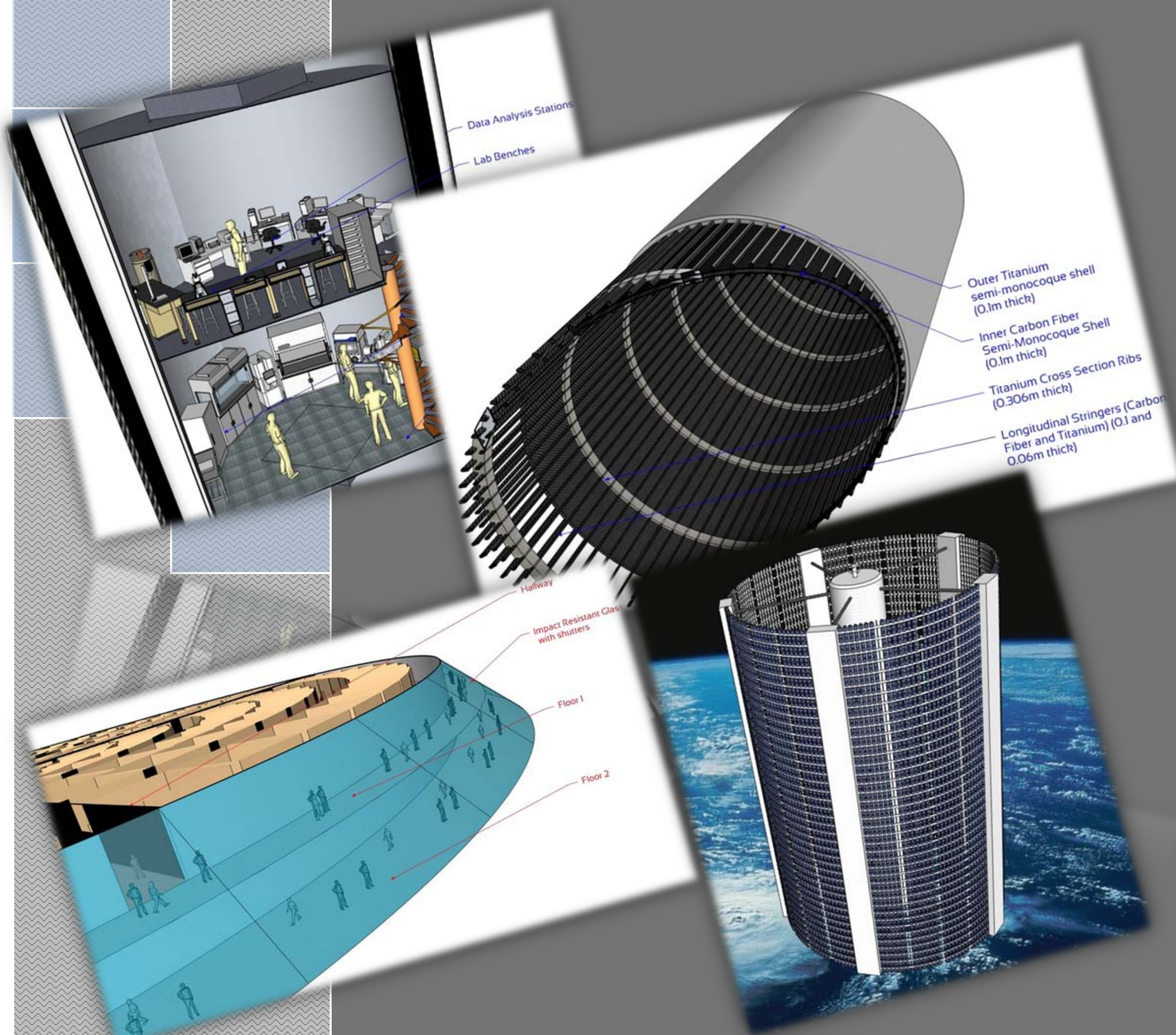
ASTEN



Eric Yam
Northern Secondary School

3/31/2009

TABLE OF CONTENTS

Section 1: Project Objectives

Section 2: Project Challenges and Assertions

Section 3: Structural Design

TABLE OF CONTENTS

Section 4: Construction of Asten

Section 5: Asten Life Support Systems

TABLE OF CONTENTS

Section 6: Asten Social Structure

Section 7: Acknowledgements and Works Cited

Why Asten?

Asten is an alternate name for the Egyptian god Thoth, who was tasked with maintaining the balance between Good and Evil, and was the master of divine and physical law. He is said to have directed the motion of the heavenly bodies, and the Egyptians credited him with as the author of all works science, philosophy and magic.

Similar to Thoth, the space station Asten seemingly directs the heavenly bodies in its location orbiting Earth, and opens up multiple possibilities in extending our knowledge and application of science. And who knows, perhaps there is some magic involved too.

Section 1: Project Objectives

The project objectives are divided into two categories: Short Term and Long Term. Short Term objectives are defined as goals that will be fulfilled with the construction of Asten. Long Term Objectives are defined as goals that are assisted with its construction, but are not achieved.

1.1: Short Term objectives

To promote human space exploration

Over the past century, humans have launched thousands of satellites and probes into space and have had hundreds of manned missions to the Earth's orbit and the moon. We've built a number of space stations such as Mir and the ISS to learn how to survive in the hostile environment of space. Therefore it is logical to assume that the next step in space exploration is the construction of a permanent space settlement.

The construction of a permanent space settlement will kick-start a whole new era of long term human interstellar exploration. The project will help us learn how to design manned spacecraft that can travel for extended periods of time, and will be considered a landmark achievement. It will show that humans are not restricted to living on the Earth, and are in fact capable of living in the most extreme environment, such as other planets.

To serve as a launching pad for future interplanetary expeditions

So far, the sizes of spacecraft such as satellites and probes have been restricted to the size and weight that the booster rocket can carry. In fact, the majority of the weight of a rocket is fuel, which very large and heavy rockets transport small and light payloads. This makes it very expensive to launch objects into space.

Consructing and launching probes and satellites from a space station drastically reduces the price of satellites, and also eliminates the size and weight restrictions of ground launched payloads. This also makes the construction of large interstellar spacecraft technologically and economically feasible, and provides a major source of revenue for the space station.

To advance research in Space

The International Space Station has four research facilities – Destiny, Columbus, Kibō and the Multipurpose Laboratory Module- of which Destiny and Columbus are already in orbit (Wikipedia, 2007). The four facilities conduct a whole range of research in multiple fields, from fluid physics to the affect of microgravity on the Human body (ex. Muscle atrophy and bone loss) (Wikipedia, 2007).

A permanent settlement would allow for longer and more extensive research projects in space. There is the opportunity of the installation of larger and more complex facilities on the settlement which will allow for a more in-depth exploration into the effects of microgravity, and perhaps even the development or manufacture of new materials. In addition, the leasing of research space could be a source of revenue for the space station, which would help to repay the extremely large construction costs.

In addition to research about microgravity, the space station could serve as an observatory for scientists interested in social interactions and the effect of putting humans into an isolated environment such a space station for extended periods of time. It will also allow for more research into how to repair damaged Earth ecosystems, seeing as Asten is an artificially engineered environment.

1.2: Long Term Objectives

To save the future human race

The famous British physicist Stephen Hawking said in April of 2007, "[…] I believe that life on Earth is at an ever increasing risk of being wiped out by a disaster such as sudden global warming, nuclear war, a genetically engineered virus, or other dangers. I think the human race has no future if it doesn't go into space. I therefore want to encourage public interest in space." (Wikipedia, 2007).

It is predicted that the sun will die out within 5 billion years, and with it life on Earth will cease to exist. Assuming that the human race survives that long, we would have to find a new place to live and call home, which means planet colonization. The effects of global warming, war and overpopulation will only reduce the amount of time that humans have to find another planet to live on. The difficulties of making our own self-sustaining habitat will serve as a guide to finding a new homeworld and to maybe even terraforming other planets such as Mars.

Section 2: Project Challenges and Assertions

This section identifies the challenges that will be faced when building a permanent human settlement in space, as well as the assertions this project needs to make in order for it to be considered feasible.

2.1: Challenges

As with any other project, there are many challenges that have to be overcome in order for the construction and habitation of the space station to be successful. However there are much more risks in Space than on Earth, as humans are not made to live in the cold, harsh environment.

Space Construction

Construction in space will be much more difficult, dangerous and expensive then construction on Earth, as there is no gravity, no air, and extreme temperature fluctuations. Also harnessing the raw materials required to build the space station will be difficult, as there are few available sources of building materials.

Replicating conditions for life

As humans, we usually take life for granted. Nature provides all the processes and elements necessary for the sustaining of life on Earth, but nothing that we know of lives in the far reaches of space. This means we must find a way to artificially replicate the conditions necessary to support life, including abundant oxygen levels, gravity, clean water, food, and heat.

Radiation

Radiation is extremely dangerous for those who work and live in space, as there is no protection from the deadly ionizing radiation (Cosmic Rays, solar photons, and especially high energy electrons/protons). This could cause temporary sterility, bone-marrow damage, radiation burns, cancer, chromosone breakage and damage to the central nervous system (Paulhus, 2001). Asten must have a strong defense system to protect its inhabitants from radiation exposure.

Electricity production

The production of electricity is difficult in space because many potential energy sources are not viable, such as fossil fuels or nuclear power. Fossil fuels would result in a dependence on Earth to provide fuel (coal, oil or gas) to the space station. In addition, the oxygen required for the combustion of the fossil fuels would have to be imported, and the byproducts are toxic to both humans and the environment. Nuclear power is also unfeasible as it would also require a dependence on Earth to provide fuel (uranium) for the space station, heavy radiation shielding, and a large amount of space.

Space Debris

Space Debris is a major concern for the space station. According to BBC, there may be over a million pieces of space debris in Earth Orbit, yet only 9000 are larger than the size of the tennis ball (BBC, 2003). However in spite of their small size, they travel at extremely high speeds up to 36 000 km/h (BBC, 2003). This high speed can cause catastrophic damage. Debris the size of a tennis ball hit objects with a force of 25 sticks of dynamite (BBC, unknown). Such debris could cause major damage by destroying crucial hardware or even punching holes in the station.

Financing

As with any megaproject, finding the money to pay for the construction of the space station will be extremely difficult. Due to the magnitude of the project, costs could run upwards of over 2-3 trillion dollars. With this staggering cost, financing could take decades, maybe even centuries.

2.2: Assertions

Humans are the constantly developing new technologies to better their lives and make naturally impossible feats (such as going into space) possible. However feasible construction of a permanent space station would require technologies that are beyond the present time, or are only in their development stages. Therefore some assertions must be made before addressing any project details. Naturally the fewest number of assertions are desired, so the project can be considered feasible within 50 years.

Solar Power

The electricity demand of the Space Station will be very large, as all life support systems require constant monitoring and adjusting, which requires electrical energy. As the sun is the closest source of energy, photovoltaic cells would be a viable option for producing electrical energy. As of now, the efficiency of solar power (the percentage of light energy converted into electrical energy) is low, between 4 and 17 percent (13 to 24 percent in the laboratory) (Solarserver, 2007). If the energy hungry space station is to depend on solar power for electricity, newer and more efficient solar power technologies need to be developed. Therefore it must be assumed that the technologies will be available for use by the time the space station begins construction.

Aerogels

Aerogel is a type of silicon gel in which the liquid component has been replaced with air. The result is a solid Styrofoam like substance that is 99.8 percent composed of empty space (NASA, 2005). Aerogel is an extremely good thermal insulator and is almost as light as air (NASA, 2005). For this reason, aerogel would be useful as a thermal insulator on the space station. It is also cheaper and easier to produce in the weightlessness of space. However the only barrier to the mass production of aerogel is the manufacturing cost. Therefore we must assume that aerogel is mass producible by the time construction begins on the space station.

Political Will and public support

In democratic countries such as Canada and the U.S., funding and support for large scientific and technological endeavours such as space exploration are largely dependent upon public perception and support. Many innovative and ground-breaking space projects (such as the X-33 space plane, the Transhab module and the ISS crew return vehicle) have been cancelled because the general public (and thus politicians) feel that space exploration is frivolous and a waste of resources. Because of this, the possibility of constructing a permanent space habitat without facing funding cuts, public backlash, and cancellation is almost zero. Therefore it must be assumed that the construction of Asten will have worldwide support from both the public and the governments and will not be under threat of cancellation.

Section 3: Structural Design

3.1: Design Philosophy

The requirements as outlined on the NASA space settlement contest website calls for the settlement to house "10 000 full time residents, plus an additional transient population, not to exceed 300 at any time, of business and official visitors, guests of residents, and vacationers" (Gale, 2007). In designing Asten, the following design philosophies were adhered to:

- Modular Design (to facilitate easy repair, expansion, modernization and alteration)
- Replicable components (to facilitate mass manufacturing which would lower costs)
- Redundancy (to provide large safety margins in the event of an emergency)
- Compact design (to reduce cost and construction time)

3.2 Size

When deciding the approximate size for the space station, two options were considered: build for a population much larger than 10 000, or build for a population of only 10 000:

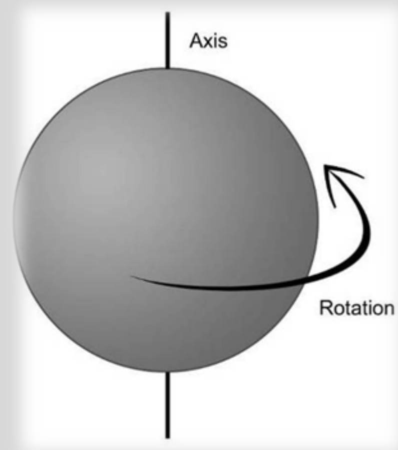
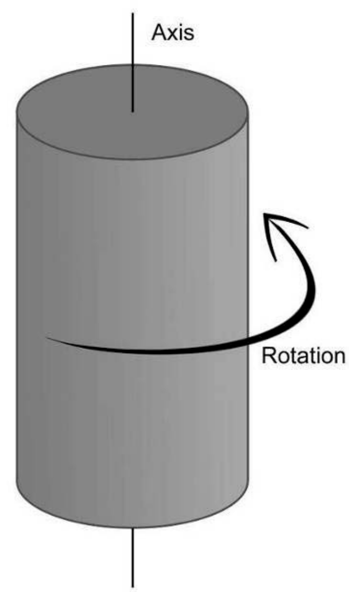
	Option 1: Build larger (big)	Option 2: Build just enough (small)
Pros	-can accommodate for an increase of the population -saves money in the long term that would be used to build new space stations -could handle more intense industry/manufacturing -provides more space for each inhabitant; more "breathing room"	-cheaper -smaller, therefore lower maintenance costs -shorter construction time
Cons	-more expensive -longer construction time -larger, therefore higher maintenance costs	-new space stations/additions must be constructed -handles less industry/manufacturing -less overall space for each inhabitant; more cramped and tight -can only accommodate the original population estimate

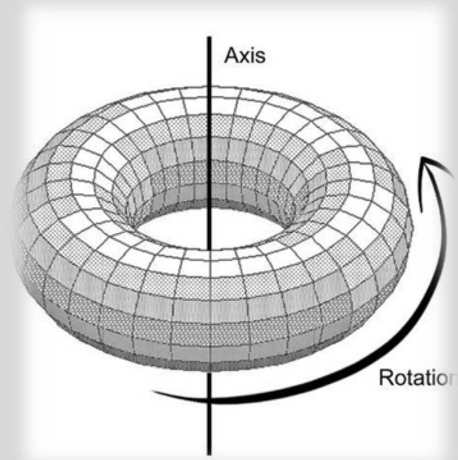
Rationale

At first glance building the station larger than what is required would save money in the long term and provide more research/industrial applications or placements. However given the already high projected cost of constructing a space station, building larger would result in even higher costs, which we feel would make the project financially unfeasible. In addition building small would reduce the amount of resources and money lost in the case the project is unsuccessful at sustaining life permanently. In order to capitalize on the benefits of large scale and small scale, it was decided to design just large enough, with the capability for expansion (modular design).

3.3 Shape

When deciding the shape for the space station, we looked at 3 possibilities: The cylinder, the sphere, and the torus.

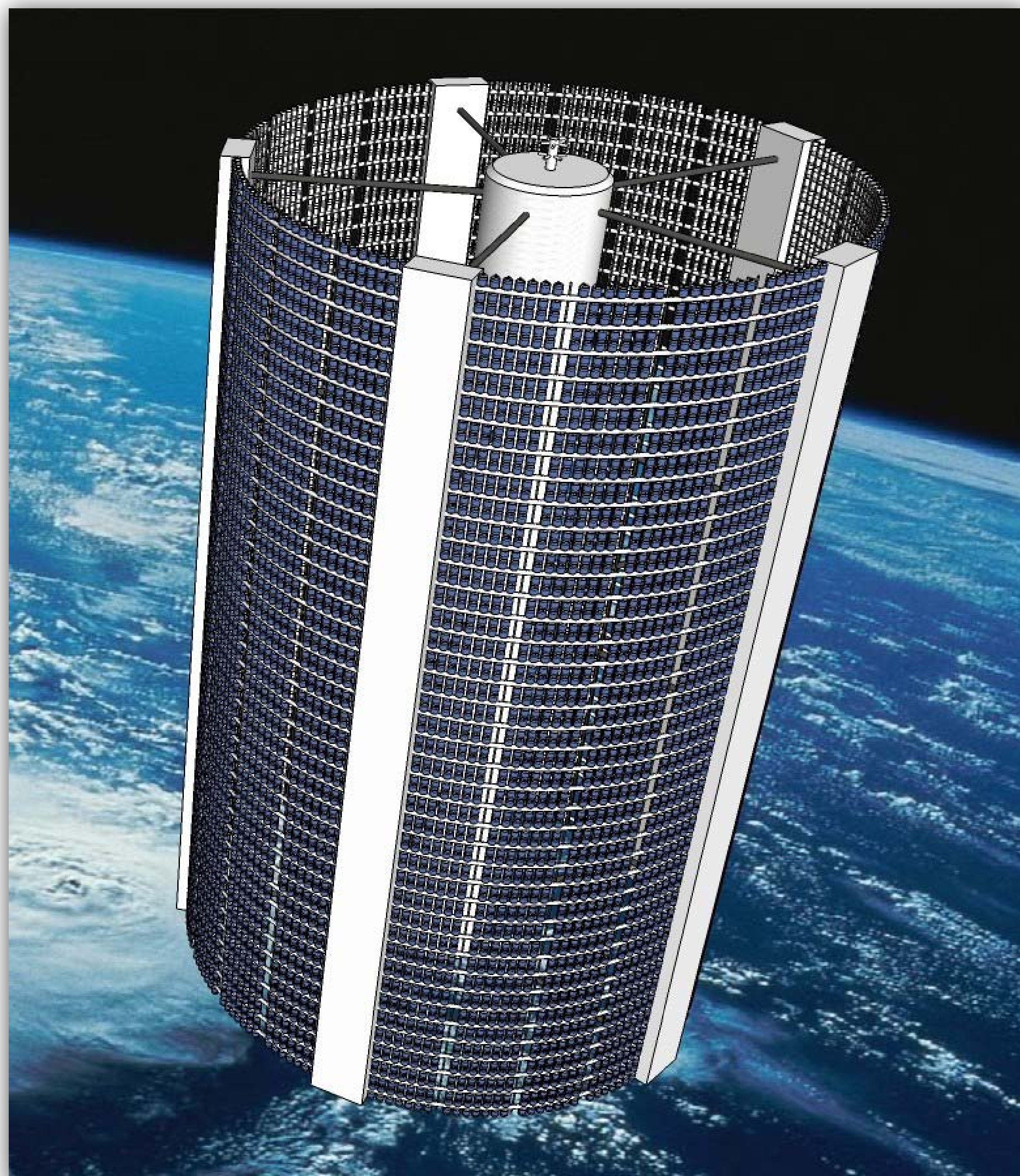
Shape	Pros	Cons	Diagram
Sphere	• largest volume • largest living area • Habitants shielded from deadly cosmic radiation by thickness of the sphere	• Gravity varies along the entire space station (the surface of the sphere at the equator spins faster than the poles) • artificial light source has to be placed in the center of the sphere • Inhabitants can see the opposite side of the sphere • in event of a puncture the affected area cannot be easily sealed off	
Cylinder	• gravity uniform throughout cylinder rotating on longitudinal axis • large liveable area • expansion achieved by simply extending length of cylinder	• natural sunlight into a cylindrical colony • inhabitants can see the opposite side of the space station • vast air volume required	

Torus	• requires much less air volume compared to Cylinder and Sphere • Light could be directed into ring with the use of mirrors • Inhabitants cannot see the opposite side of the space station	• Varied gravity levels along inner surface • increasing populations would require successively larger toruses, increasing structural stress	

<u>Rationale</u>

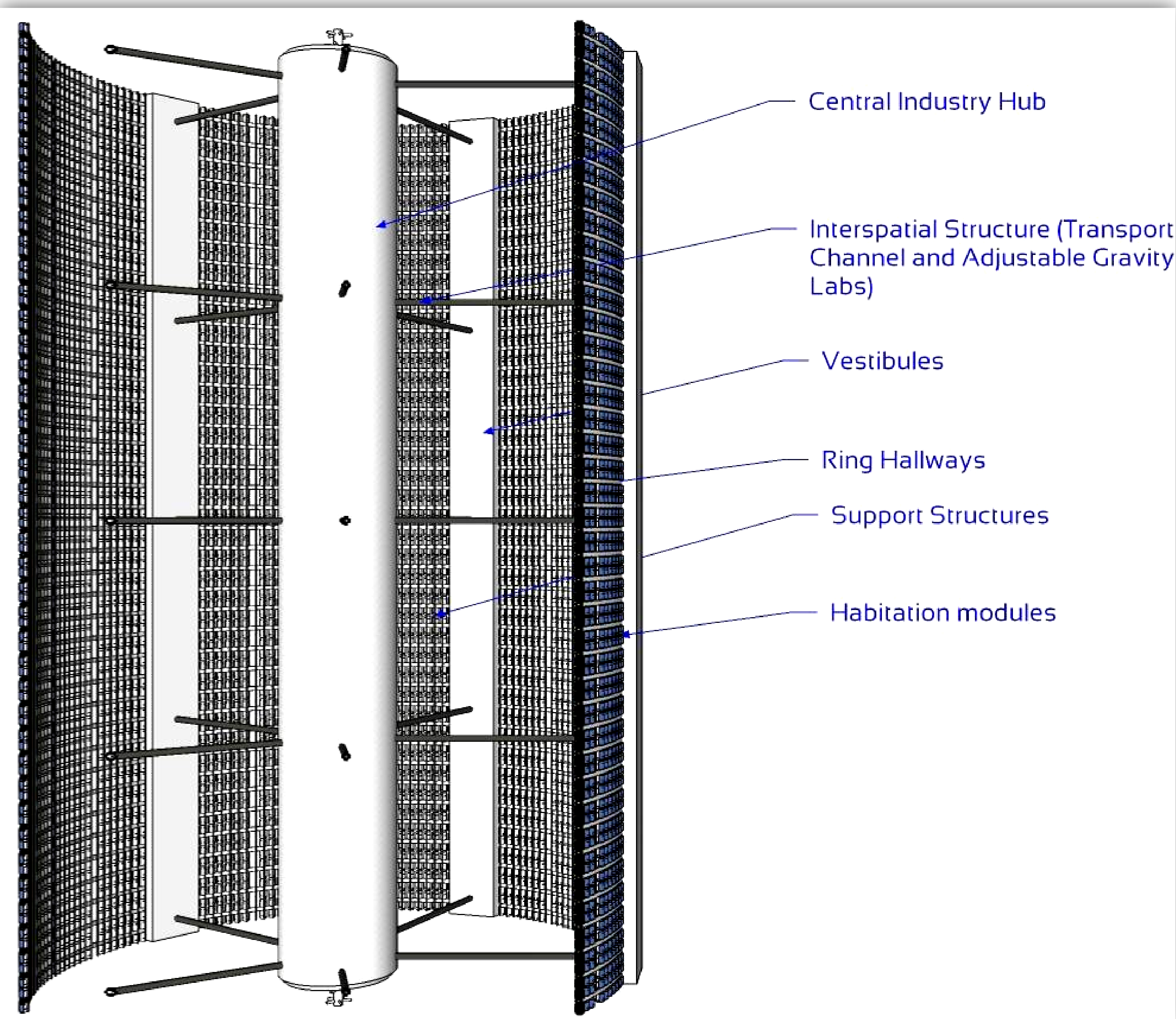
The Cylinder offered a large living area, but the torus required less air volume. It was then decided to take the best features of both shapes and incorporate them into the station. Essentially the final design called for a series of stacked rings that resembled a cylinder, to which living pods were attached to (see **3.5: Habitation Region**). This followed our philosophy of design, consisting of replicable components and being modular and compact.

3.4: Dimensions and General Layout

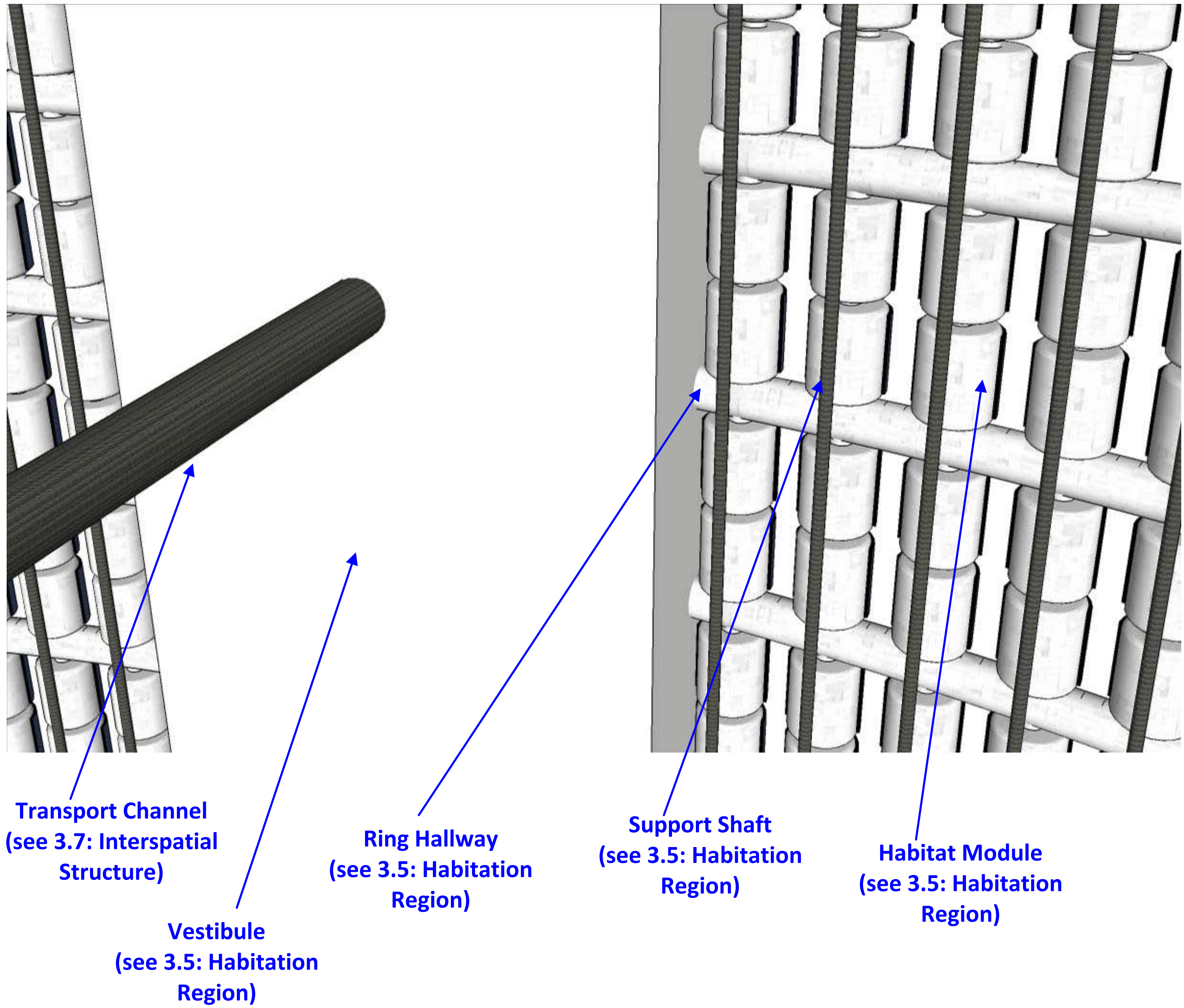


Overall view of Asten

Layout



General layout of Asten



Closeup of Transport Channel, Vestibule, Ring Hallway and Habitat Module Junctions

Dimensions

Component	Measurement	Value	formula
Entire Station	Maximum Population	22400	# of Habitat Modules x 2 beds
Entire station	Overall Height	1700m	
Entire station	Overall Diameter	1000m	
Entire station	Approximate Overall volume	$1.21 \times 10^8\ m^3$	$V_{Habitation\ Region} + V_{Interspatial\ Structure} + V_{Central\ Industry\ Hub}$
Entire station	Estimated Overall mass	$\approx 6.74 \times 10^{10}$ kg	$3 \times \sum$ mass of materials in material list (see **4.7: Materials**)
Habitation Region	Overall Height	1600m	
Habitation Region	Overall Volume	$\approx 7.4033 \times 10^7\ m^3$	$11200 \times V_{Hab\ Module} + 200 \times 30 \times V_{ring\ segment} + 5 \times V_{Vestibule}$
Habitation Region (Habitat Module)	Volume (inflated)	$\approx 540\ \pi\ m^3$ $\approx 1696.46\ m^3$	$\pi \times r_{Hab\ Module}^2 \times h_{Hab\ Module}$
Habitation Region (Ring Segment)	Volume	$\approx 693.22\pi\ m^3$ $\approx 2177.81\ m^3$	$\pi \times r_{ring\ segment}^2 \times h_{ring\ segment} + \pi \times r_{Support\ Shaft}^2 \times h_{Support\ Shaft}$
Habitation Region (Vestibule)	Volume	$\approx 8 \times 10^6\ m^3$	$L_{vestibule} \times W_{vestibule} \times H_{vestibule}$
Central Industry Hub	Overall Height	1700m	
Central Industry Hub	Overall Diameter	200m	
Central Industry Hub	Overall Volume	$\approx 4.99 \times 10^7\ m^3$	$V_{space\ hotel} + V_{spacecraft\ construction\ facilities} + V_{primary\ energy\ storage\ and\ control\ center} + V_{articulation\ segments} + V_{research\ facilities} + V_{docking\ network} + V_{central\ corridor}$
Central Industry Hub (Space Hotel)	Volume	$\approx 2.84 \times 10^5\ m^3$	$\pi \times h_{space\ hotel} / 12\ (d_{top\ floor}^2 + d_{top\ floor} \times d_{bottom\ floor} + d_{bottom\ floor}^2)$
Central Industry Hub (Spacecraft Construction Facilities)	Volume	$\approx 2.12 \times 10^7\ m^3$	$\pi \times r_{Central\ Industry\ Hub}^2 \times h_{spacecraft\ manufacturing} - \pi \times r_{Central\ corridor}^2 \times h_{spacecraft\ manufacturing}$
Central Industry Hub (Primary Energy Storage and Control Center)	Volume	$\approx 6.248 \times 10^6\ m^3$	$\pi \times r_{Central\ Industry\ Hub}^2 \times h_{Primary\ Energy\ Storage\ and\ Control\ Center} - \pi \times r_{Central\ corridor}^2 \times h_{Primary\ Energy\ Storage\ and\ Control\ Center}$
Central Industry Hub (Articulation Segments)	Volume	$\approx 6.248 \times 10^5\ m^3$	$2 \times (\pi \times r_{Central\ Industry\ Hub}^2 \times h_{Articulation\ segment} - \pi \times r_{Central\ corridor}^2 \times h_{Articulation\ segment})$
Central Industry Hub	Volume	$\approx 2.12 \times 10^7\ m^3$	$\pi \times r_{Central\ Industry\ Hub}^2 \times$

(Research Facilities)			$h_{\text{Research Facilities}}$ - **π** × $r_{\text{Central corridor}}{}^{2}$ × $h_{\text{Research Faciities}}$
Central Industry Hub (Docking Network)	Volume	≈2.14×10^{4} m^{3}	2 × (**π** × $r_{\text{Central Corridor}}{}^{2}$ × $h_{\text{docking network}}$ + 10 × **π** × $r_{\text{docking channel}}{}^{2}$ × $h_{\text{docking channel}}$)
Central Industry Hub (Central Corridor)	Volume	≈2.83×10^{5} m^{3}	**π** × $r_{\text{Central corridor}}{}^{2}$ × $h_{\text{central corridor}}$
Interspatial Structure	Overall volume	≈5.89×10^{5} m^{3}	25 × $V_{\text{Connecion Channel/Adjustable Gravity lab}}$
Interspatial Structure (Connection Channel/ Adjustable Gravity Lab)	Volume	≈2.36×10^{4} m^{3}	**π** × $r_{\text{Connection Channels}}{}^{2}$ × $h_{\text{Connection Channels}}$

3.5 Habitation Region (HR)

The Habitation Region consists of multiple ring hallways, which intersect 5 equally spaced Vestibules. Attached to the Ring Hallways are the Habitat Modules, where the inhabitants of the space station reside.

Habitat Modules

Inflatable space modules were first pursued by NASA's Johnson Space Center in the form of the Transhab program, which began in 1997 (Dismukes, 2003). A revolutionary concept, the Transhab module (figure 3.5A) consisted of a one foot thick bladder wrapped around a composite structural core, which inflated to full size when pumped with air in space (Dismukes, 2003). Although cancelled in 2001, the technology was purchased by Bigelow Aerospace, which is seeking to develop it into a space hotel. With a diameter of 12m, and a length of 15m, the Transhab style habitat modules (figure 3.5B, 3,5C) onboard Asten serve as an inhabitant's residence, and are constructed using some of the same materials as the Transhab modules (Kevlar, Nextel, Nomex, carbon fiber) as well as some new ones (Titanium to reinforce the core, RTV adhesive to bond the layers together and increase protection from micrometeoroids). Following our design philosophy, thousands of modules will be found on the space station, which allows them to be mass produced, lowering costs. Each module contains a bedroom, bathroom, open concept kitchen and living room, and a "basement" where emergency water storage tanks and batteries can be found (see **5.3: Water Cycle** and **5.4: Energy**). Attached to the outside is a photovoltaic array, which provides electricity for the entire station (see **5.4: Energy**). Entrance in and out of the module is provided by a hatch located at one end, which also contains interfaces for water, electrical and air connections with the rest of the station. In the event of an emergency, the module can be sealed off from the rest of the station, or even ejected (see **5.7: Safety/Security**).

Figure 3.5A

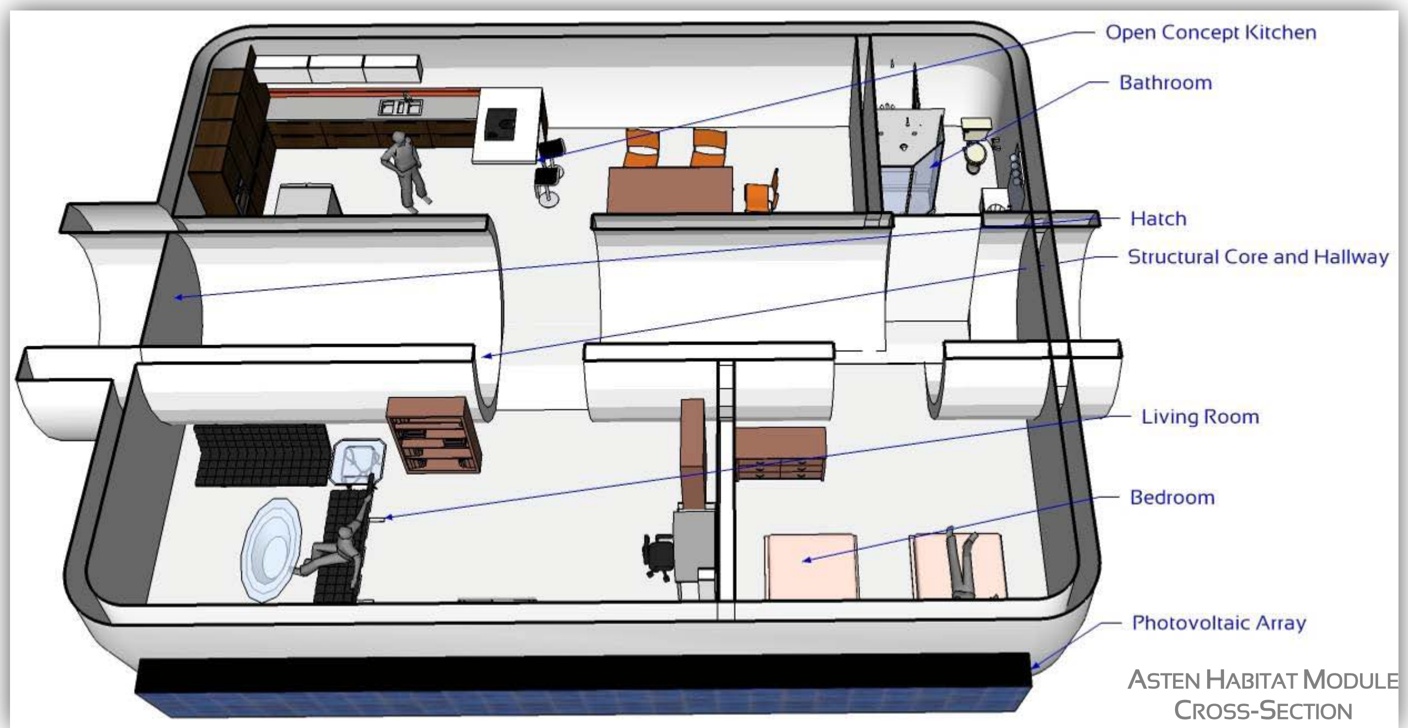


Figure 3.5B

Habitat Module Scale Diagrams

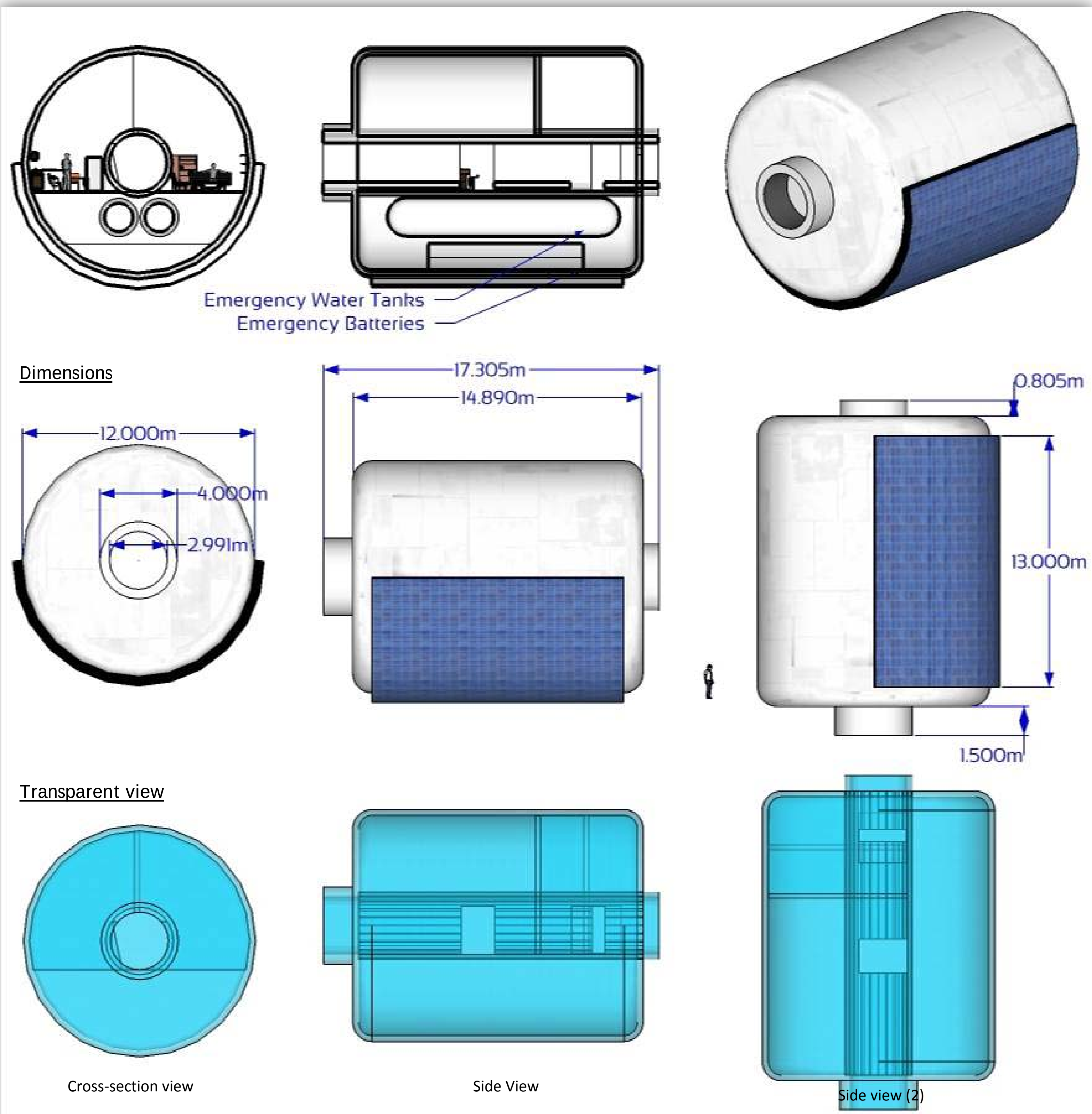


Figure 3.5C

Ring Hallways

Ring Hallways connect the numerous Habitat Modules to the 5 Vestibules, and also maintain the cylindrical shape of the station. There are 200 ring hallways on the station -40 between every 2 Vestibules. Each ring hallway is approximately 534m long and has docking ports for 56 habitat modules and 6 escape pods (see **5.7: Safety and Security**). Following the design philosophy, the structure itself is made from multiple smaller identical Ring Segments (figure 3.5D), each consisting of a 19m long tunnel that is 8m in diameter with two 4m wide ports –one on each side of the tunnel. The hatches on the Habitat Modules connect to the ports found on these Ring Segments, which provides access to the rest of the station from the module, as well as plumbing, electrical and air connections (figure 3.5E). The pipes and wires that supply the modules with water, electricity and air are found under a false floor within the Ring segment, allowing for easy access (figure 3.5D). Each segment is constructed from a Titanium and carbon fibre semi-monocoque structure for strength (see **3.8: Structural strength**), and protected from radiation and micrometeorites with multi-shock shields (see **5.7: Safety/Security**). The identical nature of the ring segments allows them to be mass produced and easily assembled -30 ring segments coming together to form one ring hallway.

