundance of plants will provide an earth-like and pleasing environment where anybody will be able to spend their free time. Each residential community will have several public recreation centers, viz. gymnasiums, pools, fields, courts, &c. These recreation areas are left open for residents to use freely, except during intramural settlement-hosted sporting events. In addition to entertainment provided by the infrastructure of Aynah, room for improvement by the private sector will be possible and encouraged, as companies will have the opportunity to participate in the colony's commerce, should they have the inclination and resources to do so. Also, twice a year, Aynah puts on a settlement-wide festival, consisting of small, carnival-like amusement rides, and fair foods. Residential communities are invited to showcase their artistic talents in performing arts events and expositions. Also, beneath the terraced communities, below the hydroponics and infrastructure utilities, are viewing decks so that residents may gaze down at Mercury when it passes underneath their cylinder. This is accomplished without compromising safety provided by the shielding by replacing a few small sections of the reardonium plating with radiation-resistant, durable, and yet perfectly clear windows, retaining the 0.5 m layer of water between them.

4.1.3 Health Considerations

Wherever people live, it is essential to have proper and efficient medical care readily available at all times. However, DNA screening processes have been developed and perfected to the point of near-complete accuracy and remarkable efficiency at predicting people's risk of contracting certain diseases. As such, the need for yearly checkups is almost eliminated, being only necessary for those who have identified potential medical conditions that can be treated early on and thereby mitigated. Aynah's medical system always provides the latest vaccines for Earth diseases so that visitors do not cause epidemics. The self-same modular robots used for maintenance and repair will be

equipped for the transportation of personnel through the same pathways used for the distributions of goods and repair to the residential capsule's hospital.

4.1.4 Business and Consumables

Businesses will be able to purchase space by auction in Aynah for the purposes of manufacture and vending of products and services within residential communities. By providing a number of storefronts on the terraces with appearances and brands similar to that of those on Earth or other settlements, businesses will be able to provide an urban- or suburban-like lifestyle, creating virtually limitless arrays of purchasable consumer goods. These goods include physical items such as food, toiletries, accessories, decor, supplies, electronics, and tools, as well as services for robot repair.

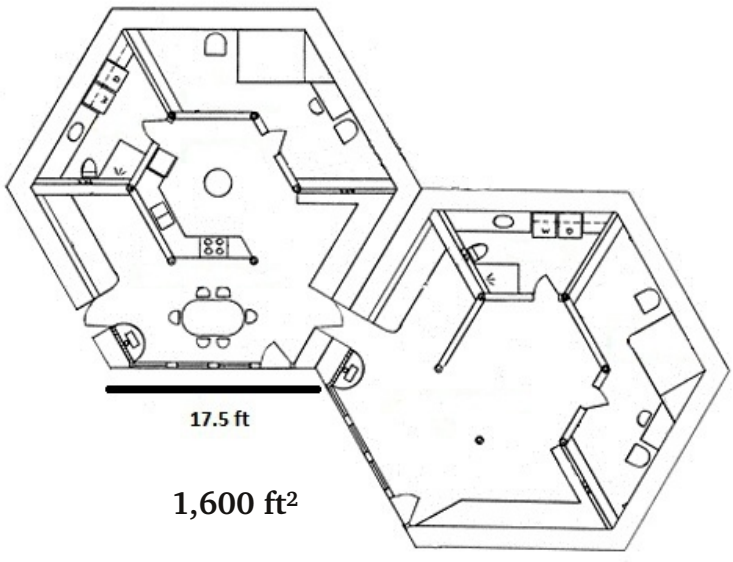
Beneath the terraced community in each residential cylinder is a hydroponics system providing a complete and diverse supply of crops for the residents. In addition to basic cereal grains and vegetables, the agriculture on Aynah includes assorted spices and plants for use in dishes from a variety of cultures. Also, in vitro meat production systems provide standard meats, including beef, pork, chicken, and fish.

Using the intranet framework of the settlement, access to a wide and enthralling variety of entertainment content will be available from decentralized databases, DRM free, through a defined protocol for media purchases that will be implemented on all personal devices, both stationary and mobile. Social networking and art-sharing services will be provided via internet.

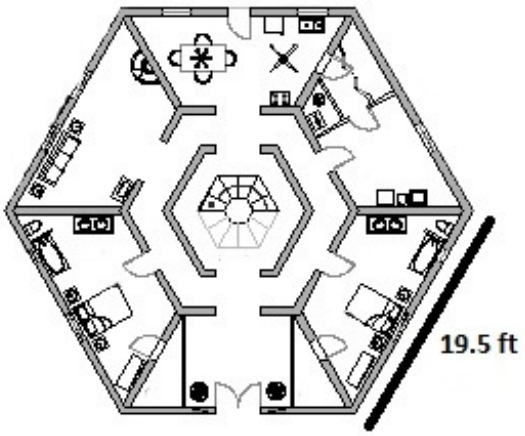
The public will be provided not only with already existing products and fashions, but with the opportunity to innovate and invent their own; storefronts will be available for purchase by companies or individuals on Aynah even after the initial allocation. This allows residents to start up their own capitalistic endeavors and privately-owned businesses.

4.2 Home Designs

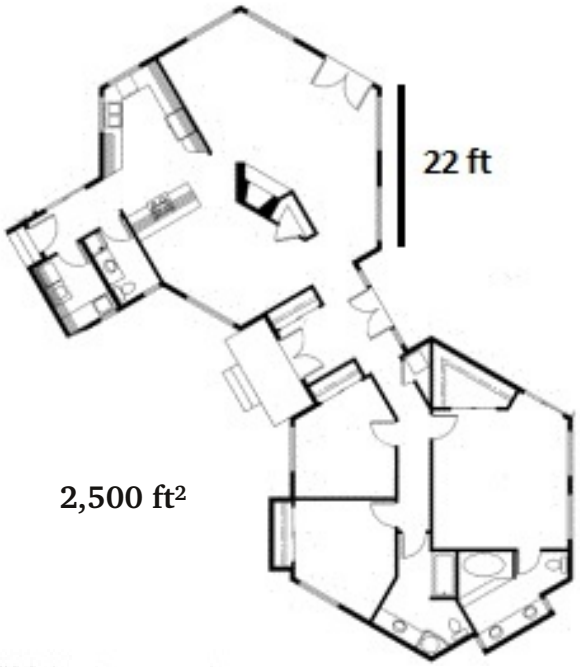
To accompany the hexagonal formation of the terraces, the internal layout of the houses on Aynah will also be hexagonal in nature. The following images are floor plans of four basic home designs of varying square footage, although many more home designs are possible.