Connecting the Ring Hallways to each other are multiple Support Shafts, each 1m in diameter. In addition to reinforcing the Ring Hallways and keeping them a set distance apart, the Support Shafts have multiple hydraulic clamps, which grip small rings embedded within the Habitat Module's structure, locking the module in place and supporting its weight while the station rotates (figure 3.5E).

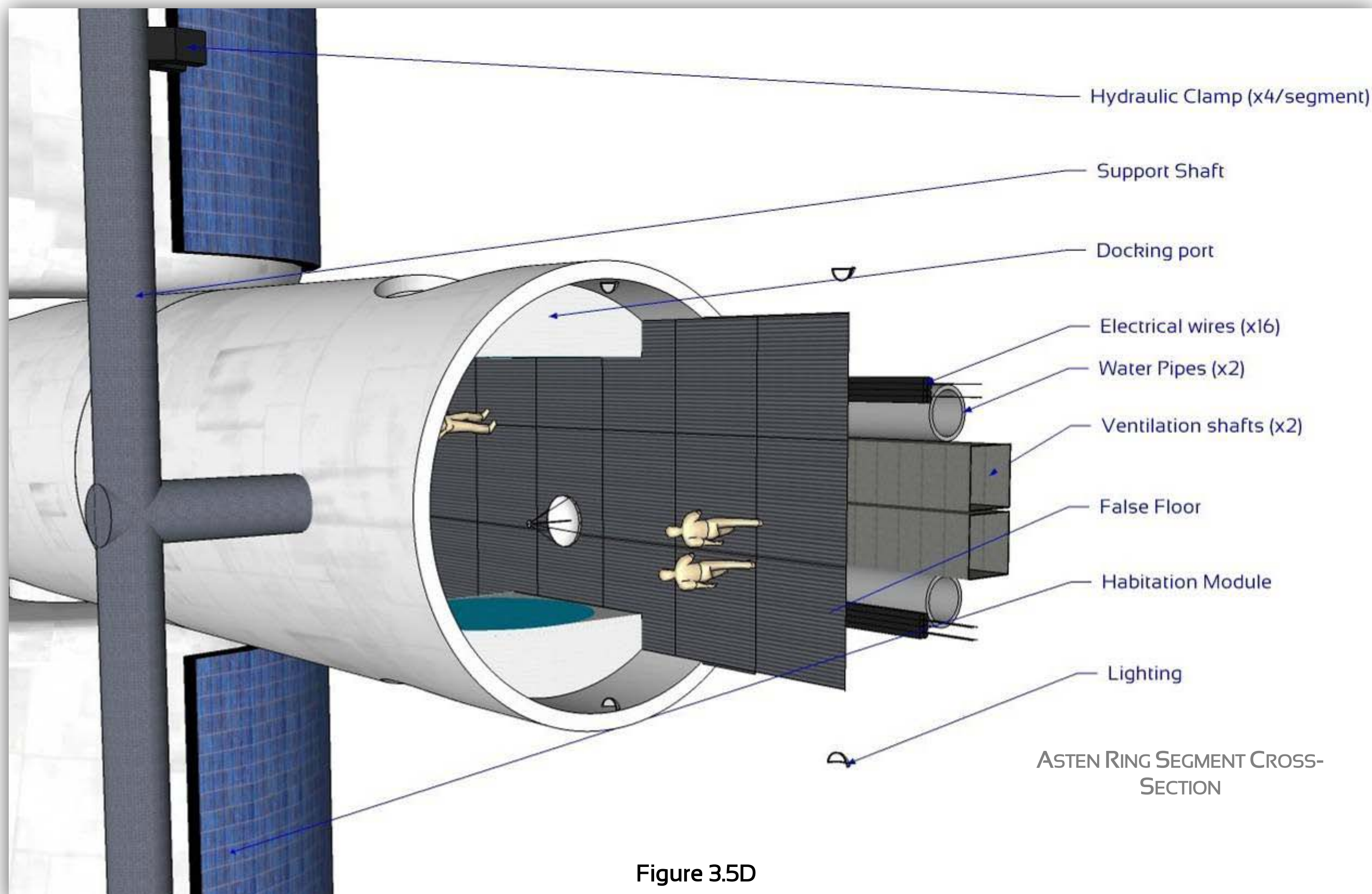


Figure 3.5D

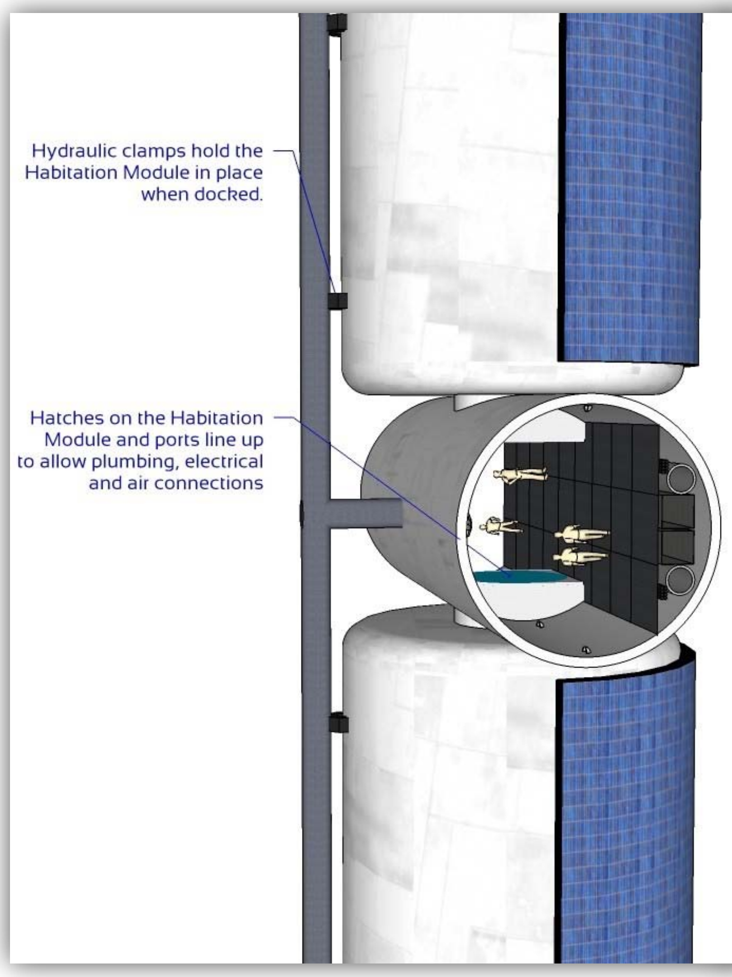


Figure 3.5E

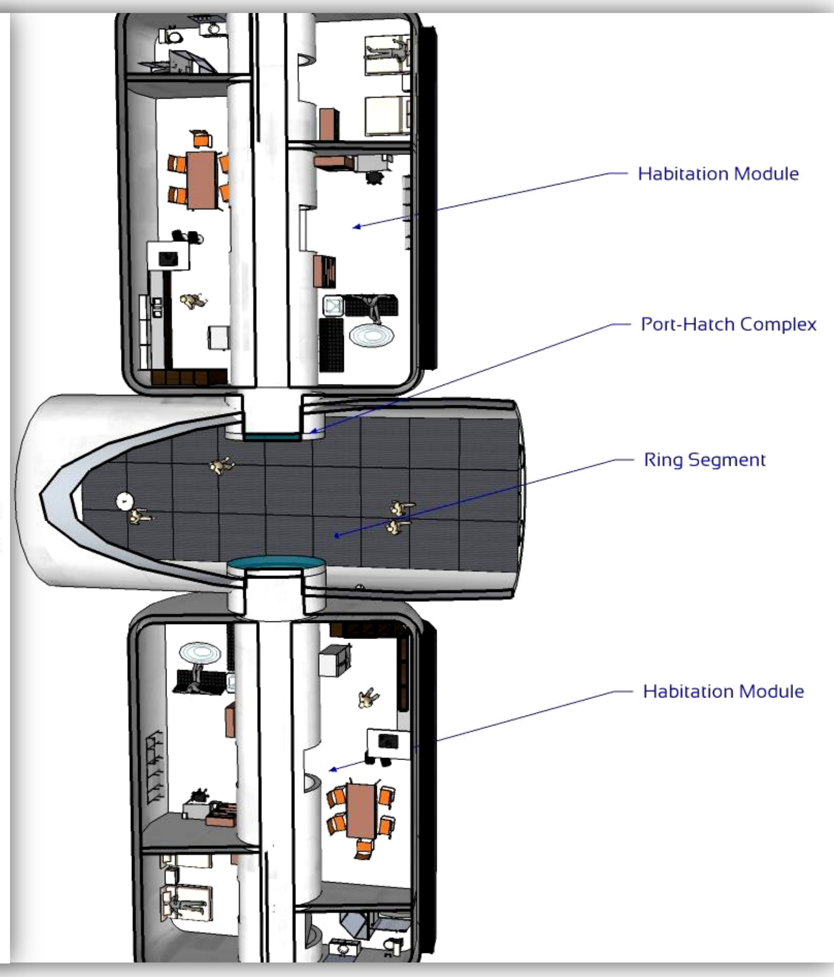


Figure 3.5F

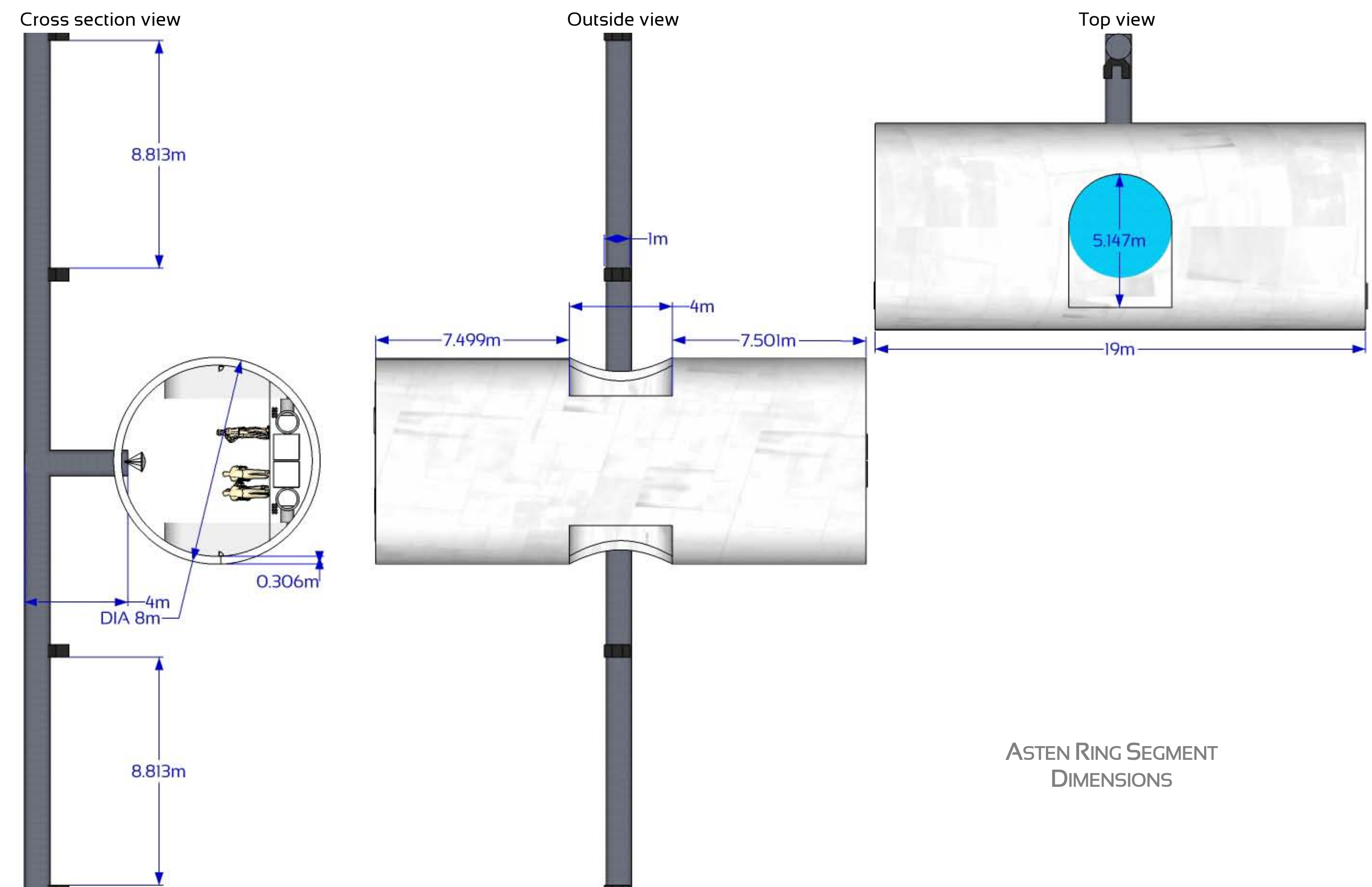


Figure 3.5G

Vestibule

In addition to linking the Ring Hallways to each other and to the Central Industry Hub, the Vestibules act as community/ activity centers –housing all the facilities necessary to keep the inhabitants alive and comfortable. They provide the following services:

- Oxygen production (**see 5.3: Oxygen**)
- Secondary Energy Storage (**see 5.5: Energy**)
- Water recycling and storage (**see 5.4: Water Cycle**)
- Agriculture –food growing, meat production, food processing (**see 5.6: Food and Nutrition**)
- Government and emergency services (**see 6.3: Public Services**)
- Educational facilities (**see 6.3: Public Services**)
- Recreational facilities –gyms, pools, exercise rooms, theatres, etc. (**see 6.4: Entertainment and Recreation**)
- Businesses (**see 6.6: Economy**)
- Parks (**see 6.4: Entertainment and Recreation**)
- Connection networks –hallways, elevator access, etc.

Following our design philosophy, each of the 5 Vestibules on the station are identical to one another, increasing redundancy in the life support systems (see **5: Life Support Systems**). 1600m long, 100m wide and 50m tall (figure 3.5K), each Vestibule is divided into 4 levels, numbered from 1-4 according to their proximity to the Central Industry Hub (figure 3.5H). Level 1 is 17m tall and contains all agricultural facilities. Level 2 is 10m tall and is the point at which all the ring hallways attach to the Vestibule. Government facilities, emergency services, recreation facilities, educational institutions, businesses and the park are all found on level 2. Level 3 is 6.5m tall and contains the Water recycling and storage facilities. Level 4 is 14m tall and houses the oxygen production and secondary energy storage facilities. Because gravity is simulated on the station by the rotation of the entire station (**see 5.2: Gravity**), the force of simulated gravity varies depending on the level in the Vestibule, and is only equal to 1g at level 2 (figure 3.5J).

Connecting the levels to each other are multiple elevators, each shaft being 8m in diameter and arranged in pairs distanced 100m apart (figure 3.5K). Connecting the Vestibules to the Central Industry Hubs are the Transport channels (**see. 3.7: Interspatial Structure**), which only penetrate to level 3 (figure 3.5K).

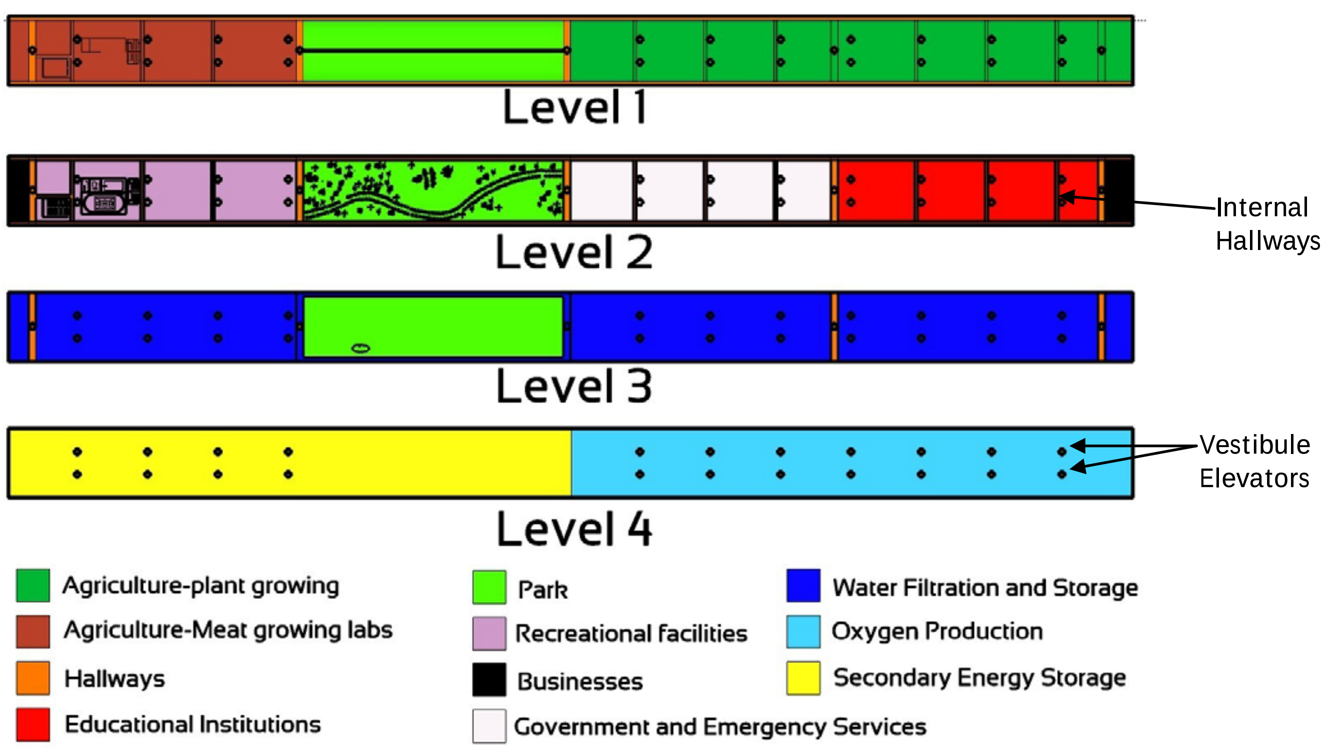


Figure 3.5H

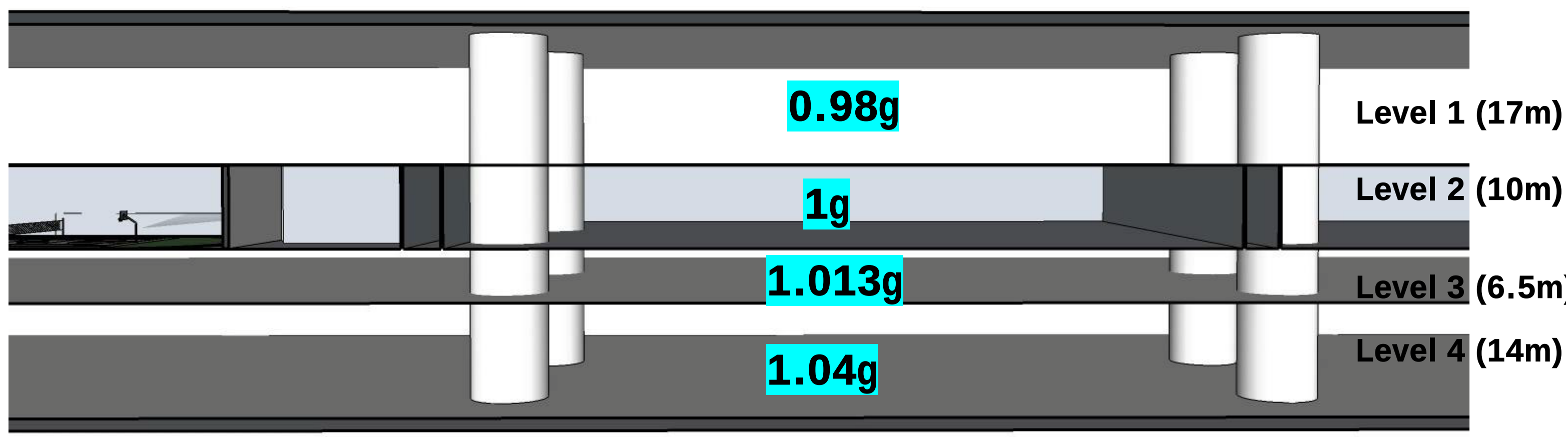


Figure 3.5J

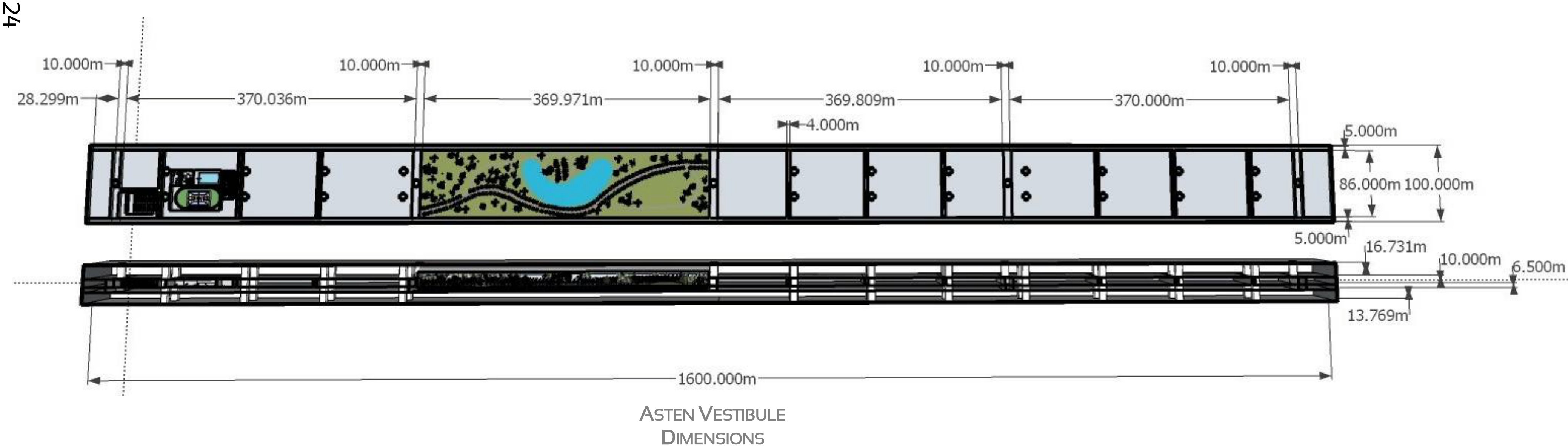
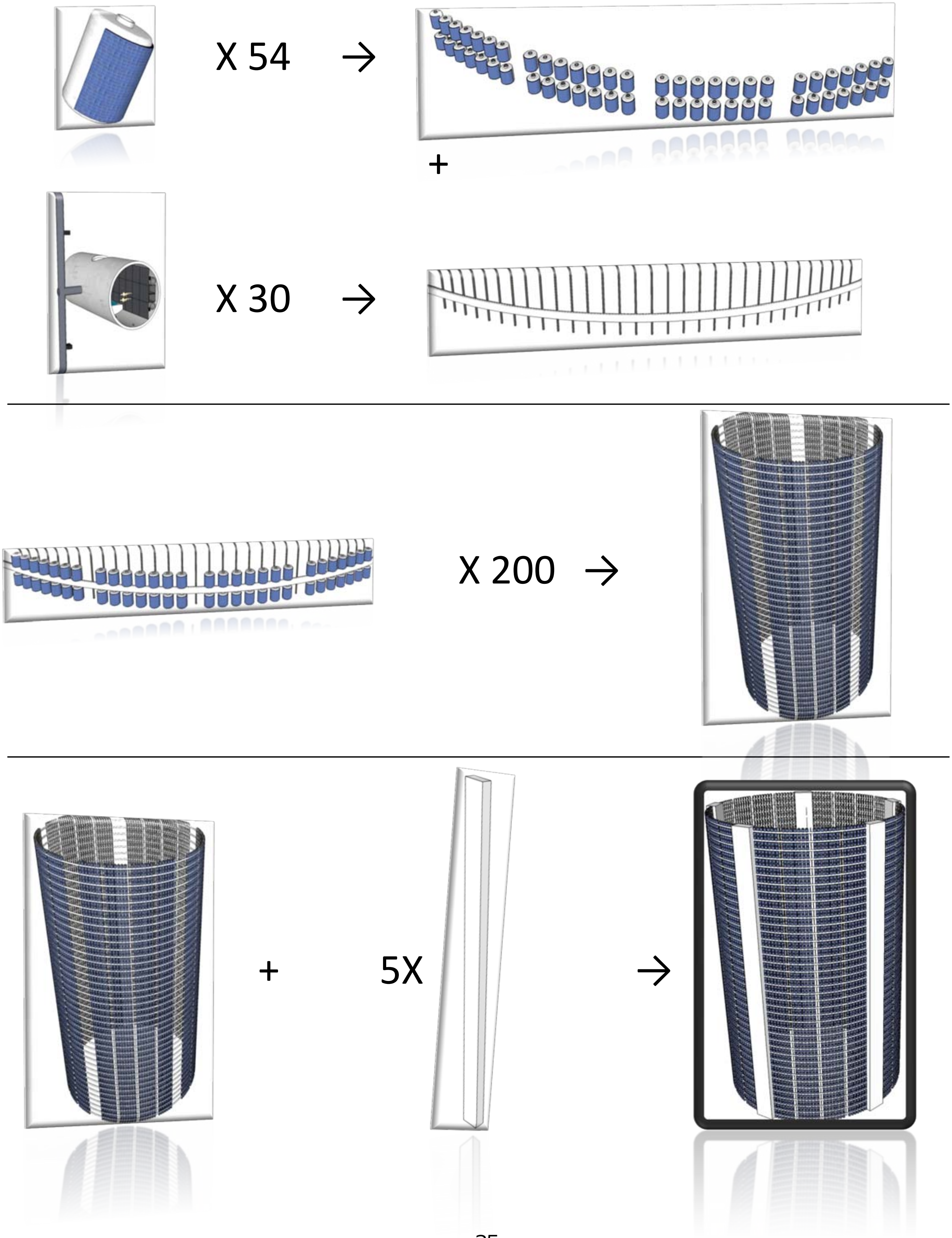


Figure 3.5K

Habitation Region structure



3.6: Central Industry Hub (CIH)

200m in diameter and 1700m long, the Central Industry Hub is located at the center of Asten, and is divided into five areas: a zero-gravity hotel, research facilities, Spacecraft Construction facilities, a station control and primary energy storage center, and a docking network (figure 3.6A). Because the main benefit of research and manufacturing in space stems from the lack of gravity (**see 6.6: Economy**), the Central Industry Hub must be isolated from the rotation of the rest of the station. This is accomplished with detached segments (called Articulated Segments) of the CIH to which the Transport Channels connect to (figure 3.6A). These Articulated Segments rotate with the rest of the station, but are still attached to the rest of the CIH. The points at which the corridor meets the Articulated Segments are supported with magnetic bearings (figure 3.6C).Transport within Central Industry Hub is mainly accomplished by the Central Corridor- a shaft 15m in diameter running lengthwise in the middle of the structure (figure 3.6A).

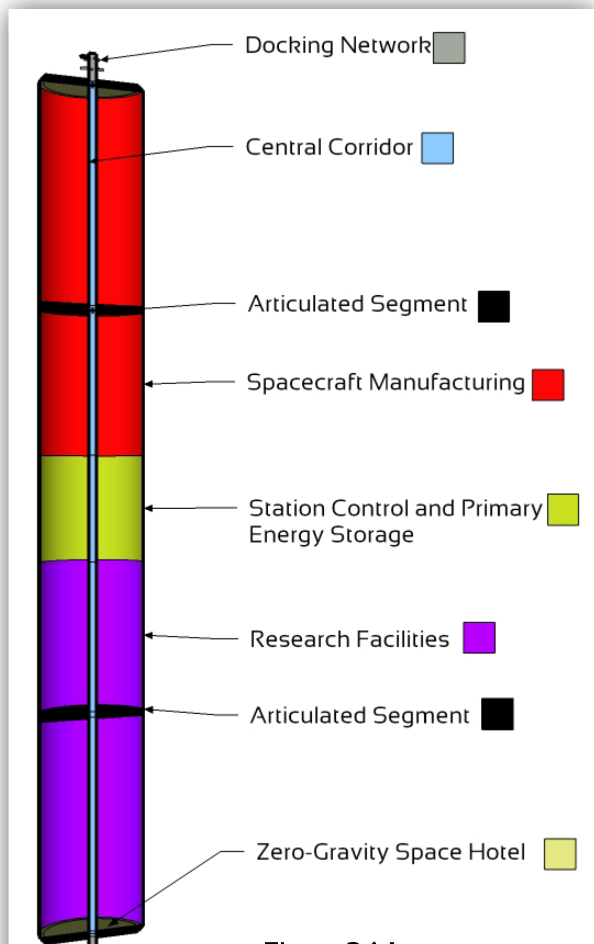


Figure 3.6A

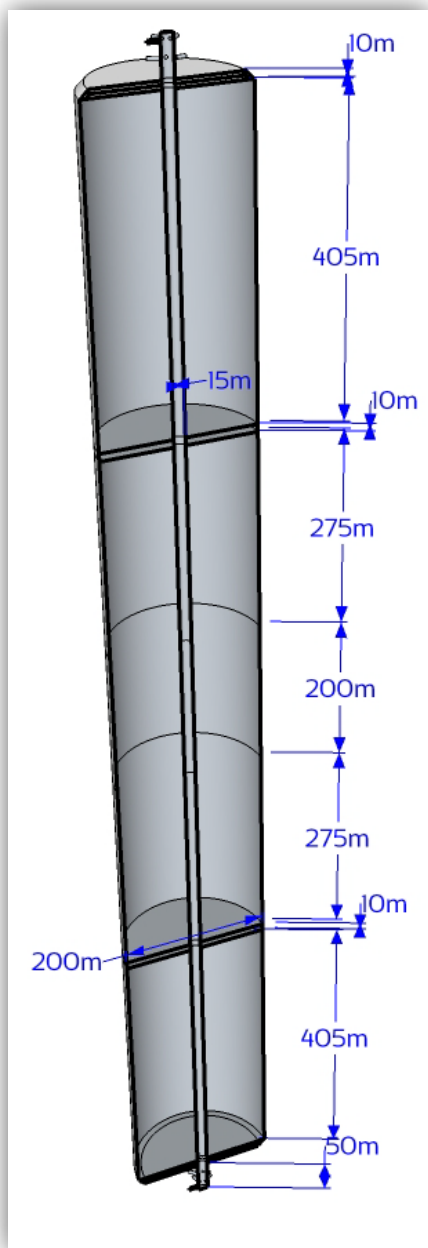


Figure 3.6B

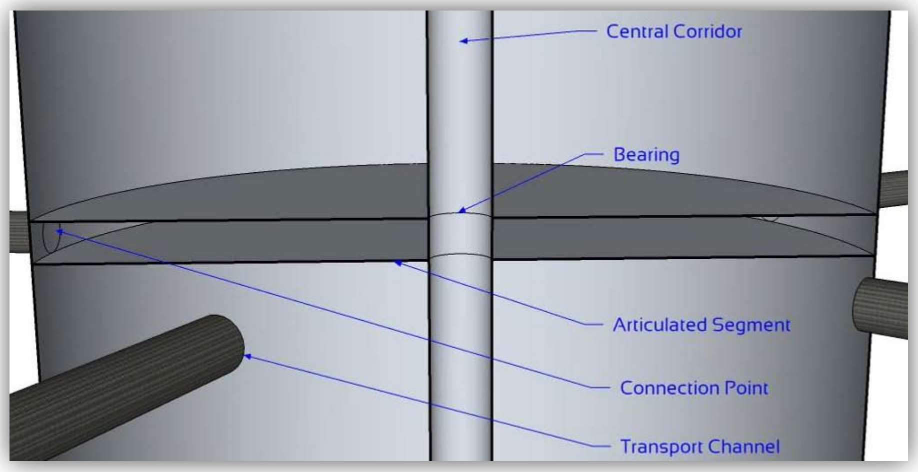


Figure 3.6C

Docking Network

Located at the ends of the Central Industry Hub, the Upper and Lower Docking Networks consist of 20 channels 4m in diameter connected to the Central Corridor (figure 3.6A). Because only the Articulation Segments are rotating with the rest of the station, the docking networks remain motionless, making it easier for spacecraft to dock with the channels. Spacecraft carrying passengers and cargo dock to each 15m long channel, which are equipped with airlocks at either end (figure 3.6D). Oversized Cargo ships attach directly to the ends of the Central Corridor. In the case of an emergency, each of the docking channels can be used as an escape vessel, being covered with an ablative heat shield and equipped with a parachute and fold-away seating (**see 5.7: Safety and Security**).

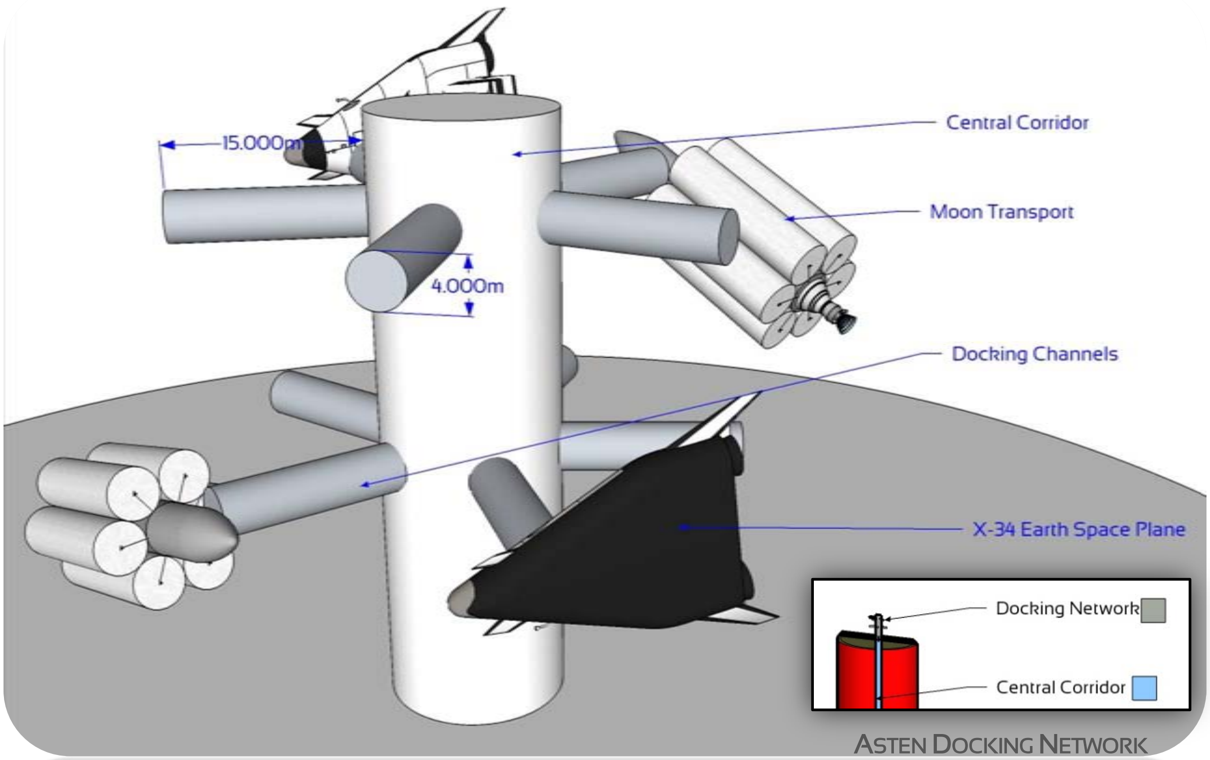


Figure 3.6D

Zero-Gravity Hotel

Located near the bottom of the Central Industry Hub is the zero gravity hotel (figure 3.6A), which exists to generate revenue for the space station -housing up to 300 transient population members (tourists, family members, business visitors) on two floors for up to 3 weeks (figure 3.6E) (**see 6.6: Economy**). Rooms are arranged around the Central Corridor (figure 3.6F), and are furnished with two sleeping bags, a vacuum shower and toilet, and a television. The hotel features a unique panoramic “observation” hallway, which allows guests to look at the Earth below and the surrounding space (figure 3.6E).

Spacecraft Construction facilities

These facilities are used to construct new satellites and private and public spacecraft too large or expensive to be built and launched from Earth. Placed near the top of the Central Industry Hub underneath the Upper Docking Network (figure 3.6A), the Spacecraft Construction facilities are divided into 12 distinct fabrication plants (figure 3.6G). Construction of the spacecraft components takes place in the Parts Assembly areas, before being assembled and launched in the Final assembly area. Each Fabrication plant can open to outer space to launch any completed spacecraft.

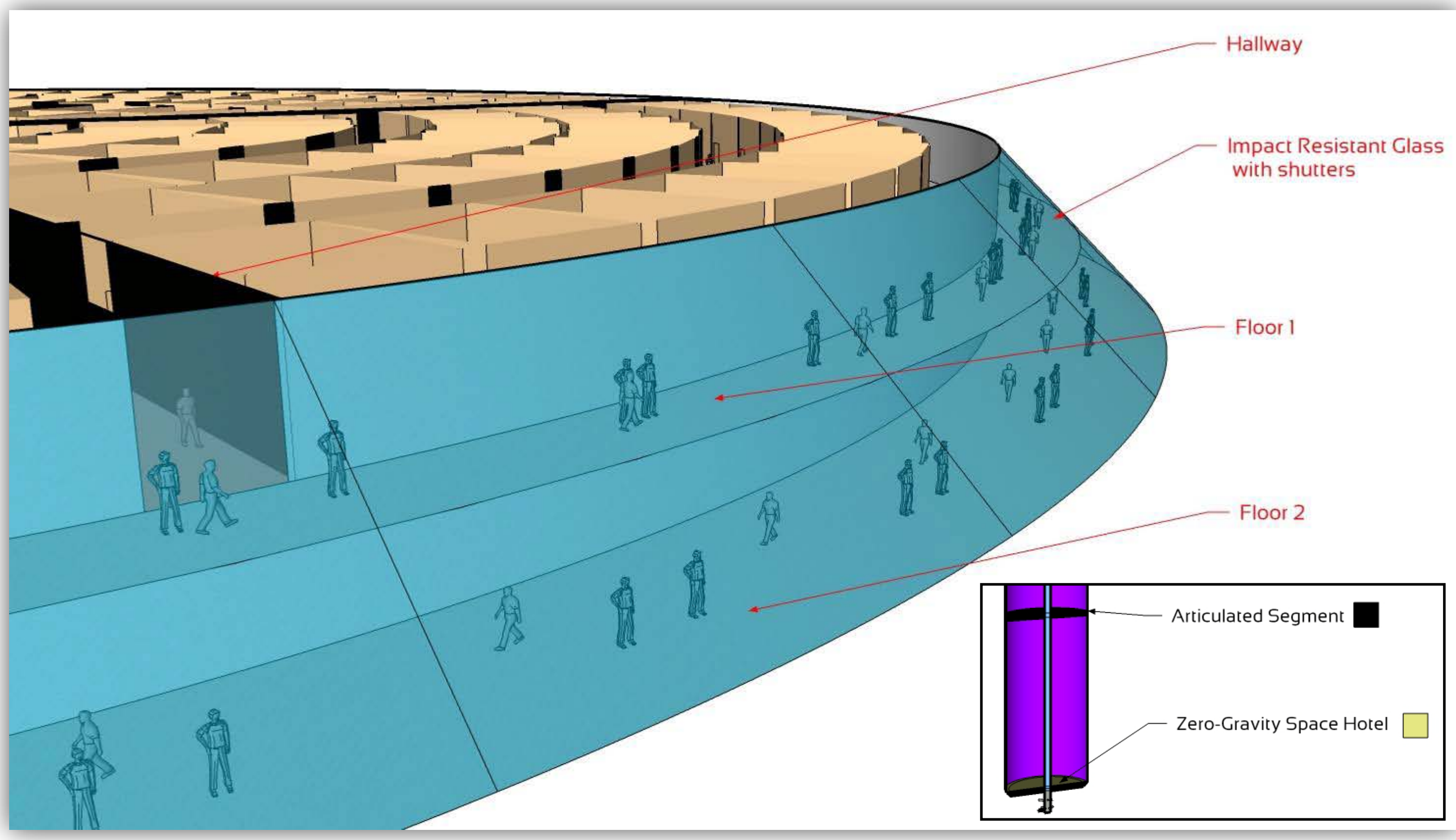


Figure 3.6E

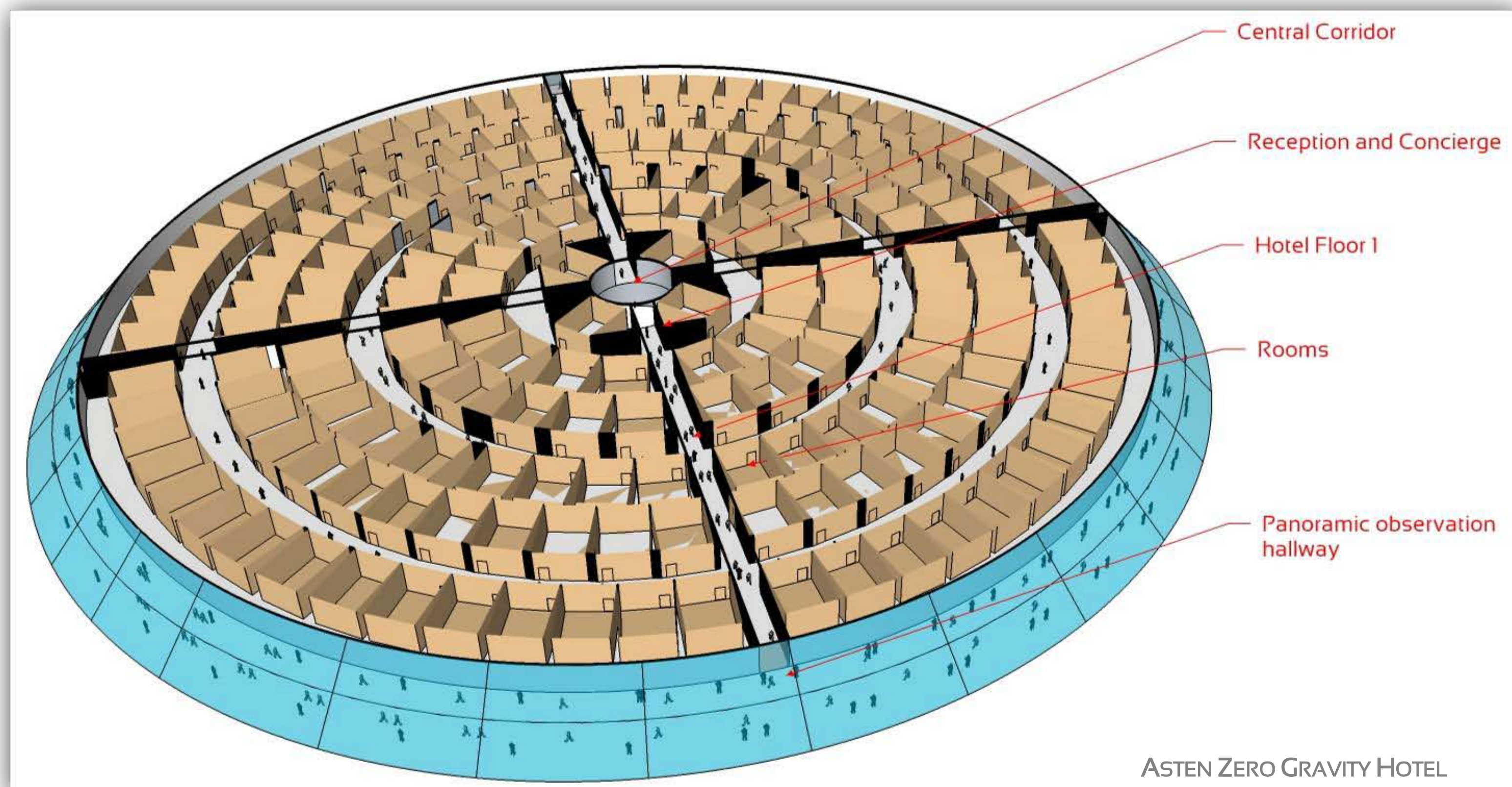


Figure 3.6F

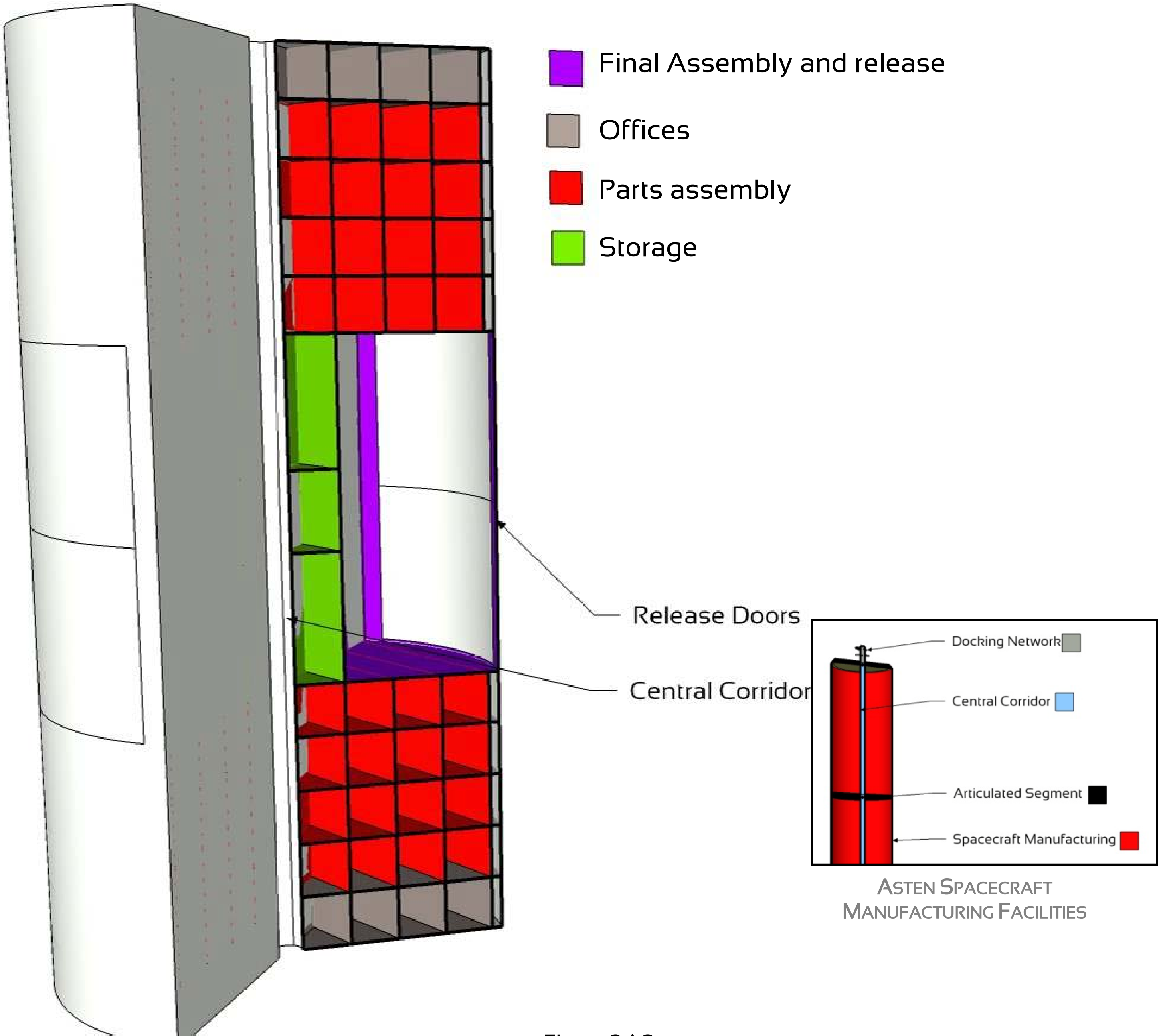


Figure 3.6G

Primary Energy Storage and Station Control Center

Found beneath the Manufacturing facilities, the Primary Energy Storage and Station Control Center monitors and controls all of Asten's life support systems and orientation. It also contains a number of flywheels –which store most of the electrical energy generated onboard adcdefg in the form of rotational energy (**see 5.4: Energy**).

Research Facilities

Found above the Zero-Gravity Hotel are the research facilities, which can be configured and customized according to the needs of the leasing companies (**see 6.6: Economy**).

3.7: Interspatial Structure

Bridging the gap between the Central Industry Hub and the Habitation Region, the Interspatial Structure consists of Transport Channels and Adjustable gravity labs (figure 3.7A).

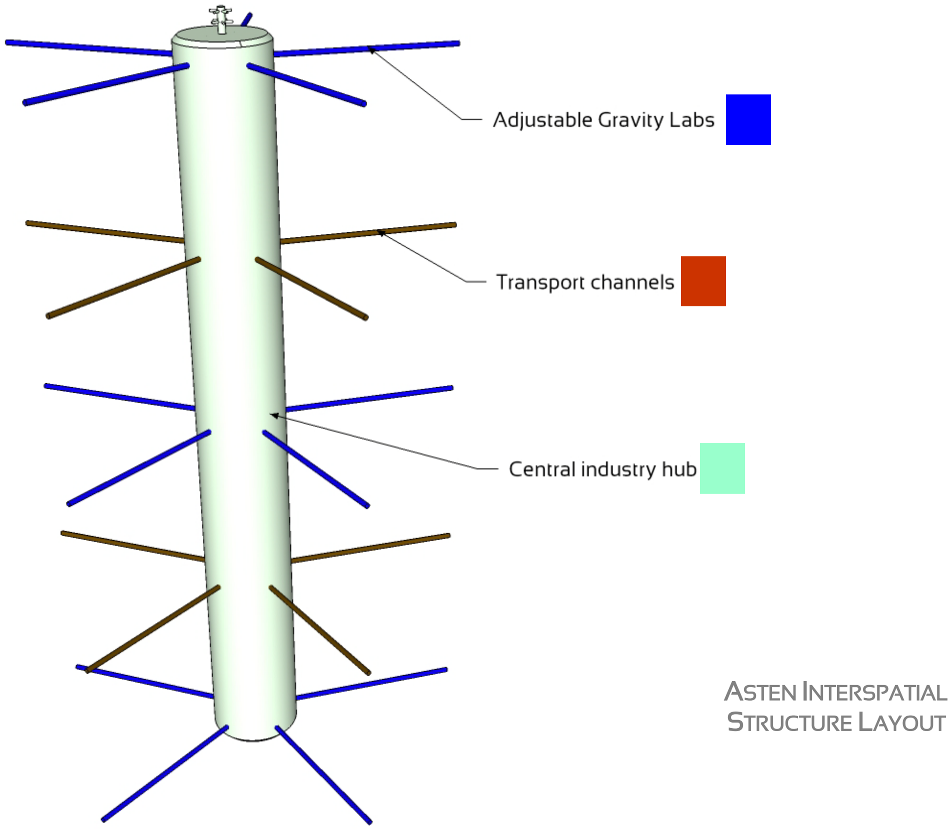


Figure 3.7A

Transport Channels

The 10 Transport channels found in the central two spoke networks allows for the organized movement of cargo, water, electricity, oxygen, and people between the Central Industry Hub and the Habitation Region. Within each Transport channel, a high speed elevator travels back and forth between the CIH Articulation Segments and the Vestibules. Since gravity varies along the 300m long Transport Channels, the elevator cars are tethered at both ends of the channel and are in constant tension (figure 3.7B). Transport towards the CIH is accomplished by shortening the upper tension cable and lengthening the lower tension cable. Lengthening the upper cable and shortening the lower cable causes the elevator car to move towards the Vestibules. Electrical wires, water and air pipes are fastened to the exterior of the elevator shaft (figure 3.7B).

Adjustable Gravity Labs

Although 5 spoke networks exist, three out of the five do not attach to the Central Industry Hub (figure 3.7A), and are instead used for research in varying gravity levels. Each channel contains two independently moving labs and an access elevator that transports materials, equipment and personnel between them and the Vestibules (figure 3.7C). These adjustable gravity labs can be used to simulate the gravity on the surface of Mars or the moon and help study the effects of varying gravity levels on plant and animal life or on the structure of certain materials (**see 6.6: Economy**).

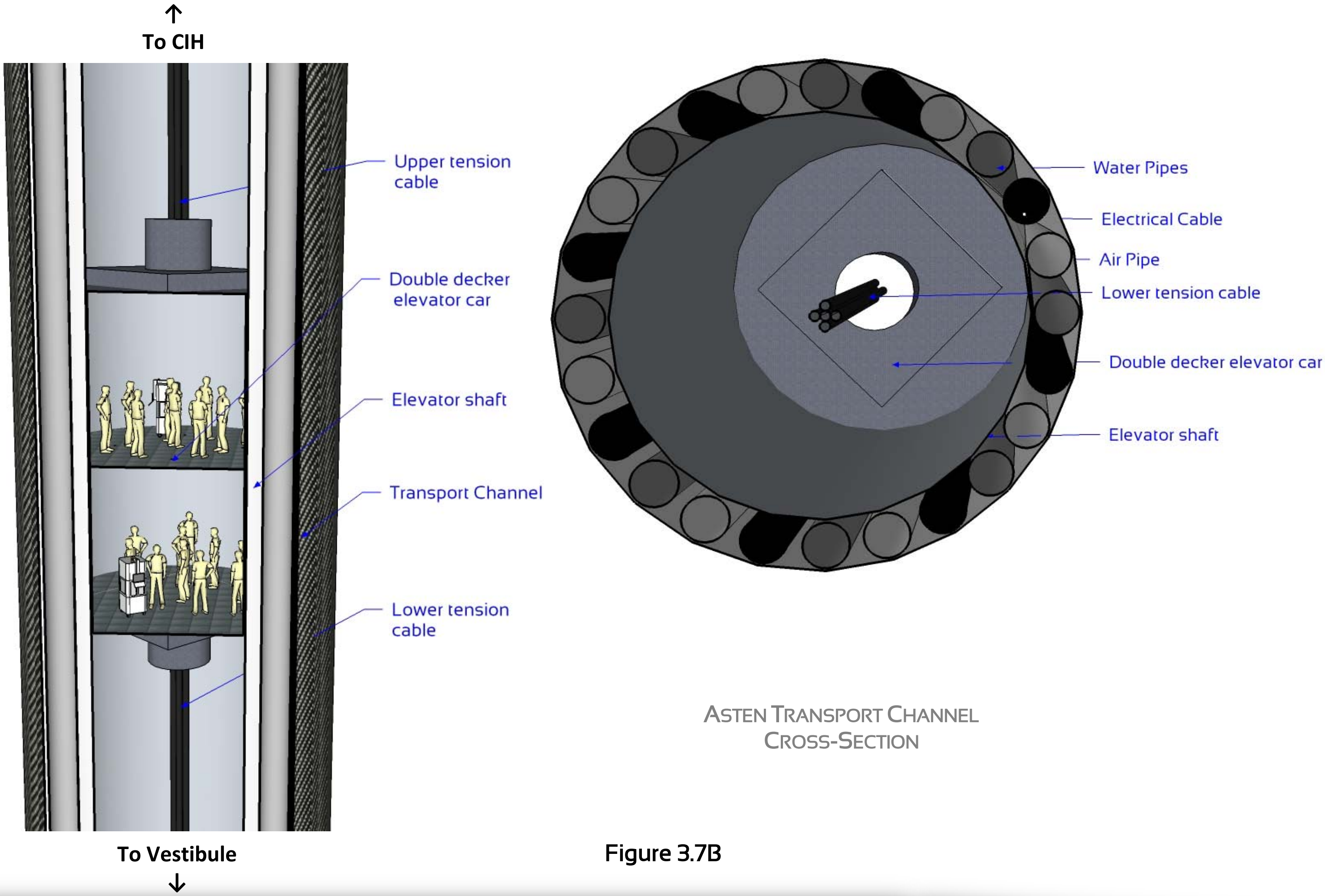


Figure 3.7B

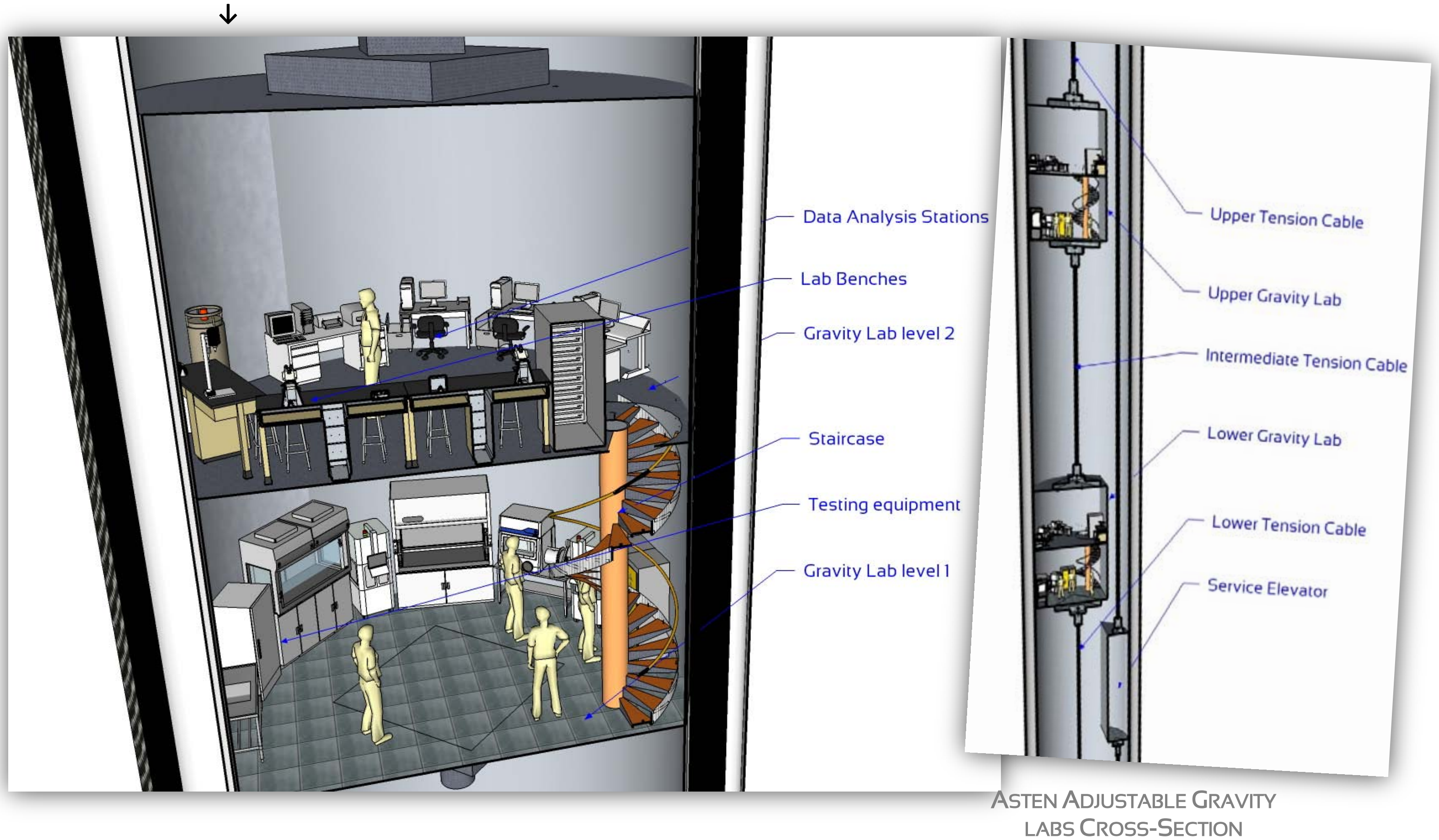


Figure 3.7C

3.8: Structural Strength

Because Asten is a permanent space station, the materials and the structure it is built with must be strong (to withstand the constant rotational forces exerted by the spinning station), lightweight (to facilitate transport from the Earth/Moon), and robust (to last for at least 200 years –the projected station lifetime).

Habitat Modules

Because the habitat modules are inflatable structures, its strength and support is chiefly derived from the structural core. The core is to be built with carbon-fiber reinforced plastic, and the shell will consist of multiple alternating layers of Nextel, open cell foam, Kevlar, Mylar and Nomex cloth (Dismukes, 2003) (figure 3.8A, taken from http://thefutureofthings.com/articles/18/a-room-with-a-view-of-mars-please.html).

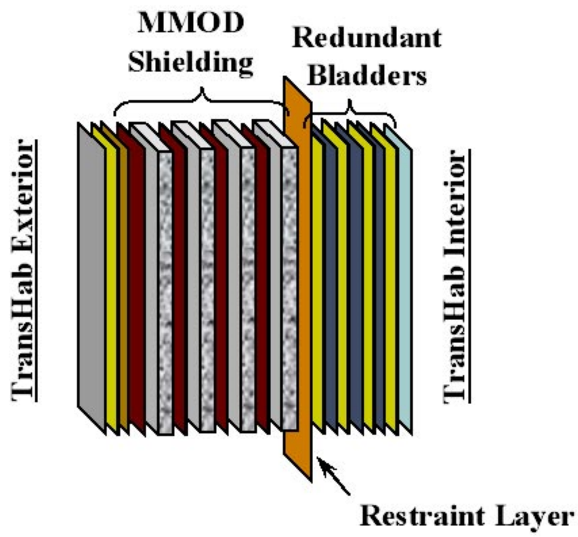


Figure 3.8A

Ring Hallways/segments

Similar to modern airplane fuselages, the Ring Hallway segments are semi-monocoque structures which are constructed in sections and then joined together. However whereas airplane fuselage structures consist of a single aluminum sheet riveted to a frame of longitudinal stringers and cross section ribs (Wikipedia, 2009), the ring hallways will consist of two semi-monocoque structures: a shell constructed with Carbon Fibre-

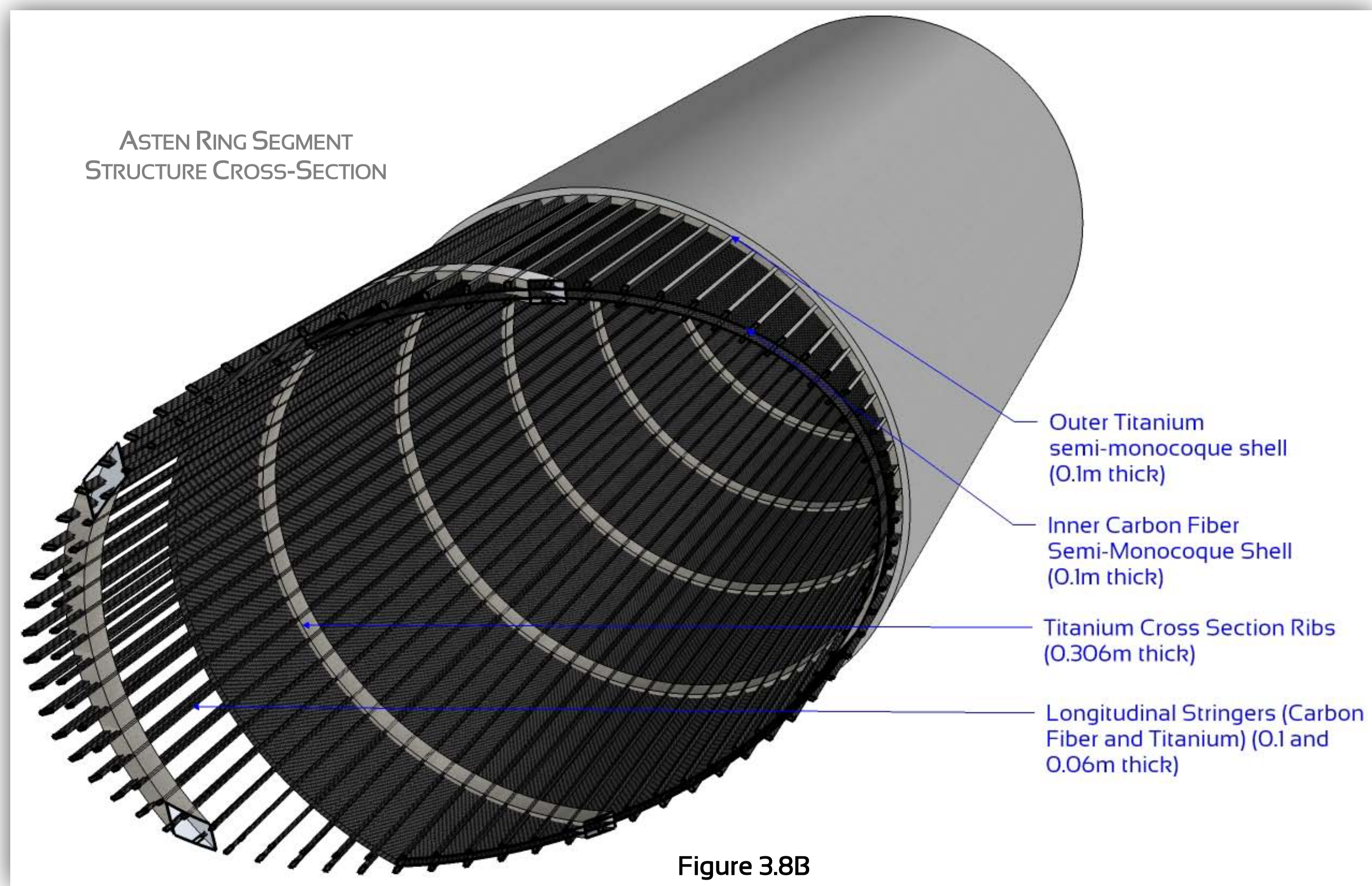


Figure 3.8B

Reinforced Plastic inside a shell constructed with Titanium (figure 3.8B). To protect the segments from micrometeoroid impacts and atomic oxygen degradation, the outer surface is covered in Multi-shock shields and Beta Cloth (see **5.7: safety and security**) (Hyde, 2006).

<u>Vestibules</u>

Structural strength in the vestibules is primarily provided by the 11 elevator shafts that traverse its 50m height. The outer surface of the Vestibule is a 5m tall tubular titanium space frame, with reinforcing ribs placed every one hundred metres (figure 3.8C). This frame is then covered on both the inside and outside with a sheet of stainless steel, Multi-shock shields and Beta Cloth.

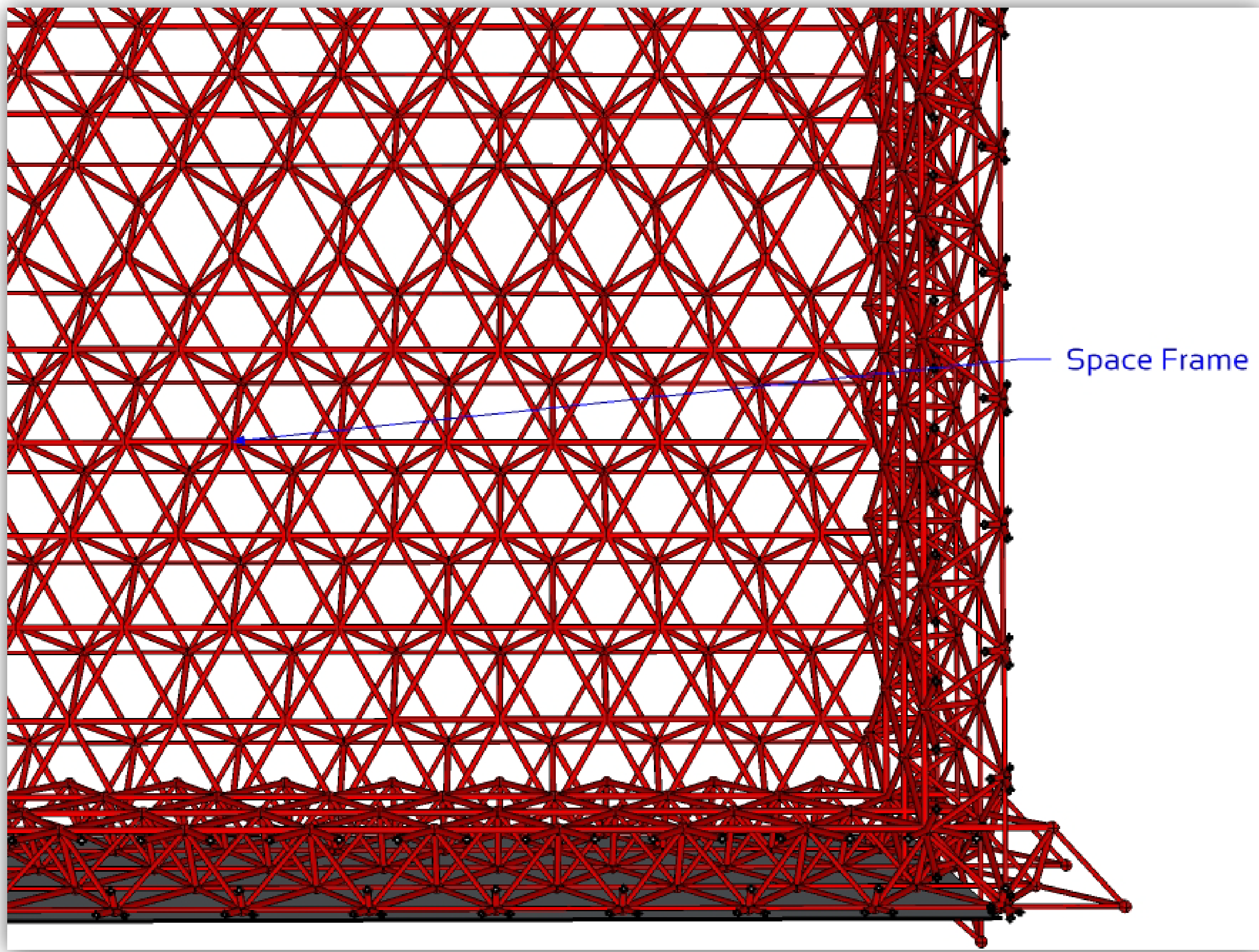


Figure 3.8C

<u>Central Industry Hub</u>

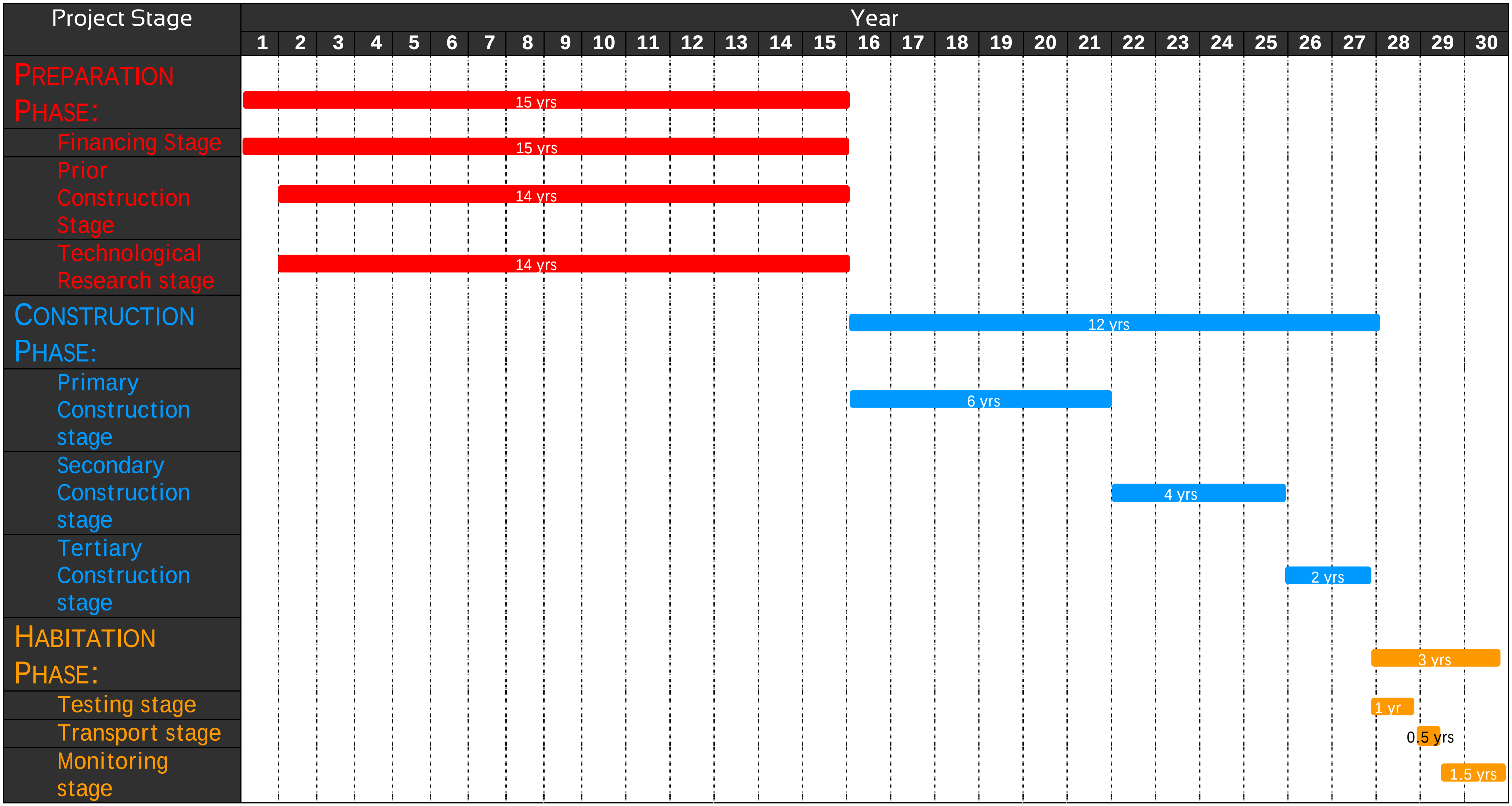
Similar to a modern day skyscraper, the Central Industry Hub is built from a large steel lattice frame, to which a curtain wall of stainless steel is attached, and covered with Multi-shock shields and Beta Cloth.

Interspatial Structure

The Transport Channels and Adjustable Gravity Labs consist of ten multiple steel and titanium alloy segments each forty metres long that are threaded into one another to form the full four hundred metre long channels.

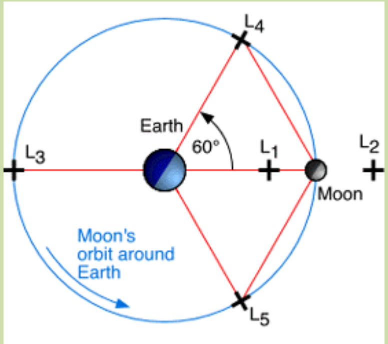
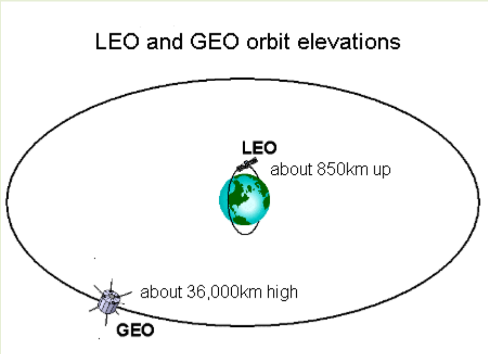
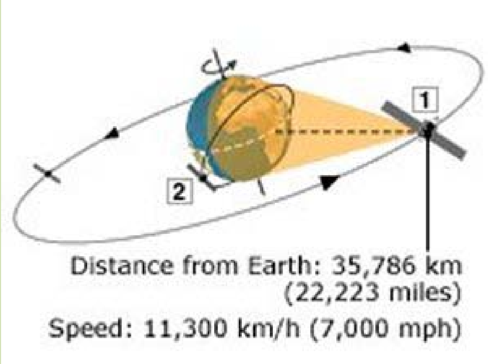
Section 4: Construction of Asten

4.1: Project Timeline



4.2: Station Placement

The location of the Space station is extremely important because its position affects everything from orbital stability to the station's economy. Looking at acdefg's orbital position, we had three options: one of the Lagrange points, Low Earth Orbit (LEO), or Geostationary Equatorial Orbit (GEO).