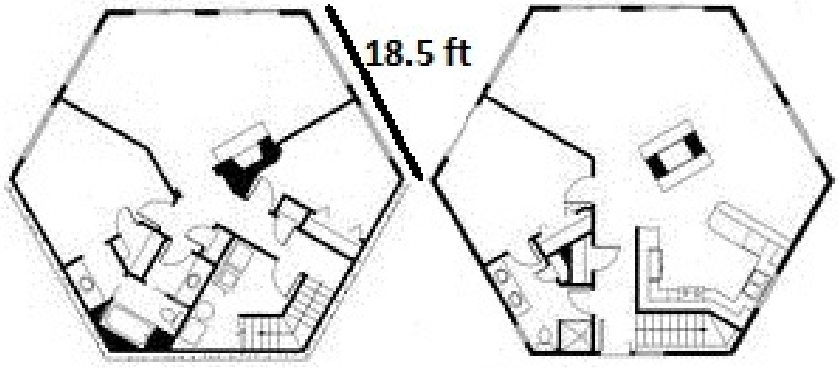
1,600 ft²



1,000 ft²



2,500 ft²



1,900 ft²

4.3 Space Suit and Airlock Security

While much of the external operation of the settlement is performed by robots, at times it may be necessary that humans perform space-walks for detailed repairs and situations requiring special judgment outside of the capabilities made available by the neural network formed by the maintenance robots. Also, personnel ships and cargo transport vessels will frequently need to dock with the settlement at the airlocks. Systems such as these will be made fail-safe through extensive use of redundancies and security access protocol.

4.3.1 Space Suits

The radiation protection capabilities of space suits available space-walkers consists of layers of flexible polystyrene foam, Kevlar weave, lead alloy, and dark-dyed, tightly-woven fabrics, in order to filter out some of the higher frequency forms of light from the sun, like UVC. Maximum radiation allowances for work will be 50 mSv/yr. in normal

circumstances, but in circumstances when a clear and definite risk is posed to human lives, this allowance will be increased to 250 mSv/yr. Space-walks on the sun-side of the settlement will be avoided when possible; however, if necessary, as in the case of an emergency, space-walkers will take a small panel of reardonium-based shielding with them to block out a significant portion of the radiation. Space-walkers, and their shields, will remain tethered to the nearest airlock at all times, and toolkits will remain tethered to the space-walker. Should the person become unconscious, the tether can be retracted. For this reason, spotters remaining on the settlement are designated for all space-walkers. Upon return to the settlement, all space suits undergo a thorough inspection for scratches, leaks, and other deficiencies that may have been incurred during use.

4.3.2 Airlocks

All airlocks will feature a double-shield to prevent problems caused by radiation inside the airlock. The first shield will be on the inner door of the airlock, to protect it from radiation, and will also include a layer of reardonium, when available, to protect the water shield from any abrasive particulate or solid matter. The exterior door will have a large, sliding shield over it in order to provide shielding to the airlock, but yet be retractable as to allow the movement of vehicles or persons through it. Moving parts in the airlocks, specifically those in direct contact with space, are lubricated and sealed with ferrofluids held to the surfaces by electromagnets. This way, joints can be exposed to space without risk of leaking air. Because these ferrofluids may attract charged particulate matter in space, valves to and from the ferrofluid-lubricated surfaces will be accessible from the inside for replenishment and filtering. In order to prevent unauthorized airlock function that would pose a threat to people and property, it will be necessary for two people to input biometric authorization codes.

4.4 Full Gravity for Children

Aynah's population of minors will be exposed to full earth gravity for at least three hours a day, if not more, to ensure proper physical growth and development. Since all children will attend school, the train system can conveniently fulfill both of these requirements. By hosting school on two trains always kept on opposite sides of Aynah traveling at 16 m/s in the same direction as the settlement's rotation, the children experience a full gravity environment during the course of their school day. Because the system is symmetrical, problems with unbalancing the rotation of the settlement are eliminated. This track runs through the same train tube that runs around to each residential cylinder.

At the beginning of each school day, the trains will make a stop at each cylinder, where students may board. Each of the two school trains will include sixteen cars, each 9 meters by 4.5 meters—one each for preschool, kindergarten, grades 1-12, plus a kitchen and an office. Technology will be integrated into each classroom and will provide a measure of convenience as well as efficiency in the school environment. Students may

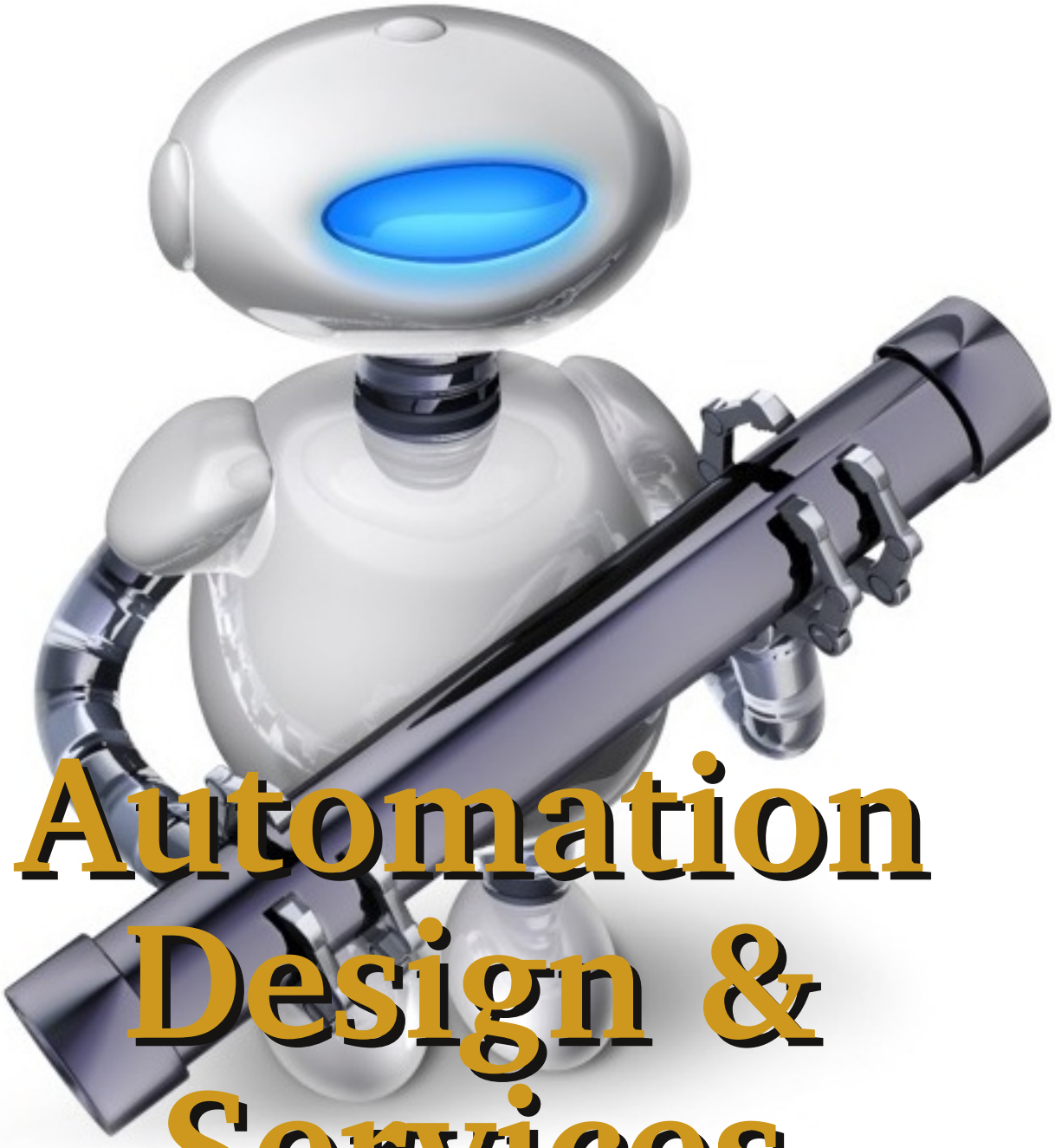
choose to provide their own lunches, or they may eat food from the kitchen. The capacity of these school rooms will be larger than the initial population of children to allow for demographic shift and population growth.