Position	Pros	Cons	Image
Lagrange points (L4/L5 specifically)	-very stable orbit (most stable of all three in fact) -receive unlimited amounts of sunlight	-very far (384 000km) from both the Earth and the Moon for efficient transport of people and goods	
Low Earth Orbit (LEO)	-very close to Earth and low-earth satellites, which allows improved economic prospects	-very unstable orbit (easily decomposes and requires constant orbit boosting manoeuvres) -close to orbital debris (such as low earth orbit satellites, rocket boosters, paint chips, etc.)	
Geostationary Orbit (GEO)	-constantly over one point on the Earth, allowing for constant access and easier communication with Earth -relatively stable orbit, with only osciallating North-South Drift that returns the station back to equatorial orbit every 53 years (Wikipedia, 2009) -almost always in view of the Sun (because of the tilt of the Earth) (Potter, 1998). This allows for continuous generation of electricity	-GEO relatively crowded with telecommunications satellites	

Rationale

Since GEO provided the best mix of proximity to Earth, allowed for continuous communication and access to one point on Earth, and was relatively stable; GEO was chosen as the location for Asten.

4.3: Preparation Phase

The first phase of the construction process of Asten –Preparation, is also the longest. The phase is itself divided into three separate stages: Financing, Technological Research, and Prior Construction.

Financing

The Financing stage involves the acquisition of the funds necessary to construct the station (see **4.8: Cost**). In order to facilitate financing, a joint venture company "Asten Holdings Inc." will be created, with each sponsor claiming a certain percentage of the company shares depending on the amount of capital they contribute. In addition to the initial capital provided by the sponsor companies, Asten Holdings Inc. will take out loans from development and commercial banks to begin the Technological Research phase. As the technological research phase continues, Asten Holdings Inc. will explore additional financing options for the construction of the station, including:

- Becoming involved in the global real estate market as a developing company
- Purchasing other natural resource or new start-up companies, siphoning off the profit to fund Asten's construction
- Selling products developed from the Technological Research Phase
- Becoming involved with Space Tourism industry, providing a service to launch people into space for a short duration of time (similar to Virgin Galactic) or building small short-term orbital hotels
- Establishing an subsidiary company focused on video game development
- Selling "Plaques"- small plastic sheets consumers can personalize that can be attached to the exterior of the space station, putting "themselves" in space
- Authoring and publishing a number of science fiction novels related to a completed Asten
- Grants from the world governments by making it an international project (similar to the International Space Station)

Technological Research

The Technological Research stage involves the development, testing and refining the design of all the systems used on Asten, from the energy storage systems to the ejection of Habitat Modules. The testing process begins with an analysis of the system requirements, then proceeds to the construction of a scale test model of the system on Earth, and then another testing of a scale model in space. Only after multiple successful trial runs of the system in Space is the system integrated into the final design of the station.

Prior Construction

The Prior Construction stage involves the construction of all the facilities needed to make the construction of Asten possible. Those facilities include (but are not limited to): A ground base, manufacturing facilities, Moon-based mining facilities, and an adaptation center.

1. The Ground base will be the control and communications center during the construction of Asten. After the station is completed, the Ground base will serve as a government facility, controlling and monitoring all activity on Earth related to the station.
2. The manufacturing facilities allows for the mass production of the Transhab-like Habitat Modules, Ring Segments, and other space station parts manufactured on Earth.
3. The Moon-based mining facilities will provide the raw materials needed to build Asten. Seeing as the moon is a major source of building materials mining facilities would allow us to exploit its rich natural resources. The mining facilities can also extract and refine minerals that can be exported to Earth, thus forming a mining industry that would benefit Asten's economy (see **6.6: economy**).

4. The adaptation center serves as a sort of training facility for the inhabitants and workers, teaching them how to work in the hazardous environment of space or the moon, and how to cope with the confined environment of the space station. The adaptation center also serves as a border, with customs offices, security and medical checkpoints, and connections to the launch loop.

All these facilities are to be located in Florida, because of its status as the southernmost point of the U.S–the probable location for most of the manufacturing facilities- and proximity to an existing launch facility (Kennedy Space Center).

4.4: Construction Phase

The construction phase has three major stages: Primary, Secondary, and Tertiary.

Primary stage

The Primary Stage is the construction of all the major components needed to protect the inhabitants from the hazardous environment of space. This means the construction of the exterior surfaces of the Central Industry Hub, Habitation Region, and Interspatial Structure. Primary Construction begins in Lunar Orbit, with the construction of the Central Industry Hub (figure 4.4A). Construction continues with the mass production of the Transport Channels and Adjustable Gravity Lab segments, which are not attached, but strapped to the exterior of the CIH (figure 4.4B). External Thrusters are also attached to the CIH, and fire to transfer the complex to Geostationary orbit via a Hohmann transfer orbit (The more efficient Interplanetary Transport Network would take too long).

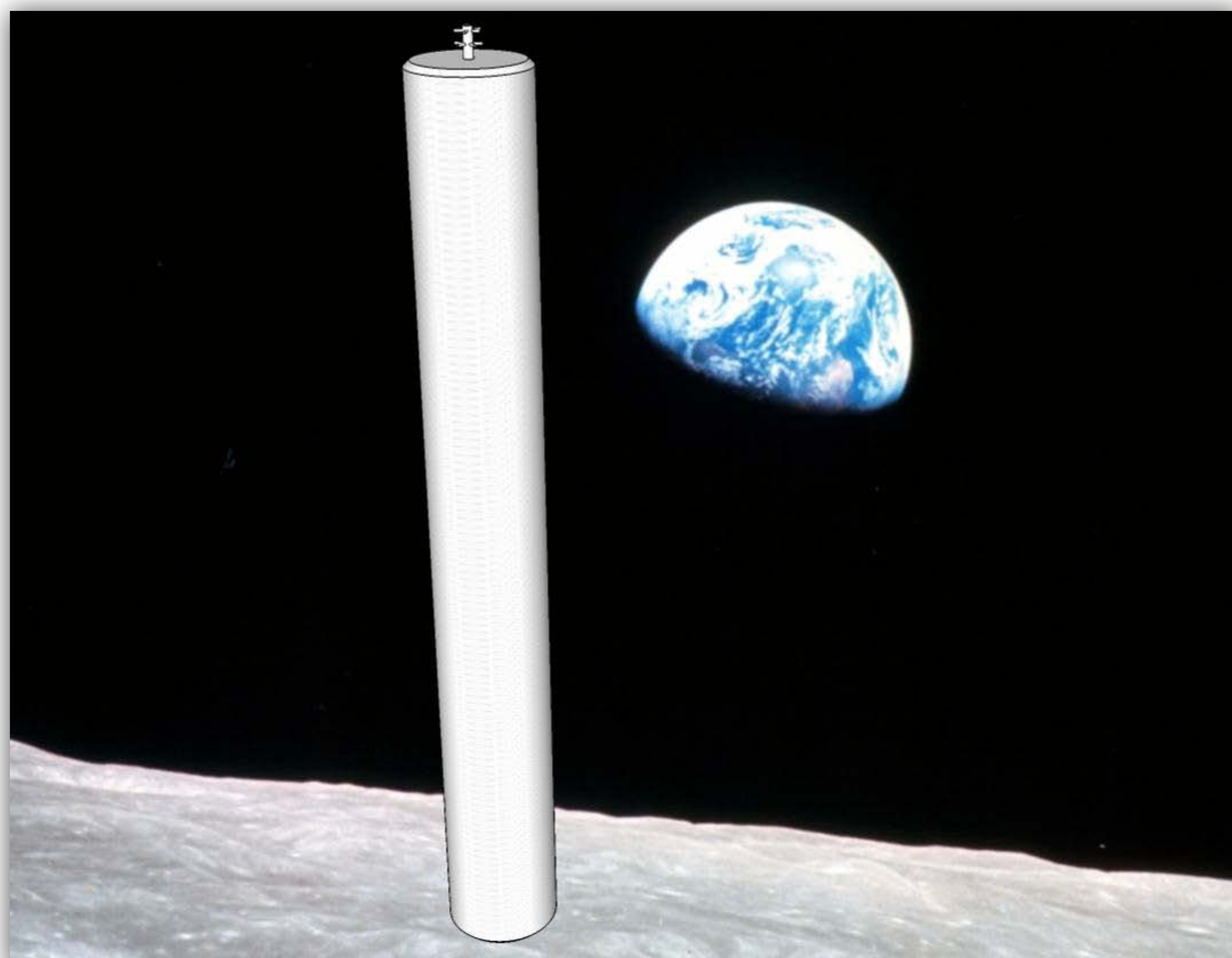


Figure 4.4A

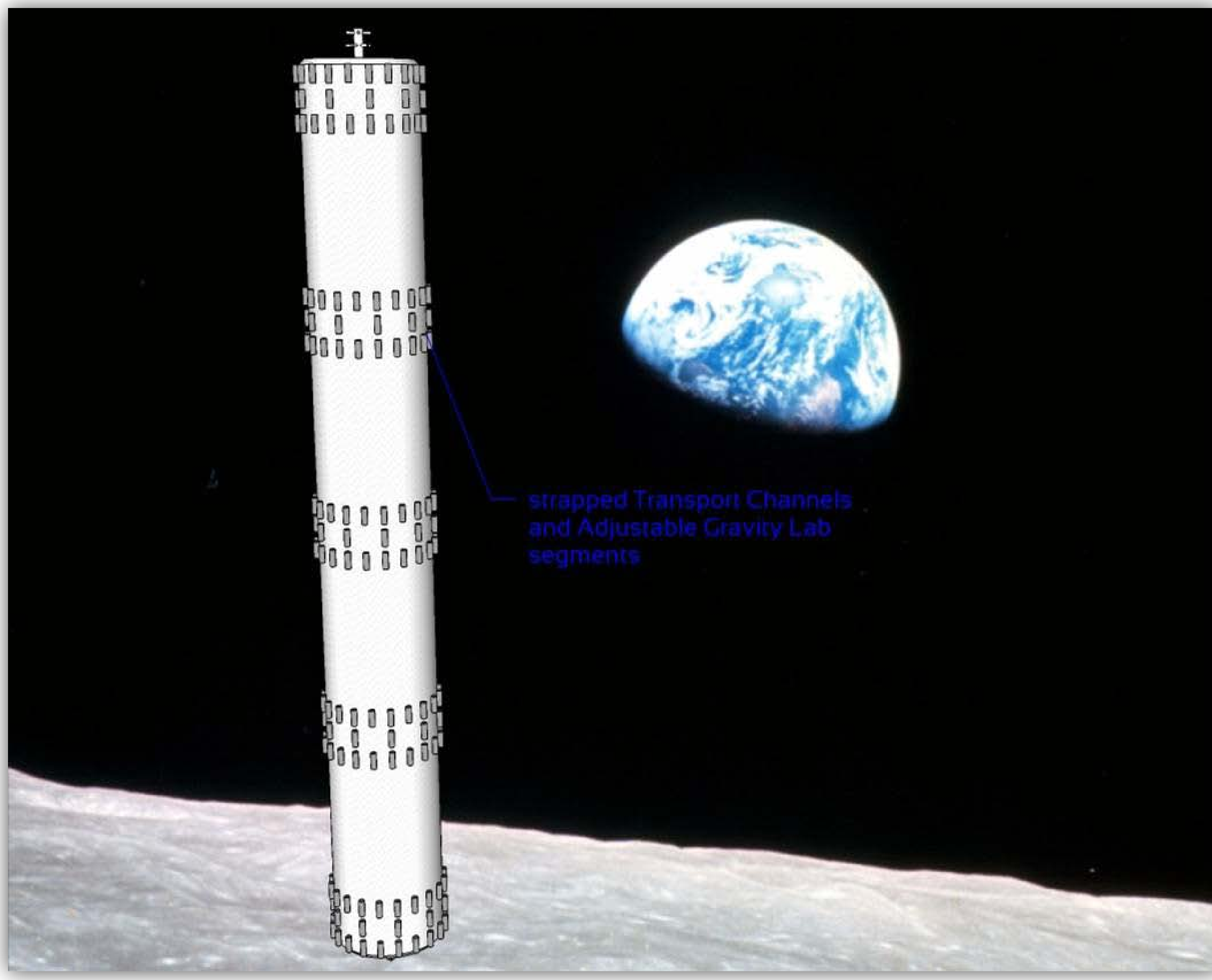


Figure 4.4B

After reaching GEO, the Transport Channels are unstrapped, and attached to the Articulated Segments. Vestibule truss and space frame components are shipped up from Earth (via rocket, space plane, space elevator or launch loop, depending on the technology available at the time) and assembled together to form the frame of the Vestibules (figure 4.4C). After the Vestibule frames are assembled, they are covered, and the remaining Adjustable Gravity Labs segments are unstrapped from the CIH and assembled (figure 4.4D).

Up to this time, ring segments and Habitat Modules are mass produced on Earth, and stockpiled. The required 200 Ring Segments are now transported and fastened together to build the forty Ring Hallways and Support Shafts (figure 4.4E). Then the Habitat Modules are transported, fastened to the station, and inflated (figure 4.4F). The Primary Stage ends with the pressurization of the station by the addition of oxygen, nitrogen and argon gas. This allows for workers to complete the secondary and tertiary stage without bulky oxygen tanks.

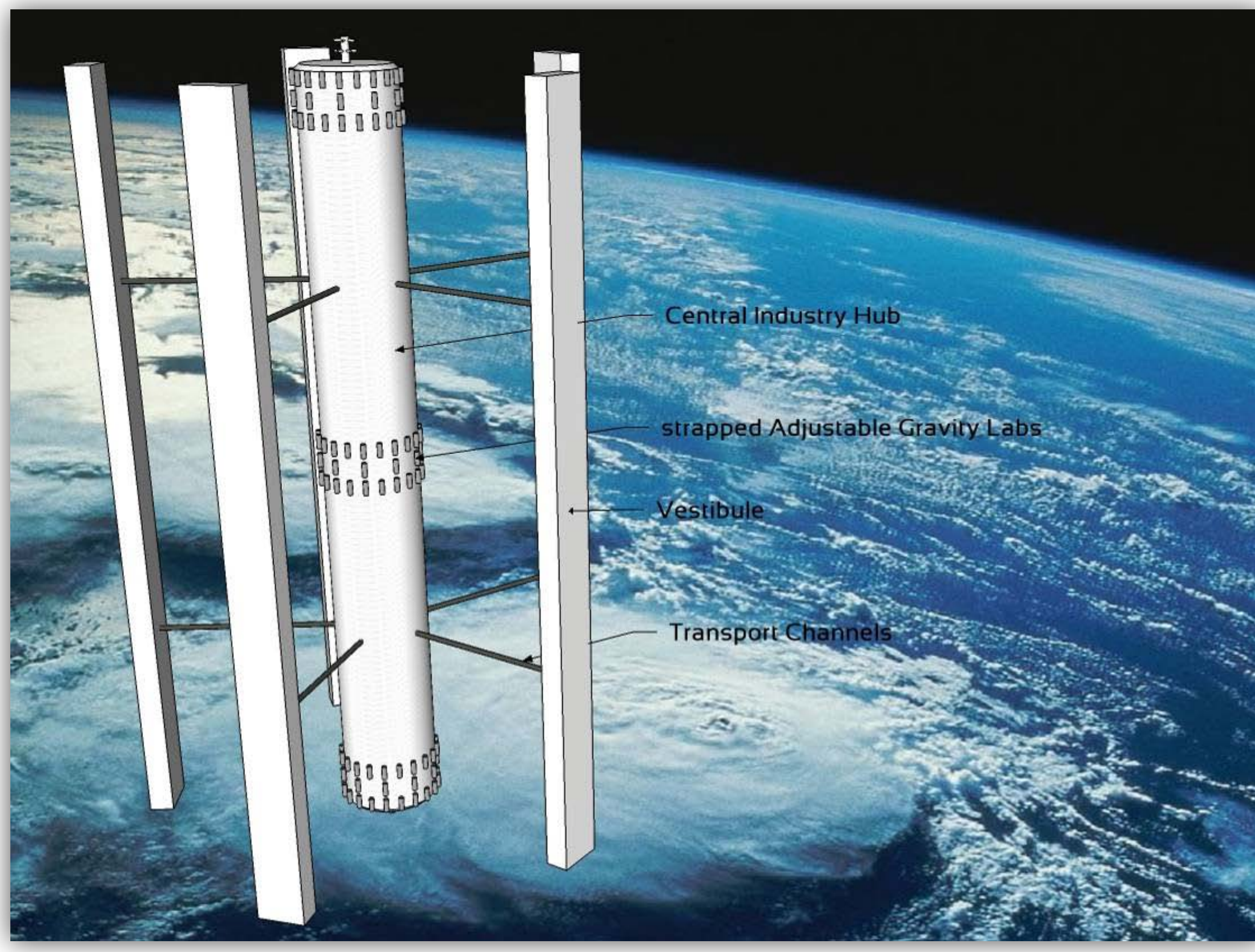


Figure 4.4C

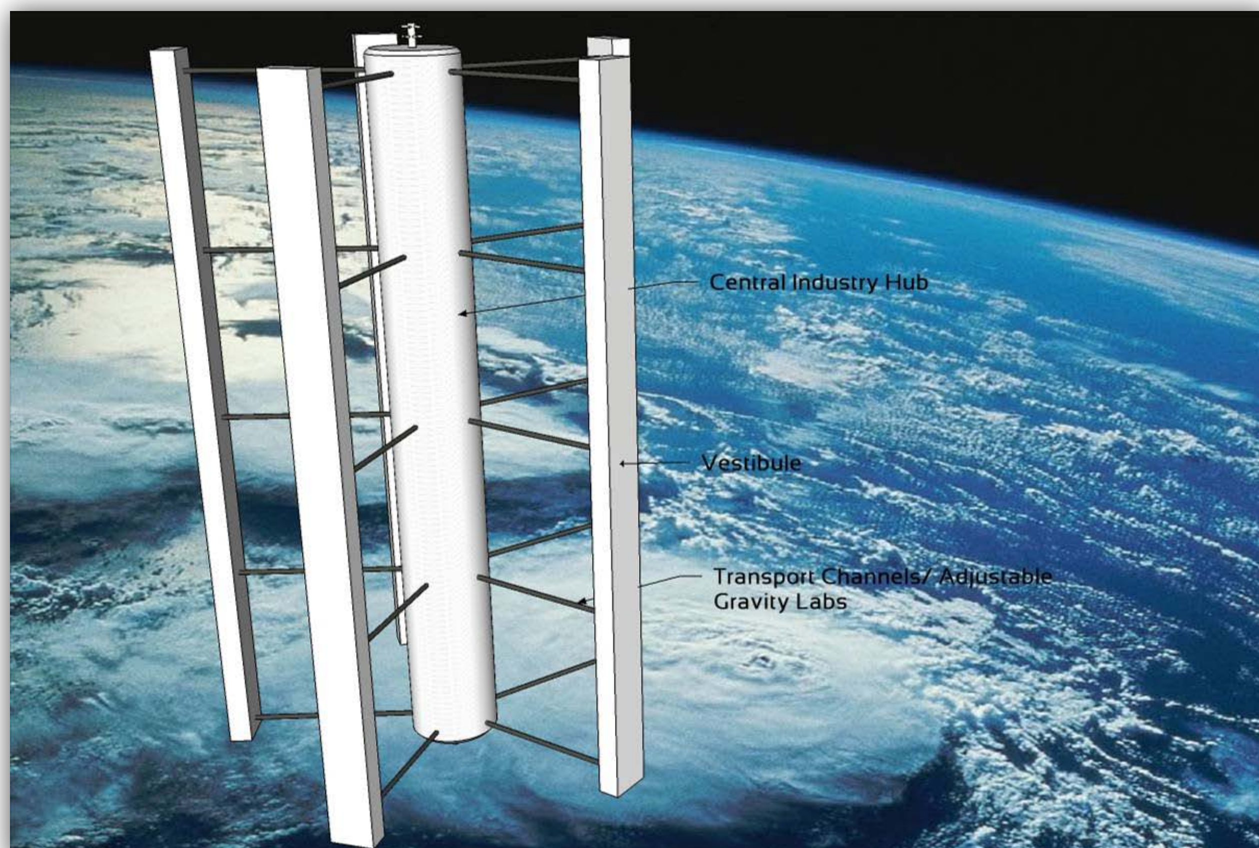


Figure 4.4D

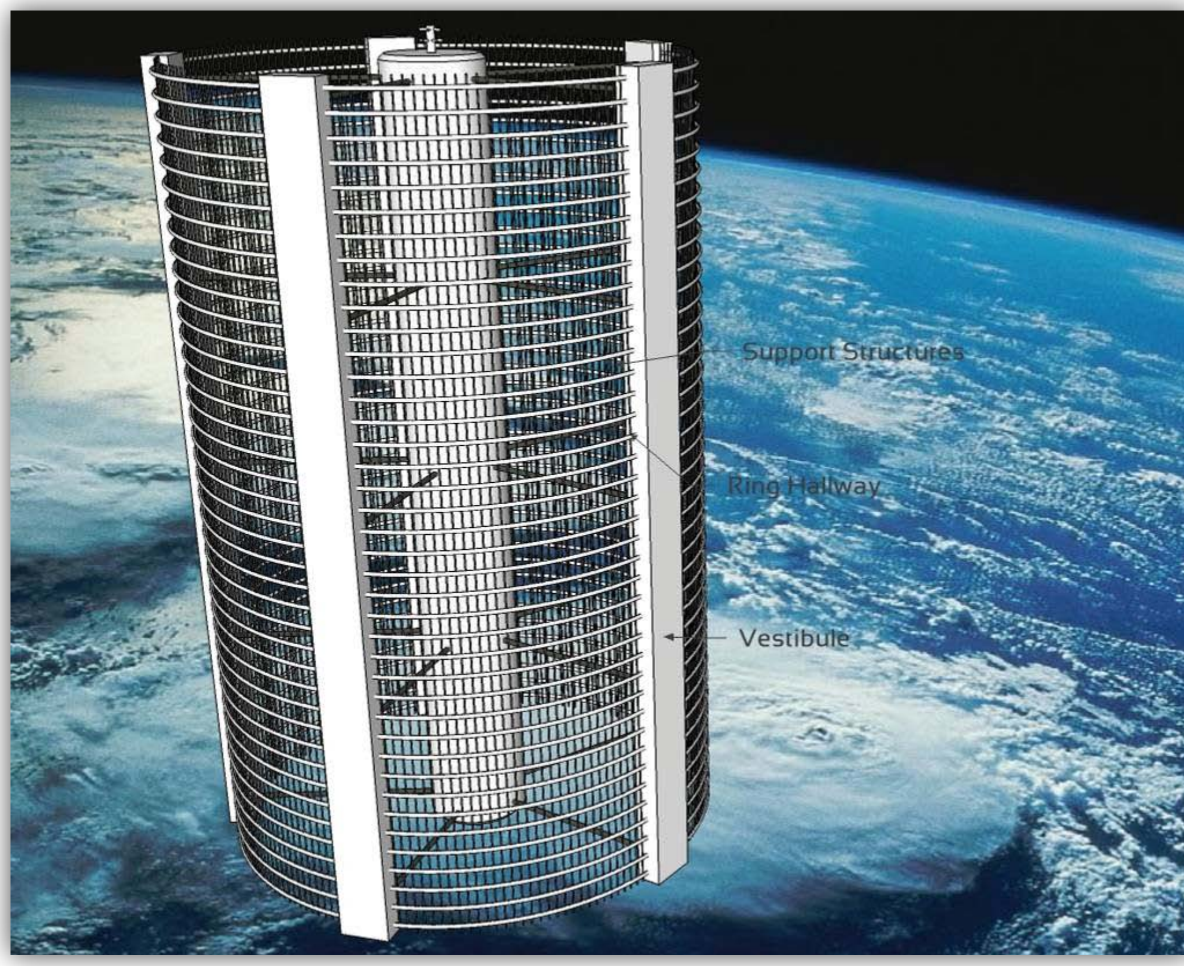


Figure 4.4E

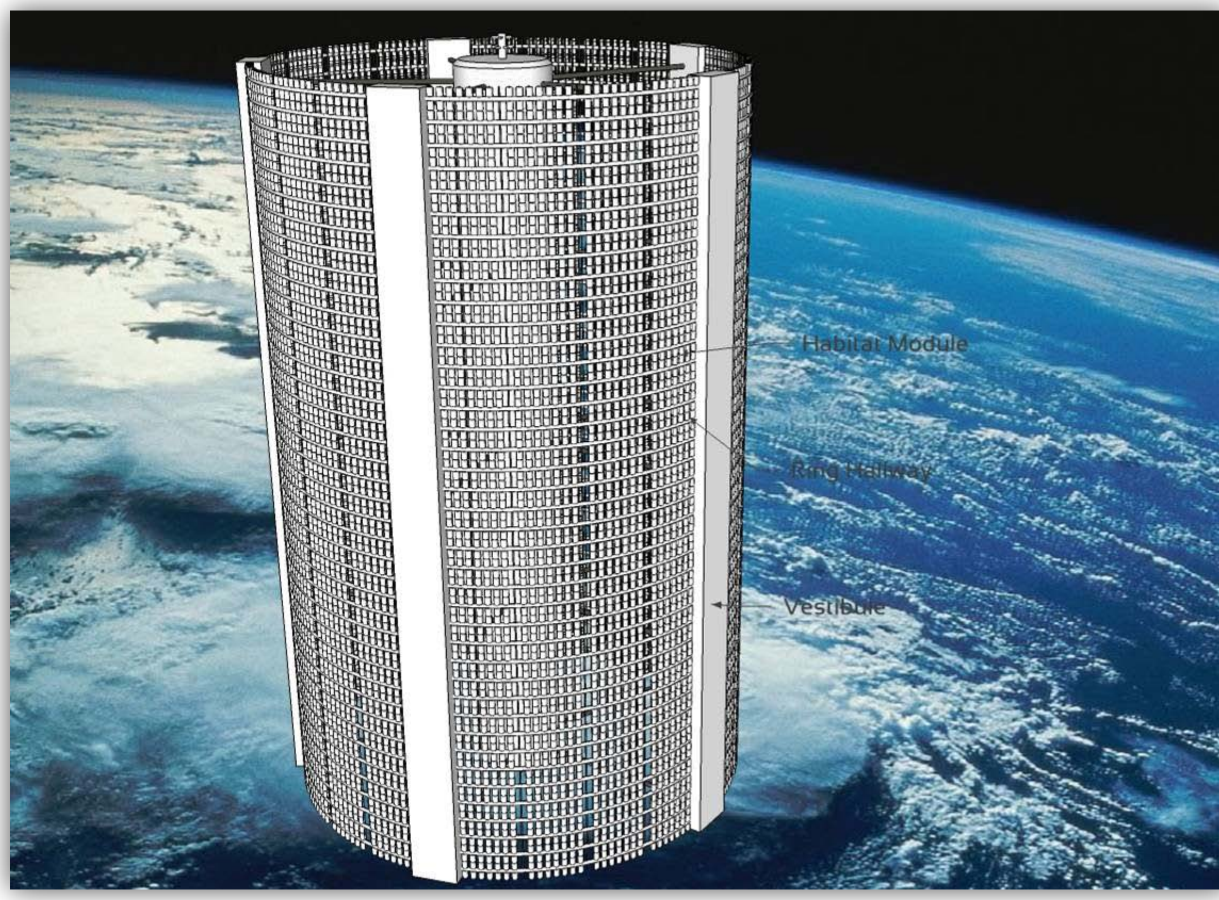


Figure 4.4F

Secondary Stage

The Secondary stage involves the assembly of all the life support systems needed to sustain life aboard the station. Pipes, wiring and ventilation shafts are installed throughout the station. The oxygen production system, water storage and recycling system, and energy production systems are installed. Photovoltaic arrays are also added to all of the now inflated Habitat Modules and Vestibules (figure 4.4G). By the end of the Secondary stage, Asten should be able to generate electricity, should have breathable air, and should have water. The Secondary Stage ends with the attaching and firing of external thrusters located on the Vestibules, rotating the station and simulating gravity (see 5.2: gravity).

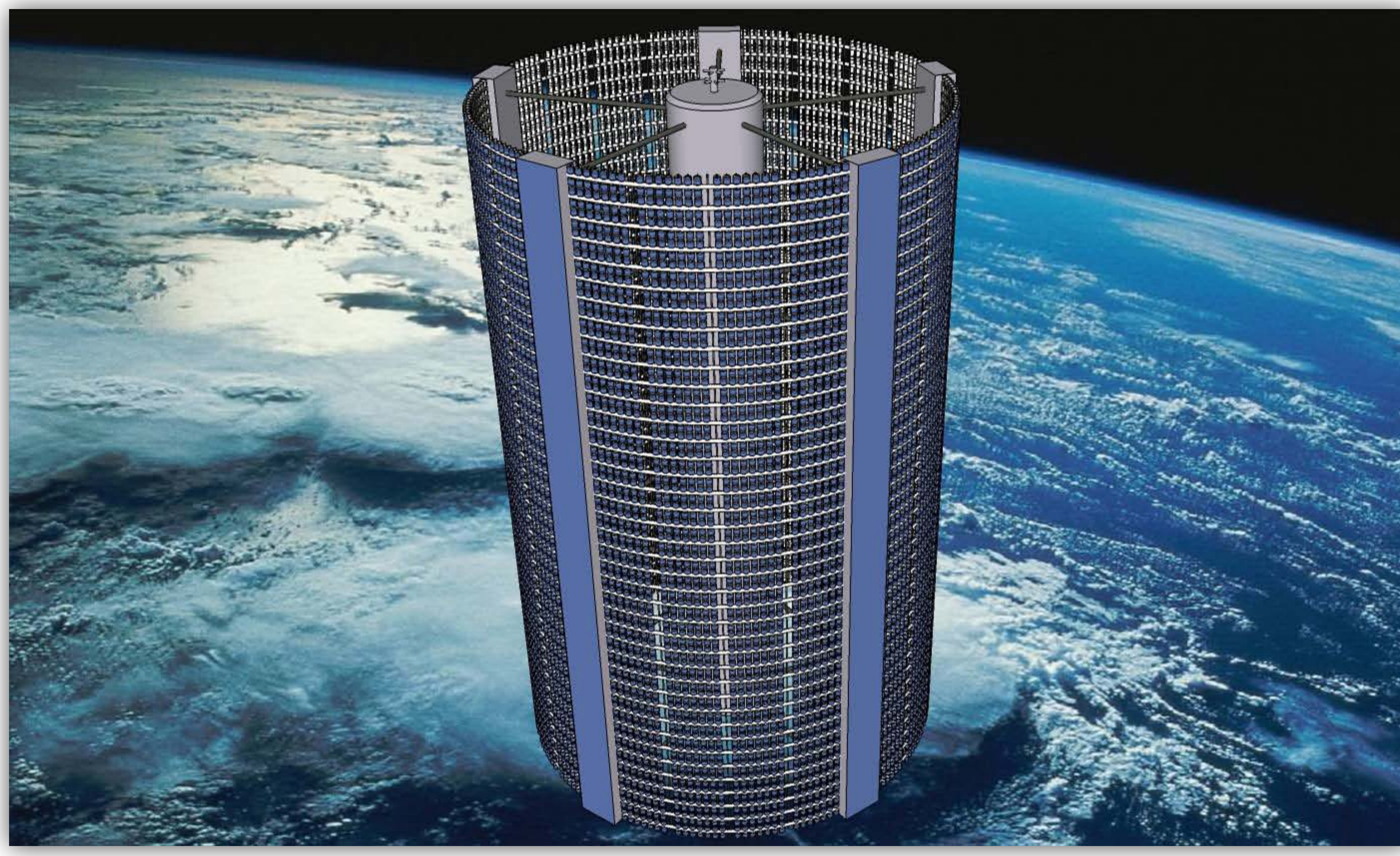


Figure 4.4G

Tertiary Stage

The tertiary stage involves the installation of all the systems needed to provide the inhabitants with the necessities for life. This includes the addition of plants and soil in the parks, the construction of smaller rooms, research labs and industrial facilities. Furniture and other supplies are transported and installed inside Asten. By the end of the Tertiary Stage Asten should be ready for human habitation.

4.5: Habitation Phase

The Habitation phase of construction refers to the introduction of humans to Asten. The phase can be divided into three stages: Adaptation and Testing, Introduction, and Monitoring.

Adaptation and Testing

The Adaptation and testing stage lasts three months, and consists of the inhabitants living in the adaptation center and learning about how to live on the station, and what to do in an emergency. At the same time all the systems aboard Asten are tested to ensure that they are working properly, and any revisions are quickly completed (The bulk of systems testing would have been completed during the technological stage of Preparation).

Introduction

The Introduction stage lasts around 9 months, and consists of the gradual transport of all inhabitants from the adaptation center to Asten at a rate of 1150 inhabitants per month. Transport is accomplished using either space planes, passenger rockets or with the launch loop (see **4.6: Spacecraft**).

Monitoring

The Monitoring stage lasts 1 year, and involves the close observation of Asten's life support systems and its inhabitants. The purpose of the Monitoring stage is to ensure that the life support systems can handle the addition of people. Medical tests would be conducted regularly on the entire population to ensure that the inhabitants are healthy and happy.

4.6: Spacecraft

The construction of Asten and the transport of resources and people require the use of specialized spacecraft. When designing the spacecraft we looked at recycling designs/technology previously tested by NASA, or reasonable extensions of present-day technology, to reduce cost and increase the feasibility of the project.

Earth-Station Passenger Transport: Space Plane

Nearly identical to the VentureStar Space Plane project cancelled in 2001, the Space Plane will be the chief method of passenger transport from the Earth to the station (figure 4.6A). The space plane will boast seven linear aerospike engines (which are efficient at all altitudes compared to standard bell-nozzle engines efficient at only one specific altitude), a metallic Thermal Protection System (TPS) and a wedge shaped lifting body built from composite materials (Stathopoulos, 2009). For this reason, an X-33 derived space plane would be a good choice for an Earth-Station Passenger transport.

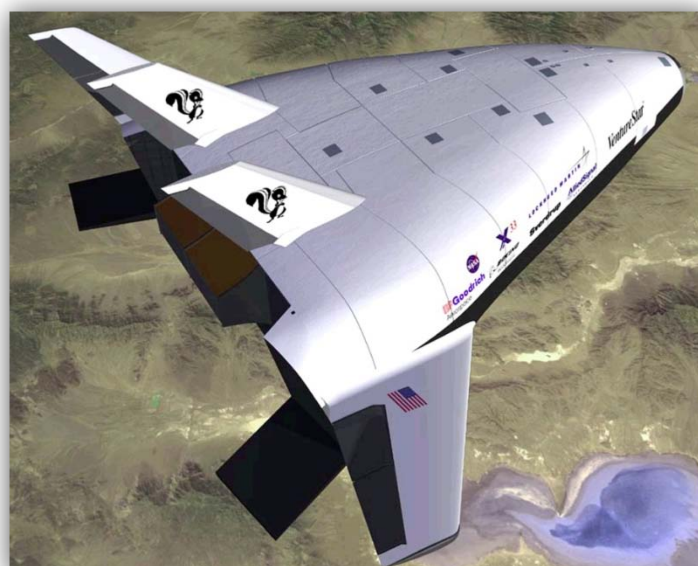
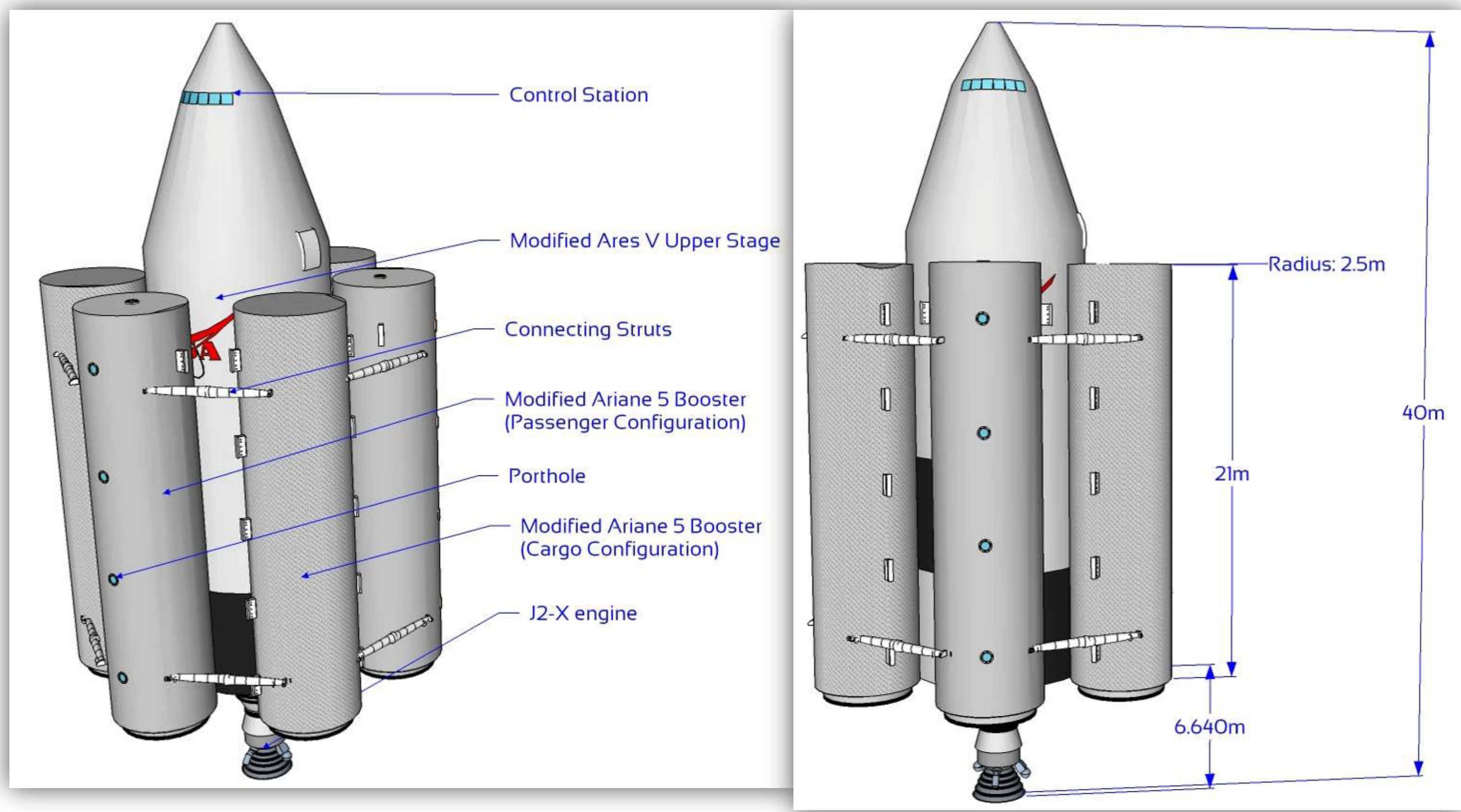


Figure 4.6A

Moon-Station transport: Strapped rockets

The Moon-Station transport consists of the modified Earth Departure stage of the Ares V Cargo Launch Vehicle, to which a control station is attached (figure 4.6B). Strapped to this central rocket are a cluster of gutted Ariane 5 booster shells leftover from the construction of the lunar moon base (figure 4.6B). These shells are converted into pressurized compartments to carry either passengers or cargo. This modular design allows for multiple configurations and eliminates the need for separate passenger and cargo transports –saving time and money.



Modular Construction Vehicle (MCV)

The Modular Construction Vehicle (or MCV) is an interchangeable construction spacecraft 10m in diameter, designed to fit within the new Ares V Cargo Launch Vehicle (Boen, 2008). The MCV consists of a long tubular frame, with one end attached to a modified Earth Departure Stage, and the other end attached to Command Pod (figure 4.6C). The modified Earth Departure Stage allows the MCV to move around Asten' construction site in GEO. The Command Pod contains controls for the movement of the MCV and the different tools, as well as a docking port/airlock, to allow for humans to enter from other spacecraft, and perform Extra-Vehicular Activity (EVA). In between the Command Pod and modified Earth Departure Stage is the Work Area, which can be arranged in two configurations.