The size of each train car will allow a comfortable arrangement of five rows of four children. On average, each class will contain around eighteen people, allowing for a more individualized learning experience. In preschool through 8th grade, each class will have one teacher. In high school, each teacher will be required to teach 1-3 subjects, and the teachers move from class to class rather than the students. This will prevent overcrowded hallways. As to that matter, there will be two hallways—one on each side of the cars—for people to travel on, further dissipating the congestion of inter-car travel. Approximately 700 students are expected on Aynah, so these accommodations should prove to be more than adequate. Should unexpected population growth occur, is it possible to add a third train to the system.

4.5 Surface Vehicles for Humans

For surface transport on Mercury, a two-wheeled vehicle, similar to a self-balancing motorcycle, will be used. In addition to tires specially designed to grip the Mercurial terrain, when said terrain becomes difficult or unnavigable, ion hover engines will fire to levitate the vehicle until smoother terrain is encountered. This vehicle, viz. the STV, or Surface Transport Vehicle, will have an enclosed and shielded compartment for up to two passengers. Rather than windows, which would let in harmful radiation during Mercury days, video camera with live feeds to monitors inside will provide a view of the environment. These spatial sensors will also be useful in mapping the surface of Mercury, to develop and maintain a useful knowledge base of Mercury's geography that will be of use in traveling and mining. An auto-navigation system can be activated that uses advanced image analysis techniques, as well as relative position to any of the signal buoys in orbit around Mercury to automatically transport people to their required destination.

5



Automation Design & Services

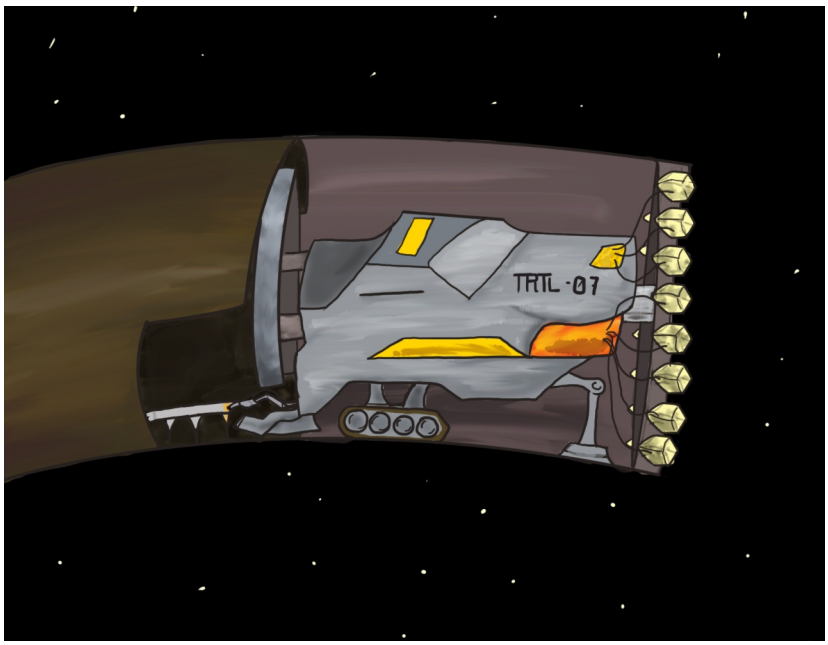
5 Automation Design and Services

5.1 Construction Automation

5.1.1 Seed Colony

The "Seed Colony" will be composed of two types of robots: one robot for use as a non-mobile refining/manufacturing station and operations base, with duplicates of said robot for redundancy and efficiency purposes. Each of these refining/manufacturing robots, upon arrival on Mercury, will release several smaller robots for mobile mining on the surface of Mercury, and include sufficient facilities for the recycling of any other robot when they are no longer required. Ceramic radiation shielding, coupled with hydrogen-rich plastics, will allow all robots to perform unhindered by the massive amount of electromagnetic noise around them. All robots will communicate via a mesh network on a variety of frequencies in order to mitigate interference from solar activity and ensure proper assignment and execution of orders. All robots used for construction will also be solar-powered, but will be equipped with back-up batteries for locations where solar power is not available, namely, the dark side of Mercury.