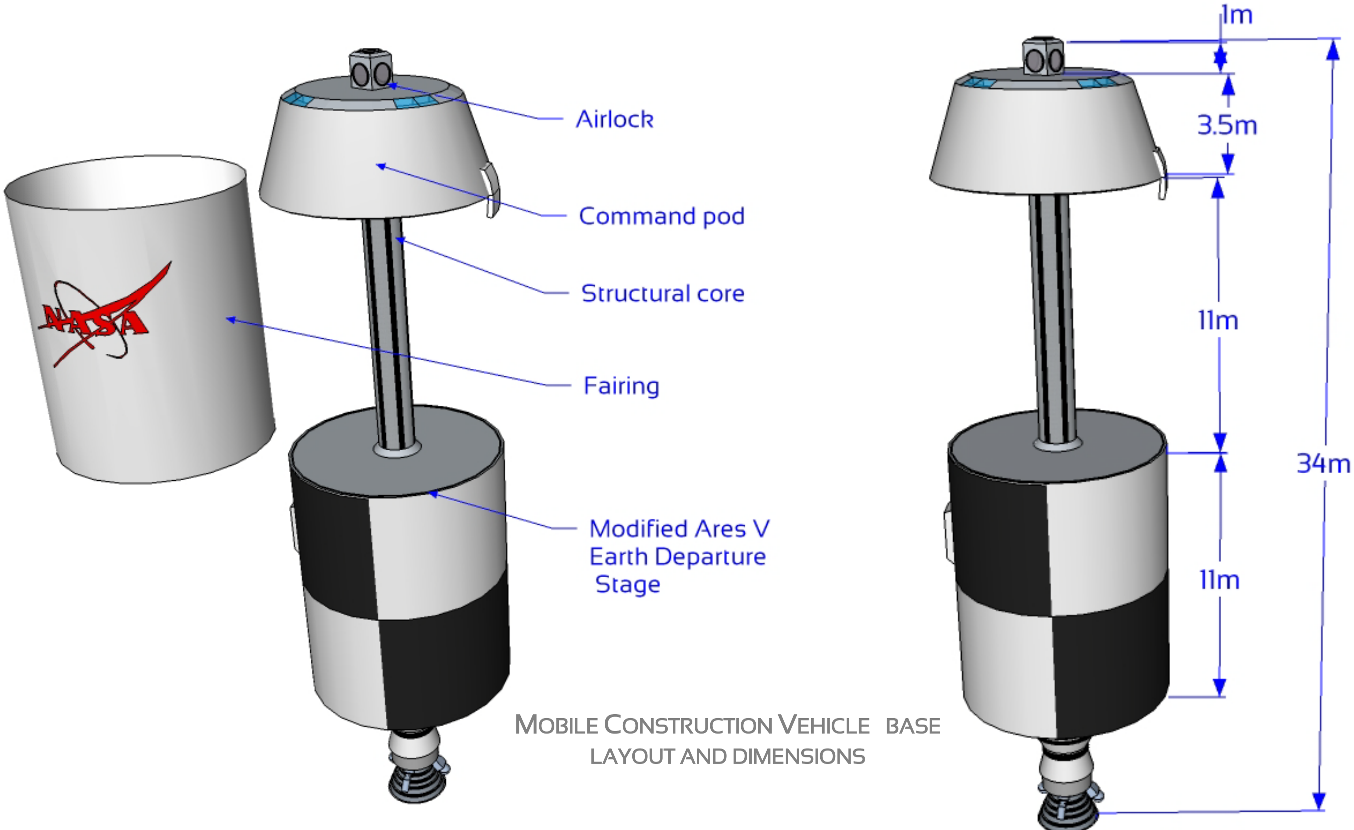


Figure 4.6C

In one configuration, the Work Area contains four robotic arms (figure 4.6D) that have seven degrees of freedom, and are derived from the Canadarm 2 currently used on the ISS (Kauderer, 2007). However unlike the Canadarm2, the ends of the arm cannot detach and reattach. These arms are used to transport and assemble much of the station, and will make heavy use of the Dextrous Manipulator (also found on the ISS). The use of robotic arms to do most of the construction work reduces the number of EVA missions required and reduces the risk posed to construction workers.

In the second configuration, the MCV can act as a "mothership", carrying 2 smaller mobile

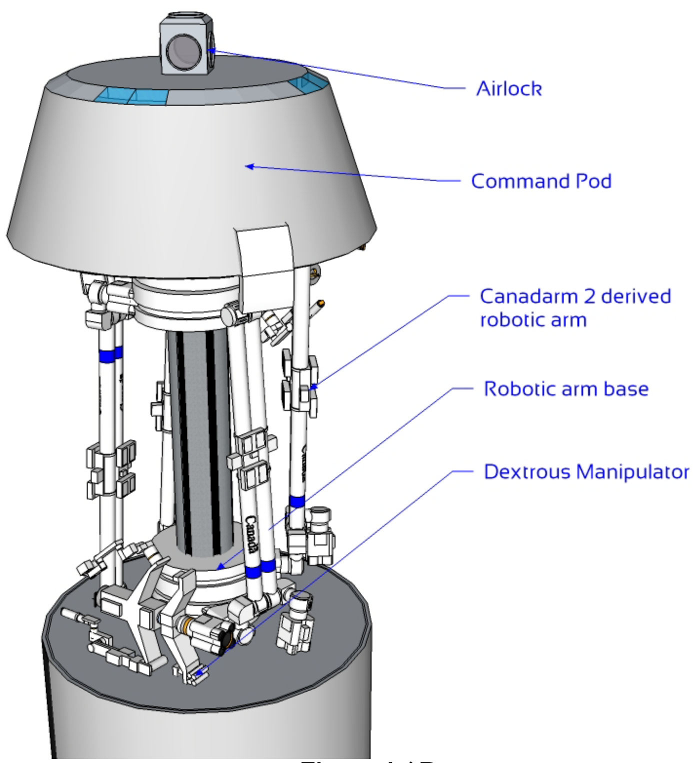


Figure 4.6D

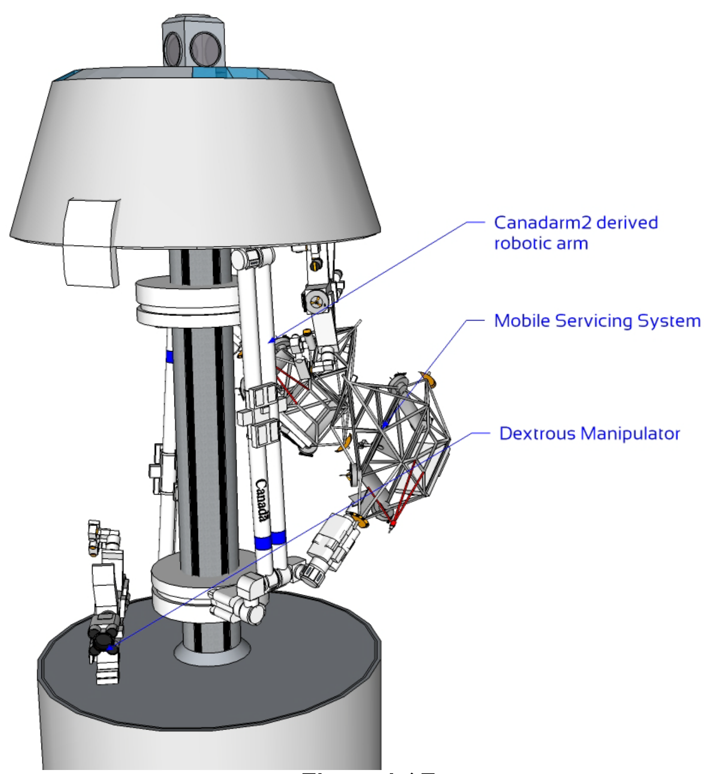


Figure 4.6E

robots –derived from the Mobile Servicing System also found on the ISS- that can attach directly to the exterior of Asten, on a temporary rail scaffold (figure 4.6E). Although they carry the same tools as the MCV arms, these smaller assembly robots have greater mobility, and can travel the entire length of a vestibule, ring hallway, or transport channel by means of the rail scaffold.

<u>Launch Loop</u>

A radical form of space transportation proposed by Keith Lofstrom in 1983, the space launch loop consists of a four kilometre long iron belt travelling at high speeds inside a magnetically bearinged sheath (Wikipedia, 2009). The high speed of the belt causes it to curve into an arch shape reaching eighty kilometres into the sky (figure 4.6F, taken from http://en.wikipedia.org/wiki/File:LaunchLoop.svg). Cargo is transported to the top of the loop atop pallets that accelerate at roughly 30m/s^2 by producing a magnetic field and eddy currents in the belt. Once the pallets reached the apogee of the curve, they are released, and a rocket engine boosts it into orbit (Wikipedia, 2009).

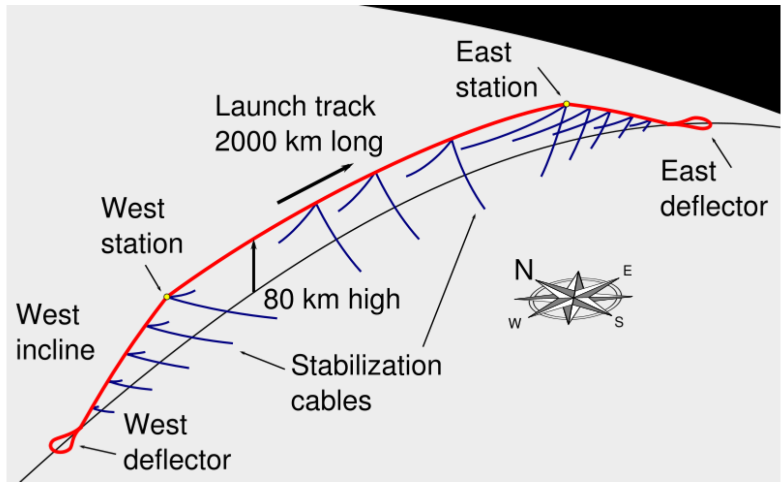


Figure 4.6F

Although it poses to significantly decrease the price of space launch, the launch loop requires large amounts of power to operate, and only exists in theory. Therefore the launch loop is classified as a possible method of transport into space, but will only be constructed if the technology has been successfully tested.

4.7: Materials

Choosing the right materials for constructing Asten is extremely important, as building it using the wrong materials would mean a weaker station that ages faster than designed. Using the structural design of Asten, we came up with a basic list of materials to use in its construction:

<u>Preliminary Material List</u>

Material	Quantity (Estimated)	Use and placement	Material Rationale
Aerogel	=(Surface area$_{\text{Ring Segment}}$ × 6000 × thickness$_{\text{semi-monocoque shell}}$) + (Surface area$_{\text{Vestibule}}$ x 5 x thickness$_{\text{space frame}}$) + (Surface Area$_{\text{CIH}}$ x thickness$_{\text{insulation layer}}$) + (Surface area$_{\text{Transport Channels}}$ × 25 × thickness$_{\text{insulation layer}}$) =(144πm^2 × 0.306m × 6000) + (490 000m^2 × 5 × 5m) + (34 000πm^2 × 0.3m) + (7500πm^2 × 25 × 0.2m) =13,230,440.8m^3	-insulation material -found within Vestibule Space Frame, in between semi-monocoque structures of ring hallways, underneath surface of CIH and Transport Channels	-lightweight, and an excellent thermal insulator

	(25,137,837.52kg)		
Woven Kevlar	=Surface $area_{Habitat\ Module}$ × 11200 $=244\pi m^2 \times 11200$ $=8{,}585{,}344.404m^2$ (1,262,045,627kg)	-used for structural strength and micrometeoroid protection -found in Habitat Module Shell	-light, durable and strong
Titanium	=(Surface $area_{Structural\ Core}$ × $thickness_{reinforcement}$ × 11200) + (Surface $area_{Ring\ Segment}$ × $thickness_{shell}$ × 6000) + (Surface $area_{Vestibule}$ × 1/3 $thickness_{space\ frame}$ × 5) $=(78\pi m^2 \times 0.1m \times 11200) + (144\pi m^2 \times 0.1m \times 6000) + (490\ 000m^2 \times 1/3 \times 5m \times 5)$ $=4{,}619{,}414.70m^3$ (20,972,142,740kg)	-provides most of structural support and strength -found in Habitat Module Structural Core, outer shell of Ring Hallway, Vestibule Space Frame	-relatively light, extremely strong, corrosion resistant
Precipitation Hardening Stainless Steel	=(Surface $Area_{Support\ Shafts}$ × $Thickness_{Steel\ Layer}$ × 150) + ([Inner Surface $Area_{Vestibule}$ + Outer Surface $Area_{Vestibule}$] × $Thickness_{Steel\ Layer}$ × 5) + (Surface $Area_{Transport\ Channel}$ × $Thickness_{Steel\ Layer}$ × 25) + ($Volume_{CIH}$ × 1/30) $=(1602\pi m^2 \times 0.15m \times 150) + ([420\ 600m^2 + 490\ 000m^2] \times 0.15m \times 5) + (7500\pi m^2 \times 0.3m \times 25) + (160\ 000\ 000\pi m^3 \times 1/30)$ $=5{,}975{,}486.63m^3$ (46,310,021,380kg)	- structural support and strength -found in Ring Hallway Support Shafts, Outer and inner surface of Vestibule, Transport Channel, frame of Central Industry Hub	-Extremely corrosion resistant -easier to work with and cheaper than titanium
Aluminum	=Surface $Area_{shafts}$ × $Thickness_{shafts}$ $=9\ 120\ 000m^2$ (est.) × 0.003m $=27{,}360m^3$ (73,872,000kg)	-Ventilation shafts,which are found throughout the entire station	-cheaper and lighter than steel -rust resistant
Carbon Fibre-Reinforced Plastic	=(Surface $Area_{Habitat\ Module\ Structural\ Core}$ × 11200) + (Surface $Area_{Ring\ Hallway\ Inner\ Shell}$ × 6000) $=(70\pi \times 11200) + (132.372\pi \times 6000)$ $=4{,}870{,}197.463m^2$ (87,176,534.59kg)	-serves as structural support -found in Habitat Module Structural Core, Inner Shell of Ring Hallway,	-extremely light, rigid, and strong
Chlorinated Polyvinyl Chloride piping	$=Length_{pipes\ Ring\ Segment}$ × 6000 × 2pipes per segment × 3 =19 × 6000 × 2 × 3 =684 000m	-provides channels for liquids and gases to be transported throughout the station	-light,corrosion resistant, easily manufacturable
Nextel ceramic cloth	=(Surface $Area_{Habitat\ Module\ Shell}$ × 11200) + (# of layers in Multi-Shock Shield) × (Surface $Area_{Ring\ Segment}$ × 6000 + Surface $Area_{Vestibule}$ × 5 + Surface $Area_{CIH}$)	-micrometeoroid barrier -found in Habitat Module Shell and Multi-Shock Shields of the Ring Hallways, Vestibules and Central Industry Hub	-breaks micrometeoroids into smaller pieces,reducing the chance of damage to the

	$=(244\pi m^2 \times 11200) + 5 \times (144\pi m^2 \times 6000 + 490\ 000m^2 \times 5 + 340\ 000\pi m^2)$ $=39\ 441\ 112.74m^2$		structure (see **5.6: Safety/Securtity**)
Beta Cloth	=(Surface $Area_{Ring\ Segment}$ × 6000) + (Surface $Area_{Vestibule}$ × 5) + (Surface $Area_{CIH}$) + (Surface $Area_{Transport\ Channels}$ × 25) $=(144\pi m^2 \times 6000) + (490\ 000m^2 \times 5) + (340\ 000\pi\ m^2) + (7500\pi m^2 \times 25)$ $=6\ 821\ 526.77m^2$	-protects station from atomic oxygen degradation -found on surface of Ring Hallway, Vestibule, Central Industry Hub and Interspatial Structure	
Photovoltaic array	=(Surface $Area_{Habitat\ Module\ PV\ array}$ × 11200) (Surface $Area_{Vestibule\ PV\ array}$ × 5) $=(78\pi m^2 \times 11200) + (160\ 000m^2 \times 5)$ $=3\ 446\ 477.65m^2$	-generates electricity from Sun -attached to the half of Habitat Modules that face outwards, as well as Outer Surface of the Vestibules	-Only constant source of energy from the environment is the Sun
Nitrogen Gas	=[($Volume_{Habitat\ Module}$ × 11200) + ($Volume_{Ring\ Segment}$ × 6000) + ($Volume_{Vestibule}$ × 5) + ($Volume_{Transport\ Channel}$ × 25) + ($Volume_{CIH}$)] × Air Percent $Composition_{Nitrogen}$ $=[(540\pi m^3 \times 11200) + (304\pi m^3 \times 6000) + (5\ 724\ 000m^3 \times 5) + (7500\pi m^3 \times 25) + 16\ 000\ 000m^3] \times 0.78084$ $=54,081,823.25m^3$ (67,656,360.89kg)	-required to maintain an Earth-like atmosphere	
Oxygen Gas	=[($Volume_{Habitat\ Module}$ × 11200) + ($Volume_{Ring\ Segment}$ × 6000) + ($Volume_{Vestibule}$ × 5) + ($Volume_{Transport\ Channel}$ × 25) + ($Volume_{CIH}$)] × Air Percent $Composition_{Oxygen}$ $=[(540\pi m^3 \times 11200) + (304\pi m^3 \times 6000) + (5\ 724\ 000m^3 \times 5) + (7500\pi m^3 \times 25) + 16\ 000\ 000m^3] \times 0.20947$ $=14,508,118.84m^3$ (19,643,992.91kg)	-required for life to exist	
Argon Gas	=[($Volume_{Habitat\ Module}$ × 11200) + ($Volume_{Ring\ Segment}$ × 6000) + ($Volume_{Vestibule}$ × 5) + ($Volume_{Transport\ Channel}$ × 25) + ($Volume_{CIH}$)] × Air Percent $Composition_{Argon}$ $=[(540\pi m^3 \times 11200) + (304\pi m^3 \times 6000) + (5\ 724\ 000m^3 \times 5) + (7500\pi m^3 \times 25) + 16\ 000\ 000m^3] \times 0.00934$ $=646,898.506m^3$ (1,154,066.935kg)	-required to maintain an Earth-like atmosphere	

Material sources

There are three possible sources of materials: the Moon, Earth and nearby asteroids.

The Moon

The moon is home to vast untouched natural resources. Setting up a mining camp on the Moon helps to reduce the strain on Earth's natural resources. Figure 4.7A (taken from Northeastern Illinois University) shows the general composition of the moon's crust:

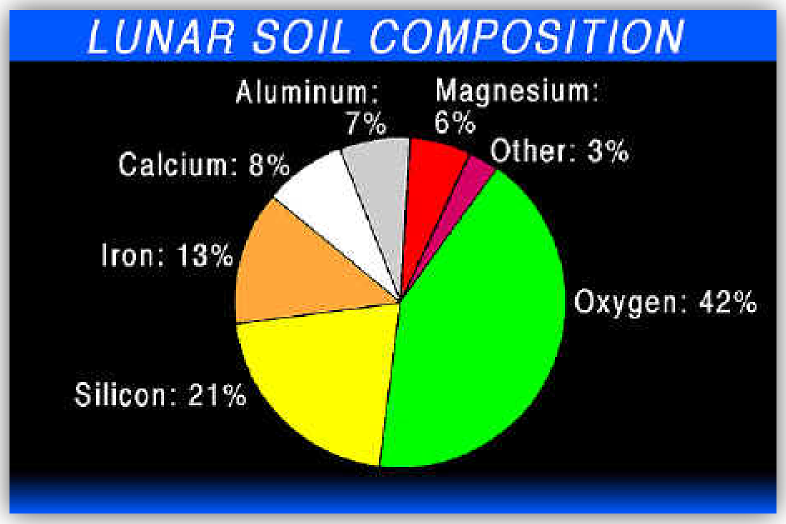


Figure 4.7A

The majority of the moon's crust is composed of Silicon Dioxide (SiO2). Seperating the molecule yields pure Silicon and Oxygen, both of which are vital materials (Silicon to make photovoltaic cells, glass, and Aerogel; and Oxygen to allow life to exist). The aluminum present would be used to make the ventilation shafts, and the iron would be used to make steel (which is an alloy of iron and carbon).

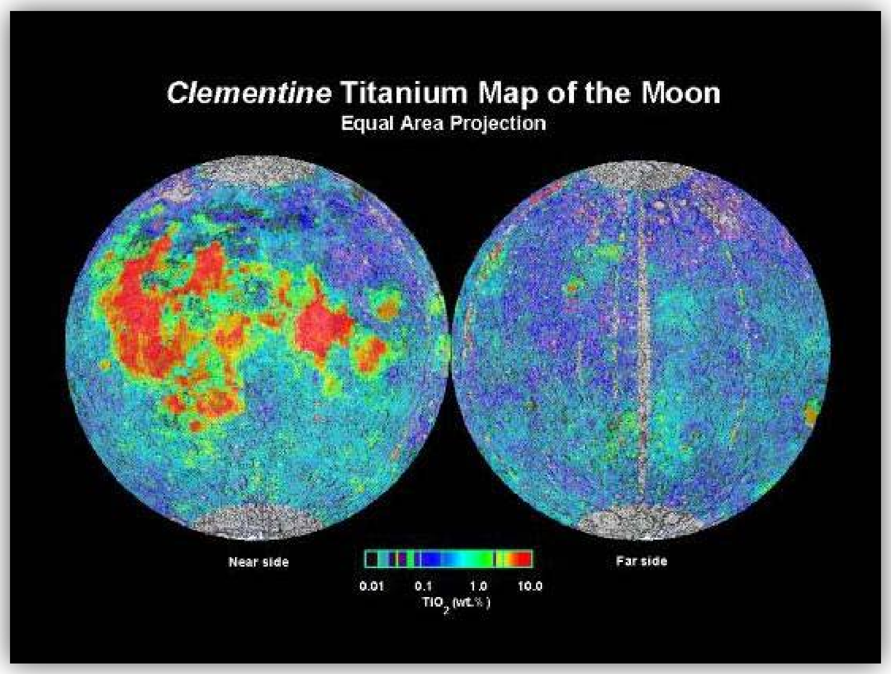


Figure 4.7B

The importance and quantity of the materials found on the moon means a large mining facility and processing/manufacturing plant (shipping raw ore back to Earth for processing and manufacturing is too costly in the long run) will need to be constructed. The location of the facilities is especially important, as they need to be easily accessible, and must be near areas that are rich in important minerals. Using maps developed from the Clementine probe mission launched in 1994 (figure 4.7B and 4.7C), deposits of important minerals can be seen and a suitable settling point can be determined (taken from Lunar Republic):

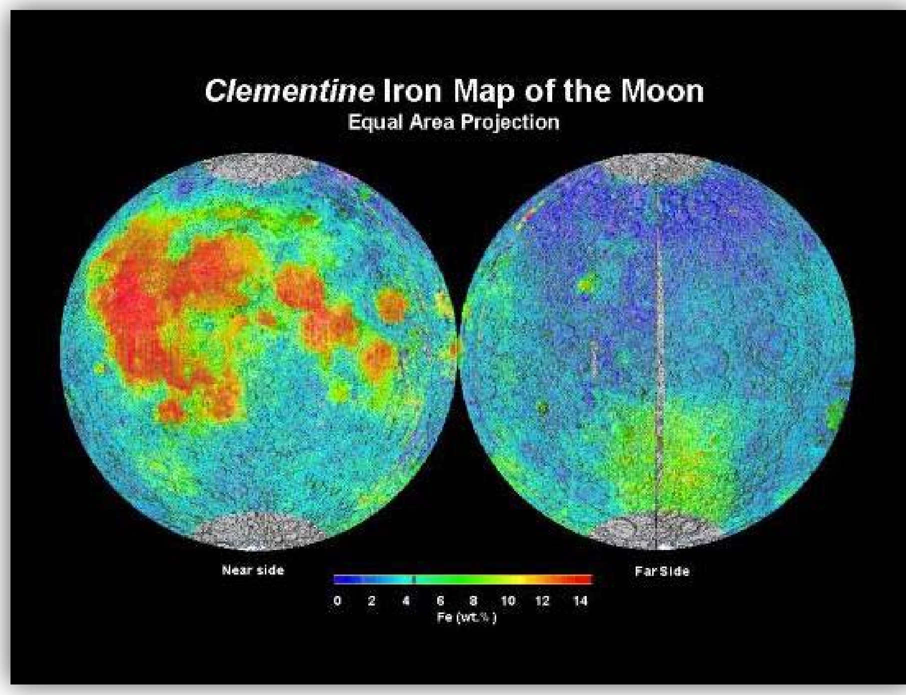


Figure 4.7C

Looking at the two maps, the most suitable location for mineral extraction facilities would be the mare Oceanus Procellarum (The red area on both maps. On top of being an area rich in Titanium and iron, it is located on the near side of the moon, which allows for easy access –as the near side always faces the Earth (and consequently Asten).

Earth

While the moon can provide many of the raw materials used to construct Asten, it cannot provide any complex machines or organic materials. The only possible source for complex machines and organic materials is Earth. All the machines used to extract and process minerals and manufacture parts from the moon will need to be shipped from Earth. All delicate machinery (such as computers, sensors, etc.) will be manufactured on Earth and shipped to the construction site(see **4.4: Construction**). In addition soil, water, and other materials unique to Earth will have to be shipped to the construction site.

Asteroids

Both the Earth and the moon can provide many of the materials needed to construct Asten, however there are a number of asteroids can be reached with less fuel then it takes to reach the moon. These "Near-Earth asteroids" can be divided into three families according to their distance from the Earth: The Atens, The Apollos, and The Amors (Wikipedia, 2008). They range in distance between 0.963 and 1.3 astronomical units, and can provide various minerals, such as iron, nickel, magnesium, gold, platinum and even water (Wikipedia, 2008). However it is difficult to land and transport mining equipment to these asteroids. For this reason, they are not classified as a necessary source of building materials, and mineral extraction will only be pursued if the conditions are favourable.

4.8: Cost

The cost of constructing Asten was compiled into a chart, and was organized into four categories: labour, material, support facilities (such as factories, moon mining facilities, transports, etc), and Research and Development.

1. Labour Expense	**Formula (number employed x salary x years employed)**	**Value (2008 U.S. Dollars)**	**Source**
Engineering technicians	5000 x salary x 27 years	=5000 x $ 53 000 x 27 =$7 155 000 000	"Aerospace Engineering and operations technicians" (U.S. Bureau of Labour, 2007)
Financial advisors/managers	100 x salary x 15 years	=100 x $105 410 x 15 =$158 115 000	"Financial Managers of Companies and enterprises" (U.S. Bureau of Labour, 2007)
Engineer	1000 salary x 30 years	=1000 x $87 610 x 30 =$2 628 300 000	"Aerospace Engineers Median Salary" (U.S. Bureau of Labour, 2007)
Construction workers	10 000 x salary x 27 years	= 10 000 x $34 130 x 27 =$9 215 100 000	"Nonresidential Building Construction Labourers" (U.S. Bureau of Labour, 2007)
2. Material Expense	**Formula (quantity x rate)**	**Value (U.S. Dollars)**	**Source**
Titanium	20 815 082 640kg x $12.35/kg	=$257 066 270 600	MetalPrices.com
Precipitation Hardening Stainless steel	Rate cannot be found	Unknown	
Aerogel	13230440m^2 x $53.82/$m^2$	=$712 062 323.90	http://aerogel.nmcnetlink.com/aerogel-cost-manufacturability.html
Woven Kevlar	8 278 724.96m^2 x $37.62/$m^2$	=$311 445 633	http://uscomposites.com/kevlar.html
Aluminum	73 872 000kg x $1.43/kg	=$51 658 741.26	http://www.metalprices.com/#

Carbon Fibre Reinforced Plastic	4 870 197.163m^2 x $10.05/m^2	=48 945 484.50	http://www.ecosyn.us/ecocity/Palaces/Concrete/Carbon_Palace/Carbon_Fiber_Palaces.html
CPVC Piping	684 000m^2 x $227.362/m	=$155 515 608	10" diameter CPVC piping: http://www.usplastic.com/catalog/product.asp?catalog_name=USPlastic&category_name=13668&product_id=12858#
Nextel ceramic cloth	Rate cannot be found	Unknown	
Beta Cloth	Rate cannot be found	Unknown	
Photovoltaic Array	10 800 inhabitants x 125423.70kWh per capita x $0.22/kWh	$298 006 711.20	http://en.wikipedia.org/wiki/Photovoltaics#Power_costs
3. Support Facilities	**Equivalent sized project**	**Value (U.S. Dollars)**	**Source**
Earth manufacturing plant	Construction of the Boeing Everett Factory	$520 000 000	http://www.boeing.com/commercial/facilities/index.html
Launch Facility	Construction of Launch Complex 39 at the Kennedy Space Center	$800 000 000	Nationmaster.com
Moon Mining Facility	Construction of the Three Gorges Dam	$2 634 4676 180.02	NationMaster.com
Control Center	NORAD Cheyenne Mountain Complex	$2 000 000 000	http://www.fas.org/nuke/guide/usa/c3i/cmc.htm
Technological Research Facility	Construction of the Large Hadron Collider	$4 600 000 000	http://www.sciencebase.com/large-hadron-collider.html
Adaptation Center	Construction of Biosphere 2	$200 000 000	http://en.wikipedia.org/wiki/Biosphere_2
4. Research and Development	**Equivalent sized project**	**Value (U.S. Dollars)**	**Source**
Spacecraft (space plane, moon transport, MCV)	Development of the Space Shuttle	$145 000 000 000	http://www.space.com/news/shuttle_cost_050211.html
Station systems (eg. Oxygen, water, energy production/storage)	Development and Construction of the ITER nuclear fusion project	$4 500 000 000	http://www.ofes.fusion.doe.gov/News/ITERCostReport.pdf
Station structure	Development of the International Space Station	$100 000 000 000	http://www.space.com/businesstechnology/051102_techwed_iss_fifthyear.html
Construction processes (eg. Moon mining, assembly in space, etc.)	Manhattan project	$2 000 000 000	http://www.fas.org/nuke/intro/nuke/intro.htm
	Total Cost	$563 765 096 300	

Section 5: Asten Life Support Systems

This section describes how Asten achieves the forces necessary for life to exist on the station; such as gravity, water, oxygen, and food. This section also describes how Asten generates electricity, as well as safety and security.

5.1: Environmental Control

Thermal Control System

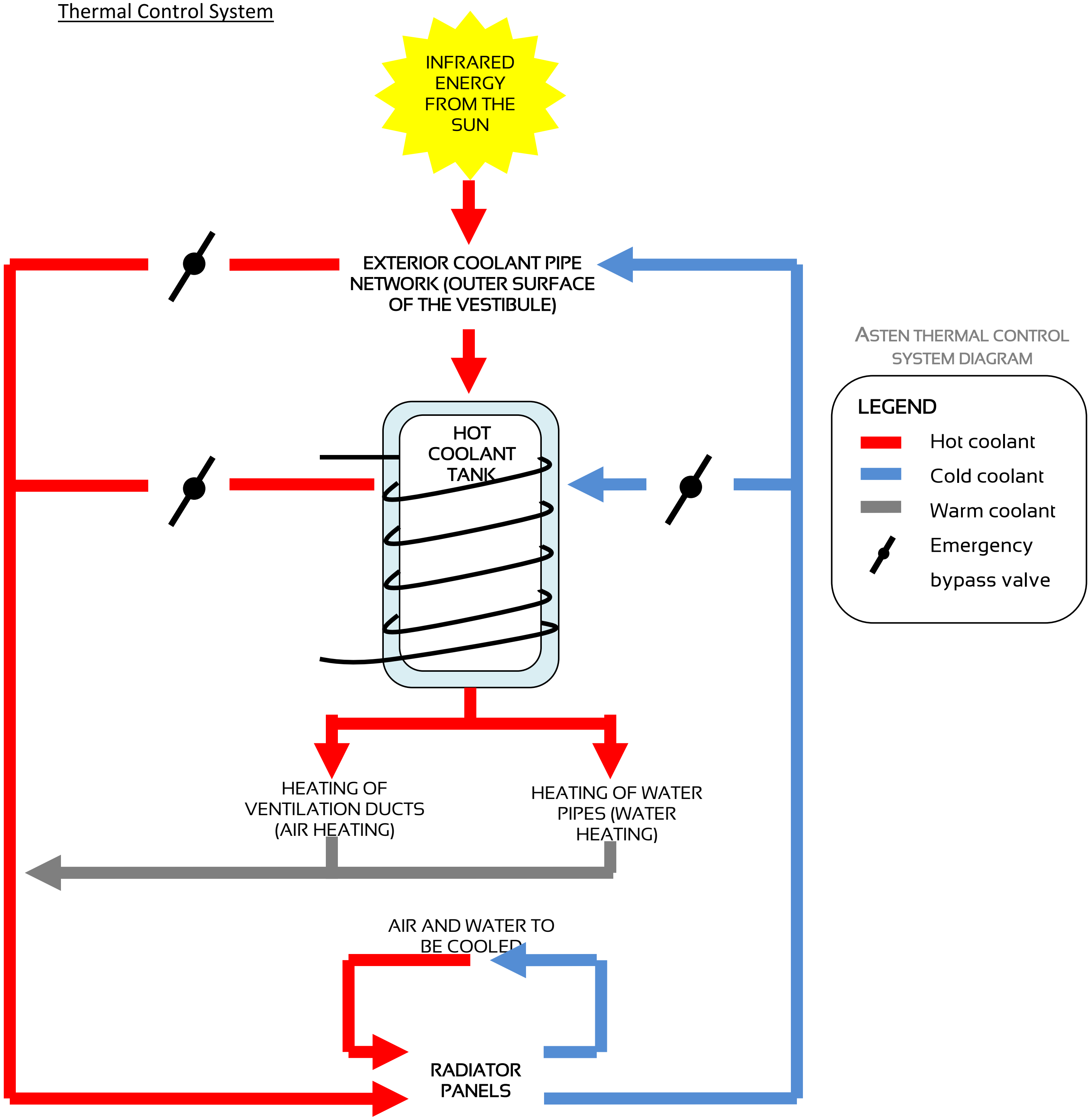


Figure 5.1A

Asten Thermal Control System is unique in that it uses the sun's infrared energy to help heat the air and water used by its inhabitants, which will reduce the amount of energy needed to heat the station.

The Thermal Control System begins with the Exterior Coolant Pipe Network. Found on the outer surface of the Vestibule (on top of the Photovoltaic cells [see **5.5: Energy**]), the network consists of a number of copper tubes filled with silicone oil, which absorb the heat radiated by the Sun and transfer it to a Hot Coolant Tank (figure 5.1A). The Hot Coolant Tank is a large vacuum vessel meant to maintain the temperature of the coolant heated by the sun. In the case that the outer side of the Vestibule is facing away from the sun, or if the coolant is not hot enough, its temperature can be raised by means of a large induction coil wrapping around the inner stainless-steel lined cast-iron vessel (figure 5.1B). The heat results from the magnetic field hysteresis loss –much like a modern induction cooker- producing heat in ferromagnetic metals (Wikipedia, 2009).

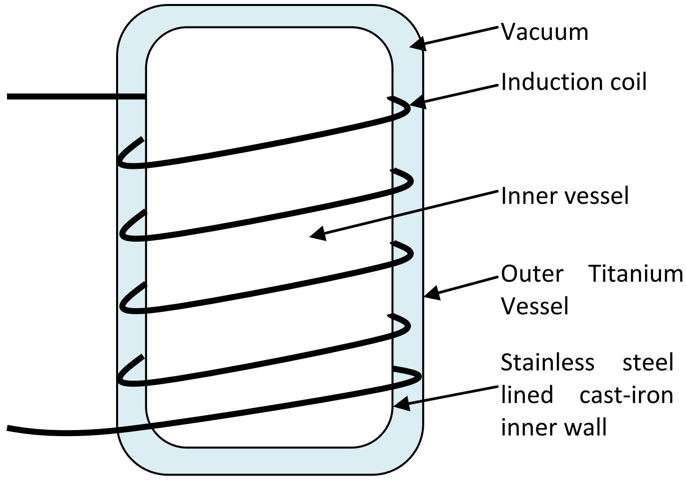


Figure 5.1B

Once heated, the coolant travels separates into two different heat exchangers, where water is heated to 60 degrees Celsius, and air is heated to 21 degrees Celsius (figure 5.1A). The now cooler -or "warm"- coolant travels to a special composite radiator panel network located on the inner surface of the Vestibule (the side facing the Central Industry Hub). The particular radiator panel design was developed in 2005 by NASA's Glenn Research Center, and features a Titanium heat pipe embedded within a aluminum honeycomb structure and graphite foam sandwiched between two layers of graphite fibre reinforced composite laminate (figure 5.1C, taken from .1-act.com/htlhpptd.pdf) (Stern and Anderson, 2005). Air and Water are also cooled down using the radiator panels, by means of a secondary closed coolant loop (figure 5.1A).

The now cold coolant returns to the Exterior Pipe Network, and begins the cycle again. In the case that the coolant in the pipe network or the Hot Coolant tank becomes too hot, emergency bypass values open, allowing the overheated oil to bypass the heat exchangers and travel directly to the radiator panels (figure 5.1A).

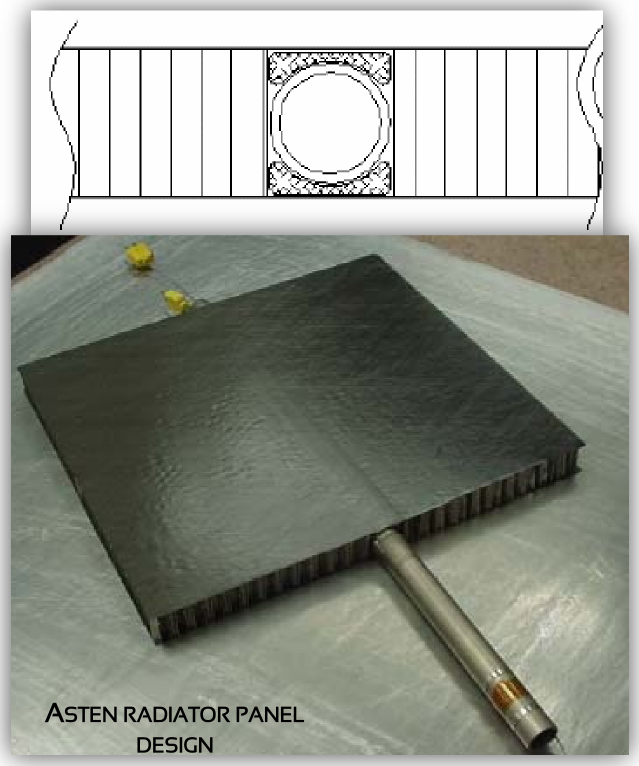


Figure 5.1C

CARU's

In order to accommodate for special environments in labs, and to let the inhabitants feel more comfortable, every Habitat module and every large room/laboratory contains one or more Compact Air Regulating Units (CARU's). Found at the mouth of every air duct entrance into a room/Habitat module, each base CARU contains an air filter, dehumidifier/humidifier, air conditioner and ceramic resistance heater. It can be controlled either by a touchscreen panel on the wall or from the Station Control Centre in the CIH (through a fibre-optic network), allowing for customizable environments, depending on the requirements of the inhabitant/experiment. Modular in design, individual components of the CARU can be removed and replaced. For example, an extremely sterile laboratory can be formed by replacing any of the dehumidifier/humidifier/air conditioner/ceramic resistance heater with additional air filters.

Sunlight

Aside from the windows found in the panoramic observation hallway of the zero-gravity hotel (see **3.6: Central Industry Hub**), natural sunlight does not enter the station. Light Emitting Diodes (LED's) found in the artificial sky of the recreational park (see **6.3: Recreational facilities**) are used to mimic the appearance of natural sunlight. Fluorescent lighting is generally avoided within the station because of the harsh white light it produces. Instead High Intensity Discharge lamps or LED's are used for lighting purposes.