5.1.2 Ring Construction

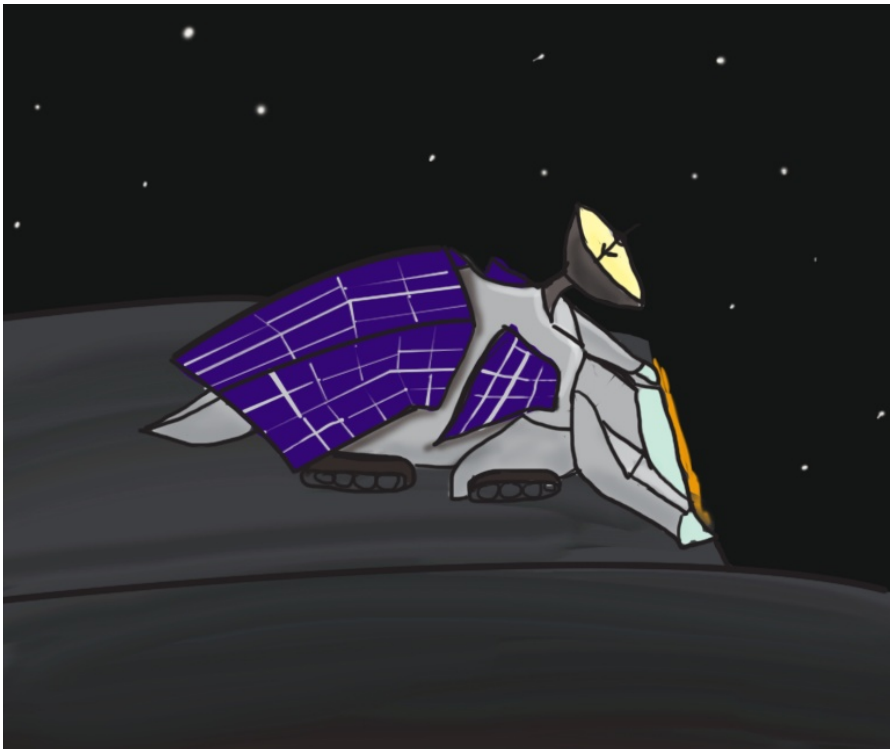


TuRTLe: Transportation Rail Tunnel Layer

The space settlement will be constructed from the outside inward, starting with the train system used for transit and education aboard the settlement. The ring and track for the trains will be placed by a specialized robot—the TuRTLe, or Transport Rail Tube Layer. This robot will function in a two-fold process, with two corresponding and gradually advancing rings: One ring, towards the front, will be responsible for creating the base iron structure which the second ring will then perform finishing tasks on, such as perfecting the rail on which the trains run. The TuRTLe will be restocked with materials continually throughout the process by using packages sent up from the surface of Mercury. Because the TuRTLe will operate inside the very tunnel that it is responsible

for creating, it will be unable to receive adequate solar power. Therefore, a large solar panel structure will be placed on the superconductive rail at the position where the TuRTLe begins its work, from which the TuRTLe will draw power for the duration of the construction process.

5.1.3 Cylinder Construction



CEB: Cylinder Exterior Builder

Cylinder construction will be managed by two specialized robots—the CEB, or Cylinder Exterior Builder, and the RIA, the Residential Interior Assembler. The CEB is inspired by the work of small wasps on Earth to construct large nests. It will work by circling around the lateral surface of what will be become the exterior of the cylinder, laying down the surface of the cylinder as it goes, and then makes a second pass over the cylinder for water shielding. When the CEB has completed its work, it leaves by walking along the transit rail to another location for the creation of a new cylinder, and then the next part of the process begins with the RIA. The RIA will systematically construct the wide-spectrum lighting in the cylinder, then the agricultural sections, and finally the houses and public areas of the cylinder. Interior finishing will be conducted by the modular repair and maintenance robots documented in 5.2, once a basic working infrastructure has been established, later on in the construction process, as well as the replacement and addition of iron parts with corresponding, superior reardonium parts.

5.1.4 Construction of Industrial and Other Sectors

Construction of the industrial sector will be performed by a robot pair similar to the CEB and RIA that would operate in a very similar fashion, but will create and furnish spheres, as opposed to cylinders, and then adapt them internally to whichever manufacturing process they were planned to be used for. Some of the enclosures in the industrial sector

will be left minimally altered, as not to hinder customization and adaptation by any company who will purchase them for the manufacture of custom materials or objects. Any infrastructure between these discrete spheres will be in the form of circular train rings running around the settlement and elevator shafts running from the central hub. This transportation grid will be created by fabricating skeletal parts on the surface of mercury, and sending them up and having them welded on by the CEB robots present.

5.2 Maintenance, Repair, and Safety

In order to perform critical maintenance and repair tasks, each cylinder of the space settlement will be equipped with several general-purpose "robot hubs," which will house a small team of modular robots, with the parts that are attached to a base unit to form a machine capable of a specific repair task. This approach allows unnecessary tools and parts to be left behind, where they can be examined for wear and tear by humans or the computerized robot hub. Having more than one of these hubs is also significant, as it will both allow redundancy in case of spontaneous failure of any one unit, as well as promote logistical simplicity for the movement of robots to repair sites. The "base" portion of all internal maintenance robots will be equipped with a low-frequency wireless transmitter for the purpose of communicating with other robots to form a meshed neural network for efficient repair, and rapid detection of erratic maintenance robot behavior. All robots will be equipped with adequate sensory equipment, such as both a visible light and infrared camera, as well as a proximity sensor, to determine if people are physically to close to the site of the repair in order to begin the repair. All repairs will be easily reported by use of the main console in the house or workplace. The main console will be required to send a heartbeat signal every half-hour across an internal network to provide assurance of proper function. A simple, albeit effective, fall-back button will be added for the purpose of reporting an undetected problem with any console.

For data security, command, and account information and servers, in addition to exceptional, biometrically-protected physical security, significant steps will be taken to ensure adequate security of all such systems. All servers for communication, data storage, robot management, backup, infrastructure, logistics, or otherwise, will be separate servers that each utilize strong encryption and require biometric data for any management and access. In this manner, the compromisation of one system/service will not aid in the compromisation of another. As computer security is exceptionally disposed to the discovery of sudden and formerly unrecognized flaws, a monetary reward will be given to any resident who, upon finding such a flaw, was able to document and report his/her findings and aid in a resolution of them, thus encouraging continuous security testing of all computer systems. In the event that a computer system were compromised by an attacker, creating a near-unmitigated disaster, monthly backups stored on two separate servers could be deployed manually by an administrator, only by physical access to the server area.

In the event of a problem, the robots are equipped with the sensors necessary to

detect it, and the vast neural network will generally be able to figure out the cause and find a solution to be carried out by the robots. If a suitable solution cannot be found within a specified amount of time, or if the situation is an immediate danger to the occupants or function of the settlement, the networked robots will alert residents who are in danger, maintenance personnel, engineers, and other important bodies of the station. Minor problems will be solved quickly and efficiently, and more serious problems will be resolved under the supervision of humans. All robots will be built with a transponder that is hardwired to transmit its model number, serial number, current attachments, current directive, and recent error logs to any machine that asks. This allows robots to detect failures of other robots, and lets them act accordingly.

External work will be performed by the same robots that work on the inside of the station. The robots to work externally will be equipped with large electromagnets that will allow them to hold themselves to the exterior of the spacecraft. The robots will be equipped with reardonium plate shielding with hardened internal electronics to allow them to work in high-radiation and unpressurized environments.

A more centralized computer system for each pod handles routing and information movement and storage for its internal networks. This then feeds into a central supercomputer that handles the movement of information between different pods in the settlement. Should any stage in the information routing fail, the work will be distributed across the network to allow normal function of the networks. The extreme redundancy of this system provides stability and dependability, only a situation in which the entire system were destroyed allowing any single part to be completely shut down. Information provided by an intricate system of sensors allows the status of any portion of the spacecraft to be called from anywhere in the network at any time, and allows careful monitoring to detect small problems before they become larger.

5.3 Livability, Productivity, and Convenience

A number of convenient and useful automation robots and devices will be present throughout Aynah to enhance day-to-day life and save time from dull, repetitive work, so that time can be better used for enjoyable, productive, and/or creative tasks. Each home and workplace would be equipped with an array of convenient and useful robots at the immediate disposal of the occupants. Each house would be equipped with a services terminal at the center of the household, for managing and scheduling automated activities, equipped with the ability to interpret voice commands regarding scheduling or configuration tasks. Primarily, this would allow the configuration of the household's multipurpose cleaning robot, which will be capable of disposing of trash, organizing miscellaneous objects on the basis of size or type or frequency of use, and cleaning any specified surfaces in the household. Manual cleaning supplies will also be provided, in case human precision is desired for a specific task.

The household's center console will be responsible for a number of other tasks, including being the basis for a decentralized networking, processing, and cache system

that will be responsible for serving and storing networked content throughout the settlement. Triplicate copies will be made of each file in storage on a randomly chosen node on the distributed computations network, in order to prevent tampering with data by majority error correction. Any personal, private, or otherwise sensitive information will be able to be conveniently encrypted with state-of-the-art quantum encryption keys. By using such a distributed, peer-to-peer network, it is possible to ensure constant and uninterrupted operation of the majority of the network at any given time.

Laundry Instructions for a Robot

Each household, in addition to the cleaning robot, will also be equipped with equally configurable robots capable of such tasks as laundry, with wash instructions formatted as 2D bar-code matrices on shirt tags, cooking any of a predefined and extensible set of recipes (but of course easily overridden by the culinarily inclined!), monitoring caloric and nutritional intake, and advising accordingly, and, necessarily, maintenance. Every house will also have configurable lighting to allow the unhindered function of circadian rhythms and create a more aesthetically pleasing and customizable environment, in addition to a wall-mounted panel for the creation and display of digital art during free time. Each residence and workplace will utilize a fully automated system for the removal and processing of waste materials, as well as the delivery and appropriate packaging, in the case of wrapped gifts, of goods to and from the location.

A variety of options will be available for use as portable computers aboard Aynah: By providing a wide array of devices with different form factors and open-source operating systems, conforming to published network operations protocols and guidelines, it will be possible to find a device well-tailored and easily customized for an individual and their life and occupation, as well as enhance the stability and security of the network by avoiding any large, homogeneous, and equally vulnerable group of identical devices. Automation services will be responsible for doing tasks in dangerous areas, such as refining, on the surface of mercury, and maintenance in hard-to-reach or otherwise hazardous locations.

5.4 Reardonium Processes

A number of automated services will be implemented in logistics operations between the settlement and Mercury. A specialized facility will be included in the industrial processes side of the space settlement, equipped with electromagnets to guide packages of ore sent via mass driver into a loading/unloading bay where they can be processed or sent back to the surface of Mercury, to one of several relocatable "parent" bases located on the surface of Mercury for the purpose of robot repair and resending and receiving packages using a inside-out mass driver for package delivery and receipt. These mining bases will be in the twilight region of Mercury for a suitable balance between solar efficiency and protection from direct sunlight. Reardonium-curing robots, defined in 5.5, will be able to receive metal to cure, by unloading packages sent to the base with integrated unpacking and repackaging facilities, equipped with a number of small, multipurpose robots capable of maintaining operation and cleanliness, as well as assisting in the loading/unloading process. Ore will be transported through the stationary industrial disk of the settlement by use of the train and elevator system, described in 3.2.6. When at their respective destinations, the ores can be refined or reardonium shaped for packaging, use, or movement to another location, at one of the many different facilities for each and every kind of manufacturing process required for a particular item.