5.2 Gravity

Gravity

Gravity is of the utmost importance in replicating earth, and necessary for proper human physical development. It has been found that long term exposure to weightlessness results in a number of medical problems, such as muscle atrophy, spaceflight osteopenia and a weakening of the immune system. Because of this, a 1g living environment is necessary to sustain comfortable human life. Asten simulates gravity by harnessing centripetal force, rotating the space station to produce artificial gravity.

To create a 1g living environment, fifty liquid hydrogen/liquid oxygen thrusters placed on the outer surface of the five Vestibules (ten on each Vestibule) fire, slowly accelerating the station until the centripetal acceleration reaches $9.81 m/s^2$, or 1g.

Basic calculations for the rotation of Asten can be found on the following page.

Station Dynamics

Angular velocity of the station:

$$F_{cen} = F_g$$

$$\frac{\cancel{m_{station}} \times v_{tangential}{}^2}{r_{station}} = \cancel{m_{station}} \times g$$

However, $v_{tangential} = r\omega$,

where ω = angular velocity (in rad/s)

and r= radius of the station

$$\therefore \frac{(r_{station}\omega)^2}{r_{station}} = g$$

$$\frac{r_{station}{}^{\cancel{2}} \times \omega^2}{\cancel{r_{station}}} = g$$

$$\omega = \sqrt{\frac{g}{r_{station}}}$$

$$\omega = \sqrt{\frac{9.81m/s^2}{500m}}$$

$$\omega \approx 0.14401rad/s$$

Tangential acceleration of the station:

$A_{tan} = \frac{\Delta v_{tan}}{\Delta t}$, **where A_{tan} is the Tangential Acceleration in m/s^2, and Δt is the amount of time it takes to spin the station up to speed in s.**

$$\Delta t = 1\ month\ (4\ weeks)$$

$$= \frac{24h}{day} \times 30days \times \frac{3600s}{h}$$

$$= 2\ 592\ 000s$$

$$A_{tan} = \frac{r\omega}{\Delta t}$$

$$= \frac{500m \times 0.11401rad/s}{2\ 592\ 000s}$$

$$= 2.1993 \times 10^{-5} m/s^2$$

Force exerted by each tangentially placed thruster:

$$F_{thrusters} = \frac{m_{station} \times a_{tan}}{50\ thrusters}$$

$$F_{thrusters} = \frac{6.74 \times 10^{10} \times 2.1993 \times 10^{-5}}{50\ thrusters}$$

$$= 2964.61N/\text{thruster}$$

5.3: Oxygen Production and Recycling

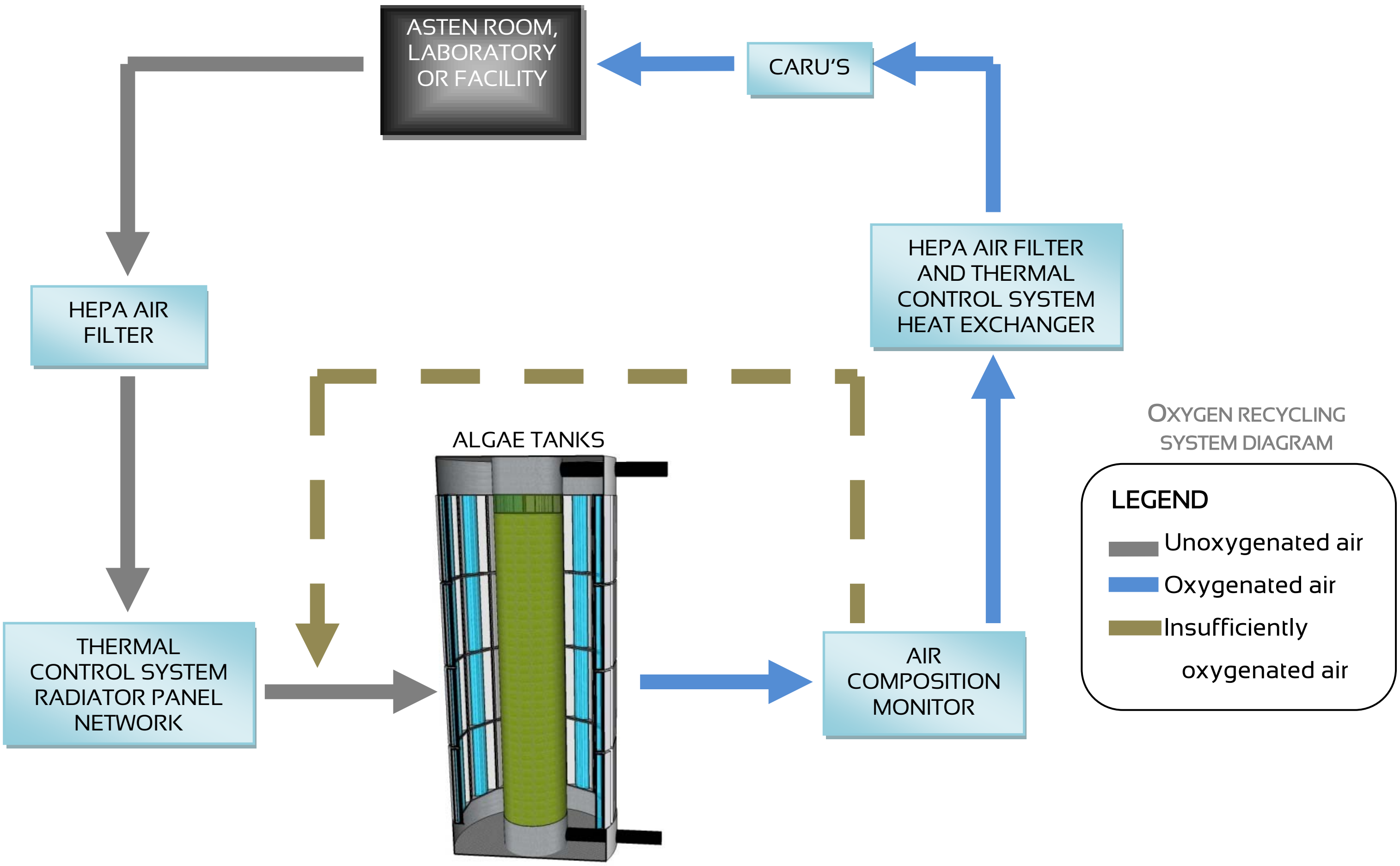


Figure 5.3A

Through cellular respiration, all living organisms are able to produce energy. Without oxygen, cellular respiration would be impossible and life would cease to exist. For this reason, an efficient oxygen recycling system must be built onboard Asten.

The Oxygen Recycling System begins with the receiving of deoxygenated air from the numerous rooms and laboratories found on the station. This deoxygenated air first goes through a HEPA air filter to remove any dust, particles or contaminants present, and then is cooled down by passing through a heat exchanger near the radiator panel network of the Thermal Control System (figure 5.1A). Once cooled down sufficiently, the air enters a complex of algae tanks found on level 4 of the Vestibule (see **3.5: Habitation Region**), which absorbs carbon dioxide and produces oxygen through the biological process of photosynthesis (figure 5.3B). Derived from an algae based oxygen recovery system constructed by The Boeing Company in 1961, each algae tank consists of a large glass-lined polycarbonate vessel filled with water and Chlorella algae (TIME, 1961). This tank is illuminated by a bank of High Intensity Discharge fixtures, which provide the light energy necessary for photosynthesis to occur. The deoxygenated air is bubbled from the bottom of the algae tank, and is changed into oxygen by the time it reaches the top of the tank (TIME, 1961). The Chlorella algae used itself is genetically modified so it does not release any toxic waste, requires less water, is less susceptible to being killed by foreign pathogens, and is more efficient at photosynthesis (TIME, 1961). Every week, the excess algae growth from the tank is removed and processed for use in agriculture and meat growing (see **5.6: Food and Nutrition**).

Once oxygenated, the air travels to an Air Composition Monitor, which analyzes the percent composition of the air, and ensures the carbon dioxide percentage does not exceed 0.5%. If the CO_2 concentration is greater than the 0.5% limit, then the air is redirected back to the algae tanks for another photosynthesis treatment (figure 5.3A). Air that passes the monitor is directed to a second HEPA filter to remove any odours acquired during the algae process, and is heated again to 21°C through the Thermal Control System Heat Exchanger (figure 5.1A). Finally the clean warmed oxygenated air is distributed throughout the entire station to the CARU's, which can make adjustments to the humidity and temperature of the incoming air (see **5.1: Environmental Control**). If the Air Composition Monitor detects an oxygen composition greater than 30%, it shuts off the lights in one or more algae tanks –stopping the photosynthesis reactions and causing the affected algae to hibernate- and mixes the oversaturated air with deoxygenated air until the concentration returns to 21%.

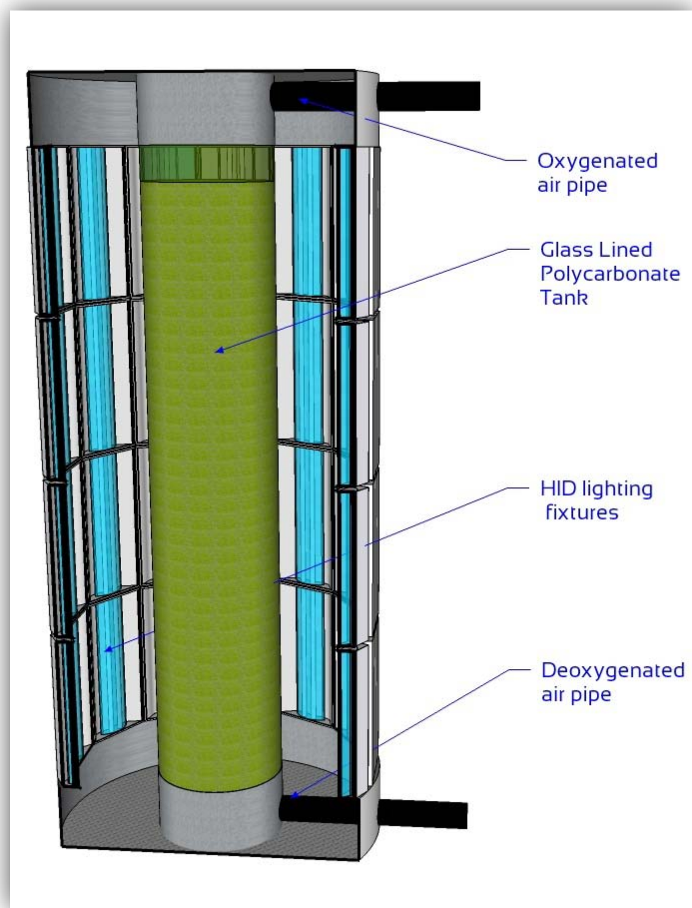


Figure 5.3B

5.4: Water Cycle

On Earth, water is found on 70% of the planet's surface, and infectious pathogens and other organic material found in waste water are often broken down by biological organisms found in the environment. On Asten, there is not enough space and water to allow for the natural breakdown of human fecal matter and other waste water. Instead artificial processes are used to mimic the natural actions of the environment, and recycle the waste water into potable water in a faster and more efficient manner.

The water cycle begins with the usage of the water in the station in the station's numerous habitat modules, rooms and laboratories. Before even entering the water filtration and storage sector of the Vestibules, the wastewater is separated into two different categories: Blackwater and Greywater. Blackwater represents water containing human fecal matter and urine, and is supplied only by the toilet drains from the numerous bathrooms found throughout the station. Greywater represents water from other sources (eg. Sink and bath drains, etc.). To conserve clean water, Greywater is used in the water ballasts of toilets (figure 5.4A). Both Blackwater and Greywater are then disinfected using Ozone (O_3) gas (produced by exposing oxygen to UV light) (figure 5.4A). The instability of Ozone causes it to react with the organic compounds in the effluent, killing any pathogens (Wikipedia, 2009). From there the paths of the Blackwater and Greywater diverge.

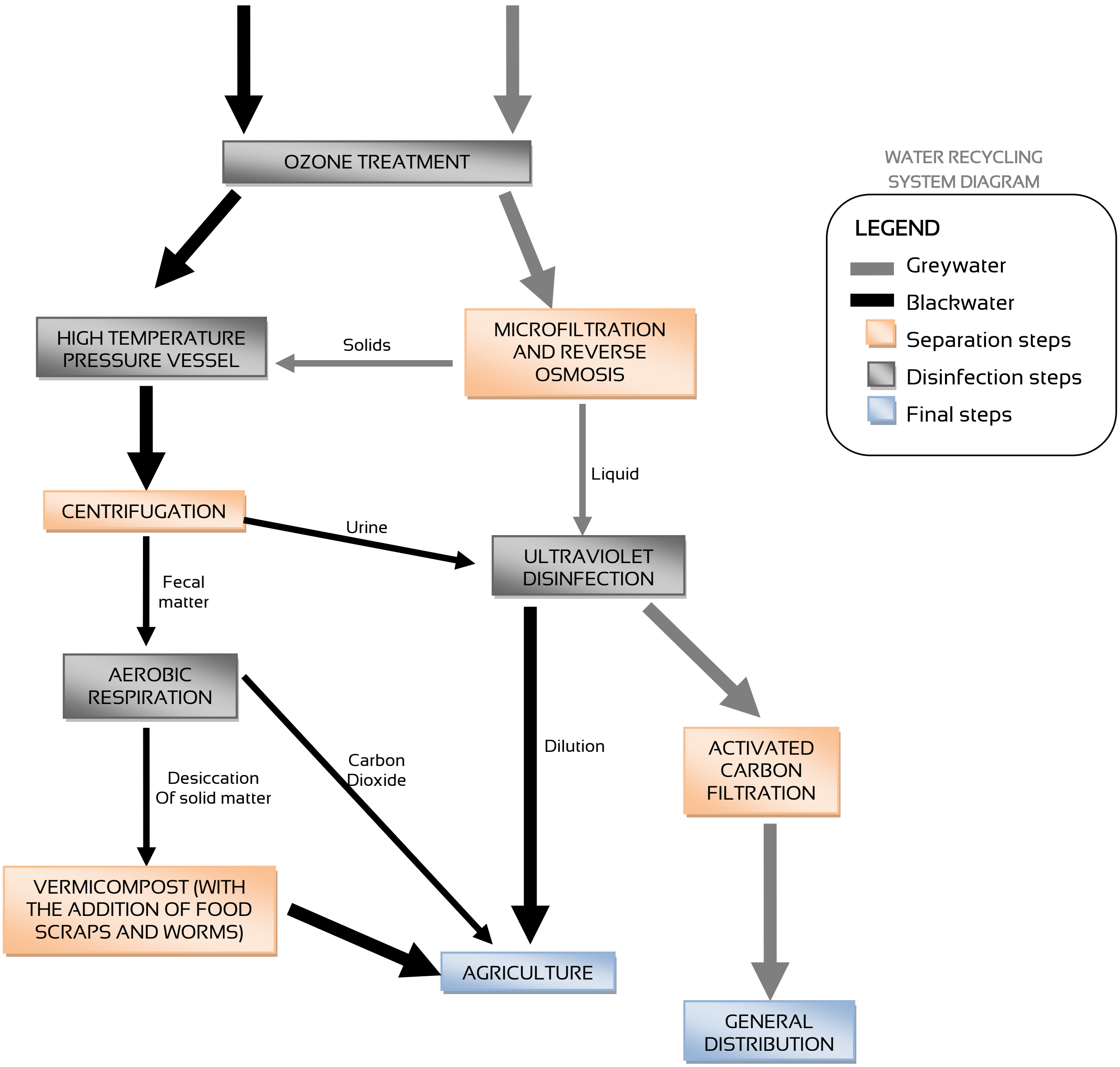


Figure 5.4A

The Blackwater first enters a high temperature pressure vessel at 300°C for 30 minutes, which kills off any remaining pathogens (figure 5.4A). It then travels to a centrifuge, which separates the fecal matter from the urine. The now disinfected sludge undergoes aerobic respiration, where bacteria consume organic matter and convert it into carbon dioxide. The carbon dioxide is pumped to the agriculture sector of the Vestibule (see **3.5: Habitation Region**), and the sludge is desiccated (dried) to form a cake-like material that can be combined with organic waste composts (eg. apple cores, banana peels) and earthworms to make vermicompost (figure 5.3A). This vermicompost is then used as fertilizer for the food crops (see **5.6: Food and Nutrition**). After being centrifuged, the urine is disinfected for a third time using UV radiation, before being diluted and used as a nitrogen fertilizer on the food crops (see **5.6: Food and Nutrition**).

After Ozone treatment, the Greywater passes through a series of microfilters and undergo reverse osmosis (the forcing of the effluent through a thin-film composite membrane permeable only to water), which removes any organic materials found in the Greywater (figure 5.4A). The filtered solids are added to the Blackwater effluent being centrifuged, and the now clean water is disinfected using ultraviolet radiation (figure 5.4A). After ultraviolet disinfection, the potable water passes through an activated carbon filter, which removes any unwanted odours, before being distributed to the rest of the station (figure 5.4A). Water samples are tested twice daily, to ensure that they are safe enough to use and drink.

5.5: Energy

Given that all life support systems rely on electricity to run, its production and storage is extremely important.

Energy Production

The only viable and reliable source of electricity available in space is the Sun. Asten relies on photovoltaic cells found on the Habitat Modules and the Vestibules to generate electricity.

The specific type of photovoltaic cell used onboard the station depends on the technology available at the time of construction. Three different technologies are considered: Multijunction photovoltaic cells, Concentrated Photovoltaic cells, and Nanoantenna arrays.

Currently in use on the International Space Station, Multijunction photovoltaic cells consist of multiple thin semiconductor films deposited onto a germanium or gallium arsenide wafer, and have been demonstrated with efficiencies of over forty percent (Wikipedia, 2009). They function by combining multiple semiconductors that operate in specific wavelength ranges (known as band gaps) to generate electricity from the entire solar spectrum, yielding more electricity (figure 5.5A, taken from http://www.stanford.edu/~slansel/projects/solar.htm) (Lansel, 2005). Its complexity of construction makes it much more expensive than monocrystalline cells, but the lightweight and high efficiency make it appealing for space applications.

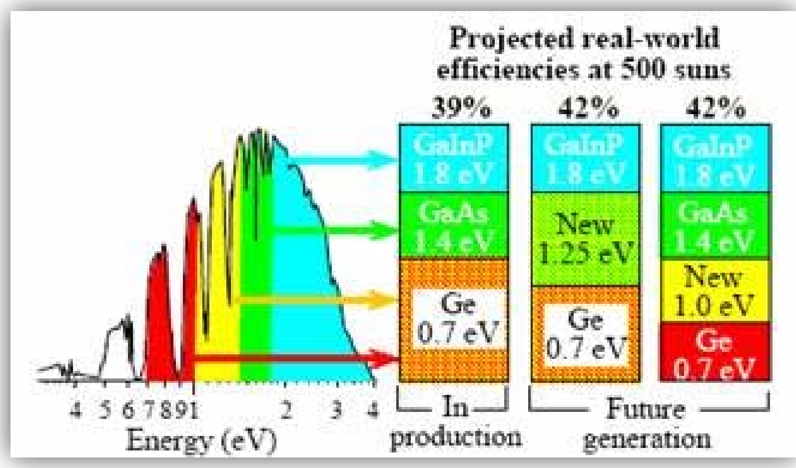


Figure 5.5A

Concentrated Photovoltaic (CPV) cells attempt to reduce the cost of multijunction cells by concentrating the sunlight over a large area onto a single high efficiency solar cell. Older generations of CPV technology involve the use of parabolic dish and trough collectors, or Fresnel lenses (Wikipedia, 2009). Although efficient, they must constantly track the sun’s movement in order to generate electricity, and their profiles are prohibitively large. Newer generations of CPV technology involve light-

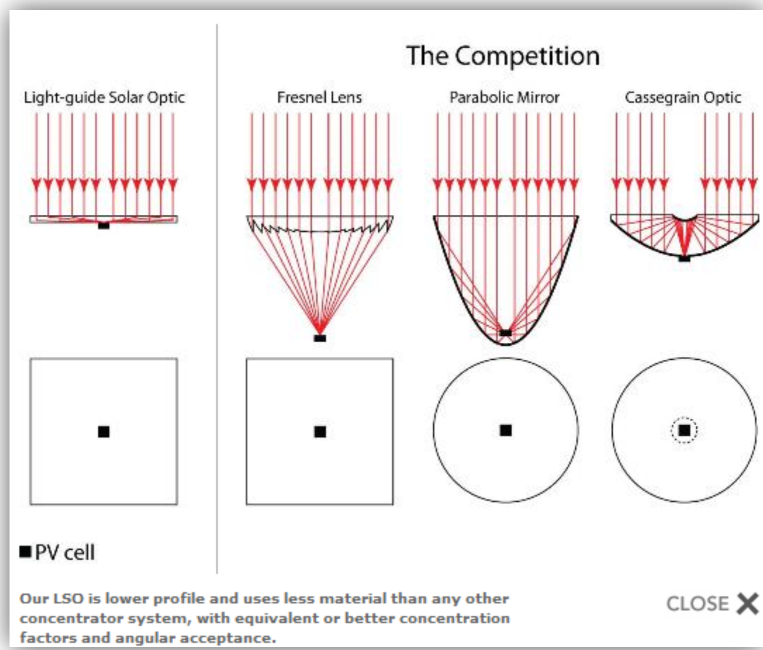


Figure 5.5B

guided solar optics (LSO), where the sunlight is trapped in a layer of acrylic only 5mm thick, and concentrated onto a single photovoltaic cell (figure 5.5B, taken from http://www.morgansolar.com/lgo.php)(Morgan Solar, 2009). Such technologies boast the ability to concentrate 1400 suns between 26 and 30% efficiency, making it attractive for large scale solar applications (such as Asten's energy system) (Morgan Solar, 2009).

The final option, Nanoantenna arrays, generate from the Infrared wavelengths of the sun using a new technology developed by the Idaho National Laboratory, Microcontinuum Inc. and the University of Missouri (Courtland, 2007). This technology consists of small metal "nanoantennas" printed on a sheet of plastic (figure 5.5C, taken from http://www.solarpowerauthority.com/archives/2008/01/is-the-future-of-solar-a-tiny-antenna.html) (Courtland, 2007). When struck with infrared light, the nanoantennas resonate and produce alternating electric current, thus generating electricity at an estimated 80% efficiency (Courtland, 2007). The only drawback to the technology is that the frequency of the generated current is ten thousand billion hertz, when compared to standard home appliances that use sixty hertz, is much too high (Courtland, 2007). However given that the station is presumed to be built within the near future, it can be assumed that a method to reduce the oscillation will be found.

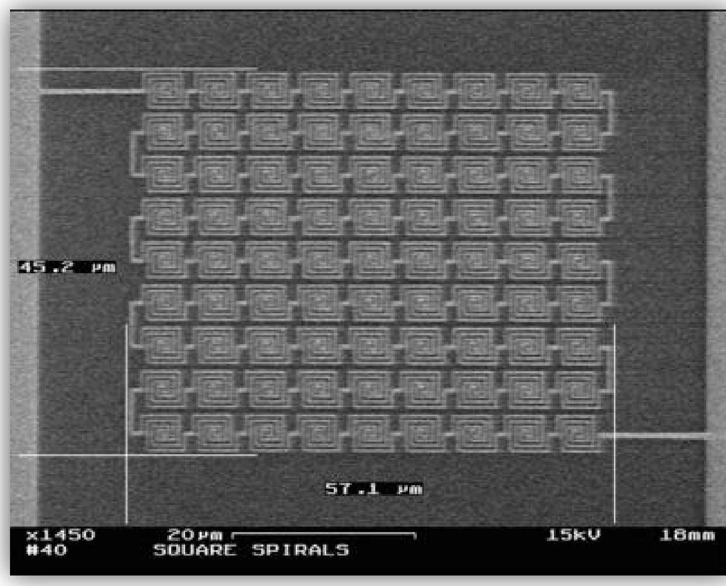


Figure 5.5C

The system used onboard Asten depends upon the technology available at the time of construction. Given that the ideal photovoltaic system desired is a fine balance between cost and efficiency, the best option at present would be the LSO CPV cells. If the manufacturing costs decrease substantially within the next few years, then the higher efficiency Multijunction option will be used. Finally if the technology for rectifying the high current frequency of Nanoantenna is developed and available, then they will be used to generate electricity.

Energy storage

Because the station is planned to be located in Geostationary Earth Orbit, it will always be in view of the sun (due to the tilt of the Earth) except for a duration of one hour during the spring and fall equinoxes (Potter, 1998). Therefore continuous electricity can be generated onboard acbdefg. In order to deal with fluctuations in energy demand (greater during the day then at night) energy storage system is required. These energy storage facilities are located in the "Station Control and Primary Energy Storage" sector in the CIH (see **3.6: Central Industry Hub**), the fourth level of the Vestibules, and the "basement" area in each Habitat Module (see **3.5: Habitation Region**)

When looking for possible methods of storing electricity onboard Asten, we came across three possibilities: rechargeable batteries, flywheels, and superconducting magnetic energy storage. Batteries take the electrical energy and convert it into chemical energy with the buildup of electrons on the negative terminal of the battery (Brain and Bryant, 2008). Commercially available rechargeable batteries such as nickel-cadmium or rechargeable alkaline batteries are not viable for grid energy storage, as they have a low cycle life. Flow batteries such as Vanadium Redox batteries or Sodium-sulfur batteries are the best option, as they can be charged and discharged multiple times, and can store large amounts of energy (Wikipedia, 2007). Of the two, vanadium redox batteries are safer, but they require a larger amount of space.

Flywheels work by converting the electrical energy into the mechanical energy of a spinning wheel (figure 5.5D, taken from http://www.vyconenergy.com/). They can last years with minimal maintenance and have energy efficiencies up to 90% (where the energy outputted is up to 90% the energy inputted) (Wikipedia, 2007). In addition, they do not contain any toxic chemicals found in batteries, and can store up to 133kWh (with present day materials). The spinning of the flywheel also produces a gyroscopic effect, which can help in maintaining the orientation of Asten towards the sun. The only downside to flywheels is that expensive and technologically complex magnetic bearings are required in order for flywheels to be considered viable for grid energy storage.

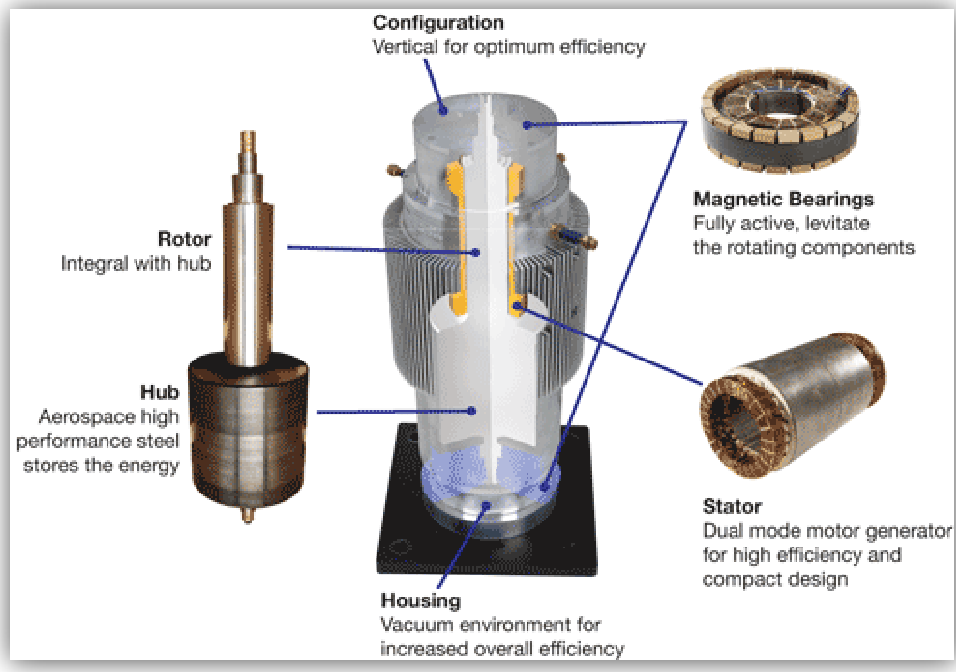
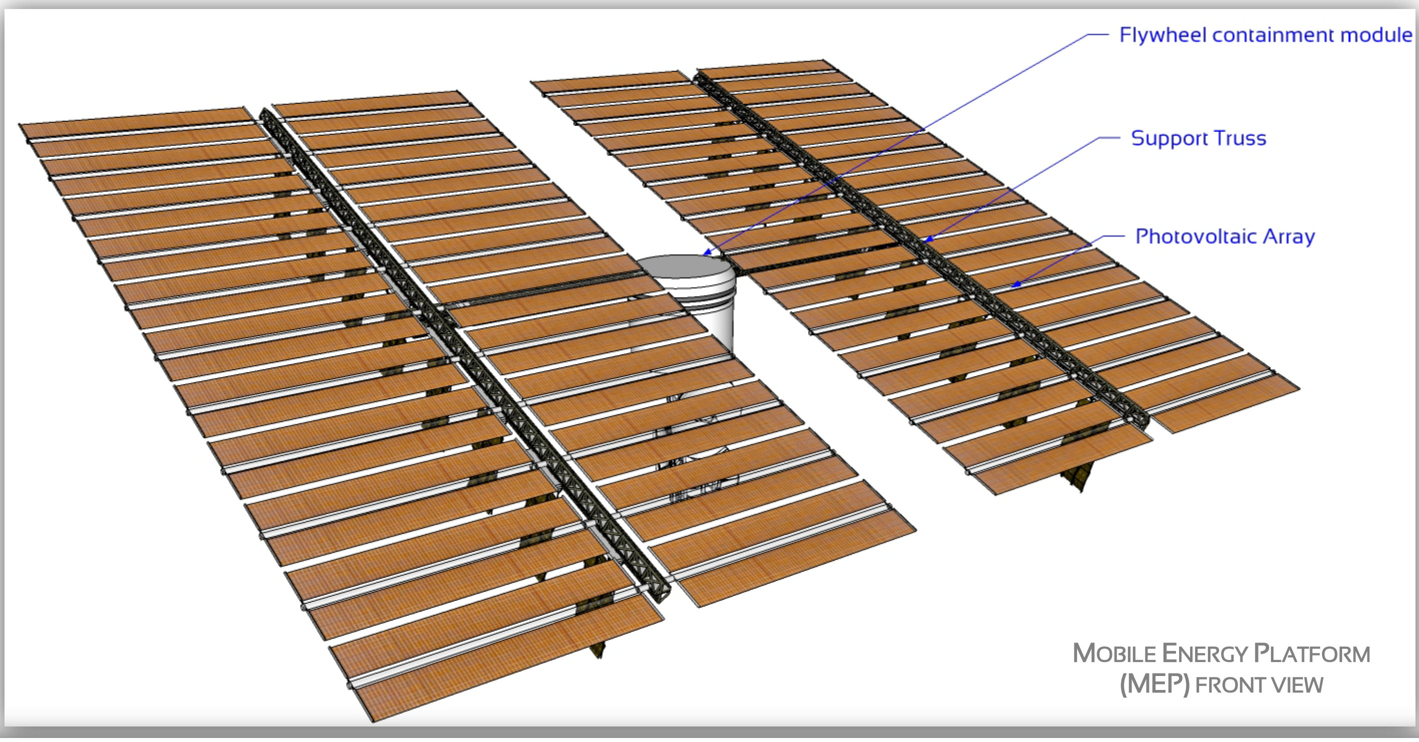


Figure 5.5D

Superconducting magnetic energy storage (SMES) is superior to both flywheels and batteries in that they are have no moving parts, no chemicals, and are over 95% efficient at storing energy. They work by converting the electrical energy into magnetic energy by flowing electricity through a superconducting wire, producing a magnetic current which can be stored and harnessed at a later time to produce electricity (Unknown, 2002). Although extremely efficient and safe, the length of superconductive wire needed can exceed 160 kilometres. In addition, the large magnetic fields produced will affect nearby machinery, and the long term effects of large magnetic fields on humans are not known (Wikipedia, 2007).

Given present day technology, Flywheel Energy storage appears to be the best option, and will be used to store the majority of electrical energy onboard the station. Sodium Sulfur batteries are used as secondary storage options, and will also be used as emergency energy storage for each Habitat Module (see **3.5: Habitation Region**). Although more efficient, Superconducting Magnetic Energy Storage is not viable because of its complexity and the strong magnetic field generated.



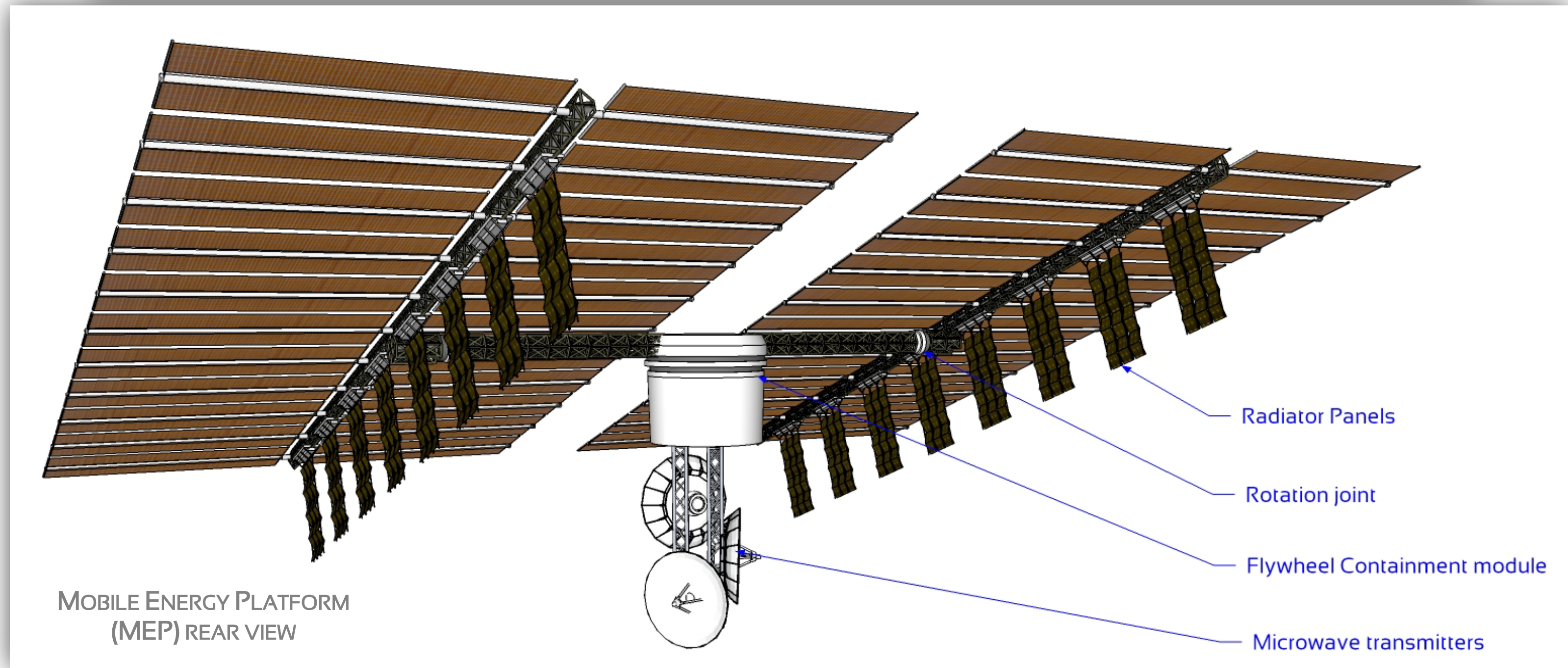


Figure 5.5D

Mobile Energy Platforms

Also located in geostationary orbit near the station, the Mobile Energy Platforms (MEPs) serve as an additional power source for Asten. MEPs are large solar power satellites, whose sole purpose is to generate electricity from the sun. Electricity is generated with the use of photovoltaic cells, and is stored in a flywheel located in the center of the satellite, which also ensures the MEP is constantly facing the sun (figure 5.5E). This energy can also be transmitted to Asten or the Earth to via microwaves, where they are rectified back into electricity. A buildup of heat is prevented by means of radiator panels located on the far side of the platform (figure 5.5E).

5.6: Food and Nutrition

Nutrition Charts

The following chart shows the main crops to be grown onboard Asten and the amount of nutrients they each carry arranged from most nutritious to least (taken from http://www.nal.usda.gov/fnic/foodcomp/search/). These specific foods were chosen because they contained are the most nutritious and are the easiest to grow.

Fruit/Vegetable Grown	Serving Size (in g)	Nutrients (% of daily recommended value)
Spinach	180	vitamin K (1110.6), vitamin A (294.8), manganese (84), folate (65.6), magnesium (39.1), iron (35.7), vitamin C (29.4), vitamin B2 (24.7), calcium (24.5), potassium (24), vitamin B6 (22), tryptophan (21.9), fiber (17.3), copper (15.5), vitamin B1 (11.1), protein (10.7), phosphorous (10.1), zinc (9.1), vitamin E (8.6), omega 3 fatty acids (6), vitamin B3 (4.4), selenium (3.9)
Sesame Seeds	36	copper (74), manganese (44), tryptophan (37.5), calcium (35.1), magnesium (31.6), iron (29.1), phosphorous (22.6), zinc (18.7), vitamin B1 (18.7), fiber (17)
Lettuce	112	vitamin K (143.5), vitamin A (58.2), vitamin C (44.8), folate (38), manganese (35.5), chromium (13.1), potassium (9.3), molybdenum (9), fiber (7.6), vitamin B1 (7.3), iron (6.8), vitamin B2 (6.5), phosphorous (5), calcium (4), protein (3.6), omega 3 fatty acids (3.2), tryptophan (3.1), vitamin B3 (2.8), vitamin B6 (2.5)
Onions	160	chromium (20.7), vitamin C (17.1), fiber (11.5), manganese (11), molybdenum (10.7), vitamin B6 (9.5), tryptophan (9.4), folate (7.6), potassium (7.2), phosphorous (5.3), copper (5)
Tomatoes	180	vitamin C (57.3), vitamin A (22.4), vitamin K (17.8), molybdenum (12), potassium (11.4), manganese (9.5), fiber (7.9), chromium (7.5), vitamin B1 (7.3), vitamin B6 (7), folate (6.8), copper (6.5), vitamin B3 (5.6), vitamin B2 (5.3), magnesium (5), iron (4.5), vitamin B5 (4.4), phosphorous (4.3), vitamin E (3.4), tryptophan (3.1), protein (3.1)

Crimini mushrooms	141.75	selenium (52.6), vitamin B2 (40.6), copper (35.5), vitamin B3 (26.9), tryptophan (25), vitamin B5 (21.3), potassium (18.1), phosphorous (17), zinc (10.4), manganese (10), vitamin B1 (8.7), vitamin B6 (8), protein (7.1), folate (5), fiber (3.4), magnesium (3.2), iron (3.2), calcium (2.6)
Seaweed	20	iodine (276.7), vitamin K (16.5), folate (9), magnesium (6), calcium (3.4), iron (3.2), tryptophan (3.1)
Strawberries	144	vitamin C (136.1), manganese (21), fiber (13.2), iodine (8.6), potassium (6.8), folate (6.4), vitamin B2 (5.9), vitamin B5 (4.9), omega 3 fatty acids (4.4.), vitamin B6 (4), vitamin K (4), magnesium (3.6), copper (3.5)
Raspberries	123	manganese (62), vitamin C (51.3), fiber (33.4), folate (8), vitamin B2 (7.1), magnesium (5.5), vitamin B3 (5.5), potassium (5.3), copper (5)
Soybeans	172	molybdenum (172), tryptophan (115.6), manganese (71), protein (57.2), iron (49.1), phosphorous (42.1), fiber (41.3), vitamin K (41.3), omega 3 fatty acids (41.2), magnesium (37), copper (35), vitamin B2 (28.8), potassium (25.3)
Peanuts	36.5	manganese (35.5), tryptophan (28.1), vitamin B3 (22), folate (21.9), copper (21), protein (18.8)
Oranges	131	vitamin C (116.2), fiber (12.5), folate (9.9), vitamin B1(7.3), potassium (6.8), vitamin A (5.4), calcium (5.2)
Corn	164	vitamin B1 (24), folate (19), fiber (18.4), vitamin C (16.9), phosphorous (16.9), manganese (16), vitamin B5 (14.4)
Carrot	112	vitamin A (686.3), vitamin K (20.1), vitamin C (18.9), fiber (14.6), potassium (11.3), vitamin B6 (9), manganese (8.5), molybdenum (8.1), vitamin B1 (8), vitamin B3 (5.6), phosphorous (5.4), magnesium (4.6), folate (4.3)

The next chart shows which foods contain the following nutrients, and are listed in alphabetical order.