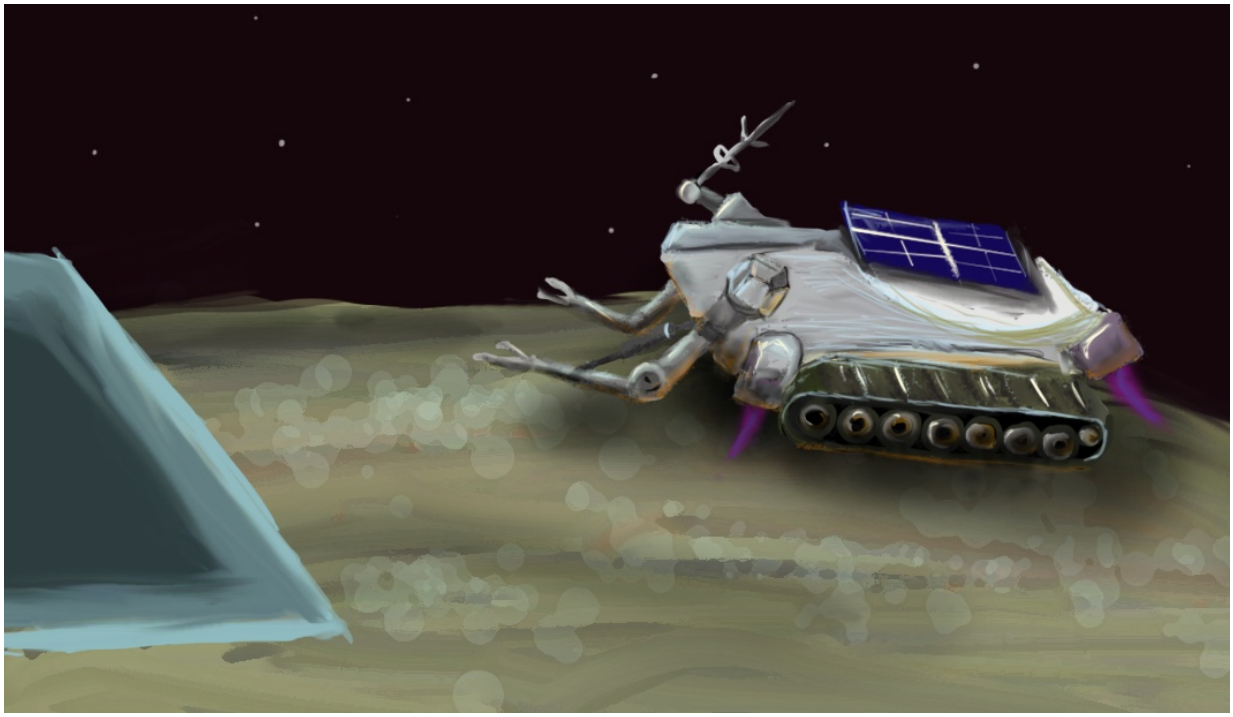
5.5 Curing Management Robots

On the surface of Mercury, three types of robots will be deployed for safe and efficient mining. Each robot operating on the surface of mercury will make use of a battery that can be charged at any of the parent bases or by a portable solar array common to all robots deployed for mining purposes. All robots will feature two directional fractal antennae capable of simultaneous transmission on several bands in order to communicate with a network of high-amplitude, solar-powered relay towers around the area, as well as with the parent bases to mitigate communications difficulties presented by solar activity. Furthermore, every robot will be shielded with hydrogen-rich plastics, water shields, or, once available, reardonium plates.

Firstly, a large number of small mining robots equipped with portable spectrometers for identifying and mining minerals and other useful resources will be deployed for the gathering of raw materials which will be piled to be delivered to processed on the settlement. These tread-powered robots, however, are too small and without adequate power reserves for long-distance transport, therefore, there will be an additional robot with which they will operate simultaneously for transportation—the Mining Robot Transportation Vehicle, or MRTV. Each MRTV will be able to hold 8 of the mining robots, and, with the use of a larger battery bank and solar array, be able to travel much longer distances on its replaceable treads, powered by an electric engine. Should the MRTV encounter any terrain impassible by treads, it will use bismuth-fueled ion thrusters to travel to its required destination, and will use more powerful antennae

to stay in contact with the mining robots that it has unloaded.

For the purpose of curing reardonium, a process essential to the productivity, correct function, and financial success of the settlement, a robot similar to the MRTV, called the HRPR, or Hybrid Reardonium Part Relocator, will be used. While slightly larger, groups of HRPRs will lift entire platforms of reardonium parts with the same curing requirements using multiple electromagnetic appendages, and will share the hybrid metal track/bismuth-fueled ion thruster propulsion system used by the MRTV. They will also be capable of individually relocating and turning over specific reardonium parts as necessary. In addition to the critical role of the HRPR in reardonium manufacture, idle HRPRs will be able to collect damaged, malfunctioning, or otherwise incapacitated mining robots and return them for repair or recycling.



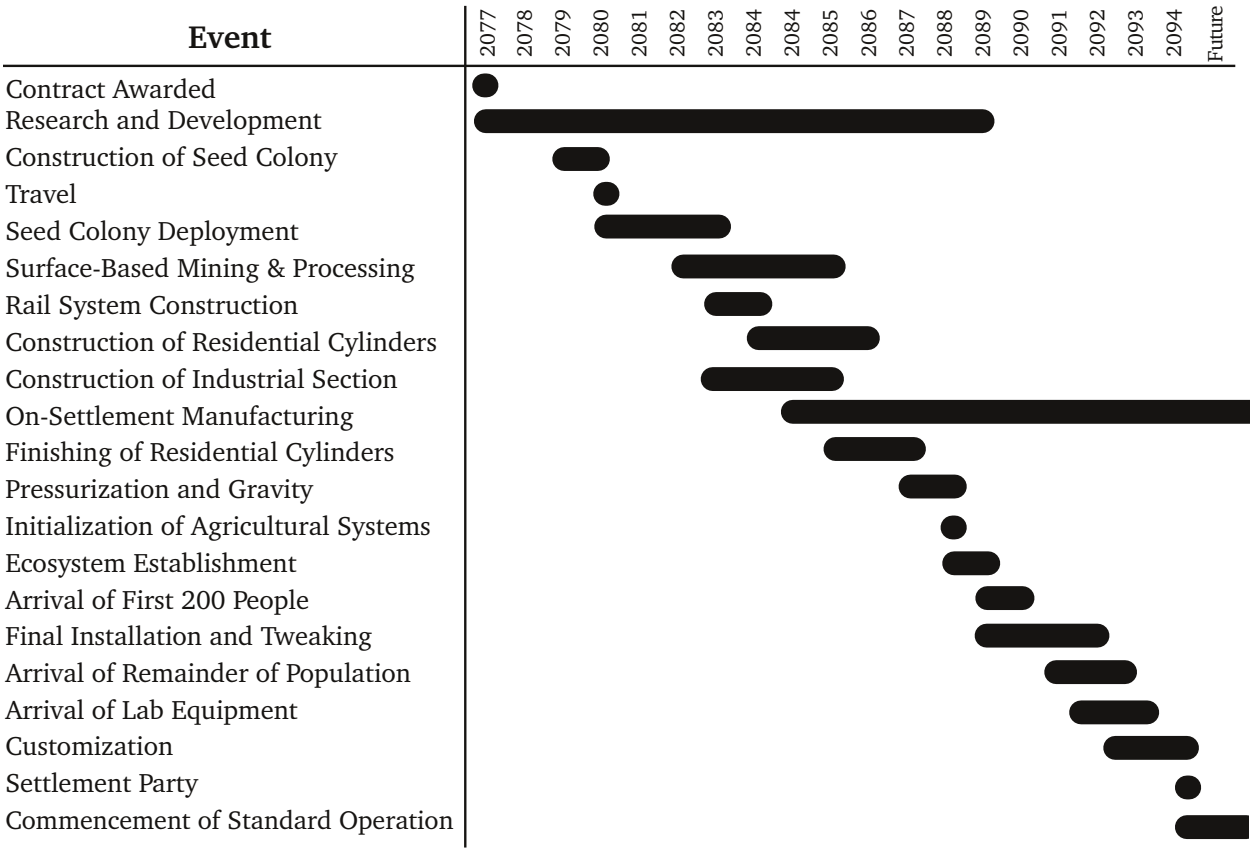
HRPR: Hybrid Reardonium Part Relocator

6

Schedule & Cost

6 Schedule and Cost

6.1 Schedule



6.2 Cost

Raw Materials Costs			
Material	**Costs ($/kg)**	**Amount (kg)**	**Total Cost ($)**
Nickel (for Invar)	65	7.04×10^7	4.576 B
Titanium Alloy	50	6.22×10^8	31.1 B
Carbon Nanotubes	75	7.98×10^6	598.5 M
Detail Materials:			
Superconductors	450	4.21×10^5	189.45 M
Rare-Earth Metals	380	3.70×10^5	140.6 M
Others	200	2.50×10^6	500 M
Total			37.105 B

Salaries				
Category	**Job**	**Man-Years**	**Salary ($/yr)**	**Total ($)**
Engineers	Aerospace	375	80,000	30 M
	Design	500	85,000	42.5 M
	Automation	700	95,000	66.5 M
	Electrical	350	90,000	31.5 M
	Operations	300	75,000	22.5 M
	Biological	250	70,000	17.5 M
	Agricultural	250	70,000	17.5 M
	Information	300	90,000	27 M
Researchers	Medical	100	90,000	9 M
	Behavioral	50	60,000	3 M
	General	20	70,000	1.4 M
	Systems	20	55,000	1.1 M
Management	General	300	130,000	39 M
	Engineering	75	125,000	9.375 M
	Public Relations	50	110,000	5.5 M
Other	Communications	50	60,000	3 M
	Facilities Upkeep	75	30,000	2.25 M
	Astonauts	500	180,000	90 M
Total				$418.6 M

Transit Costs				
Location	**Transit Type**	**Price**	**Number**	**Total Cost ($)**
Earth Orbit to Mercury Orbit	Seed Colony	$850 B	1	850 B
Earth to Aynah	Personnel	$200,000/person	14,200	2.8 B
	Equipment	$3,000/kg	17,500,000	52.5 B
Total				**905.3 B**

Equipment Costs		
Category	**Type**	**Price ($)**
Robotics	Electronics	40 M
	Motors	48 M
	Misc. Parts	147 M
Agriculture	Minerals	12 M
	Hydroponics	600 M
	Misc.	44 M
Instruments	Communications	150 M
	Computers	560 M
	Radar	35 M
	Scientific	1,100 M
Other	Ion Thrusters	25,000 M
	Solar Paneling	78,000 M
Assembly	Seed Colony	87,000 M
Total		**192.7 B**

Total Costs	
Section	**Cost**
Raw Materials	$37.1 B
Salaries	$418.6 M
Transit	$905.3 B
Equipment	$192.7 B
Total	**$1.1355 T**

7

Business & Development

7 Business and Development

7.1 Infrastructure for Reardonium Manufacture

While the investment costs for any operation of this scale are inevitably high, Aynah's reardonium mining, curing, and production processes can be executed with very low maintenance expenses, resulting in funds quickly soaring past the break-even point. This is because energy on Mercury, obtained through solar panels, is so convenient and abundant due to proximity with Sun and because the very material produced by the operation can reinforce the structures and robots involved in it, protecting them from excessive radiation and wear. Since this reardonium is so miraculous in its capabilities and diversity of function, extremely high demand for it will cause it to be a most lucrative and valuable export.

All manufacturing processes involving ores or other resources directly shipped from the surface are performed in isolated spheres, and no part or person may leave these spheres without first having any dust removed by passing through electrostatic fields and mild wind tunnels. Similar cleaning protocol will be in place at every manufacturing sphere, so that by the time parts have been completed they have been thoroughly purged of all dust and grit, long before entering the residential sectors

Fundamentally built into the structural design of Aynah is the capability for varying gravity and pressure in its manufacturing spheres. Refer to sections 2.1.6 and 2.4 for a more complete description of various gravity levels of different spheres and their ability to alter atmospheric pressure individually. Many manufacturing processes, including refining, are facilitated by the lesser or zero gravity and lesser pressures that may be achieved.

For security reasons regarding hazardous manufacturing operations, all manufacturing takes place in completely separated spherical sectors that share no common infrastructure with the residential cylinders except the solar arrays and the elevator shafts leading from the residential sectors to the central node. Chemical leaks, water supply contaminations, unplanned depressurization, and even explosions cannot interfere with residential infrastructure

Since other companies may wish to rent or purchase manufacturing space from Aynah, some of the spheres will be left largely unconfigured on the inside to allow these businesses to set up a system of production most efficient to their needs. Other efficiencies of movement are had by giving each of the zero-gravity spheres their own external docking ports so that ships with ores and parts can deliver supplies and resources directly to the manufacturing areas where they are needed. Also, the transportation network within Aynah's two disks allows for movement radially and circularly around the settlement, with rings for cargo and personnel trains, operating on high-temperature magnetic levitation rails, at varying radii and elevators running from all the spheres to the central hub.

7.2 Receiving and Shipping Reardonium Parts

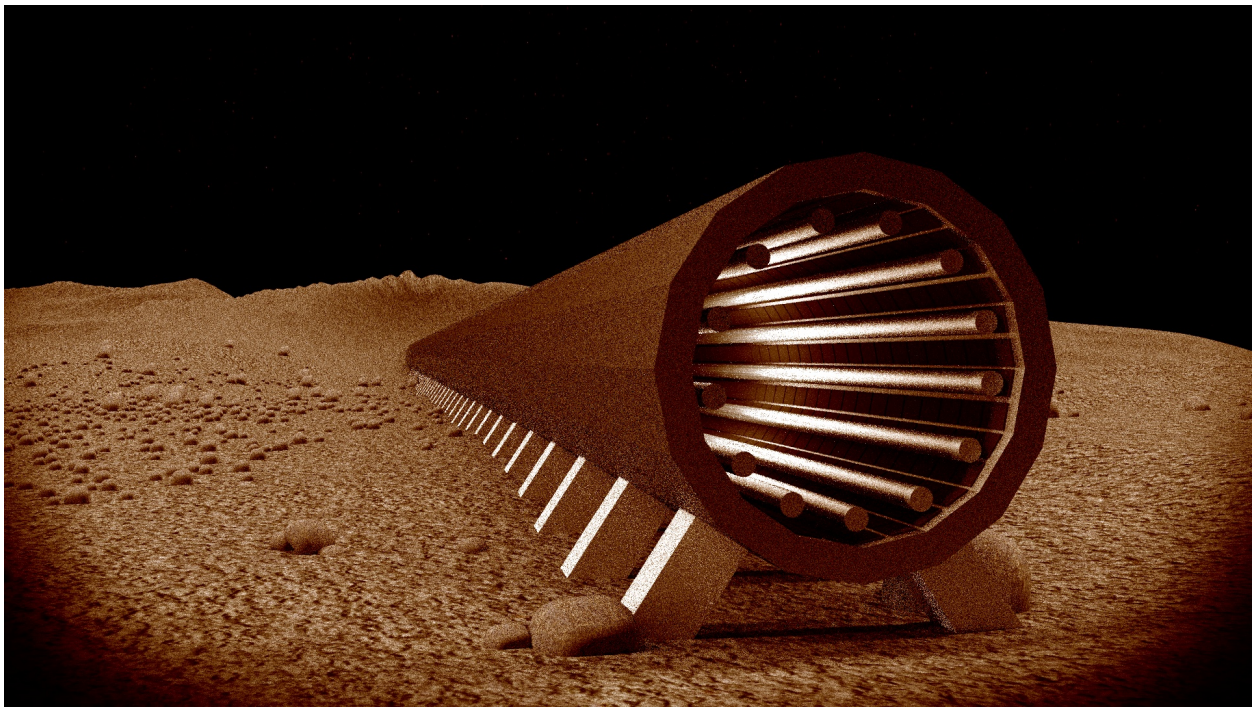
When parts arrive from the Mercurial surface and are delivered directly into the necessary manufacturing spheres or when parts have just been prepared for shipment to the surface for curing, they undergo quality assurance inspections by both automated eyes and QA personnel. Refer to 8.A. Since there are docking facilities within every zero-gravity manufacturing sphere, as soon as any parts are completed, they are already in position for loading onto ships or other cargo platforms to be distributed abroad to other settlements and Earth. Devices on Aynah similar to the HRBRs on the surface will be capable of handling parts directly, carefully loading them into containers and ships, as well as unloading them from shipments that arrive, navigate, and dock automatically from the surface.