NUTRIENT	FOOD (% OF DAILY RECOMMENDED VALUE)
Calcium	sesame seed (97.5), sea weed (17), spinach (13.6), lettuce (3.6), orange (4), mushroom (1.8)
Chromium	onion (12.9), lettuce (11.7), tomato (4.2)
Copper	sesame seed (205.6), peanut (57.5), mushroom (25), soy bean (20.3), spinach (8.6), raspberry (4.1), tomato (3.6), onion (3.1), strawberry (2.4)
Fiber	sesame seed (47.2), raspberry (27.2), soy bean (24), carrot (13), corn (11.2), spinach (9.6), orange (9.5), strawberry (9.2), onion (7.2), lettuce (6.8), tomato (4.4), mushroom (2.4)
Folate	peanut (60), sea weed (45), spinach (36.4), lettuce (33.9), corn (11.6), orange (7.6), raspberry (6.5), onion (4.8), strawberry (4.4), carrot (3.8), tomato (3.8), mushroom (3.5)
Iodine	seaweed (1383.5), strawberry (6)
Iron	sesame seed (80.8), soy bean (28.5), spinach (19.8), sea weed (16), lettuce (6.1), tomato (2.5), mushroom (2.3)
Magnesium	sesame seed (87.8), sea weed (30), spinach (21.7), soy bean (21.5), raspberry

	(4.5), carrot (4.1), tomato (2.8), strawberry (2.5), mushroom (2.3)
Manganese	sesame seed (122.2), peanut (97.3), raspberry (50.4), spinach (46.7), soy bean (41.3), lettuce (32), strawberry (14.6), corn (9.8), carrot (7.6), mushroom (7.1), onion (6.9), tomato (5.3)
Molybdenum	soy bean (100), lettuce (8), carrot (7.2), onion (6.7), tomato (6.7)
Omega 3 fatty acids	soy bean (24), spinach (3.3), strawberry (3.1), lettuce (2.9)
Potassium	soy bean (14.7), spinach (13.3), mushroom (12.8), carrot (10.1), lettuce (8.3), tomato (6.3), orange (5.2), strawberry (4.7), onion (4.5), raspberry (4.3)
Phosphorus	sesame seed (62.8), soy bean (24.5), mushroom (12), corn (10.3), spinach (5.6), carrot (4.8), lettuce (4.5), onion (3.3), tomato (2.4)
Protein	peanut (51.5), soy bean (33.3), spinach (5.9), mushroom (5), lettuce (3.2), tomato (1.7)
Selenium	mushroom (37), spinach (2.2)
Tryptophan	sesame seed (104.2), peanut (77), soy bean (67.2), mushroom (17.6), sea weed (15.5), spinach (12.2), onion (5.9), lettuce (2.8), tomato (1.7)
Vitamin A	carrot (612.8), spinach (163.8), lettuce (52), tomato (12.4), orange (4.1)
Vitamin B1	sesame seed (51.9), corn (14.6), carrot (7.1), lettuce (6.5), spinach (6.2), mushroom (6.1), orange (5.6), tomato (4.1)
Vitamin B2	mushroom (28.6), soy bean (16.7), spinach (13.7), lettuce (5.8), raspberry (5.8), strawberry (4.1), tomato (2.9)
Vitamin B3	peanut (60.3), mushroom (19), carrot (5)raspberry (4.5), tomato (3.1), lettuce (2.5), spinach (2.4)
Vitamin B5	mushroom (15), corn (8.8), strawberry (3.4), tomato (2.4)
Vitamin B6	spinach (12.2), carrot (8), onion (5.9), mushroom (5.6), tomato (3.9), strawberry (2.8), lettuce (2.2)
Vitamin C	strawberry (94.5), orange (88.7), raspberry (41.7), lettuce (40), tomato (31.8), carrot (1.69), spinach (16.3), onion (10.7), corn (10.3)
Vitamin E	spinach (4.8), tomato (1.9)
Vitamin K	spinach (617), lettuce (128.1), sea weed (82.5), soy bean (24), carrot (17.9), tomato (9.9), strawberry (2.8)
Zinc	sesame seed (51.9), mushroom (7.3), spinach (5.1)

<u>Agriculture and Nutrient Cycle</u>

Because of the limited space, the higher crop yield, and the disadvantages of soil-based growing, hydroponic crop growing –specifically Passive sub-irrigation- is used to grow the foods eaten by Asten inhabitants. The growing technique of hydroponics involves the growth of plants in a nutrient solution rather than soil, and has been demonstrated to be a much more efficient way of growing plants and crops. Passive sub-irrigation (also known as passive hydroponics) is a subsection of consists of the growing of plants within an inert and porous non-soil medium, such as expanded clay pellets, perlite, vermiculite and rockwool (Wikipedia, 2009). At the base of the growing medium is a reservoir of nutrient solution. Plants grow in the liquid saturated medium, taking up water and nutrients from the solution through capillary action (Wikipedia, 2009). There are a number of advantages of Passive sub-irrigation when compared to normal hydroponics/aeroponics. The first is that the plant only takes up as much as it needs, and as such is not subjected to over-watering and "root rot". The second is that the porous nature of the growing medium allows for air to reach the roots, a common problem faced by soil-based agriculture. Finally, Passive sub-irrigation is almost maintenance free, requiring no pumps or sprays or complex machinery to operate.

On Asten, the hydroponic crops can be found in the agricultural area on level 1 of the Vestibule (see **3.5: Habitation Region**). The plants themselves grow on racks, each equipped with a removable tray of non-soil medium in which the plant seeds are placed (figure 5.6A). This removable tray sits on a second tray of nutrient solution, allowing the medium to be saturated and providing the plant with the minerals it needs to grow. Each rack contains a series of violet, blue and red LED lights, which provide light energy for the plants to grow, without increasing the rate of evaporation (photosynthesis works best under violet, blue and red light). These racks are stacked one atop another, allowing for a much greater number of crops to be grown over the same floor area. Carbon dioxide generated from the aerobic decomposition of human waste (see **5.4: Water Cycle**) is pumped from the wastewater treatment facility to the growing racks, where it is used by the plants to perform photosynthesis.

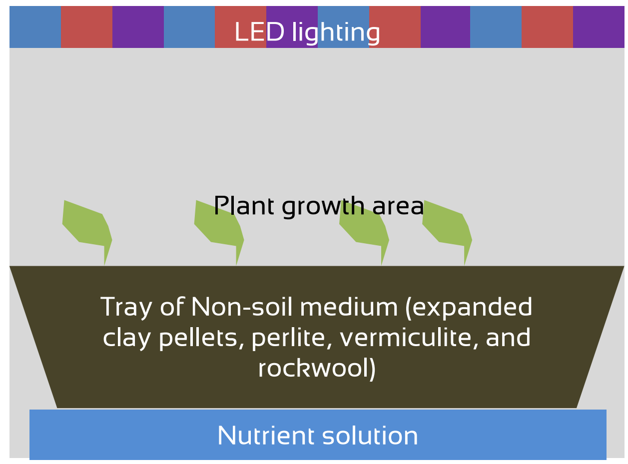


Figure 5.6A

Rather than having a nutrient solution filled with artificial fertilizer (which would make Asten dependent upon the Earth for survival and non-self-sufficient), the nutrient solution consists of treated and disinfected human sewage (see 5.4: Water Cycle). Although it sounds repulsive at first, human waste contains all the 7.5kg of nitrate, potassium, and phosphorus needed to grow 250kg of crops (Water Policy International, 2000). Feces contains 12% of the nitrogen, 33% of the phosphorus 29% of the potassium and 46% of the carbon in wastewater (Water Policy International, 2000). Urine holds the remaining 88, 67 and 71 percent of nitrate, potassium and phosphorus. By recycling the clean and disease free waste of humans, a closed nutrient cycle is developed (figure 5.6B).

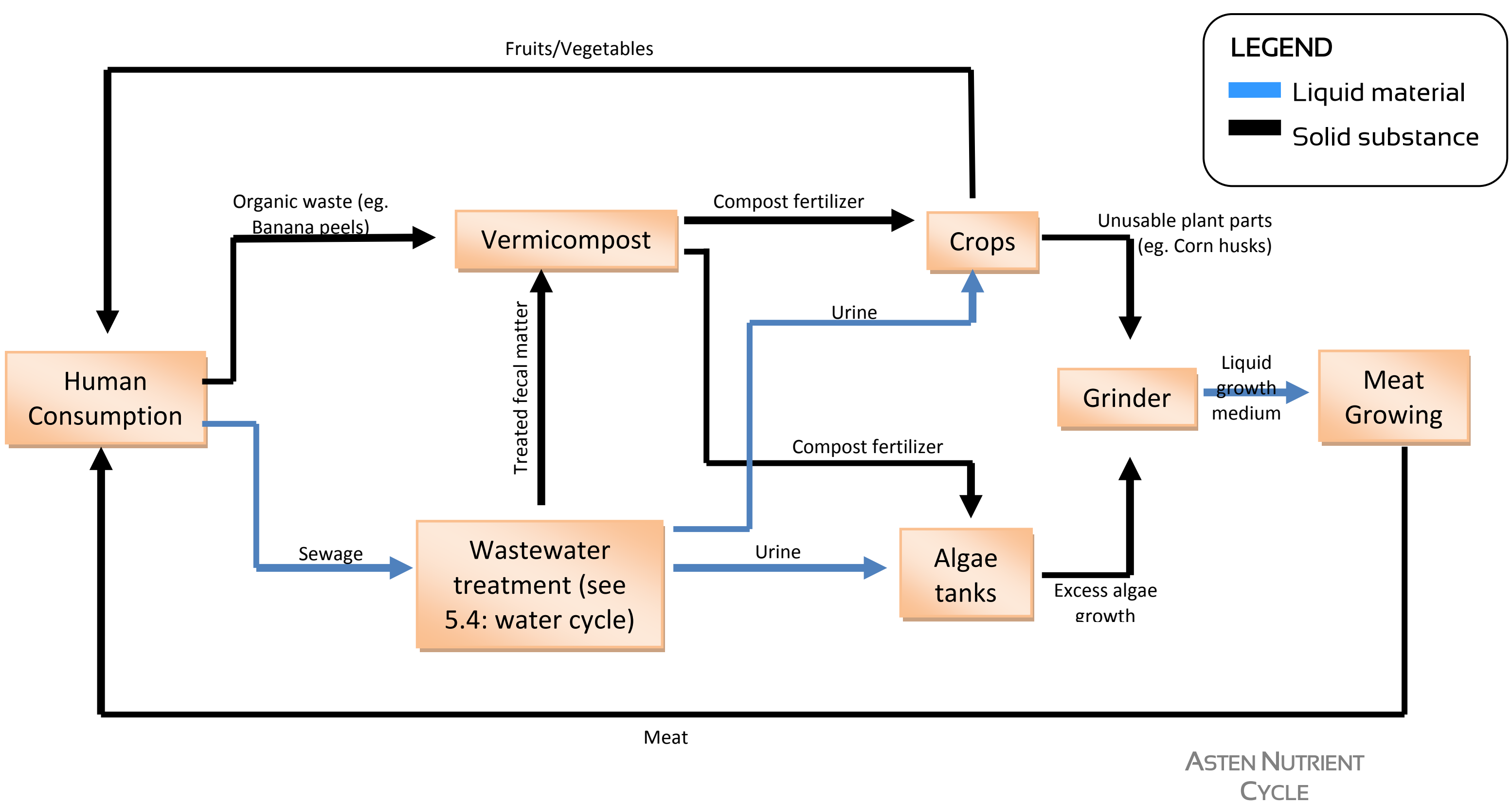


Figure 5.6B

Meat Growing

Meat is a food commonly consumed by humans today. It is a source of a vast amount of nutrients that are necessary for the good health and well being of humans. These nutrients include: amino acids, proteins, calcium, zinc, and even vitamins. The wide range of meats supply humans with many nutrients and is a source that outmatches many plants and other forms of foods. Thus, to fully benefit from the repertoire of food available to the human race, meat consumption is essential.

Meat growing is a process in which cells are reproduced in laboratories without the actual animal which voids the ethical issues of whether the animal is fairly treated or not. Cells, such as skeletal muscle, which makes up the majority of the meat, are grown in thin sheets. This is done by seeding a collagen matrix with muscle cells, submerging it in a nutrient solution and inducing the replication and growth of the cells. In order to keep the same texture and quality as the products from organic meat, the cultured meat will be mechanically stretched, exercised, and electrically stimulated.

In order to keep the cultured meat alive, a nutrient solution derived from grinded unusable plant parts (eg. corn husks) and excess algae taken from the oxygen recycling system (see **5.3: Oxygen Production and Recycling**). Oxygen is bubbled through the nutrient solution in order to keep the cells alive.

5.7: Safety and Security

Safety and security onboard Asten is extremely important, as a disaster on the station could result in major structural damage and the loss of thousands of lives.

Micrometeoroid protection

Rather than develop entirely new ways of protecting the Asten from the threat of micrometeoroids, it was decided to use existing technology that has been tested and is being used by NASA spacecraft. For the majority of the station, micrometeoroid protection is provided by multi-shock shields, which consist of three Nextel layers spaced apart at specific distances combined with an aluminum rearwall (figure 5.7, taken from http://hitf.jsc.nasa.gov/hitfpub/shielddev/basicconcepts.html). The Nextel layers repeatedly shock the incoming projectile, causing it to break apart into smaller and smaller fragments until they can no longer perforate the rearwall (Hyde, 2006). They are currently in use onboard the ISS as protection against possible micrometeoroid collisions, and have been demonstrated by NASA's Hypervelocity Impact Technology Facility (HITF) to withstand the impact of 10mm projectiles travelling at speeds of 6.1km/s (Hyde, 2006). The additional Beta cloth layer that protects against atomic oxygen degradation also serves as a layer of protection against micrometeoroids.

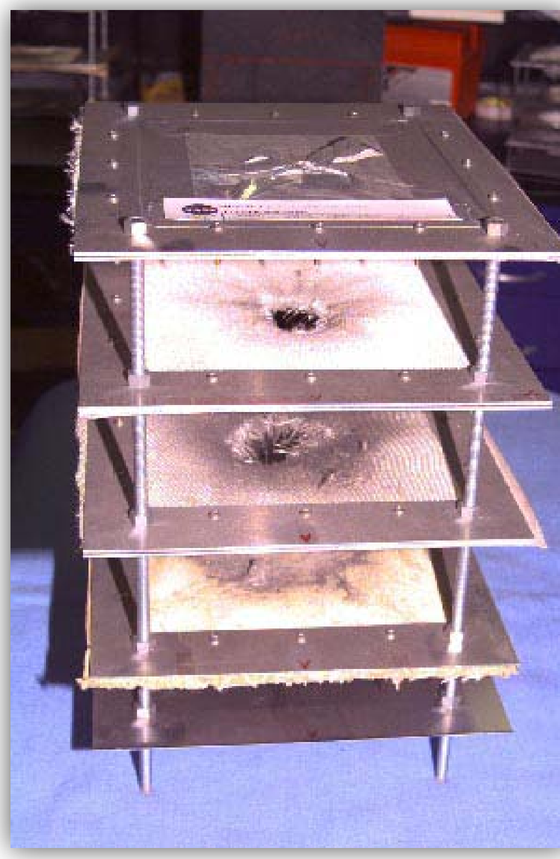


Figure 5.7A

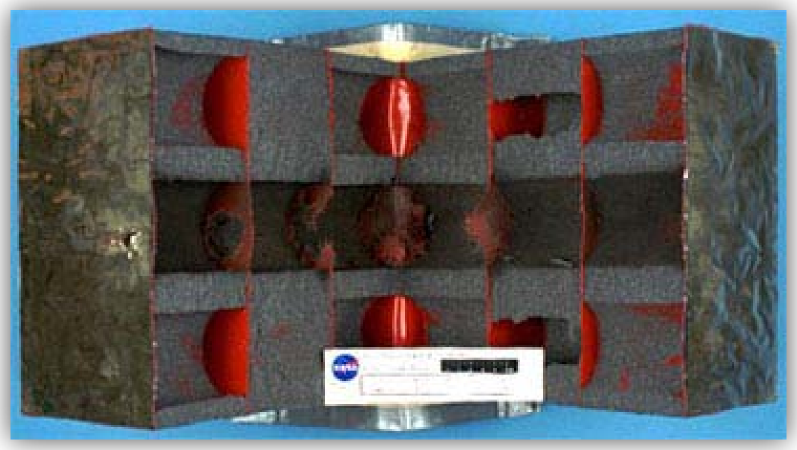


Figure 5.7B

The Habitat modules are protected by a similar system, using layers of Kevlar, Mylar and Nextel to shock any incoming projectile (Hyde, 2006). The only difference is that the open space between the layers is replaced with open cell foam, and has been tested by HITF to withstand particles up to 6.35mm in diameter and travelling at a speed of 6.5km/s (figure 5.7B, taken from http://hitf.jsc.nasa.gov/hitfpub/analysis/mars3.html) (Hyde, 2006).

Radiation protection

Radiation is also another hazard, as described in ***Challenges*** section. Protection from radiation onboard Asten is provided by multiple layers of Demron –a lightweight and flexible nanopolymeric compound developed by Radiation Shield Technologies currently being considered for use by NASA (Ashley, 2003). Demron's structure consists of a variety of organic and inorganic salts embedded in a polymer composite of polyurethane and polyvinylchloride, the salts mimicking the atomic structure of heavy metals like lead because of high atomic numbers (Ashley, 2003). The electron clouds of these salts absorbs the energy of gamma and x-ray radiation and converts it into heat, or scatters them, where they are absorbed by surrounding particles (Ashley, 2003). A sample thickness of 0.38mm was found to provide a factor three protection against beta radiation and a factor ten protection against low-energy gamma radiation. By layering multiple sheets of lightweight, fabric-like Demron under the Multi-Shock Shields; Asten is able to provide the same amount of protection from solar and cosmic radiation as thick heavy lead plates.

Five Code system

The Five Code system is the warning system used aboard Asten to inform all inhabitants and personnel onboard of an emergency or problem (figure 5.7C):

Five Code System

Code White

- Minor Mechanical failure (ex. Broken valve for ventilation of HR)
- Life support systems unaffected
- General populace not informed
- Control centre informed every two hours
- Event recorded and sent to Ground Control for analysis

Code Yellow

- Major mechanical failure/ emergency (ex. Small fire/ failure of monitoring systems)
- Life support systems may be affected
- General populace not informed
- Control centre informed every five minutes
- Event recorded and sent to Ground Control for analysis

Code Orange

- Failure of a life support system/ large fire
- Entire station informed every 2 minutes
- All personnel readied to evacuate within a moment's notice
- Event recorded and sent to Ground Control for analysis

Code Red

- Failure of most life support systems
- Evidence of structural failure/ depressurization risk present
- Complete emergency evacuation of Asten within 10 minutes
- Warning siren every two seconds
- Event recorded and sent to Ground Control for analysis

Code Black

- Complete failure of all life support systems/structural failure and depressurization of Asten
- Asten stops rotating
- Any remaining personnel must immediately evacuate
- Repair/Salvage Crew sent from Earth to repair/salvage station
- Event recorded and sent to Ground Control for analysis

Figure 5.7C

Emergency evacuation

Evacuation of Asten occurs when a Code Red is issued, and consists of the inhabitants entering specially designed escape vehicles that take them back to Earth. Essentially larger versions of the cancelled Crew Return Vehicle (CRV), the 1200 escape vehicles can be found within the Habitation Region, and are located every 7 Habitat Modules (figure 5.7D). Capable of holding twelve people, the escape vehicles are programmed to fly away from Asten using the centripetal force and rocket engines, re-enter the atmosphere, and glide down to the Eastern U.S. Coast, where recovery ships will pick them up. Each escape vehicle holds emergency water and food supplies, as well as a GPS tracker and spacesuits, in the case of a depressurization of the vehicle, or a crash landing in an uninhabited area.

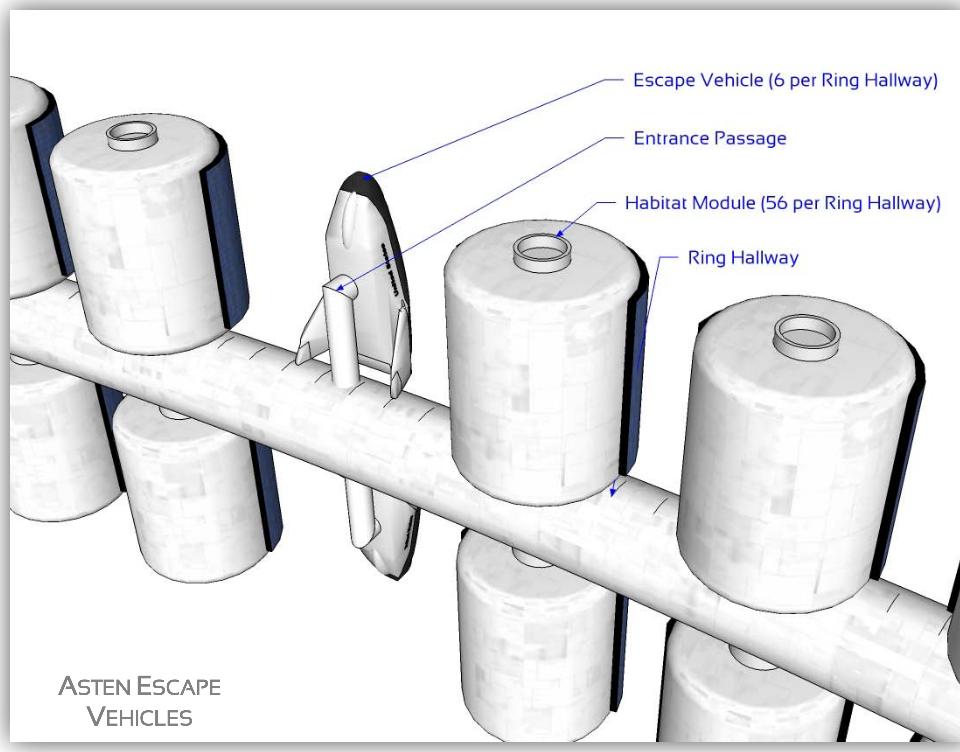


Figure 5.7D

Escape vehicles capable of holding 25 people can also be found in the Docking Network of the Central Industry Hub. The Docking Channels that link the Central Corridor to the docking Spacecraft are each equipped with ablative heat shields and a parachute, as well as emergency supplies and fold down canvas seating. In the case of an evacuation, inhabitants in the Central Industry Hub can escape in the Docking Channels, which can separate from the station and re-enter the atmosphere in the same fashion as the Escape Vehicles of the Habitation Region.

Authorized Access

To reduce the possibility of vandalism and accidents, certain areas of the space station will be off-limits to the general population. These areas include the Support Sector of the Habitation Region and the Station Control and Energy Sector of the Central Industry Hub. Access to these areas will be restricted to those who have a card pass and pass an iris scan.

Firearms and explosives

Firearms and explosives are strictly prohibited onboard Asten, even to law enforcement personnel, as there is a risk of damaging any life support systems or worse, opening a hole to outer space, depressurizing a segment of the station.

Section 6: Asten Social Structure

6.1: Station Demographics

Choosing Inhabitants

Given that the economy of Asten depends upon the mining industry, the construction of satellites, and the research expected to take place on the station, highly skilled and professional employees chosen by the leasing companies will make up the majority of the population of Asten. The use of experienced workers reduces the need for lengthy retraining programs, and allows for research, development and manufacturing facilities on board the station to be used to their fullest potential. However even though companies will have the ability to choose the initial population of Asten, the potential inhabitants will still be required to undergo a battery of tests to ensure they are fit to live on a rotating space station.

There are three evaluations administered to all potential residents to determine their suitability:

1. An adaptation test: settlers are placed in a special area of the adaptation center, where they live for three to four weeks in a windowless facility without access to the outside world. Physical and psychological examinations take place before and after the test, to determine the effect on the settlers and evaluate their ability to live for an extended period of time in a confined environment.
2. A medical and criminal examination: Each settler is examined by a doctor, who ensures that they are healthy and do not carry any dangerous diseases (such as tuberculosis). Then the settler undergoes a criminal examination, where their name is checked with every world government's criminal database to see if they possess any criminal record.
3. An interview: Each settler/settler's family meets with a psychologist, who evaluates their social behaviour and can identify any troubling personality traits that could affect other settlers (eg. aggressive and violent behaviour, alcoholism, etc.).

Any settlers not sponsored by the leasing companies are further evaluated using a point system. Points are awarded based upon level of education, age, marital status, work experiences and language skills (each tested or supported by official documentation). Total points of each individual would then be tallied, with the highest scoring candidates being chosen to live on the station. The point system can be explained in the following table:

Evaluation Criteria	**Level Attained**	**Points Awarded**
Work Experience	No work experience/work experience of no value (eg. serving in fast food restaurants)	0
	0-2 years of work experience	5
	2-4 years of work experience	10
	4-6 years of work experience	15
	6-8 years of work experience	20
	8+ years of work experience	25
	Work experience in two different fields	Work Points awarded x 1.5
	Work experience in three or more different fields	Work Points awarded x 2
Education level	Did not complete High School	-10
	Completed only High School	-5

	Two-four year community college diploma/ trade certificate/apprenticeship	5
	Two-four year community college diploma/ trade certificate/apprenticeship in more than one field	7
	Two-five year university/college bachelor degree	11
	Two-five year university/college bachelor degree in more than one field	17
	Master's/Post Doctorate degree	21
	Master's/Post Doctorate degree in more than one field	25
Age	16 and younger	5
	17-20	8
	21-49	10
	50-55	8
	55-60	4
	60+	2
Language skills	No English skills	-8
	Low English proficiency	-5
	Moderate English proficiency	0
	Fluent in English	5
	Fluent in Mandarin/Hindu	4
	Fluent in three or more languages	10
Marital status	Single/Common law/Divorced or widowed without children	5
	Single/Common law/Divorced or widowed with children	8
	Married with no children	5
	Married with one-three children	10
	Married with four or more children	-5
	Total possible points	**114**

The importance of each evaluation is shown with the following table:

EVALUATION	WEIGHT (%)
1. Point system*	**50**
2. Interview	**25**
3. Adaptation test	**15**
4. Medical/Criminal examination	**10**

**sponsored inhabitants are exempt from this category, and are compared amongst themselves using the other three evaluations*

<u>Population demographics:</u>

Because the majority of the population is to be sponsored by the leasing companies or may have families, it would be unethical and unrealistic to impose a strict division of the population according to age or sex. However at the same time it would also be impractical to have a population that is 90% female and 10% male, or 80% over the age of forty-five and only 20% under the age of forty-five for example.

Therefore for sex distribution, 50% male and 50% female is the target, with a tolerance of 15% (up to 65% male and 35% female, or vice versa). Age distribution can be shown in the following table:

Age	Ideal percentage of population (in %)	Number of people (total=10 800)	Tolerance (in %)
0-9	5	540	± 2
10-19	8.5	918	± 2 to 4
20-29	24	2592	± 4 to 5
30-39	26	2808	± 4 to 5
40-49	23	2484	± 2 to 3
50-59	9.5	1026	± 2
60-69	3	324	± 1
70-79	0.5	54	± 1
80-89	<0.5	<54	± 1

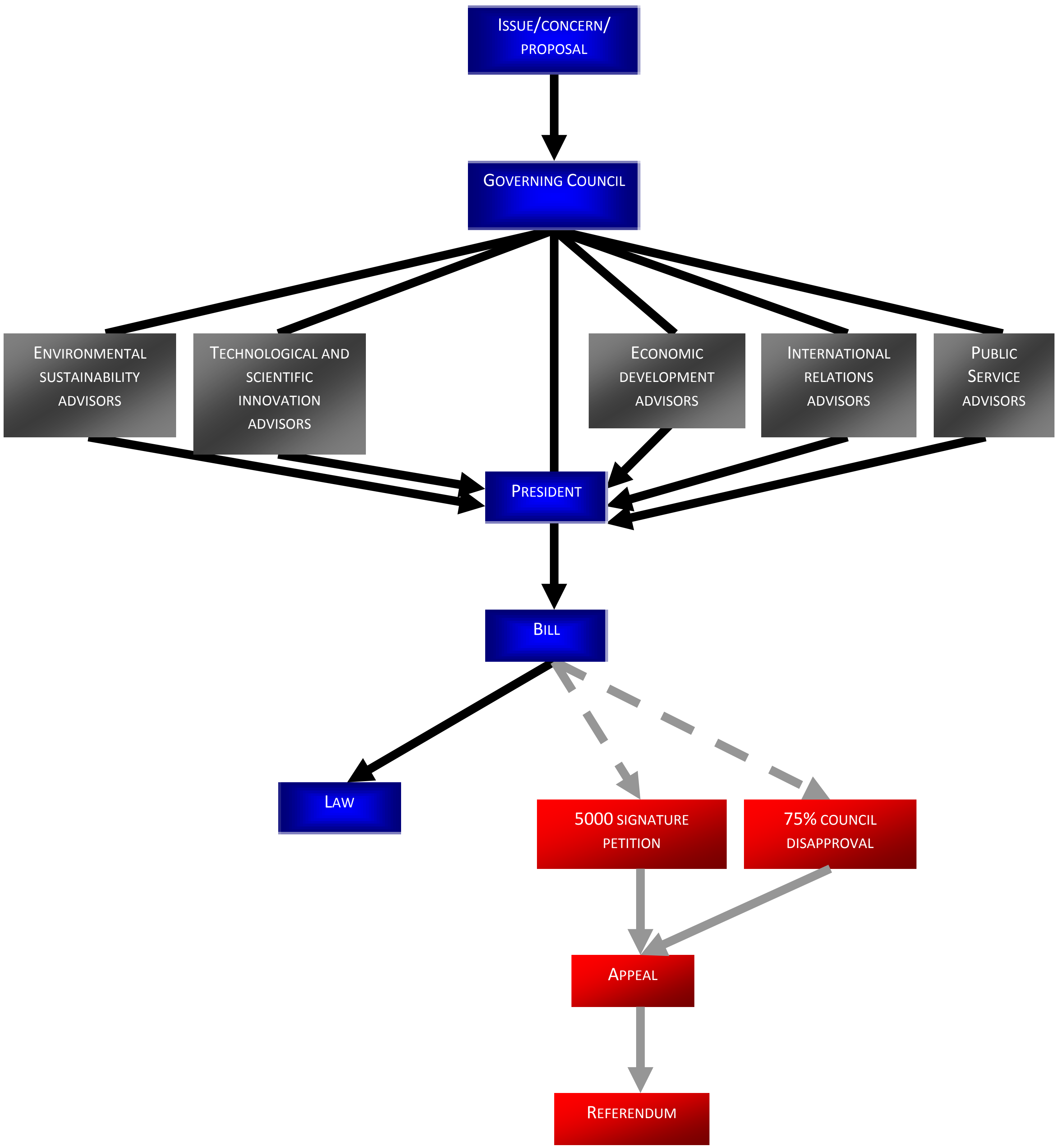
6.2: Public Services

Government/Political System

A crucial aspect of long-term space colony settlement is setting up a political system that is able to support the variety of demands and wants of all the inhabitants. The development of the space settlement is dependent on the stability and efficiency of the political system in coordinating the various aspects of life on Asten. Since humans will inhabit the space ship, the government system should be not only ideal in its doctrine but also familiar and practical for the human practices. Therefore, democracy is the best type of government for such a small and tight community.

The principle of democracy will ensure that every individual has the right to voice their opinions and protect the liberty of all citizens. The democracy will be a representative democracy in which all the inhabitants on Asten will elect a single president along with a council of twenty experts in each of five fields (four members in each field) of the station: environmental sustainability, public services, technological and scientific innovations, economic development, and international relations. The council members act as advisors for the president in areas of decision making. Inhabitants on Asten can voice their issues to the council members and these issues can then be brought up in the council during bi-weekly sessions. After hearing from his/her advisors, the president will make a decision and pass a bill. (figure 6.2A).

Any passed bill can be appealed in the case that a petition with more than 5000 signatures (50% of the population) is brought before the council, or if 75% of the council members do not agree with the president's decision. A referendum will then be called in order to resolve the issue (figure 6.2A).



Asten government system

Figure 6.2A

Education

Given that 13% of Asten's ideal population is between the ages of 0 and 19, having a strong education system is extremely important. With the appropriate education, children can be thinkers and make right decisions for themselves and the society, but more importantly, they will be able to maximize their potential for success.

The 1458 students are divided relatively equally into each of the five schools in Asten (each one located on level 2 of the Vestibule [see **3.5: Habitation Region**]). Because there are approximately only 292 students in each school and the amount of physical space is limited, there is no separate junior and senior school, and physical facilities (gyms, pools, etc.) are shared with the rest of the inhabitants in the recreation area of the Vestibule (see **3.5: Habitation Region**).

The education curriculum will have three areas of focus: social development, academic development and linguistic development. Social development ensures that the students grow up to be law-abiding, insightful and caring citizens. Academic development ensures that each student excels at the math and sciences, and can easily solve problems with logic and analytical skills. Finally linguistic development ensures that each and every child educated on board Asten is fluent in English, Mandarin and Hindu. English is taught because it is the official language of Asten, and is currently the world's language of business. Mandarin and Hindu are taught because India and China are currently seen as upcoming global superpowers, and it would give the students a major advantage to know their language.

Post-Secondary Education onboard Asten consists of a mix of lectures and hands-on experience. As a stipulation of their lease, companies operating aboard the station are required to loan facilities to post-secondary classes as teaching aids, allowing students the opportunity to learn and perform advanced scientific experiments not found anywhere else in the world. Companies are also required to provide co-op placements for students –which gives the students real world work experience, and reduces the need for companies to look far for new talented employees.

Asten university itself is separated into five campuses –one on each Vestibule and adjacent to the primary/secondary school. Each campus focuses on different fields (engineering, biological and health sciences, social sciences, arts, physical and chemical sciences, and math and business), allowing for a specialization of educational facilities to fit each field. For example, the arts campus would have multiple studios focusing on structural, visual and musical art, whereas the humanities would include a large reference library focusing on psychology, law, history, languages, and sociology.

Because education is valued as a long term investment that benefits both the economy and society of Asten, it is offered free of charge to all inhabitants.

Health Care

Because good health leads to increased productivity and quality of life, Health care is a public service offered to all inhabitants on Asten free of charge. The medical facilities found in the public services area of each Vestibule (see **3.5: Habitation Region**) contain:

- 5 hospital beds
- A medical imaging facility (containing an MRI machine, a CAT scan machine, a portable X-ray machine, and an ultrasound machine)
- 2 examining rooms
- 1 operating room
- A waiting room and check in desk
- A Trauma room
- Triage area
- A negative/positive pressure room (adjustable)
- An intensive care room

- A small pharmacy

Each medical facility will also be equipped with an electric medical cart, which will function as a miniature ambulance, transporting incapacitated inhabitants from their habitat module to the nearest medical facility.

Taxes

Only two major taxes exist in Asten: corporate and income.

The first -income tax- applies to only inhabitants, and relies on a gear to income scale similar to the Canadian income tax system (Canadian government, 2009).

Income (in $)	Tax (in %)
0-19 000	16
19 000 – 40 000	22
40 000 – 53 000	28
53 000 – 62 000	32
62 000+	38

The gear to income scale can be explained as thus: if an inhabitant earns 52 000 dollars per year, the first 19 000 dollars is taxed at 16%. The next 21 000 dollars (from 19 000 to 40 000) is then taxed at the 22% rate, and the final 12 000 dollars (from 40 000 to 52 000) is taxed at 28%.

The second -Corporate tax- applies only to leasing companies, and is set at a flat rate of 20% of company profits from Asten derived products, 1% higher than Canada's current corporate tax (Canadian government, 2009). This corporate tax can be permanently lowered if a corporation agrees to pay for the construction of a certain part of the station (eg. if Company A decides to pay the construction cost for an entire Vestibule, their corporate tax can be lowered to 5%). This corporate tax supplements, rather then replaces the lease companies must pay to use the space inside the Central Industry Hub.

Such a high tax rate is necessary to pay off the enormous debt that is sure to arise from construction (see **4.8: cost**), and to support the free public education and healthcare system.

6.3: Entertainment and Recreation

As humans, relaxation, communication, and interaction among people is absolutely necessary; if deprived, they can lead to serious behaviour disorders. This is why special attention is paid to entertainment and recreation on the space settlement. To simulate the entertainment on Earth, radio and TV signals will be transmitted to Asten and distributed to each family. As well there are a number of recreational facilities inside each station vestibule, from exercise facilities to theatres to a park.

Exercise facilities

Physical exercise is expected to be an important part of an inhabitant's life onboard Asten. There are three exercise facilities found in each Vestibule: a gymnasium/track, a pool, and an exercise room. The gymnasium is a hybrid facility, with a hardwood floor circled by a rubberized track (figure 6,3A, 6.3B). The full-sized pool can be found adjacent to the gymnasium, and shares a pair of change rooms with the facility (figure 6.3C, 6.3D). Finally the exercise room contains a full assortment of different machines, and is accessed through the gymnasium (figure 6.3E).