7.3 Port of Entry for Mercury

Large, long-distance vessels may find it inconvenient or inefficient to enter into orbit around Mercury at such a low altitude as Aynah. Thus, for shipment of reardonium exports and for the receiving of supplies and resources from other areas of the solar system, modified HRBRs, whose movement capabilities consist only of high-thrust bismuth-fueled ion engines and not the treads of their surface-dwelling counterparts, will shuttle pallets and floating cargo holds to and from the interplanetary ships waiting in higher orbit. There is no need for on-board personnel, nor remote pilots as these robots have external sensors and are always in networked communication with one another so that they may coordinate, plan, and navigate their shipments autonomously.

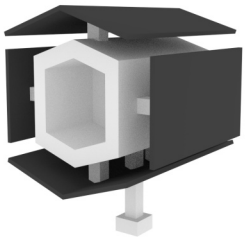
A Mining Base

A team of traffic control personnel will schedule and monitor flights to and from the Mercurial surface by launch vehicles provided by other contractors. Mining bases on the surface automatically submit launch requests when reardonium parts and ores are ready to be shipped to Aynah. To aid these launch vehicles in achieving orbit, especially when very massive shipments are required during periods of high traffic volume, each mining base will operate an inside-out mass driver. This device is a long hollow tunnel designed to propel ships and shipments into orbit by accelerating them horizontally. Rather than have electromagnetic coils around the outside like a



Inside-Out Mass Driver

standard mass driver, however, these will consist of several small tubes with internal coils. This way, the ships and shipments to be accelerated do not need to be propelled by exceedingly large magnetic vehicles. Rather, small carrier devices which fit around the tubes can attach to ships and shipments and accelerate them. Launch vehicles may also fire their engines during acceleration to expedite the process.



Carrier Device for the Mass Driver

Finally, for warehousing of cargo awaiting transfer between ships, the central hub of the settlement will have its excess space utilized as storage facility. This is the same facility that houses resources produced by Aynah's infrastructure for visiting ships, such as stores of food and water. The same shuttles that bring cargo to and from awaiting vessels in higher orbits also transport the cargo intended for storage at the hub.

8

Appendices

8 Appendices

8.A Operational Scenario

A single mining robot, covered in solar panels and the very reardonium for which it is the first step in manufacturing, wanders towards a valuable ore deposit previously identified with the aid of an integrated spectrometer. Mining over the course of some hours, using its laser drill, rake, and small, metal claws, it fills its cargo hold. The mining robot wonders away from the ore deposit, and dispenses the raw, freshly mined ore into a pile. Before returning for another load of minerals, the robot reverses and moves its two directional antennae in the twilight of Mercury, signaling nearby solar communications buoys and towers of its presence and need for transportation of the continually growing ore heap. This message is broadcast through a network of other high-powered buoys and eventually to nearby mining bases. Some minutes later, an MRTV arrives, bounding across the pitted landscape with its bismuth-fueled ion thrusters, and quickly collects the contents of the pile for delivery and processing.

The MRTV flies and rolls along the surface, arriving at its mining base to recharge energy that was quickly depleted by its propulsion systems, while unloading the ore into a containment vessel for shipment back to the settlement. The vessel, once full, moves along the wall of the mining base, past the repair facilities, rescue droids, and into a cargo hold for shipment as soon as a window becomes available for movement on-board the settlement, as smiling humans inside the base perform a routine inspection of the pristine facility. A few stand stoically in watch over the array of sensors in the work quarters available down there, monitoring for any unusual activity or potential rogue, malfunctioning, or otherwise destructive robots. Over the course of several hours, as the window for mass driver shipment draws near, the capacitor banks inside the base begin to charge with a high-pitched chirp, as the first vessel of ore is loaded into the tube of the mass driver. As the interval for immediate shipment to the settlement dawns, the mass driver sends off its cargo with a sudden, dull hum.

While the package approaches the settlement, electromagnets activate to guide the magnetic vessel to its exact location in the docking area of the industrial region, some even activating after its passing to further decelerate it for a gentle landing, aided by small ion thrusters on the vessel. Several small shuttles are ready to unload the ore and transport it to its necessary destination for further refining and shaping. As the ore passes through multiple furnaces in varying levels of gravity, over the course of many days, it begins to acquire the appearance of reardonium, but is yet far away from its completion as a product. Metal ingots are then shipped to the proper facilities for their shaping - one goes to a vacant micro-machining chamber, purchased by a private entity for the manufacture and sale of the strongest protective cases in the solar system, the other nine towards a much larger chamber reserved for internal functions.

In the micro-machining facility, the metal ingot is cut into chunks and carved by a die grinder into its desired shape - dozens of extraordinarily durable protective cases for residents of Aynah, as well as those on any other settlement. The remaining nine ingots

are melted down and slowly carved to form their eventual shape, a replacement rail brace for the settlement's train system in case of a contingency. With the approval of human QA personnel, both are sent back aboard another cargo vessel for transport to the surface of Mercury once more, but this time, for curing. Upon arrival, again by mass driver, decelerated in the tube of a different mass driver tube on a different base, the parts are loaded onto an HRPR for movement to their destinations on the surface of Mercury, where they remain for one Earth year, placed alongside parts with similar curing requirements, only disturbed once by the HRPR gently turning them over for an even cure, when they are again collected and sent again by mass driver. On their arrival in a low-gravity section, they begin to make their way through the grid of tunnels aboard the settlement, where they diverge. The multitude of small tablet cases make their way on to be packaged and distributed, or even exported, and the replacement rail migrates on the exterior of the settlement towards its final destination on the train ring.

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