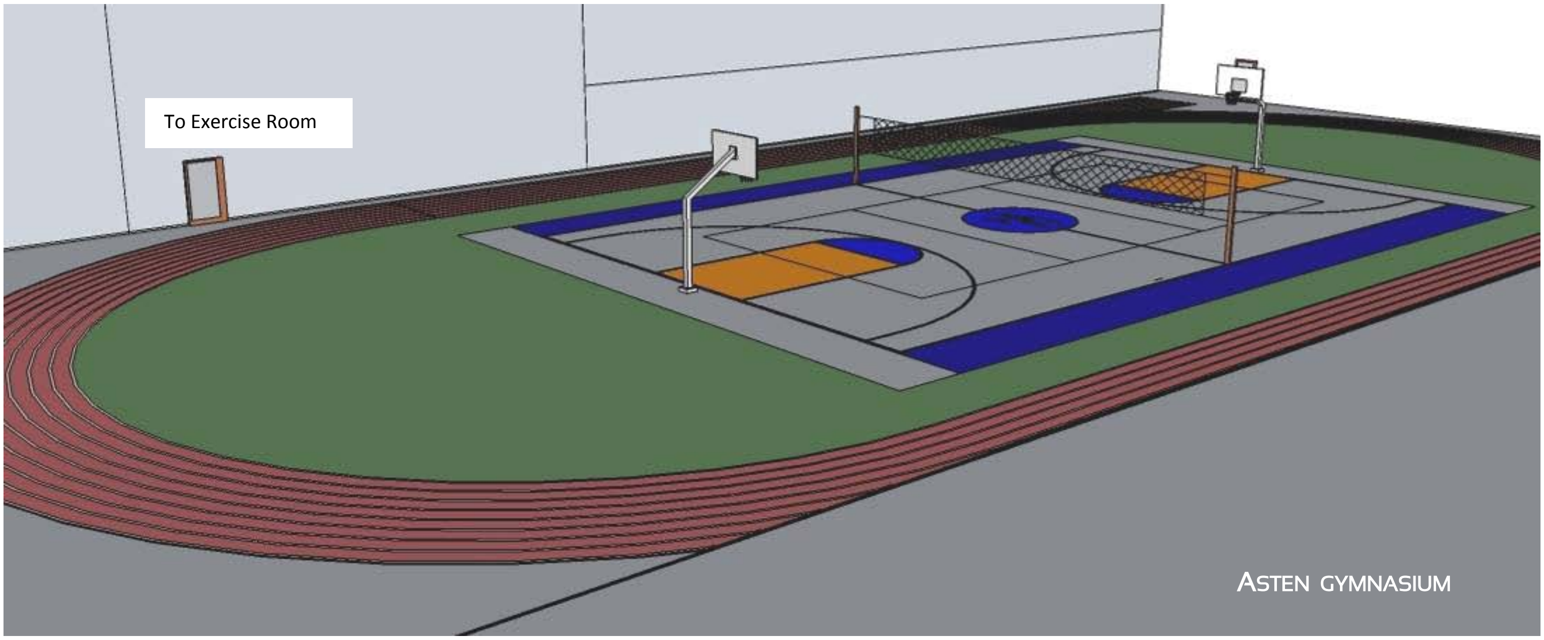


Figure 6.4A

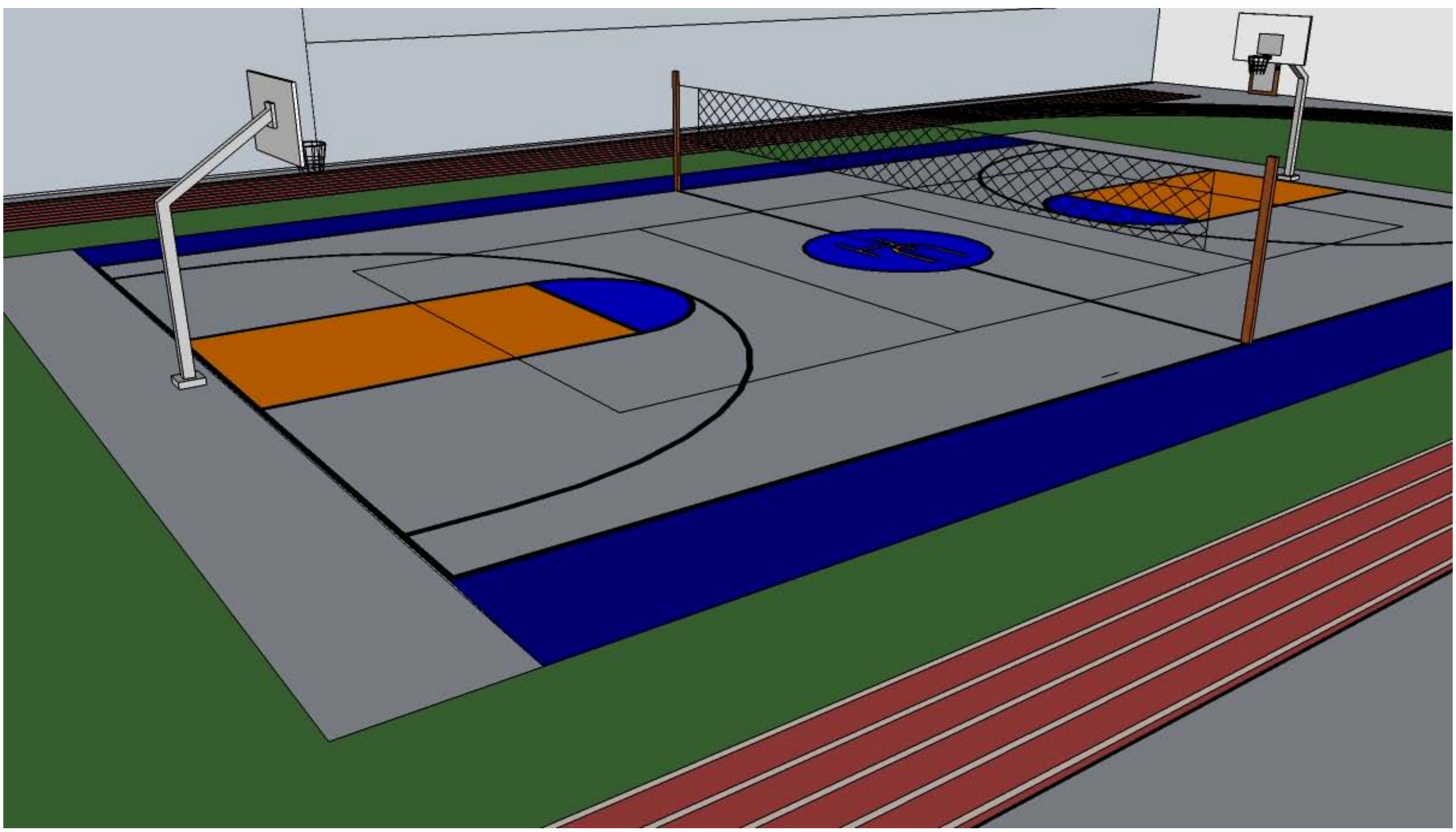


Figure 6.4B

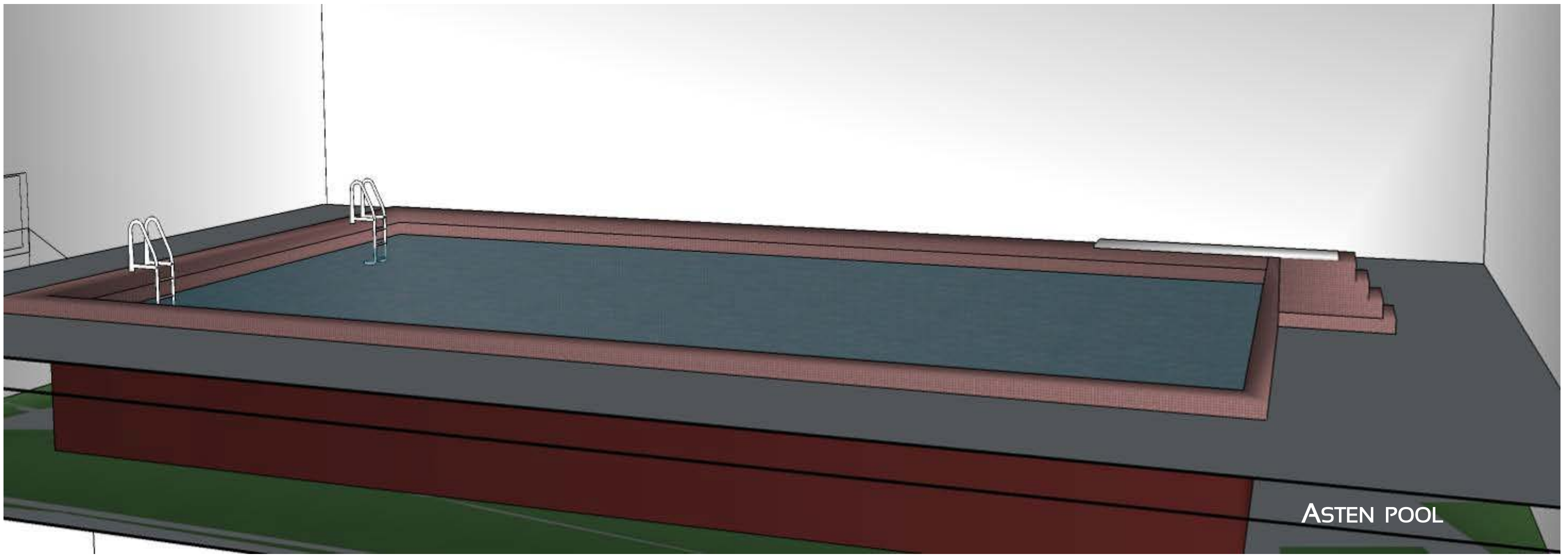


Figure 6.4C

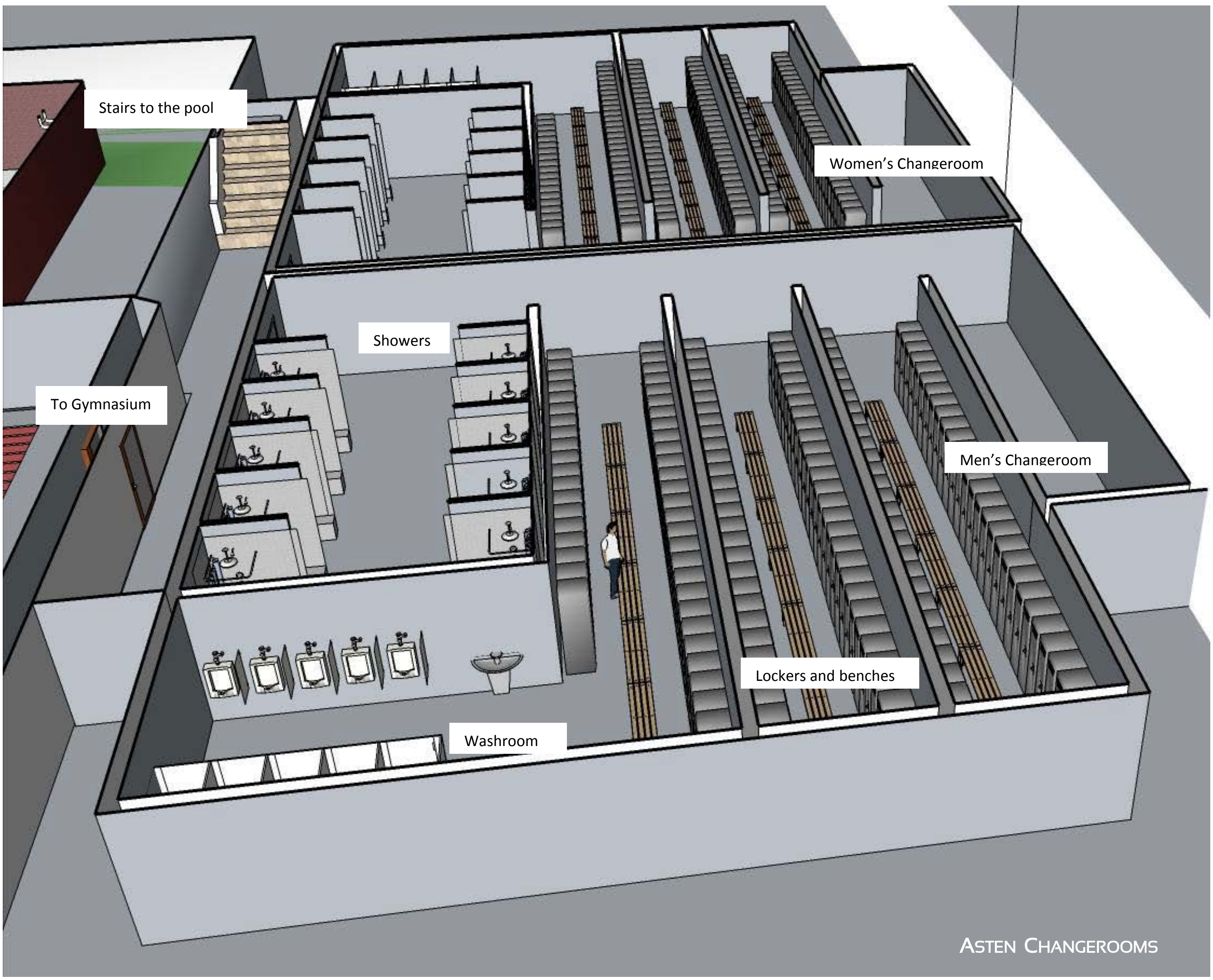


Figure 6.4D

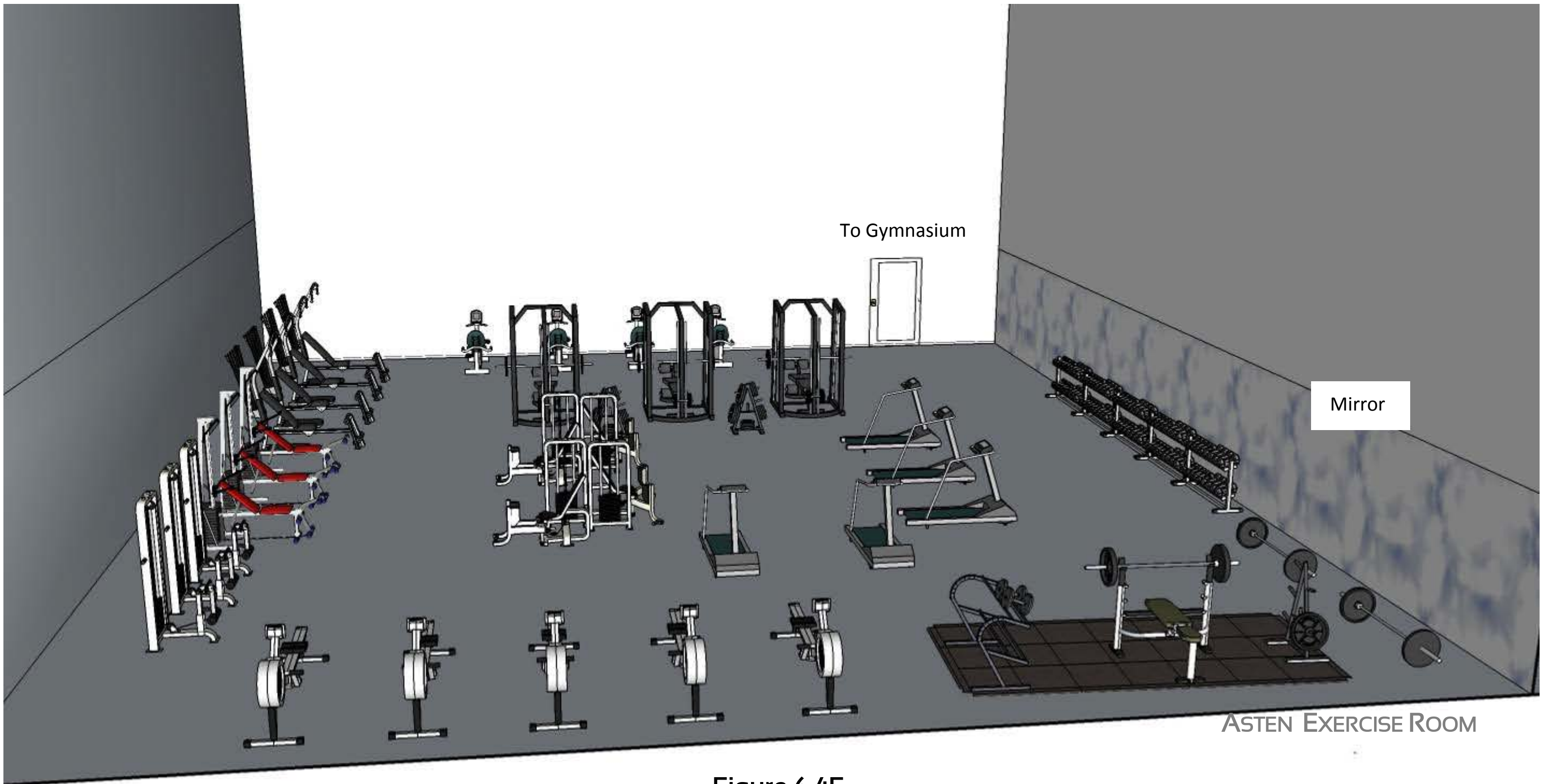


Figure 6.4E

Entertainment facilities

There are two entertainment facilities found in each Vestibule: a multipurpose auditorium, and a games room. The multipurpose auditorium can be used as a stage to show plays and host lectures, and can also be used as a cinema theatre, showing the latest Hollywood movies from Earth (figure 6.3F). The games room is accessed through the gymnasium, and contains two pool tables, a table tennis table, a dart board, arcade games, and other games that can keep youth from becoming bored (figure 6.3G).

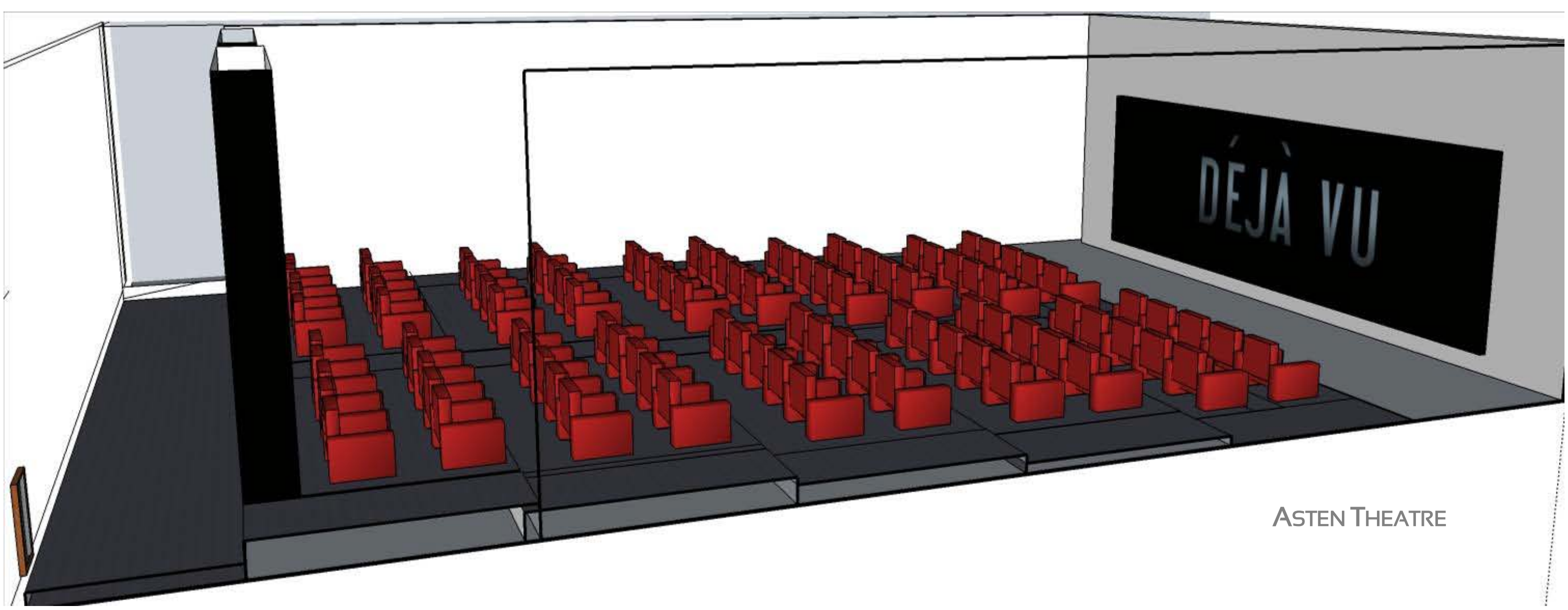


Figure 6.4F

Figure 6.4G

Park

At three hundred and seventy meters in length and eighty meters in width, the park is the largest open area in the Vestibule. It serves as a natural meeting point for inhabitants and brings an Earth-like setting to the otherwise cramped space settlement environment (figure 6.3H). The park features an artificial painted sky, with artificial sunlight that changes in intensity according to the time of day (figure 6.3J), as well as a tree-lined path that winds between the various hills and valleys and circles the large pond found at the park's center (figure 6.3K, 6.3L). The park's central purpose is to provide a natural open area that would preserve the psychological health of the inhabitants, who normally encounter only hallways, doors and rooms.

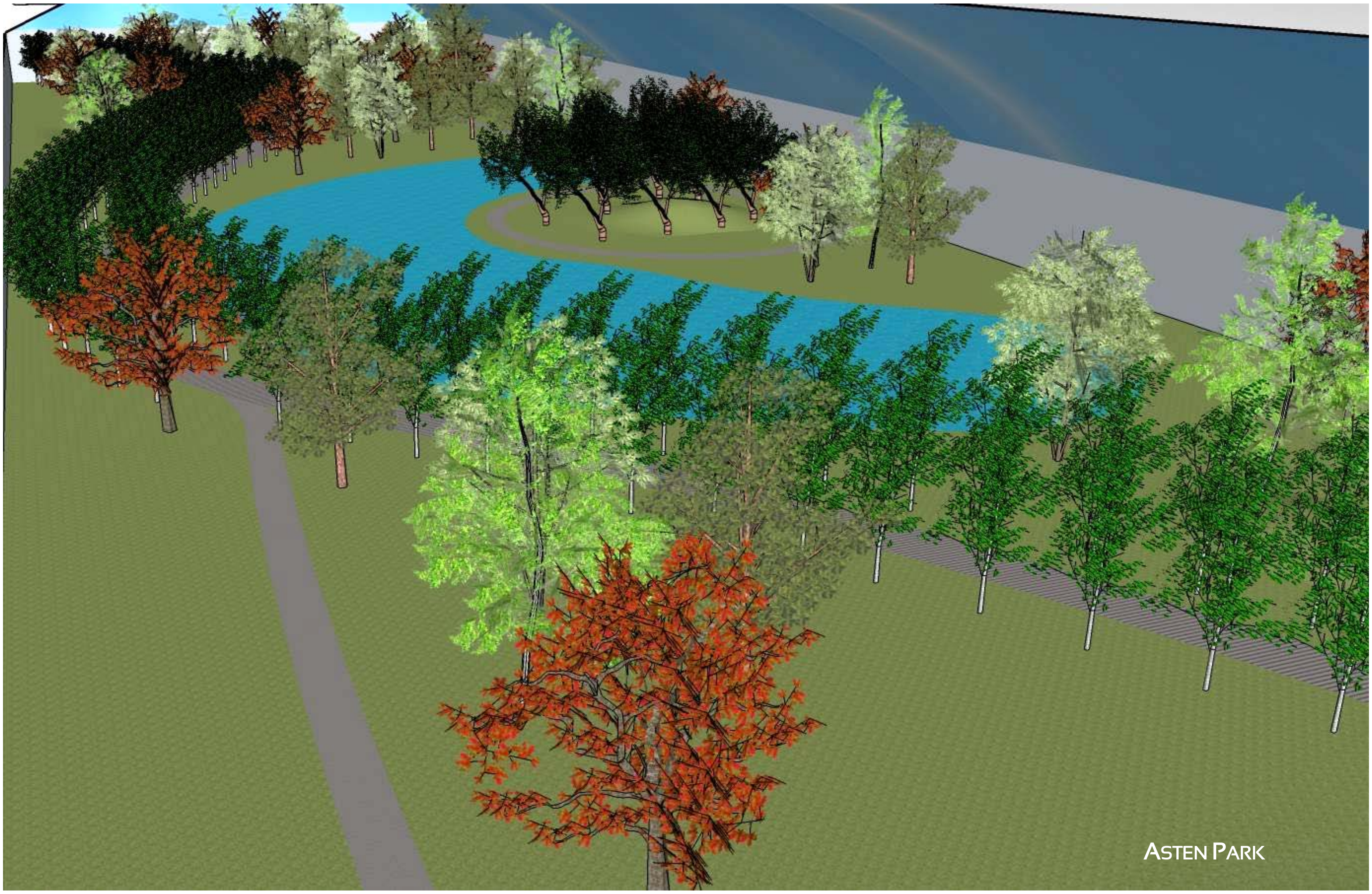


Figure 6.4H

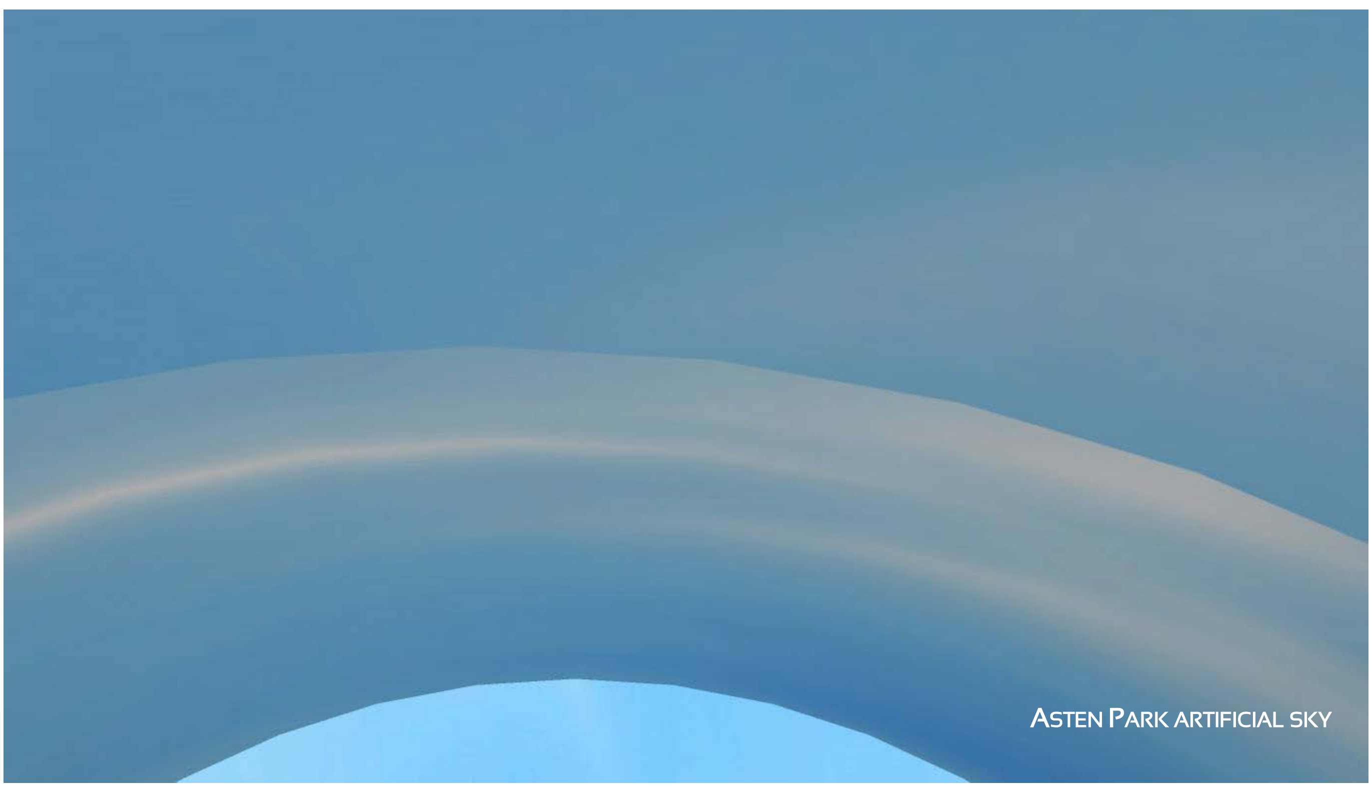


Figure 6.4J

Figure 6.4K

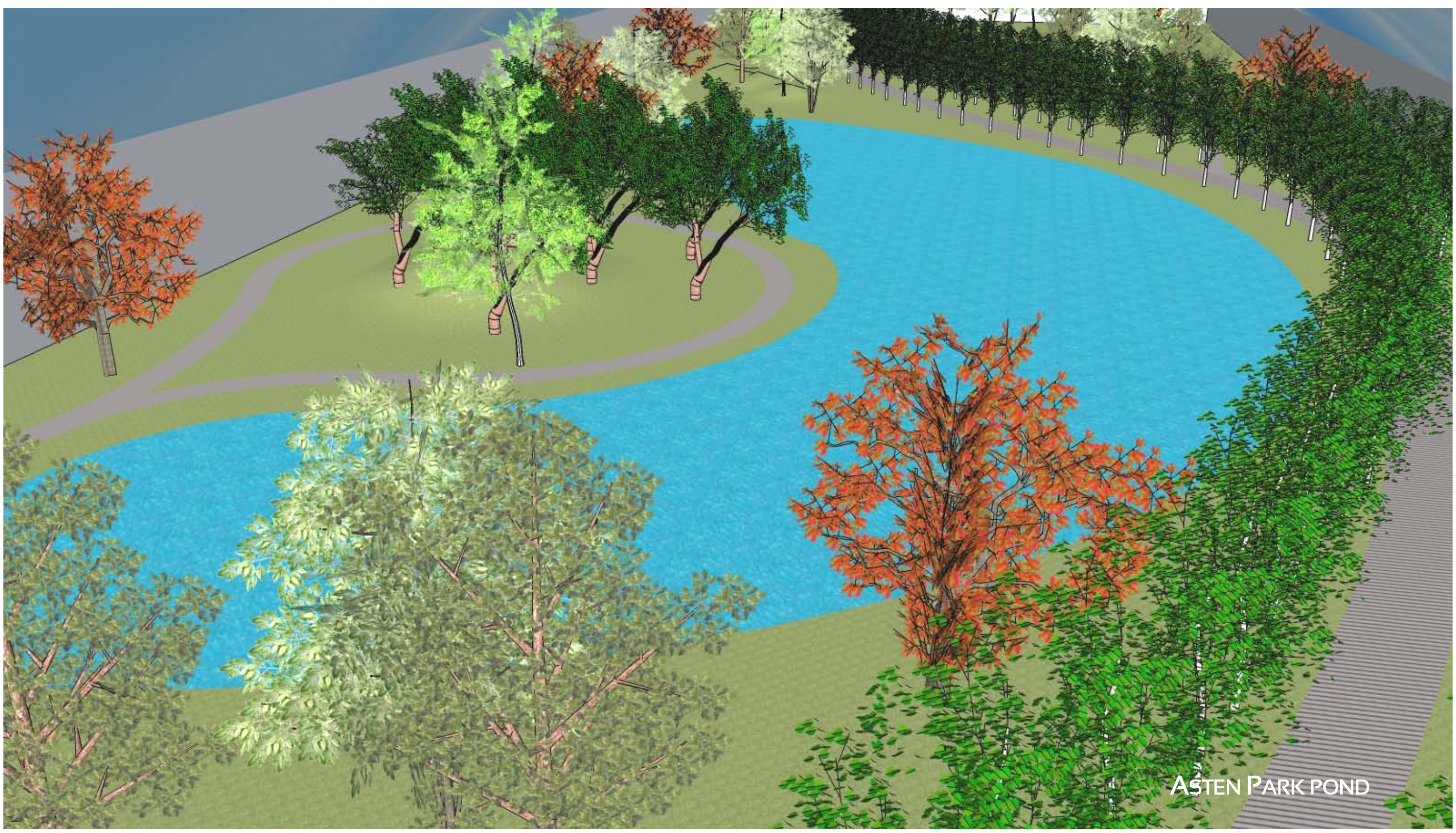


Figure 6.4L

6.4: Communication

Communication is extremely important for Asten, as it is a means of keeping in touch with Earth, as well as the mining facilities on the moon and spacecraft. It is achieved by two large arrays of antennae that transmit and receive signals from Earth, the moon and near/distant spacecraft. These antennae are located at the extreme ends of the Central Industry Hub, underneath the docking networks. The antenna array located on the lower end of the CIH is for communications with Earth, as it is the closest to the array. The array located on the upper end of the CIH is for communication with the moon and nearby/distant spacecraft (ex. interstellar probes, moon-station transport ships, etc.). Additional antennae can also be found on the end faces of the rotating Vestibules.

6.5: Economy

Like other countries in the world, Asten's economy is divided into four sectors: Primary Sector, Secondary Sector, Tertiary Sector and Quaternary Sector (Wikipedia, 2009).

Primary Sector

The Primary Sector is defined as industry associated with the acquisition of natural resources, such as forestry and agriculture (Wikipedia, 2009). With Asten, the only primary industry is the mining of the moon -accomplished with the mining facilities built during the Preparation phase of construction (see **4.3: Preparation phase**). Rather than abandon the facilities after construction of Asten is complete, the mining facilities will be taken over by "Asten Industries" -a subsidiary company of Asten Holdings Inc. (itself established during the financing stage of construction (see **4.3: Preparation phase**)). Any valuable minerals (such as Aluminum, Iron, Titanium, Magnesium and Silicon) extracted and refined by the moon mining facilities are thus the property of Asten Industries, and can be sold back to Earth.

Secondary Sector

The Secondary Sector is defined as industry associated with the manufacturing of goods and products. The unique microgravity and vacuum environment of space allows for a number of manufacturing possibilities onboard Asten, and can be shown in following table:

Secondary Industry (listed from largest to smallest)	Advantages over Earth based manufacturing	Estimated % of manufacturing GDP
Spacecraft Construction	-larger and heavier spacecraft (current spacecraft have certain size and weight restrictions) -more reliable, as there is no booster rocket that can malfunction -cheaper, because there is no booster rocket needed to propel the spacecraft -can be in any shape, because gravity is too low to stress any structural part of the spacecraft	80
Crystal growing	-perfect crystals can be formed in the sterile and weightless environment of space -high-quality protein crystals can be used in pharmaceutical research -crystal wafers can be used in electronics to make circuits even smaller and more efficient	9
Homogenous Mixtures	-more thorough mixtures can be made in microgravity -could be applied in metallurgy, producing stronger metal alloys	6
Perfect Spheres	-perfect spheres can be formed because there is no deformity due to gravity -can allow for better ball bearings, and can be used in the pharmaceutical industry with microencapsulation drug delivery (Wikipedia, 2009)	3
Luxury Products	-perfect crystals/spheres and mixtures can be sold as specialty items to Earth inhabitants (eg. perfect crystals on engagement rings)	2

Tertiary Sector

The Tertiary Sector is defined as industry associated with providing services to others (eg. banking, entertainment, etc.). There are two major Tertiary Industries onboard Asten: Banking and Tourism.

Because of Asten's physical location in Earth's orbit, it is impossible to enter or leave without being noticed, and is invincible to any country or terrorist attack –short of a nuclear missile. As such, it is very secure, and a good choice for those on Earth looking for a place to store their money and valuables. Asten could establish banks and rent out safety deposit boxes and savings accounts aboard the station, touting Asten as the new Switzerland of banking.

With the zero-gravity hotel in the Central Industry Hub, Asten has the capacity to handle up to 300 tourists (see **3.6: Central Industry Hub**). However rather than being a final destination, the station can act as a base for space-related expeditions (such as an orbit around the Earth and re-entry, or a week-long expedition to the moon), giving other world citizens the opportunity to experience living and traveling in space which is a trip they are sure to not forget. Opening the station to tourists will also hopefully make more people aware of the fragile nature of the planet and encourage them to do more to protect their environment.

Quaternary Sector

The Quaternary Sector is defined as industry associated with the research and development of new processes and products (eg. developing new renewable energy technologies, or new medications, etc.). Asten's weightless environment provides a number of research and development opportunities, some of which are explained in the following table:

Research field	What can be researched	Application
Biomedical Research	-affect of varying gravity levels on the human body	-can develop methods to counteract the negative effect weightlessness has, such as bone and muscle loss -could also lead to some medical cures of tissue degenerative diseases
Fundamental biology	-behaviour of plants and animals in varying gravity levels	-leads to genetic modification of plants to better suit different gravity levels, which can facilitate plant growth in zero-gravity ,as well as the terraforming of other planets
Fluid physics	-behaviour of fluids in weightless environments, and improving mathematical algorithms for model fluid movement	-improvement of liquid fuel systems in future spacecraft and industrial facilities on other planets -better understanding and countering of soil liquefaction during earthquakes (Wikipedia, 2009)
Material behaviour	-how different elements and materials interact in space (eg. mixing, etc.)	- can lead to development of stronger metal alloys (see Secondary Industries)
Combustion behaviour	-physical properties of combustion reactions	-more efficient spacecraft engines
Celestial navigation and astronomy	-new methods of navigating and orienting in space -stars and galaxies farther away form the Earth can be seen and studied (because future space telescopes have no size limit)	-simpler and more efficient methods of space travel and navigation can be developed -more knowledge could be acquired about black holes, quasars, and other space phenomenon

Section 7.1: Acknowledgements

Thank you:

1. To my staff advisor, Ms. Gillian Evans, for pointing out technical flaws and grammar problems when reviewing my proposal, and for being such a supportive and helpful Physics teacher and mentor.
2. To NASA's Ames Research Center, for giving me the opportunity to design all aspects of a permanent space settlement and combine all my thoughts and ideas on engineering, technology, biology and sociology into one project.
3. To Google, for their free-use software Google Sketchup 7 (of which the 3d models are made), and the Google 3D warehouse (where components such as furniture and people were found)
4. To my parents, for putting up with my long sleepless nights, and for encouraging me to follow my dreams in becoming an aerospace engineer.

And most importantly:

Thank you to the quote on my bedroom wall, which never ceases to remind me that-

"When you believe, anything is possible."

7.2: Works Cited

1. Anderson, W. and Stern, T. (2005). High Temperature Lightweight Heat Pipe Panel Technology Development. Retrieved February March 18th 2009 from http://www.1-act.com/htlhpptd.pdf
2. Ashley, S. (2003, May). X-ray Proofing: To save himself, a physician enters the rag trade. *Scientific American*, unknown, 34-35. Retrieved January 19th 2009 from http://www.radshield.com/pdf/Scientic%20American%20May%202003.pdf
3. Boen, B. (2009). Ares V Cargo Launch Vehicle. Retrieved January 30th 2009 from http://www.nasa.gov/mission_pages/constellation/ares/aresV/index.html
4. Courtland, R. (2008). Harvesting The Sun's Energy with Antennas. Retrieved February 15 2008 from http://www.inl.gov/featurestories/2007-12-17.shtml
5. Dismukes, K. (2003). TransHab Concept. Retrieved October 18th 2008 from http://spaceflight.nasa.gov/history/station/transhab/index.html
6. Hyde, J. (2006). Hypervelocity Impact Technology Facility: Shield Development. Retrieved January 19th 2009 from http://hitf.jsc.nasa.gov/hitfpub/shielddev/index.html
7. Kauderer, A. (2007). International Space Station: Space Station Assembly. Retrieved January 30th 2009 from http://www.nasa.gov/mission_pages/station/structure/elements/mss.html
8. Lansel, S. (2005). Technology and Future of III–V Multi-junction solar cells. Retrieved March 1st 2009 from http://www.stanford.edu/~slansel/projects/solar.htm
9. The Owlcroft Company (2008). Induction Cooking: Induction Cookware. Retrieved March 18th 2009 from http://theinductionsite.com/induction-cookware.shtml
10. Potter, S. (1998). Solar Power Satellites: An idea whose time has come. Retrieved March 2nd 2009 from http://www.freemars.org/history/sps.html
11. Stathopoulos, V. (2009). X-33. Retrieved January 31st 2009 from http://www.aerospaceguide.net/space_planes/x-33.html
12. United States Department of Labor (2008). Occupational Outlook Handbook, 2008-2009 Edition. Retrieved February 2nd 2009 from http://www.bls.gov/oco/
13. Unknown (2009). Passive Hydroponics. Retrieved March 24th 2009 from http://en.wikipedia.org/wiki/Passive_hydroponics
14. Unknown (2009). Fuselage. Retrieved December 23rd 2008 from http://en.wikipedia.org/wiki/Fuselage
15. Unknown (2009). Project Finance. Retrieved January 26th 2009 from http://en.wikipedia.org/wiki/Project_finance
16. Unknown (2009). Orbital Station-Keeping. Retrieved January 24th 2009 from http://en.wikipedia.org/wiki/Orbital_stationkeeping
17. Unknown (1961, March 24th). Algae for Oxygen. *Time Magazine,* unknown, unknown. Retrieved March 22nd 2009 from http://www.time.com/time/magazine/article/0,9171,827762,00.html
18. Unknown (2009). Chlorella algae. Retrieved March 22nd 2009 from http://en.wikipedia.org/wiki/Chlorella

19. Unknown (2009). Launch Loop. Retrieved January 20th 2009 from http://en.wikipedia.org/wiki/Launch_loop

20. Unknown (2009). Industry. Retrieved March 12th 2009 from http://en.wikipedia.org/wiki/Industry

21. Water Policy International (2001). Ecological Sanitation. Retrieved March 24th 2009 from http://www.africanwater.org/ecosan_main.htm